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Petrological and rheological evolution of lithospheric mantle at extensional settings: evidence from Alpine/Apennine ophiolitic peridotites.

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The subcontinental lithospheric mantle of the Europe-Adria system underwent Triassic-Jurassic lithosphere extension and continental break-up, leading to the opening of the Jurassic Ligurian Tethys. It was composed of rather fertile cpx-rich lherzolites bearing widespread spinel(-garnet) pyroxenite bands, mostly outcropping at Ocean-Continent Transition (OCT) zones of the ancient basin, and commonly showing complete equilibration at spinel-peridotite facies conditions (Ol+Opx+Cpx+Sp assemblages) ($1.0 \leq P \leq 2.5$ GPa, $T \sim 1000$ °C), with structural records of previous garnet-bearing assemblages in both peridotites and pyroxenites. Isotope data suggest that these rocks were isolated from the convective mantle and accreted to the thermal lithosphere from Proterozoic to early Mesozoic (Piccardo, 2008).

Triassic-Jurassic lithosphere extension under the action of far-field tectonic forces is marked by the development of km-scale mantle shear zones under spinel, plagioclase, and amphibole+chlorite facies conditions (Vissers et al., 1991; Montanini et al., 2006; Piccardo and Vissers, 2007) suggesting that they played a fundamental role in lithosphere thinning and lithospheric mantle exhumation to the sea-floor.

The asthenosphere underwent fractional melting on decompression, most probably beginning in Late Triassic times. The asthenospheric fractional melts percolated by diffuse porous flow the overlying extending mantle lithosphere, before being delivered to shallow lithospheric levels to form Jurassic gabbroic intrusions and Late Jurassic

basaltic extrusions, i.e., the oceanic crustal rocks of the Ligurian basin.

Melt percolation through the extending mantle lithosphere produced significant petrological and rheological modification of the pristine peridotites, as recorded by the ophiolitic peridotites outcropping at More Internal Oceanic (MIO) settings of the basin. Melt percolation at spinel-facies conditions was highly reactive and transformed pristine lherzolites to pyroxene-depleted harzburgites and dunites by means of pyroxene dissolution and olivine precipitation. When reaching shallower plagioclase-facies conditions the percolating melts underwent interstitial crystallization of microgabbroic material, producing significant impregnation and refertilization of the previous lithospheric lherzolites as well as reactive harzburgites-dunites.

Accordingly, several stages can be recognized in the extensional and rifting evolution of the lithospheric mantle in the Europe-Adria system, preceding complete oceanic opening:

1) *Subsolidus exhumation of lithospheric mantle* (from spinel-peridotite facies conditions) as a consequence of initial lithosphere extension;

2) *Decompressional partial melting of the asthenosphere* as thinning of the lithosphere continued;

3) *Porous flow reactive percolation of the lithospheric mantle by asthenospheric melts,* transforming pristine pyroxene-bearing/rich lherzolites to olivine-rich, pyroxene-poor/free harzburgites and dunites, with a concomitant temperature increase from $\sim$ 1000 to $\sim$ 1250 ^{o}C;

4) *Melt impregnation and interstitial crystallization*, transforming both pristine lherzolites and percolated harzburgites/dunites to plagioclase lherzolites at T $\sim$ 1250 ^{o}C.

The temperature and compositional changes resulting from lithosphere/asthenospheric melts interactions produced important modifications in rheological properties. A previous model (Ranalli et al., 2007) has shown that, if percolation and impregnation affect the bulk of the lithospheric mantle and the lithosphere deforms by pure shear, the resulting decrease in TLS (total lithospheric strength) is of the order of 80%. The deformation of the lithosphere, however, is always highly heterogeneous, and sometimes approximates conditions of simple shear along trans-lithospheric low-angle normal faults. If these shear zones in the lithospheric mantle are subject to localized percolation by asthenospheric melts (as described by Kaczmarek and Müntener, 2006, for km-scale shear zones in the Lanzo Massif, Western Alps), the rheological effects are considerable. On the basis of petrological constraints on composition and temperature, a decrease of one order of magnitude in local creep strength is expected, which translates into a decrease of approximately the same amount in the tectonic force required to deform the lithosphere at significant strain rates.

Therefore, lithosphere/asthenosphere melts interaction can result in a significant decrease in TLS in both the cases of bulk impregnation of the lithospheric mantle and heterogeneous impregnation along shear zones. This decrease is likely to be an important factor in the transition from continental extension to sea-floor spreading.

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