



Short Communications (Research Advances)

Zircon U-Pb dating of the Shazibu Pluton in the Guocheng gold belt, Jiaolai Basin, Shandong Province: Implications for metallogeny of the Jiaodong gold province

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Three stages of Mesozoic magmatic activity have been identified in the Jiaodong area, namely early magmatic emplacement, the magmatic emplacement prior to mineralization, and magmatic activity post-mineralization, from early to late. Of these, the early magmatic emplacement, spanning 166 Ma to 142 Ma, primarily involved crust-derived magma and occurred throughout the Jiaodong area. The magmatic emplacement prior to mineralization, characterized predominantly by crust-derived magmas, was confined to the northwestern Jiaodong Peninsula at 130–123 Ma. The last stage, magmatic activity post-mineralization, occurred between 120 Ma and 108 Ma, peaking at 115 Ma. Magmas in the Jiaodong area are chiefly derived from crust-mantle mixing, with magmas of this source widely spreading across the area. Meanwhile, A-type granites are found along the southern margin of the Jiaolai Basin.

The magmatic rocks surrounding the study area are composed primarily of Paleoproterozoic Muniushan monzogranites and Mesozoic Shazibu mylonitized biotite monzogranites (Fig. 1), with intrusions of Mesozoic mafic veins such as diorite and lamprophyre also found in the area. Of these, the Mesoproterozoic Muniushan Pluton was emplaced between 1900 Ma and 1850 Ma, the Shazibu Pluton at 155 Ma, and the magnesia-iron vein rocks in the Tudui gold deposit were formed at around 117 Ma.

The Guocheng gold belt, located along the northeastern margin of the Jiaolai Basin, hosts many geological structures such as the Guocheng Fault, the Yazhi Fault, and ductile shear

zones in the contact area between the Jiaolai Basin and the Shazibu Pluton (Wu J et al., 2021; Chen Y et al., 2023). This gold belt exhibits a highly complex metallogenic geological background. The metallogenic model of a deposit offers a comprehensive synthesis of its origin, involving geological structures, surrounding rocks, sources of ore-forming materials, and the migration, precipitation, and mineralization processes of ore-forming fluids. Such models can serve as an important guide for both the peripheral and in-depth prospecting of a deposit (Duan LA et al., 2022). Based on field geological surveys and geochemical analysis, as well as the regional geodynamic conditions, the formation of ore-hosting spaces, and the metallogenic age and sources of ore-forming materials, this study establishes the metallogenic model for the Longkou-Tudui gold deposit. In addition, it delineates both the peripheral and deep prospecting targets while considering the metallogenic pattern and the implications derived from the metallogenic model.

2. Methods

Zircon U-Pb dating was conducted using laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) at Beijing GeoAnalysis Co., Ltd. This process utilized a NWR193UC laser ablation system from Elemental Scientific Lasers, LLC, USA, coupled with an Agilent 7900 ICPMS also from the USA. Zircons were mounted in epoxy discs, polished to expose their grains, ultrasonically cleaned in ultrapure water, and then cleaned again using AR grade methanol. Pre-ablation was conducted for each spot analysis using five laser shots (about 0.3 μm in depth) to remove potential surface contamination. The analysis was performed using 30-μm-diameter spots at 6 Hz and a fluence of 5 J/cm².

3. Results

The sensitive high-resolution ion microprobe (SHRIMP)

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zircon U-Pb dating of medium-fine-grained quartz monzonite samples collected in this study yielded ages of 117.3 ± 1.6 Ma (Table 1), representing the magmatic age during the Late Early Cretaceous (Fig. 1). The zircons in the samples are mostly of long prismatic shapes with a long-axis length of 200 μm and length-to-width ratios ranging from 1:1 to 1:4, along with a few being incompletely broken. These zircons predominantly presented gray cathodoluminescence (CL) images, with a few exhibiting grayish black CL images, revealing a core-mantle structure (Fig. 1). They contained magmatic oscillation growth zones, and some of them showed signs of corrosion, with black solid inclusions being also observed. The zircons showed moderate U (63×10^6 to 1064×10^6) and Th (89×10^6 to 494×10^6) contents with high Th/U ratios (0.10 to 2.01), indicating a magmatic origin. The analyses of thirteen zircon grains yielded relatively consistent apparent $^{206}\text{Pb}/^{238}\text{U}$ ages varying from 109 Ma to 119 Ma, with a weighted mean age of 117.3 ± 1.6 Ma.

To investigate a deposit, it is important to determine its age. Investigations into zircons from the Shazibu Pluton reveal that this pluton was formed at 117.3 ± 1.6 Ma (Fig. 1), while the basalt dikes and monzonite porphyry in the Longkou-Tudui gold deposit were formed at 116 ± 1 Ma and 114 ± 2 Ma, respectively. Based on these observations, it can be inferred that 117 Ma could represent the upper limit of the gold mineralization age of the Longkou-Tudui gold deposit. Therefore, the mineralization age of the Longkou-Tudui gold deposit can be constrained between 120 Ma and 117 Ma, which is consistent with the period when the regional tectonic stress field transitioned from tectonic compression to extensional uplift.

Previous research achievements and the stratigraphic distribution in the Jiaolai basin indicate that the Taocun, Guocheng, and Yazhi faults exhibit both sinistral strike-slip deformations and the characteristics of normal faults. The W-E-trending section of the basin provides a clear depiction of

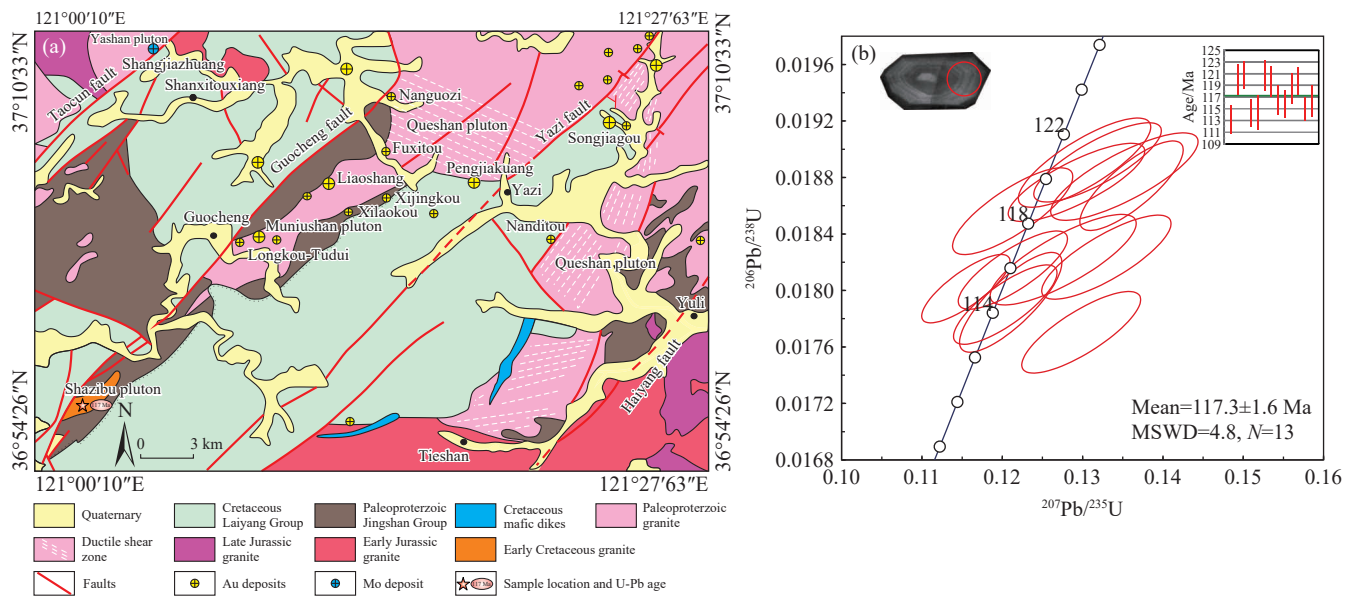


Fig. 1. a–Regional geological map of the Guocheng gold belt along the northeastern margin of the Jiaolai Basin (modified from Wu J et al., 2021; Chen Y et al., 2023). b–zircon U-Pb concordia diagram of the quartz monzonites of the Shazibu Pluton.

Table 1. SHRIMP Zircon U-Pb data from the quartz monzonites of the Shazibu Pluton.

Spot	Element/ 10^{-6}			Isotopic ratio				Age /Ma								
	Pb	Th	U	Th/U	$^{207}\text{Pb}/^{206}\text{Pb}$	$^{207}\text{Pb}/^{235}\text{U}$	$^{206}\text{Pb}/^{238}\text{U}$	$^{208}\text{Pb}/^{232}\text{Th}$	$^{207}\text{Pb}/^{206}\text{Pb}$	1σ	$^{207}\text{Pb}/^{235}\text{U}$	1σ	$^{206}\text{Pb}/^{238}\text{U}$	1σ	$^{208}\text{Pb}/^{232}\text{Th}$	1σ
ZK1-112-1	3.52	247	123	2.01	0.053142	0.129820	0.017704	0.005636	345	81	124	4	113	1	114	2
ZK1-112-2	2.33	121	84.8	1.43	0.052451	0.135191	0.018806	0.006058	306	104	129	5	120	1	122	2
ZK1-112-3	2.56	118	98.0	1.20	0.050443	0.131859	0.018907	0.005994	217	85	126	5	121	1	121	2
ZK1-112-4	2.81	165	106	1.56	0.048703	0.120378	0.017900	0.005602	200	78	115	4	114	1	113	2
ZK1-112-6	4.10	238	140	1.70	0.049199	0.121056	0.017916	0.006924	167	83	116	4	114	1	139	22
ZK1-112-8	3.95	236	136	1.74	0.049937	0.130238	0.018905	0.006100	191	93	124	5	121	1	123	1
ZK1-112-9	2.40	116	91.0	1.27	0.052797	0.136092	0.018742	0.005893	320	68	130	4	120	1	119	2
ZK1-112-10	1.87	105	69.9	1.50	0.052846	0.132959	0.018236	0.005899	320	89	127	5	116	1	119	2
ZK1-112-14	2.88	164	106	1.55	0.048717	0.121311	0.018144	0.005939	200	89	116	4	116	1	120	2
ZK1-112-17	2.38	111	93.1	1.19	0.047447	0.121291	0.018561	0.005876	72	93	116	4	119	1	118	2
ZK1-112-19	1.88	109	63.3	1.72	0.050089	0.129233	0.018765	0.005900	198	102	123	5	120	1	119	2
ZK1-112-22	3.39	184	126	1.46	0.046635	0.115471	0.018013	0.005974	32	74	111	3	115	1	120	1
ZK1-112-23	1.87	89.1	68.4	1.30	0.050853	0.127585	0.018218	0.005942	235	110	122	5	116	1	120	2

the combined relationships among these faults. Furthermore, the northern margin of the study area exhibits a nearly W-E-trending ductile shear zone. The elongated, eyeball-like structure indicates the E-W-trending shear strike-slip deformations. Notably, the presence of gravels in the Early

Cretaceous Linsishan Formation within the shear zone of the Shazibu Pluton suggests the substantial uplift and denudation of the pluton during this period. This geological process resulted in nearly synsedimentary N-SE-W-directed slip, which corresponds closely to the metallogenic event (Fig. 2).

NE–SW striking arch-shaped structures in which ductile shear zones

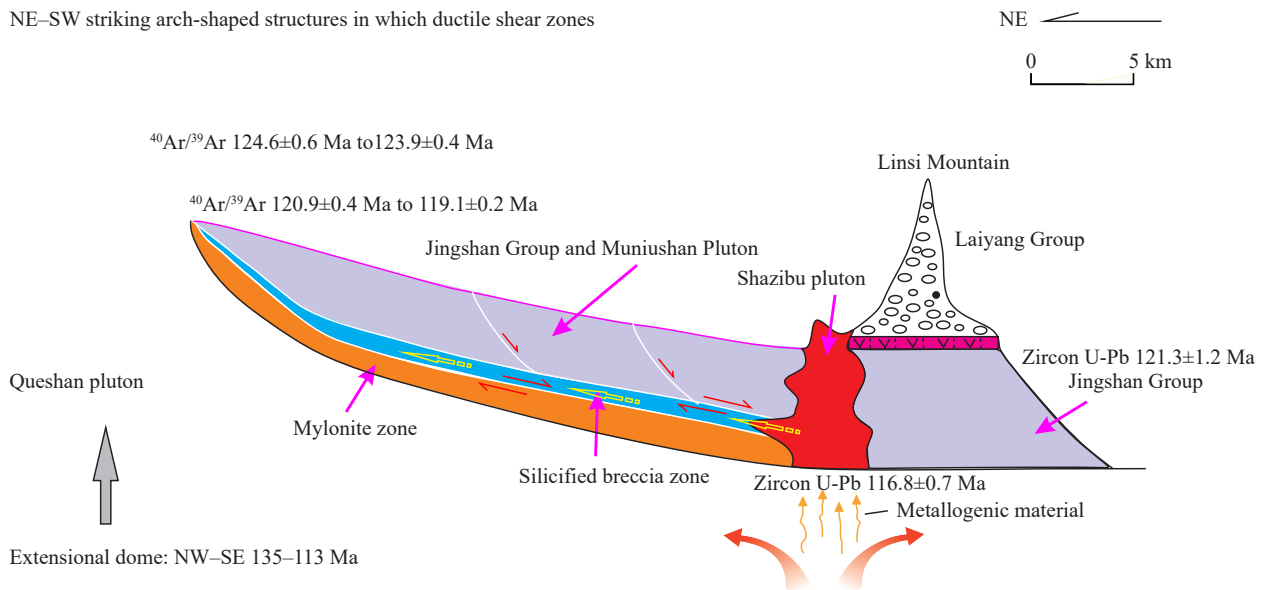


Fig. 2. Structural detachment metallogenic model of the Guocheng gold belt in the Jiaolai Basin, North China (modified from Chen Y et al., 2023).

4. Conclusions

(i) The Shazibu Pluton is dated at 117 Ma, which belongs to the late Early Cretaceous. Given that vein rocks intersect ore bodies, the gold deposits in the Guocheng gold belt along the northeastern margin of the Jiaolai Basin are estimated to have formed between 120 Ma and 117 Ma.

(ii) A regional metallogenic tectonic model is developed for the gold deposits in the Guocheng gold belt based on the tectonic background of the basin, the tectonic evolution model and metallogenic system of the deposits, the origins of the ore-forming fluids, and the *in-situ* characteristics of the ore bodies surrounding the deposits.

CRedit authorship contribution statement

Yuan-yuan Feng conceived the presented idea and verified this theory. Ya-dong Li, An-kai Geng, and Da-dou Li collected and analyzed the samples, as well as providing detailed data. Yuan-yuan Feng and Liu-an Duan prepared the original draft. All authors discussed the results and contributed to the final manuscript.

Declaration of competing interest

The authors declare no conflict of interest. This paper was supported by the geological research projects of the Shandong Yantai Xintai Gold Mining Co., Ltd. under China National

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