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Research Advances

Newly identified Caledonian gabbro (450 Ma) in the eastern Guangxi, South China: Production of intraplate orogenic process

Yang Tian[a, b], Si-fang Huang[c], Ling-zhan Wang[a, b,*], Xiang Li[a, b], Guo-gang Xie[a, b]

[a] *Research Center for Petrogenesis and Mineralization of Granitoid Rocks*, *China Geological Survey*, *Wuhan* 430205, *China*
[b] *Wuhan Center of China Geological Survey*, *Ministry of Natural Resources*, *Wuhan* 430205, *China*
[c] *State Key Laboratory of Geological Processes and Mineral Resources*, *School of Earth Sciences*, *China University of Geosciences*, *Wuhan* 430074, *China*

1. Objectives

As one of three major tectonic blocks of China, the South China Block has undergone multiple periods of tectonic-magmatic-metamorphic events. Among these events, the Caledonian orogeny results in the formation of NE-trending Wuyi−Yunkai orogen in South China. This orogen shows complex characteristics, including widespread angular unconformity between Ordovician and Devonian strata, pre-Devonian intense deformation and metamorphism (amphibolite to granulite facies), and extensive crustal remelting (Shu LS et al., 2020). However, the tectonic nature of this orogeny remains controversial, and two main models are present: (1) Intracontinental orogen (Wang YJ et al. 2013) and (2) subduction-accretionary orogenic belt related to the amalgamation between the Yangtze and Cathaysia blocks (Liu SF et al., 2018).

The Chenzhou-Linwu fault, regarded as the suture zone between the Yangtze and Cathaysia blocks (Wang YJ et al., 2003; Tian Y et al., 2020), passes the Yingyangguan district and connects Yunkai domain to the southeast. Therefore, the outcropping Pre-Devonian rocks in the Yingyangguan area are significant agencies in deciphering the tectonic evolution of the South China Block. To address this, the authors present here a typical study, for the first time, on a Caledonian gabbro from the Yingyangguan area. Whole rock geochemistry and zircon U-Pb-Hf isotopes are analyzed on the Yingyangguan gabbro to constrain their petrogenesis and tectonic implication, as well as the nature of the Caledonian orogen in South China.

First author: *E-mail address*: 41834572@qq.com (Yang Tian).

* Corresponding author: *E-mail address*: ycwanglingzhan@126.com (Ling-zhan Wang).

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2. Methods

A fresh gabbro (SJC18-1) was collected near Shuijingchong village, eastern Guangxi (111°59 ′24 ″N; 24°45 ′18 ″E) (Fig. 1). About 8 kg sample was crushed and separated for zircon crystals using standard density and magnetic separation techniques. Zircon grains were handpicked under a binocular microscope and subsequently mounted on epoxy resin. CL images were photographed by Tescan-Mira3 at Nanjing Hongchuang Geological Exploration Technology Service Co. Ltd. Zircon U-Pb dating and Hf isotopic analyses were conducted using LA-ICP-MS at Wuhan Sample Solution Analytical Technology Co., Ltd. Major and trace elements were determined by XRF and ICP-MS at State Key Laboratory of Geological Processes and Mineral Resources, China University of Geoscience, Wuhan, with the relative standard derivations of less than 5% and 3%, respectively.

3. Results

Sample (SJC18-1) exhibits medium-grained gabbroic texture (Fig. 2a), whereas petrography analyses argue that most pyroxene grains have been altered by amphibole (Fig. 2b) with metasomatic pseudomorphic texture. Accordingly, the sample is mainly composed of hornblende (65%), plagioclase (35%) and some accessory phases of magnetite and zircon.

Zircon grains from sample SJC18-1 are euhedral to subhedral and 150−250 μm in length with aspect ratios of 2∶1 to 3∶1. Most zircon grains display light to dark luminescence, with faint or no obvious zoning in the CL images (Fig 2c). Twenty analyzed zircon grains have high and variable U (1654×10^{-6}–5294×10^{-6}) and Th (1552×10^{-6}–11998×10^{-6}) contents, with Th/U ratios of 0.89 to 1.64 (except spot #19 with 2.27 value) (Table 1), indicating an

igneous origin of these zircons. Seventeen of twenty zircon grains yield concordant $^{206}Pb/^{238}U$ ages, ranging from 445 ± 3 Ma to 460 ± 4 Ma with a weighted mean age of 450 ± 1.9 Ma (MSWD = 0.97) (Fig. 2d), indicating the emplacement age of the gabbro. Fifteen zircons display consistent $\varepsilon_{Hf}(t)$ values between −1.0 and −5.8 (mean = −4.1) with Hf single-stage model ages range from 1103 to 1282 Ma (Table 1).

The gabbroic sample has low SiO_2 (52.30%), high MgO (12.49%), CaO (9.88%), Cr (906.00×10^{-6}), Ni (315.75×10^{-6}) and Nb (8.84×10^{-6}) contents. The low Nb/Y (0.39) and FeO^T/MgO (0.57) ratios indicate its calc-alkaline affinity. In the chondrite normalized rare earth elements (REE) diagram, the gabbro display highly fractionated LREE pattern [$(La/Sm)_N$=2.35] and HREE [$(Gd/Yb)_N$=1.96] with moderate negative Eu anomaly (Eu/Eu*=0.66). In the primitive mantle normalized multi-element spider diagram, the studied gabbro show pronounced negative Nb, Zr and Ti anomalies and enriched LILE (eg., Rb, U and Pb).

4. Conclusion

The studied gabbro was emplaced at ca. 450 Ma, representing the first reported Caledonian mafic intrusion with arc-related geochemical affinity in the Yingyangguan area of South China.

High MgO, Cr and Ni contents and high $(Gd/Yb)_N$ ratio (1.96) of the studied sample suggest the parental magma was derived from a garnet peridotite source. Furthermore, the low Ta/Yb (0.52), high Th/Yb (5.25) ratio and negative zircon $\varepsilon_{Hf}(t)$ values (−1.1 to −5.8) indicate an enriched material source. Therefore, we suggest that the studied gabbro was derived from a deep mantle source with input of fluid/melt from the subduction slab and/or sediment (Wang YJ, et al., 2013).

In conjunction with other available observations, this study implied that there was a 1.3−1.1 Ga paleosubduction-modified wedge column beneath the South China Block, which might be undisturbed until the Kwangsian intracontinental orogen.

CRediT authorship contribution statement

Yang Tian and Ling-zhan Wang conceived of the

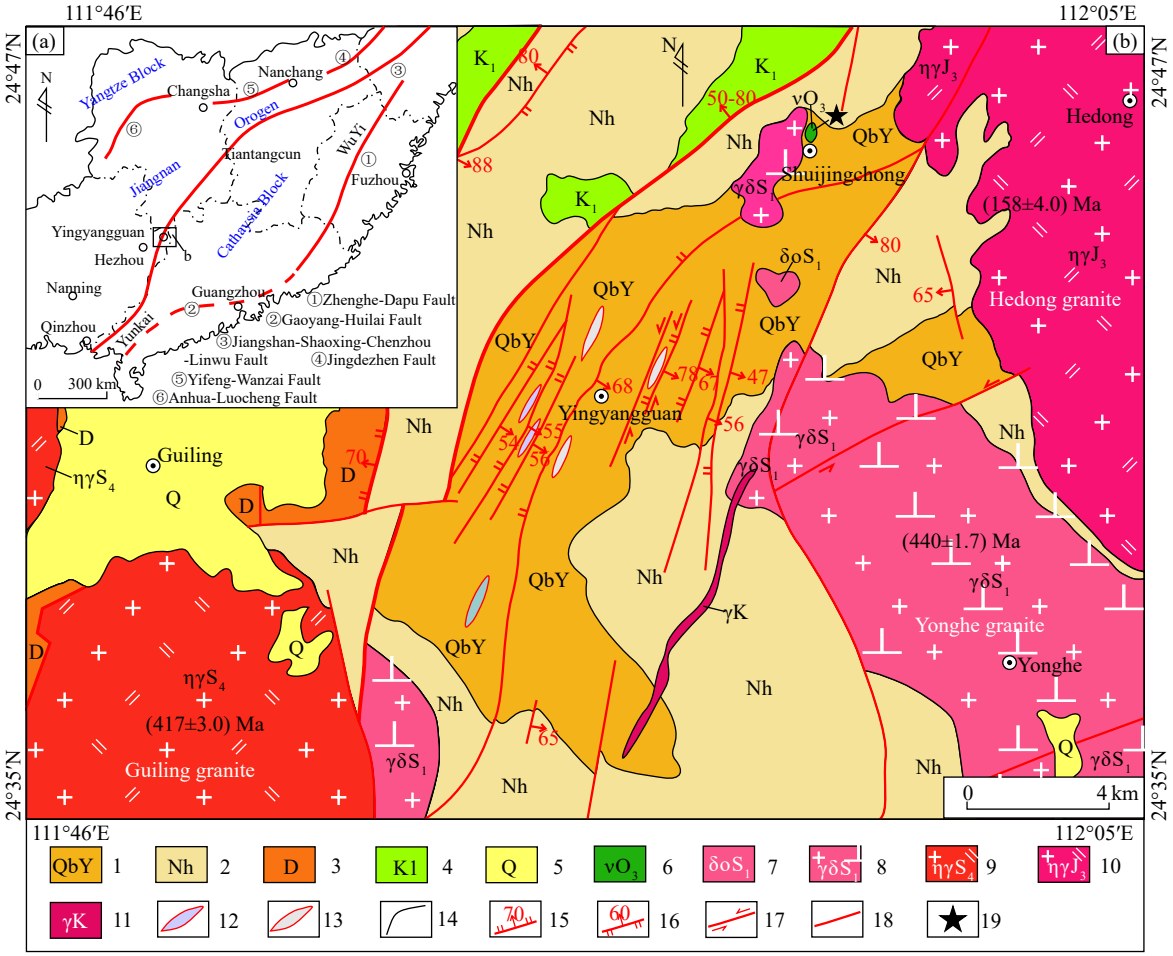

Fig. 1. Sketch geological map of the Yingyangguan area, eastern Guangxi ((a) after Wang YJ et al., 2013; (b) after Tian Y et al., 2020). 1−Yingyangguan Group; 2−Cryogenian; 3−Devonian; 4−Lower Cretaceous; 5−Quaternary; 6−Upper Ordovician gabbro; 7−Lower Silurian quartz diorite; 8−Lower Silurian granodiorite; 9−Upper Silurian monzonite; 10−Upper Jurassic monzonite; 11−Cretaceous granite; 12−micro-crystalline quartzite block; 13−marble block; 14−stratigraphic boundary; 15−normal fault; 16−reverse fault; 17−strike-slip fault; 18−unidentified fault; 9−sampling location.

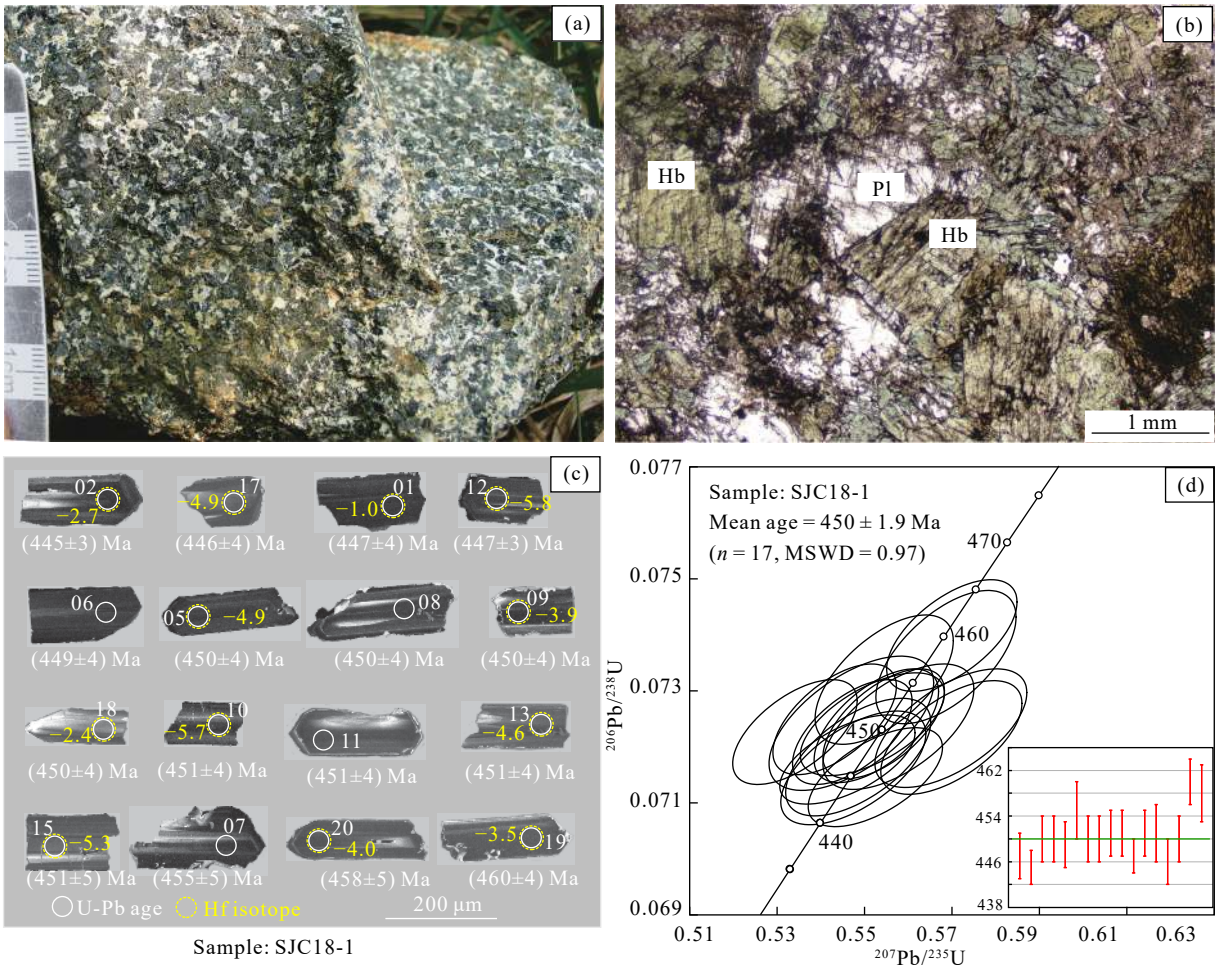

Fig. 2. Outcrop photo (a), microscope photograph (b), CL images of representative zircons (c) and U-Pb concordia diagram (d) of new discovered gabbro from the Yingyangguan area of the eastern Guangxi. Hb−hornblende, Pl−plagioclase.

Table 1. Zircon LA-ICP-MS U-Pb data and Lu-Hf isotopes of gabbro from the Yingyangguan area in the eastern Guangxi.

Spot No.	Th	U	Th/U	$^{207}Pb/^{206}Pb$		$^{207}Pb/^{235}U$		$^{206}Pb/^{238}U$		$^{206}Pb/^{238}U$		Concordia	$\varepsilon_{Hf}(t)$
	$\times10^{-6}$			Ratio	1σ	Ratio	1σ	Ratio	1σ	Age/Ma	1σ		
1	5579	3828	1.46	0.05519	0.00119	0.55172	0.01187	0.07182	0.00069	447	4	99%	−1.0
2	4546	3912	1.16	0.05588	0.00112	0.55599	0.01106	0.07146	0.00058	445	3	99%	−2.7
3	5793	3535	1.64	0.05692	0.00109	0.57467	0.01248	0.07233	0.0007	450	4	97%	
5	2596	2390	1.09	0.05478	0.00098	0.55024	0.00983	0.07226	0.00062	450	4	98%	−4.9
6	3724	3408	1.09	0.05719	0.00109	0.57481	0.01159	0.07216	0.00067	449	4	97%	
7	5617	4060	1.38	0.05491	0.00112	0.55815	0.01135	0.0732	0.00076	455	5	98%	
8	3874	2684	1.44	0.05343	0.00104	0.53605	0.01026	0.07226	0.00062	450	4	96%	
9	4923	3566	1.38	0.05536	0.001	0.55621	0.01023	0.07237	0.00067	450	4	99%	−3.9
10	5047	3809	1.33	0.05552	0.00096	0.55807	0.01	0.07241	0.00065	451	4	99%	−5.7
11	4829	3502	1.38	0.05423	0.00095	0.54583	0.01011	0.07249	0.00065	451	4	98%	
12	1552	1654	0.94	0.05517	0.00112	0.54899	0.01109	0.07177	0.00052	447	3	99%	−5.8
13	1705	1819	0.94	0.05529	0.00114	0.55524	0.01177	0.0724	0.00061	451	4	99%	−4.6
15	1756	1968	0.89	0.05473	0.00124	0.55005	0.0135	0.07242	0.00079	451	5	98%	−5.3
17	2205	2035	1.08	0.05547	0.00112	0.55063	0.01186	0.07162	0.00067	446	4	99%	−4.9
18	1642	1762	0.93	0.05604	0.00115	0.56167	0.01231	0.07236	0.00074	450	4	99%	−2.4
19	11998	5294	2.27	0.0561	0.00096	0.57494	0.01061	0.07398	0.00066	460	4	99%	−3.5
20	4616	3330	1.39	0.05631	0.00104	0.5735	0.01148	0.0736	0.00078	458	5	99%	−4.0

presented idea. Ling-zhan Wang, Xiang Li and Guo-gang Xie collected and preparing samples for analysis. Yang Tian and Si-fang Huang carried out the experiments and analyzed of results. All authors provided critical feedback and contributed to the final manuscript.

Declaration of competing interest

The authors declare no conflict of interest.

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