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Short Communications (Research Advances)

Discovery of a medium-scale tectonic altered rock type gold deposit (13.5 t) on the northeastern margin of Jiaolai Basin, Shandong Province, China and its new application of exploration direction

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1. Objective

The Qianchuiliu mining area is located on the northeastern margin of the Jiaolai Basin, Shandong Province, China. A series of gold deposits have been discovered around this area in recent years, such as the Liaoshang (super large; 69 t), Xilaokou (large; 31 t), Xijingkou (medium; 11 t), and Guocheng (large; 21 t) deposits, indicating favorable metallogenic geological conditions (Fig. 1a). However, only a series of NE-trending veins (alteration zones) inclining southeastward instead of industrial-scale ore bodies have been discovered in the Qianchuiliu mining area since 1999 through a great deal of geological and geophysical exploration as well as a large amount of engineering verification through trenching, pitting, and drilling. This has created confusion about the prospecting in the study area. For the sake of further assessment of the gold metallogenic resource potential in the study area, geological surveys and drilling construction were carried out in 2020 based on previous work. During this period, a new EW-trending tectonic ore-controlling model was proposed to substitute for the former NE-trending tectonic ore-controlling model according to the distribution of the ore deposits nearby. Meanwhile, seven boreholes were deployed to verify the new model, expecting to achieve prospecting breakthroughs and progress.

2. Methods

A 1∶10000 geological survey covering an area of 6 km^2 was carried out to verify the locations of contact zones between rock masses and strata in the study area. The 1∶10000 lithological and geochemical profiling with a length of 12.84 km was conducted for the multielement analysis of surface alteration zones and borehole cores. Meanwhile, 4539 m of drilling construction was performed to verify and control the newly discovered ore bodies in the Qianchuiliu mining area. Moreover, a large number of samples and sections were collected and processed for supporting analyses of the gold reserves, including 2252 samples for basic analyses, 40 thin and polished sections, 40 fluid inclusion sections, and 20 samples for sulfur isotopic tests.

3. Results

A nearly EW-trending tectonic alteration zone was inferred and newly discovered (Fig. 1b), and all the seven boreholes intersected with gold ores. Specifically, a thick concealed tectonic alteration zone (elevation: −280 – −470 m; the elevation of ore body: −335 – −450 m) was found deep in the boreholes. It is in nearly EW trending, with a dip angle of 13°–21° and an apparent thickness of 130–207 m. It mainly consists of tectonic breccias, beresitized granitic cataclasites bearing carbonate veins, silicified granitic cataclasites, and diorite intrusions. A considerable amount of alteration was observed, such as silicification, sericitic alteration, pyritization, and carbonation. Besides, a small amount of galena and hematite were also discovered. Among them, major gold ore bodies occur in the concealed tectonic alternation zone, with the occurrence consistent with that of the tectonic alteration zone.

Ten gold ore bodies were delineated, with a total inferred gold resources preliminarily estimated to be 13504 kg. Among them, ore body No. 2 is the main ore body. It is in nearly EW trending, with a dip angle of 13°–21° and a length

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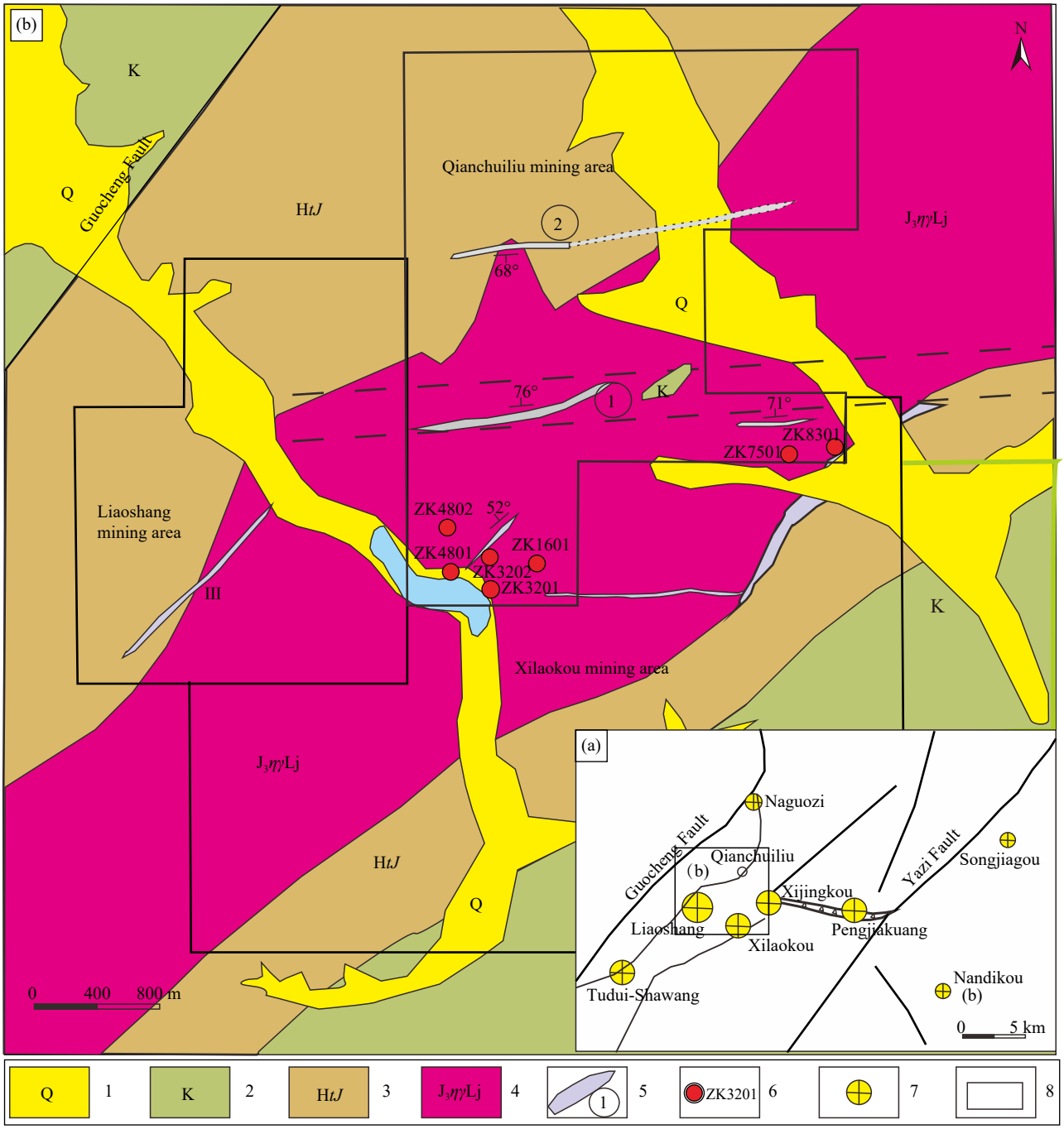

Fig. 1. Regional geological sketch of the Qianchuiliu gold mining area and its surrounding areas (after Duan LA et al., 2020). 1–Quaternary; 2–Cretaceous strata; 3–Jingshan Group; 4–Linglong granite; 5–alteration vein and No.; 6–borehole and number; 7–gold deposit; 8–name and scope of a mining area.

constrained by drilling engineering of 640 m. Meanwhile, it has a depth of 220 m in the inclination direction, an average vertical thickness of 8.65 m, and an average and maximum gold grade of 3.47×10^{-6} and 252.05×10^{-6}, respectively. Native gold grains were observed in the hand specimen and thin sections. Meanwhile, ore body No. 2 consists of beresitized granitic cataclasites bearing carbonate veins and contributes more than 10405 kg of inferred gold resources (Table 1) and 16953 kg of associated silver resources (average silver grade: 5.50×10^{-6}).

As indicated by comprehensive research, the large-scale concealed tectonic alteration zone is located between the overlying Muniushan granite and the underlying Queshan granite intrusion, and its main ores are similar to the altered rock type gold ores in the Northwest Jiaodong area. Temperature measurement of fluid inclusions shows that the metallogenic temperature was 188–338℃, which is a medium-high temperature. The sulfur isotope $\delta^{34}S$ of the ores is 10.13 ‰ –12.39 ‰, indicating the characteristics of much sulfate involvement in the ore sources.

The ore body characteristics and ore types in the Qianchuiliu mining area are similar to the characteristics of

Table 1. Calculated gold resources of ore body No. 2 in Qianchuiliu gold mining area, Jiaolai Basin.

Orebody	Block/segment No.	Category	Thickness /m	Area /m^2	Volume/m^3	Density/(t/m^3)	Ore content/t	Average grade/10^{-6}	Gold content /kg
2	2-1	TD	6.17	34976.63	215689	2.90	625499	2.08	1303
	2-2	TD	10.12	17286.00	174877	2.90	507142	2.89	1466
	2-3	TD	8.95	18972.12	169800	2.90	492421	2.63	1297
	2-4	TD	8.60	35496.95	305274	2.90	885294	4.03	3571
	2-5	TD	12.55	15718.70	197270	2.90	572082	4.84	2769
Total									10405

Note: TD denotes inferred resources.

Table 2. Characteristics of the Qianchuiliu mining area and its surrounding gold deposits.

Name	Characteristics of main ore bodies	Gold deposit scale	Average grade (gold, silver: 10^{-6}; others: %)	Elevation of main ore bodies
Liaoshang mining area	56 ore bodies. The main ore bodies are 310 m long, 587 m deep in the inclination direction, and 16.79 m thick on average. Orebody No. III-9 has the largest scale, with a strike of 35°–39°, an inclination of SE, and a dip angle of 24°–38°	Gold: 69003 kg; associated silver: 5437 kg; associated pure sulfur: 844700 t	Gold: 3.33; silver: 2.64; sulphur: 4.10	−518 –−952 m
Xilaokou mining area	168 ore bodies. Orebody No. III-26 is the main ore body. It has a strike of 87°–105° (average: 95°) and inclines southward, with a dip of 15°–44° (average: 30°)	Gold: 31094 kg; associated silver: 3957 kg; associated pure sulfur: 605000 t	Gold: 2.53; silver:2.32; sulfur: 4.95	−500 –−702 m
Xijingkou mining area	19 gold ore bodies, six lead ore bodies, and six zinc ore bodies. Orebody No. VI-1 is the main ore body. It is in nearly EW trending and inclines southward, with a dip angle of 0°–12°	Gold: 11004 kg; lead: 304 t; zinc: 621 t; silver; 19393 kg; pure sulfur: 460900 t	Gold: 2.73; lead: 0.73; zinc: 1.37; silver: 5.62; sulfur: 12.15	−127 –−634 m
Qianchuiliu mining area	10 gold ore bodies. Orebody No.2 is the main ore body. It is in nearly EW trending and inclines southward, with a dip angle of 10°–21°	Gold: 13504 kg; associated silver: 16953 kg	Gold: 3.47; silver: 5.50	−335 –−450 m

adjacent Liaoshang, Xilaokou, and Xijingkou gold deposits, and their ore bodies all consist of beresitized granitic cataclasites occurring in thick concealed tectonic alteration zones (Table 2). Therefore, it can be inferred that their main ore bodies are controlled by the same tectonic setting. Therefore, the Qianchuiliu mining area has great metallogenic potential for gold prospecting.

4. Conclusions

(i) Ten gold ore bodies were found in the Qianchuiliu mining area in 2020, with inferred gold resources estimated to be 13504 kg. This marks the breakthroughs and progress made in gold prospecting and will provide bases and support for the subsequent exploration.

(ii) The new understanding of an EW-trending ore-controlling tectonic zone was proposed, guiding the discovery of the Qianchuiliu gold deposit. Furthermore, this understanding contributes to the solving of the problem of where and how to find gold deposits in peripheral areas and thus plays a notable leading and exemplary role.

CRediT authorship contribution statement

Liu-an Duan conceived of the presented idea and verified this theory. Yun-cheng Guo, Xiao-meng Han, Jian-tian Wang, Peng-fei Zhao and Li-peng Wang collected and analyzed the samples, provided detailed data. Liu-an Duan and Yun-cheng Guo wrote the original draft. You-feng Wei reviewed and edited the manuscript. All authors discussed the results and contributed to the final manuscript.

Declaration of competing interest

The authors declare no conflict of interest.

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