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Geochemical Characteristics and Genesis of the Dahongshan Copper Deposit in Yunnan Province

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Yunnan Dahongshan Copper Mine is one of the largest copper mines in Yunnan Province with an important economic value. Based on the spatial-temporal evolutionary structure and metallogenic characteristics of the Dahongshan Copper Mine, this paper studied the geological conditions, rock characteristics and ore geochemical characteristics of the Dahongshan Copper Mine. The results have shown that the basalt has highly consistent geochemical characteristics, while the geochemical characteristics of rocks and granites are island arcs. The geochemical analysis of rare earth elements in the mining area indicates that the mining area possesses sedimentary characteristics, and skarn enriches iron elements and supplies iron elements such as pyrite in the mining area. The metallogenetic genesis of the mine indicates that the mineralization of the mining area involves multiple phases and multiple stages, including the sedimentation of the sedimentary rocks in the Hercynian period and the laminar filling of the magmatic rocks. The research results can provide a reference for the structural environment, the metallogenetic genesis, and the prospecting direction of the deposit.

1. Introduction

The Yunnan Dahongshan Copper Mine, located in Yunnan. is of large scale and important economic value (Fei et al., 2015). The mine has undergone long-term geological evolution, with complex metallogenetic genesis and special output background. At present, there are some research results on regional exploration, metallogenic zoning, and remote sensing analysis of the mining area (Anwar and Stevenson, 2011; Ghoriu et al., 2000), but the metallogenetic genesis and the prospecting prediction are seldom studied. And those studies on metallogenetic genesis give different explanations (Zahedi et al., 2014) Zahedi et al. believe that metallogenetic genesis is mainly the ocean basin and mantle polume activities (Li et al., 2013). Li et al. hold that the mine area is formed in an island arc environment (Wilde et al., 2006). Wilde et al. believe that the deposit originates from the sediments erupted from seafloor.

On this basis, the paper, with the spatial-temporal evolutionary structure and metallogenic characteristics of Dahongshan Copper Mine as the starting point, studied the geological features, geochemical characteristics and metallogenic genesis of Dahongshan Copper Mine, laying a foundation for the mineral occurrence identification and prediction.

2. Geological conditions of Dahongshan

The Dahongshan Mountain in Yunnan Province has a diverse geological structure and active magmatic activity. As a mountain, its topography fluctuates greatly. The copper deposits are distributed along the Mangang River to the west. The existing regional stratigraphic data of the mining area shows (Yang et al., 2012; Qu et al., 2007), the mine has significant stratigraphic characteristics, and are mainly distributed in line with ages as shown in Table 1.

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Table 1: Stratigraphic characteristics of the mining area

	Classification	Thickness
Upper proterozoic	Base	H=1788m
Siluric	Contact with the lower overlying proterozoic fault	H=760m
Devonian system	Copper deposit	H=2562m
Carboniferous system	It is divided into lower carboniferous and middle carboniferous	H>1200m
Permian	More with the lower Devonian basin. Upper proterozoic fault contact, overlying contact with triassic unconformity	H>5000m
Triassic system	Widely distributed	H>2000m
Paleogene	Unconformable contact with the lower strata	H=900m
Quaternary	Distributed on gentle Slope Meadows and valleys	H<100m

Due to the geological tectonic movement, faults and folds have developed in the Dahongshan area, which has important influence on the storage location of minerals (Hu et al., 2015). On the whole, Dahongshan Copper Mine is located in a monoclinic strata in the southern wing of the anticline of Dibadu, and the copper deposits spread one way around the anticline. There are mainly three types of folds in the area as shown in Table 2.

Table 2: Major fold types

Classification	Characteristics
Fish wave anticline	First order fold, flexure development
Sheep pull syncline	The shaft is flat, the wing is gradually steeper and inclined inward
Debar anticlinal	Axial north and south, soft fold, wide core

The Dahongshan Copper Mine has significant fault features due to drilling, mining, and survey (Chen et al., 2016). The ore body is a complete, uniform plate-like fault with a small angle of section and a ladder-like arrangement. This type of fault structure has damage to the integrity of the ore deposits and affects the continuity of mining.

The Dahongshan mining area has seen development of magmatic rocks, intrusive rocks, and ejected rocks, with many types of rocks, including neutral rocks, acid rocks, and ultrabasic rocks. Among them, intrusive rocks are mainly distributed along the fault zone and spread out in bands. Volcanic rocks and spurts of rock are exposed, spreading from west to east in strips. The metamorphic rocks are located on the west side of the Mangang River, mainly including the Mangang Formation, the Hongshan Formation, and the Feiwei Formation. Their spreadin directions are basically consistent with the regional tectonic lines.

3. Geochemical features and genesis of Dahongshan copper mine deposit

The Dahongshan Copper Mine is rich in mineral resources (Zhu et al., 2007; Li, et al., 2010). The types of the deposits are shown in Table 3. Among them, the main types of deposits are contact metasomatic ore deposit and stratabound ore deposit. Feiwei copper, as a contact metasomatic ore deposit, is located in the contact zone of metamorphic rocks, with the ore body's length of 500m, thickness of 2m, and grade of Cul. 82%. Hongshan copper ore, as a contact metasomatic ore deposit, is located on the west side of the volcanic rock mass. It has three ore bodies, with the length of 250m to 1600m, the thickness of 1.96m to 8.32m, and the grade of Cul. 36%. Mangang copper ore, as a stratabound ore deposit. is located under the granite rock body and has three ore bodies. The longest ore body in the three is 1500m in length, 2.2m in thickness, and Cul. 26% in grade.

Table 3: Main types of deposits

Number	Name of mine	The major minerals	Scale	Working level
1	Mann hillock river copper mine	Cu	large-scale	reconnaissance
2	Hongshan copper point	Cu	large-scale	reconnaissance
3	Fat flavour river copper mine	Cu	large-scale	reconnaissance
4	Old changhe copper mine	Cu	small-scale	reconnaissance

3.1 Rock features in the mining area

The paper carried out geochemical analysis of basalt, diabases and granites exposed by a large area in the mining area. Five samples of Carboniferous amygdaloidal basalt and one of granites (MGH-6*) were selected from the Mangang Formation.2 samples of basalt from Devonian ophiolite section and 2 of diabases from

Devonian chlorite slates were selected from the Hongshan Formation. And then, There are 2 basalt in the green rock profile, 2 diabase in the Devonian chlorite slate, and 4 samples of Carboniferous pillow-shaped basalt were selected from the Feiwei Formation. The main mineral composition, main element contents, and trace element contents were analyzed as follows.

3.1.1 Rock characteristics of the Mangang formation

The basalt of the Manganghe Formation are amygdaloidal and subalkaline, and are mainly composed of plagioclase with a small amount of perovskites and ordinary pyroxenes. The rock matrix is mainly labradorite, with a small amount of chlorite and quartz sand to fill the gap. The amygdaloidal fillers are calcite and quartz stones. Granite is moderately acidic, and show obviously different characteristics from basalt. The main elements and trace elements are shown in Table 4 below.

Table 4: Major and trace element analysis of basalt and granite from Mangang ore

	MGH-1	MGH-2	MGH-3	MGH-4	MGH-5	MGH-6*
SiO_2	49.87%	50.98%	48.10%	47.28%	50.11%	73.65%
Na_2O+K_2O	5.23%	2.37%	1.81%	7.09%	4.31%	5.51%
LOI	2.80%	6.55%	8.63%	6.36%	2.66%	8.21%
DI	42.25%	31.93%	16.58%	48.54%	36.89%	40.32%
SI	36.18%	33.61%	49.93%	22.27%	34.81%	33.23%
Ce/Ce^*	$0.96X10^{-6}$	$0.93X10^{-6}$	$0.94X10^{-6}$	$0.94X10^{-6}$	$0.96X10^{-6}$	$0.21X10^{-6}$
Eu/Eu^*	$1.43X10^{-6}$	$1.12X10^{-6}$	$1.20X10^{-6}$	$1.04X10^{-6}$	$0.83X10^{-6}$	$0.71X10^{-6}$
∑Ce/∑Y	$0.75X10^{-6}$	$0.88X10^{-6}$	$0.79X10^{-6}$	$0.61X10^{-6}$	$0.66X10^{-6}$	$10.64X10^{-6}$
∑REE	$81.21X10^{-6}$	$70.55X10^{-6}$	$64.12X10^{-6}$	$91.27X10^{-6}$	$100.99X10^{-6}$	$271.96X10^{-6}$

3.1.2 Rock characteristics of Hongshan formation

The basalt (HS-1, HS-2) of the ophiolite section of Hongshan Formation have two different structures. It is mainly typically tholeiitic dense massive basalt structure and consists of mainly subalkaline and fine columnar plagioclase, with a small amount of glassy micro-pyroxene and hornblende particles to irregularly fill, basically with no secondary alterations. The other small amount of basalt shows porphyritic weakly altered basalt structure in subalkaline nature. The phenocryst is basic laminar plagioclase, and the matrix consists of small columnar plagioclase, and volcanic glass and devitrified glass as fillers, as well as flaky chlorite and carbonate minerals obviously produced by weak alterations.

Table 5: Major and trace element analysis of basalt and diabase from Hongshan ore

	HS-1	HS-2	HS-3*	HS-4*
SiO_2	55.62%	48.68%	51.27%	57.32%
Na_2O+K_2O	4.81%	6.58%	4.08%	4.67%
LOI	4.82%	1.53%	8.69%	10.76%
DI	51.36%	44.82%	38.82%	53.82%
SI	24.87%	25.86%	40.77%	18.93%
Ce/Ce^*	$0.91X10^{-6}$	$0.93X10^{-6}$	$0.89X10^{-6}$	$0.85X10^{-6}$
Eu/Eu^*	$0.98X10^{-6}$	$1.12X10^{-6}$	$1.07X10^{-6}$	$0.55X10^{-6}$
∑Ce/∑Y	$0.75X10^{-6}$	$0.69X10^{-6}$	$2.61X10^{-6}$	$2.60X10^{-6}$
∑REE	$96.92X10^{-6}$	$103.59X10^{-6}$	$113.37X10^{-6}$	$87.99X10^{-6}$

The main components of diabase (HS-3*, HS-4*) in the Hongshan Formation are perovskites, hornblenders, and plagioclases, which are in the vicinity of alkaline and subalkaline decomposition, and there is chlorite around the crystal edges subject to weak alterations. The major elements and trace elements are shown in Table 5 below.

3.1.3 Feiwei formation

The pillow-shaped basalt in the Feiwei Formation is an interstitial structure in subalkaline nature. It is mainly composed of long columnar plagioclase, filled with pyroxene, olivine, vitric and devitrified glass, and associated with siliceous rocks. The major elements and trace elements are shown in Table 6 below.
From the above data, it can be seen that the basalt of the Mangang Formation and the Feiwei Formation have highly consistent geochemical characteristics, and both are products of the Carboniferous submarine eruption. The geochemical characteristics of diabase, in island arc, are obviously different from that of basalt. Granite

also features island arc, which occurred in the Middle and Late Triassic. In this stage, large-scale magmatic activities are closely related to the mineralization of the copper polymetallic ore.

Table 6: Major and trace element analysis of basalt from Feiwei ore

	FWH-1	FWH-2	FWH-3	FWH-4
SiO_2	50.49%	52.84%	49.87%	48.23%
Na_2O+K_2O	6.86%	4.58%	5.71%	5.17%
LOI	1.86%	4.54%	4.69%	7.76%
DI	56.36%	47.82%	38.95%	44.82%
SI	15.55%	22.86%	27.19%	28.96%
Ce/Ce^*	$0.98X10^{-6}$	$0.93X10^{-6}$	$1.07X10^{-6}$	$0.89X10^{-6}$
Eu/Eu^*	$0.93X10^{-6}$	$0.99X10^{-6}$	$1.09X10^{-6}$	$1.15X10^{-6}$
∑Ce/∑Y	$0.65X10^{-6}$	$0.75X10^{-6}$	$0.61X10^{-6}$	$0.60X10^{-6}$
∑REE	$104.33X10^{-6}$	$104.86X10^{-6}$	$103.37X10^{-6}$	$103.99X10^{-6}$

Table7: Rock content of rare earth elements

Rock Type	Sample	La	Ce	Pr	Nd	Sm
Skarn Metamorphic Volcanic Rocks	PD-1	51	76.9	9.42	32.1	5.03
	PD-2	79.3	131	15.2	55.2	9.24
Manganghe Sandy Slate Rock	PD-3	31	54.2	6.85	25.7	5.39
	PD-4	32.3	59.9	7.14	28	5.32
	KT-1	28.1	46.2	5.77	21.98	4.1
	KT-2	17.2	31.7	4.11	16.3	4.72
	KT-3	25.9	42.3	7.32	25.21	5.21
Feiweihe Sandy Slate Rock	PD-5	35.5	69.3	8.83	32.9	5.94
	LP-1	23.5	41.9	6.01	22.7	4.1
	LP-2	27.6	37.5	5.24	19.4	3.45
Griotte Rock	PM-1	2.35	1.87	0.43	1.32	0.222
	PM-2	0.739	0.873	0.166	0.562	0.261

3.2 Geological characteristics of the mine

Based on the field investigation and the analysis of the relationship between the rock characteristics and the mineral association in the mining area, the Dahongshan Copper Mine in Yunnan is a submarine volcanic and argillaceous siliceous flysch structure (Chattopadhyay et al., 2008; Cha et al., 2013). According to the eruptive deposition state, rock characteristics and combination type, it can be preliminarily judged that this mining area is formed in the sub-deep-sea environment during the initial rift-diverging ocean basin stage. The ore structure indicates that the mining area is the result of three joint actions: syngenetic jet-hot water deposition, hydrothermal reforming and supergene oxidation. The formation of the representative Manganghe Formation has undergone four stages: dry skarn, degeneration, sulphide and carbonate. The magmatic activity in the indo-china period also affected the mineralization, resulting in the further Enrichment of mineral composition.

3.3 Geochemical characteristics of the deposit

The paper samples the elevation of the ore body and the component type of rare earth is measured, as is shown in Table 7. The content of Ce element is higher in the four types of rock edge groups and the reason for this is that the shale content of siliceous rocks is high in the Ce element enrichment and argillaceous components, so the Ce element content also increases.

Table 8: Mineral element correlation table

	Cu	Zn	Pb	Co	Ni	Mo
Cu	1					
Zn	0.6	1				
Pb	-0.3	0.2	1			
Co	-0.5	-0.3	0.7	1		
Ni	-0.4	-0.15	0.2	0.6	1	
Mo	-0.2	0.2	0.9	0.6	0.2	1

Table 8 shows the statistics of the correlation coefficient of layered ore bodies. It can be seen from Table 8 that the content of Cu is high and the iron-rich feature of the deposit is significant. Combined with the ore-forming element analysis, the analysis results show that the deposit is an iron-rich copper deposit.

3.4 Analysis of genesis of mineral deposit

Based on the above analysis of the geochemical characteristics of the deposit, this paper analyzes and determines that present layer ore body of the copper deposit have been formed under the superposition of rock deposits and magmatic flows. The boundary between the ore body rocks and the surrounding rock body is clear and it can be inferred that sandy slate and volcanic rock form the base layer of the rock in the mining area. After analysis of the rock composition in the mining area and analysis of the ore-forming elements of the ore body in the 3.3, the rock in the mining area is based on the layered ore body of volcanic sedimentary rock, supplemented with skarn, so the iron elements can be greatly supplemented.

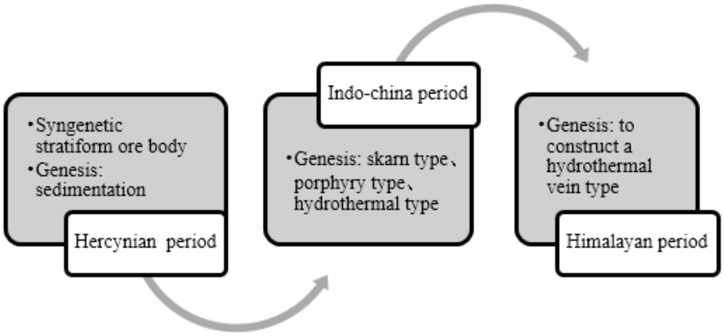

Figure 1: Metallogenic stage and the Metallogenic stage of copper mine are divided

The mineralization of the ore deposit is divided into three stages and the metallogenic cuases and metallogenic stages are shown in Figure 1. The metallogenetic genesis is mainly the multistage effect, including the sedimentation of sedimentary rocks in the Hercynian period and the laminated filling effect of magmatic rocks. The layer ore body is formed by intrusive rocks forming in the contact area of surrounding rocks and the internal contact area of rocks, forming the typical feature of contact deposits; at present, about 6% of the copper-bearing slate can be observed in a cup of copper ores, which is of great reference significance for the searching of plates copper mine.

4. Conclusion

The paper studies the geological features, geochemical characteristics and metallogenic factors of the Dahongshan Copper Mine and obtains the following conclusions:
(1) This paper analyzes the characteristics of the major elements and trace elements in the rocks of the Manganghe Formation, Hongshan Formation, and Feiwei Formation. The results of the study show that there are highly consistent geochemical characteristics in the basalt of the Manganghe Formation basalt and the Feiwei Formation. The geochemical characteristics of diabase and granite geochemistry have arc nature.
(2) The geochemical analysis of rare earth elements in the mining area shows that the mining area possesses sedimentary characteristics and skarn enrichmnet iron elements. It can be inferred that the skarnized tube rice is distributed in the mining area and provide iron elements for pyrite in the mining area;
(3) This paper analyzes the metallogenetic genesis in the mining area and the analysis results suggest that the metallogenetic genesis in the mining area is mainly multi-stage effect, including the sedimentation of sedimentary rocks in the Hercynian period and the laminated filling effect of magmatic rocks. The layer ore body is formed by intrusive rocks forming in the contact area of surrounding rocks and the internal contact area of rocks, forming the typical feature of contact deposits.

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