Fluid flow systems offshore Costa Rica revealed by 2-D seismic MCS data (IODP proposal 633)

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Quantification of the global carbon and water cycle requires improved understanding of complex forearc dewatering processes of erosive subduction zone systems. The same processes are furthermore pertinent to the functioning of seismogenic zones in erosive subduction settings. Such processes can be best studied at seafloor mounds which are related to mud diapirism/volcanism and precipitation of authigenic carbonates, and at large-scale slides related to the subduction of seamounts. These areas are windows to the deep parts of the subduction zones as they are cold seeps where fluids from different depths of the subduction zone system get expelled into the water column and can be sampled.

Because of their size and high fluid expulsion rates Mound Culebra and Mounds 11&12 on the Pacific continental margin of Costa Rica, are targets for fluid sampling proposed in IODP drilling proposal 633-Full2. Analysis of 2-D MCS seismic data across these mounds constrains the architecture and formation mechanisms of mound structures and provides information on how the ascending fluids interact with gas hydrate formation and dissociation.

The conditions for the formation of mounds at the erosive margin off Costa Rica seem to be fundamentally different from those described for many accretionary prisms and passive margin settings. This is attributed, in this area, to a lack of high sedimentation rates, which are generally assumed as a pre-requisite for the generation of overpressured mud. Geochemical analyses of methane hydrate and chloride anomalies as well as heat flow modeling of the mounds indicate deeply sourced fluids discharged by clay dehydration at the decollement [Hensen et al., 2004; Grevemeyer et al., 2004; Schmidt et al., 2005]. At Mounds 11&12, an observed preferred NW-SE orientation on the scale of individual carbonate outcrops [Klaucke et al., 2008] as well as of both mounds coincides with the observed general slope-parallel trend of normal faulting at the Costa Rica margin [Hensen et al., 2004]. Hence, the fracture porosity of faults which extend through the overriding plate and provide the paths for fluids liberated by early dehydration reactions from the plate boundary appears to dominate the hydrogeological system and may also control the long-term tectonics at erosive margins, e.g. the onset of seismogenic behaviour [Ranero et al., 2008].

In order to test the hypothesis of deeply sourced and fault-controlled dewatering sites and to better understand the interactions between gas hydrate formation and dissociation with fluid ascent from deep sources, new pre-site survey seismic profiles were acquired using the 36-gun four-string linear gun array of R/V Marcus Langseth, and a 240-channel streamer comprising 3000 m of active length. MCS seismic data processing included cmp crooked line binning with 6.25 m, bandpass filtering 4/8-180/240 Hz, resampling from 0.5 ms to 2 ms, spherical divergence correction using the smoothed depth migration velocity field, and a shot gather consistent predictive deconvolution. The seismic lines were prestack depth migrated, in which the velocity model is iteratively improved from top to bottom using depth focussing analysis and residual moveout correction on common image point gathers. Additionally, a true amplitude prestack time migration was applied to the data.

Data processing and analysis of the uppermost portions of the subsurface beneath BSR depths reveal an upbending of the bottom-simulating reflection (BSR) towards the mounds and an absence of the reflection in the area of the fluid conduit, which may indicate a build-up of free gas within the gas hydrate stability zone, probably due to increased fluid flow and associated hydrate dissociation [Wood et al., 2002]. Improvement of the deep imaging currently involves multiple attenuation (radon transformation, wavefield extrapolation methods) and detailed velocity analysis for the lower sedimentary portions and beneath the basement. We are investigating the role of the acoustic basement for the fluid ascent and the location of fault structures with respect to surface features. The selected mound sites are both related to deep-reaching fault systems, corroborating preliminary estimates of the source depth of fluids and extruded material. In addition, the new seismic data shows differences in terms of the mounds' activity and stage of development.

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