Pb-isotope of Fe-Ni alloy associated with serpentinite: Geochemical constraints on the fluid-mediated hyper-reducing environment in mantle wedge

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Although the occurrence of Fe-Ni alloy is very limited in the vicinity of modern Earth’s surface due to the highly oxidized state, serpentinization in the forearc mantle wedge can rarely provide extraordinary reducing environments that stabilizes the Fe-Ni alloy.

In order to understand those fluid-mediated hyper-reducing environments in serpentinizing mantle wedge of an active convergent plate margin, we revisited so-called ‘josephinite' ―an unusual ‘metallic rock' composed mainly of Fe-Ni alloy (awaruite)― found in the Josephine Ophiolite, by engaging in microtextural and geochemical analyses.

Microtextural analyses using high-resolution FE-SEM and FE-EPMA found the presence of Ni-As mineral within aggregates of Fe-Ni alloy; the Ni-As mineral also occurs as discrete grains in ‘josephinite'-hosting serpentinite, suggesting that Ni-As mineral acted as a precursor seed before the crystallization of Fe-Ni alloy.

Since each leachate obtained by stepwise leaching of a ‘josephinite' pebble confirmed compositional homogeneity, this allows to calculate weighted mean values that give much precise Pb isotope compositions of aliquots of seventeen leaching steps determined by ID-TIMS; the values yielded 207Pb/204Pb = 18.3378 ±0.0016, 206Pb/204Pb = 15.5693 ±0.0015, and 208Pb/204Pb = 38.0879 ± 0.0044. These newly obtained high precision Pb isotope compositions revealed that the ‘josephinite'-forming fluids have a minor GLOSS-like sedimentary component. The presence of Ni arsenide also supports the infiltration of arsenic-bearing external fluids derived from sedimentary rocks.

Considering the geological context of the Josephine Ophiolite, the ‘josephinite’-forming fluids might have been derived from the top layer of subducting sediments. The lack of high-pressure metamorphic rocks such as blueschist in ‘josephinite'-hosted serpentinite implies that the ‘josephinite' formation might have occurred at a relatively shallow level of serpentinizing mantle wedge.
The absence of carbonate minerals further postulates that redox agent of the ‘josephinite' forming hyper-reducing environment was H_2 evolved by the serpentinization rather than CH_4 that is commonly preserved in blueschist and eclogites. This fact would speculate a widespread hyper-reducing environment caused by H_2 fluids in a shallow level of serpentinizing mantle wedge.

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