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3-D/4-D Seismic Reflection Imaging of the East Pacific Rise Integrated Study Site at 9°50'N

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We propose a 3-D seismic reflection survey of the Ridge 2000 Integrated Study Site (R2K ISS) on the northern East Pacific Rise (EPR) between 9° 45' N and 9° 55' N. The survey will provide an optimal 3-D seismic reflection image of the size, distribution, and physical properties of magma bodies and upper crustal structure at the ridge axis, and a benchmark against which changes in the crustal magmatic and hydrothermal system can be documented in the future through time lapse 3-D seismic reflection studies, also known as 4-D seismic imaging.

The 3-D seismic reflection survey we propose will image a 400 sq km area centered on the EPR ISS site to the level of the mid-crustal magma body (~1-2 km depth). The magma lens is the heat source for hydrothermal processes that are known to be active and variable in space and time on this ridge segment, and is the source for surface volcanism also known to be recently active here. The 6 km offset available from R/V Maurice Ewing's digital streamer will permit the establishment of a highly accurate 3-D seismic velocity field in the oceanic crust above the magma lens which is of intrinsic interest for understanding crustal property variations in the region, including its temperature and permeability structure. It will also allow application of processing techniques such as 3-D pre-stack depth migration that are needed to produce a geometrically accurate seismic reflection image of the EPR axial magma chamber. These images will provide the ideal foundation for understanding the variation and distribution of surface phenomena at the ridge axis such as hydrothermal circulation, biological activity, volcanism and seismicity and their linkages with subsurface tectonic and magmatic processes within the oceanic crust.

The EPR ISS is located in one of the most dynamic areas of the mid-ocean ridge system. The variability in space and time of surface volcanic, hydrothermal and other phenomena must reflect or be strongly modulated by changes in the properties of the magmatic system, but the extent to which changes at the seafloor directly respond to those beneath is not known. At a spreading rate of 11 cm/year, magmatic diking events are expected to take place at an average of 10 year intervals, but they are unlikely to be regular. The last observed volcanic event at the 9°50'N area was in 1991, and recent studies suggest that a new eruption may be imminent. Repeat 3-D seismic reflection studies, or 4-D seismic imaging, can track changes in subsurface magma distribution throughout the rifting and diking cycle at the EPR ISS. Developed by the exploration industry, this approach has been highly successful in monitoring fluid flow in oil and gas reservoirs. We propose to apply this same technique to study the dynamics of the magmatic and hydrothermal system at the EPR ISS. Ongoing studies of hydrothermal activity, seismicity, vent fluid chemistry, biological activity, and seafloor morphology as part of the R2K program at the EPR ISS would be used to guide the timing and detailed location of subsequent 3-D surveys. The 3-D grid would be reoccupied several years after the original survey and a second 3-D image made of the same volume and analyzed for changes. Methods developed by the Lamont 4-D Technologies Group will be used to correct the 3-D data volumes for differences in survey parameters and to quantify the differences between the 3-D images in order to identify real changes in the physical system. This technique is not theoretically or practically possible with conventional 2-D reflection profiles due to the inherent inability to correct for differences in navigation and streamer feathering within a 2-D image plane. Only 3-D seismic reflection imaging is capable of providing images with sufficient resolution and detection ability to remotely observe and track the flow of magma and changes in its physical properties at depths of 1-2 km below the seafloor.

What we propose at this stage is 1) to acquire a high-resolution 3-D seismic reflection image of the EPR ridge axis and axial magma chamber at the 9°50'N EPR ISS; 2) to integrate the seismically observed ridge axis crustal structure and physical properties of the axial magma chamber with observations from related studies of hydrothermal and biological activity, geochemistry, petrology, seafloor morphology, faulting and seismicity; and 3) to conduct a suite of 4-D modeling studies that begin with the imaged 3-D volume to determine the amount of change in the magmatic plumbing system that is needed to be detected by repeated reflection seismic images. We do not, at this point, propose subsequent 3-D surveys to produce the 4-D images. The outcome of the 4-D modeling studies will establish the viability of the 4-D approach to imaging the dynamics of magma system behavior at mid-ocean ridges. We believe that the proposed 3-D survey will provide a crucial data set for understanding the crustal magmatic and hydrothermal system at the EPR ISS site, regardless of any future work, while simultaneously providing the opportunity for later time lapse studies of this dynamic system.