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Contamination of heterogeneous lower crust in Hannuoba tholeiite: Evidence from in situ trace elements and strontium isotopes of plagioclase

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Abstract

The Hannuoba basalt, located in the northern margin of the North China Craton, is a typical intracontinental basalt with ocean island basalt-like geochemical features and has been extensively studied. However, its origin and deep processes, such as magma mixing and crystallization conditions, are still unclear. To further understand the mechanisms leading to the compositional heterogeneity and magmatic processes of Hannuoba basalt at crustal and/or mantle depth, in situ major element, trace element, and $^{87}Sr/^{86}Sr$ compositional heterogeneity of four representative plagioclase crystals in three Hannuoba tholeiite samples, as well as whole-rock major and trace element data, are reported. According to the petrographic characteristics, the basalts are divided into fine-grained and coarse-grained groups. The anorthite content in plagioclase of samples varies in a small range (56–64%), but the content of trace elements in plagioclase from the coarse-grained samples is generally higher than that of the fine-grained samples. Clinopyroxene-melt equilibrium thermobarometer and plagioclase-clinopyroxene magnesium and rare earth element exchange thermometers show that the magma for the two types of basalt was stored and crystallized at a similar depth, and crystallized within a 20 °C (fine-grained basalt) and 50 °C (coarse-grained basalt) temperature window, which may be a reason for the grain size differences between the two types of basalts. We found that $^{87}Sr/^{86}Sr$ of all the studied plagioclase crystals varied from 0.70333 ± 0.00018 (2SE) to 0.70556 ± 0.00031 (2SE), a much large range than the whole rock of Hannuoba basalts reported previously and consistent with that of Cenozoic basalts in North China. Therefore, at least two kinds of melts with significant differences in isotope and minor heterogeneity in major and trace elements are injected into each magma plumbing system. The content of trace elements in the Hanuoba tholeiite is between the Hanuoba alkaline basalt and the lower crust, which may be explained by the mixing of the alkaline basalt and the lower crust, but the low $^{87}Sr/^{86}Sr$ (<0.704) characteristics of plagioclase cannot be derived from alkaline basalts, because trace element abundances in the plagioclase are not in equilibrium with the alkaline basalt. Therefore, we believe that the compositional heterogeneity of Hannuoba tholeiitic basalt is caused by the mixing of heterogeneous lower crust rather than different mantle-derived melts. In turn this indicates that the contribution of the continental lower crust to the continental basalt is more complicated than previously recognized.

Keywords: Basalt, plagioclase, strontium isotope, magmatic process, lower continental crust, Hannuoba