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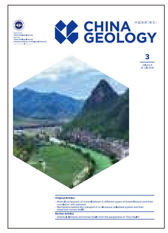

Short Communications (Research Advances)

Zircon U-Pb age of the mafic microgranular enclaves in the ore-forming porphyry of the Tongchanggou Mo (Cu) deposit, northwestern Yunnan, China

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1. Objective

The Yidun arc within the Tethys-Himalaya metallogenic belt formed during the westward subduction of the Ganzi-Litang Ocean (237–206 Ma) during the Indosinian period, and then underwent the evolution stages of the collisional orogeny (206–138 Ma) and the post-collisional orogeny (135–75 Ma). In recent years, a series of large and medium-sized Late Yanshanian intracontinental porphyry-skarn Mo-Cu-W deposits have been discovered in the southern part of the Yidun arc, including Xiuwacu, Relin, Hongshan, Tongchanggou, and Donglufang (Fig. 1a). These deposits have a mineralization age of 88 Ma to 78 Ma, representing a significant metallogenic event following the Indosinian subduction-related porphyry mineralization in this region. Due to the rarity of mafic microgranular enclaves (MMEs) in the Late Yanshanian porphyry, little research has been done on them. The Tongchanggou deposit in northwest Yunnan Province is the largest porphyry molybdenum (copper) deposit in the region. In this paper, the newly discovered mafic MMEs, including the microphysiography and in situ zircon LA-ICP-MS U-Pb chronology in the ore-forming porphyry of the deposit have been investigated to fill the gap of no reported MMEs in the Tongchanggou deposit.

2. Methods

The MME samples were collected from the TZK0149 drilling core of the Tongchanggou deposit (No. TCG8-20, 27°43'30"N, 100°04'30"E, H2762 m) (Fig. 1b). The host rock is granite diorite porphyry (Figs. 1c–e). After the MMEs were crushing and sorting, the zircons were selected for target making, polishing, cathodoluminescence (CL) and transreflective photography. The zircon particles with good crystal form and no cracks were selected for LA-ICP-MS U-Pb dating (Fig. 2a). An Excel-based software ICPMSDataCal was used to perform off-line selection and integration of background and analyzed signals, time-drift correction and quantitative calibration for trace element analysis and U-Pb dating (Liu YS et al., 2008). Concordia diagrams and weighted mean calculations were obtained using the Isoplot/Ex_ver3 (Ludwig KR, 2003). The entire testing and analysis process was completed at the Wuhan Sample Solution Analytical Technology Co., Ltd., Wuhan, China.

3. Results

The mineral grains in the MMEs are relatively small (Figs. 1c–e). Microscopic analysis reveals that the MMEs possess a magmatic structure. The dark minerals are mainly biotite, with flake sizes ranging from 0.1 mm to 0.7 mm, comprising approximately 10%–20%. The feldspar consists of K-feldspar and plagioclase, with grain sizes around 0.3–0.6 mm, both accounting for roughly 40%. Quartz grains measure approximately 0.2–0.8 mm, constituting about 5%–10% of the composition. Accessory minerals include apatite, zircon, and hematite.

Zircon grains are light yellow to colorless, euhedral and prismatic, 80 μm to 230 μm in length with length/width ratios of 3:2 to 2:1, exhibiting clear oscillatory zoning in CL images. The results of LA-ICP-MS analysis show that the Th content ranges from 81.7×10^{-6} to 861.7×10^{-6}, and the U content ranges from 478.1×10^{-6} to 1247.6×10^{-6}, with a Th/U ratio ranging from 0.28 to 3.27, indicating they are magmatic zircons (Table 1). Two sets of zircon U-Pb age data are depicted, where $^{206}Pb/^{238}U$ ages are concentrated between 85.3–81.3 Ma and 243.6–235.7 Ma. The weighted average ages for $^{206}Pb/^{238}U$ are 83.0±0.6 Ma (2σ, MSWD=2.0, *n*=18) and 239.8±2.8 Ma (2σ, MSWD=1.07, *n*=5), respectively (Fig. 2). The former zircon U-Pb age is consistent with the age of the

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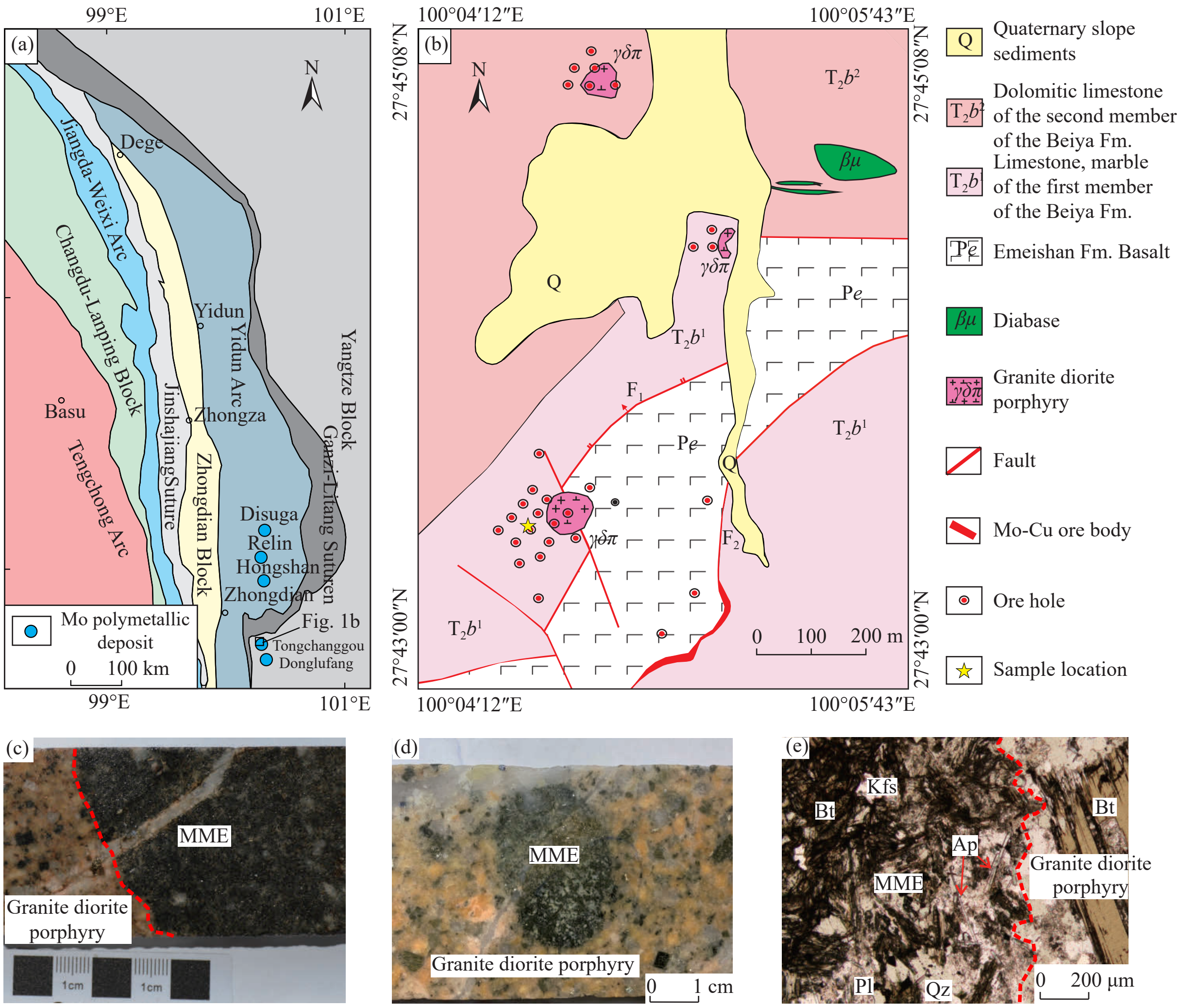

Fig. 1. a–Generalized tectonic map of the Yidun Arc (modified from Wang P et al., 2016); b–simplified geological map of the Tongchanggou deposit; c, d–hand-specimen photo of the MME; e–photomicrograph (crossed-polar) of the MME. Bt-biotite; Kfs – K-feldspar; Pl–plagioclase; Qz–quartz; Ap–apatite.

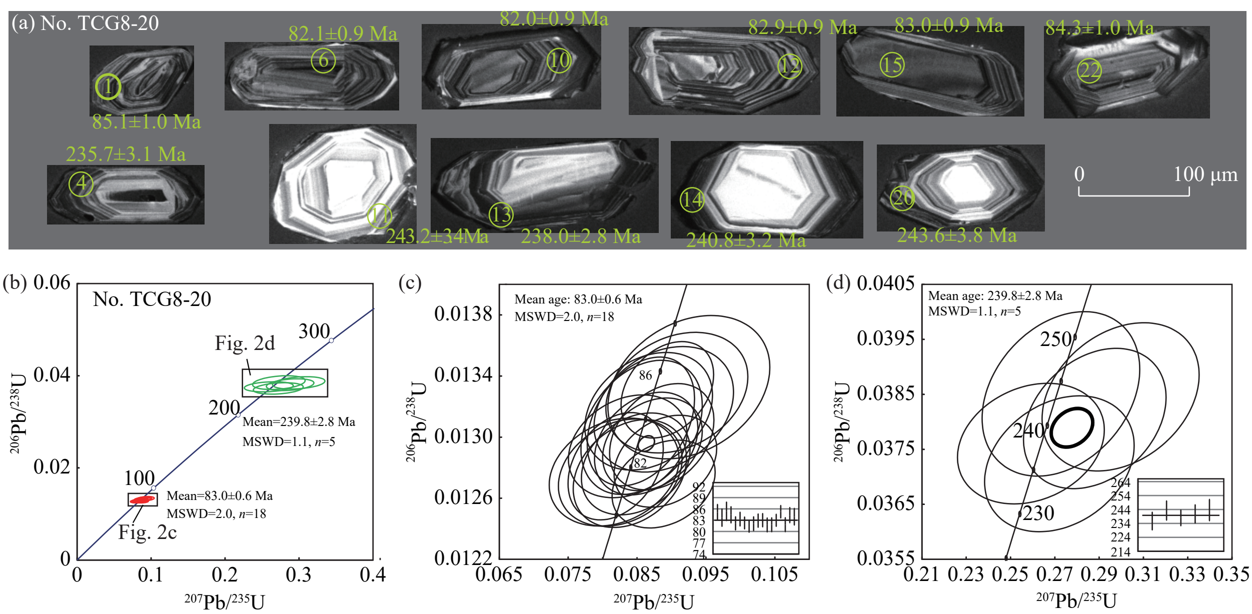

Fig. 2. a–Representative zircon cathodoluminescence images of the MMEs; b, c, d–zircon LA-ICP-MS U-Pb concordia diagrams. Note: Verdant circles denote U-Pb dating spots, with values outside the circles indicating their $^{206}Pb/^{238}U$ ages. The numbers within the circles correspond to measurement identifiers.

Table 1. Zircon LA-ICP-MS U-Pb data of the MMEs from the Tongchanggou deposit.

Sample	Pb	Th	U	Th/U	$^{207}Pb/^{206}Pb$		$^{207}Pb/^{235}U$		$^{206}Pb/^{238}U$		$^{207}Pb/^{235}U$		$^{206}Pb/^{238}U$		Concordance %
	$\times10^{-6}$				Ratio	2σ	Ratio	2σ	Ratio	2σ	Age/Ma	2σ	Age/Ma	2σ	
TCG8-20-1	14.3	414	888	0.47	0.0494	0.0023	0.0908	0.0042	0.01329	0.00016	88.2	3.9	85.1	1.0	96
-2	12.2	327	793	0.41	0.0472	0.0020	0.0857	0.0036	0.01306	0.00018	83.5	3.4	83.7	1.1	99
-3	8.4	153	552	0.28	0.0500	0.0027	0.0925	0.0048	0.01333	0.00019	89.9	4.5	85.3	1.2	94
-5	20.0	1813	870	2.08	0.0484	0.0022	0.0889	0.0041	0.01318	0.00017	86.5	3.9	84.4	1.1	97
-6	19.9	873	1195	0.73	0.0475	0.0018	0.0848	0.0032	0.01282	0.00014	82.7	3.0	82.1	0.9	99
-7	18.6	805	1080	0.75	0.0492	0.0017	0.0886	0.0031	0.01300	0.00014	86.2	2.9	83.3	0.9	96
-8	19.8	781	1214	0.64	0.0502	0.0018	0.0891	0.0030	0.01284	0.00012	86.7	2.8	82.3	0.8	94
-9	29.6	2917	1287	2.27	0.0505	0.0017	0.0889	0.0031	0.01269	0.00012	86.4	2.9	81.3	0.7	93
-10	20.0	826	1233	0.67	0.0463	0.0016	0.0819	0.0028	0.01281	0.00014	79.9	2.7	82.0	0.9	97
-12	16.7	678	1013	0.67	0.0466	0.0019	0.0836	0.0035	0.01294	0.00014	81.6	3.3	82.9	0.9	98
-15	19.6	710	1211	0.59	0.0480	0.0016	0.0863	0.0031	0.01296	0.00014	84.1	2.9	83.0	0.9	98
-16	33.2	3808	1239	3.07	0.0477	0.0019	0.0840	0.0034	0.01276	0.00014	81.9	3.2	81.7	0.9	99
-17	15.0	460	962	0.48	0.0468	0.0021	0.0826	0.0037	0.01277	0.00014	80.6	3.4	81.8	0.9	98
-18	28.5	2785	1181	2.36	0.0488	0.0017	0.0872	0.0030	0.01295	0.00012	84.9	2.8	83.0	0.8	97
-19	38.0	3823	1509	2.53	0.0485	0.0015	0.0894	0.0027	0.01331	0.00013	86.9	2.6	85.2	0.8	98
-21	11.9	455	750	0.61	0.0467	0.0022	0.0817	0.0039	0.01277	0.00014	79.7	3.6	81.8	0.9	97
-22	13.5	480	831	0.58	0.0479	0.0021	0.0867	0.0038	0.01317	0.00016	84.4	3.5	84.3	1.0	99
-23	14.4	532	894	0.59	0.0474	0.0018	0.0856	0.0032	0.01310	0.00017	83.4	3.0	83.9	1.1	99
-4	26.8	587	524	1.12	0.0524	0.0025	0.2721	0.0138	0.03724	0.00050	244.4	11.0	235.7	3.1	96
-11	5.9	67	126	0.53	0.0569	0.0028	0.2997	0.0145	0.03845	0.00055	266.2	11.3	243.2	3.4	90
-13	9.9	123	209	0.59	0.0504	0.0027	0.2592	0.0135	0.03760	0.00045	234.0	10.9	238.0	2.8	98
-14	8.0	86	173	0.50	0.0550	0.0026	0.2881	0.0132	0.03806	0.00052	257.0	10.4	240.8	3.2	93
-20	7.5	81	158	0.51	0.0522	0.0030	0.2728	0.0145	0.03851	0.00061	244.9	11.6	243.6	3.8	99

host rocks (ca. 83 Ma, He J et al., 2018) within the error range, while the latter U-Pb age is significantly older than the host rocks, indicating that the zircons are the Triassic inherited zircons.

4. Conclusions

The U-Pb ages of the young zircons (85.3–81.3 Ma) in the MMEs of the Tongchanggou deposit are consistent with the U-Pb ages of zircons reported in the host rock by previous researchers. The zircons dated between 243.6–235.7 Ma found in the MMEs closely resemble the zircon U-Pb ages of intrusive rocks associated with the Indosinian oceanic crust subduction in the southern Yidun Arc. However, there was no direct involvement of oceanic slabs in the Late Yanshanian intracontinental porphyry mineralization stage. Therefore, the inherited zircons were likely derived from the arc magmatic rocks formed during the Indosinian ocean-continent subduction stage, indicating that the early-formed arc magmatic materials were most likely involved in the formation of the Late Yanshanian post-collisional porphyries and may have contributed to the pre-enrichment of ore-forming elements for the formation of the Late Yanshanian deposits.

CRediT authorship contribution statement

Shou-kui Li, Xue-long Liu and Shi-tao Zhang conceived of the presented idea. Jie-hu Zhou, Bo-de Lu and Yun He carried out the experiment. All authors discussed the results and contributed to the final manuscript.

Declaration of competing interest

The authors declare no conflicts of interest.

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