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Extreme isotopic and chemical alteration in an extensional detachment fault, 15^{o} 45' N, mid-Atlantic ridge: a reaction zone for Rainbow-type vent fluids?

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Expedition JR63 sampled exposed extensional detachment fault rocks on a corrugated domal massif at 15^{o}45N, using the BGS/BRIDGE wireline drill. The same massif was later the location of Hole 1275 on IODP Leg 209. The surface of the massif consists of talc-tremolite-chlorite schists cut by metabasaltic intrusions with chilled margins, and also incorporating clasts of altered basaltic rock. The schists show brittle-ductile fabrics, and mineral assemblages and chlorite geothermometry suggest that deformation and alteration occurred under greenschist facies conditions (Escartin et al., 2003). The footwall consists of serpentinised harzburgite and dunite intruded by a 3 km sized gabbro, although no gabbroic rocks have been found exposed on the corrugated surface. Only minor ductile deformation has been observed in the footwall (Escartín et al, 2003; Leg 209 Shipboard Scientific Party, 2003).

Major and trace element analyses show that the dominant protolith of the schists was ultramafic, with either physical or chemical mixing with mafic rocks leading to enrichment in trace elements in some cases. Relatively undeformed talc-rich rocks in some cores contain pseudomorphs after pyroxene and relict olivine altering to carbonates, confirming the ultramafic protolith. Analysis of activity diagrams shows that the talc-tremolite assemblage can be formed from an ultramafic protolith if hydrous fluids

pass from mafic into ultramafic rocks. The same fluid passing from ultramafic or talc-tremolite rocks into mafic rocks would alter plagioclase to chlorite, as is observed in the basaltic intrusions.

Both the metabasaltic intrusions and the fault rocks show extreme alteration of oxygen isotopes with values ranging from +2 to -0.4 permil. These are amongst the lowest values ever reported from oceanic rocks, and are consistent with equilibrium between seawater and chlorite at about 300 ^{o}C. Gabbros from the footwall show values of +2 to +3.5, which are more typical of greenschist-facies alteration of ocean crust or ophiolites in zones of intense hydrothermal circulation. These gabbros have $^{87}Sr/^{86}Sr$ ratios of 0.703 to 0.7045, indicating reaction with evolved seawater. In contrast, ratios in the talc-tremolite fault rocks range from 0.705 to 0.7083, almost the same as seawater. The combination of oxygen and strontium isotopes is inconsistent with these being due to seafloor weathering, and hence the fault rocks must have been altered by a fluid maintaining seawater compositions to temperatures of at least 270 ^{o}C (the lowest values found from chlorite geothermometry). Again, this has never been observed in previous studies of oceanic or ophiolitic hydrothermal systems, where seawater invariably exchanges Sr isotopes along the flow path before entering greenschist facies reaction zones, so that values close to seawater are not observed.

Our data are consistent with intense, focused hydrothermal circulation of seawater within the fault zone, probably during active extensional faulting and gabbroic intrusion into the footwall. The fluid needs to have equilibrated with mafic rocks before entering the fault zone in order to cause the talc-tremolite alteration, yet maintain seawater Sr isotope ratios. This suggests focused recharge through a fractured basaltic hangingwall, with a Sr isotope front of seawater composition propagating throughout the recharge flow path. Rainbow-type (ultramafic-hosted) vent fluids have a chemistry consistent with equilibrium with talc-tremolite assemblages under greenschist facies conditions (Allen and Seyfried, 2003). We suggest that the talc-tremolite fault rocks represent a reaction zone for Rainbow-type vents. Rainbow-type vent fluids have unusually high REE and trace element contents (Charlou et al., 2002). A 5mm schistosity-parallel amphibole-ilmenite vein with the fault rocks is also enriched in LREE and other trace elements, as are ferrohornblende veins cutting footwall gabbros. These veins may give a direct link to subsurface hydrothermal fluids.

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