

Research on geological features of Huaniushan Gold Deposit in Beishan of Gansu province

Zhouyuan Zhang *, Zhaofeng Lin, Haili Liu

Shaanxi Provincial Land Engineering Construction Group Ming Development and Environmental Management Co., LTD, xi'an 710075, China

*Corresponding author e-mail: E-mail: 393855200@qq.com

Abstract. The Beishan orogenic belt is located in the south rim of central Asia orogenic belt, the intersection of east Tianshan and Tarim plates. Thus, the geological structure is extremely complex. The gold deposits are widely distributed in various types and the met allogenic mechanism is complex. Overall, the gold deposits in Beishan orogenic belt are mostly developed in Palaeozoic continental plate collision and butting belt, which has a certain spatial and temporal distribution law. Huaniushan gold deposit is a typical gold deposit in Beishan Orogenic belt. This paper carried out a detailed study of the geology of Huaniushan gold deposit, to provide some basis for the classification of met allogenic stage.

1. Background of Huaniushan Gold Deposit

The ore body of Huaniushan Gold Deposits symmetrically occurred in the calcium siliceous hornstone and the interlayer fractured zone in the contact zone between marble and biotite felsic hornstone (whose original rock is argillaceous silty clastic rock) of third lithologic section in Jixian system, and also in the skarn zone of Indosinian-Yanshanian syenogranite and marble [1-3]. The mining area is the secondary anticlinal structure of east side. The biotite felsic hornstone is in the core, and the marble is developed in both sides. The ore-bearing rocks are skarn, marble, granite, biotite felsic hornstone, quartz diopside hornstone, biotite cordierite hornstone and skarnized marble. The quartz diopside hornstone is the main mineralized rock. A total of 6 ore bodies were discovered during the first detailed investigation of Huaniushan Gold Deposits (fig.1). The strike of the whole orebody is nearly from east to west (N90°-110°E), the tendency is S-SSW and the dip angle is 55° to 75°, which is basically identical to the occurrence of surrounding rock. The reserves of proved Au is 0.85t and the average grade of Au is 5.4g/t.

The scale of No.1 orebody is relative large, appearing in layered and vein form. The length of orebody is 243.5m, with the thickness of 4.3m and the slant depth of 40.5m. The average grade of Au is 56 ppm. The No.2 orebody is layered, whose length is 56.5m, thickness is 1.9m, and the average grade of Au is nearly 116ppm. The scale of No.3 orebody is also relative large, appearing in stratiform. The length of orebody is 183m with the thickness of 5.7m and the slant depth even 93.5m. The average grade of Au is 54 ppm. The No.4 orebody is lenticular, whose length is 20m, thickness is 1m and the depth is 5m respectively. The average grade of Au is 15ppm. The No.5 orebody is lenticular, with a length of 30m, a thickness of 3 m, and a depth of 15m, and the average grade of Au is 16ppm. The No.6 orebody is lenticular. The orebody is 8.5m long with a thickness of 1 m and a control slope



of 4.3m. And the average grade of Au is 110ppm. Detailed elements of each orebody are shown in table 1.

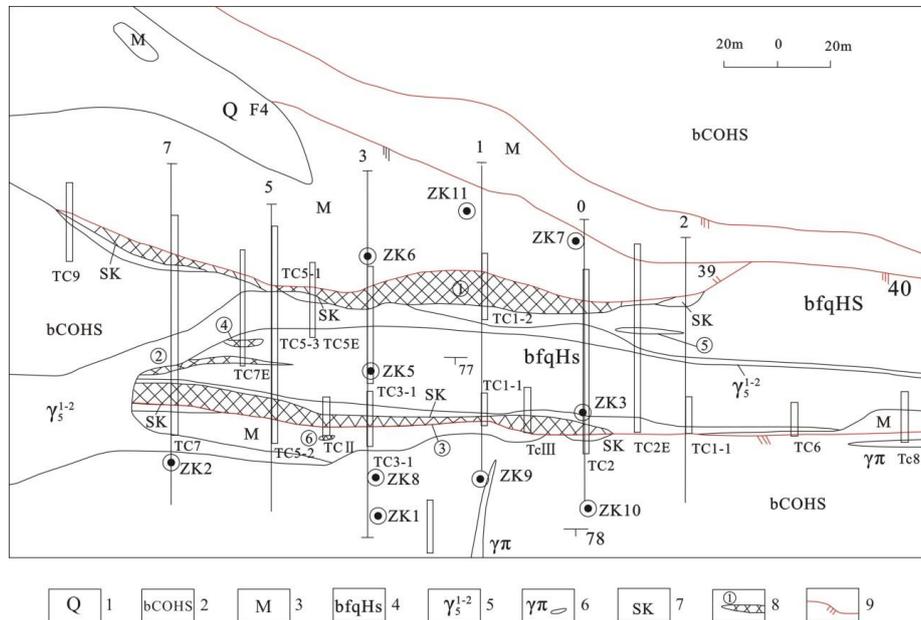


Figure.1. The geological sketch of Huaniushan Gold deposit
 1-Quaternary; 2-biotite cordierite hornstone with phyllite slate; 3-marble;
 4-biotite felsic hornstone; 5-lindosinian to Yanshanian syenogranite; 6-granite vein;
 7-garnet actinolite diopside skarn; 8-Number of gold ore body; 9-Fault

Table 1. The basic parameters of Huaniushan Gold deposit orebody

Number of orebody	Types of orebody	Types of wall rocks	Morphology of orebody	Occurrence	Scale of ore body			Average grade of Au (10-6)	
					Length	Slant depth	Thickness	Au	Ag
1	Arsenopyrite-pyrite-limonite type	Skarn; Marble	stratoid	180°~200°∠54°~65°	243.5	19~40.5	4.3	5.6 1.8	5.3 3.6
2	Arsenopyrite-pyrite-limonite type; Biotite felsic hornstone type	Granite; Biotite felsic hornstone	stratoid	180°∠64°	56.5	16	1.9	11.6 1.8	11.0 3.5
3	Quartz diopside hornstone type (primary ore); Arsenopyrite-pyrite-limonite type (oxidized ore)	Quartz diopside hornstone; Skarn; Marble; Biotite cordierite hornstone	stratoid	180°~183°∠55°~73°	183	25~93.5	5.7	5.4 1.6	3.5 3.2
4	Biotite felsic hornstone type	Biotite felsic hornstone	lentoid	180°∠75°	20.0	5.0	1.0	1.5	3.0
5	Biotite felsic hornstone type	Biotite felsic hornstone	lentoid	180°∠60°	30.0	15.0	3.0	1.6	4.7
6	Arsenopyrite-pyrite-limonite type	Marble	lentoid	180°∠63°	8.5	4.3	1.0	11.0	2.0

2. Ore characteristics of Huaniushan Gold Deposit

2.1. Types and characteristics of Ore

The orebody of Huaniushan Gold Deposit is composed of metamorphic sedimentary clastic, dikes with quartz and sulfide and kinds of minerals in altered granite. According to the degree of oxidation, it can be divided into primary ore and oxidized ore [4-5].

The oxidized ore is the arsenopyrite-pyrite-limonite type, and the primary ore is mainly gold-bearing pyrrhotite. According to the significant differences of associated mineral, the primary ore is divided into seven types naturally. They are: ① gold-bearing pyrrhotite felsic hornstone type, ② gold-bearing pyrrhotite quartz diopside hornstone type, ③ gold-bearing pyrrhotite quartz actinolite hornstone type, ④ gold-bearing pyrite-quartz vein type, ⑤ gold-bearing fluorite-polymetallic quartz vein type, ⑥ gold-bearing copper tungsten polymetallic sulphide altered granite type, ⑦ hybrid type. The four types of ①, ②, ③ and ⑦ are the main ore types, which accounted for 80% of the total ore. The second are the types of ④ and ⑤, which may be the most important high-grade gold ore of the deposit. The sixth type with copper and tungsten polymetallic mineralization is rare and the value of comprehensive recovery is high. The mineral assemblage and typical fabric characteristics of different types of ores are shown in Table.2.

Table 2. The characteristics of Huaniushan Gold Deposit ore

Type of ore	Primary ore						Oxidized ore	
	gold-bearing pyrrhotite felsic hornstone type	gold-bearing pyrrhotite quartz diopside hornstone type	gold-bearing pyrrhotite quartz actinolite hornstone type	gold-bearing pyrite-quartz vein type	gold-bearing fluorite-polymetallic quartz vein type	gold-bearing polymetallic sulphide altered granite type	hybrid type	arsenopyrite-pyrite-limonite type
Ore mineral assemblage	pyrrhotite; a few of pyrite and chalcopyrite	pyrrhotite; a few of chalcopyrite and arsenopyrite; few pyrite and bornite	pyrrhotite, a few of chalcopyrite, few pyrite	pyrite, a few of chalcopyrite and arsenopyrite	pyrite, arsenopyrite, a few of pyrrhotite, chalcopyrite and tetradymite	pyrrhotite, pyrite, a few of molybdenite, chalcopyrite, tetradymite, bismuthinite, scheelite, electrum	superposition by the six natural types above	limonite, jarosite, arsenopyrite, pyrite, chalcopyrite, gold, silver
gangue mineral assemblage	quartz, plagioclase, calcite, fluorite, biotite, sericite	quartz, diopside, fluorite, calcite, actinolite	quartz, actinolite, calcite, fluorite	quartz	quartz, fluorite, diopside, biotite	quartz, fluorite, diopside, chlorite, calcite, a few of plagioclase, actinolite, biotite	superposition by the six natural types above	quartz, sericite, clay impurities, diopside, ouralite
typical composite structure	anhedral granular structure, replacement relict structure; disseminated, massive, fine vein and palimpsest-banded texture	hypidiomorphic-anhedral granular structure, replacement relict structure, replacement corrosion structure; palimpsest-banded texture, disseminated and massive texture	Idiomorphic-hypidiomorphic long column or acicular structure, anhedral granular structure, skeletal structure; disseminated texture	Idiomorphic-hypidiomorphic and anhedral granular structure, skeletal structure; glomerophytic vein, disseminated and massive texture	Idiomorphic-hypidiomorphic and anhedral granular structure, replacement corrosion structure; crystalloblastic, glomerophytic, disseminated texture	Idiomorphic-hypidiomorphic, anhedral granular structure, emulsion, lamellar, eutectic and replacement relict structure; disseminated, glomerophytic, massive and vein texture	replacement corrosion structure and replacement relict structure; taxitic and relic texture	replacement relict structure, illusion structure; cellular, massive and vesicular texture

It is found that the ore in Huaniushan Gold Deposit belongs to gold metal-polymetallic sulphide type through specimen observation and rock slices identification. In this ore area, the content of sulfide is high and the mineral assemblage is quite complex. This study identified nearly 30 species of minerals. The ore minerals are mainly pyrrhotite, pyrite and arsenopyrite, and the secondary are chalcopyrite, molybdenite, scheelite, tetradymite, bismuthinite (natural tellurium), galena, sphalerite, magnetite and so on. The precious metals are mainly electrum and kustelite. In gangue minerals, quartz, diopside, actinolite, fluorite, calcite, manganese calcite, ankerite, hornblende are the main ones; in contrast, chlorite, barium zeolite, barite (witherite), biotite, anorthite are minor ones. The secondary minerals include limonite, bornite, scorodite, cerussite, jarosite, malachite and gypsum.

Pyrite: over 20% of the total content of sulfide. Under the microscope, the pyrite is yellowish white with homogeneity. Pyrite, as the most important gold-bearing mineral in this deposit, is formed in every stage of gold mineralization. The pyrite in the mine area is usually hypautomorphic-

xenomorphic granular, and a few are in the shape of cube or glomerocryst formed by the above two grains, and the gelatinous pyrite oolite is locally visible. The grain size is generally 0.2~5mm, and it can reach to 3cm in the massive pyrite-toxic sulfide veins. The fine grain even only be 0.00n~0.0 nmm, mostly the residual body or cube grain. The degree of self-formation of crystals varies significantly with the mineralization stage. According to the mineral assemblage and characteristics of output distribution, it can be divided into three phases at least, including the pyrite formed in sedimentary met allogenic epoch, the pyrite formed in the early stage of high temperature hydrothermal met allogenic stage and the pyrite formed in the late stage of middle temperature hydrothermal met allogenic stage.

Pyrrhotite: the content in metallic sulfide is the highest, which is most widely distributed in the deposit, accounting for more than 70% of the total sulfide. The content of pyrrhotite can be up to 90% in the rock of diopside or actinolite skarn and felsic hornstone. It is formed in the early stage of gold mineralization as an important gold-bearing mineral. Under the microscope, the color of pyrrhotite is rosy with significant heterogeneity. According to the characteristics of mineral assemblage and output distribution, the pyrrhotite can be divided into two genetic types. The first one is related to hydrothermal metasomatism of pyrite which formed in the early sedimentary met allogenic epoch. The second is the product of magmatic hydrothermal phase. Based on the experimental analysis, the content of Au in pyrrhotite was 4.34g/t, revealing that most were separated out during the early transformation stage in which the pyrite transformed into pyrrhotite by thermal metamorphism.

Arsenopyrite: formed in the met allogenic stage of fluorite - quartz - pyrite - arsenopyrite - chalcopyrite, associated with pyrite and chalcopyrite. In particular, arsenopyrite is the intergrowth with pyrite. Arsenopyrite is bright white under the reflector with remarkable heterogeneity, displaying obvious pleochroism of blue, brown and green. The crystals show automorphic to hypautomorphic, and the section is diamond-shaped. The particle size is relatively uniform from 0.1mm to 0.6mm of single crystal, but the polycrystalline grain diameter is 1~2mm.

2.2. *Texture and structure of ores*

The ores of Huaniushan Gold Deposit mainly occurred in two kinds of rocks. One is hornstone and skarns (mainly include quartzite, quartz pyroxenes hornstone, quartz actinolite hornstone, etc.), which are derived from thermal metamorphism of sedimentary clastic rock, the other is altered rock and quartz or sulfide veins rooted to the magmatic hydrothermal alteration of granite. The deposit belongs to multiperiodic mineralization experiencing thermal water sedimentary and magmatic hydrothermal reformation. As a result, during sedimentary mineralization period, it remained some fabrics, including all kinds of residual structure after replacement and palimpsest-banded structure, such as residual structure of pyrite replaced by pyrrhotite. During magmatic hydrothermal alteration, metasomatic residues and dissolution textures were developed extensively, such as etching texture and skeletal texture of pyrite replaced by chalcopyrite, metasomatism residual texture of pyrite replaced by pyrrhotite, palimpsest polysynthetic twin texture of plagioclase, including crystalloblastic texture of pyrite and arsenopyrite. The minerals mentioned above would form automorphic to xenomorphic grain texture, intersertal texture, emulsion droplet texture, foliaceous texture, etc. through crystallization. The gelatinous texture, the inclusion of crystalloblastic texture and fragmentation texture were locally developed. The ore texture is composed of massive texture, banded texture, disseminated texture, vein and mesh-vein texture. It is developed with honeycomb texture and breccia texture in the surface oxidation zone.

3. **Wall-rock alteration**

There are significant differences in surrounding rock alteration and mineral assemblage of Huaniushan Gold Deposit due to the different features of protolith. It mainly contains silicification, diopsidization, actinolitization, sericitization, biotitization, fluoritization, chloritization, carbonatization, ferritization, pyritization, arsenopyritation, etc. Among them, ferritization, pyritization, and pyrrhotitization are closely related to gold mineralization. Gold mineralization is mainly found in various kinds of

calcareous siliceous hornstone, skarns and skarnization granites, which is proportional to the content of metal sulfide [6-9].

4. Met allogenic epoch and mineralization stage

The Huanishan Gold Deposit is produced in a jet- sedimentary source bed by strata bound formation. According to mineral assemblage, replacement relationship, residual fabric and mineral symbiosis, it can be divided into three met allogenic periods: the exhalation sedimentary stage, the magmatic hydrothermal stage and the supergene stage. The early exhalation sedimentary stage is the main ore-forming period with hydrothermal minerals formed, consisting of pyrite, pyrrhotite, galena, sphalerite, actinolite, sericite. And gold may be scattered existing in these metal sulfides. The magmatic hydrothermal stage and the supergene stage have an effect on superposition, enrichment and transformation. The magmatic hydrothermal superposition period can be further divided into skarn stage and quartz - sulfide stage, and the mineral assemblages in each stage are shown in table 3.

Table 3. The met allogenic epoch, met allogenic and mineral par agensis of Huanishan Gold deposit

Mineral	Mineralizing stage	Exhalative sedimentation stage	Hydrothermal stage		Supergene stage
			Skarn stage	Quartz-sulfide Stage	
Galena		■		■	
Sphalerite		■		■	
Pyrite		■		■	
Chalcopyrite		■		■	
Diopside			■		
Garnet			■		
Magnetite			■		
Tremolite			■		
Actinolite			■		
Hornblende			■		
Epidote			■		
Plagioclase			■		
Biotite			■		
Quartz			■	■	
Pyrrhotite				■	
Scheelite				■	
Molybdenite				■	
Arsenopyrite				■	
Fluorite				■	
Native gold		■		■	
Electrum		■		■	
Kustelite		■		■	
Native silver		■		■	
Chlorite				■	
Calcite				■	
Limonite					■
Jarosite					■

Acknowledgments

Scientific research project: Shaanxi provincial land engineering construction group DJNY2018-7; China Geological Survey Bureau, project code: 12120113046700.

References

- [1] Yang H Q, Li Y, Li W M, et al. General Discussion on Metallogenic Tectonic Setting of Beishan Mountain, Northwestern China [J]. *Northwestern Geology*, 2008,(1):22-28.
- [2] Wang X H, Yang J G, Wang L, et al. Analysis of Non-ferrous Metal Mineral Resources

- Potential in Ganxinmeng Beishan Area[A]. Geological Society of China. Geological Society of China Geological Society Abstract of Abstracts Compendium—S11 Important metallogenic belt metallogenic regularity and prospecting breakthrough in northwestern China[C]. Chinese Geological Society, 2013: 5.
- [3] Yang J G, Xie X, Wang X H, et al. Metallogenic geological background and resource potential of copper-nickel ore in the prospecting area of Yingmaotuo, Beishan, Gansu[A]. Geological Society of China. Geological Society of China Geological Society 2013 Abstract of Abstracts Compendium-S11 Important metallogenic belt metallogenic regularity and prospecting breakthrough in northwestern China[C]. Chinese Geological Society: 2013: 4.
- [4] Yang J G, Xie C L, Wang X H, et al. Basic tectonic framework and features of metallogenic series in Beishan area, Gansu Province. Geological Bulletin of China, 2012, 31(2/3): 422-438
- [5] Wang L, Yang J G, Wang X H, et al. Analysis on the Geological Characteristics and Prospecting of Baishitan Gold Deposit in Beishan, Gansu Province[J]. Gold Science and Technology, 2012, 05:28-33.
- [6] Yang J G, Zhai J Y, Yang H W, et al. Metallogenic and Prospection of the Huaniushan Exhalogene Gold-Silver-Lead-Zinc Deposit in Beishan, Gansu Province[J]. Geotectonica et Metallogenia, 2010, 02:246-254.
- [7] Yang H Q, Li Y, Zhao G B, et al. Stratigraphic Correlation and Its Significance of Xinjiang-Gansu- Inner Mongolia Join Area [J]. Northwestern Geology, 2009, 04:60-75.
- [8] Yang J G, Zhai J Y, Yang H W, et al. LA-ICP-MS zircon U-Pb dating of basalt and its geological significance in Huaniushan Pb-Zn deposit, Beishan area, Gansu, China. Geological Bulletin of China, 2010, 29(7):1017-1023.
- [9] Yang J G, Ren Y X, Wang X H, et al. Metallogenic regularity and prospecting prediction of Huaniushan gold-silver polymetallic ore field in Beishan, Gansu [M]. Beijing: Geological Publishing House