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

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Abstract

Several recent papers have purported to find ultra-reduced minerals—as natural examples—within ophiolitic mantle sections, including SiC moissanite, Fe-Si alloys, various metal carbides, nitrides, and borides. All those phases were interpreted to be mantle derived. The phases are recovered from mineral concentrates and are assigned to the deep mantle because microdiamonds and other ultrahigh-pressure (UHP) minerals are also found. Based on these findings, it is claimed that the mantle rocks of ophiolite complexes are rooted in the transition zone (TZ) or even in the lower mantle, at redox states so reduced that phases like SiC moissanite are stable.

We challenge this view. We report high-temperature experiments carried out to define the conditions under which SiC can be stable in Earth's mantle. Mineral separates from a fertile lherzolite xenolith of the Eifel and chromite from the LG-1 seam of the Bushveld complex were reacted with SiC at 1600 K and 0.7 GPa. At high temperature, a redox gradient is quickly established between the silicate/oxide assemblage and SiC, of ~12 log-bar units in f_{O_2}.

Reactions taking place in this redox gradient allow us to derive a model composition of an ultra-reduced mantle by extrapolating phase compositions to 8 log units below the iron-wüstite equilibrium (IW-8) where SiC should be stable. At IW-8 silicate and oxide phases would be pure MgO end-members. Mantle lithologies at IW-8 would be Fe° metal saturated, would be significantly enriched in SiO_2, and all transition elements with the slightest siderophile affinities would be dissolved in a metal phase. Except for the redox-insensitive $MgAl_2O_4$ end-member, spinel would be unstable. Relative to an oxidized mantle at the fayalite-magnetite-quartz (FMQ) buffer, an ultra-reduced mantle would be enriched in enstatite by factor 1.5 since the reduction of the fayalite and ferrosilite components releases SiO_2. That mantle composition is unlike any natural mantle lithology ever reported in the literature. Phases as reduced as SiC or Fe-Si alloys are unstable in an FeO-bearing, hot, convecting mantle. Based on our results, we advise against questioning existing models of ophiolite genesis because of accessory diamonds and ultra-reduced phases of doubtful origin.

Keywords: Ultra-reduced minerals, moissanite, ultra-reduced mantle, ophiolites, oxidation state