China Geology 7 (2024) 592−595

China Geology

Journal homepage: http://chinageology.cgs.cn
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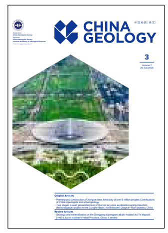

Short Communications (Research Advances)

U-Pb dating of monazite in the Bainiuchang silver polymetallic deposit, Yunnan Province, and its limitation on Mesozoic mineralization

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1. Objective

The Gejiu-Bozhushan-Laojunshan tin-tungsten polymetallic metallogenic belt is located in southeastern Yunnan. It is bounded by the Mile-Shizong Fault and the Yangzi Plate to the north and west, respectively, while the Honghe Fault represents its southwestern boundary. It is adjacent to the Ailaoshan Fault, and extends to Guangxi and Vietnam to the southeast (Fig.1a; Liu JP et al., 2021). The Bainiuchang silver polymetallic deposit is an important component of the Gejiu-Bozhushan-Laojunshan tin-tungsten polymetallic metallogenic belt in southeastern Yunnan, and is located on the NW strike of the Bozhushan granite body (Fig. 1b). Previous studies have shown that the Bozhushan granite body is an S-type granite, which is closely associated with metal mineralization (Zhang YH, 2013). The magmatic rocks in the study area are mainly acidic rocks and controlled by deep drillings. Granitic magma intrusion is the main dynamic mechanism of mineralization in the area. Owing to the lack of effective constraints on the diagenesis and metallogenic age of concealed granite bodies in the Bainiuchang silver polymetallic deposit, there are numerous viewpoints on the genesis of deposit, such as magmatic hydrothermal, submarine exhalative sedimentary, and magmatic hydrothermal mineralization superposition transformation. The newly discovered paragenetic monazite at the Bainiuchang silver polymetallic deposit is an crucial research object for the precise determination of the age of the rock formation. The U-Th-Pb dating technique can provide significant temporal parameters for the geological evolutionary history and exploration of important geological processes, such as diagenesis and mineralization (Zhang HY et al., 2022; Sakuwaha KG et al., 2022). In this study, laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) U-Th-Pb isotope dating was conducted on monazite from a deep-seated occult granite body in the Bainiuchang silver polymetallic deposit, with the aim of providing new evidence on magmatic intrusive events and mineralization in the mine area.

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Literary editor: Li-qiong Jia
doi:10.31035/cg2023052
2096-5192/© 2024 China Geology Editorial Office.

2. Methods

The monazite U-Pb dating sample was obtained from the granite body of the 1360 m tunnel in the Bainiuchang silver polymetallic deposit (Fig. 1c), close to the disseminated pyrrhotite ore body. Monazite single mineral selection, target preparation and cathodoluminescence (CL) photography were conducted at the Beijing Phanerozoic Technology Corporation. LA-ICP-MS monazite U-Pb isotope dating was performed at the Wuhan SampleSolution Analytical Technology Corporation. The laser beam spot and frequency used in this analysis were 16 μm and 2 Hz, respectively. Monazite reference material 44069 and the glass reference material NIST610 were used as external standards for isotope and trace element fractionation correction. Offline processing of the analytical data was performed using software ICPMS DataCal software (Liu YS et al., 2010). Isoplot/Excel3 was used to draw the U-Pb age harmonic diagram and calculate the age-weighted average of the monazite samples.

3. Results

The lithology of the sample was medium-fine grained porphyritic biotite monzonitic granite, which was composed

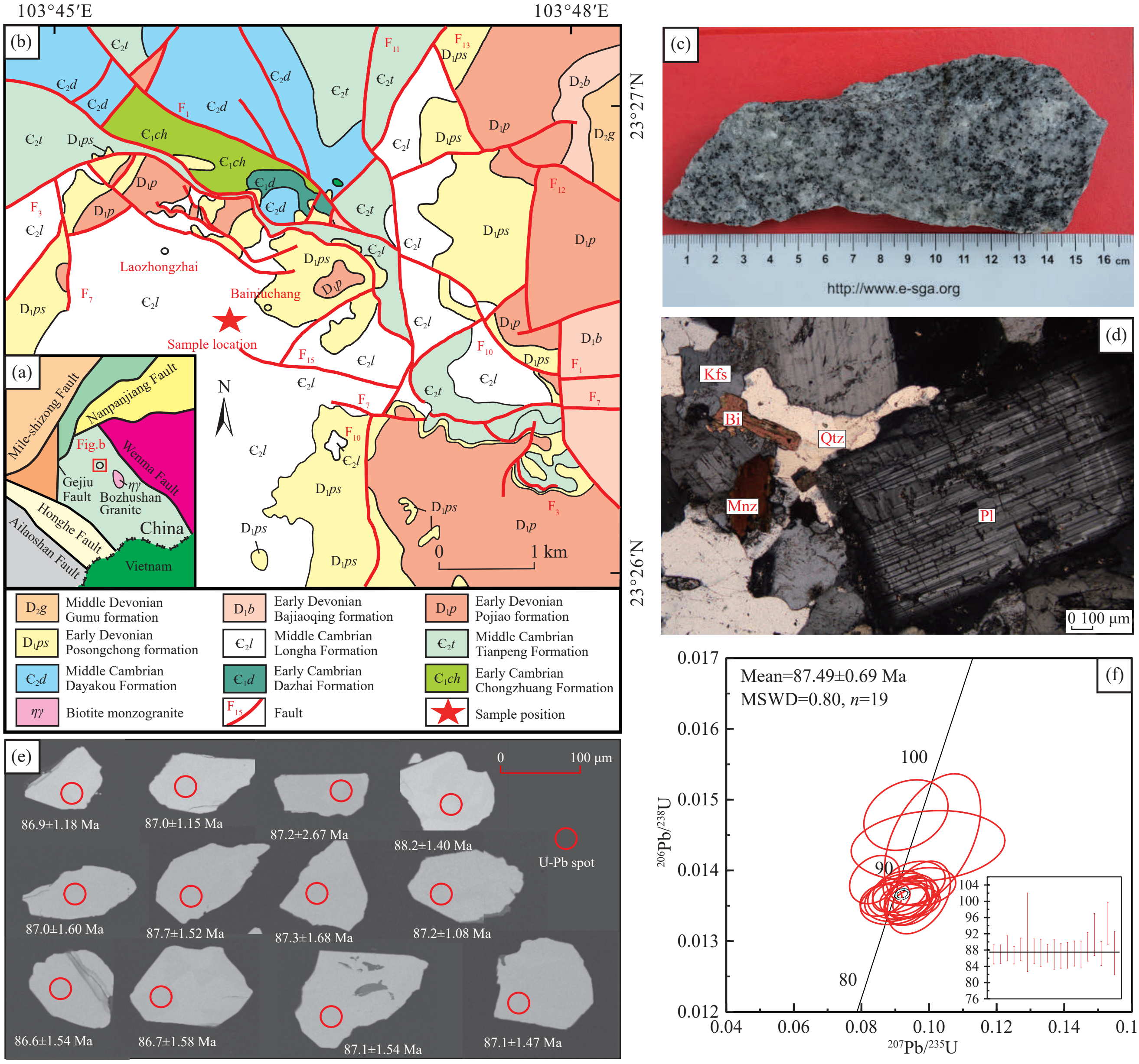

Fig. 1. Geological map of Bainiuchang silver polymetallic deposit (a) and simplified geological map (b); monzionitic granite (c); microscope photograph (d); CL images of monazite (e); monazite U-Pb age harmonization diagram (f). Bi–biotite; Kfs–K-feldspar; Mnz–monazite; Pl–plagioclase; Qtz–quartz.

of plagioclase (40%), quartz (25%), potassium feldspar (10%), biotite (15%), and a small amounts of zircon, monazite and other minerals (Fig. 1c). The sizes of the selected monazite particles varied from 40 μm to 150 μm along the long axis, with individual particles reaching 150 μm. The aspect ratio ranges from 1∶1 to 2∶1; the majority were rounded and ellipsoidal (Fig. 1d), and a few of were columnar. Several of the monazites were cracked, and most had uniform gray-white luminescence in the backscattered electron image (Fig. 1e), as is typical of magmatic monazites.

The *in-situ* LA-ICP-MS U-Pb chronology results of the monazite from sample BNC22-39 (Table 1; Fig. 1c) indicate that, except for one outlier measurement point (BNC22-39-19), the remaining 19 monazites have highly variable Th and U contents, ranging from 51.7×10^{-3} to 112.4×10^{-3} and 711×10^{-6} to 4154×10^{-6}, respectively. The corresponding Th/U values range from 101.78 to 990.51. The $^{206}Pb/^{238}U$ ages of the 19 monazites are relatively concentrated, with data points distributed on or near a consistent curve, and the corresponding weighted average age is 87.49±0.69 Ma (MSWD=0.80, *n*=19) (Fig. 1f), representing the crystallization age of monazite, and its diagenetic age was the Late Cretaceous of the Yanshanian period.

4. Conclusions

In this study, the LA-ICP-MS monazite U-Pb method was employed to determine the formation age of the monazite, yielding a result of 87.49±0.69 Ma, and identified the Bainiuchang silver polymetallic deposit diagenetic age as the Late Yanshanian period, which providing strong new evidence for the study of Late Yanshanian period magmatic

Table 1. U-Pb dating results of monazites from Bainiuchang silver polymetallic deposit.

Spots	Content/10^{-6}			Th/U	Isotopic ratios						Age/Ma						Concordance /%
	Pb	Th	U		$^{207}Pb/^{206}Pb$	1σ	$^{207}Pb/^{235}U$	1σ	$^{206}Pb/^{238}U$	1σ	$^{207}Pb/^{206}Pb$	1σ	$^{207}Pb/^{235}U$	1σ	$^{206}Pb/^{238}U$	1σ	
BNC22-39-01	352	111277	3381	770.46	0.0465	0.0029	0.0858	0.0050	0.0136	0.0002	20.5	144.43	83.6	4.71	86.9	1.18	96%
BNC22-39-02	230	68376	2749	1801.27	0.0495	0.0034	0.0924	0.0057	0.0136	0.0002	172	-37.96	89.7	5.26	87.0	1.15	96%
BNC22-39-03	187	55850	2046	249.28	0.0512	0.0049	0.0956	0.0075	0.0138	0.0003	250	224.05	92.7	6.94	88.5	1.59	95%
BNC22-39-04	307	92106	4154	672.22	0.0519	0.0031	0.0963	0.0057	0.0135	0.0002	283	137.02	93.4	5.32	86.8	1.09	92%
BNC22-39-05	384	119511	3104	542.39	0.0529	0.0051	0.0982	0.0079	0.0138	0.0002	324	220.34	95.1	7.32	88.2	1.40	92%
BNC22-39-06	163	51676	1221	165.14	0.0564	0.0079	0.1010	0.0116	0.0144	0.0008	478	312.92	97.7	10.72	92.4	4.84	94%
BNC22-39-07	299	95619	2495	537.94	0.0489	0.0039	0.0913	0.0066	0.0137	0.0002	143	177.75	88.7	6.11	87.7	1.52	98%
BNC22-39-08	230	72253	1860	354.74	0.0503	0.0047	0.0923	0.0085	0.0136	0.0003	209	203.68	89.6	7.89	87.3	1.68	97%
BNC22-39-09	351	108213	3891	990.51	0.0474	0.0025	0.0888	0.0045	0.0136	0.0002	77.9	109.25	86.4	4.23	87.2	1.08	99%
BNC22-39-10	265	87112	1708	468.13	0.0523	0.0041	0.0938	0.0058	0.0136	0.0003	298	186.09	91.0	5.40	86.9	1.82	95%
BNC22-39-11	231	73086	2263	461.65	0.0509	0.0036	0.0945	0.0061	0.0135	0.0002	239	158.31	91.7	5.69	86.6	1.54	94%
BNC22-39-12	293	95566	2086	452.73	0.0503	0.0049	0.0899	0.0084	0.0135	0.0002	209	211.09	87.4	7.80	86.7	1.58	99%
BNC22-39-13	351	112446	2699	731.68	0.0509	0.0034	0.0942	0.0059	0.0136	0.0002	239	153.68	91.5	5.45	87.1	1.54	95%
BNC22-39-14	282	89731	2235	369.92	0.0514	0.0056	0.0903	0.0077	0.0136	0.0003	257	242.57	87.8	7.12	87.0	1.60	99%
BNC22-39-15	223	71421	1896	378.16	0.0461	0.0041	0.0839	0.0060	0.0139	0.0003	400	-188.87	81.8	5.65	88.8	1.77	91%
BNC22-39-16	197	59402	2131	101.78	0.0684	0.0235	0.0997	0.0186	0.0143	0.0004	881	583.65	96.5	17.15	91.8	2.59	95%
BNC22-39-17	328	105938	2302	661.43	0.0500	0.0035	0.0949	0.0066	0.0136	0.0002	198	160.17	92.1	6.13	87.1	1.47	94%
BNC22-39-18	174	59384	711	196.76	0.0491	0.0068	0.0932	0.0102	0.0148	0.0004	154	301.81	90.5	9.45	94.6	2.58	95%
BNC22-39-19	233	75707	1495	329.73	0.0585	0.0061	0.1025	0.0088	0.0137	0.0003	550	229.60	99.0	8.13	88.0	2.04	88%
BNC22-39-20	253	80182	1710	299.69	0.0566	0.0069	0.0970	0.0076	0.0136	0.0004	476	267.56	94.0	7.06	87.2	2.67	92%

intrusion events in this region. The concealed granite body of Bainiuchang was emplaced during the Late Cretaceous and formed in a rift trough environment under an extensional background. It is part of a large-scale diagenesis and mineralization event in the Gejiu-Bozhushan-Laojunshan tin-tungsten polymetallic metallogenic belt in southeastern Yunnan, China. It not only provides thermal power for the components in the activated ore source, but also superposes and enriches with some useful components in the process of activation and migration. Driven by magmatic heat, the ore-bearing fluid and the extracted ore-forming materials migrate to favorable lithologic and structural parts to precipitate, forming Ag-Pb-Zn ore bodies and Sn ore bodies. The results of this study are significant in finely delineating the age frame of the formation of the crypto granite body from the silver-polymetallic deposit in Bainiuchang, and providing a scientific basis for the study of Late Yanshanian period tectonic-magmatic activity and silver-lead-zinc polymetallic mineralization in the Bozhushan region of southeastern Yunnan.

CRediT authorship contribution statement

Bo-de Lu, Wen-chang Li and Xue-long Liu conceived of the presented idea. Bo-de Lu carried out the experiment. Bo-de Lu and Xue-long Liu wrote the manuscript. Jie-hu Zhou and Zhen-liang Cao processed the experimental data, and performed the analysis. All authors discussed the results and contributed to the final manuscript.

Declaration of competing interest

The authors declare no conflicts of interest.

Acknowledgment

This study was supported by Yunnan Major Scientific and Technological Projects (202202AG050006); National Natural Science Foundation of China (42362010); Bozhushan Late Yanshanian magmatic metallogenic system and metallogenic regularity project (202202AG05006-2).

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