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Lower plate deformation structures along the Costa Rica erosive plate boundary – results from IODP Expedition 344 (CRISP 2)

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The primary objective of Integrated Ocean Drilling Program (IODP) Expedition 344 offshore the Osa Peninsula in Costa Rica was to sample and quantify the material entering the seismogenic zone of the Costa Rican erosive subduction margin. Fundamental to this objective is an understanding of the nature of both the subducting Cocos plate crust and of the overriding Caribbean plate. The subducting Cocos plate is investigated trying to define its hydrologic system and thermal state. The forearc structures recorded by the sediment deposited on the forearc, instead, document periods of uplift and subsidence and provide important information about the process of tectonic erosion that characterizes the Costa Rica margin.

Offshore the western margin of Costa Rica, the oceanic Cocos plate subducts under the Caribbean plate, forming the southern end of the Middle America Trench. Subduction parameters including the age, convergence rate, azimuth, obliquity, morphology, and slab dip all vary along strike. The age of the Cocos plate at the Middle America Trench decreases from 24 Ma offshore the Nicoya Peninsula to 15 Ma offshore the Osa Peninsula. Subduction rates vary from 70 mm/y offshore Guatemala to 90 mm/y offshore southern Costa Rica. Convergence obliquity across the trench varies from offshore Nicaragua, where it is as much as 25° oblique, to nearly orthogonal southeast of the Nicoya Peninsula. Passage of the Cocos plate over the Galapagos hotspot created the aseismic Cocos Ridge, an overthickened welt of oceanic crust. This ridge is ∼25 km thick, greater than three times normal oceanic crustal thickness. During IODP Expedition 344, the incoming Cocos plate was drilled at sites U1381 and U1414.

Site U1381 is located ∼4.5 km seaward of the deformation front offshore the Osa Peninsula and Caño Island. It is located on a local basement high. Basement relief often focuses fluid flow, so data from this site are likely to document the vigor of fluid flow in this area. Site U1414 is located ∼1 km seaward of the deformation front offshore the Osa Peninsula and Caño Island. Primary science goals at Site U1414 included characterization of the alteration state of the magmatic basement.

Brittle structures within the incoming plate (sites U1380, U1414) are mineralized extensional fractures and shear fractures. The shear fractures mainly show a normal component of shear. Within the sedimentary sequence both types of fractures dip steeply (vertical to subvertical) and strike NNE-SSW. Deformation bands trend roughly ENE-WSW, sub-parallel to the trend of the Cocos ridge. Structures in the Cocos Ridge basalt mainly comprise mineralized veins at various orientations. A preferred orientation of strike directions was not observed. Some veins show straight boundaries, others are characterized by an irregular geometry characterized by brecciated wall rock clasts embedded within vein precipitates. The vein mineralization was analysed in detail by RAMAN spectroscopy. Precipitation conditions and fluid chemistry were analysed by fluid inclusions entrapped within vein minerals. Vein mineralizations mainly consist of carbonate (fibrous aragonite, calcite), chalcedony, and quartz. Vein mineralization is mainly characterized by zoned antitaxial growth of carbonate fibres including a suture along the central vein domains. Quartz is often characterized by fibre growth of crystals perpendicular to the vein boundaries, too. These zoned veins additinally have wall rock alteration seams consisting of clay minerals. The precipitation sequence basically indicates that fluid chemistry evolved from an CO_2-rich towards a SiO_2- rich fluid.