

3. Analytical Methods

Detailed descriptions of analytical methods are presented in Text S1. Data for EMPA compositions of minerals (garnet, pyroxene, amphibole and plagioclase, respectively) in metabasites are listed in Table S1 to Table S4. Besides, whole rock major and trace elements analyzed by XRF and ICP–MS are presented in Table S5. Whole-rock Sr–Nd isotopes measured by MCICP–MS are listed in Table S6. Zircon U–Pb ages (33 μm +10 μm) and trace elements (32 μm) analyzed by LA–(MC)–ICP–MS are listed in Table S7–S9.

3.1. Mineral chemistry

Mineral major elements were analyzed using a JEOL JXA 8230 electron microprobe (EMPA) at the Key Laboratory of Orogenic Belts and Crustal Evolution, Ministry of Education, School of Earth and Space Sciences (SESS), Peking University (PKU), Beijing, China. The operating conditions were set at 15 kV acceleration voltage, 10 nA specimen current, 10–20 sec measuring time, and 1–2 μm beam size. Final results were calibrated using the calibration methods and Reference materials followed by [92]. Representative data are listed in Table S1–S4.

3.2. Whole-rock major and trace element

Whole-rock major-element contents for metabasites were determined by X-ray fluorescence (XRF) after fusing into glass discs at SESS, PKU. Trace elemental compositions were analyzed using an inductively-coupled-plasma mass spectrometer (ICP–MS; Thermo Scientific iCAP RQ) at the Key Laboratory of Orogenic Belts and Crustal Evolution, Ministry of Education, SESS, PKU. Chinese Geochemical National standards (GSR-1 GSR-2, GSR-11, and BCR-2) were used to calibrate the contents of major and trace elements. The detailed analytical protocol is described [95]. Analytical uncertainties are better than $\pm 2\%$ for major elements and $\pm 5\%$ for trace elements. Repeated analyses yielded consistent results for the same samples. All major- and trace-element data are listed in Table S5.

3.3. Whole-rock Sr–Nd Isotopes

Whole-rock Sr–Nd isotopes were obtained using a Nu Plasma II multicollector (MC)–ICP–MS at SESS, PKU. Approximately 150–320 mg powder samples were dissolved in HF + HClO₄ mixtures in Teflon vessels for one week. Afterward, the solutions were dried and dissolved in HCl before purification using ion exchange resins. $^{86}\text{Sr}/^{88}\text{Sr}$ and $^{146}\text{Nd}/^{144}\text{Nd}$ were fractionation-corrected to 0.1194 and 0.7219, respectively. During the period of analyses, Sr standard SRM987 yielded $^{87}\text{Sr}/^{86}\text{Sr} = 0.710237 \pm 0.000007$ (2σ , $n = 10$), and the Shin Etsu Jndi-1 Nd standard gave $^{143}\text{Nd}/^{144}\text{Nd} = 0.512191 \pm 0.000007$ (2σ , $n = 10$). During data acquisition, the measured result of BCR standard yielded $^{87}\text{Sr}/^{86}\text{Sr} = 0.704970 \pm 0.000005$ (2σ , $n = 9$) and $^{143}\text{Nd}/^{144}\text{Nd} = 0.512580 \pm 0.000005$ (2σ , $n = 7$), consistent with the recommended values reported by [91]. Analytical results are listed in Table S4.

3.4. Zircon U–Pb dating, trace element analyses and Raman Spectroscopy

Zircon was separated via standard density and magnetic separation techniques. The clearest, least cracked zircon grains (20NMH84, 20DGL97 and 20DGL97) were hand-picked and mounted in epoxy resin under a binocular microscope and polished to expose the cores of the grains. The internal structure of the zircons in polished mounts was examined using cathodoluminescence (CL) techniques with a field emission gun environmental scanning electron microscope (QUANTA-200F) equipped with a Garton Mono CL³⁺ spectrometer. The CL images were acquired with a 2 min scanning time at an accelerating voltage of 15 kV and beam current of 120 nA at the School of Physics, PKU.

Zircons U–Pb dating and trace element analyses were carried out at Key Laboratory of Orogenic Belts and Crustal Evolution, Ministry of Education, SESS, PKU, using a

Thermal iCAP RQ ICP-MS equipped with a GeoLas 193 nm laser ablation system with an in-house sample cell. A 32 μm laser spot was used, laser fluence and repetition rates were set at 8.5 $\text{J}\cdot\text{cm}^{-2}$ and 10 Hz. The 10 μm laser spot on metamorphic zircon rims has the laser fluence and repetition rates were set at 8 $\text{J}\cdot\text{cm}^{-2}$ and 4 Hz, respectively [91]. The instrumental mass bias and U/Pb fractionation were corrected using the standard zircon 91500 [94]. Data reduction was performed using the iolite software. The correction of common Pb, and all concordia plots and weighted mean age calculations were obtained using IsoplotR [93]. Elemental contents were calibrated with the NIST SRM 610 glass as an external standard and ^{29}Si as an internal standard.

The Raman spectra were acquired using a HORIBA Jobin Yvon confocal LabRAM HR Evolution micro-Raman system at the SESS, PKU. The system is equipped with a frequency-doubled Nd: YAG green laser (532.06 nm), and a $\times 20$ long-working distance objective lens with a 0.25 numerical aperture. The laser spot size was focused to 2 μm . The source power of the laser was 100 mW, and the confocal hole was set to 500 μm [90]. An 1800-groove/mm grating was selected, resulting in a spectral resolution of $\pm 0.7\text{ cm}^{-1}$. During the experiments, the Raman spectra within the ranges of 300–600 cm^{-1} and 900–1100 cm^{-1} were recorded with collection time of 15 and 20 s for quartz and zircon, respectively.