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Fluid circulations in the depths of accretionary prism: the record of quartz from the Shimanto Belt, Japan

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Fluids present in the depths of subduction zones play a major role on seismogenesis, although fluid circulations paths and physico-chemical conditions are still largely unknown. Two main reservoirs of water, either in the pores of sediments or bound to hydrous minerals, release large amounts of water in the relatively shallow and deep domains of subduction zones, respectively. The usual model of circulation assumes then a bottom-up circulation driven by fluid pressure gradients.

This study aims at reassessing this model, using the record of rocks from a paleo-accretionary prism, the Shimanto Belt in Japan. These rocks, buried to 5kbars and 300°C (Toriumi and Teruya, Modern Geology, 1988), were affected by pervasive fracturing throughout their history, from burial to exhumation. The quartz filling these fractures and the fluid inclusions that it contains keep the track of the fluid associated with the rock evolution.

Using a combined approach of microstructural observations by optical microscopy and cathodoluminescence (CL), and chemical characterization by electron and ion microprobe as well as microthermometry, we show that there are actually two distinct fluids that have cyclically wetted the rock at depth. The first one is an “external” fluid penetrating through macroscopic fractures and precipitating a quartz blue in CL. In contrast, a “local” fluid attended the formation of quartz brown in CL, precipitating in microfractures or associated with ductile recrystallization. The two fluids are also chemically distinct: Both have a salinity close to seawater, but the local fluid is fresher than the external one. In addition, the external fluid is richer in aluminum than the local one. Finally, the external fluid is very slightly depleted in δ^{18}O, although the difference is probably not significant and the first-order isotopic signal is a buffering by host rock.

Our interpretation of microstructures and chemical signatures is that the external fluid is seawater, penetrating to accretionary prism depths during transient phases of large-scale fracturing and fluid circulation. Macroscale fractures then close, permeability drops, and the fluid is progressively reequilibrated at depth with water produced in-situ by metamorphic reactions. The general scheme is therefore a top-down circulation, contrasting with the usually proposed bottom-up flux. We finally discuss geodynamical scenarios, such as during the postseismic phase or in association with thermal anomalies, where such a counter-intuitive top-down flux of water could prevail in subduction zones.