



Petrogenesis of the Late Triassic Ultrapotassic Fanshan Fe-P Ore-bearing Complex in the North China Craton: Constraints on the Mineralization

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Fanshan is a concentrically zoned complex with syenite in the core (unit 1), surrounded by ultramafic rocks (clinopyroxenite and biotite clinopyroxene; unit 2) and the outer rim of garnet- and orthoclase clinopyroxenite (unit 3). The rocks are composed of variable amounts of diopside, biotite, orthoclase, melanite, magnetite and apatite, with minor primary calcite. Monomineralic apatite rocks (apatite), nelsonite and glomerite exclusively occur in the unit 2. Geochemically, the Fanshan rocks are strongly enriched in light rare earth elements (LREE) and large ion lithophile elements (LILE; e.g., K, Rb, Ba, Sr), moderately depleted in high field strength elements (HFSE; e.g., Nb, Ta, Zr, Hf and Ti), and have a limited range of Sr-Nd-O isotopic composition ($^{87}\text{Sr}/^{86}\text{Sr}_i = 0.70513 - 0.70601$, $\varepsilon_{Nd}(t) = -6.8$ to -5.5 ; $\delta^{18}\text{O} = +7 - +9\text{‰}$). Similar mineralogy, mineral compositions, and primitive mantle- and chondrite-normalized trace element patterns observed in the three units suggest that all the rocks are co-magmatic. New mineralogical and bulk-rock geochemical data presented in this study and volume relationships provide mass balance estimate of the major element bulk composition of the complex and its parental magma. The calculated parental magma to the Fanshan complex can be classified as Group III ultrapotassic magma with elevated P_2O_5 (~ 2.0 wt.%) content. Very low-degree partial melting of metasomatized lithospheric mantle best explains the geochemistry and petrogenesis of the Fanshan complex. The source may have been metasomatized by a hydrous carbonate-bearing melt, which has imprinted the enriched Sr-Nd isotopic signature and incompatible element enrichments with conspicuous negative Nb-Ta-Zr-Hf-Ti anomalies and positive LREE anomalies seen in the resulting ultrapotassic parental magma. The mantle enrichment may have been associated with oceanic sediment recycling in the process of southward subduction of the Paleo-Asian oceanic plate during the Carboniferous and Permian. On the basis of the data presented in this study, we suggest that the Fanshan complex formed from the subduction-related lithospheric mantle source by continuous emplacement of hydrous primitive magma and mixing with fractionated magma, which led to extreme concentration of apatite in monomineralic apatite rocks and glomerite.