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Research Article

Research on Metallogenic System and Deposit Genesis: With Zhacun Goldmine in Weishan County of Yunnan as an Example

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This paper mainly takes Zhacun goldmine as the research object and carries out research on the metallogenic system and genesis of the deposit in the area. The research methods are as follows: according to the geological characteristics of the metallogenic mining area in the Zhacun goldmine, combined with the comparative analysis of the metallogenic age, alteration characteristics and lithology between the Zhacun goldmine and the Lianhuashan alkali rich rock mass, and the analysis of the isotopic data in the Zhacun goldmine, this paper demonstrates that the magmatic activity of the Lianhuashan quartz monzonite porphyry plays an important role in the mineralization of this area, which is both an important ore source and fluid source. It is also the main heat source driving the circulation of ore-forming fluid. On this basis, through the analysis of the metallogenic elements in the area, the metallogenic system model of Zhacun goldmine is constructed. It is considered that under the action of long-term horizontal compressive stress, the atmospheric precipitation infiltrated into the formation continued to penetrate along the fractures and fissures to deep crust and finally mixed with the magmatic water sealed in the thick formation. During this period, a series of shallow and ultrashallow porphyry mass intruded, providing heat source and part of the ore-forming materials and resulting in incomplete homogenization under high temperature and high pressure, which formed highly mineralized mixed water. Under the combined action of long-term compressive stress and various deep thermal dynamics, these mineral fluids migrated along the buried deep faults near the core of the duplex anticline to the upper part of the crust. When the metal elements in these ore fluids migrated over long distances to the nappe fault zone of the gold-bearing fracture zone, the gold began to precipitate, and the native gold and the coarse-grained pyrite and quartz formed at the same time or earlier started to fill the fracture zone along the fissures and accumulate into minerals. Then, through the analysis of metallogenic conditions, gold mineralization process, and genetic mechanism of the deposit, it is proposed that the genetic type of the ore deposit in this area is magmatic mesothermal-epithermal gold deposit. The establishment of metallogenic system model in Zhacun goldmine will provide theoretical and practical guidance for deep and peripheral prospecting prediction in the area, carry out targeted and reasonable prediction, and improve prospecting effectiveness.

1. Introduction

Zhacun goldmine is located in the "Sanjiang" area of western Yunnan [1], with superior mineralization geological conditions and rich mineral resources such as gold, silver, copper, lead, zinc, and antimony [2, 3]. Therefore, as one of the important metal and precious metal metallogenic belts in Yunnan Province, the deposit types are diverse and the prospecting prospects are broad. Since 1960, the Geological Bureau of Yunnan Province, Dali Geology Bureau, and the Third Geological Team have conducted various levels of investigations and general surveys of gold mineral resources in the area. Importantly, from 1960 to 1971, the upper Huangshan gold heavy sand anomaly area was delineated, which provided basis and geological data for gold prospecting in the Yanzijiao-Shanghuangshan area. Further from 1984 to 1990, the distribution range, size, shape, and occurrence of ore-controlling structure-gold-bearing fracture zone in the area have been roughly ascertained; later on, from 2005 to 2008, the distribution characteristics of ore-hosting strata, structures, and mineralization points in Zhacun goldmine have been roughly ascertained [4, 5]. According to the larger number of accumulated scientific research results and a series of understandings and opinions on the metallogenic geological background of the Zhacun goldmine, the law of mineralization and the geological characteristics of the ore deposit were put forward, which played an active guiding role for the prospecting work of gold mining areas [6, 7]. However, the research level of Zhacun goldmine is still relatively low, which concentrates in the problems such as the relationship between the mineralization and intrusive rocks in the area, whether there are hidden rock bodies in the deep, the metallogenic system, and the genesis of the deposits. Thus, much more work needs to be further conducted.

In order to find out the gold resource potential in the deep and periphery of the mining area and meet the needs of sustainable development of the mine, the metallogenic system and genesis of the deposit in the area are studied, and the following problems are planned to be solved [8, 9] (1) By studying the relationship between the mineralization and alkaline porphyry in the Zhacun goldmine, the possibility of concealed porphyry bodies in the deep is discussed, the relationship between the magmatic activity and mineralization in this area is inferred, and important clues for prospecting in the area are provided. (2) By studying the geological and metallogenic factors of the Zhacun goldmine, the relationship between the mineralization and the alkaline porphyry, and the genesis of deposit, a model of the metallogenic system of the Zhacun goldmine is constructed, which provides theoretical and practical guidance for the deep and peripheral prospecting forecasts, as well as targeted and reasonable forecasts and improve prospecting effectiveness, which are of important practical significance for sustainable development of the mine.

2. Geological Characteristics of the Mining Area

The mining area consists of formations from the Upper Triassic Sanhe Cave (T_3s) limestone to the Middle Jurassic Huakaizuo Formation (J_2h) redbed, which is a monoclinic structure inclines to the east and extends along the north-south direction. The Zhacun goldmine studied in this paper is present in the fracture zone of the nappe-detachment fracture structure produced in the central part of the mining area [10, 11]. Due to the multistage activity of tectonic action, the secondary minor faults, fissures, and small corrugations are particularly special in the area, especially those in the gold-bearing fracture zone, which provide wide channels and storage space for the ore-bearing hydrothermal fluids [12].

3. Metallogenic System

The term "metallogenic system" first appeared in the Russian geological dictionary in 1973 [13], which is interpreted as "a natural system composed of sources of ore-forming materials, migration channels, and sites of mineralization accumulation." Later, Mazulawen [14], Senyakov [14], Chekoff, Jaquith [15], Chinese scholars Yu Chongwen [16], and Li Renshu [17] also discussed the metallogenic system before and after. And then, Zhai Yusheng [14, 18, 19] put forward that "metallogenic system refers to a natural system with metallogenic functions in a certain spatiotemporal domain, which is composed of all geological elements controlling the formation and preservation of ore deposits and the dynamic process of mineralization, as well as the whole formed ore deposit series and anomaly series," and there are five basic elements in the metallogenic system [17, 20]: (1) metallogenic materials, (2) metallogenic fluids, (3) drive energy for metallogenesis, (4) metallogenic fluid channels, and (5) precipitation places where the metallogenic materials are accumulated.

3.1. Relationship between Metallogenesis and Alkaline Porphyry. The intrusive rocks in the area are not developed very sufficiently. In the Weishan Lianhuashan Village-Nanjian Jindingzhuang Village area, 13 km south of Zhacun goldmine, a large group of shallow-ultrashallow porphyry consisting of quartz hornblende monzonite-porphyry and masanophyre intrudes along the Weishan River fault zone [21–23] (Figure 1). The Lianhuashan porphyry generally has gold placer mineral anomalies, and gold mineralization exists in local sections. The metallogenesis of Zhacun goldmine bed is related to the alkali-rich magmatic activity in the Himalayan tension-rifted environment [24–26], which may have a direct relationship with the magmatic activity of Lianhuashan masanophyre. The masanophyre is not only an important source of mineral resources and fluids but also a major heat source for driving the circulation of ore-forming fluids. The main basis is as follows:

(1) The determination of minerals, methods, and ages of Zhacun goldmine, Dalianhuashan goldmine, and Lianhuashan alkali-rich rock mass are listed in Table 1. From this table, it can be seen that the metallogenic epochs of Zhacun goldmine, Dalianhuashan goldmine, and Lianhuashan alkali-rich rock mass are all Himalayan periods [27–29]. The distribution of alkaline rock mass around Zhacun goldmine is plotted in Figure 1, which shows that the diagenetic age of the rock mass in Lianhuashan is 36.89-46.9 Ma [21, 30]. The Dalianhuashan goldmine is located within the alkali-rich rock mass concentrated area in Lianhuashan Mountain. Illite, the mineral of Lianhuashan for determination, is processed and sorted out from the pelitic siltstone of surrounding rock mineralization, gray corner rock diagenesis, and pyritization [31, 32]. By the K-Ar method, the deposit age is determined as 38.67 ± 0.58 Ma, which proves that the surrounding rock of Lianhuashan was mineralized and altered at the same time with the diagenesis of the rock and that the gold mineralization in Dalianhuashan was caused by the intrusion of Lianhuashan rock mass. Zhacun goldmine has an age of 46.5 Ma [33], falling

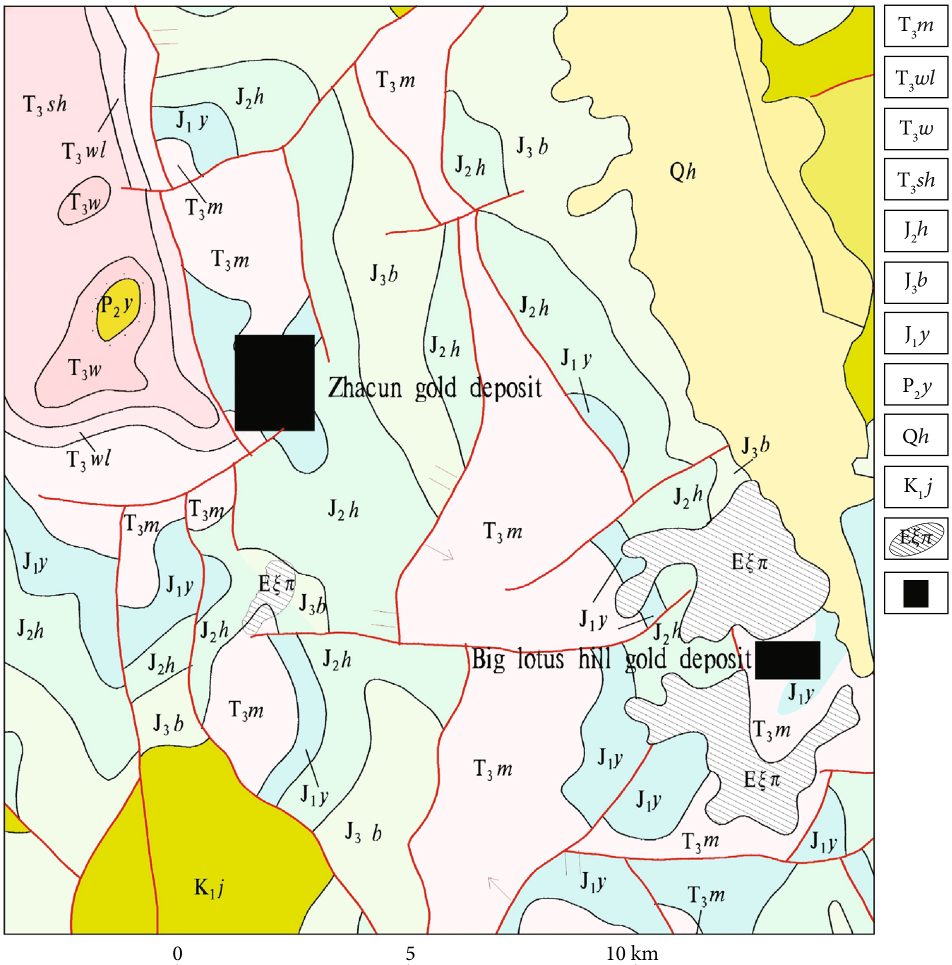


Figure 1: Distribution of alkaline rock mass around Zhacun goldmine. 1: Triassic Maichuqing Formation; 2: Triassic Waluba Formation; 3: Triassic Waigucun Formation; 4: Triassic Sanhedong Formation; 5: Permian Huakaizuo Formation; 6: Permian Bazhulu Formation; 7: Cretaceous Yangjiang Formation; 8: Permian Yangbazhai Formation; 9: Holocene series; 10: Cretaceous Jingxing Formation; 11: alkaline porphyry mass; 12: ore deposit range.

Table 1: Metallogenic epochs of Zhacun goldmine, Dalianhuashan goldmine, and Lianhuashan alkali-rich rock mass [34].

Ore deposit/mine area/rock mass	Mineral determined	Age (Ma)	Determination method	Data source
Zhacun goldmine	Hydromica	46.5	Rb-Sr isochrone	Institute of Geological Science of Yunnan Province, 1999
Dalianhuashan goldmine	Illite	38.67 ± 0.58	K-Ar	Research Institute of Petroleum Exploration and Development
Dalianhuashan	Biotite	46.9	Ar-Ar	Yunnan Survey Team, 1990
Dalianhuashan monzonitic granite porphyry	Biotite	48	Ar-Ar	Yunnan Survey Team, 1990
Dalianhuashan biotite pyroxene monzonite	Biotite	48	K-Ar	Weishan 1/200,000 Regional Survey Report
Dalianhuashan hornblende monzonite-porphyry	Total rock	37.53	K-Ar	Weishan 1/200,000 Regional Survey Report
Dalianhuashan pyroxene syenite	Total rock	38.6 ± 2.5		Dong Fangliu, 2002
Masanophyre	Potash feldspar	38.81 ± 0.17	K-Ar	Dong Fangliu, 2005
Syenogranite-porphyry	Total rock	37.02 ± 0.48	U-Pb	Yunnan Provincial Research Institute, 2008
Amphibolite monzonite porphyry	Total rock	36.89 ± 0.50	U-Pb	Xiao Yuanfu, 2013

within the diagenetic age range of Lianhuashan rock mass, indicating that the metallogenesis of Zhacun goldmine is closely related to the intrusion of Lianhuashan alkali-rich rock mass

(2) Zhacun goldmine and Dalianhuashan goldmine have some mineralization characteristics in common [35], that is, both the orebodies of Zhacun gold deposit and Dalianhuashan gold deposit occur in the alteration cataclastic zone or the inner contact zone of the rock mass within the porphyry body. The mineralization is closely related to pyritization, silicification, limonidation, and carbonation, so the orebodies are controlled by both rock mass and structure, indicating that just like the Dalianhuashan goldmine, the metallogenesis of Zhacun goldmine is also related to the Himalayan magmatic (porphyry) activity

It is worth noting that in addition to the gold-arsenic-antimony mineralization, the graywacke ore also shows strong copper-lead-zinc mineralization. The presence of such types of ore makes it possible to compare the mineralization characteristics of this area with the general polymetallic mineralization characteristics of alkali-rich porphyry in other areas. This implies that just like other areas, the metallogenesis in this area is also related to the regional alkali-rich magmatic activity.

(3) According to previous research [19], ore lead derived from magmatic hydrothermal fluids usually exhibits the properties of normal lead, and the isotopic composition has no much changes, generally $Pb^{206}/Pb^{204} < 19.5$, $Pb^{207}/Pb^{204} < 16$, and $Pb^{208}/Pb^{204} < 39$. As shown in Table 2, in the lead isotopic composition of the pyrite in Zhacun goldmine, the ratios of Pb^{206}/Pb^{204}, Pb^{207}/Pb^{204}, and Pb^{208}/Pb^{204} all have small changes, with the ranges of 18.412~18.4199, 15.5984~15.6365, and 38.6183~38.7613, respectively, all within the range of lead isotopic variation of the ore origin of the above-mentioned magmatic hydrothermal fluid, indicating that the ore-forming fluid in Zhacun goldmine is related to the hydrothermal fluid formed by magmatic activity. The lead isotopic variation range of Zhacun goldmine is related to the typical alkali-rich rock-type. The Beiya gold deposit [36, 37] and the Machangqing gold deposit [38, 39] have similar lead isotopic variation ranges, which shows that the mineralization in Zhacun goldmine is directly related to the alkaline-rich porphyry

3.2. Metallogenic Factors

3.2.1. Ore-Forming Material Sources. The ore-forming materials in this area came from multiple sources. The sulphur isotopic composition of pyrite which is closely related to gold mineralization and the hydrogen and oxygen isotopic compositions in the quartz inclusions all indicate that the minerals came from both crust and mantle.

The sulphur isotope composition and distribution of 30 pieces of pyrite, 1 piece of galena, and 1 piece of stibnite are shown in Figure 2 [40]. As can be seen from Figure 2, first, the sulphur $\delta^{34}S‰$ in the ore has two main peaks, and the tower effect is significant, indicating that the source of sulphur is stable. Second, the sulphur isotopes of the mineralized zone and the surrounding rock are in two different intervals, with apparent differences, showing that their sulphur sources are different. Detailedly, the mineralized sulphur in the mineralized zone mainly comes from mantle while the sulphur in the surrounding rock mainly comes from shell. The $\delta^{34}S$ value is close to that of mineralized sulphur, which also indicates that it has undergone homogenous displacement with the mineral sulphur, and part of the materials in the surrounding rock has also participated in metallogenesis. This result further indicates that the ore-forming fluids in this area are mainly related to the hydrothermal fluid formed by magmatic activity and partly related to the surrounding rock of sedimentary formation, while the magmatic activity in the area is related to the buried deep fault and the buried porphyry mass in the Tertiary Lanping-Simao depression belt. Third, for early coarse-grained pyrites, the $\delta^{34}S$ values are all close to zero, while the $\delta^{34}S$ values of pyrites and galena in the middle and late stages of mineralization slightly deviate from zero. The deviation of the $\delta^{34}S$ value indicates that the hydrotherm has been mixed with sulphur from atmospheric precipitation in some formations, which induces incomplete homogenization.

Based on the above analysis, it can be concluded that the gold deposit in Zhacun goldmine comes from the magmatic (porphyry) activity in the Himalayan period.

3.2.2. Ore-Forming Fluid. The samples for testing the δD and $\delta^{18}O$ values in the ore-forming fluid were all taken from the gold-bearing fracture zone, including 8 pieces of quartz, 1 piece of dolomite, 1 piece of calcite, and 4 pieces of hydromica, and the δD and $\delta^{18}O$ values were determined from the mineral gas-liquid inclusion solutions, as listed in Table 3. In addition, the contents of the components, the main homogenous temperatures, as listed in Table 4, and salinities and main homogenization temperatures in the area were also tested, as listed in Figures 3 and 4 [38].

From Table 3, it can be seen that δD ranges from -85.8 to -117.4 and mainly from -97.3 to -105. $\delta^{18}O$ ranges from -7.8 to +9.56, with a difference of 17.45. Some samples, such as quartz of W440-10, occur in early fractures, with δD value of -85.8 and $\delta^{18}O$ value of +8.35, indicating that the mineral fluid in early mineralization (the fracture zone is in a semi-closed state) mainly comes from magmatic water. In the middle stage of mineralization, the fracture zone is in an open state, and the mineral fluid consists of a mixture of magmatic water and meteoric water. Combined with the geological characteristics of this area, the ore-forming hydrothermal fluid has both meteoric precipitation origin and primary magmatic water. Combined with the analysis

Table 2: Composition of the lead isotopes in Zhacun Village, Beiya and Machangqing goldmine areas.

Mine area/mineral	Pb^{206}/Pb^{204}	Pb^{207}/Pb^{204}	Pb^{208}/Pb^{204}	Remarks
Magmatic hydrothermal ore lead	<19.5	<16	<39	—
Zhacun goldmine	18.412-18.4199	15.5984-15.6365	38.6183-38.7613	Yunnan Geological Team No. 3
Beiya goldmine	18.581–18.637	15.598–15.728	38.754–39.094	Liu xianfan 1999
Machangqing goldmine	18.502–18.960	15.608–15.992	38.787–39.393	Bi xianwu 2001

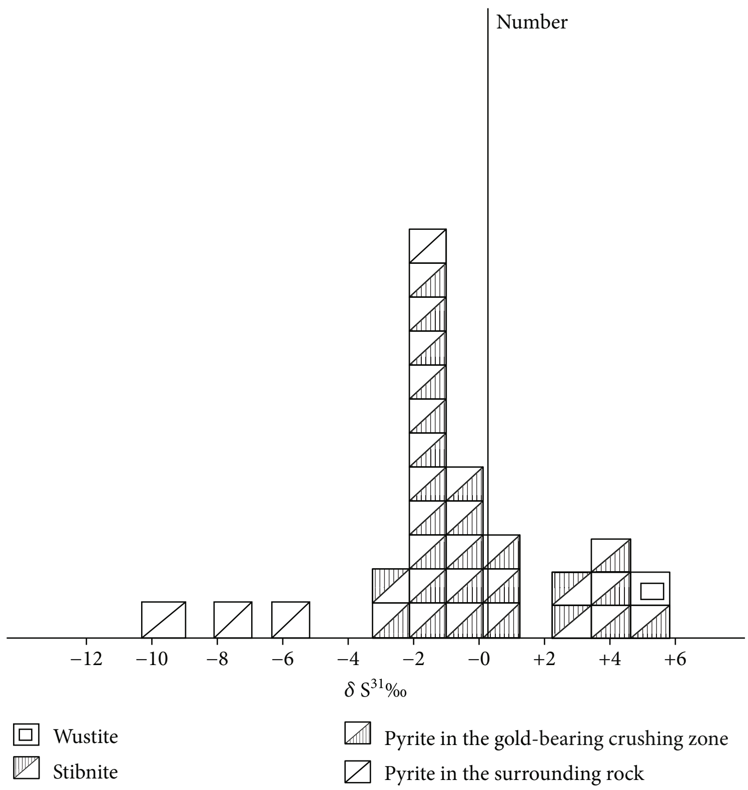


Figure 2: Sulphur isotopic composition and distribution in Zhacun goldmine.

Table 3: Isotopic determination results of δD and $\delta^{18}O$ in Zhacun goldmine.

Sample no.	Mineral tested	δD (‰)	$\delta^{18}O$ (‰)
H-2	Quartz	-103	-7.8
H-3	Quartz	-111	-7.0
H-5	Quartz	-86	-4.6
H-6	Quartz	-105	-4.6
W166	Hydromica	-104.2	+3.77
W166	Calcite	—	+5.79
W169	Hydromica	-105.4	+3.82
W169	Dolomite	—	+0.12
W174	Hydromica	-97.3	+4.72
W440-9	Quartz	-117.4	+9.56
W440-10	Quartz	-85.8	+8.35
P-8	Quartz	-111.5	+9.02
P-9	Quartz	-89.6	+8.65
P-10	Hydromica	-102.6	+3.96

of surrounding rock alteration, the early dolomitization-silicification stage is mainly magmatic water. Therefore, the ore-forming hydrothermal fluid in this area is a mixture of magmatic water and meteoric water.

From Table 4, it can be seen that the main cations were Na^+ and Ca^{2+}, followed by K^+ and Mg^{2+}, with Na^+ content ranging from 7.0 to 8.4 ($\times10^{-9}$), K^+ content ranging from 0.31 to 2.40 ($\times10^{-9}$), Ca^{2+} content ranging from 5.7 to 8.9 ($\times10^{-9}$), Mg^{2+} content ranging from 0.99 to 2.40 ($\times10^{-9}$). The anions are mainly SO_4^{2-} and Cl^-, the content of SO_4^{2-} is 20.9~30.2 ($\times10^{-9}$), Cl^- is 10.1~13.9 ($\times10^{-9}$), and the content of F^- in quartz inclusions is low, ranging from 0.34 to 0.55 ($\times10^{-9}$), while the content of F^- in pyrite inclusions is up to 14.0×10^{-9}. The inclusions mainly consist of H_2O and CO_2.

It is characterized by the inclusion fluid phase rich in Na^+, Ca^{2+}, Cl^-, and SO_4^{2-}, belonging to Na^+, Ca^{2+}, Cl^-, and SO_4^2 type. The ore-forming solution consists of H_2O-CO_2-NaCl solution and SO_4^{2-} natrium solution. Its salinity ranges from 1.5 to 14%, and temperature and salinity can be

Table 4: Component contents of inclusions in Zhacun goldmine.

Sample no.	Mineral tested	Water volume (mg)	Cation ($\times 10^{-9}$)				Anion ($\times 10^{-9}$)			CO_2
			Na^+	K^+	Ca^{2+}	Mg^{2+}	F^-	Cl^-	SO_4^{2-}	
Z-2	Quartz	24.9	7.0	0.65	8.9	2.2	0.44	10.1	24.4	
Z-3	Quartz	18.1	8.7	0.61	8.8	2.4	0.55	13.9	30.2	
Z-5	Quartz	29.2	8.4	0.31	5.7	0.99	0.34	12.4	20.9	
In the ore belt	Pyrite	444	0.59	4.39	12.9	1.507	14.0	3.8		29.0
In the ore belt	Pyrite	1778	3.57	0.83	0.50	0.05	0.10	7.4		3.1

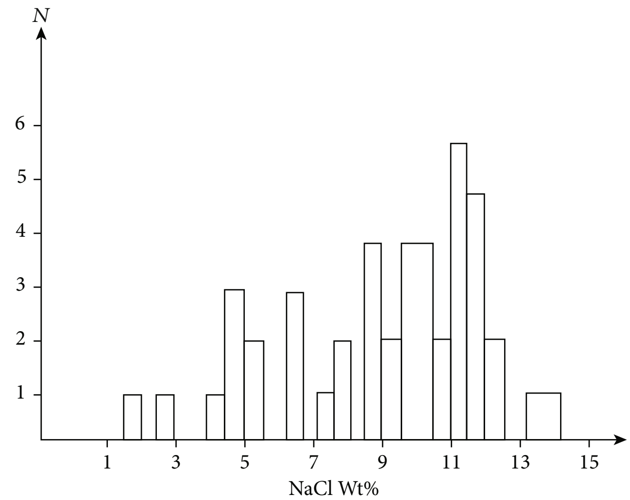


Figure 3: Salinities in Zhacun goldmine.

divided into four intervals consistent with the mineralization stage (Figures 3 and 4). The gold mineralization occurs in the interval of i and ii, the Au-Cl-S-Na-H_2O relationship is roughly observed in the ore fluid, the migration is mainly in the form of Au-S complex, and the secondary migration is in the form of Au-Cl complex.

To sum up, it can be seen that the ore-forming fluid is medium-temperature and low-salinity mineralized fluid. The gas phase in the Zhacun goldmine mainly consists of H_2O and CO_2, and the liquid phase the cations are mainly consisted of Na^+ and Ca4, followed by K^+ and Mg^{2+}, while the anions are mainly SO_4^{2-} and Cl^-, and there are high contents of Sb, Co, Cu, and As. It is speculated that under the combined action of the hydrothermal fluid brought by the intrusion of the Lianhuashan masanophyre and the fluid in the basin, part of the ore-forming materials was brought by the rock mass [41, 42], and part of them was metals extracted from the basin, rising along the structural fault zone and precipitating and forming the ore body in the oxidation-reduction interface between the Triassic and Jurassic systems.

3.2.3. Drive Energy for Metallogenesis. Ore source alone is not enough for mineralization, ore-forming materials also need appropriate driving force to activate and migrate, so as to be enriched and ore-forming in appropriate places. Himalayan period magma (porphyry) activities especially large lotus mountain nearby alkaline porphyry mineralization provide part of the source of ore-forming elements and ore-forming fluid and ore-forming thermodynamic conditions, and according to the current research [42–44], through 1 : 200000 aeromagnetic anomalies infer the existence of concealed rock mass, so the area of concealed porphyry is also one of the important metallogenic driving force.

3.2.4. Ore-Carrying Channels and Storage Space. The gold-bearing fracture zone of Zhacun goldmine is a brittle ductile structural combination zone superimposed by multiple tectonic activities, which has the characteristics of complex structural combination and alteration combination. The Himalayan movement caused the folding and mountain-building in this area, and a series of longitudinal discontinuities occurred successively along the fold axis with the formation of the Purple Mountain compound anticline, including the nappe faults in the gold-bearing fracture zone. The fault experienced two major tectonic stages and four subsections of tectonic activity, and each tectonic activity was accompanied by hydrothermal activity. Such tectonic activity and hydrothermal activity appeared alternately in different time in the same space, which constituted the gold guide and storage structure of the gold deposit in this area, namely, the gold-bearing fracture zone. At the same time, a large number of studies [45–48] have shown that fault structures can provide transport channels and storage space. The faults in the studied area most closely related to the metallogenesis and ore control are in the near-SN direction (i.e., gold-bearing fracture zone), followed by the NEE and the NE faults [49–51]. The above-mentioned faults might be tensile in the early stage and later converted into compresso-shear ones (or nappe-sliding structures) under the Himalayan horizontal compressive stress, forming a fault breccia belt with a length of tens of kilometres and accompanied by the intrusion of medium-acid-alkaline magma, which resulted in extensive hydrothermal alteration. Therefore, this group of faults is the most important ore-carrying and ore-depositing structures in the area and provides good channels and storage space for the ore-bearing hydrothermal fluid in the area.

3.3. Metallogenic System Model. In this paper, the main metallogenic factors of Zhacun goldmine are analyzed from the perspective of metallogenic system, and based on these analyses, a metallogenic system model is constructed, as shown in Figure 5 [19]. The Himalayan movement caused

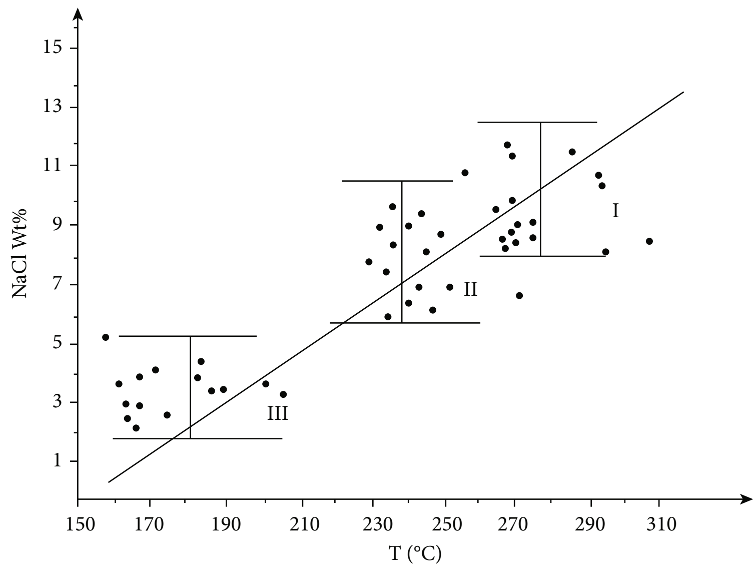
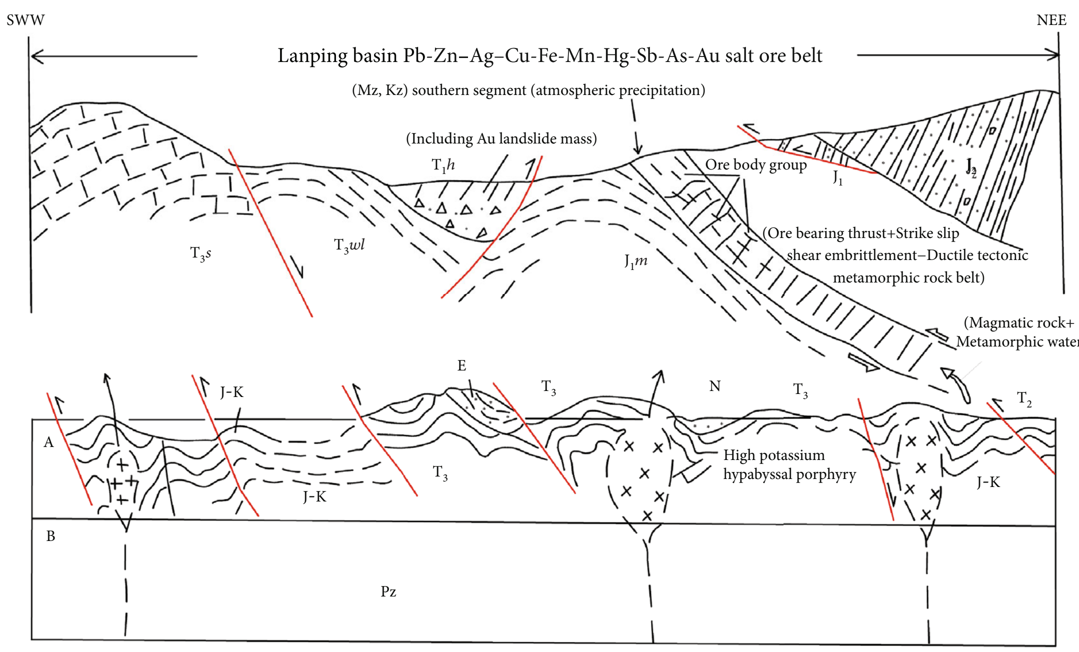


Figure 4: Main homogenization temperatures.



A.Meso Cenozoic Rock Series Thrust Nappe+Strike Slip Fold Deformation+Hypabyssal Porphyry–Fluid Structural Belt
B.Metamorphic Basement Rock sSeries of Block+Cenozoic Tectonic–Magmatic Fluid Zone

Figure 5: Zhacun goldmine metallogenic system model.

the Lanping-Simao [52, 53] depression to rise as a whole, resulting in strong folds in the entire graben zone, e.g., the Weishan-Yangbi fault block [54], and forming the Zijinshan duplex anticline in the middle of the zone. Under the action of long-term horizontal compressive stress, the atmospheric precipitation infiltrated into the formation continued to penetrate along the fractures and fissures to deep crust and finally mixed with the magmatic water sealed in the thick formation. During this period, a series of shallow and ultra-shallow porphyry mass intruded, providing heat source and part of the ore-forming materials and resulting in incomplete homogenization under high temperature and high pressure, which formed highly mineralized mixed water.

Under the combined action of long-term compressive stress and various deep thermal dynamics, these mineral fluids migrated along the buried deep faults near the core of the duplex anticline to the upper part of the crust. When the metal elements in these ore fluids migrated over long distances to the nappe fault zone of the gold-bearing fracture zone, the gold began to precipitate, and the native gold and the coarse-grained pyrite and quartz formed at the same time or earlier started to fill the fracture zone along the fissures and accumulate into minerals. In summary, Zhacun goldmine is a hydrothermal metallogenic system.

4. Ore Genesis

4.1. Metallogenic Conditions. Himalayan tectonic and magmatic activities provided ore-bearing hydrothermal and metallogenic geological structural conditions. The tectonic activities of gold-bearing fracture zone are characterized by multistage, multistage (pulsation), and diversity. It has roughly experienced more than two cycles of tectonic evolution, first compression and then tension, resulting in multistage and multistage hydrothermal alteration. In terms of gold mineralization, its enrichment is most obvious in the stage of transformation from compressive structure to extensional structure and is closely related to the formation of various metal sulphides. The decompression space was formed in the stage of strong tectonic activity, resulting in the sharp change of the physical and chemical environment of ore-forming fluid, the destruction of gold complex, and the precipitation of gold and other minerals (including altered minerals) in the favorable ore storage space. Therefore, the structurally broken breccia zone (gold-bearing fault zone) in the mining area is not only an ore guiding structure but also an ore storage (ore holding) site. Its evolution controls the occurrence and development of wall rock alteration and gold mineralization in the mining area.

4.2. Migration Forms of Gold and Associated Elements Hg, Sb, and As. According to the study of the inclusion temperature and liquid phase composition in this area, the average temperature of mineralization is about $T = 250°C$, $fo_2 = 10^{-38}$ atm, $fs_2 = 10^{-10}$ atm, and $pH = 6$. When $Au(HS)_2^-$ reaches equilibrium with native gold, the concentration of $Au(HS)_2^-$ can be as high as 7.23×10^{-8}, while the concentration of $AuCl_2^-$ is only $4.7 \times 10 - 10$, indicating that gold in this area is mainly transported by sulphur complex. This founding is consistent with the features that the ore solution was in the reducing environment in the early mineralization period, i.e., the mineralization type is pyrite (coarse grained)-quartz-ferrodolomite-native gold, and the coarse-grained pyrite is the gold-carrying mineral in the mineralization period.

In the middle mineralization period, the gold-bearing fracture zone was in an open state, and the physicochemical conditions changed significantly compared with the early stage. As the ore-forming temperature gradually decreased, the pressure gradually decreased, accompanied by continued natural precipitation. In the ore solution, the reaction function is $[Au(HS)_2^- + 1/2H_2O + H^+ = Au\downarrow + 2H_2S + 1/4O_2]$. With the increasing S^{2-} and large amount production of pyrite, the sulphides of Hg, Sb, and As were also formed, which constituted the pyrite-quartz-dolomite-polymetallic sulphide-native gold mineralization stage. The sulphur complexes and chlorine complexes of Hg, Sb, and As are more stable than the complexes of Au; thus, they have greater mobility, except that some precipitated in the ore zone and continuously diffused towards the surrounding rock and constituted the remote mine halos.

In the late stage of mineralization, with the infiltration of rainwater, the ore solution gradually changed into atmospheric-temperature groundwater with a decreasing mineral concentration, of which the mineral came mainly from shell. Due to the essential changes in the physicochemical conditions, the gold mineralization was gradually terminated in the fracture zone and only small amount of mercury and arsenic mineralization occurred, and then, the gold mineralization will be terminated when the ore-forming conditions are no longer met.

4.3. Discussion on Metallogenic Mechanism. As mentioned above, under the action of long-term compressive stress and various deep thermal dynamics, the mixed water migrated towards the upper part of crust along the buried deep faults near the core of duplex anticline and further dissolved and absorbed the sulphur and small amount of metal elements in surrounding rock during migration process. When the metal elements of the sulphur and chloride complexes contained in the ore fluid migrated over long distances to the nappe fault zone of gold-bearing fracture zone, the changes in physical and chemical conditions, e.g., pressure drop, induce slightly increase of fo_2 (still in the reducing environment). At the meantime, the pH value decreased, and the Fe^{2+} in surrounding rock entered the ore fluid, whose temperature was 260~300°C and pH value was neutral alkaline. Then, the gold began to precipitate, and the native gold occurred the following reaction $[Au(HS)_2^- + Fe^{2+} \longrightarrow FeS_2\downarrow + Au\downarrow + 2H^+]$ and the coarse-grained pyrite and quartz formed at the same time or earlier filled the fracture zone along the fissures and accumulated into minerals. Part of the arsenic precipitated, and the other part has extended towards the surrounding rock, forming the remote mine halos.

In the middle stage of mineralization, due to continuous deformation and imbalanced and discontinuous force, a strong extension-detachment structure was formed in the west-east direction on the east side of the fracture zone. The upper plate of the gold-bearing fracture slid down, and the fracture zone transformed from semiclosed state to open state, but as the lithologies of the upper and lower plates of the fracture zone were the interbedded layers of sand mudstone, which works as good barriers, the fracture zone became a self-contained hydrothermal activity zone. At this stage, the ore-forming temperature was 190~250°C, and the fo_2 continued to increase, but still in a reducing environment. The decline of pressure greatly increased the vitality of the large amount of ore fluid moving upwards, which resulted in an extensive displacement reaction in the surrounding rock. At this time, the mineralization was transformed from filling-based type to metasomatism-based type, accompanied by the precipitation of pyrite, quartz, and dolomite as well as native gold. The precipitation of trace elements like As, Sb, Hg, Cu, Pb, and Zn as monominerals of sulphides formed the second stage of mineralization in the area, i.e., the pyrite (veined)–quartz–dolomite–polymetallic sulphide–natural gold stage. Due to the decrease in pressure and temperature, the pyrite crystallization was accelerated, making the particle size smaller than the early stage.

The superposition of the above two major mineralization stages formed the Zhacun goldmine bed.

In the late stage of mineralization, the fracture zone experienced a second tectonic cycle with a lower intensity than the first and second stages, which extruded first and then detached, making the scale of the fracture zone further expand. Due to the change of tectonic environment and infiltration of rainwater, the ore fluid was transformed from high-concentration hot brine containing rich minerals to atmospheric-temperature groundwater with less minerals and atmospheric precipitation. At this stage, gold mineralization was gradually weakened till it totally disappeared, and the type of alteration was chalcedonic quartz-calcite-microparticle disseminated pyrite.

4.4. The Type of Ore Genesis. Himalayan tectonic and magmatic activities provide ore-bearing hydrothermal fluids and ore-forming geological tectonic conditions. The tectonic activities of the gold-bearing fracture zone have the characteristics of multiphase, multistage (pulsation), and diversity. The tectonic evolution above the cycle, which leads to hydrothermal erosion and mineralization, also presents the characteristics of multistage and multistage. For the gold mineralization, its enrichment is most significant when the compressive structure transforms into tensile structure. The formation of metal sulphides is closely related. During the period of intense tectonic activity, a decompression space was formed. Due to the drastic change in the physical and chemical environment of the ore-forming fluid, gold complex was destroyed, along with the precipitation of gold and other minerals (including altered minerals) into the favorable storage space. Therefore, the structural fractured breccia zone (gold-bearing fracture zone) in the mining area is not only an ore-conducting structure but also a place for ore storage (ore hosting). Its evolution controls the surrounding rock alteration and the occurrence and development of gold mineralization.

Through the above analysis of metallogenic conditions, gold mineralization process, and ore deposit genetic mechanism of Zhacun goldmine, it is found that this goldmine is multisource, multistage, and multigenesis. In the whole metallogenic process, the mineralized hydrothermal activity presented the monophyletic evolution feature of an inherited homologic and cocurrent system (that is, the mineralized hydrotherm is from the mixed hot brine throughout the process). Despite the different characteristics of the gold-bearing fracture zone in each tectonic evolution stage, the minerals and element combinations formed in each stage have a similar feature, i.e., the natural gold+pyrite+dolomite+quartz is the most important and basic combination form. Therefore, the genetic type of the ore deposit in this area is magmatic mesothermal-epithermal gold deposit.

5. Conclusions

Based on the study of the geological characteristics, metallogenic factors, the relationship between mineralization and alkaline porphyry, and the genesis of the deposit in Zhacun goldmine, the following conclusions are drawn:

(1) Based on the analysis of the relationship between mineralization and alkaline porphyry in the area, this paper holds that the magmatic activity of the Lianhuashan quartz monzonite porphyry has a direct relationship with the mineralization of the Zhacun goldmine, which is not only an important mineral source and fluid source but also a major heat source driving the circulation of ore-forming fluids

(2) Based on the analysis of the relationship between mineralization and alkaline porphyry and the characteristics of various mineralization elements in Zhacun goldmine, it is proposed for the first time that this goldmine belongs to the hydrothermal (water) metallogenic system, and the Zhacun goldmine metallogenic system model is constructed, which can be used to evaluate the newly discovered mineral deposits and undiscovered area with good mineralization conditions in the area and lay the foundation for future systematic prospecting

(3) Through the analysis of mineralization conditions, the gold mineralization process, and genetic mechanism of Zhacun goldmine, it is concluded that the genetic type of the goldmine is a magmatic hydrothermal type medium-low temperature type

Data Availability

The data used to support the findings of this study are included in the article.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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