Melt freezing at the lithosphere-asthenosphere interface: Geochemical evidence from the Oman peridotites

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Although the mantle section of the Oman ophiolite is mainly composed of extremely refractory harzburgites, some less refractory peridotites are observed in the lower mantle section. These less refractory peridotites are generally ascribed to a lower degree of melt extraction, the deeper peridotites being supposedly less affected by pressure-release partial melting. However, the Oman harzburgites do not show a gradual decrease of their refractory character from the top to the base of the mantle section, as it would be expected in this scheme. In order to better understand the origin of the less refractory peridotites in the Oman ophiolite, we carried out a whole rock major and trace element study of more than 80 peridotites, sampled along the Oman ophiolite mantle section, from the northern Fizh massif to the southern Wadi Tayin massif.

The Oman harzburgites are characterised by low clinopyroxene fractions (cpx<3%) and extreme trace element depletion (e.g., Yb = 0.08-0.35 x chondrite). Their chondrite-normalised REE patterns are steadily depleted from HREE to LREE. The less refractory peridotites display higher cpx contents (on average > 4%), higher HREE contents (Yb up to 0.8 x chondrite) and "spoon-shaped" REE patterns. Yet, these cpx-rich harzburgites are virtually indistinguishable from the other Oman harzburgites with respect to their Mg# ratios and olivine proportions. In fact, their more "fertile" character is mainly reflected in higher cpx/opx ratios and CaO content (0.25-1 wt.% for harzburgites and up to 2.6 wt.% for the more fertile peridotites). These variations suggests that they were individualised from the other harzburgites by a melt-rock reaction involving precipitation of cpx at the expense of opx.

Cpx-enriched harzburgites are unevenly distributed along the Oman ophiolite. They are found mainly in the deeper part of the massifs (Fizh, Wadi Tayin) but there is no direct correlation between their distribution and the distance to the mantle-crust transition zone. However, it should be noted that they are found in areas where lithosphere re-opening has been documented. We suggest that cpx precipitation in the Oman harzburgites underlines the lower boundary of pre-existing oceanic lithosphere thermally eroded by upwelling, partially molten asthenosphere. The occurrence of harzburgite re-fertilisation implies freezing of partial melts infiltrated across this boundary. This process would be related to the opening of the propagators identified in the Oman ophiolite.

Snowball Earth and basaltic traps

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The causes of the Neo-Proterozoic glaciations is still a matter of debate. One potential trigger for those glaciations is a major perturbation of the global carbon cycle, leading to the consumption of atmospheric CO_2, and finally to the cooling of the global climate.

The two main glacial episodes are characterized by intense rift formations. The Proto-Pacific ocean starts to open within the Sturtian stage, while the Iapetus ocean appears during the Varangian stage. In both case, the onset of rifts cutting through continental surfaces might have been coeval with the spreading of continental flood basalts. As demonstrated by Dessert et al (2001) for the K-T boundary, such events might severely impacts the long term evolution of the global climate, through intense consumption of atmospheric CO_2 by fresh basaltic surfaces, leading to non negligible global cooling at the million year timescale.

In the present contribution, we test such hypothesis using the COMBINE model (Goddéris and Joachimski, 2002), which couples a model of the C, O and P global cycles with a climatic model. We perform a study of the likelihood of the "basaltic" hypothesis, as a function of the pre-glaciation geochemical state of the exospheric system, and of the model parameters. In the case of the Sturtian glaciation, and assuming a pre-perturbation level of 280 ppm of CO_2, the onset of continental flood basalts over 8 million square km^2 along the equator (crossed by the Proto-Pacific rift) will drive the Earth into global glaciation 1.5 My after the event. The $\delta^{13}C$ of carbonates accumulating between the start of the continental plume and the onset of the global glaciation fall by 3 to 4 ‰, in response to the degassing of large amount of mantle carbon into the atmosphere. The global glaciation is calculated to last 14 My before the PCO_2 accumulation is big enough to melt the Earth surface. This hypothesis raises the question of the cyclicity of the glaciations. Once the glaciation ends, the basaltic surface starts again to weather, and plunge the Earth into a new deep glaciation. We calculate that the interglacial episode lasts 1.7 My. The migration of the basaltic trap southward can drive the Earth out of this cyclicity. Within 30 My (two "glacial cycles"), the basaltic trap, originally located at the equator, might have migrated 3500 km southward, within the dryer tropical area. Such migration reduces the consumption of CO_2 by the basaltic surface, preventing the Earth from a new global glaciation.