Petrological, geochemical, geochronological, and Sr-Nd-Hf-O isotopic constraints on the origin of the Dongcaohe ophiolite from the North Qilian Mountains, NW China

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Abstract

The Dongcaohe ophiolite, located in the southern margin of the North Qilian Mountains, is a tectonic block with an areal extent of 3 km×6 km. Its lithostratigraphic column, from the bottom upward, is dunite-troctolite-gabbro cumulates, isotropic gabbro and gabbronorite, sheeted dike diabase and basalt. Besides, there are numerous discordant late-intrusive layered troctolite-dunite lenticular bodies scattered in the dunite-troctolite-gabbro cumulates. The sequence of mineral crystallization, deduced from the mineralogy of the cumulate and isotropic rocks, is olivine-plagioclase-clinopyroxene-orthopyroxene and Fe-Ti oxide minerals. The Cr-spinel in dunite-troctolite cumulates and present-day abyssal peridotites have similar compositions. Also, the compositional variations of the plagioclase and clinopyroxene in the gabbroic rocks reflect crystallization from melts compositionally similar to the present-day ocean basalts.

In MORB-normalized multi-element plots, the gabbroic cumulates and isotropic gabbro-gabbronorite are characterized by enriched Th and U and depleted Nb, Ta, Zr, and Hf, very similar to the gabbroic rocks from the cores of the ODP hole 735B from SW Indian ocean. The multi-elements plots of the diabasic and basaltic rocks are generally flat and slightly enriched in incompatible elements Th and U. U-Pb zircon dating from gabbronorite, obtained by secondary ion mass spectrometers (SIMS), yielded an average $^{207}Pb/^{206}Pb$ age of 501±13 Ma. Coupled O and Hf isotopic compositions of zircons from the same gabbronorite, obtained by cathodoluminescence imaging-guided SIMS and LA-ICPMS methods, show the initial εHf_i and $\delta^{18}O$ isotope ratios ranging from -5.1 to 1.6 and from 6.9 to 8.1‰ respectively. Nd-Sr isotopic study shows that the age-corrected $\varepsilon Nd(t)$ and $(^{87}Sr/^{86}Sr)_t$ of the Dongcaohe ophiolite range from 4.0 to 6.1 and from 0.7028 to 0.7066 respectively.

Whole-rock Nd isotope and compositions of basalt and diabase reveal that the εNd(t) values are less and Th and U abundances are higher than typical MORB. They do not suggest that the Dongcaohe ophiolite originated in a typical MORB environment. Plots of $\delta^{18}O$ vs. $(^{87}Sr/^{86}Sr)_t$, $\delta^{18}O$ vs. εHf_i, and εNd(t) vs. εHf_i suggest that the magma forming the Dongcaohe ophiolite originated from a depleted mantle contaminated with a $\delta^{18}O$-enriched and εHf_i-depleted end member. Oceanic sediments and altered oceanic crust with high $\delta^{18}O$ could be a candidate of contamination. However, a plot of Nb/U vs. La/Th rules out subducted oceanic sediments and altered oceanic crust as a component of contamination. Some Precambrian lower continental crust (granulite) is low in εHf_i and high in $\delta^{18}O$. Therefore, we consider that the Dongcaohe ophiolite originated in a continental back arc basin. In such tectono-magmatic environment, upwelling asthenosphere provided a direct source for original magma and the raising magma could assimilate the preexisting delaminates of the lower continental crust.