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Oxidation of arcs and mantle wedges by reduction of manganese in pelagic sediments during seafloor subduction

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Abstract

Plate subduction links the Earth's surface and interior and may change the redox state of the Earth's mantle. Mantle wedges above subduction zones have high oxygen fugacity compared with other mantle reservoirs, but the cause is debated. Here we analyze high-pressure metamorphic rocks derived from ferromanganese pelagic sediments in the Qilian subduction complex, northwest (NW) China. We show that progressive metamorphism is a process of reducing reactions, in which Mn^{4+} is reduced to Mn^{2+}. On the global scale, such reactions would release significant amounts of oxygen ($\sim 1.27 \times 10^{12}$ g year^{-1}), estimated from the global flux of MnO in sediments passing into subduction zones. This budget is sufficient to raise the oxygen fugacity of the mantle wedge, hence arc magmas, to a higher level than other mantle reservoirs. In contrast, ferric iron (Fe^{3+}) enters hematite, aegirine, and garnet, without valence change and plays little role in the oxidation of the mantle wedge. Fe^{3+} remains stable to depths of >100 km but will transfer to the deeper mantle along with the subducting slab. The manganese reduction process provides a new explanation for high oxygen fugacity in the mantle wedge.

Keywords: Ferromanganese pelagic sediments, high-pressure metamorphism, reductive reactions, subduction zone, mantle oxidation