Letters of Intent: EPR
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High-Resolution Mapping of the Axial Trough and Lava Channels at the East Pacific Rise 9° 46'-51'N: ROV Jason2 - SM2000 Near-Bottom Multibeam Sonar and Magnetics Surveys

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Project Overview

Volcanic and hydrothermal activity are very narrowly focused within the ~40-100 m-wide axial summit trough (AST) of the East Pacific Rise (EPR) between 9° 46'-51'N [Haymon et al., 1991; Fornari et al., 1998a]. In 1991, the first 'witnessed' submarine volcanic eruption was observed and preliminarily mapped within the AST between 9° 46'-50'N, and samples of the hydrothermal fluids and biology were recovered [Haymon et al., 1993; Lutz et al., 1994; Gregg et al., 1996; Shank et al., 1998;Von Damm, 2000]. However, fine-scale baseline bathymetric mapping available for this area a decade ago consisted only of single, near-bottom altimeter profiles acquired during Alvin dives. As a result, no comprehensive high-resolution (sub-meter vertical accuracy) bathymetric maps have been made of what is perhaps one of the best studied fast-spreading mid-ocean ridge crests; the EPR Ridge2000 Integrated Study Site (ISS). It has only been within the past few years that available sonar and vehicle technology have allowed very detailed (~<1m resolution) bathymetric surveys to be carried out [Chadwick et al., 2001; Johnson et al., 2002; Yoerger et al., 2002; Fornari et al., 2002].

Our proposal seeks to acquire SM2000 (200 kHz) near-bottom multibeam sonar [e.g. Johnson et al., 2002] and vector magnetic and vertical gradient data [e.g. Tivey and Johnson, 2002] covering a ~300 m-wide swath centered on the EPR axial trough between 9° 46'-51'N (~ 9 km). This is the primary area over which 11 high-temperature hydrothermal vents and numerous low-T diffuse flow biological communities occur; these sites are currently being studied by a wide range of investigators and will continue to be a focus of EPR ISS chemical and biological research [e.g., Haymon et al., 1993, Lutz et al., 1993; Shank et al., 1998, Fornari et al., 1998a,b, Von Damm et al., 1995; Mullineaux et al., 1998; Goffredi, 1998; Von Damm, 2000]. The bathymetric maps we propose to produce would be gridded at 1m horizontal spacing and provide vertical resolution of ~20-50 cm; a scale that can be considered to be of biological and geological relevance when considering temporal changes that occur over the course of multi-year to decadal studies such as envisioned within R2K ISS science objectives. The compiled magnetic maps will provide ~5-20 m spatial resolution of the inferred subsurface hydrothermal up-flow zones down to depth of ~100-200 m [e.g. Tivey and Johnson, 2002].

The EPR axial trough between ~9° 10'-55'N was mapped in 1989 using the Argo II 100 kHz side scan sonar [Haymon et al., 1991; Fornari et al., 1998], and again in 2001 using the DSL-120A (120 kHz) side scan sonar [Fornari et al., 2001; Schouten et al., 2002]. A small along-axis portion of the trough between 9° 49.5'N and 9° 51'N was mapped in 2001 using the 675 kHz Imagenex pencil-beam altimeter on the autonomous vehicle ABE resulting in a map with 1m vertical resolution and 5 m horizontal resolution [Schouten et al., 2002]. Our proposed Jason2/SM2000 bathymetric survey would significantly improve the areal coverage and resolution of the existing maps providing for accurate baseline topography for areas that will be subjected to time-series biological and chemical investigations. The near-bottom magnetic data will help delimit the subseafloor areas impacted by currently active hydrothermal vents as well as possibly identifying relict areas of hydrothermal fluid flow that are not apparent beneath the fresh lava flows in the AST. As part of our proposed field effort we would establish and maintain a long-baseline transponder network to service the EPR AST between 9° 46'-51'N that could be used by all EPR ISS investigators. In addition, the very high spatial and vertical resolution of the data to be collected will permit bathymetric comparison studies to be made in the future, as well as providing an ability to confirm the nature of bathymetric change due to volcanic and hydrothermal constructional and erosional (collapse) processes over the ~ 9 km length of the focused area where hydrothermal venting is occurring.

Two scientific objectives provide the driving force for our proposed Jason2/SM2000 mapping at the EPR ISS. These goals are consistent with several of the stated Ridge2000 ISS objectives for the EPR. Our proposed work will specifically address and contribute to knowledge of the spatial linkages between volcanic and hydrothermal/biological processes by producing a very high resolution map of the AST that includes volcanic, hydrothermal and biological features. The spatial arrangement of the various hydrothermal, biological and volcanic features, including the types of volcanic morphologies exposed at the surface and inferred to be within the upper crustal section, will provide clues to the shallow crustal permeability and possible hydrologic flow paths. The near-bottom magnetic data will provide quantitative data to correlate with the surface exposures of hydrothermal venting and biological colonization and help constrain the geometry of fluid flow paths - both current and relict.

We seek to address the following hypotheses:

1) The 1991-1992 eruptive volcanic fissures within the EPR AST between 9° 46'-51'N, and the underlying feeder dikes, provide the first-order control on hydrothermal vent distribution within the AST. High-temperature vents within the AST are primarily located along the trace of the 1991 eruptive fissure, hence the hydrothermal system there is being focused by the vertical to near-vertical dike(s) that sourced the 1991 eruption. The three northernmost vents are located along the bounding wall or at the rim of the AST. Mapping the position and along/across strike morphology and topography of the primary fissure, and it's spatial relationship to the AST walls, as well as the position of adjacent volcanic constructs, high-temperature vents and surrounding low-temperature, biological communities will permit a detailed spatial analysis of all the relevant hydrothermal and volcanic features of the AST. Correlating these data to the identification of small-scale magnetic lows attributable to hydrothermal venting within the AST will permit us to test the notion that the near-surface dike is providing a primary control on vent location and shallow circulation. The combination of these high-resolution geophysical and bathymetric data will define the volcanic structure of the AST and its relationship to the high-temperature vent positions and locations of all biological communities. In this manner, a holistic perspective of the current high- and low-temperature fluid outflow sites within the zone of focused hydrothermal venting at the EPR ISS can be established. These data will be critical to future studies that seek to develop hydrologic models of the shallow crustal permeability and are necessary to both model and design experiments to study hydrothermal flux at this site.

2) Breakout channels within the AST walls serve as long-term (100s to 1000s of years) controls on lava distribution, and the study of channelized sheet flow can provide important first-order constraints on submarine volcanic effusion rates. Detailed study of these channels and the detailed micro-morphology and topography, and geochemical analyses of channelized sheet lava can provide important estimates of lava effusion rates and the processes controlling submarine lava morphologic transitions. In addition, baseline mapping of the AST, such as we propose, will permit quantitative comparison over long time periods (5-20 years) of the topography and morphology of the EPR ISS site that are critical should subsequent volcanic eruptions or significant tectonic events alter the AST and the hydrothermal features and system that exist there.

Linkages to Other EPR ISS Proposals

1) Our proposal provides a very detailed, nested survey of the AST within the EPR ISS 'bulls eye' that can be placed within the broader-scale EM300 bathymetric and additional DSL-120A side scan sonar mapping planned by White and Macdonald, and the MCS experiment designed to map the current geometry of the axial magma lens by Carbotte et al. S. White is a co-PI on our proposal and would be involved in our field program. A few days of our planned Jason2 mapping would be dedicated to reconnaissance surveying of any hydrothermal sites discovered by the White/Macdonald regional mapping of the EPR crest between Siqueiros and Clipperton.

2) The detailed SM2000 sonar and near-bottom magnetic maps we will produce of the EPR crest, including the primary fissure system and the AST, will serve as the topographic and spatial baseline for the detailed

biological and chemical experiments such as those proposed by Shank et al. and Lutz et al., to study discrete low-temperature biological communities within the EPR ISS ‘bullseye’ in the 9° 49’-50’N area, and Van Dover et al. for site-specific biological sampling.

3) Our proposed mapping of the AST and identification of the spatial arrangement and inferred geometry of sub-surface fluid flow paths beneath the high and low-temperature vent sites will provide the physical context for the Sohn, Fornari, Shank micro-seismic and vent fluid temperature monitoring study that seeks to understand the nature of thermal cracking beneath the EPR ISS ‘bulls eye’ and it’s influence, over 3 years, on the hydrothermal system at this site.

Proposed Field Program Logistics

Transit (r/t Manzanillo, MX): 6 days (includes 2d for transit during the field program)
Transponder Net Install (8 total): 2 days (permanent net for 5 year deployment)
Jason2-SM2000/magnetic mapping: 7 days
Jason2- volcanic & hydrothermal & detailed magnetic mapping: 9 days (includes 3-4 days for recon. for White/Macdonald hydrothermal sites discovered on their leg)

= 24 days total field time