Nature and evolution of the subcontinental mantle along the Adria ocean-continent transition: the peridotite-pyroxenite association from the External Liguride ophiolites

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The architecture and tectonic evolution of non-volcanic continental margins has been extensively investigated in the last two decades in the western Iberian margin showing the existence of a zone of exhumed continental mantle, between continent and newly formed oceanic crust. On the other hand, the record of the Ligurian Tethys ophiolites has provided fundamental clues about the nature of this continent-ocean transition and the fate of the mantle in the extensional processes from rifting to continental breakup and inception of ocean spreading. In particular, some External Liguride peridotite bodies from the Northern Apennine represent a rare tectonic sampling of deep levels of old subcontinental lithosphere of the former Adria-Europe system exhumed at an ocean-continent transition. They therefore offer a good opportunity of throwing light into the evolution of mantle involved into rifting.

In the External Liguride (EL) units, the ophiolites consist of slices of exhumed subcontinental mantle, basalts and rare syn- to post rift gabbroic rocks, together with continental crust bodies locally displaying primary relationships with the ophiolites. Many EL peridotites have been affected by refertilization by asthenospheric melts during the Ligurian Tethys formation (Piccardo et al., 2004) and were eventually intruded by small MOR-type gabbro lenses and basalt dikes. However, some mantle bodies escaped these events retaining their old subcontinental origin and showing a beautiful record of their decompression history. The pristine mantle rocks are Ti-pargasite-bearing spinel-plagioclase lherzolites with a fertile geochemical signature. Available Nd-Sr-Os isotope data (Rampone et al., 1995; Snow et al., 2000) show a Proterozoic age as the time of accretion to the subcontinental lithosphere. The peridotites are in places characterized by garnet-bearing clinopyroxenite to websterite layers, possibly recording multiple events in the subcontinental mantle (crustal recycling, high-P crystal accumulation, melt-peridotite reaction) and testifying for an early stage of equilibration under high pressure and temperature conditions (~2.8 GPa and ~1100 °C). In the enclosing peridotites, the oldest recognisable texture is a spinel-facies low-strain tectonite. The spinel-facies assemblage was widely overprinted by plagioclase-facies recrystallization associated with development of a mylonitic fabric along hectometre-size shear zones. Textural, chemical and mineralogical evidence indicate that plagioclase formation and concomitant deformation occurred under subsolidus, melt-absent conditions (T ~ 950 °C). The fine-grained plagioclase-bearing mylonites were subsequently overprinted by a widespread polyphase brittle deformation (F1-F4 stages) under decreasing temperature conditions, coupled with hydration. The formation of Mg-hornblende ± chlorite in veins and as pseudomorphs after clinopyoxene (F1 stage) marked the onset of mantle hydration. The F2 stage included multiple serpentine veining episodes, associated with static serpentinization, to various extents, of the host rock. The subsequent brittle event F3 pervasively overprinted the former vein systems yielding cohesive "jigsaw" breccias recording intermittent fracturation of the serpentinized peridotite, fluid infiltration and precipitation of new phases (Cl-rich serpentine, Ni and Fe-sulphides, carbonates). Structural and mineralogical characteristics suggest development of a serpentinite-hosted hydrothermal system at this stage. Multiple calcite vein generations, commonly associated with Fe-sulphides and massive green serpentine, crosscut the F3 jigsaw breccias and bound the clasts, finally yielding ophicalcite-like rocks (F4 stage).

The ubiquitous brittle structures are consistent with a shallow detachment fault event that re-activated rheological weaknesses of the lithospheric mantle developed under high temperature conditions (i.e. the plagioclase-facies shear zones) and led to mantle exhumation at the seafloor.

The timing of the early decompression of the External Liguride mantle section, from the garnet stability field, is unconstrained. It presumably occurred in relation to the Late Variscan (Late Carboniferous to Early Permian) continental extension. Conversely, Lu-Hf and Sm-Nd ages obtained on garnet pyroxenites indicate that the low-pressure (< 0.9 GPa) portion of the exhumation, including the plagioclase-facies mylonites, was related to the Upper Triassic-Lower Jurassic rifting that led to continental break-up. The External Liguride plagioclase mylonites probably formed by an extensional shearing event related to a lithospheric "necking stage" caused by the ascent of underlying asthenosphere, as predicted by numerical, analogue and conceptual models of formation of non-volcanic-rifted margins, and marked the onset of the Mesozoic rifting evolution.