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Supplemental Material

Text. Analytical methods.

Table S1. Summary chemical composition data of representative minerals of mafic granulites and amphibolites in the Chengde Complex.

Table S2. LA–ICP–MS U-Pb analytical results of the zircons of mafic granulites and amphibolites from the Chengde Complex.

Table S3. LA-ICP-MS REE analytical results of the zircons of mafic granulites and amphibolites from the Chengde Complex.

1. Analytical methods

1.1 Whole-rock geochemistry

Whole-rock major element compositions were determined by X-ray fluorescence (XRF) spectrometry methods with the equipment of PANalytical PW2424 at the Australian Laboratory Services (ALS) in Guangzhou, China. Loss on ignition (LOI) was performed on dried rock powder by gravimetry after heating at 1,000 ℃ for 90 min and then recorded the percentage weight loss. FeO contents were determined by the potassium dichromate titration method. The whole-rock analyzing results of representative samples are listed in Table 1.

1.2 Electron microprobe analysis

Representative mineral composition analysis and the acquisition of backscattered electron (BSE) images were conducted on an electron microprobe analyzer (JEOL JXA-8230) at the Xi'an Center of Geological Survey, China Geology Survey. The operating conditions were 15 kV accelerating voltage and 10 nA beam current, with a beam diameter of 5 μm for most mineral grains and 3 μm for a few smaller-sized mineral grains. The counting times were 10–20 s. Natural standards were used, and the program ZAF was employed for matrix corrections. Representative mineral compositions are presented in Supplementary Table S1.

1.3 Zircon U-Pb dating and trace element analyses

Zircon grains were separated by heavy-liquid and magnetic separation at the Laboratory of Geological Team of Hebei Province, China. All analyses were conducted at the Isotopic Laboratory, Tianjin Institute of Geology and Mineral Resources of China Geological Survey. The element analyses were carried out by a Neptune laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) facility equipped with a New Wave 193 nm laser with a 29 μm diameter spot and a repletion rate of 8 Hz. Zircon 91500 was used as an external standard and thirty analyses yielded a concordant $^{206}Pb/^{238}U$ age of 1062.4 ± 5.0 Ma, which is consistent with its recommended age of 1064.2 ± 1.7 Ma (Yuan et al., 2004). Plešovice was used as the secondary standard with a concordant age of 336.9 ± 1.6 Ma, same as its recommended age of 337.13 ± 0.37 Ma (Sláma et al., 2008). NIST SRM 610 glass was used as an external standard to calculate the trace element concentrations of zircons. The normalized value of ^{29}Si from NIST SRM 610 is 72.26 wt.%, which is consistent with the value of 71.79 wt.% recommended by Pearce et al. (1997). Raw data were processed by ICPMSDataCal (Liu et al., 2008, 2010).

Plot of concordia diagrams and calculation of weighted mean ages were plotted using Isoplot (v.4.15) program (Ludwig, 2012). The uncertainties on individual analysis are 1 level and the errors on weighted mean ages are given at 95% confidence level. The analytical results of zircon U-Pb dating and rare element concentrations are listed in Supplementary Table S2 and Table S3 respectively.

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