Effects of geodynamic setting on the redox state of fluids released by subducted mantle lithosphere

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Release of ferric iron by magnetite breakdown during subduction of serpentinised ultramafic rocks has the potential to oxidise the deep Earth and/or the sub-arc mantle because ferric iron can oxidise other elements. However, so far, there is no consensus on the oxidation state of fluids released during subduction of ultramafic rocks.

A comparison of opaque phase assemblages in subducted samples from a magma-poor rifted margin and supra-subduction zone geodynamic settings was undertaken to look for evidence of changes in ferric iron content as a consequence of subduction, and as a function of geodynamic setting. Thermodynamic calculations in the system Fe-Ni-O-H-S and Fe-Ni-O-S at the pressures and temperatures of interest were used to constrain oxygen activities and fluid compositions.

Samples from New Caledonia, which exemplify supra-subduction zone mantle, contain awaruite ($FeNi_3$) and equilibrated with hydrogen-dominated fluids at oxygen fugacities less than FMQ (quartz-fayalite-magnetite). In contrast, samples from the Zermatt Saas ophiolite, Western Alps, which represent mantle from a subducted magma-poor rifted margin, contain magnetite plus sulfur-rich phases such as pyrite (FeS_2), and are inferred to have equilibrated with water-rich fluids at oxygen fugacities greater than FMQ. This major difference is independent of differences in subduction pressure-temperature conditions, variation in peridotite protolith composition, or the nature of adjacent units. We propose that the Zermatt-Saas samples would have undergone more complete serpentinisation prior to subduction than the supra-subduction zone (SSZ) New Caledonian samples, and would have contained less awaruite prior to subduction than the SSZ samples. This difference explains the different fluid compositions, because awaruite-bearing assemblages buffer fluid compositions to hydrogen-rich compositions.

Thus, the redox contribution of subducted ultramafic rocks to the deep Earth and sub-arc mantle depends on the extent of protolith serpentinisation, and, therefore, on the pre-subduction geodynamic setting.