BRECCIATION AND GOLD MINERALIZATION OF ORE-HOSTING ROCKS IN LAOYACHAO GOLD DEPOSIT①

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ABSTRACT It was pointed out through field and laboratory investigations that, ore-hosting breccia resulted from gas-liquid concealing explosion is fallen into mixed, broken-slackened and split phases. In addition, there are also two especial phases, that is, gushing phase and grouting phase; gold mineralization is confined within the gas-liquid concealed-explosion breccia body and gold orebodies are completely included in the gushing phase and grouting phase, ore-forming physico-chemical condition is of a low-pressure, low-temperature, sub-alkalinite and reducing condition; ore-forming fluid belongs to the Na-Ca-Cl type with a low salinity.

Key words: gold deposit ore-hosting breccia gas-liquid concealed explosion

1 INTRODUCTION

There are independent lead-zinc orebodies and pyrite orebodies as well as independent gold orebodies in Laoyachao Orefield of Shuikuoshan, Hunan. Among them, the lead-zinc orebodies and pyrite orebodies constitute the famous Shuikuoshan skarn-type lead-zinc deposit, in which the gold contents are less than 1g/t. Hence, it belongs to the associated gold deposit. As for independent gold orebody (No. 4) located in the brecciated rock zone, it was considered as an associated or paragenetic gold deposit for a long time.

Under the guidance of the theory of the non-associated gold formation, it has been shown that gold-mineralized area which has been demonstrated at pressent, exceeds the lead-zinc-mineralized range and reaches the scale of large-sized independent gold deposit. However, up to now, it's still placed into the skarn-type Pb-Zn-Au deposit or associated (paragenic) gold deposit in some works[1]. Although most researchers had noticed that the gold ore-formation was closely associated with the rock brecciation in Laoyochao, a commonly-accepted viewpoint on the gold type and the law of gold enrichment wasn't available. In order to solve the problems, the authors of this paper, in recent years, applying the criterion method of the hydrothermal mineralbody, restored and analysed the gas-liquid concealed explosion hydrothermal fluid upwelling and filling breccia type gold deposit.

2 GEOLOGICAL FEATURES OF THE ORE DEPOSIT

Laoyachao gold deposit is located in the edge of Jiangnan Old Landmass, in the north end of south-north Leining fold zone, in the southern rim of Henyang Graben Basin and in the northeast of Shuikoushan orefield (Fig. 1). Main strata in this area are Qixia Formation of Permian, which consists of limestone, Dang-Chong Formation consisting of shale and mudstone, and DouLing Formation consisting of sand shale. The main structures in this area are Laoyachao overturned anticline, its core is made up of limestone of Qixia Formation,

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with granodiorite intruding along its axis. At its outer contact zone, there are lead-zinc orebodies and pyrite orebodies, which make up Shuikoushan Pb-Zn deposit. Located in eastern limb of the anticline, gold orebody occurs in the broken zone, which lies at the intersection site of limestone of Qixia Formation and siliceous shale of Dangchong Formartion with granodiorite, which makes up Laoyachao deposit. The main fault in this area is the reverse fault F_2. Granodiorte exposed in the orefield is dated 143 Ma by the K-Ar method, which intrudes along the axis of the overturned anticline, taking the form of rock basin. The rocks are intermediate-acid.

Gold mineratized belt of Laoyachao is 220 ~560 m long, 15~115 m wide and extends to a depth of about 500m. There're more than 10 different-sized orebodies in all. According to the different elevation control, the length of orebodies varies from 47 m to 138 m and the thickness varies from 3. 5 m to 19 m, with an average of about 10 m. The orebodies are bed-like, chain-shaped, lendicular and pipe-like etc. Gold orebodies occur in the rock brecciation zone, which lies at the intersection of magmatic rockbody and Qixia Formation and Dangchong Formation or in Dangchong Fomation (Fig. 2). Gold grades vary from 4. 59 g/t to 9. 99 g/t, with an average of 6. 068 g/t. Gold, taking the form of native gold, appears in the microfractures and intergranular openings or around the grain rim of quartz and calcite. In addition, gold also presents in the grains or around grains of pyrite, sphalerite, magnetite and hematite, but this case is less important. The grain size of gold is mainly medium-fine grain, the fineness of gold (or silver) varies between 88. 0%~96. 0%. The wallrock alterations are silicfication, carbonation and hematitization. This research proves that galena, sphalorite and pyrite of gold ores are mainly the products of the breccia and debris of lead-zinc and pyrite orebodies, rather than the paragenous minerals of gold metallization.

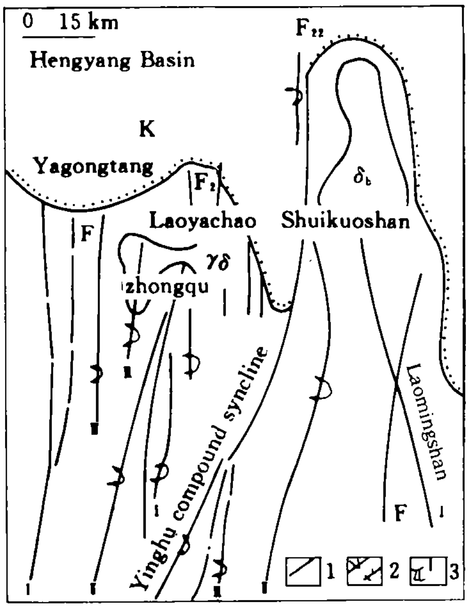

Fig. 1 Shuikuoshan orefield tectonic sketch map

K —red-beds of Cretaceous; $\gamma\delta$ —grandiorite; δ_s —dacite poropyrite X_s —liparite porphyry; 1—fault; 2—axis of fold; 3—tectonic grade

3 GENETIC RESTORING CRITERIA OF ORE-HOSTING ROCKS BRECCIATION

3. 1 Judgement of Hydrothermal Mineralbody

Based on the restoring judgement methods put forward by the authors[2], the study indicated that there are two types of hydrothermal mineral bodies in Laoyachao orefield: one is Pb-Zn-bearing hydrothermal mineral body, which constitutes Shuikuoshan lead-zinc-pyrite deposit (not dicussed here); the other is gold-bearing hydrothermal mineralbody, which makes up Laoyachao gold deposit. Comparision of two types of hydrothermal mineralbody is listed in Table 1. In addition, gold-bearing hydrothermal mineralbody is of the following features: (1) Besides minerals listed in Table 1, the mineralbody also contains considerable amount of fragments and dusts of lead-zinc ore and pyrite ore. (2) In the gold-bearing hydrothermal mineralbody, pyrite appears as fine-grained euhedral or hypidiomorphic crystal, taking the forms of disseminated-form, micro-dikes, film-form surrounding rock-fragments, or irregular form

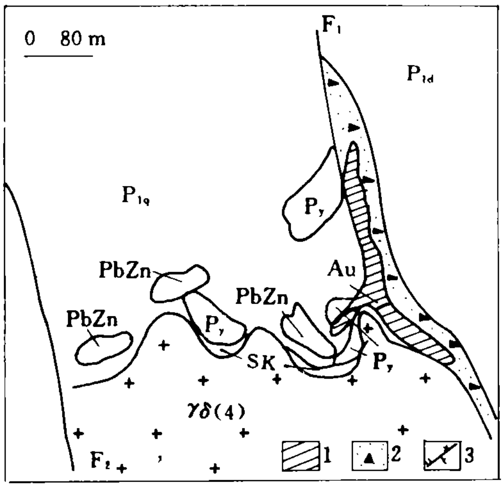

Fig. 2 The 11th level plain figure of Laoyachao ore district

P1d—Dangchong Formation of Permian; P1q—Qixis Formation of permian; PbZn—lead-zinc orebody; V,(4)—grandiorite and its number; Py—Pyrite orebody; 1—gold orebody; SK—skarn breccia body; 2—breccia; 3—fault

filling and replacing debris. Larger-grain pyrite always contains the rock fragments and dusts and forms the texture looking 'like sideronitic texture, whose colors appear somewhat light yellowish-white, and whose polished degree under microscope is better than breccia pyrite. The Co/Ni value, S/Se value and sulphur isotopic composition of the pyrites of two kinds of hydrothermal mineralbody are shown in Table 2. (3) In the hydrothermal mineralbody, calcite mostly presents pink, and fluorite always appears in a dark-purple colour. (4) Miarolitic texture can be seen in the hydrothermal mineralbody. (5) Gold-bearing hydrothermal mineralbodies in the form of dike or irregular mass are completely included in the rock's broken belt, occurring as welding and cementing materials of ore breccia. They make up the breccia-type gold deposit. The contents of elements such as lead, zinc, sulfur depend not on richness of galena, sphalerite and pyrite in the hydrothermal mineralbody, but on the amount of galena-pyrite-containing breccia in the broken belt. Field investigation suggests that the composition of breccia varies from the brecciation of lead-zinc-pyrite orebodies in situ to the rock breccia mixed with the breccia and fragm-

Table 1 Comparsion of some feature between two types of hydrothermal mineralbody in laoyachao

Type of mineralbody	Main component minerals	Main induserial minerals	Shape of mineralbody	Homogenization temperature of quartz/℃	Forming pressure /MPa
gold-bearing hydrothermal mineralbody	natural gold, quartz, chalcedony, pyrite, hematite, galena, sphalerite magnetite, fluorite, chalcopyrite, marcasite dolomite, arsenopyrite etc	natural gold gold	vein network, irregular massive body	141～235	2～19
lead-zinc-bearing hydrothermal mineralbody	sphalerite, galena pytite, skarn etc	galena, sphalerite, pyrite, silver-mineral	pocket shaped body,	360	25.8

Table 2 The features' comparsion of trace elements and sulfur isotopic composition of pyrite

Type of mineralbody	Co /g·t⁻¹	Ni /g·t⁻¹	S (%)	Se /g·t⁻¹	Te /g·t⁻¹	$\frac{Co}{Ni}$	$\frac{S}{Se}$	δS^{34}‰ average	δS^{34}‰ deviation
gold-bearing hydrothermal mineralbody	145	73.9	48.14	32.2	2.29	1.94	1.53	+1.61	5.008
lead-zinc-bearing hydrothermal mineralbody	122	141	48.96	108	14.3	0.83	0.53	+0.48	+16.498

ent of allochthonous Pb-Zn-pyrite orebody.

3.2 *Genetic Judgement of the Ore-hosting Rocks' Brecciation*

The study indicates that the gold-bearing hydrothermal mineralbodies are completely restricted within the breccia zone, occurring as the cementing and welding materials among breccia. So the brecciated ore-hosting rocks' features are shown as fowllows: (1) For the homogeneous granodiorite, the model is characterized as (along the horizontal direction to the centre): original rocks→half-split brecciation→fully-split brecciation→slackened brecciation→mixed brecciation. Various brecciation zones present an transitive relation. (2) The three dimension model of the rock brecciation system has the same like non-isotaxial pipe. Along the same horizontal direction as the mineralized belt extended, several brecciation systems are seen. However, overlapping areas of the mixed and slackened zone aren't found in various brecciation systems.

The model of rock brecciation system indicates that ore-hosting rocks' brecciation belongs to the gas-liquid concealed explosion. The gold-bearing hydrothermal mineralbody is apparently differnt from that of tectonic breccia or of palaeo-karst "structure-colluviation" or that of brecciatied zone rock-formation (all not discussed here). This brecciation system exactly coincides with the zoning feature caused by the gas-liquid concealed explosion. The gas-liquid concealed-explosion type brecciation system is divided into four zones.

(1) Mixed brecciation zone

While the gas-liquid concealed explosion takes place, the high-speed swelling gas produces a high pressure within the rocks which serves as the gas-liquid trap, and thus forms a compressed cavity in the rock. The elastic deforming energy is stored up in rock formation of the compressed cavity due to the drastic compressing effect. When the compressing stress is removed, this elastic deforming energy is sequently released, and moves the damaged rock mass toward the explosion origin. On the other hand, due to gas-liquid exploding and releasing, the pre-existing gas-liquid cavity instantly become an empty cavity, and together with the compressed cavity, constitutes a extended cavity, which enables rockmass to move toward the explosion origin and also causes the overlying rock-formation of the explosion center to collapse. So rockmass and breccia pile up in the concealed-explosion centre cavity, and make up the polygenetic mixed brecxciation zone with far-apart grain sizes.

(2) Brocken-slackened brecciation zone

The zone is located at the outer side of the mixed breccia zone. When the swelling high-pressure gas and the blast wave exert great pressure upon rocks, the rocks are brecciated in company with the formation of the mixed breccia zone. This kind of breccia makes a short-distant migration toward the explosion center, but the breccia compositions aren't mixed during the rotation and migration of breccia. The rubbles of the breccia come from locally available materials, but they are not matchable to each other. So this zone is referred as the slackened brecciation zone.

(3) Split brecciation zone

In accordance with the physical process of rock-explosion, most of explosive energy is used to smash rock. Stress wave abruptly declines with the enlargement of the spreading area of stress wave. When it spreads through the margin of rock-split zone, the stress value is less than the compressive strength of rocks, so it only cause the radial extension and sheartensile strain. On the other hand, stress-concentration occurs at the end of radial cracks due to the gas-wedge effect. For this reason, cracks don't stop extending until the velocity of high-pressure gas is reduced to less than that of sound. In the zone of radial cracks, rocks lay aside still parts of elastic deforming energy due to the strong compression. When stress is relieved, this energy will be released to bring about rocks' centripetal movement and produce a radial tensile stress. When the tensile stress is larger than the strength of rock, the concentric cracks will appear. In this way, the intersecting radial cracks and concentric cracks make up the network of cracks, which cuts the rocks into fragments of different size.

(4) Rock quaking deformation zone

It is located at the outer side of the split zone, with rock unsplit. Due to the consumption and decrease of the explosive wave energy in the above two zones, the residual energy only causes elastical vibration of rocks. The coverage of vibration exceeds that of the zones mentioned above, but the energy is too weak to destory rocks. Under long-term vibration, fracture may occur and even fault forms.

4 GOLD-BEARING BRECCIA DUE TO THE GAS-LIQUID CONCEALED EXPLOSIN AND GOLD MNERALIZATION

4. 1 *Features of the Breccia Body*

According to the brecciation zoning due to the gas-liquid concealed explosion and the features of various brecciation zones, it is concluded that the gas-liquid breccia bodies are of the following features.

(1) Typical lithophase zoning, that is, from the explosive center to its both sides, symmetrically occurs the differnt lithophases: the mixed breccia phase → brocken-slackened breccia phase → split breccia phase.

(2) Two especial phases, i. e., hydrothermal fluid upwelling breccia phase (gushing phase) and grouting phase, have the same features as follows: (a) The breccia composition of phases is allochthonous and polygenetic. The size of breccia is small, mostly varying from 10 mm to 12 mm. (b) Marginally-spreading breccia are of preferred dimensional orientation, that is, the long axis of breccia spreads intersecting at acute angle with the margin or subparallelling to the margin. (c) The breccia grain-size distribution histogram is simlar to that of fluvial conglomerates, with a doublepeaking feature and showing the regularity of the breccia carried and transported by liquid. (d) Most breccia are of certain roundness. (e) The hydrothermal minerals obviously increase in the cementing materials. The distribution law of the two especial phaese shows that the gushing phase may occur in each phase zone of breccia body and hasn't obvious boundary with them.

(3) According to the criteria of mixed brecciation zoning, the gas-liquid concealed explosion breccia bodies are of colonization. The research indicates that Laoyachao breccia body of the gas-liquid concealed explosion is made up of many connected lotus-root-joint-shaped breccia bodies, and the number of the breccia bodies is different at the different level, e. g., there are two breccia bodies at the level of −260 m and three breccia bodies at −336 m level.

4. 2 *Gold Mineralization of Breccia Bodies*

The gold mineratization regularities of gas-liquid concealed explosion breccia bodies are listed as follows (shown in Fig. 3～4).

(1) Gold mineralization appears at all kinds of phases. Its tenor is about 1. 5 g/t.

(2) Gold is enriched in hydrothermal gushing phase and grouting phase. The statistic result shows the characteristics of the gold enrichment in gushing phase, that is, a total varied range of gold tenor from 1. 5～16 g/t with a optimum range of 1. 5～4 g/t and a secondary of 4. 0～1. 2 g/t. The gushing phase will disappear when the tenor is less than 1. 5 g/t. It may be seen that gold mineralization is closely associated with the gas-liquid concealed explosion, and the gold mineralization and enrichment concide in space and time with the occurrence of the gushing and grouting phases. According to the concealed-explosion ore-formation features mentioned above, we refer it as the breccia-type gold deposit by the filling of the upwelling hydrothermal fluid from gas-liquid concealed explosion.

According to the fluid inclusions in calcite, quartz, light sphalerite of the gold-bearing hydrothermal mineralbody, and the exchange equilibrium data of sulfur isotope between the paragenetic paired minerals of pyrite-sphalerite, sphalerite-galena, it is shown that Laoyachao gold deposit occurs under a medium-low temperature, low pressure, subalkinite reducing condition, ore-forming fluid is of a Na-Ca-Cl type with a low salinity.

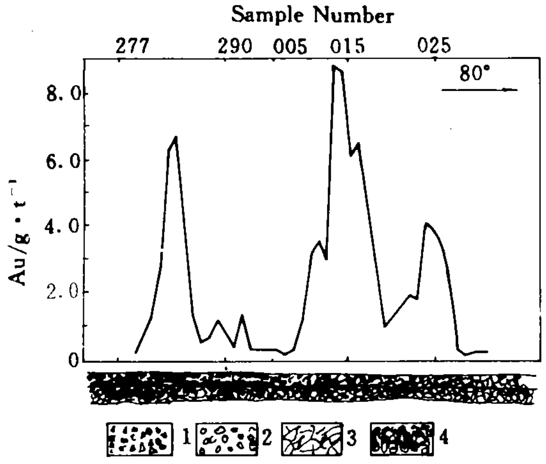

Fig. 3 The gold-tenor change curve of XII 003-1 cross
1—mixed breccia phase;
2—broken breccia phase;
3—split breccia phase;
4—hydrothermal fluid gushing phase

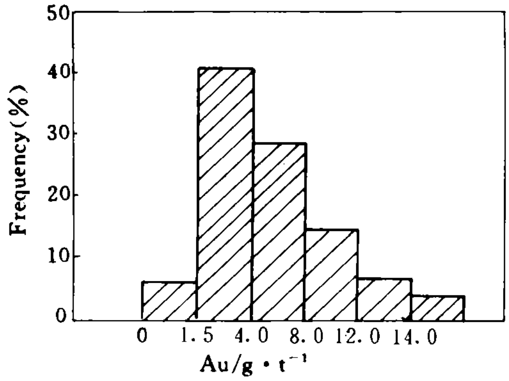

Fig. 4 The gold-tenor frequency histogram of the hydrothermal solution gushing phase in the levels No. 8, No. 10, No. 11 and No. 12

5 CONCLUSIONS

(1) There are two types of absolutely different hydrothermal mineralbodies in Laoyachao orefield of Shuikuoshan. One constitutes Shuikaoshan skarn-type lead-zinc deposit, the other makes up Laoyachao gas-liquid concealed explosion breccia-type gold deposit.

(2) Gold hosting rock's brecciation reflected by the gold-bearing hydrothermal mineralbody is attributed to the gas-liquid concealed explosion. This kind of breccia body is divided into mixed breccia phase, broken (slackened) breccia phase and split breccia phase as well as two especial phases of the gushing phase and grouting phase.

(3) Gold mineralization is restricted within the scope of gas-liquid concealed explosion breccia body, and gold orebody is completely included in the two especial phases.

(4) The physical-chemical condition of the gold mineralization is of a low-pressure, low-temperature, sub-alkalinite reducing condition; ore-forming fluid is of the Na-Ca-Cl type with a low salinity.

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