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Petrology, chalcophile element (PGE, Se) geochemistry and Sr-Nd-Os-S isotopes of the Neoproterozoic Lengshuiqing magmatic Ni-Cu ore deposits in western margin of Yangtze craton, SW China

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The Lengshuiqing magmatic Ni-Cu ore deposits are hosted in four small Neoproterozoic mafic-ultramafic intrusions that occur in a small area in the western margin of the Yangtze craton. Country rocks to these intrusions are Proterozoic metamorphosed volcanic-sedimentary rocks, granite and diorite. Major rock types of the ore-bearing mafic-ultramafic intrusions are peridotites, olivine pyroxenite and gabbro. Sulfide mineralization is associated with the ultramafic rocks that occur mainly in the bases of the intrusions. Olivine crystals in these intrusions are all depleted in Ca (<1000 ppm), which is most common for arc-type mafic-ultramafic intrusions worldwide. The forsterite contents of olivine in the Lengshuiqing ore-bearing intrusions are up to 83 mol%, indicating that their parental magmas experienced moderate fractional crystallization before. The whole rocks are all characterized moderate light REE enrichments relative to heavy REE, variable degrees of negative Nb-Ta anomalies [$(Th/Nb)_N$ from 1.3 to 6], positive $\varepsilon_{Nd}(t)$ from +1.1 to +5.8, and low $(^{87}Sr/^{86}Sr)_i$ from 0.7038 to 0.7050. The isotope data indicate that the parental magmas for these intrusions experienced only minor amounts of crustal contamination and that the negative Nb-Ta anomalies in the whole rocks are not due to crustal contamination alone but also record a primary feature for the parental magmas. This strongly supports the view that these intrusions are subduction-related, not mantle plume-related. The occurrence of rare rounded sulfide inclusions in some olivine and spinel crystals in the samples from these intrusions indicate immiscible sulfide droplets were present in the magma during olivine and spinel crystallization. The variations of olivine compositions and whole-rock incompatible trace element ratios indicate the involvement of multiple pulses of magmas with different compositions in the formation of the intrusions studied by us. Like other arc-type magmatic sulfide deposits worldwide, the PGE tenors in the Lengshuiqing deposits are very low. The estimated initial contents of PGE in the parental magmas of the Lengshuiqing deposits are two orders of magnitude lower than those in the undepleted picritic basalts in the world. The inferred PGE depletions in the parental magmas of these deposits are likely due to previous sulfide segregation during magma ascent or sulfide retention in the source mantle which in turn is likely due to low degree of partial melting in the mantle. The $\delta^{34}S$, $\gamma_{Os}(t)$ and S/Se of the sulfide ores are from -4.0 to +1.3 ‰, from 115 to 320, and from 4, 800 to 12, 500, respectively. These values are significantly different from the mantle values, indicating the addition of crustal sulfur to the mantle-derived magmas for these deposits. Sulfide saturation in the parental magmas for these deposits could have been triggered by addition of external sulfur alone or a combination of this with a moderate degree of fractional crystallization. Based on the results from this study, we suggest that future Ni exploration in the western margin of the Yangtze craton focus on the mafic-ultramafic intrusions that have ages and petrological-geochemical characteristics similar to those of the Lengshuiqing ore-bearing intrusions.