

# RIDGE 2000 IMPLEMENTATION PLAN FOR THE 8-11°N SEGMENT OF THE EAST PACIFIC RISE INTEGRATED STUDY SITE

## 1. INTRODUCTION

The Integrated Studies theme of Ridge 2000 (R2K) is a program of focused, whole system research of global oceanic spreading-center processes. This component of R2K addresses the complex, interlinked array of processes that support life at and beneath the seafloor as a consequence of the flow of energy and material from Earth's deep mantle, through the magmatic and hydrothermal systems of the oceanic crust, to the overlying ocean. The complex linkages between life and planetary processes at ocean spreading centers can only be understood through coordinated studies that span a broad range of disciplines. Thus, R2K Integrated Studies consists of multidisciplinary research that is focused on a small number of "type" areas that are designed to characterize segments of the global spreading system. The objective of Integrated Studies is to develop quantitative, whole-system models through coordinated and interdisciplinary experiments. It is necessary for scientists to understand the interactions and linkages among the volcanic, tectonic, geochemical and biological systems to achieve this goal.

Most of the present day ocean crust and most ocean crust that is presently being subducted was created at fast spreading ridges. Because crustal magma reservoirs are typically present beneath fast spreading ridges, hydrothermal activity is prolific, and fast-spreading ridges may dominate global mid-ocean ridge hydrothermal fluxes. Fast spreading ridges are dynamic and present excellent opportunities to observe and measure mid-ocean ridge processes on a decadal time-scale. The section of the fast spreading East Pacific Rise (EPR) between 8°N to 11°N (Figure 1) has been intensively studied since the early 1980's, and is one of the best characterized sections of the global mid-ocean ridge system.

Important attributes of the 8-11°N EPR ISS include:

- The accelerated time scale of the natural perturbations inherent in a fast-spreading (mid-ocean ridge (MOR) which provide an unique opportunity to examine all of the linkages between physical, chemical and biological process on the time scale of the R2K program;
- The high probability of observing accretionary events (e.g., episodes of cracking, intrusion, or eruption) over the time scale of the program, including the apparent high probability for an event in the very near future; the tectonic and morphologic diversity encompassing segments at the full range of scales observed along mid-ocean ridges;
- The well-documented history of the plate boundary over the last few million years;
- The absence of nearby subduction zones and mantle plumes;
- Significant knowledge of shallow (<10 km) seismic properties and velocity structure;
- The abundance and diversity of hydrothermal vents, plumes, and biological communities;
- The high potential for discovery of additional hydrothermal sites;
- The ongoing multidisciplinary/interdisciplinary time-series studies of the impact and aftermath of a 1991-92 volcanic eruption;
- The evidence for direct magmatic influences on hydrothermal systems;
- The opportunity to compare active hydrothermal vents that lie within and outside of the eruption area;
- The extensive petrologic/geochemical, photographic, and acoustic databases;
- Previous and planned ODP programs in the area;

- The close proximity to major port facilities; and
- Almost year-round accessibility.

The diverse data sets that have been collected at the EPR ISS are being assimilated into a web-accessible data repository for the use of the scientific community (<http://www.soest.hawaii.edu/HMRG/EPR/index.htm>). Data types archived to date include swath bathymetry, side-scan sonar, photoimagery, and ALVIN data and links to metadata. A list of relevant publications is also available. In addition, the EPR ISS is within an array of six moored hydrophones in the eastern equatorial Pacific that are owned and maintained by NOAA/PMEL. The locations of acoustically recorded events that have occurred within the region of the EPR ISS since 1995 can be obtained at (<http://autochart.pmel.noaa.gov:1776/autochart/GetPosit.html>). A variety of durable markers have been left at all of the vents where fluids have been sampled, and in most diffuse flow communities, including a line of 210 well-located polyethylene markers deployed in 1992 along the "BIOGEOTRANSECT" from 9°49.6'N - 9°50.3'N. See Shank et al. [1998, Deep Sea Research, II, 45:465-515] and Lutz et al. [2001, American Scientist, 89:422-431] for more information.

## **2. SITE BULL'S-EYE: INTEGRATED STUDY SITE FOCUS**

As with the other R2K integrated study sites, integrated studies at the EPR site will be carried out at various spatial scales defined by their scientific objectives. The site can be visualized as a target consisting of concentric bands about a designated focal point or bull's-eye. Proponents are required to demonstrate the relationship of the proposed science to a vertically integrated "type-section" at the designated "bull's-eye". The 8°-11° EPR ISS encompasses diverse fast spreading environments including a hierarchy of axial segments and discontinuities (Figure 1). The "bull's-eye" is at 9°49' - 9°51' N where numerous high temperature vents and diffuse flow communities have been mapped and monitored over the past 10 years. The first concentric ring from 9°46' - 9°52' N encompasses a fourth order segment and includes the extent of the 1991 and 1992 eruptions. The second concentric ring from 9° to 10°N includes several third order segments as well as a second order ridge segment around 9°03'N. The outermost concentric ring extends from just south of the Siqueiros Fracture Zone to north of the Clipperton Fracture zone. This ring incorporates additional diversity in ridge structure at the first-order segment scale that can be exploited for comparative studies as well as including the two bounding transforms.

## **3. FUNDAMENTAL QUESTIONS AND GOALS**

The overarching goal for this ISS is to understand a typical fast-spreading ridge system "from mantle to microbe" by elucidating the linkages between energy and mass transfer from mantle upwelling and magmatism, through and into the crust via the hydrothermal systems, and on through the hydrothermal biosphere to the overlying ocean.

Significant progress towards achieving this goal can be made through addressing the following questions.

**3.1. What are the patterns of mantle upwelling and the magmatic flux from the mantle to the crust and their relationship to ridge morphology and segmentation?**

Neither the fundamental causes of ridge segmentation nor the manner of melt focusing from the mantle to crust are well understood. For example, what is the underlying cause of apparent concentrations in melt supply, such as at the 9°50'N "inflated" section of ridge? Such underlying variations in melt supply may, in a broad sense, control the location of hydrothermal venting and the location of vent communities along a ridge.

**3.2. How does hydrothermal circulation impact characteristics of the melt zone, crustal structure and composition, and ridge morphology?**

This question and 3.1 are tied together, as hydrothermal circulation is strongly linked to magma supply and crustal thermal structure, both of which may strongly affect morphology and segmentation. Cracking and faulting in response to hydrothermal cooling may create new fluid pathways, modifying circulation and thermal structure and potentially influencing the geometry and location of new magma bodies. Hydrothermal circulation may influence the size and distribution of magmatic heat sources, which will in turn influence the geometry and vigor of hydrothermal circulation and possibly the evolution of magmas in the crust. Because hydrothermal activity exchanges mass in addition to heat, the impacts of hydrothermal circulation on the composition of oceanic crust must also be understood. For example, the EPR axis north and south of the Clipperton fracture zone has strongly contrasting morphologies and structures. North of the Clipperton the axis is more strongly tectonized with more deeply penetrating faults, more extensive crustal alteration, and smaller magma bodies. This contrast provides an ideal framework for studies of the linkages between hydrothermalism, magma bodies and ridge morphology.

**3.3. What is the thermal and permeability structure of the crust and the underlying magmatic system?**

The thermal and permeability structure of the oceanic crust is dependent on both the mechanisms and distribution of heat input and removal. We do not at present understand why there are hydrothermal vents in some locations but not in others. Ultimately, this is a result of the locations of the heat sources, the permeability structure of the crust, and the buoyancy of the fluids. To understand the distribution of the hydrothermal systems and biological communities, we must understand the magmatic drivers for the thermal and permeability structure of the crust, and this question must be considered in concert with 3.1 and 3.2.

**3.4. What are the interactions between biological activity, vent chemistry, physical processes, and hydrothermal features?**

As macro- and microorganisms utilize energy and material from the hydrothermal system, they will alter the chemistry of the subsurface fluids and their surroundings, thereby affecting the compositions of hydrothermal vent fluids. Conversely, changes in chemistry whether biotic or abiotic, may have significant impact on biological communities associated with the hydrothermal systems. Biological-chemical feedbacks will fundamentally affect the nature of vent fluids, hydrothermal deposits and associated biological assemblages both above and below the ocean floor. The hydrothermal biosphere will, of necessity, only encompass regions in which the energy conditions meet the biological needs. We therefore need to obtain a better understanding

of the energy and environmental requirements of the hydrothermal biosphere, as well as the physical processes that lead to these conditions being met. It must be kept in mind that biological effects deeper in the system may influence the biosphere living further up the flow system. Therefore the links within the biological system, in addition to the links of the biosphere to the physical conditions, must also be considered.

### **3.5. How and to what extent are hydrothermal products (heat and material) and organism larval stages dispersed to the ocean?**

Understanding how hydrothermal products and larval stages of vent organisms are dispersed is fundamental to quantifying energy transfer from deep within the Earth to hydrothermal systems to the overlying ocean. The needed measurements will likely occur at or above the seafloor, but will need to be examined in the context of how much energy is coming into the system.

### **3.6. How and to what extent does hydrothermal flux influence the physical, chemical and biological characteristics of the vent ecosystem and the overlying ocean?**

Understanding the heat budget at the EPR ISS is crucial to quantitatively constraining the processes occurring within it and would contribute significantly to our understanding of the dynamics of heat derived from the Earth's interior that ultimately drives the ridge crest system. In order to understand how the ocean operates, the various sources and sinks of important components within it need to be quantified. Because of the intervening water, it is much more difficult to quantify heat and material fluxes across the ocean floor than those across the atmosphere-ocean, and continent-ocean boundaries. The worldwide ridge system constitutes a substantial portion of the ocean floor; hence, to understand the physics, chemistry and biology of the ocean system, we must understand the inputs to it from the mid-ocean ridge system. As an example, the 9°50'N area is one of only two known on the mid-ocean ridge system with extremely high volatiles (e.g., CO<sub>2</sub>, He, CH<sub>4</sub>) in the hydrothermal system. The reason for the high volatiles is not well defined, nor are the potential consequences of this to eruptive processes or the biological communities in this area.

### **3.7. Five-year goals**

Over the next five years, studies at the 8-11°N EPR R2K Integrated Studies Site should aim to provide:

- A working model for the pattern of mantle flow and melt supply in the 8-11°N area, including an understanding of the variation in melt supply along the ridge with respect to ridge offsets, morphology, hydrothermal venting, and geochemical variations.
- Quantitative information about microbes and their link to macrofauna, hydrothermal fluid flow paths, tectonics, and magmatic processes.
- Quantification of the heat flux to the water column at the 9°50'N site
- Detailed imaging of subseafloor structure and how it relates to the location of eruptive centers, hydrothermal vents, biota, and the chemistry and temperatures of hydrothermal venting.
- An understanding of seafloor properties and motions associated with hydrothermal, tectonic and magmatic events through seismic and geodetic monitoring.

- An understanding of the linkages between and temporal variation in biological, geological and chemical parameters at the site.
- New information on flow paths of hydrothermal fluids.
- Mapping of structures associated with melt transport and their manifestation at the seafloor.
- The underlying causes of ridge segmentation.

#### **4. COMMUNITY-WIDE DATA AND INSTRUMENT/TECHNOLOGY DEVELOPMENT NEEDS**

##### **4.1 Identified community data needs**

In order to facilitate understanding of the linkages and processes at this site, a suite of synchronous monitoring studies at the ISS bulls-eye is essential. These studies should provide baseline data that will enable the responses of hydrothermal and biological systems to tectonic and/or magmatic perturbations to be identified/recognized and quantified. Such measurements could be obtained through a combination of periodic visits to specific sites and increasingly as appropriate instruments become available, long-term deployments of *in situ* instrumentation. Long-term, time-series studies should include observation, measurement, and analysis of at least the following data types:

- Seismicity
- Vent temperature
- Vent chemistry
- Vent biology
- Hydrothermal deposits
- Seafloor deformation and/or motion
- Water column parameters

Seafloor mapping at scales relevant to biological studies, volcanological mapping and mapping of the general distribution and characterization of hydrothermal plumes features in certain areas where it is lacking, may be required to complement existing maps (*e.g.* multibeam sonar, and scanning altimetric).

##### **4.2 Community instrument development needs**

The following instruments and/or technologies are potentially important components of the implementation plan for the EPR 8-11°N ISS:

- Improved tools for organism studies and collections to lessen the human disturbance to these communities.
- *In situ* chemical sensors for long-term analysis of hydrothermal vent fluids.
- Improved long-term temperature recording devices.
- Capability for networking instruments in a local area network and for transferring data to shore.
- Conversion of non-real time hydrophone arrays to (near) real time data transmission.
- Improved geodetic tools for measuring deformation (*e.g.*, inflation and extension).
- Small-scale drills and/or fluid sippers and probes to sample within the upper few meters of the oceanic crust with minimal disturbance.

## 5. STAGING AND LOGISTICAL CONSIDERATIONS

The 8-11°N EPR ISS has an excellent weather window and is accessible three-quarters of the year. It is only during hurricane season, mid-June to mid-October, that there can be operational problems in visiting the site.

This section of the EPR is located in international waters; hence, no clearances are necessary. The site is readily accessible from several major port facilities. While Acapulco is the closest larger port, the usual port of choice because of its major port facility is Manzanillo, Colima, Mexico; either is less than a two-day steam from the study site. There are direct daily airline flights from Los Angeles, CA to Manzanillo. San Diego, CA, the closest U.S. port, is about a five-day transit.

### ***5.1 Obstacles Present on the Seafloor at the EPR ISS***

There are several potential obstacles to research in this area from previous activities directly on the ridge axis at this site that investigators need to be aware of in planning experiments:

- Dredge wire: ~3km of 9/16 steel dredge wire, a dredge and a 12 kHz pinger were lost in Nov. 1989 during the Scripps expedition Venture, Leg 3 in 1989 using Argo I on R/V Washington. The wire parted while vertical (wire out equaled depth = 2520 m) at the sheave.
  - The location of the dredge wire is 9°44.93'N, 104°16.45'W.
- ODP Leg 142, Hole 864 guide base and bottom hole assemblies: a standard ODP guide base (1992 vintage) is present on the seafloor in the axial trough. It was left during ODP Leg 142 drilling operations. In addition, within a few tens of meters of the guide base, two bottom hole assemblies are sticking out (1-2 m) of the seafloor.
  - The guidebase is located at 9°30.87'N, 104°14.67'W.
- Rock Drill: The seafloor rock drill developed by Dr. H. Paul Johnson at University of Washington was entangled around the ODP Leg 142 guidebase on the floor of the axial trough at the EPR.
  - The rock drill is located at 9°30.87'N, 104°14.67'W.

The community may decide it is a priority to dedicate the resources to removing or further surveying one or more of these impediments to research in order to provide the baseline data to permit future submersible operations around these sites.

## 6. RELATION TO OTHER PROGRAMS

Wherever possible R2K ISS research should seek to collaborate with and benefit from other US and international science initiatives.

### ***6.1 Acoustic Hydrophone Array (AHA)***

The EPR between 8–11°N is within NOAA/PMEL's equatorial hydrophone array. Six hydrophones are spaced ~1000 km apart with two each at 10°N, 0°, and 10°S. The array has been monitoring seismicity throughout this region since 1995. Although the hydroacoustic data are not currently transmitted to shore in real time, NOAA services the hydrophones every 6 months, and the data retrieved. Earthquake locations can be obtained from the NOAA/PMEL website [www.pmel.noaa.gov/vents/oceanseis.html](http://www.pmel.noaa.gov/vents/oceanseis.html).

## **6.2 International Ocean Drilling Program (IODP)**

The International Ocean Drilling Program (IODP) is an international initiative, which is scheduled to resume deep ocean scientific drilling operations in 2005. The IODP is the ideal vehicle for extending ISS studies into the third dimension beneath the seafloor as well as back in time through off-axis drilling.

In the early 1990s, 9°30'N along the EPR crest was selected by the Ocean Drilling Program (ODP) as the best site at which to initiate bare rock drilling on the MOR. Drilling was attempted at this site in 1992 (Leg 142), but due to technological problems the hole was not completed. Many of these site data are available in the ODP database at <http://www.ldeo.columbia.edu/databank>.

A new proposal for drilling on the EPR was highly ranked during the final years of the ODP and is being revised for consideration by IODP. The proposal calls for future drill sites to be emplaced along the ridge axis at 9°32'N, 9°40'N and 9°08'N and 5 km east of the ridge axis at 9°32'N. Proposed sites are located well outside the 9N ISS bulls-eye to ensure the hydrothermal systems at the site will not be disturbed by drilling operations.

## **6.3 US Ocean Observatories Initiative**

In response to increasing demands by researchers for sustained observations in the oceans and as a result of recent advances in technology, the NSF has developed an Ocean Observatories Initiative (OOI). The OOI (which has grown out of the DEOS program) would provide the basic hardware and infrastructure needed to establish both relocatable (buoyed) and cabled observatories. It is evident that many of the activities planned for each of the ISS would be greatly enhanced by real-time communication with instruments and potentially by the supply of significant power to the sea floor. In fact, part of the rationale for the OOI is its role in support of initiatives like Ridge 2000 and MARGINS, both of which are planning for intensive integrated studies at a few specific sites. Planning and feasibility studies for both relocatable and cabled observatories have been conducted and several such projects have already begun and have a life of their own. Thus it is both reasonable and prudent to plan on the availability of buoys and in some cases perhaps even a cable providing power and two-way communications to sea floor instruments at Ridge 2000 Integrated Study Sites in the near future.

## **6.4 InterRidge**

InterRidge is an international association of national organizations that promotes collaboration and cooperation in spreading center research. It has had remarkable success in the last decade in coordinating activities along the Southwest Indian Ridge in particular. There is a long history of international collaborative scientific activity in this area of the EPR. This ISS is an excellent location for continued international collaboration that can lead to more rapid progress than would be achieved by any single nation.

# **7. POLICIES AND INFRASTRUCTURE**

## **7.1 Physical Infrastructure Needs**

The following are infrastructure needs for the EPR 8-11°N ISS:

- A permanent transponder net deployed at 9°50' ± 1°N with provisions for battery, etc. servicing as needed (most likely every 4 years, at a minimum). At present an expendable transponder net is

located at 9 50N. The system had new batteries installed in Spring 2000. The origin for all transponder nets used for *all* ALVIN dives at the EPR since 1991 (and the Argo 1989 survey) has been:

Origin: 9°08'N, 104°20'W

ID	X	Y	Latitude	Longitude	Depth (m)	Frequency	Type
A	6297.9	76416.9	9°49.45750'	-104°16.56115'	2388.5	10.0	XPENDABLE
B	5979.1	77947.9	9°50.28809'	-104°16.73626'	2387.6	11.0	XPENDABLE

- Continued coverage by the Equatorial Pacific autonomous hydrophone array and planning to transition it to a “real time” system as the hardware becomes available and cost-effective.
- A mooring to provide data transfer and some power as the hardware to do this becomes available and cost-effective.

## ***7.2 Integrated Study Site Policies***

Open discussion among the various groups working at an ISS is required to coordinate the program elements. To ensure scientific communication and coordination among R2K investigators, all proponents of R2K proposals are required to publish a brief description of the intended proposal submission on the R2K website at least thirty days before each target date. This moderated online bulletin board will also serve as a forum for communication among R2K scientists working at the ISS. PIs are also reminded that one copy of each proposal submitted for R2K funding must be sent to the R2K office within two weeks of the NSF target date to enable relevancy review. This copy need not include budgetary information.

In addition, PIs of funded programs must provide timely updates on planned field programs so that potential disciplinary overlap, logistical and equipment considerations and other issues related to coordinated field programs at an ISS may be identified and optimized. To further facilitate communication among R2K scientists at each ISS site, a site coordinator is needed. The ISS Coordinator will be a volunteer or person nominated from among the funded PIs at the ISS. The Coordinator may request a moderate supplement to a funded proposal to support this effort.

### **7.2.1 Integrated Study Site Coordinator Responsibilities**

The EPR ISS Coordinator’s main responsibility will be to foster communication and to ensure the organization of information and materials important to the EPR ISS community. These responsibilities will include:

- Instigate, facilitate, and coordinate preproposal communication, including the use of a web-based “bulletin-board” hosted by the R2K web server to foster dialog.
- Ensure that PIs provide timely proposal summaries and information concerning study areas, instrument deployments, and timing of field programs to the Ridge 2000 Office at least one month before proposal deadlines.
- Ensure that funded PIs provide timely updates on planned field programs.
- Tabulate goals of pending and funded programs, instrument deployments, and duration of each experiment to facilitate in planning for all PIs.
- Aid in communication through an EPR email list and/or bulletin board by providing notices of cruise opportunities, updates on site relevant programs such as InterRidge.

- Facilitate annual or bi-annual meetings of active or potential PIs to ensure communication and coordination of experiments.
- Ensure that a transponder/acoustic plan is maintained and that overlapping frequencies and other potential conflicts are avoided.
- With help from the Ridge 2000 Office, maintain an updated EPR ISS bibliography.
- Work with the PIs and Data Management Office to ensure that metadata and data for the ISS field programs are submitted in a timely manner.
- Periodically update the R2K steering committee on the status of the EPR ISS.

### ***7.3 Data Management***

The R2K Data Policy will apply to all ISS. It is available from the R2K website (<http://r2k.bio.psu.edu/>).

Effective data management will be an essential element of the R2K program, to ensure timely sharing of information to the broader R2K community and to facilitate effective multi-disciplinary integration of the broad suite of studies at each site. Well-designed and integrated databases will also enhance outreach to the general public and educators. Eventually, the databases will be an important component of the long-term legacy of the program.

The R2K Data Policy mandates the adoption of a Data Management System (DMS) and outlines its structure. The data management needs listed below build upon this Data Policy and represent priority issues for the DMS. A request for proposals to build the R2K Data Management System and establish the R2K Data Management Office (DMO) has been released by the R2K office, and contains additional information concerning the DMS and DMO. It is also available on the R2K website.

- 1) A single data management office will be established for all ISS and will serve as the metadata repository for all ISS. The DMO will also archive data not included in discipline specific archives. In general, the DMO will not duplicate existing discipline-specific databases (*e.g.* PetDB, Ridge Multibeam Synthesis, Deep Submergence Lab archives), but it will do so to the extent necessary to permit cross-disciplinary queries.
- 2) Standardized digital forms provided by the ISS data management office must be used to record metadata for all sampling and station work carried out in the field. These forms should be filled out at sea and submitted to the ISS data portal immediately following each field program. These forms will be developed, with community input, as early as possible.
- 3) Digital cruise reports are required; a standard digital cruise report format will be provided by the ISS DMS. The NSF MG&G data management workshop held in La Jolla, in spring 2001 strongly endorsed the establishment of a national MG&G metadata catalog that would include basic cruise information (Level 1 metadata), as well as digital cruise reports (Level 2 metadata). The metadata needs for the R2K Program follow those of the broader MG&G community and development efforts will be linked. The MG&G data management workshop report is online at [hummm.who.edu/DBMWorkshop/](http://hummm.who.edu/DBMWorkshop/).
- 4) A web-based database front end is necessary to provide interactive mapping and search capability for the ISS. Given the multi-disciplinary nature of the Ridge 2000 ISS community, access to easy-to-use interactive tools that permit co-located data to be readily displayed and searched by the non-specialist user will be vital.

#### **7.4 Integrated Study Site Oversight**

A subcommittee of the Ridge 2000 Steering Committee will oversee each ISS. The oversight committee will be responsible for ensuring that the scientific program is on track to meet the scientific goals within the stated timeframe.

#### **7.5 Education and Outreach**

Education and outreach is essential to the success of the Ridge 2000 program. Scientists are encouraged to initiate or collaborate in efforts to convey ridge science to a broader audience, including the scientific community, the general public, educators, and students. The Ridge 2000 Education and Outreach Coordinator will provide guidance and coordination, when needed, to facilitate these efforts. The Coordinator will also actively seek participation by scientists in community-wide education and outreach programs.

The EPR 8-11°N site, especially the area around 9°50'N has been featured in a number of web-based outreach efforts including Dive and Discover ([www.divediscover.who.edu](http://www.divediscover.who.edu)) Expeditions 2 and 3, and Extreme 2000 and 2001 ([www.ocean.udel.edu/expeditions/index.html](http://www.ocean.udel.edu/expeditions/index.html)).

#### **7.6 Ridge 2000 Office Support and Resources**

The R2K office will continue to host a website that will serve as a clearinghouse for all communications ([r2k.bio.psu.edu](http://r2k.bio.psu.edu)). Links to the ISS websites, databases, and bulletin boards, will be maintained. In addition, ISS bibliographies, presentations and other relevant information will live on the R2K website.

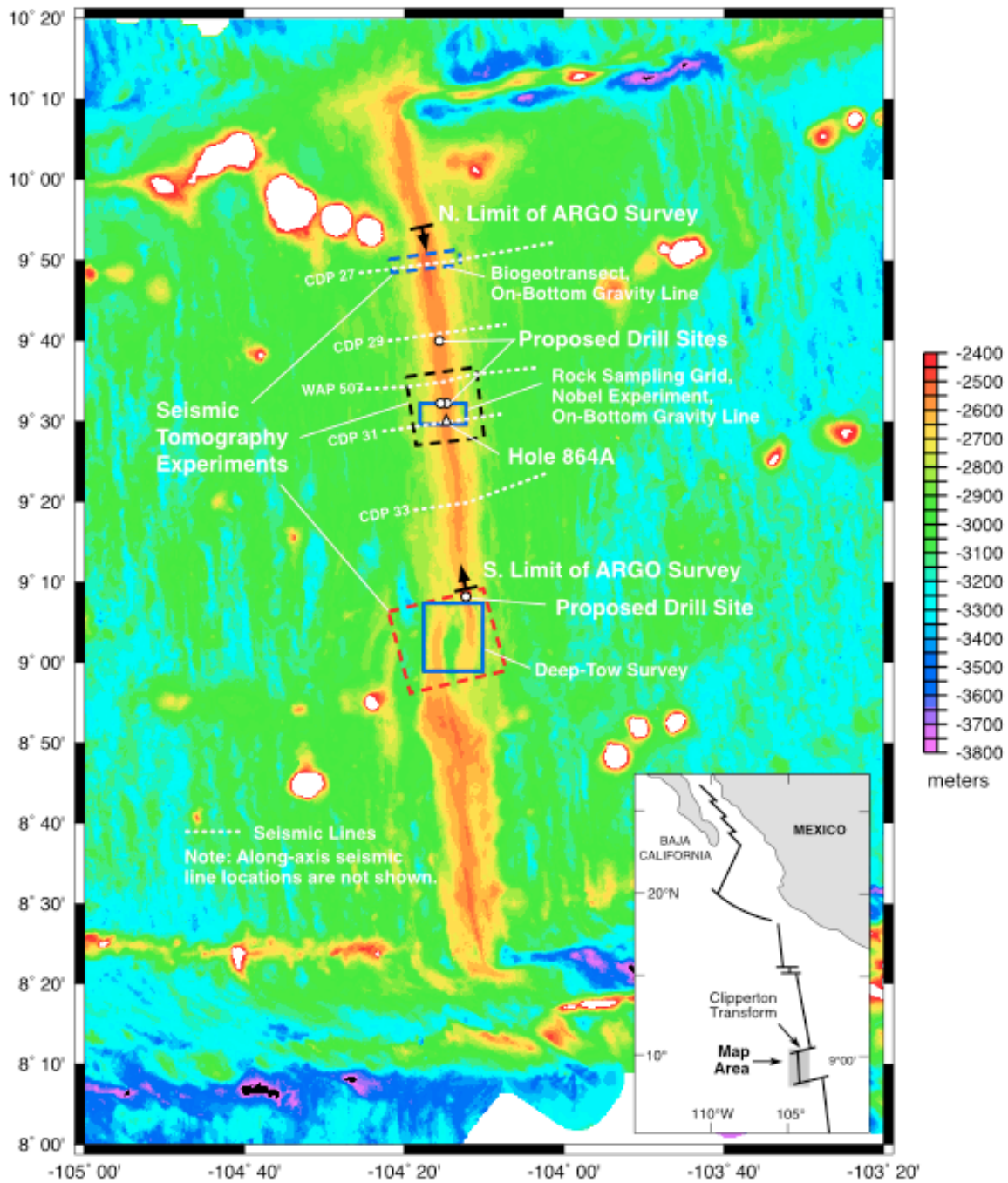


Figure 1.