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Static and fault-related alteration in the lower ocean crust, IODP Expedition 345, Hess Deep

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IODP Expedition 345 drilled the first holes in the lower plutonic crust at a fast-spreading ridge, recovering primitive layered gabbros (Gillis et al 2014). Alteration can be subdivided into two series: 1) a largely static pseudomorphic alteration affecting predominantly olivine. This began in the amphibolite facies with minor secondary cinopyroxene and hornblendic amphibole replacing primary pyroxene, and sporadically developed corona textures with tremolite and chlorite replacing olivine and plagioclase respectively, but was predominantly in the greenschist and sub-greenschist facies with talc, serpentine, clay minerals,oxides andsulphides replacing olivine, and prehnite and locally other calcsilicates replacing plagioclase, commonly in micro-vein networks. Albitic plagioclase is sporadically developed, and locally zeolite and carbonate. 2) An overprinting metasomatic alteration under sub-greenschist or perhaps lowermost greenschist conditions(<350 °C) dominated by prehnite and chlorite, with subordinate epidote/clinozoisite, secondary clinopyroxene in veins, clays and zeolite. This alteration is spatially related to cataclastic fault zones and macroscopic veins. Comminuted plagioclase in cataclasites is commonly completely replaced by prehnite, while chlorite may completely pseudomorph olivine, locally with textures suggesting replacement of previous secondary minerals such as talc and serpentine. Chlorite also ubiquitously occurs as patches replacing plagioclase along grain boundaries, locally associated with carbonate and amphibole needles. Metamorphosed dykes show chilled margins within the cataclasites, and are affected by cataclastic deformation. Faults, dykes and overprinting alteration are all inferred to be related to the westward propagation of Cocos-Nazca spreading that formed Hess Deep.

Samples of different alteration and cataclastic domains were cut out of this section chips for isotopic analysis. 87Sr/86Sr ratios of cataclasites and dyke rocks are in the range 0.7037 – 0.7048, indicating alteration by seawater at moderate integrated fluxes. The highest values were in cataclasites overprinted by prehnite. δ18O values range from +1 to + 6 per mil, indicating alteration at temperatures generally >200 °C. Preliminary modelling using Comsol Multiphysics suggests that the temperatures of the overprinting alteration could be achieved in a permeable fault slot cutting through crust 0.5 to 1 m.y. old.

Our study reveals a low temperature alteration assemblage dominated by prehnite and chlorite that is not normally associated with the lower oceanic crust. Yet it is likely to be common in any location where faults intersect the Moho off-axis, including transform faults, near axis normal faults at slow spreading ridges, and bending faults at subduction zones, and would be accompanied by serpentinites in upper mantle rocks, as seen at ODP site 895 in Hess Deep. This prehnite + chlorite assemblage may therefore be significant in the release of volatiles in subduction zones.

Gillis, K.M., Snow J. E. and Shipboard Science Party (2014) Primitive layered gabbros from fast-spreading lower oceanic crust. Nature, 505,204–207, doi: 10.1038/nature12778