Research Advances

Discovery of Contact Metamorphism-Related Baddeleyite from the Bayan Obo Deposit, Northern North China Craton

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Objective

Baddeleyite (ZrO_2) occurs primarily as an accessory mineral in igneous rocks with low silica activity and has been widely used to determine crystallization ages of mafic-ultramafic rocks and alkaline rocks including carbonatites and kimberlites. The Bayan Obo deposit on the northern margin of the North China Craton (NCC) is the world's largest REE deposit. Many previous studies show that the main component of ore-hosting dolomite marble is magmatic in origin and the REE-Nb mineralization is closely related to the carbonatites in the Bayan Obo deposit. This study attempted to separate baddeleyite from the REE-Nb-rich carbonatites in the Bayan Obo deposit to determine their crystallization ages in order to better understand the timing, genesis and tectonic setting of this deposit.

Our samples were collected from two open pits for REE-Nb mining exploitation near Boluotu in the easternmost part of the Bayan Obo deposit. The sample sites are 2–6 m to 650 m from the intrusive contacts between Bayan Obo REE-Nb-rich carbonatites and Permian granitoids with zircon U-Pb ages of ca. 280–260 Ma. The REE-Nb-rich carbonatite samples consist mainly of dolomite (80 vol.%–66 vol.%), calcite (8 vol.%–5 vol.%), magnetite (8 vol.%–6 vol.%), humite (7 vol.%–<1 vol.%), bastnäsite (5 vol.%–<1 vol.%), monazite (6 vol.%–1 vol.%), fluorite (3 vol.%–<1 vol.%), pyrite (4 vol.%–0) and hematite (1 vol.%–0); other minerals include diopside, ankerite, fergusonite-Ce, cordylite, apatite, pyrochlore, aeschynite, galena, zircon and baddeleyite (Fig. 1). Some humite has been identified as mineral inclusions in baddeleyite (Fig. 1).

Methods

Baddeleyite was separated using crushing and separation

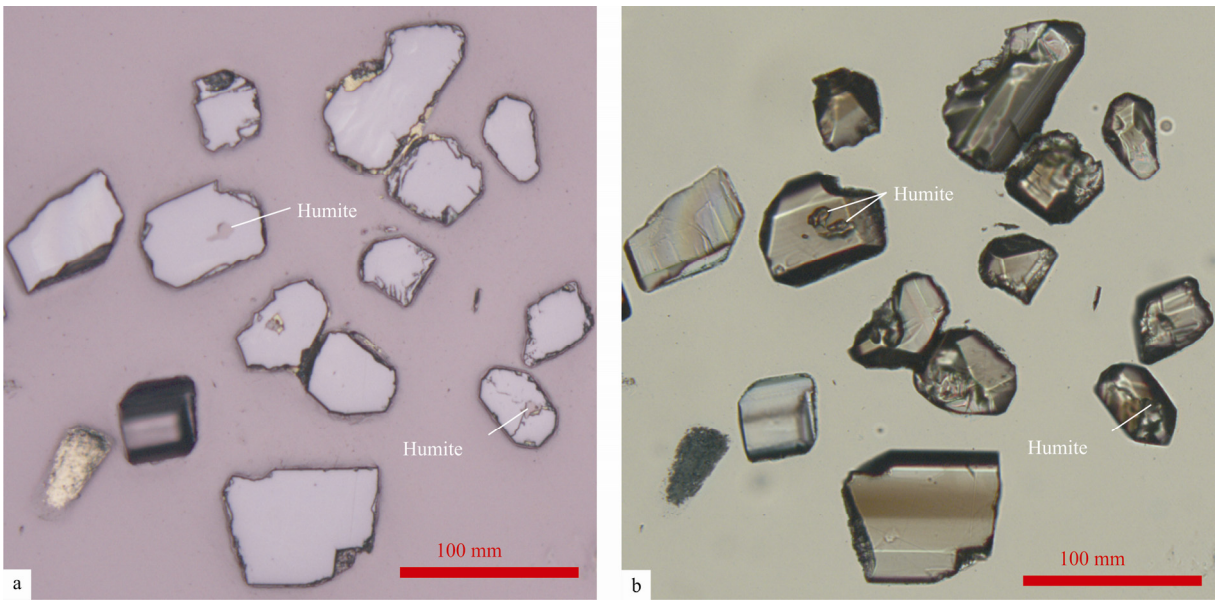

Fig. 1. Representative reflected-light (a) and transmitted-light (b) images of baddeleyite from the Bayan Obo carbonatite (sample 10185-1).

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techniques and were then handpicked under a binocular microscope. Different from conventional ‘‘water-based’’ technique for extracting baddeleyite and zircon, the samples were dissolved by chlorohydric acid (HCl) after being crushed to 40–60 meshes. This new technique significantly improved recovery rate for non-acid dissolved heavy minerals, and make it possible for us to separate enough baddeleyite and zircon from carbonatites.

Baddeleyite has been successfully separated from three REE-Nb-rich carbonatite samples (12157-1, 10185-1 and 10185-2R). They were dated by SIMS and LA-ICP-MS methods in the State Key Laboratory of Lithospheric Evolution, Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing and the State Key Laboratory of Geological Processes and Mineral Resources, China University of Geosciences, Wuhan, respectively.

Results

SIMS U-Th-Pb dating on baddeleyite separated from one REE-Nb-Th-rich carbonatite sample (10185-1) yields non-common-Pb corrected lower intercept ages of 287±21 Ma and weighted mean common-Pb corrected $^{206}Pb/^{238}U$ ages of 310±25 Ma (Fig. 2a). LA-ICP-MS U-Th-Pb dating on baddeleyite separated from the same REE-Nb-Th-rich carbonatite sample (10185-1) in the Bayan Obo ore deposit yields lightly younger lower intercept ages of 275±24 Ma, and the weighted mean $^{206}Pb/^{238}U$ ages of near-concordant analyses are 290±8 Ma (Fig. 2b). These crystallization ages are significantly younger than the ca. 1300 Ma emplacement ages of the Bayan Obo carbonatites, but similar to those of the Permian granitoid intrusions in the Bayan Obo deposit.

Conclusions

Different from baddeleyite in carbonatites that was crystallized from carbonatitic magmas, the baddeleyite we separated from REE-Nb-Th-rich carbonatite in Bayan Obo deposit was related to contact metamorphism during emplacement of the Permian granitoids. This inference is supported by existence of some magnesian skarn mineral inclusions such as humite in baddeleyite (Fig. 1). Clearly, the baddeleyite in Bayan Obo REE-Nb-Th-rich carbonatite did not crystallize from carbonatitic magmatism. Instead, they formed by hydrothermal fluids or a reaction involving zircon and dolomite during contact metamorphism resulting from emplacement of the Permian granitoids, as suggested by some previous studies on baddleyite from marble skarns in other places around the world.

Acknowledgments

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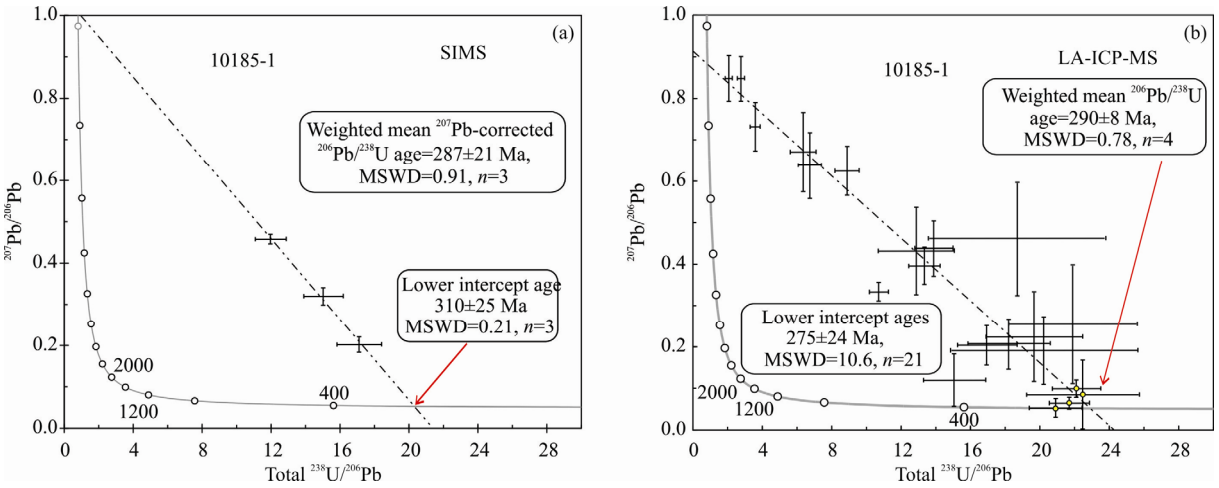

Fig. 2. SIMS (a) and LA-ICP-MS (b) U-Pb concordia diagrams for baddeleyite from the Bayan Obo carbonatite (sample 10185-1).