Ultra-reduced phases in ophiolites cannot come from Earth's mantle

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Until recently it was accepted that ophiolites form at low pressure along intra-oceanic spreading ridges. The identification of ultra-high pressure (UHP) phases in mineral concentrates of chromitites and harzburgites of ophiolite complexes in Tibet, the Polar Urals and elsewhere appears to be changing that view. It is now being argued that the mantle sections of ophiolites either originate in, or were processed within, the Earth's mantle at depths as great as 600 km [1,2]. Furthermore, UHP phases are often found associated with ultra-reduced minerals: native metals, silicides, carbides, and nitrides. The implication is that the mantle source regions of ophiolites, or at least domains within it, must be ultra-reduced, so reduced that practically all transition metals are in the metallic state.

We find this notion problematic. The UHP phases and super-reduced minerals are mostly recovered from heavy mineral concentrates of podiform chromitite ores or harzburgites, only rarely observed *in-situ* and then in texturally doubtful association. Thermodynamically, phases like SiC, TiC, and Fe-Si alloys are unstable with FeO and Cr_2O_3 bearing mantle minerals [3]. To illustrate this fact we simulate with piston cylinder experiments at 1300°C and 0.7 GPa the reactions that take place when SiC is compressed and heated together with olivine (Fo_{90}) and chromite, within a redox gradient encompassing more than 12 log-units in f_{O2}. In this redox gradient olivine is reduced to near-pure forsterite and enstatite plus metallic Fe, while trivalent Cr in chromite is reduced to Cr^{2+} and metallic Cr (in Fe metal), causing chromite to break down to a new (yet to be characterised) phase enriched in divalent Cr.

Silicon carbide and other ultra-reduced phases cannot survive in mid-asthenospheric, FeO and Cr_2O_3 bearing mantle for any length of time. The better explanation for these enigmatic phases is that they are plasma condensates, that they precipitated from plasmas generated when lightning struck mantle lithologies of exposed ophiolites [4]. When plasmas condense, the first condensates are oxygen-free precipitates including metals, metal alloys, and carbides if a plasma is C bearing. Since plasmas can condense on any type of surface, ultra-reduced phases that precipitated from plasmas do not record the origins, emplacement histories or redox states of the lithologies within which they occur.

[1] Griffin *et al.* (2016) *Journ. Petrol.* 57, 655–684. [2] Xiong *et al.* (2015) *Gondwana Res.* 27, 525-542. [3] Golubkova *et al.*(2016) *Contrib. Miner. Petrol.* 171, doi: 10.1007/s00410-016- 1253-9. [4] Ballhaus *et al.* (2017) *Geophys. Persp. Lett.* 5, 42-46.