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Chemical Composition of Spinel-group Minerals from the Paleozoic Asian Ophiolite Mélanges and Its Petrogenetic Significance

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1 Introduction

Historically, ophiolitic chromitites have satisfied more than half of the world's ore production needs despite of their small scale compared to those layerd intrusions (Stowe, 1987). Spinels are typical important accessory minerals, being the main reservoir for Cr in wide variety of mafic and ultramafic rocks from various tectonic settings (Irvine, 1965, 1967). Understanding of chromian spinel can give us sight into upper mantle process associated with mantle melting and nature of the parental melt composition from what it crystallized. Chromium behaves as a compatible element in spinel whereas Al partitions into the melt (Jaques and Green, 1980). The chromium number Cr# [a hundred times of atomic ratio of Cr/(Cr+Al)]of spinel has long been known to be an important and reliable geochemical parameter to estimate the degree of partial melting, temperatures and provenance in peridotites. Experiments and the study of natural occurrences have demonstrated that Cr-spinel from magmatic rocks depends on the composition of the parental melts and have been used to decipher the tectonic provenance of fragments of the mantle now presented in ophiolite sequences (Rollinson, 2008).

Many ophiolites have undergone hydrothermal alteration and weathering that can potentially modify Cr-spinel composition. The unusual chemical durability of Cr-spinel makes its original composition more likely to be preserved against process of alteration, particularly compared with other high-temperature silicate minerals such as olivine (Barnes and Roeder, 2001). However, original Cr-spinel compostions can also be modified during serpentinization and metamorphism (Saumur and Hattori, 2013). During these alteration, Cr is liberated from Cr-bearing silicates easily but is difficult extracted from Cr-spinel (Oze et al., 2004), this process is always accompanied with an increase in Fe^{3+} and Fe^{2+} contents at the expense of Al^{3+} and Mg^{2+} (Barnes and Roeder, 2001), producing ferrichromite and even magnetite . Replacement of Cr-spinel by ferrichromite usually takes place from crystal boundaries or fractures toward the interior of Cr-spinel grain, this process will bring about zoned grains. The zoned grain consists of mostly unaltered Cr-spinel core irregularly enveloped by variably thick feirrichromite and/or magnetite rims. Hence, only unaltered, primary spinel core can be used as a reliable petrogenetic indicator, and the compositional change occurring on the Cr-spinel may reflect the process of its metamorphic evolution (Proenza et al., 2008).

2 Results and Discussion

To decipher the petrogenesis of the serpentinized peridotites from the mantle sequences of Paleozoic Paleo-Asian ophiolite mélanges, including Aermantai (AMT) and Karamaili ophiolite mélanges (KRM) in Eastern Junggar, Bayingou ophiolite mélange (BYG) in North Tianshan, and Heiyingshan (HYS), Serikelayilake (SR) and Qiqijianake ophiolite mélanges (QQJ) in South Tianshan, we carried out detailed major elements in spinel group minerals analyzed by electron microprobe and the concentrations of a complete suite of minor and trace elements (Sc, Ti, V, Mn, Co, Ni, Zn, Ga) in primary Cr-spinel cores, using laser ablation-inductively coupled plasma-mass spectrometry. Cr-spinel cores Cr numbers [$Cr^{\#}$=100*Cr/(Cr+Al)] from the mantle sections are 57-87 (57-60 in low-$Cr^{\#}$ spinels and 84-87 in high-$Cr^{\#}$ spinels) in AMT, 42-68 in KRM, 55-67 in BYG, 43-58 in HYS, 36-62 in SR and 41-66 in QQJ, corresponding to various degree of partial melting of approximately 30-47% 17~37%, 27~37%, 18~26%, 13~33% and 16~34%, respectively. The TiO_2 contents of the Cr-spinels are usually below 0.3 wt% and the $Fe^{3+}/\Sigma Fe$ ratios (usually below 0.15 except for AMT which is about 0.2 in average) are very low. In particular, the bimodal groups of major

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element of Cr-spinels presented in AMT comprise of high-Cr# and low Cr#, characterized by the boninitic affinity. Compared to the composition of chromite from MORB, the studied Cr-spinels except for high-Cr# spinels have higher contents of Ti, V, Mn, Co, Zn and lower Sc, Ni and Ga concentrations, whereas the high-Cr# spinels in AMT have Sc enrichment. Experimental data are used to recover the compositions of the melts (eg. Al_2O_3, TiO_2, FeO/MgO) parental to the peridotites, showing the affinity with bonintic melts in AMT, whereas with MORB-like melts in others. Geothermobarometrical calculations on the olivine-spinel mineral pairs revealed average formation temperatures between 700-900 ℃ under a relatively high oxygen fugacity with $\Delta \log f_{O2}$ +1-3 above FMQ. Initial Cr-spinels commonly were altered during serpentinization and the post-magmatic tectonism, as evidence by the formation of ferrichromites and magnetites. The Fe^{3+}-Cr-Al chemical composition of spinel group minerals correlates well with the Cr spinels from the low amphibolite to greenschist metamorphic condition with estimated temperature of 500-600 ℃. Apart from AMT, it is inferred that the studied ophiolites formed in a supra-subduction zone environment, whereas the AMT perhaps formed in a marginal basin or back arc basin setting.

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