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Research Advances

Zircon U–Pb Ages for TTG Gneiss and a Concomitant Felsic Vein from the South Hengshan Complex, Trans-North China Orogen: New Evidence for Late Archean Metamorphism

QIAN Jiahui[1, 2, *] and LI Shun[3]

[1] *Guangdong Provincial Key Lab of Mineral Resources and Geological Processes, School of Earth Sciences and Engineering, Sun Yat-sen University, Guangzhou 510275, China*
[2] *Southern Marine Science and Engineering Guangdong Laboratory, Zhuhai, Guangdong 519080, China*
[3] *School of Oceanography, Shanghai Jiao Tong University, Shanghai 200030, China*

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Objective

The Trans-North China Orogen (TNCO) is widely considered as a Paleoproterozoic (1.95–1.85 Ga) continental collisional belt along which the Eastern and Western blocks amalgamated to form the North China Craton. In recent years, several late Archean (~2.50 Ga) metamorphic ages were reported in this belt (Yang et al., 2015; Xiao et al., 2019; Wang et al., 2020), arousing widespread discussion on late Archean metamorphism. In the South Hengshan Complex (SHC) of the TNCO, an interesting outcrop has been discovered (Fig. 1), which shows a clear truncation relationship between a strongly deformed tonalite–trondhjemite–granodiorite (TTG) gneiss and a weakly deformed mafic dyke with 'red-eye socket' texture (Fig. 1a). Such mafic dykes in the SHC have an intrusive age of ~2.06 Ga (Peng et al., 2012), indicating that there might have existed a metamorphism/deformation responsible for the formation of the principle foliation in the TTG gneiss earlier than 2.06 Ga. In this study, we present zircon U–Pb age data from the TTG gneiss (Fig. 1b) and a concomitant felsic vein (anatectic product of the TTG gneiss: Fig. 1c) from the Yanmenguan outcrop in the SHC, Shanxi Province of China, in order to bring new insights on their formation and metamorphic ages and the tectonic affinity. Our results validate the existence of a late Archean metamorphism in the Hengshan area.

Methods

TTG gneiss sample H1701 (Fig. 1b) and felsic vein sample H1702 (Fig. 1c) were collected outside the gate of the Yanmenguan tourist site, in the western SHC (39°11′35.62″N, 112°51′23.19″E). Zircon grains were separated by conventional heavy liquid and magnetic separation followed by hand-picking under a binocular microscope. Selected grains were mounted in epoxy resin, polished down to expose the grain centers, photographed in transmitted and reflected light, and imaged using cathodoluminescence (CL). Zircon U–Pb dating was performed by the LA–ICP–MS method at Beijing Geoanalysis Co., Ltd, using an ESI NWR 193 nm laser ablation system and AnlyitikJena PQMS Elite ICP-MS instrument. Zircon GJ-1 was used as external standard and zircon Plesovice was dated as an unknown sample. U, Th and Pb concentrations were calibrated by NIST 610. Off-line raw data selection and integration of background and analyte signals, time-drift correction and quantitative calibration for U–Pb dating were performed by ICPMSDataCal. Age calculations and concordia plots were made using Isoplot (ver. 4.15).

Results

Sample H1701 is gray, with foliated, medium- to fine-grained tonalitic mineral composition. Zircons in H1701 are subhedral prismatic in shape, and show core-rim textures (Fig. 2a), including oscillatory zoned cores typical of magmatic growth and darker blurred rims indicative of metamorphic modification. Sixteen analyses from 15 zircon grains (12 from core and 4 from rim) were obtained (see results in Fig. 2c; Supp. Table 1). Twelve analyses from the zircon cores yield apparent $^{206}Pb/^{207}Pb$ ages of 2498–2577 Ma and Th/U ratios of 0.32–0.94, with a weighted mean $^{206}Pb/^{207}Pb$ age of 2538 ± 12 Ma and an

Fig. 1. (a) A mafic dyke crosscuts the foliation of TTG gneiss in Yanmenguan, South Hengshan, Shanxi Province; (b) close-up of TTG sample H1701; (c) close-up of the felsic vein.

* Corresponding author. E-mail: qianjh5@mail.sysu.edu.cn

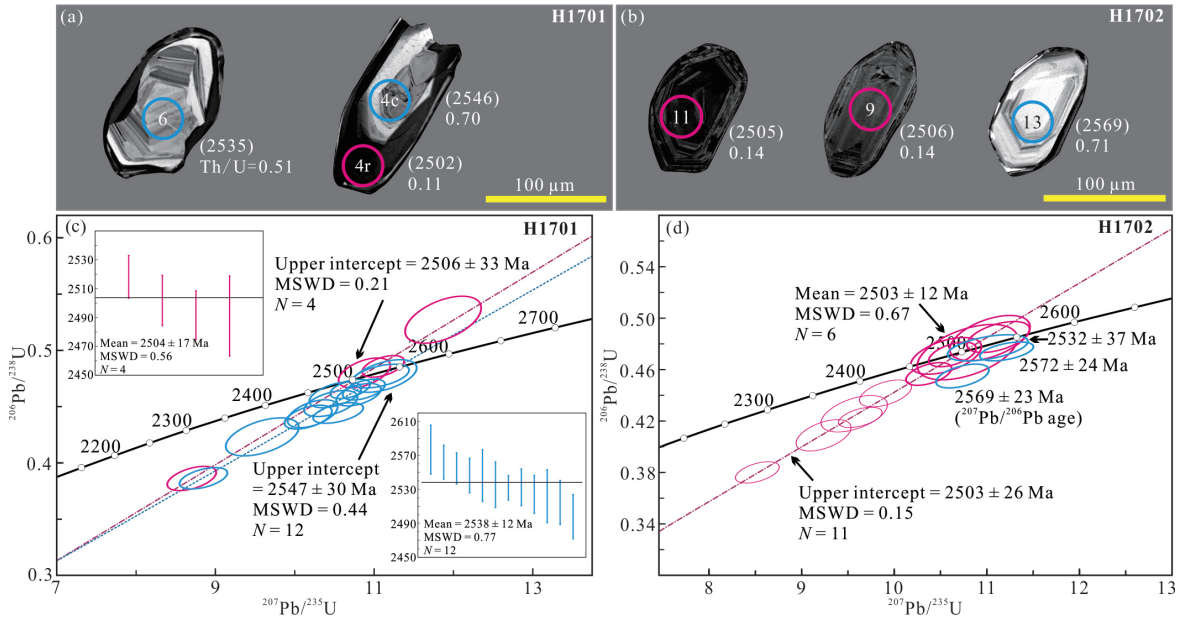

Fig. 2. (a–b) CL images of representative zircons and (c–d) concordia diagrams zircon U–Pb dating results of TTG gneiss (H1701) and felsic vein (H1702) samples from Yanmenguan.

Circles in CL images show positions of LA–ICP–MS analytical sites, with their identification numbers as in Supp. Table 1, and Th/U ratios and ages in Ma, respectively.

upper-intercept age of 2547 ± 30 Ma. Four analyses from the zircon rims yield apparent $^{206}Pb/^{207}Pb$ ages of 2491–2518 Ma and low Th/U ratios of 0.02–0.11, with a weighted mean $^{206}Pb/^{207}Pb$ age of 2504 ± 17 Ma and an upper-intercept age of 2506 ± 33 Ma.

Sample H1702 is off-white, mainly composed of quartz, plagioclase and k-feldspar, with minor mica and garnet. Zircon in H1702 exhibits two morphological types (Fig. 2b). Type-i grains show oscillatory zoning with low-luminescence, which can be interpreted to reflect crystallization from the felsic vein. Type-ii grains are rare, and have core-rim textures similar to the grains in sample H1701, presumably inherited from the TTG gneiss. Eleven analyses from type-i grains and three analyses from type-ii grains were obtained (see results in Fig. 2d; Supp. Table 1). The analyses of type-i zircon yield a weighted mean $^{206}Pb/^{207}Pb$ age of 2503 ± 12 Ma and an upper-intercept age of 2503 ± 26 Ma, with Th/U ratios of 0.11–0.61. The analyses of type-ii zircon yield apparent $^{206}Pb/^{207}Pb$ ages of 2532 ± 37 Ma, 2569 ± 23 Ma and 2572 ± 24 Ma.

Conclusions

(1) TTG gneiss from Yanmenguan in the SHC was emplaced at ~2.54 Ga and records a late Archean metamorphism at ~2.50 Ga.

(2) Felsic vein melted from TTG gneiss yields a crystallization age of ~2.50 Ga, further supporting the existence of the late Archean metamorphism.

(3) Taking into account field occurrence of rocks and published age data, there is a late Archean metamorphism in the Hengshan area and several other places of the TNCO. However, evidence for this metamorphism is only sporadically preserved, and more work needs to be done to address the geodynamic setting.

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