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Study on genesis of the primary orebody in Shewushan gold deposit

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ABSTRACT: *Shewushan gold deposit is located at 16 km southwest of Jiayu County, Xianning City, Hubei Province, with approximately 10 Mt reserve and average around 2.2 g /t gold grade. That resulted from chemistry of carlin-type orebody hosted in Cambrian-Permian strata under tertiary tropical rainforest climate, which exposed to the oxidation interface by the regional uplift movement. Shewushan gold deposit is a closed negative terrain controlled by faults, where broad karst landform also developed in the fault and unconformity boundary, and obviously is a favorable environment for weathering gold deposit.*

Primary orebody is controlled by Shewushan overturned anticline and Shewushan thrust nappe structure, which respectively belongs to EW trend tectonic belt developed in Indosinian-ealry Yanshanian and NE, NW trend tectonic belt developed in Himalayan. The low-middle temperature serials of alteration minerals include silicide, pyritization, baritization, calcite, realgar and orpiment in outcrop area of Shewushan deposit, which is an important alteration mineral assemblage for carlin-type deposit.

The "Cherts hat", associated with primary orebody, is hydrothermal mineral in Shewushan deposit, and result from filling-metasomatism when SiO_2-rich ore-forming fluid flowed to the F_{12} fault. Besides that, our further research implies that Si element is derived from the Cambrian-Permian stratum or older stratum in the area.

The characteristic of fluid inclusions is 5-20% at gas-liquid ratio, 10μm± at size, and its homogenization temperature is from 80 to 240 ℃, salinity is 2.20-9.34 wt% NaCl, average density is 0.817~0.990 g/cm^3, pressure is 420×10^5~430×10^5Pa (equivalent 1.5-2.0 km at depth), which can be referred to high density, low salinity and low temperature ore-forming fluid. What's more, the compositions of gas phase in fluid inclusion contain CO_2 and CH_4, which indicates that it is a reducing ore-forming fluid. Finally, we conclude that the ore-forming fluid is hot brine based on evidence from baritization, "Cherts hat", and reserves ratio of Au/Ag.

KEYWORDS: *Genesis, Primary orebody, Carlin-type gold deposit, Shewushan deposit.*

I. INTRODUCTION

In China, this kind of gold deposit has been paid more attention (Cao, 1998; Tu, 1999; Chen and Yang, 1999; Wang and Tan, 2002). Shewushan gold deposit located in southern Hubei, central China (Fig 1-1), was the first lateritic gold deposit discovered in central China in 1989, which is also the largest one in Asia. Since then, a series of laterite gold deposits have been found in succession from end of 1980's to beginning of 1990's, and have become an important type of gold resource in China (Cao, 1998; Chen et al., 2001; Wang and Tan, 2002).

Shewushan gold deposit is a new type of economically gold deposit that is currently being exploited in China. Economic grade of the ore is confined largely to the lower portion of the 30-m-thick weathering profile rather than to the fresh, unweathered parts of the deposit. However, both the climate and the tectonic settings in Shewushan are different from the area where typical lateritic gold deposits are located. For example, the climate is warm and humid in the Shewushan area. The annual rainfall is ~1100 mm, falling mainly between April and October, and the average temperature is 18 ^{0}C, with a mean of 4.1 ^{0}C during the coldest month (January) and 29.2 ^{0}C during the warmest month (July).

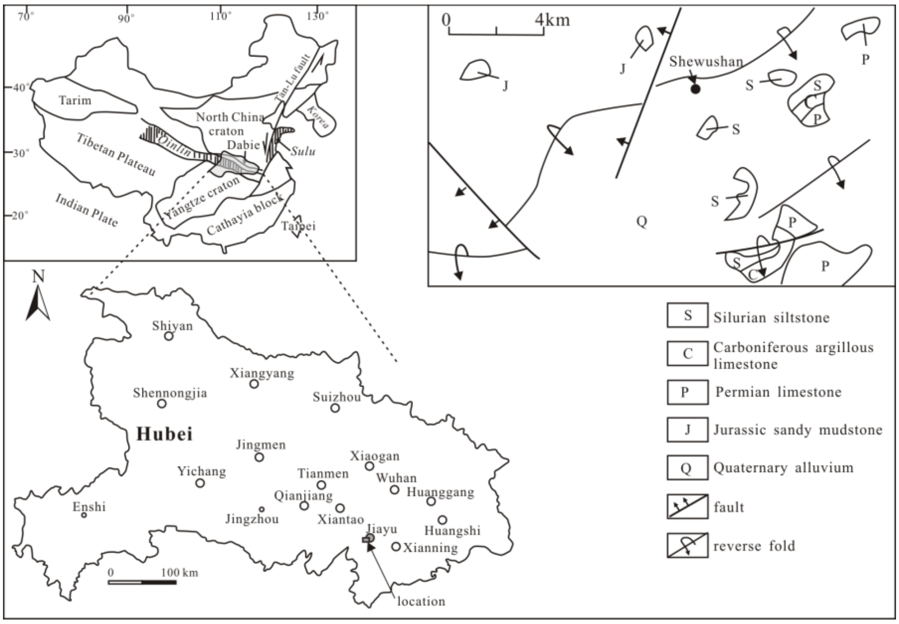

Fig. 1-1: Location of Shewushan gold deposit (after Hong, 2001)

The landscape consists of hills covered with evergreen trees and bushes and comprises relatively flat aggraded and coalesced alluvial fans, with the base level of erosion 20 m above mean sea level (Hong and Tie, 2005). The intensive tectonic movement during the Cenozoic limited the development of an erosional plain, and most of the bedrock is primary carbonates. As a result, the particle size of the gold in the weathering profile is extremely small; most grains are <0.02 mm in size and occur at the rims of clay mineral grains (Hong, 1996; Hong et al., 1999).

The gold in the ore is not visible by reflected- and transmitted-light microscopy at high magnification. It is, therefore, extremely difficult to study the occurrence of gold and its distribution by conventional means.

Previous studies of the Shewushan gold deposit have mainly focused on the geological setting, geochemical characteristics, and genetic model of this type of weathering-related gold deposit (Li, 1993; Li et al., 1994; Yu, 1994; Liu, 1996; Hong et al., 2000). However, the genesis of the primary orebody is still argued. There exist two viewpoints: weathered residual type (Yu, 1994; Li, 1998) and carlin type (Li and Liu, 1995; Liu and Li, 1995).

The Shewushan gold deposit, hosted in weathered mantle above the Shewushan thrust zone, is probably an example of a type of deposit where all the ore-grade gold is related to surficial weathering processes of a previously uneconomic gold deposit. Based on regional strata, from bottom to top, as the first large scale laterized gold deposit to this day, Shewushan gold deposit is characterized by large scale, lower grade, easy mining, easy dressing, top economic benefits etc... In the weathering type gold deposit, a part of the Shewushan gold deposit, whose orebodies occur in the loose clay bed, and contain different amounts of gravel and sand serving as the host rock.. In this paper, we illustrate the genesis of the primary ore body by fluid inclusion, geochemistry and electron microprobe analysis.

II. REGIONAL GEOLOGICAL SETTING

2.1 Strata

The basement in the area is mesoproterozoic strata, and the cap consists of Sinian-Jurassic strata. Lengjiaxi group is the most important part of mesoproterozoic strata in the southern minerals area of Hubei province, which comprise lower metamorphic rock with flysch rhythm, and primary rock is slate and tuffaceous sandstone. The sedimentary strata mainly comprise carbonate rock with mud, sandstone and silicified coal. The rift basin in the local area, resulted from extension in Late Yanshanian, contain red terrigenous clastic rocks.

In this area, Doushantuo Formation and Pingyuan Formation of Lengjiaxi proup, mainly hosted mineral deposit, comprised dolomite with mud, limestone, shale and slate. Some mineral spots can also be observed in Cambrian strata.

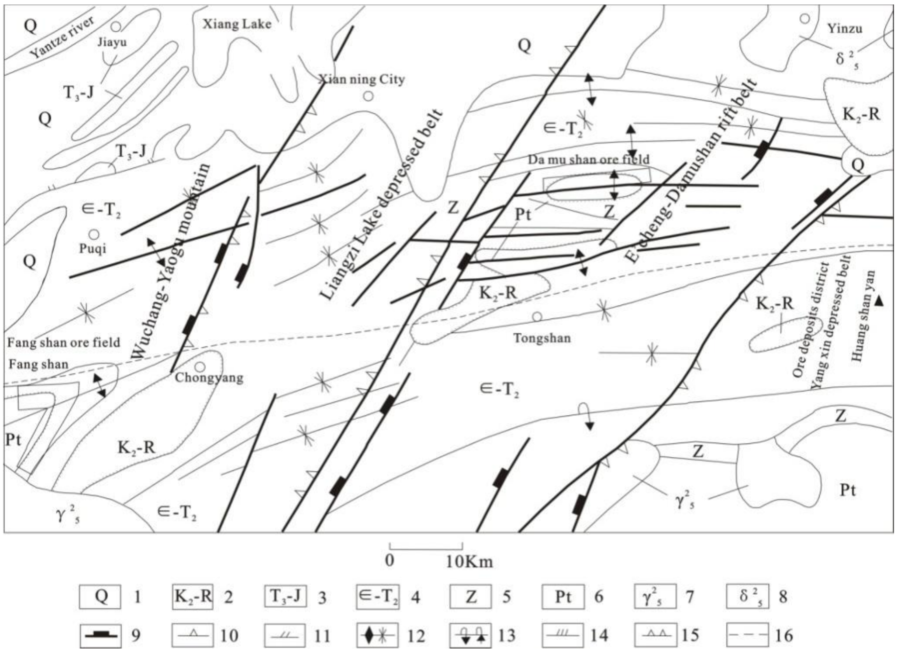

Fig.2-1 Simpled regional map of ore district in the south of Hubei province (after Wang et al., 2011)

Strata: Q: Quaternary; K_2-R: Upper Cretaceous-Tertiary; T_3-J: Triassic-Jurassic; ∈-T_2: Cambrian-Triassic; Z: Sinian; Pt: Proterozoic

Magmatic rocks: γ^2_5 -granite; δ^2_5 -diorite

Structure: 1. compressive fracture; 2. tenso fracture; 3. fracture; 4. anticline, syncline; 5. inverted anticline inverted syncline; 6. complexing faults with several stages; 7. uplift and depression boundaries

2.2 Structures

The ore deposit district in the south of Hubei province is located in the Wuling-Pengze folded zone belonged to Wuling-Xiushui depression belt, Fangshan anticline and Damushan-Mugang anticline at the west of Tongshan-Duanchang folded zone. The deep tectonic, at the north of Tongshan-Chongyang fault, consists of basement with center type of Sichuan, the cap, and basement with south type of Yangtze River from bottom to top, but at the south of the fault, consists of basement with south type of Yangtze River and basement with center type of Sichuan from top to bottom. The covering relationship of them respond southern strata thrusts to the basement with center type of Sichuan along the faults, and lead to EW trend folds and EW trend faults, NE trend faults, NW trend faults occurred together, which bring about the alternating characteristic between depression and uplift.

2.3 Igneous rock

The Yanshanian magmatism is frequently in the area (Fig.2-1), when Mufu mountain melting-type granite emplaced in the Tongcheng, Jiugong Mountain, Shadian and some other place, most of the rock is diorite (i.e. Yinzu diorite) and common granite. It is suggested that igneous rock possibly is at the depth of Tongshan and Shewushan based on aeromagnetic reports (1:50000 at scale).

2.4 Regional mineral resources

Mineral resources in the area, mainly in non-metallic mineral, followed by metal ores, energy, water and gas mineral. 37 kinds of minerals have been found, but only 18 species of them were identified at mineral reserves, including two kinds of energy minerals, metal ores, non-metallic mineral, mineral water. 11 kinds of mineral resources, at reserves, rank in the top five in Hubei Province, the first in the province of minerals include magnesium, antimony, monazite, tantalum, geothermal, the second includes gold, niobium, metallurgical dolomite and so on, finally, the fourth include coal, vanadium and manganese.

Most of gold mineralization in the south of Hubei province are laterite gold deposits, for example, large Shewushan deposit and small-scale Bazimen deposit, Fushui deposit and Tongshan deposit, in addition to a large number of anomalous area, which mainly are associated with the glacial warm and humid climate between middle Pleistocene and late Tertiary, lead to intense chemical weathering, at same time, many gold-bearing silicified rocks are also crystallization. Recently, some researches indicate that Carlin-type gold deposit, possibly origin of the laterite gold deposits, may be at the depth.

Antimony mineral deposit is another important mineral types in the south of Hubei province, including Fangshan, Damushan and Huangshanyan mineralization concentrated area, very similar genesis to each other, is associated with early Yanshanian tectonic-magmatism. Recent researches suggest that metals are mainly derived from the Middle Proterozoic Lengjiaxi group and magmatic hydrothermal of granite.

III. GEOLOGICAL SETTING OF SHEWUSHAN ORE DRISTRICT

3.1 Strata

Shewushan gold deposit lithologically overall constituted by the lower strata, middle strata ore body and upper strata. Constitute the slopes - basinal platform facies and restricted platform facies, but the water depth is obvious by the shallowing upward variation. The bottom portion of the middle strata and the upper strata constitute the main bedrock area of lateritic gold.

The water deep facies lower part of the rock formations in the anticline, the main body by a thin layer of mud calcareous slate folder in the thin layer of mudstone, set lithology subject may be equivalent subtidal zone half, slowly deposited debris content the product, including calcareous slate color is dark, and local to see asphalt may indicate higher biological content. Mud calcareous and argillaceous rocks staggered indication the subtidal environment Porgy surface under the shallow part of the terrigenous material containing terrigenous material relative water deeper mutual transition of the environment, that it may phase to the edge of the Wilson cycle Basin the bathyal slot basin facies and basinal quite.

The central body of a thick layer of marl, calcarenite containing shelly limestone component, the shelly limestone are often thin, local shelly limestone may Department reef shattered redeposition part. Rock and mineral identification indicate the segment containing dolomitic and a small amount of quartz sand and other debris ranging from 5-30 % (of course, the vast majority of quartz is a product of hydrothermal activity), so this set must contain some restricted platform components, the results from this rock and mineral identification containing the dolomitic located near the F.3-1 fracture. Saw another strong siliceous rocks of the local zone part of the original Department of rocks may be impure calcium quartz sandstone, some limestone has rounded siliceous gravel, and support it. Short, the central rock body is opened or semi-occlusive platform facies, and clip part of the platform margin shoal (shelly limestone), reflecting an unstable tidal

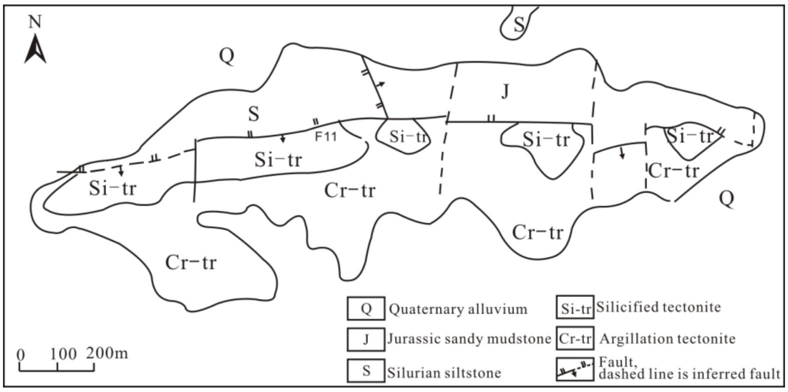

Fig. 3-1. Geological sketch map showing mine structure and lithology in Shewushan gold deposit

zone and the intertidal environment with constantly alternating. Early emergence of terrigenous material, reflect the early hydrodynamic conditions extremely turbulent, set strata at least represents a transgressive phase sequence. Upper strata body composed of thick-bedded marl, the lower part of the folder also have some of the thin layer of calcarenite, whose main shallow shelf phase (Fig. 3-1).

For mine set of strata area predecessors, has been controversial. Observed to lower strata based on regional geological maps prepared by the Hubei four teams, mine quite Silurian strata, middle and upper strata equivalent to the Carboniferous - Permian strata. The work in the central limestone collected a small amount of brachiopods, crinoids' layer foraminifers' fossils poor fossil preservation, according to the preliminary identification of paleontology Department of China University of Geosciences Professor Cai Xiongfei, speculated that there may belong to the Devonian.

3.2 Structure

The Carlin-type gold deposits in China are structurally controlled by both faults and folds formed in the Yanshanian orogeny (Cunningham et al., 1988; Ashley et al., 1991; Gao, 1992; Mao, 1992; Yang, 1992; Jian, 1996).The deposits are usually located along second-order faults (e.g., Lannigou) near major faults, but a few of them are hosted in large regional fault zones (e.g., Dongbeizhai).

The deposit occurs in the Shewushan Thrust Zone (Fig.3-2), which was a conduit for epithermal mineralization as well as the present site of formation of the weathered mantle formed at the expense of the mineralized tectonic melange (Ding, 1992). The orebodies are located mainly in the lower portion of the weathered mantle, which comprises brown to red-brown clay and gravelly clay, and consists of an assemblage of illite, kaolinite, goethite, quartz, and oxides of Fe and Mn (Hong, 1995).

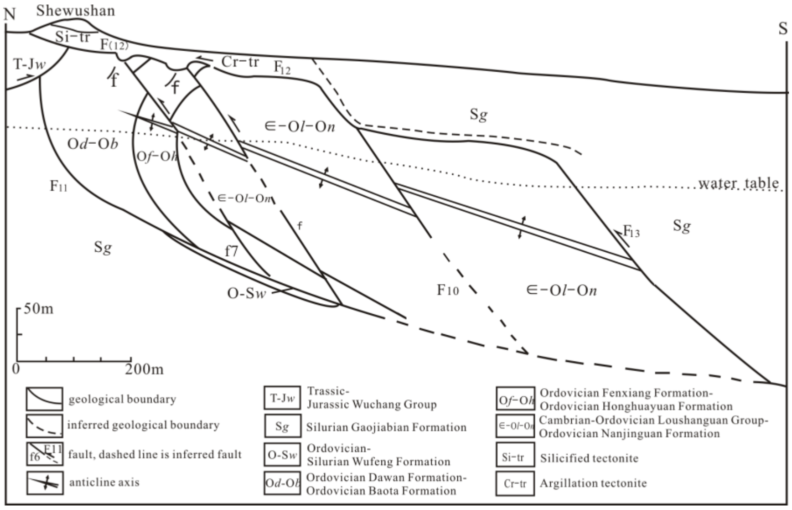

Fig. 3-2. The generalized model of the bimodal thrust faults in Shewushan gold deposit (modified from Wang and Yang, 1992)

This deposit occurs within the over thus in the southern limb of Shewushan reversed anticline. The distribution of the ore at Shewushan is structurally controlled. The sequence of structures observed is: east-west-trending structures, including the major anticlines and faults.

The structures in the deposit show features of multistage deformation. The east-west structures may represent the regional north-south-trending Indosinian orogeny in earlier stage. The north-south structures may be related to the later tectono-magmatic event with east-west maximum principal stress (Yu, 1995).

Shewushan deposit has its own feature including the structural location of occurrence, mineralization, gold-bearing weathering crust laterite profile, gold-forming resources, and gold occurrence features. This gold deposit belongs to carlin-type which can be divided into two subtype-original gold ore and, the weathered gold ore has been formed from exposed original gold ore which occurred in tectonite within the gently dipping fault by weathered and leaching. Shewushan gold deposit consists of series of mineralization faults containing high gold grade in a larger lower grade zone peripheral. Shewushan orefield occur the Middle-upper Cambrian and Ordovician, which bear plenty of gold deposits; mineralization and geochemical abnomalies evidently, reflect the source bed characteristic. The hydrother mal circulation passage is composed of gently dipping overthrust and steep extensive slide fault.

3.2.1 Fault

In geology, a fracture in the rocks of the Earth's crust, where compressional or tensional forces develops, causes the rocks on the opposite sides of the fracture to be displaced relative to each other. Faults range in length from a few inches to hundreds of miles, and displacement may also range from less than an inch to hundreds of miles along the fracture surface (the fault plane). Most, if not all, earthquakes are caused by rapid movement along faults. Faults are common throughout the world.

However Shewushan gold deposit developed north-south-trending faults, which are the second important structures observed (Fig.3-3). The north-south-trending structures, a set of faults oriented at 3°- 8°, which appear to postdate east-west faults and fractures and thus probably postdate mineralization. The faults dip east at around 30°, showing local interference with the east-west structures especially, and offset silicified limestone.

The hypogene mineralization is closely associated with the well-developed faults and fractures present mainly on the crest of the reverse anticline.

3.2.2 Fold

Fold is used in geology when one or a stack of originally flat and planar surfaces, such as sedimentary strata, are bent or curved as a result of permanent deformation. Many folds are directly related to faults, associate with their propagation, displacement and the accommodation of strains between neighbouring faults.

Thus Shewushan gold deposit, structural orientations of folds are roughly southeast-northwest. East–west structures are dominant in the deposit and include the major anticline and associated parasitic fractures. The major anticline is a reversed fold with shallowly dipping southern limbs in the Shewushan region and the axial zone just beneath the deposit. They occur as axial-plane fanning fractures in fold crests. Away from the crests they are at high angles or even normal to bedding. Comb-textured or massive veins, which may be truncated by slip along the bedding or terminated against adjacent mudstone, commonly fill such fractures. These folds and faults have been interpreted as the result of sliding movement of the sediment cause by the Indosinian orogeny.

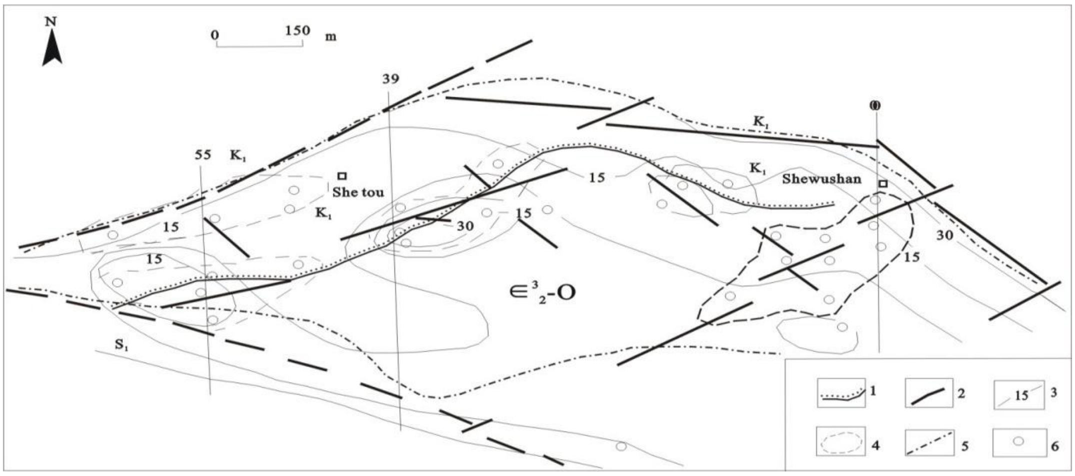

Fig. 3-3 Structural sketch map of basement rock in Shewushan gold mine Yu Renyu (1995)
K_1: Lower Cretaceous; S_1: Lower Silurian; $\in_2^3$-O: the upper Cambrian-Ordovician;
1. Unconformity; 2. Fault; 3. Contours of the bedrock surface (m); 4. Native gold mineralization boundary line;
5. Weathering boundary line type gold; 6. View native gold drilling location.

The elevation of the ore body occurrence is strongly controlled by structures, and the thickness and grade of the ore body increases in the fracture zone. The mineralization is confined to the structural area with the metasediments and crushed quartz veins and calcitization. East-west-trending fractures are most intense in the limestone, with a spacing of 5-60 cm (average 20 cm). The ore bodies are confined between the North Boundary Fault (F_{11}, with dip angle between 30-50°) and South Boundary Fault (F_{13}) (Fig.3-4a, b), where developed crushed limestone and tectonic breccias (Fig.3-4c, d). East-west-trending fractures occur as axial plane fanning fractures in fold crests. Away from the crests they are at high angle or even normal to bedding. Comb-textured or massive veins, which may be truncated by slip along the bedding or terminated against adjacent mudstone, which commonly fills such fractures.

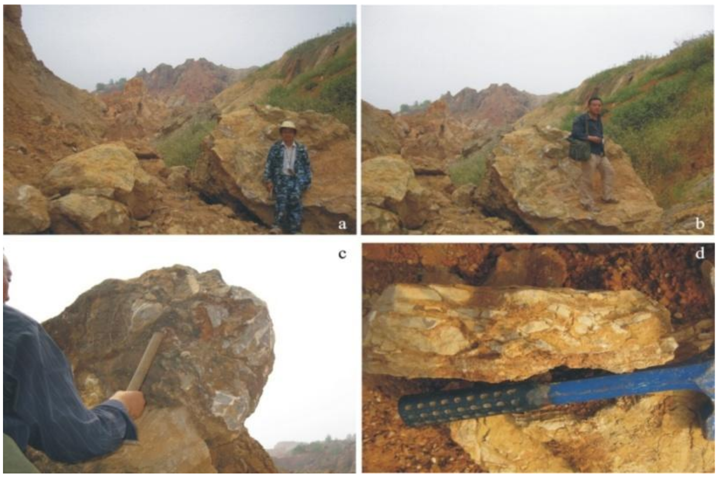

Fig.3-4. Characteristics observed in the field.
a- North Boundary Fault (F_{11}), about 120° trending; b-South Boundary fault (F_{12});
c-crushed limestone near F_{12}; d-tectonic breccias occurs near F_{11}

3.3 Alteration of Wall Rock

Above the water table, silification, argillation, ferritization occurred, whereas pyritization, realgarization, baritization, bituminization, occurred below the water table.

Silification is the wide spreading alteration in Shewushan gold deposit, which also called 'silicon cap' by on-site producers. It is limited to the faulted crushed zone and limestone units. The most intense areas of silification are the faulted crushed zones, where the massive siliceous rock occurs (Fig. 3-5a, b). It presents discontinuous shaped, trending mainly southwards and projecting at the surface for weathering. The areas of intense silification are generally related to a higher gold grade.

Argillation develops mainly in the weathering profile, where clay minerals occur in the matrix and in fractures, with kaolinite and halloysite mainly in the upper portion and illite and minor kaolinite in the lower portion, which caused gold occurs within small Ag-bearing particles, nm-scale in size, adsorbed at the edges of illite and kaolinite (Wang and Yang, 1992; Hong, 1996; Hong et al., 1999; Hong and Tie, 2005).

Ferritization is the most intense surficial alteration in the mine. It is confined to weathering profile. Ferritization occurs as psendomorphs of the earlier sulfide (pyrite and marcasite), disseminated in the oxidized zone.

Pyritization develops widely in limestone, especially in western part of the mine, i.e. jarosite widely occurs, implying pyritization development (Fig. 3-5c). In addition, realgarization develops together with orpiment (Fig. 3-5d). They could be recognized in the calcite vein or in limestone, which occurred as granulous or filmated in calcite vein (Fig. 3-5e), or disseminated in limestone (Fig. 3-5f). Baritization occurs in vein or breccias, and coexist with calcite (Fig. 3-5g).

Bituminization occurs in bedrock outcrop, which cement or cut calcite vein, later than calcite (Fig. 3-5h).

In brief, both hypogene and supergene mineralization are present in Shewushan gold deposit. The hypogene mineralization, i.e. primary mineralization, is closely associated with silification. Three silification stages are observed: 1) the first stage is barren, characteristically coplanar to the axial plane, and devoid of sulfides; 2) gold-bearing sulfide quartz veins and calcite veins postdate the first stage chalcedony quartz veins, which crosscut the former chalcedony quartz veins and probably represent the primary gold-bearing mineralization; 3) the third stage is characterized by the disrupting of sulfide quartz veins and calcite veins by barite quartz veins.

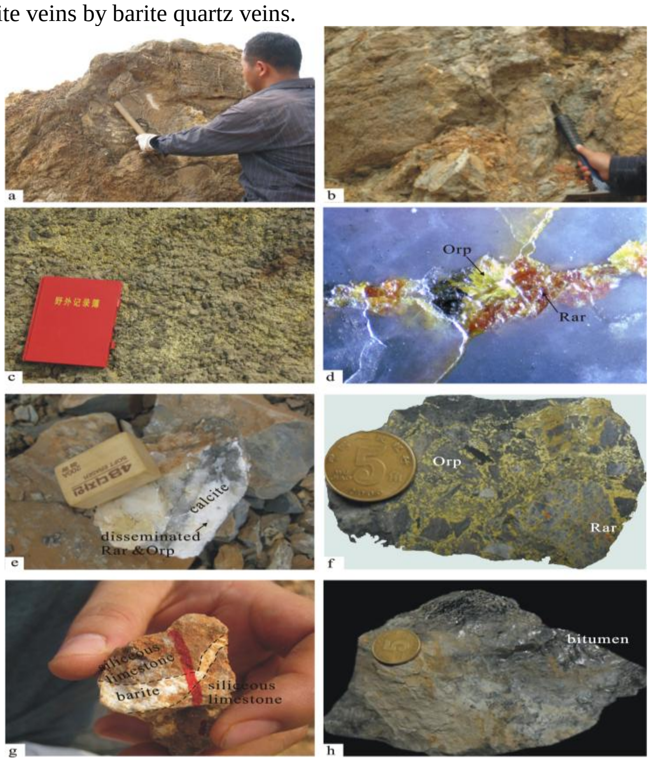

Fig. 3-5 Various alterations in Shewushan gold deposit.
a-chalcedony cement brecciaous limestone in fault crushed zone; b-Silicified limestone (primary mineralized bodies) outcrop in fault crushed zone; c-jarosite widely occurs in western part of ore mine; d-realgarization coexist with orpiment in polished section with oblique light, five times magnification; e-realgarization, orpiment disseminated occurs in calcite vein in fault zone; f-realgarization and orpiment in brecciaous limestone; g-barite cut across the siliceous limestone; h-bitumen envelope the calcite in fault zone

3.4 Characteristic of Orebody

The oxidated ore body (Ⅱ) in the Shewushan deposit is above over weathered surface and at the bottom of gold-bearing silicious belt (Ⅰ). The shape of ore body (Ⅱ) is layered, stratiform and lenticular, 1.8 km at length and n~100n m at width. All sulfides are oxidated and only leaving quartz, chalcedony, clay and limonite in the oxidated ore (Fig. 3-6). The range of gold grade is wide, from 1×10^{-6} to 3×10^{-6}, and 18.26×10^{-6} at most.

The primary ore body (Ⅲ) at the bottom of the oxidated ore body (Ⅱ) consist of Ordovician gold–bearing broken (brecciated) limestone (contains some clay) and gravel silty claystone (contains some siltstone).The gold grade of ore body (Ⅲ) is at the range of $1\text{-}2\times10^{-6}$.

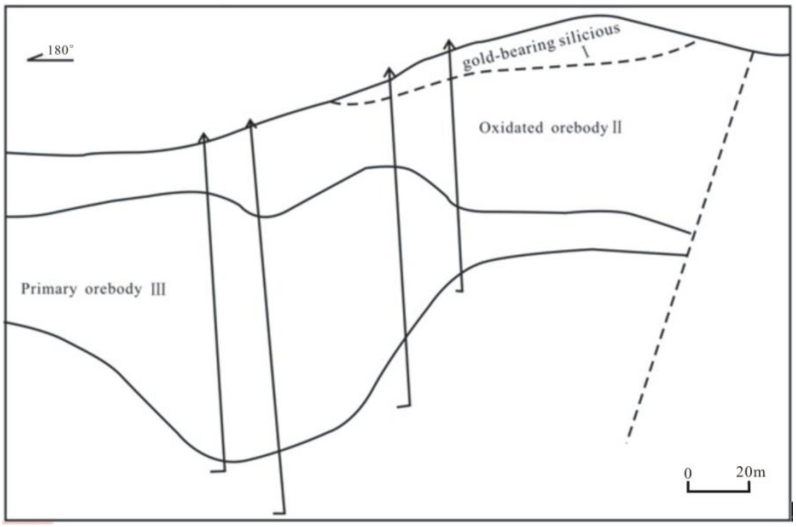

Fig. 3-6. Shewushan arnica mine 0 line schematic cross-sectional view (after Wang, 1992)
I, the silicon cap; Ⅱ, oxidized ore body (of); Ⅲ primary ore (of) the body

3.4.1 Minerals

Ore minerals occur in open faults, stock works, and breccias and replace adjacent strata resulting in the formation of disseminated ore (Fig3-7). In brittle, impermeable, and unreactive rocks, the bulk of the ore is along faults and fractures. In less competent, permeable, and reactive lithologies, ore extends outward from faults to form large tabular bodies.

The increment of fine grade size aggregates is of great significance to absorb Au particles and to form the economic ore bodies.

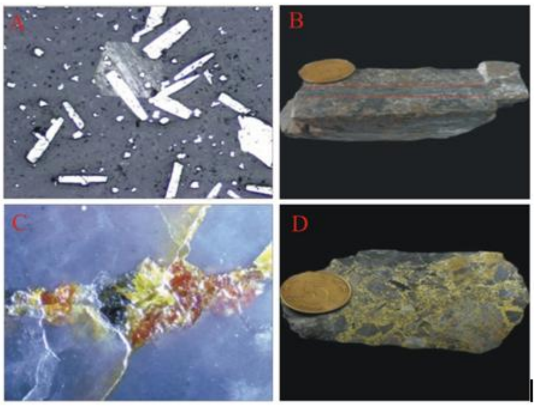

Fig.3-7 Ore minerals in Shewushan gold deposit
A. pyrite and arsenopyrite symbiotic (×10), B. limestone interspersed with pyrite and arsenopyrite veins, C. Symbiosis with realgar and orpiment (×5), D. Brecciated limestone realgar, orpiment

3.4.2 Gauge minerals

Primary ore body contains gangue minerals calcite, dolomite, barite, fluorite, and clay minerals.

3.4.3 Texture and structure of ore

There are three types of ore in Shewushan deposit, contain gold-bearing silicious (Au Ⅰ), oxidation and primary ore.

Gold-bearing silicious orebody (Au Ⅰ), which is brown, gray and maroon, and its' structure includes clastoporphyritic fragmentation, brecciated structure seen limonite leaching phenomenon (Fig.3-8A).

The characteristic of oxidation ore is cataclastic structure,argillaceous structure, containing structure, residual structure, brecciated structure, disseminated structure, banded structure, vein structure, and honeycomb structure.

The characteristic of primary ore is cataclastic structure, interspersed structure, micritic biological structure, brecciated structure, vein structure, and higher gold grade in broken rocks. The ore was crushed, fragmentation structure (Fig.3-8B), the film-like structure (Fig.3-8C), interspersed structure (Fig.3-8D), pulse-like structure (Fig.3-8E), brecciated structure (Fig.3-8F).

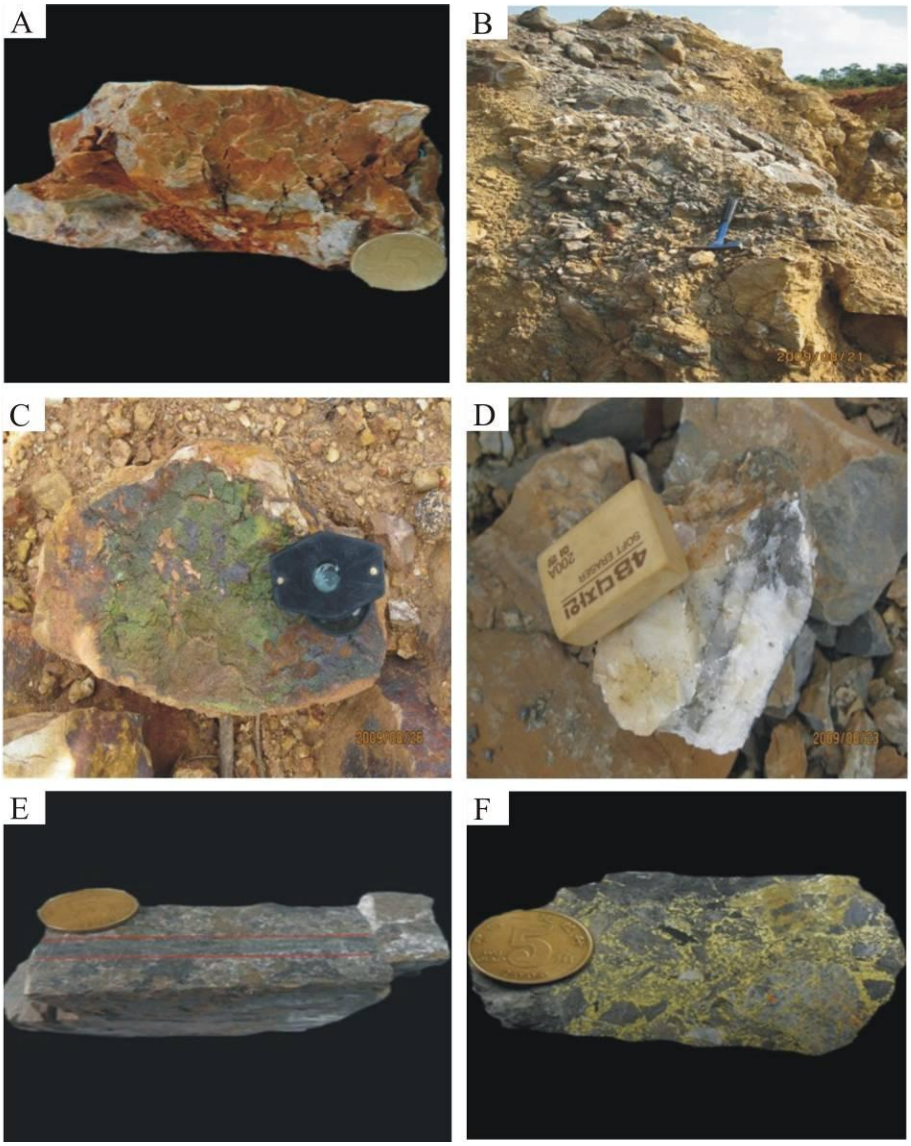

Fig. 3-8 Typical ore structure of primary orebody in Shewushan gold deposit
A-silicified tectonic rock, B-fragmentation structure Ore nearly F_{13}, C-film-like structure nearly F_{11}, D-realgar, orpiment disseminated structure nearly F_{11}, E-arsenopyrite vein, F-brecciated structure

IV. ANALYSIS OF ORE GENESIS

4.1 Study on Fluid Inclusions

Several studies on the petrography, and microthermometry, of fluid inclusions have recently been on samples in the Laboratory of China University of Geosciences (Wuhan). Nineteen samples were observed for homogenization temperature. The location of the samples could be seen in Fig 4-1. Limestone, dolomite, cryptite and silicite samples were collected from outcrop. These samples were cut and double polished into around 0.3 mm thick sections to observe.

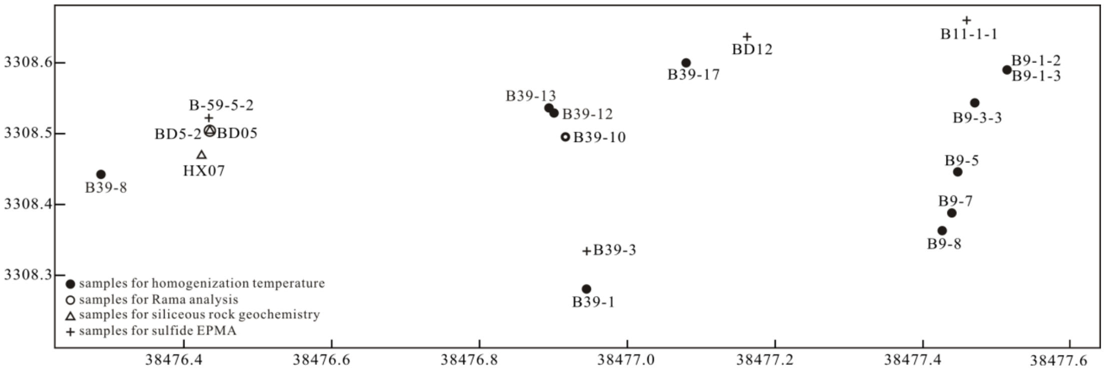

Fig. 4-1. The location map of the analyzed samples in Shewushan deposit

All the three types' inclusions have been observed in samples, i.e. primary (Fig. 4-2a, b), pseudosecondary (Fig. 4-2c) and secondary (Fig. 4-2d) fluid inclusions.

Primary inclusions are typically larger (maximum 20 μm) and isolated. Pseudosecondary and secondary fluid inclusions define linear trails and are much smaller (typically <5 μm). Analysis was in most cases confined to inclusions thought to be of primary origin and hence allows us to document temperature in mineralized fluid.

Two kinds of inclusions exist, i.e. aqueous (most abundant) fluid inclusions and CO_2-rich fluid inclusions. For the first type, the vapor phase occupies 5% to 10%, and to a lesser extent 15% to 40% of the total volume of individual inclusions. They are mostly irregular and elliptic in shape. Most of them are less than 8 μm in diameter; some are large, reaching 20 μm in the longest dimension. They occurred either in the small cluster without obvious planar orientation or in wide hands. The homogenization temperatures range from 70 ^{0}C to 350 ^{0}C, concentrating between 140 ^{0}C and 220 ^{0}C, which is middle-low temperature (Fig. 4-3).

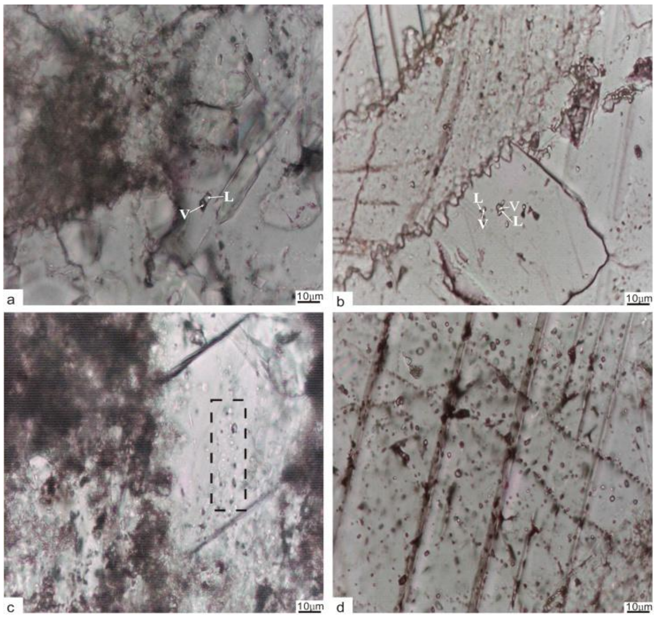

Fig. 4-2. Fluid inclusion petrography in Shewushan gold eposit
a-Primary fluid inclusion with isolated occurrence; b-Primary fluid inclusion in small clusters; c-Pseudosecondary fluid inclusion distributed in calcite fissure; d-Secondary fluid inclusion in calcite fissures

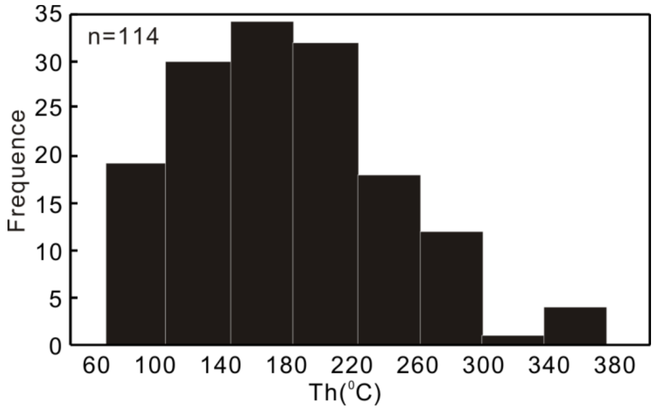

Fig. 4-3. Histogram showing homogenization temperatures of aqueous fluid inclusions in Shewushan gold deposit

At the room temperature, these CO_2-rich fluid inclusions contain liquid and vapor carbonic phase and an aqueous liquid phase. These inclusions have a dark appearance, and therefore, the boundary between the liquid and vapor carbonic phase is not always evident. According to the previous study by Liu and Li (1995), the salinity ranges from 2.2 wt. % to 9.34 wt. %, and the density ranges from 0.817 to 0.990 g/cm^3, with pressure from 42 to 46 MPa, showing low salinity and high density fluid characteristics, which implies the forming depth is about 1.5-2 km (Liu and Li, 1995).

4.2 Geochemistry of Siliceous Rocks

As mentioned in Chapter 3, silification is the wide developing and important alteration associated with gold mineralization. We collected laminate-lenticular siliceous rocks in the field. Samples were washed with distilled water, and were ground and passed through a 75 μm mesh sieve.

The siliceous rocks mainly consist of SiO_2, with the SiO_2 contents vary from 96.87% to 97.9%, and 97.24% on average, showing the better pure composition. The secondary constitutes are Al_2O_3, and the content of the other elements are very low (Table 4-1). The Al/ (Al+Fe+Mn) atomic ratio is an important indicator to evaluate the content of hydrothermal sedimentary components in various sediments, and the ratios decrease with the increase of the content of hydrothermal components. In addition, low TiO_2 contents are the typical characters of the hydrothermal siliceous rocks. In Shewushan deposit, the Al/ (Al+Fe+Mn) ratios of our samples range from 0.244 to 0.317, and TiO_2 contents are 0.01% (Table 4-1), showing the hydrothermal characteristics. In the Al-Fe-Mn triangle diagram, we plot samples of Shewushan, West Qinling, Franciscan and Shimanto, showing their hydrothermal characteristics (Fig. 4-4).

Table 4-1 Major elements contents of siliceous rocks in Shewushan gold deposit (%)

Sample	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	Al/(Al+Fe+Mn)
HX07	97.9	0.01	0.30	0.54	0.38	0.01	0.06	0.01	0.10	0.244
BD05	96.87	0.01	0.44	0.69	0.25	0.01	0.06	0.01	0.11	0.317
WestQinling[1]	95.30	0.04	0.41	1.03	0.58	0.03	0.19	0.68	0.06	0.153
Franciscan[2]	92.30	0.09	1.31	0.27	2.36	0.53	0.28	0.11	0.16	0.293
Shimanto[3]	87.87	0.05	1.09	0.52	2.52	1.08	0.86	1.05	0.35	0.209

1. Average composition of cherts from West Qinling, data from (Liu et al., 1999); 2, 3. data from Yamamoto, (1987). Al/ (Al+Fe+Mn)= Al_2O_3/(Al_2O_3+ Fe_2O_3+ FeO+ MnO).

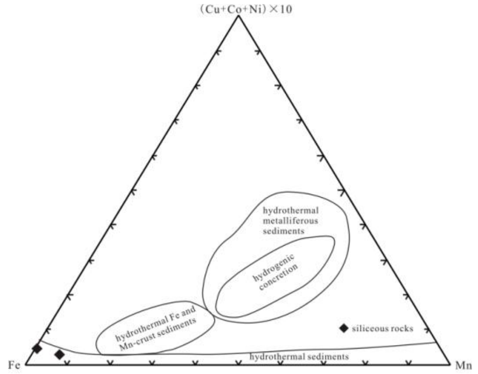

Fig. 4-6 Ternary diagram of Fe-Mn-(Cu+Co+Ni)×10, modified from Crerar et al., 1982

Hydrothermal sediments are relatively enriched in Cu, Ni and depleted in Co (Crerar et al., 1982), and high contents of As, Ba and Sb in sediments (Bostroem et al., 1979; Marchig et al., 1982). In the U-Th diagram, the siliceous rocks fall into hydrothermal field (Fig. 4-5). In the triangle diagram of Fe-Mn-(Co+Ni+Cu)×10, the siliceous rocks fall into the hydrothermal field close to the Fe-end member (Fig. 4-6). Sum up, the trace elements indicate that the siliceous rocks are hydrothermal sediments in the Shewushan gold deposit.

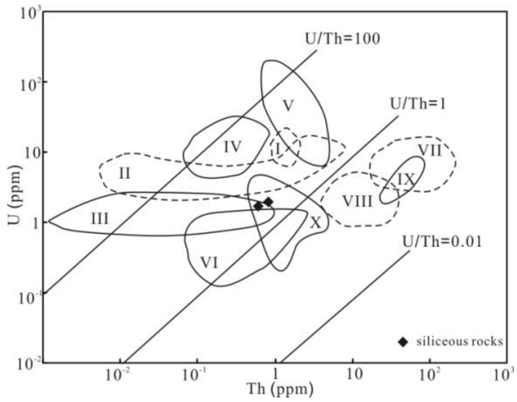

Fig. 4-5 The plot of U v.s. Th of siliceous rocks in Shewushan deposit, (based on Bostroem et al., 1979)

I-TAG hydrothermal area, at the Mid-Atlantic Ridge; II-Galapagos spreading center deposits; III-Amphitrite expedition, dredge site 2; IV- Red sea hot brine deposits; V-East Pacific Rise crest deposits; VI-Lanban hydrothermal sediments; VII-ordinary manganese nodules; VIII-ordinary pelagic sediments; IX-Laterites; X-fossil hydrothermal deposits

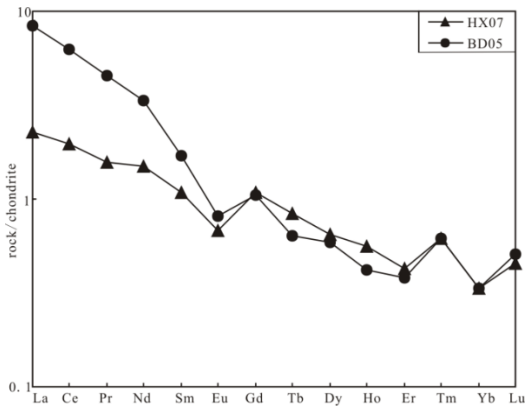

Fig. 4-7. The REE pattern of the siliceous rocks from the Shewushan gold deposit

In addition, REE compositions are also the important indicators distinguishing hydrothermal sediments from non-hydrothermal sediments (Marchig et al., 1982). The total REE contents of the siliceous rocks vary from 3.575 to 11.347 $\times10^{-6}$ (Table 4-2). LREE/HREE >1, the values of Eu anomaly (Eu/Eu*) and Ce anomaly (Ce/Ce*) vary from 0.365 to 0.630 and from 0.889 to 1.038, respectively. The REE patterns are right-inclined (Fig. 4-7), and a lack of negative Ce anomaly, which usually appears in marine hydrothermal cherts (Bostroem et al., 1979; Bostrom, 1983; Adachi et al., 1986; Yamamoto, 1987), showing these siliceous rocks formed in the continental depositional environment.

Table 4-2 The REE contents of the siliceous rocks from the Shewushan Au deposit (10^{-6})

Sample	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm
HX07	0.7	1.6	0.19	0.9	0.21	0.05	0.28	0.04	0.21	0.04	0.09	0.02
BD05	2.6	5.1	0.55	2	0.33	0.06	0.27	0.03	0.19	0.03	0.08	0.02

Continued:

Yb	Lu	∑REE	LREE	HREE	LREE/HREE	Eu/Eu*	Ce/Ce*	(La/Yb)N	(La/Sm)N	(Gd/Yb)N
0.07	0.02	4.42	3.65	0.77	4.74	0.63	1.038	6.742	2.097	3.228
0.07	0.02	11.35	10.64	0.71	14.986	0.597	0.979	25.041	4.956	3.113

4.3 EMPA on Pyrite and Arsenopyrite

To make certain the occurrence of gold in Shewushan gold deposit, we choose EPMA to detect the elements content in pyrite and arsenopyrite. The chemical compositions were analyzed by electron microprobe analysis (JCXA-733, Japan) with five X-ray wavelength-dispersive spectrometers in the State Key Laboratory of Geological Processes and Mineral Resources, China University of Geosciences. Pyrite and arsenopyrite were analyzed for Au, Ag, Co and Ni at 25 keV accelerating voltage and 10-40 nA beam current, keeping 10s counting times.

Pyrite and arsenopyrite are the most widely distributed minerals in the mine samples selected for electron microprobe analysis seen in Table 4-3, the microscope photo shown in Fig. 4-8.

Table 4-3 EMPA results of pyrite and arsenopyrite from the Shewushan deposit (%)

Samples	Point	Mineral	Au	Co	Ag	Ni	Co/Ni
B2-1	1	Apy	0.113	0.079	-	0.013	
	2		0.118	0.083	0.01	0.024	
	3		0.155	0.085	-	0.013	
	4		0.13	0.088	0.023	0.016	
	5		0.112	0.074	-	0.017	
	6		0.142	0.079	-	0.021	
B11-1-1	1	Apy	0.12	0.098	-	0.052	
	2		0.106	0.101	0.019	0.082	
	3		0.123	0.073	-	0.026	
	4		0.091	0.08	0.029	0.03	
	5		0.123	0.08	0.036	0.044	
	6		0.113	0.082	0.021	0.028	
B39-3	1	Py	0.112	0.076	0.008	0.018	4.22
	2		0.047	0.089	0.035	0.013	6.85
	3		0.125	0.088	0.021	0.014	6.29
	4		0.134	0.065	-	0.014	4.64
	5		0.078	0.068	-	0.01	6.8
	6		0.091	0.064	-	0.026	2.46
B59-5-2	1	Apy	0.107	0.075	-	0.019	
	2		0.101	0.089	0.013	0.031	
	3		0.105	0.085	-	0.025	
	4		0.111	0.067	-	0.026	
	5		0.146	0.1	-	0.095	
	6		0.119	0.08	-	0.018	
BD12	1	Apy	0.085	0.092	0.012	0.025	
	2		0.124	0.063	0.01	0.012	
	3		0.121	0.081	0.004	0.024	
	4		0.104	0.082	-	0.028	

The results show that both pyrite and arsenopyrite are gold-bearing minerals. As we all know, the Co/Ni value in pyrite is the key index to confirm the pyrite genesis. The Co/Ni values range from 2.46 to 6.85, indicating its hydrothermal genesis. To some extent, the Co content in pyrite could indicate the pyrite genesis: the high temperature pyrite with Co content higher than 1000 $\times10^{-6}$, middle temperature pyrite having Co content between 100 $\times10^{-6}$ to 1000 $\times10^{-6}$, while the low temperature pyrite having Co content lower than 100 $\times10^{-6}$.

The Co contents in pyrite range from 640 $\times10^{-6}$ to 890 $\times10^{-6}$ in Shewushan gold deposit, suggesting the pyrite was generated in middle temperature.

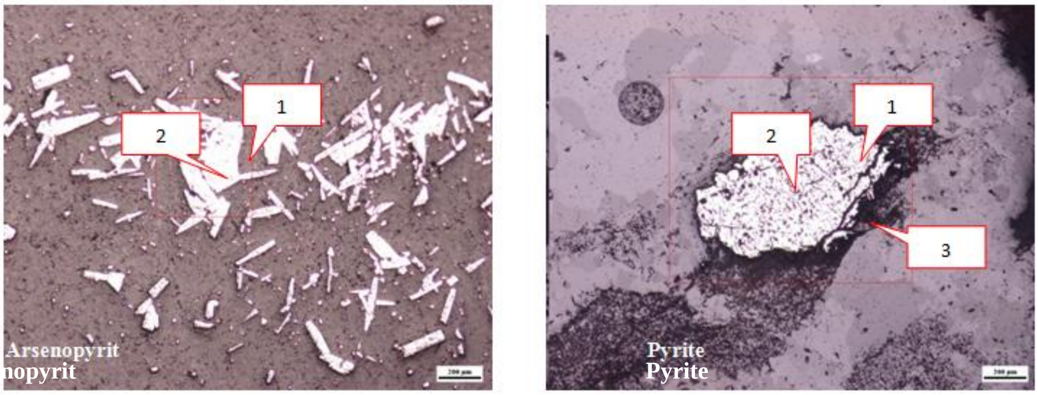

Fig.4-8 The typical map showing electron probe points

V. CONCLUSION

Shewushan gold deposit is a kind of lateritic gold deposit in Jiayu County, Hubei Province, located in Yangtze platform fold belt, southeast edge of Jianghan basin. The ore body is greatly controlled by strata, placed between quaternary red net-like clay and brown clay, in lamellar or lentoid shape. The deposit exists an overturned anticline related with structure, and developed a double thrust structure, in which the crush of original rocks may do efforts to the ore formation.

The ore resources of the deposit mainly contains Au, other elements are in low content. And the deposit has different kinds of wall rock alterations, such as silicification, carbonatation, pyritization, realgar change, orpiment change, barite change, fluoritization etc. Sometimes gold (Au) can exist in pyrite crystal lattice.

The opinions about the ore genesis are different, however, the Carlin-type model show its priority, the model discusses about the genesis of the primary gold deposit and weathering gold deposit, amid expounds the source of ore forming materials, and conditions for the ore forming period, such as physicochemical conditions and low-lying land.

As mentioned above, the genesis of primary ore in Shewushan Au deposit is controversial. However, several points concerning the features, which are pertinent to understand the genesis of the primary ore, can be summarized as follows.Primary mineralization is typified by gold-bearing arsenopyrite and pyrite and hosted by tectonic mélange and crushed clay-rich limestone, which is the typical gold-bearing mineral in carlin type Au deposit.

The geochemistry data of siliceous rock illustrate that it is hydrothermal sediments, which are deposited near fault surface by bearing SiO_2 mineralized fluid migrated deep along the fault.

Primary mineralization was structurally controlled and formed in closely association with the well-developed faults and fractures mainly on the crest of the reverse anticline, which it’s axis is oriented approximately east-west at Shewushan area and is the product of the Indosinian orogeny, which is adhere to the geotectonic setting and metallogenic characteristics of carlin Au type in China (Liu, 1994). Besides, the widely developed silicification, argillaceous alteration and pervasive limonitization, mild pyritization and realgarization are the typical alteration of carlin Au type.

The fluid inclusions are significantly small in size within the minerals. The homogenization temperature ranges from 110 ℃ to 290 ℃. The salinity varies from 2.2 % to 9.34 % w (NaCl, equivalent). The pressure falls in the range of 42 to 46 MPa, which indicate that the gold mineralization took place in low temperature, low pressure and low salinity hydrothermal fluid conditions. Therefore, all the above make sure that the genesis of primary ore in Shewushan Au deposit is carlin type.

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