Geophysical Research Abstracts
Vol. 17, EGU2015-4563, 2015
EGU General Assembly 2015

The evolution of passive rifting: contributions from field and laboratory studies to the interpretation of modelling results

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Direct field/laboratory, structural/petrologic investigations of mantle lithosphere from orogenic peridotites in Alpine-Apennine ophiolites provide significant constraints to the rift evolution of the Jurassic Ligurian Tethys ocean (Piccardo et al., 2014, and references therein). These studies have shown that continental extension and passive rifting were characterized by an important syn-rift "hidden" magmatic event, pre-dating continental break-up and sea-floor spreading. Occurrence of km-scale bodies of reactive spinel-harzburgites and impregnated plagioclase-peridotites, formed by melt/peridotite interaction, and the lack of any extrusive counterpart, show that the percolating magmas remained stored inside the mantle lithosphere. Petrologic-geochemical data/modelling and mineral Sm/Nd age constraints evidence that the syn-rift melt infiltration and reactive porous-flow percolation through the lithosphere were induced by MORB-type parental liquids formed by decompression melting of the passively upwelling asthenosphere. Melt thermal advection through, and melt stagnation within the lithosphere, heated the mantle column to temperatures close to the dry peridotite solidus ("asthenospherization" of mantle lithosphere).
Experimental results of numerical/analogue modelling of the Ligurian rifting, based on field/laboratory constraints, show that: (1) porous flow percolation of asthenospheric melts resulted in considerable softening of the mantle lithosphere, decreasing total strength TLS from 10 to 1 TN m-1 as orders of magnitude (Ranalli et al. 2007), and (2) the formation of an axial lithospheric mantle column, with softened rheological characteristics (Weakened Lithospheric Mantle – WLM), induced necking instability in the extending lithosphere and subsequent active upwelling of the asthenosphere inside the WLM zone (Corti et al., 2007).
Therefore, the syn-rift hidden magmatism (melt thermo-chemical-mechanical erosion, melt thermal advection and melt storage) caused important compositional and rheological modifications in the mantle lithosphere and played a fundamental role in the evolution of rifting, favouring, in particular, faster divergence of future continental margins and active upwelling of deeper/hotter asthenosphere. Active divergent forces probably changed the extension regime from passive to active rifting (as envisaged by Huismans et al., 2001). Accordingly, melt thermal advection and melt storage, and the rheological modifications induced in the mantle lithosphere, had a fundamental role in the evolution of the Ligurian rifting (Piccardo, 2014; Piccardo et al., 2014).

Observations from the natural laboratory are pivotal when interpreting modelling results on the formation of rifted continental margins by extension of continental lithosphere leading to seafloor spreading.
The rheological characteristics of the melt-modified mantle lithosphere can provide natural constraints for the interpretation of variously termed components ("oceanic lithosphere, Huismans & Beaumont, 2014; "oceanic and syn-rift lithospheric mantle", Whitmarsh & Manatschal, 2012), located in some models at non-oceanic, sub-continental settings, either below the extending continental crust or between the sub-continental lithosphere and the upwelling asthenosphere.

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