

Supplementary Material

Backscattered electron (BSE) observations and in situ major elemental analyses were carried out at the Institute of Geology and Geophysics, Chinese Academy of Sciences, using a JXA-8100 Electron Microprobe Analyzer (EMPA) with a voltage of 15 kV, with 10 nA beam current, and a spot size less than 10 μm . EMPA standards include andradite for Si and Ca, rutile for Ti, corundum for Al, hematite for Fe, eskolaite for Cr, rhodonite for Mn, bunsenite for Ni, periclase for Mg, albite for Na, and K-feldspar for K.

Whole-rock geochemical analyses were performed at the National Research Center of Geoanalysis, Chinese Academy of Geological Sciences (CAGS), Beijing, China. Whole-rock powder samples (0.7 g) were mixed with 5.3 g $\text{Li}_2\text{B}_4\text{O}_7$, 0.4 g LiF, and 0.3 g NH_4NO_3 in a 25-ml porcelain crucible. The powder mixture was transferred to a platinum alloy crucible. 1 mL LiBr solution was added to the crucible, and the sample was then dried. The sample was then melted in an automatic flame fusion machine and the major elemental composition of the quenched glass was analysed using the X-ray fluorescence (XRF) major elements analyses. Major elements were analysed by X-ray Fluorescence Spectrometer. Analytical errors were <2%.

Trace and rare earth elemental compositions were analysed according procedure was therefore adopted for analyses of trace elements and REEs according to the procedure of State Standard of the Peoples Republic of China (GB): Methods for chemical analysis of silicate rocks-Part 30: Determination of 44 elements (2010). Whole-rock powder samples (50 mg) were dissolved in distilled 1 mL HF and 0.5 mL

HNO₃ in 15-ml Savillex Teflon screw-cap capsules at 190°C for 1 day and this process was tried for two times. The capsule content was digested with 0.5 mL HNO₃ and dried again to ensure complete digestion. Then, the sample was digested with 5 mL HNO₃ and sealed at 130 °C in the oven for 3 h. After cooling, the solution was transferred to a plastic bottle and diluted to 50 ml before analysis. The sample solutions were analysed for trace elements by inductively coupled plasma–mass spectrometry (ICP–MS). The analytical precision for most elements was better than 5% and repeatable and reproducible against standard sample measurements. To verify the accuracy and precision of the procedure in this study, several standard samples of GBW07120, GBW 07103, GBW 07105 and GBW 07187 were also analysed.

Sr and Nd isotope compositions of 13 samples were measured using the MAT262 mass spectrometer at the State Key Laboratory of Lithospheric Evolution, IGG-CAS. About 100 mg of sample powder were weighed and placed in 7 ml Savillex™ Teflon beakers, and then spiked with appropriate amounts of ⁸⁷Rb–⁸⁴Sr, ¹⁴⁹Sm–¹⁵⁰Nd. The samples were dissolved in an acid containing 2 ml HF and 0.2 ml HClO₄, using a hotplate at 120 °C for more than 1 week. After the samples were completely dissolved, the solutions were dried on the hotplate at 120 °C and then heated to 180 °C to completely remove the HF. The sample residues were re-dissolved overnight in 4 ml of 6 M HCl at 100 °C, and then dried again. Finally, the samples were completely dissolved in 1 mL of 2.5 M HCl solution. Rb, Sr and the REEs were separated from the matrix elements with cation exchange columns packed with 2 mL AG50W×12 resins (200–400 mesh). Subsequently, the Nd and Sm were separated from the other REEs

with HEHEHP chromatographic columns or Eichrom-LN columns. Procedural blanks were 100 pg for Rb, 200 pg for Sr, 20 pg for Sm and 50 pg for Nd, respectively. Rb/Sr and Sm/Nd isotopes were determined using an Isoprobe-T thermal ionization mass spectrometer (TIMS). Rb and Sm isotopes were measured using single Ta filament. Sr and Nd isotopes were determined using single tungsten filament with TaF₅ as an ionization activator. In particular, Nd isotopes were determined as NdO⁺. The measured ⁸⁷Sr/⁸⁶Sr and ¹⁴³Nd/¹⁴⁴Nd ratios were corrected for mass fractionation using ⁸⁶Sr/⁸⁸Sr=0.1194 and ¹⁴⁶Nd/¹⁴⁴Nd= 0.7219, respectively. During the period of data collection, the measured values for the NBS987–Sr and JNdi–Nd standards were ⁸⁷Sr/⁸⁶Sr= 0.710245± 20 (n=10) and ¹⁴³Nd/¹⁴⁴Nd= 0.512125± 15 (n=8), respectively. NBS-987 and JNdi-Nd were confirmed by BHVO-2, W-2a of USGS, and other rock standards.

Tourmaline in-situ B isotope analyses were conducted using Nu II multicollector inductively coupled plasma mass spectrometer (MC-ICP-MS) coupled with a Geolas HD laser ablation system (Coherent). Detailed operating conditions for the LA-MC-ICPMS and data reduction were described by [Xu et al \(2020\)](#). Corrections for instrumental drift, mass bias between ¹⁰B and ¹¹B were conducted by “standard-sample-standard” bracketing external standardization. Two spots on the IAEA B4 were measured before and after each 10 spots measurements of unknown samples, and the mass bias of the ¹¹B/¹⁰B of the unknown samples were calibrated by reference to the mean of the ¹¹B/¹⁰B ratios of the IAEA B4 (4.008764, [Tonarini et al., 2003](#)).

The final result of the B isotopic analyses is expressed in terms of δ¹¹B, which is

defined as follows:

$$\delta^{11}B (\text{‰}) = \left[\frac{\left(\frac{{}^{11}B}{{}^{10}B} \right)_{\text{sample}}}{\left(\frac{{}^{11}B}{{}^{10}B} \right)_{\text{standard}}} - 1 \right] \times 1000$$

where the standard used was NIST SRM 951 boric acid from the National Institute of Standard Technology (${}^{11}B/{}^{10}B$ NIST SRM 951 = 4.04362 (Tonarini et al., (2003))).

The internal precision for each spot of $\delta^{11}B$ value is better than 0.1 ‰ (1σ).