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Petrological insights into intermediate-depths of a subduction plate interface

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Understanding processes acting along the subduction interface is crucial to assess lithospheric scale coupling between tectonic plates, exhumation of deep-seated rocks and mechanisms causing intermediate-depth seismicity. Yet, despite a wealth of geophysical studies aimed at better characterizing the subduction interface, we still lack critical petrological data constraining such processes as intermediate-seismicity within oceanic subduction zones.
This contribution reviews recent findings from two major localities showing deeply subducted ophiolitic remnants (Zermatt-Saas, Monviso), which crop out in the classic, well-preserved fossil subduction setting of the Western Alps. We herein show that both ophiolite remnants represent large, relatively continuous fragments of oceanic lithosphere (i.e. several km-thick tectonic slices across tens of km) exhumed from $\sim$80 km depths and thereby provide important constraints on interplate coupling mechanisms. In both fragments (but even more so in the Zermatt-Saas one) pervasive hydrothermal processes and seafloor alteration, promoting fluid incorporation in both mafic and associated ultramafic rocks, was essential, together with the presence of km-thick serpentinite soles, to decrease the density of the tectonic slices and prevent them from an irreversible sinking into the mantle.
The Monviso case sudy provides further insights into the subduction plate interface at $\sim$80 km depths. The Lago Superiore Unit, in particular, is made of a 50-500 m thick eclogitized mafic crust (associated with minor calcschist lenses) overlying a 100-400 m thick metagabbroic body and a km-thick serpentinite sole, and is cut by two 10 to 100m thick eclogite-facies shear zones, respectively located at the boundary between basalts and gabbros, and between gabbros and serpentinites (the Lower Shear Zone: LSZ). The LSZ gives precious information on both seismicity and fluid flow:
(1) Eclogite breccias, reported here for the first time, mark the locus of an ancient fault zone associated with intraslab, intermediate-depth earthquakes at $\sim$80 km depth. They correspond to m-sized blocks made of 1–10 cm large fragments of eclogite mylonite later embedded in serpentinite in the eclogite facies LSZ. We suggest that seismic brecciation (possibly at magnitudes Mw $\sim$4) occurred in the middle part of the oceanic crust, accompanied by the input of externally-derived fluids.
(2) Prominent fluid-rock interactions, as attested by ubiquitous metasomatic rinds, affected the fragments of mylonitic basaltic eclogites and calcschists dragged and dismembered within serpentinite during eclogite-facies deformation. Detailed petrological and geochemical investigations point to a massive, pulse-like, fluid-mediated element transfer essentially originating from serpentinite. Antigorite breakdown, occurring ca. 15 km deeper than the maximum depth reached by these eclogites, is regarded as the likely source of this highly focused fluid/rock interaction and element transfer. Such a pulse-like, subduction-parallel fluid migration pathway within the downgoing oceanic lithosphere may have been promoted by transient slip behaviour along the LSZ under eclogite-facies conditions.
These petrological data are finally tied to bi-phase numerical models in which fluid migration is driven by fluid concentrations in the rocks, non-lithostatic pressure gradients and deformation, and that allow for mantle wedge hydration and mechanical weakening of the plate interface. We suggest that the detachment of such oceanic tectonic slices is largely promoted by fluid circulation along the subduction interface, as well as by subducting a strong and originally discontinuous mafic crust.