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Multiple reverse, normal and strike-slip faulting 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 Costarican 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.

Brittle structures within the incoming plate (sites U1381, 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. Vein mineralizations mainly consist of carbonate, quartz and pyrite. Quartz is often characterized by fibre growth of crystals perpendicular to the vein boundaries.

The top 150 m of the sediments in the prism-toe at about 2.5 km from the frontal thrust (Site U1412) are characterized by the presence of normal faults. These structures form distinct shear planes with little displacement and appear to form two conjugate sets with NW-SE and NNE-SSW trends. This reveals a sub-vertical orientation of the maximum principal stress axis, σ_1, and a sub-horizontal, ENE-WSE orientation of the minimum principal stress axis $_3$ indicating a stress regime characteristic of normal faulting. We interpret these faults as compaction-related features. As the stratigraphic age within this interval is Pleistocene, the deduced formation age of the normal faults is younger than Pleistocene. Deeper in the sediment sequence of the prism toe, fault zones are localized between 330 and 342 mbsf, and between 358 and 365 mbsf. Adjacent and within these fault zones, a well developed foliation with varying dip angles is observed.

Moving landward across the forearc, Site U1380 is located on the middle slope. There 154 fault planes were identified throughout the whole cored interval. Areas of particularly localized faulting and intense fracturing and brecciation were defined as fault zones. The brecciated domains are composed of cm- to sub-cm-sized angular fragments aligned along a preferred orientation and with polished surfaces. The lower part of Site U1380 is characterized by a downhole trend of decreasing bedding dip angles. Dip angles change from an average of 40° above 630 mbsf, to an average of 10° in the lower 100 m of the hole. The decrease of bedding dip value is not linear, but shows steps associated with brecciated zones. This interval also corresponds to a relative increased frequency of fault planes. Faults with both a normal and reverse sense of shear are common throughout the hole, equally present, and their abundance increases downhole. Strike slip faults increase in abundance downhole as well. This section also includes well consolidated/cemented sediments containing mineral veins. The veins indicate that high fluid pressure was generated just below the cemented interval.

Site U1413 is located on the upper slope of the Costa Rica forearc. Faulting-related deformation is abundant from approximately 180 mbsf to the bottom of the drilled section. Normal faulting is usually more abundant than reverse faulting. Dip angles of normal faults and reverse faults vary from subhorizontal to subvertical with a maximum dip of 75°. Both normal and reverse faults are not homogenously distributed along the entire hole. The deeper parts are additionally characterized by high-angle reverse faults with unusual steep dip angles (> 75°).

The structures within the mid- to upper slope of the Costa Rica forearc may therefore be associated with the development of an over-steepened slope margin, thrust-related anticlines, fault reactivation, structural inversion and over-printing, probably related to seamount impact. Faulting within the upper plate additionally controls the distribution of fluid seeps. Fluids released within the lower plate may migrate along the plate boundary and into the upper plate.