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# Three Distinct Fluid Systems at the Costa Rica Subduction Zone: Chemistry, Hydrology, and Fluxes

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Fluids play an important role in subduction zone processes. The pore fluids obtained from a drillhole transect across the Middle America Trench, offshore northern Costa Rica (ODP Leg 170), provide a unique opportunity to study fluid transport and dewatering processes and the resulting solute and heat fluxes at this dominantly non-accretionary subduction zone. Three geochemically distinct and mostly independent fluid flow systems have been identified. One is in the upper oceanic basement of the incoming Cocos plate, the second is in the décollement zone and upper plate sediments, and the third is in the underthrust sediment section.

The upper oceanic basement flow system is manifested by the extremely low conductive heat flow of the incoming plate, 8-13 mW/m$^2$, ~10% of the expected value for a ~24 Ma crust (Langseth and Silver, 1996); the significant heat loss is by lateral fluid advection of modern seawater in the uppermost oceanic basement beneath the sediment sequence. Results of basement flow are seen in the reversal of pore fluid concentration gradients in the overlying sediments. Dissolved Ca, Mg, Si, Sr, Li, and sulfate concentrations and Sr and Li isotope ratios return to near modern seawater values. Pore fluid profiles show that diffusion and not upward advection dominates in the basal sediment section. Therefore, using (1) the reversed chemical and isotopic gradients in the 130 m basal sediment section, and (2) the physical properties of the sediments, and assuming that (a) the thickness of the upper oceanic basement fluid flow horizon is approximately 200 m with average high porosity of ~10% (as it is at the Costa Rica Ridge, ODP Site 504B), and (b) that because of the low temperature and rapid flow rates the fluid is dominantly unmodified seawater, the calculated approximate age of the upper oceanic basement formation fluid is 15 to maximum 20 x 10$^3$ years, and the fluid flow rate is on the order of 2-5 m/yr. (Kastner et al., 2000, in preparation; Silver et al., 2000).

A main conduit, thus solute and heat transport pathway for the second hydrologic system is the décollement. Additional pathways are through thrust faults and more permeable horizons in the deformed upper plate sediments. Although the pore fluids chemistry also indicates diffusive flow in the wedge sediments, this flux must be minor because of the very low permeability sediments. The chemical and isotopic concentrations of the décollement and prism fluid system, including advected thermogenic hydrocarbons, constrain the temperature of the fluid-rock reactions at the source region to *120 and *150 C, a temperature characteristic of the culmination of the smectite to illite reaction and typical of the seismogenic zone up-dip limit (Hyndman and Davis, 1992). Assuming ~10ºC/km geothermal gradient the fluid originates at 10-15 km depth. This deep-seated fluid is characterized by lower than seawater Cl, K, Na, and Mg concentrations, significant enrichments in Ca, Li, and Sr concentrations, non-radiogenic Sr isotopes, and enrichments in $^6$Li and $^{37}$Cl.

Beneath a sharp geochemical discontinuity at the décollement is a third fluid flow system within the underthrust sediments. Despite considerable dewatering, particularly in the hemipelagic section, the underthrust section chemical profiles display essentially the same geochemical structure as in the incoming, reference, sediment section, except for significant changes in Ba, sulfate, and nutrient components concentrations (i.e. ammonium, alkalinity, phosphate). The similarities indicate that the fluids are primarily expelled laterally, thus maintaining most of the main characteristics of the concentration-depth profiles observed at the reference site. The differences are caused by bacterial reduction of sulfate to zero concentration upon underthrusting, thus inhibiting diffusional communication with overlying seawater. The rapid flow must therefore be along high permeability sediment horizons connected through a network of microfractures and/or microfaults, and the discharge is at the seafloor. The increase in pressure with depth (Saffer et al., 2000, Earth Planet. Sci. Lett.) does not permit communication with the deeper upper oceanic basement fluid flow system.

Fluid compositions and fluxes from the three systems are important for determining the return flux to the oceans as well as the composition of the residual slab subducted to the mantle.