Research Journal of Applied Sciences 3 (3): 206-215, 2008
ISSN: 1815-932X

Geology, Petrography and Structural Characteristics of Zaozigou Gold Deposit

[1,2]Mohamed Lamine Salifou Sanogo, [1,2]Lv Xinbiao, [1,2]Ciao Xiaofeng and [1,2]He Muchang
[1]Faculty of Earth Resources, China University of Geosciences, Wuhan 430074, China
[2]State Key Laboratory of Geological Processes and Mineral Resources,
China University of Geosciences, Wuhan 430074, China

Abstract: The Gold deposit of Zaozigou is hosted mainly in limestone, siltstone, argillite, shale and where igneous rocks locally appear and host also some gold. Laboratory analysis and geological map interpretation had shown that the orebodies are also located in sedimentary rocks as is in igneous rocks and the contact between these 2 types of rocks. They are found principally in high or low angle normal or reverse fault and mostly in brecciated sedimentary rocks. Through laboratory analysis the principal characteristic of the ore deposit is the presence of uranium which differentiates it from some important carlin deposits such as that of Nevada, USA. The alteration present consists mainly of silicification, argillization, carbonization and decalcification, but also chloritization, sulfidation and ferritization at different intensity. The presence of important quantity of rutile in almost all part of the deposit which occurred during the hydrothermal event suggested a magmatic contribution in the ore forming fluid.

Key words: Host rock, fault, breccia, alteration, gold, carlin deposit

INTRODUCTION

The Zaozigou Carlin Gold deposit is situated 11 km from Hezuo and 300 km from Lanzhou in the south-eastern part of Gansu province. The mining area is located in the West Qinling fault belt.

Figure 1 represents the Gold deposit of Zaozigou is hosted mainly in limestone, siltstone, argillite, shale and where igneous rocks locally appear and host also some gold. Orebodies are distributed at an altitude of 3,180-3,385 m and depth of 40-120 m.

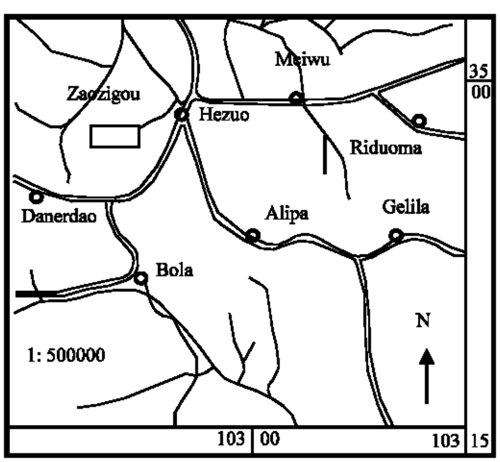


Fig. 1: Geographic situation of Zaozigou

Since 1997 till date, 48 orebodies were identified in an area of 3.6 km^2 for Gold (Au) and 4.8 km^2 for Stibnite (Sb), using geological mapping, soil geochemistry, drilling and trenching. The Au_1, Au_9, Au_{14}, Au_{15}, Au_{26}, Au_{29} and Au_{31} are the main orebodies with an up to date ore reserve estimated to be 14.7t with an average of 2.00×10^{-6}wt% to 12.00×10^{-6}wt% Au.

In an effort to understand the characteristics of the deposit, field work and laboratory petrography were carried out to elucidate the mineralization and alteration. There are no published works on this deposit. But in general, Chinese sedimentary rock-hosted Gold deposits are well documented in Chinese literatures and some journals in English.

MATERIALS AND METHODS

To achieve this research, field investigation in early July, 2007 and laboratory work at the State Key Laboratory of Geological Processes and Mineral Resource (CUG) was carried out. The field work was based on open pit and underground sampling, geological structures and lithological measure and description, in addition rock type description using hand specimens. During this research more than hundred samples were taken in which 50 were used to produce Polish and thin sections for laboratory observations. To determine different mineral association,

Corresponding Author: Mohamed Lamine Salifou Sanogo, China University of Geosciences, 430074, Wuhan, China

texture and alteration, optical examination were done using transmitted and reflected light microscope and Raman Spectrometer was used in addition to identification and confirmation of unknown minerals with a detection limit up to 2 μm

RESULTS

Most of Chinese sedimentary rock-hosted gold deposits are hosted in marine carbonate and clastic-rich sedimentary rocks and locally interbedded volcanic rock or tuff (Li and Peters, 1998).

The Zaozigou Gold deposit is located in the north of Qinling belt and centre zone of west Qinling fold (Fig. 2). In the north, the Devonian-Carboniferous constitute the formations, whereas, in the west part a fault rift is filled by the Triassic in it centre, constituted by large thickness of flysch. In the ore deposit area, it was recognized that magmatic rocks are not relatively developed extensively, however all along the ore deposit and in the mining zone intrusive rock dikes constitute an important part of the different rocks present.

Sedimentary rocks: Are characterized by the Quaternary rocks composed of flood flush gravel bed, lacustrine sandy soil, clay, accumulation of loess in terrace, humus layer and silts, with presence of coal.

The Triassic in which the main mineralization occurred is principally silt-slate, slate, argillite, conglomerates and sandstone. The limestone contains gravel and siderite with oolith, phosphorous nodule and coal. The Medium Triassic is characterized by calcareous, silty argillaceous and fine clastic slate rocks. Whereas Lower Triassic, characterized by grayish brown to grayish blue and thin to thick lithic arkose with dark gray to grayish blue silt slate. In the district this Triassic is relatively thick (3000-5000 m) striking NS and sequences distribution from the lower to the upper is EW.

Magmatic rock: Various dikes are well developed accompanying early Yanshan (Late Mesozoic to Early Tertiary) intrusive rocks. These acidic dikes are mainly, NE, NW, near WE and near NS and had undergone some fracturation. Gold ore related magmatic rocks are mainly formed dikes groups of NW-direction. These groups of dikes are often extremely mature and lithologically characterized by fine grain diorite, diorite-porphyritic, biotite diorite-porphyritic, quartz diorite-porphyritic, granodiorite-porphyry, plagio-granite-porphyritic. These dikes are mainly NNE and represent different intrusive filling pulsation at different times slowly invading fault zones.

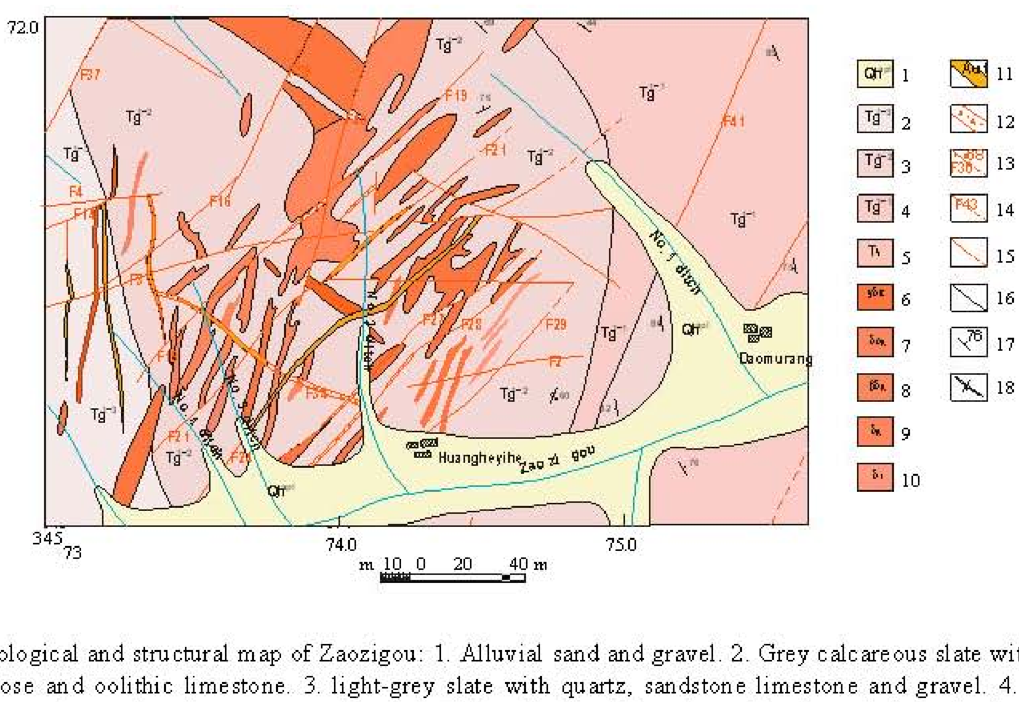


Fig. 2: Geological and structural map of Zaozigou: 1. Alluvial sand and gravel. 2. Grey calcareous slate with siltstone, arkose and oolithic limestone. 3. light-grey slate with quartz, sandstone limestone and gravel. 4. Dark grey siltstone slate, arkose limestone, sandstone. 5. Thick debris and fine arkose, fine slate. 6. Granodiorite porphyrite. 7. Quartz diorite porphyrite. 8. Biotite diorite porphyrite. 9. Diorite porphyrite. 10. Fine grained diorite 11Orebodies. 12. Fault zone. 13. Reverse faults. 14. Speculated faults. 15. Geological boundaries. 16. Lithofacies boundaries. 16. Attitudes of stratum. 17. Anticlinal axis

Metamorphic rock: Low grade metamorphic rocks, such as spotted phyllite, slate and crystalline limestone-from carbonate and clastic sedimentary protolith-host some deposits. Regional metamorphism, contact metamorphism and the hydrothermal alteration were the main activities in the area (Peters, 2002).

MINERALIZATION

In Chinese sedimentary rock-hosted gold deposits, at least fifty minerals have been identified, these mineral associations (pyrite, arsenopyrite, Stibnite, realgar, orpiment quartz, barite, calcite and illite-clay minerals) are similar to those present in the gold deposit of Nevada, USA (Li and Peters, 1998). Although, in Nevada, it is not all deposits that have the same mineral association with those in China, because there are differences in host rocks. Hence, just some of these are present in Zaozigou at considerable amount or has important associations principally pyrite, arsenopyrite, Stibnite, rutile and sphalerite, whereas gangue minerals are sericite, hydromica, kaolinite, quartz and calcite.

Pyrite: Is associated with ore and gangue mineral, the pyrite present at Zaozigou gold deposit is in various habits and it appears often as disseminated or in vein. At least five generations of pyrite were determined on hand specimen characterizing by 4 types under microscope analysis. Pyrite I (Fig. 3A) or diagenetic is a mass of ore lens like pyrite always associated with arsenopyrite. With normal microscope it resembles more of a mass of powder in the gangue mineral. The pyrite II (Fig. 3B) is disseminated in the gangue as euhedral to subhedral; they are rounded shape to subautomoph and rims. They are cubic, spheroidal aggregate or blade like, associated to arsenopyrite which sometimes indicates some intergrowth structure and overgrowth quartz is present. It often shows important inclusions or spot of manganite and some association to the Sphalerite. In some of these pyrites we observed some inclusions of pyrrhotite. The same pyrite II associated with arsenopyrite displays locally a graded bedding structure and under microscopic analysis the dark thin beds are with more ore than the clear beds. This pyrite-arsenopyrite association is sometimes corroded and gone through a deformation process. Pyrite III (Fig. 3D) is euhedral to subhedral, associated to arsenopyrite, marcasite or sphalerite. The pyrite appears in quartz veins or calcite and is often cracked, but also with good polish. Pyrite grains of this type have both cubic and pyritohedral habits but also show arsenic-rich overgrowth fabrics, but, also with rim that we observed are at cross polarization. This Pyrite III was formed as a result of hydrothermal processes (Gu *et al*., 2002). Pyrite IV is supergene, bad polish and cataclasic round to elongate shape and they are also present as dendritic or atoll texture. The pyrite is sometimes pseudomorphozed by limonite.

Arsenopyrite: The most abundant sulfide at Zaozigou is usually associated to pyrite, they are rhombic to needle like or in star like, disseminated in the gangue (Fig. 3C-G) and they are found also in quartz or calcite veins accompanied by pyrite, sphalerite and marcasite. Arsenopyrite is not linked to just one generation of quartz or calcite, but mostly all type of quartz are accompanied with it but at different degree and are sometime also cracked. The arsenopyrite is star like or acicular in gangue and appears in vein open fracture filling as skeletal of micro rhombic crystals to needle like; it seems also to appear in powdery from and where associated to framboidal pyrite and is mostly accompanied by some grain of small bud of arsenopyrite on it surface. The manganite is highly developed as inclusions in rhombic arsenopyrite more than that of pyrite.

Stibnite: Stibnite is massive but not present in all samples, they are mostly found in places which are accompanied by fracturation and under microscope or even macroscopically they crosscut veins or veinlets of quartz or calcite (Fig. 3H) but also appears surrounding some subautomoph quartz. The Stibnite occurs as laminae, sometime associated to pyrite or arsenopyrite, but also appears in networks of veins and veinlets (stockwork). The Stibnite shows some deformation structure Fig. 3I), some undulating extinction through translations was visualized during microscopic analysis indicating tectonic influence, probably post-crystalline deformation, or even some grains totally deformed due to tectonic processes. However, some micro grains of Stibnite are present and these remain intact. They are suspected of being post-deformational recrystallites due to selective mimetic crystallization of Stibnite by Stibnite probably without chemical changes of major mineral and major element composition (Gu *et al*., 2002).

The Stibnite is abundant in quartz and calcite veins and they have most of the time some inclusions of arsenopyrite crystals or pyrite. The Stibnite in these veins and veinlet often observed with round cracked pyrite which they replaced. It represents one of the most important ore mineral in Zaozigou deposit.

Sphalerite: The only base metal that is easily determined in the deposit, the sphalerite, is present in isolation and sometimes replaces the arsenopyrite (Fig. 3J). It appears

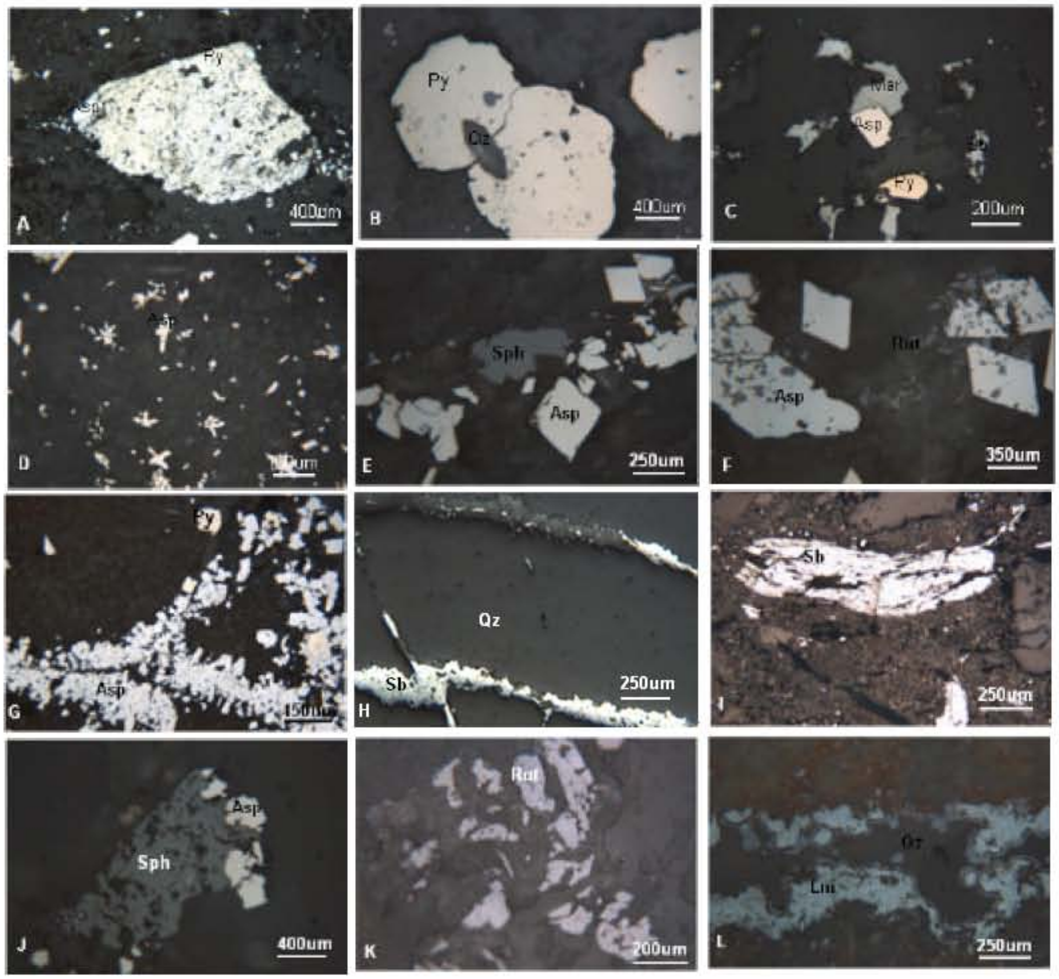


Fig. 3: Photomicrographs of ore fabric at Zaozigou Gold deposit polish sections (/ / nicols. (A) A lens of pyrite in association with arsenopyrite. (B) Rounded pyrite with rim and later crystal of quartz automorph and inclusion of manganite (C) Association of pyrite, arsenopyrite and marcasite. (D) Disseminated star like arsenopyrite with pyrite. (E) Quartz veinlet fills with rhombic arsenopyrite, pyrite and sphalerite. (F) Rhombic arsenopyrite in gangue with inclusion of manganite and spot of manganite in the gangue. (G) Quartz veinlet with skeletal arsenopyrite and pyrite. (H) Quartz veinlet filling Stibnite. (I) Deformed Stibnite in quartz crystal as gangue. (J) Sphalerite replacing arsenopyrite. (K) Grain of Rutile in the alterated zone. (L) Limonite forming along fracture filling silica

with some inclusions of pyrite and is shown in irregular form in bad polish. In quartz veins where mostly arsenopyrite and pyrites are found, they are present in good polish. In fracture quartz filling with minor pyrite/arsenopyrite, the sphalerite occurs associated with galena too. However, their paragenesis is difficult to establish, although it seems that the galena tends to replace the sphalerite, where both of them have irregular shape.

Rutile: Abundant at Zaozigou, showed as blade, shape as needle but abundantly present as patches on the matrix, these spots seem to be relic like. The rutile (Fig. 3K)is disseminated almost in all the samples as well as in the slate as in the granodiorite and most of the time associated with pyrite or arsenopyrite, but mainly as free mineral but very few or even inexistence where Stibnite is more abundant. The rutile is mostly observed in orebody (Au_{14}) enclosed in slate rocks associated to the granodiorite, the mineralization is abundant in form of fractured lenses and brecciated and is found in the hanging wall (slate, diorite) with a footwall (slate) strongly fractured. In Betze deposit rutile and other Ti-rich ore in the carlin trend are thought to be derived from detrital components in the host sedimentary rocks (Peters *et al.*, 1997).

HYDROTHERMAL ALTERATION

Hydrothermal alterations mainly appear at the later period of the fractured zone. These alterations are not constant, so they are different from orebody to orebody. Hence, mine workers have recognized many types of alterations at different degree of intensity.

The main types of alterations present at Zaozigou are silicification, argillization and carbonization and decalcification.

Silicification: Silicification is neutralization of acidic silica-rich solution by carbonate, which is accompanied by the precipitation of silica (Asadi *et al*., 2000). The most developed alteration at Zaozigou is represented by cryptocrystalline silica and microcrystalline japeroid, druzy quartz are present with sulfide mineral (Fig. 4A). Peters *et al*. (1998) recognized a middle stage ore formation stockwork veining as a silicification in many Chinese deposits and is shown in the deposit at high intensity accompanied dominantly by pyrite, arsenopyrite Stibnite, minor marcasite and sphalerite. In Zaozigou 2 veins type of quartz are recognized, the first one is quartz mineralized, microscopically they crosscut some thin beds limestone and siltstone, composed of dark siliceous band and clear bands where the silica content is very low. The second type was recognized macroscopically, it is coarse milky grains of quartz and they are also saccharroide and occur in vein of some centimeter to 1m long and 10 cm width at the outcrop. This type of quartz is unmineralized and accompanied by an oxidation in the alteration zone. At microscopic scale this type of vein crosscut the mineralized veins in the slate (Fig. 4B).

In the diorite the silica in veinlets are grained (1-5 mm). The early quartz is rounded to oval shape, they are quartz porphyry, which show some very large crystals but also somewhere they happen to be very fine grains. It also showed under microscope some melting structures which sometimes have some inclusions of mineralization. The quartz is replaced by the biotite which is crosscut by unmineralized quartz veinlets (Fig. 4D).

Argillization: The processes of sericitization, kaolinitization, illitization and alunitization is termed as Argillization (Li and Peters, 1998), for example in Zaozigou, seritization is represented by the feldspars which are sometimes largely replaced by fine grained sericite, the plagioclases and at their boundary form a rim with relic of mica (sericite) replacing the silica Fig. 4E, F). and location.

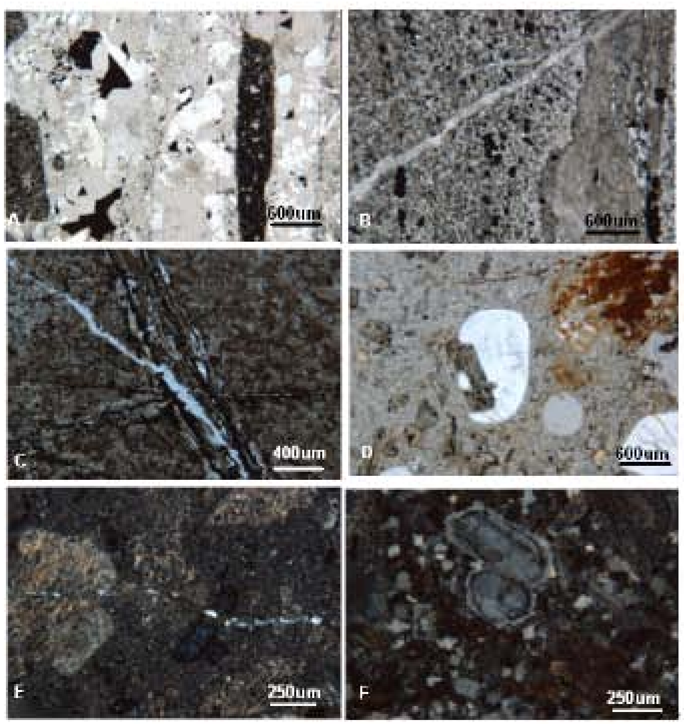


Fig. 4: Photomicrographs of thin section showing (A) Vugs and druzy quartz (/ / nicols). (B) Sulfure minerals in the slate and calcite (/ / nicols). (C) Rounded crystal of quartz replaced by biotite (/ / nicols). (D) Anatomozed quartz veinlet and Fe-oxide in the slate (/ / nicols). (E) Feldspar alteration into fine grains serite, alterated biotite crosscut by later quartz veinlet (× nicols). (F) Zoned feldspar, serite and quartz crystals (× nicols)

The weak regional metamorphism that affected the rock has probably played a role in the production of newborn sericite mineral in the argillaceous rocks and epidotization which is slightly present in the siliceous slate. Plagioclases are zoned probably due to the change from high temperature origin to low temperature at shallow level (normal zoning) and also showed some oscillatory zoning characterizing the same difference of temperature

Alteration of host rock rich in feldspar and argillaceous components by epithermal or shallow surface acidic fluid drive to argillization (Bakken and Einaudi, 1986), most of all the presence of the granodiorite and it input could explain the process that undergone. Reported as a maker for gold exploration in many Chinese Sediment hosted gold deposits argillization often convert the host rock to a pale color and is recognized as being common alteration type (Li and Peters, 1998).

Carbonization: Graphite and Uranium (pitchblende) were recognized by laser Raman spectrometer with minor coal. Their presence is typical in Chinese sediment hosted gold deposit. At Zaozigou this type of alteration is present in zone of dikes which have been fractured with micro open space filling unmineralized calcite voids.

Decalcification: Decalcification known as partial replacement of carbonate by calcite (Asadi *et al*., 2000) is present in the deposit principally in calcite filling fractures. Although not extended in the deposit it could have a meaning in the occurrence of gold. Deposits such as Jinlongshan and Gaolong have shown its spatial relationship with Gold mineralization and that siliceous and gold mineralization may have occurred simultaneously when ore forming fluid enriched in silica and Gold circulated through porous and decalcified host rock (Li and Peters, 1998).

Alterations such as, chloritization, sulfidation, ferritization have been recognized by workers. The oxidation of pyrite and other ferruginous sulfides is due to air and fluid penetration causing oxidation and acid leaching along fracture and faults caused additional porosity and opened pathways for air penetration (Asadi *et al*., 2000).

PARAGENETIC SEQUENCE

Field observations and microscopic analyses were used to establish the relationships between mineralization, the host rock and alteration minerals. There is evidence of three important stages: the primary ores were formed during crystallization-recrystallization or phase of remobilization; hydrothermal event in two stages that provided minerals formed by recrystallization (continuous) due to continuous fluid or episodic circulation into the host rock, alteration minerals such as rutile start appearing during the last stage of this hydrothermal phase; and the third stage form minerals resulting from weathering. Table 1 shows the paragenitic sequence of mineral assemblage in Zaozigou.

However, some minor minerals such as chalcocite, uranium and manganite, graphite were confirmed by Raman spectrometer, but also a presence of cinnabar in small quantity were confirmed (Fig. 5 and 6).

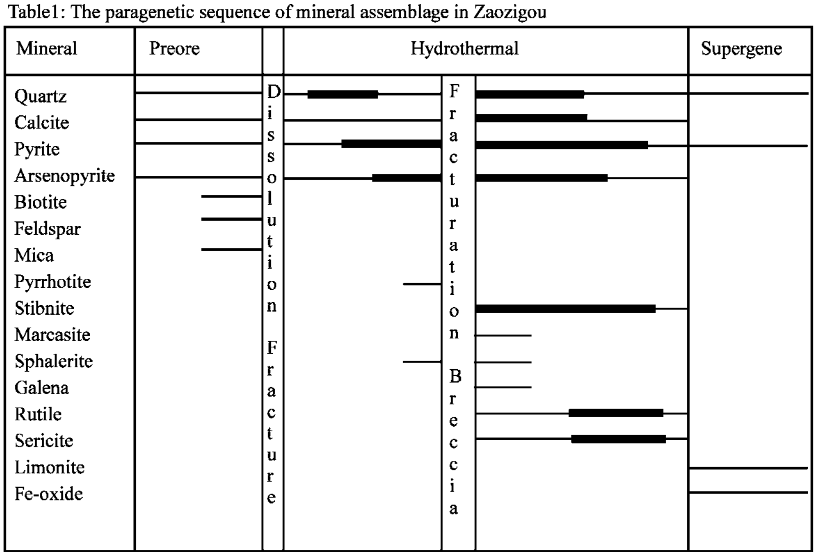
Preore: This phase was characterized by the occurrence in the sedimentary rocks of rounded to oval quartz and calcite. The large crystals of these types suggested a continuous maturation during the fluid circulation. In the intrusive, the quartz is also rounded molted replaced by biotite and feldspars. The diagenetic pyrite (pyrite I) are framboidal, or disseminated euhedral pyrite to subhedral grains associated to arsenopyrite; they also occur along bedding. However, in Getchell the preore mineralization contain quartz veins with minor disseminated pyrite, trace sphalerite, chalcopyrite, galena and arsenopyrite and also at Zarshuran, containing quartz, sericite, illite, kaolinite, pyrite and pyrrhotite (Asadi *et al*., 2000); gold was not observed in these documented deposits at this event.

Arehart (1996) considers the preore event as the result of recrystallization and remobilization of preexisting minerals, such as quartz-jasperoid, calcite and pyrite. During this event the amount of fluid were probably consistent to prepare the rock (dissolution) for future hydrothermal event.

Hydrothermal: This phase was marked by a continuous recrystallization of sulfide and sulfosalts (probably) minerals. We were able to characterize the first fracturation of the host rock which allowed quartz II, pyrite II, Arsenopyrite II and manganite to occur and in the very late of this event Stibnite, pyrite III/arsenopyrite, marcasite sphalerite, galena and rutile.

According to Arehart *et al*. (1993), gold is closely associated to arsenian pyrite hydrothermally generated from pyrite and arsenopyrite. At Zaozigou, gold started been introduced probably at the end of the first fracturation. The second fracturation comprises of Quartz II, calcite, pyrite III/arsenopyrite and later minerals of the first fracturation. Sulfide minerals are remarkably precipitated during this stage. Feldspars alteration (sericite) was introduced and replaced the silica. Quartz is abundant than calcite in open space filling which are tectonic (faulting) events generated and indicated by the

Table1: The paragenetic sequence of mineral assemblage in Zaozigou



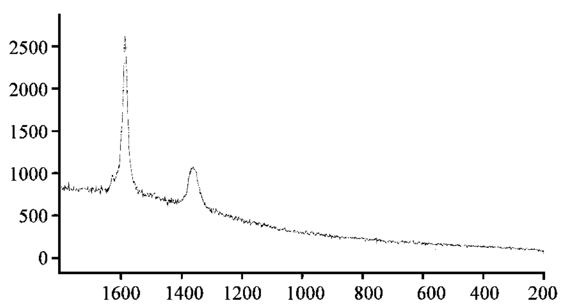


Fig. 5a: Raman spectra of chalcocite mineral

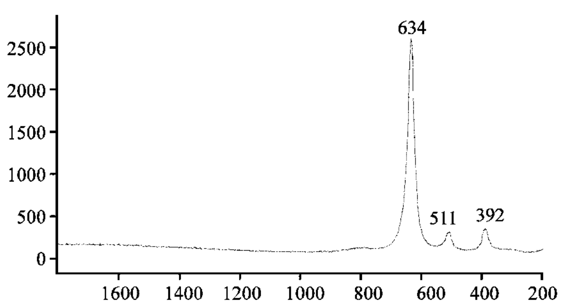


Fig. 5b: Raman spectra of manganite mineral

occurrence of small vugs and fine euhedral quartz crystals and iron sulfide minerals. The vugs and drusy quartz are also response to limestone dissolution and silica deposition but they do not occur simultaneous. They predated Stibnite open space filling or network.

The abundant rutiles present were introduced by a later intrusive rock due probably to continuous faulting and multi-stage intrusive event and also introduction of feldspars alteration (sericite) which sometimes replaced the silica.

Supergene: It is marked by oxidized pyrite (pyrite IV) often crack in bits, cataclasic or present as dendritic or atoll. This pyrite is also pseudomorphozed by limonite. The limonite occurs also along both sides of veinlets present. The colorful (brown-red) of the host rock suggested a presence of Fe-oxides minerals.

STRUCTURAL CHARACTERISTICS

The mining area has non regional faults, but at local scale the faults present are extremely concentrated, they have multi-impulsion and intersected joints associated with faults. Ore-fluids use this area of multiple structural episodes to circulate in high complex and porosity event where they may predate the main mineralization (Peters, 2001). The more intense pressure, compression and tension that the deposit was subjected to allowed the ore fluid to circulate and precipitate. The occurrence of quartz veins and calcite is caused by the strong fracturation and cleavages are well developed.

The structural geology of the mining area is characterized by 5 fault sets the EW, NW, NS, NNE and NE. Zaozigou gold mineralized zone are strictly controlled by the NE, NW, NS 3 groups of faults, where gold mineralization was produced in the slate, alterated diorite-porphyritic or contact between alterated diorite-porphyritic and slate. Orebodies are found across low to high angle normal or reverse faults (Fig. 6A and B) which postdate most of the dikes present, although some of them were favored by faults opening as a path to intrude.

The deposit is composed of NS group of faults (F_8-F_{13}) which controls the orebodies Au_{26}, Au_{29}, Au_{31},

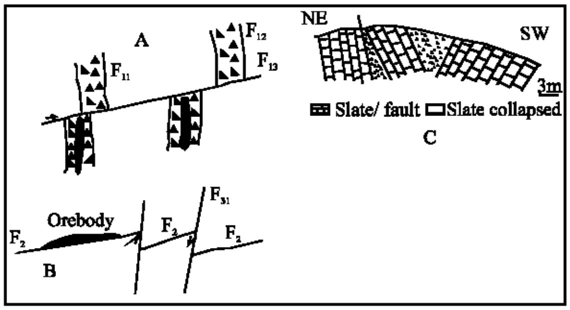


Fig. 6: Schematic structural model developed in the orebodies and in the host rocks at Zaozigou Gold deposit. Model A is a secondary fault (F_{31}) which crosscut two breccia type orebodies within dip angle faults(F_{11}, F_{12}) (not scaled). Model B shows an orebody along the fault (F_2) this fault had undergone to several slipping due to postore faults (not scaled). Model C is the sedimentary rock showing different direction of the beds. This changing direction is marked by faulting and collapsed breccia

Au_{30}, width of 3-22m. It is associated with hydrothermal alteration and strongly mineralized. This set of faults are apparently normal fault, strongly brecciated where collapsed breccia are significant in the wall rock. Peters (2001) associated this type of faults as conduits due to their mixture filling of crushed and breccia wall rock, gouge, phyllonite, clay seams, foliated rock gangue and altered wall rock. These faults are generally characterized by elongated orebodies which occur in the middle of the fault and sometime their terminations appear at the edge. Some of the NE faults (F_{15}, F_{16}, F_{16}, F_{17} and F_{18}), very narrow crosscut this group of faults.

The NE faults (F_{14}-F_{32}): strike 40-60°, width 0.5-10 m, NW dipping and angle bigger than 70° is a pressure-shearing zone strongly mineralized. Orebodies Au_1, Au_9, Au_{15} and Au_{10} are controlled by this group of faults. It is the main ore hosting structure. The orebodies controlled by this group of fault are massive to brecciated, characterized by small pieces of breccia up to 20 cm diameter.

For example, F_{20} strongly brecciated in the intrusive as well as in the slate whereas mineralization is absent in the extreme SE part of the deposit but slightly brecciated and mineralized (Au_{14}) toward the center part. This fault is crosscut by F_{21} also brecciated in which occurs the orebodies Au_9, Au_{43}. The orebodies Au_{24}, the pyrite orebody (Au_{25}) and the pyrite brecciated orebody (Au_{14}) are controlled by two parallel faults (F_{20} and F_{41}) which abruptly change directions at the SW of the deposit. This set of fault is crosscut by several secondary unmineralized anatomozed faults belonging to the NE group. The orebodies occurs as well in the slate as in the contact between the slate and the intrusive; however, only slight part of a mineralized body (Au_{25}) occurs in the intrusive.

At the orebody (Au_9), we observed intercalated beds with dark and gray color with fracturation filled with calcite, here 4 types of joints are observed: 201°89°, 325°70°, 280°84°, the direction of the slate is 25°75°. At the fault "F_{21}" (335°85°), many quartz veins are present, with presence of Stibnite and joints are filled of pyrite." The fault "F_{24}" with around 2.4 m width, the altitude observed at the 2 sides of the fault is: Footwall 334°89°; hanging wall 154°79°. In this area, appear the primary ore and the thickness of the orebody is about 2.43m. It is important to notice that in this fault the ore occurs essentially in the hanging wall. The Au_{15} occurs in the intrusive along the fault F_{25} which is parallel to F_{24} at the contact between the slate and the intrusive containing the orebody Au1 more spaced than the first and narrowed to centre south.

F_{23} is a large fault in the slate with later intrusive mass emplacement favored by the fault splay which occasion the occurrence of orebody Au_{13} in the middle and at the two sides of this intrusive in contact with the slate, orebody Au_3 and Au_8 along the fault the footwall and the hanging wall.

NW faults (F_{33}-F_{36}) are110°-125° striking, with development of ferritization alteration and strongly mineralized orebodies (Au_{14}, Au_{27}) are controlled by this group of faults.

The NNE faults (F_{37}-F_{43}) strike 25°-30°, mainly the early breaks are weakly mineralized and the faults zone with uniform spacing and massive to slightly brecciated, where the length is limited by the F_{18} in the centre of the deposit and the intrusive at the SE. The lithology in the Eastern part changes direction abruptly to EW due to post ore fault, with normal slip. However the group EW faults (F_1-F_7): striking 80°-85°, width of 1-100 m and with intense shearing, are generally ante breccia and predate the ore faults and the group NNE faults, which imply that these faults did not play an important role in the occurrence of the ore, but did probably play a role in the formation of secondary faults which contain ore and where the ore fluid circulated.

DISCUSSION

Carlin deposits from China and United States are the 2 major potential reserves of sediment hosted disseminated gold deposits known in the world have been described by Mao *et al.* (2001), Peters (2002), Bakken and Einaudi (1986) and Arehart *et al.* (1993).

A comparative petrographical study of Zaozigou to those of Nevada, USA and other carlin type mineralization in the Qinling belt and Zarshuran (Iran), but also structural analysis and ore analysis interpretation reveal much common resemblance.

Disseminated mineralization, high quantity of pyrite and arsenopyrite and the occurrence of Stibnite in open space filling or presence of deformed and crystalline Stibnite and it presence as stockwork, principally in ductile brittle areas similar to those described in Sichuan by Gu *et al.* (2002) and other carlin deposits by Bakken *et al.* (1989). Arehart *et al.* (1993) suggested a submicrometre-size at carlin deposit. In Zaozigou, Raman Spectrometer analysis up to 2 μm was not able to observe gold mineral during our work; however, workers had notified the presence of gold as dispersed colloidal and in mineral crystal lattices. Most of the textures existing in Zaozigou are similar to those described in Jinlonshan deposit (East Qinling) by Peters (2002) and are considered to be compatible to epigenetic and superimposed orogenic processes. The gold type described in Jinlonshan is superfine micro-sphere or chains (0.375-0.08 μm-sized).

Fine to large bedded sedimentary rocks changing direction which is marked by collapse of breccia and dip angle fault that affected host rocks as well as orebodies are characteristics of many carlin type deposits (Fig. 6C). Emsbo *et al.* (1999) considers this abrupt facies changes in the host rocks as synsedimentary faulting and Peters (2002) noted that abrupt ore grade contacts are present where brittle fractures control the gold ore and ductile fractures controlled much more gradational contact. These faults are brecciated pervasive and acted as reactivation engine to some subordinate faults intensively brecciated acted as permeable zones where mineralization are found. Some of the fluids moved laterally and silicified the breccia of the permeable debris flow unit. However, Jerritt canyon deposit are found in beds along low-angle normal and reverse faults east-west-northeast and high angle fault trending northwest and especially in structural intersections associated to scattered dikes which were presented but do not have any link to the mineralization (Hofstar, 1991).

The Au, Ag, As, Sb, Hg in the ores (rocks) of the deposits are much higher than their average value in the regional rocks and the Clark value of the crust; while Cu, Pb, Zn and other base-metals are lower in the deposits than their Clark value in regional and the crust. In Zaozigou Gold ore contains 0.85% S, 0.236% Sb and 1.10% As; indicating low sulfur, high arsenic, high Stibnite and high carbon (C_{total} 1.66%, $C_{organic}$ 1.26%) argillaceous gold ore type. However, As, Sb, did not reach an economic value in this deposit; they are believed to have a tie relationship with Au during mineralization events and even at the origin or probably their geochemistry (Table 2).

Table 2: Average content of ores chemical analyzes

Elements	Content (%)	Elements	Content (%)	Elements	Content (%)
Cu	0.007	Fe	6.32	S	0.85
Pb	0.0004	Hg	0.322	Ctotal	1.66
Zn	0.01	Sb	0.236	$C_{organic}$	1.26
Au	9.8×10^{-6}	As	1.1		

CONCLUSION

Petrography, structural analysis, ore chemical analysis demonstrated that Zaozigou gold deposit is similar to Carlin type deposit with high organic carbon. Although the absence of some typical carlin type minerals such as orpiment and realgar during our study open a real debate about the deposit. On the other hand we found minerals such as arsenopyrite, pyrite pyrrhotite, sphalerite and galena suggesting high temperature enrichment which is not coherent with most sedimentary hosted deposits. In addition the proximity of many magmatic intrusions and their role in the mineral emplacement encourage a possible suggestion other than that of sediment hosted Au deposit.

ACKNOWLEDGEMENT

We would like to thank the State Key Laboratory of Geological Processes and Mineral Resources (China University of Geosciences) for providing the facilities in the current research and the grant (GPMR200614) offer.

All our respect to Li Jianwei for his patience and long discussions that we had during this work. We would also like to thank David Orodu, Douty Chibamba and Catherine Masiclat for there assistance in the preparation of this manuscript. This work would not be accomplished without the help of Zaozigou Mine workers.

REFERENCES

Asadi, H.H., J.H.L. Voncken, R.A. Kuehnel and M. Hale, 2000. Petrography, mineralogy and geochemistry of the Zarshuran Carlin-like Gold deposit, Northwest Iran. Mineralium Deposita, 35 (7): 656-671.

Arehart, G.B., S.L. Chryssoulis and S.E. Kesler, 1993. Gold and arsenic in iron sulfides from sediment-hosted disseminated Gold deposits: Implications for depositional processes. Econ. Geol., 88: 171-185.

Arehart, G.B., 1996. Characteristics and origin of sediment-hosted Gold deposits: A review. Ore Geol. Rev., 11: 383-403.

Bakken, B.M. and M.T. Einaudi, 1986. Spatial and Temporal Relations Between Wall-Rock and Gold Mineralization, Main Pit, Carlin Gold Mine, Nevada. In: MacDonald, A.J., Gold, Willowdale, Ontario. Konsult International Inc., pp: 388-403.

Bakken, B.M., M.F. Hochella, A.F. Marshall and A.M. Turner, 1989. High-resolution microscopy of Gold in unoxidized ore from the Carlin mine, Nevada. Econ. Geol.,. 84: 171-179.

Bakken, B.M., R.H. Fleming and M.F., Hochella, 1991. High-Resolution Microscopy of Auriferous Pyrite from the Post Deposit, Carlin district, Nevada. In: Process Mineralogy XI Characterization of metallurgical and recyclable products. In: Hausen, D.M. and J.S. Cline, 2001. Timing of Gold and arsenic sulfide mineral deposition at the Getchell Carlin-type Gold deposit, north-central Nevada. Econ. Geol., 96: 75-90.

Emsbo, P., R.W. Hutchinson, A.H. Hofstra, J.A. Volk, K.H. Bettles, G.J. Baschuk and C.A. Johnson, 1999. Syngenetic Au on the Carlin trend: Implications for Carlin-type deposits. Geology, 27: 59-62.

Gu, X.X, J.M. Liub, O. Schulzc, F. Vavtarc and M.H. Zheng, 2002. Syngenetic origin for the sediment-hosted disseminated Golddeposits in NW Sichuan, China. Ore fabric evidence. Ore Geol. Rev., 22: 91-116.

Hofstra, A.H., J.S. Leventhal, H.R. Northrop, G.P. Landis, R.O. Rye, D.J. Birak and A.R. Dahl, 1991. Genesis of sediment-hosted disseminated-Gold deposits by fluid mixing and sulfidization: Chemical-reaction-path modeling of ore-depositional processes documented in the Jerritt Canyon district. Nevada Geol., 19: 36-40.

Li, Z. and S.G. Peters, 1998. Comparative Geology and Geochemistry of Sedimentary-Rock-hosted (Carlin-type) Gold deposits in the People's Republic of China and in Nevada, USA. U.S. Geological Survey Open-File Report 98-466.

Mao, J., Q. Yumin, R. Goldfarb, Z. Zhang and S. Garwin, 2002. Geology, distribution and classification of Gold deposits in the western Qinling belt, central China. Mineralium Deposita, 37: 352-377.

Peters, S.G., R.W. Leonardson, G.C. Ferdock and E.A. Lauha, 1997. Breccia Types in the Betze Orebody, Goldstrike Mine, Eureka County, Nevada. In: Vikre, Peter, T.B. Thompson, K. Bettles, Christensen, Odin and R. Parratt (Eds.). Carlin-type Gold Deposits Field Conference: Society Economic Geology Guidebook Series, 28: 87-100.

Peters, S.G., G.C. Ferdock, M.B. Woitsekhowskaya, R. Leonardson and Rahn, J., 1998. Oreshoot zoning in the Carlin-type Betze orebody, Goldstrike mine, Eureka County, Nevada: U.S. Geological Survey Open-File Report 98-620, pp: 49.

Peters, S.G., 2002. Geology, geochemistry and geophysics of sedimentary-hosted Au deposits in P.R. China. U.S. Geological Survey Open-File Report: 02-131. Version 1.0, htt://geopubs.wr.usgs.gov/open-file//of 02-131/OF02-131.

Peters, S.G., 2001. Use of structural geology in exploration for and mining of sedimentary rock-hosted Au deposits US Geological Survey version 1.0. http://geopubs.wr.usgs.gov/open-file/of01-151.