Paper Number: 727

Detachment faulting at the Mid-Atlantic Ridge

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Oceanic lithosphere is generated at mid-ocean ridges. It is now well established that at slow spreading ridges, melt supply may be insufficient to form a continuous magmatic oceanic crust. Plate separation is then partly accommodated by tectonic processes and in particular by long-lived, low angle detachment faults that exhume rocks originated from the deep crust and the mantle.

The ODEMAR cruise (R/V Pourquoi Pas, Nov-Dec'13) aimed at investigating two detachment faults along the Mid-Atlantic Ridge at 13°20'N and 13°30'N respectively, to better understand their morphology, geology and tectonic fabric. Both faults show striated surfaces extending ~6 km in the spreading direction, and have therefore been active for more than 0.5 Myrs, based on a full spreading rate of ~25 km/Myr. We first conducted extensive microbathymetric surveys with the AUV ABYSS (GEOMAR). The resulting high-resolution bathymetric maps guided our geological observations and sampling using ROV VICTOR (IFREMER).

Both fault surfaces display individual microbathymetric lineations throughout the >150 m of fault zone thickness, that are traced up to ~2 km in the spreading direction. Flanks of individual lineations display fault planes exposed at the seafloor and extending ~20-100 m laterally with well-developed, extension-parallel striae. In addition to active high temperature hydrothermal fields, evidence of hydrothermal activity is scattered throughout the striated fault surfaces. The southern detachment fault is largely intact, with an undisrupted corrugated surface suggesting that it is still active. An abrupt, continuous moat where the fault surface emerges from the seafloor continuously sheds rubble onto the fault plane, blanketing it. An apron surrounds the detachment dipping ~10-14° towards volcanic rift valley floor thus forming a thin wedge above the active fault, caused by uplift of hangingwall material due to drag by the emerging fault. In contrast, the northern detachment fault is cut by recent high-angle faults, shows mass wasting throughout, and therefore is likely inactive. These high angle fault scarps as well as mass wasting scars give access to 3D observations. The lithologies of the fault zone differ between the two detachments. At 13°20'N, greenschist metabasalt fault breccias mixed with minor serpentinite make up the fault zone. At 13°30'N the scarps cutting the detachment system reveal highly heterogeneous deformation, with phacoidal blocks of undeformed peridotite and gabbro enclosed in anastomosing shear zones. We infer that the faults are characterized by anastomosing zones of localized, strongly anisotropic deformation at different scales (m to km), bounding bodies of largely undeformed rock (basalt, gabbro, peridotite) elongated in the extension direction. Hangingwall material (basalt and dolerite) may be reworked into the fault and effectively accreted to the footwall, both as fault breccia and as large blocks within the fault. This mixing occurs at depth, consistent with greenschist facies recrystallisations.

These new fine-scale, *in situ* observations provide unprecedented insight into the three-dimensional and heterogeneous strain localization at oceanic detachment fault zones. They suggest that the material exposed at the fault surface may vary significantly among sites. Based on the 13°20N fault, we propose that material from the hanging wall can be incorporated into the fault at depth, resulting in a mixing with the exhuming mantle and in a very complex geology. This is further complicated by the systematic blanketing of the exposed fault surface as it emerges from the seafloor. This new understanding of the resulting geological assemblages in the fault zone should help identify fossil detachment faulting in ophiolitic massifs, and therefore contribute to deciphering the spreading rate and architecture of the oceanic lithosphere they derive from.