Macro appearance and micro evidence of geochemical anomalies using geogas prospecting for concealed gold deposit

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Abstract

Shenjiayao altered crushed belt gold deposit is located in the outside of the Xiaoqinling gold orefield--the second productive area following the Jiaodong gold orefield in China. Most of the ore district is coverd by Quaternary sediments. Observations and analyses using polarization microscope and scanning electronic microscope(TEM) and electronic probe micro analyse(EPMA) of ores indicate that the primary gold-bearing minerals in this deposit are natural gold and electrum. Chemical analyse of five typical ores shows that Au is 12,451ng/g on average and Ag is 330,424ng/g on average. We use geogas prospecting, one mothod of explorational geochemistry, on the known Shenjiaoyao gold deposit for studing its mechanism. In ores samples, Au,W and Sn are significant correlation,and Ag, Pb and Sb show significant correlation. In geogas simples, there are significant correlations between Au and W, Ag and Hg, respectively. Spatial distributions of element like Au, W,etc. show clear geochemical anomalies over the concealed gold orebodies. It can be indicated that these geochemaical anomalies are related with deep orebodies. What is more, Au-bearing nanoparticles and other metallic nanoparticles in the geogas have been observaed, practically supporting the theory that nanoparticle is a stable form of transporting and expressing the geochemical anonalies in geogas prospecting, even in deep-penetrating geochemistry.

Introduction

The geogas prospecting is a branch of deep-penetrating geochemstry, non-traditional explorational geochemstry methods for concealed deposits, which differs from conventional gas measurements because when metal elements are carried and collected by the geogas, metal elements are not in gas phase. The deep-penetrating geochemstry is to use ultrasensitive methods to analyze contents of metal elements transported by the geogas (including nanoparticles, colloids, ions, and metal complexes) from concealed ore bodies to the Earth's surface, and then hierarchical nested patterns should be recognizable(Wang et al., 1997). It is proven effective to explore concealed ore deposits(Cao, 2012; Zhang et al., 2014; Zhang et al., 2015; Zhang et al., 2016; Wang et al., 2006; Ye et al., 2013; Ye et al., 2012; Zhang et al., 2014), but the mechanism needs further study. Most researchers considered that ultrafine metals or metallic elements migrated vertically from the depth to the surface by the ascending geogas flow in the form of being absorbed in micro bubbles, and metallic nanoparticles were discovered(Cao, 2012; Cao, 2011; Cao et al., 2009; Xueqiu et al., 2016). Wang and Ye,2011 observed nanoparticles in the soil at Zhou'an Cu-Ni deposit. To ascertain the mechanism of geogas prospecting, first of all, we collect geogas samples using two kinds of carriers to study macro geochemical anomalous pattern, and then nanoparticles were made for observation and tested by transmission electron microscope (TEM). We studied characteristics of nanoparticles, like the size, shape, composition and structure for abtaining micro evidence.

Method

Four prospecting lines named SJYL1, SJYL2, SJYL3, and SJYL4 separately, were arranged across the known Au ore bodies at the Shenjiayao area in the space of 100m between two lines (Figure 1). From south to north 41 points were sampled in every line in the space of 40m except Line SJYL2 whose first points was abandoned because of unideal nature condition. In total 168 samples (163 normal samples, 3 repeated samples and 2 blanked samples) were collected. At each sampling point, two different mediums—the Polyethylene and 5% ultrapure aqua regia were used to capture elements. The 5% ultrapure aqua regia was prepared in the isotope laboratory of the institute of geology for nuclear industry in Beijing. The polyethylene was washed three times by ultrapure water, then was dried by drier in the geochemical lab of China University of Geoscience (Beijing). Lastly, transfer the polyethylene to the 5% ultrapure aqua regia and soak for at least 24 hours.

All geogas samples were collected in the depth of 60-80cm from the surface over the concealed ore bodies. In the fieldwork, firstly, drill a vertical hole lengthening 60-80cm using a 100cm of steel bar and then put the screwy drill into the hole. Secondly, connect the screwy drill, filter, carrier (polyethylene or 5% ultrapure aqua regia) and air pump in order. Finally, pump two barrels of geogas (1.5L gas per barrel) slowly and uniformly (Figure 2).

The nanoparticle samples were collected like geogas samples except using Ge-grid carrier instead of the capture carrier of polyethylene or 5% ultrapure aqua regia.

The nanoparticle samples were observed and analyzed under a transmission electron microscope (TEM) (model: H9000NAR, Japan) equipped with an X-ray energy dispersive analysis (EDS) which can analyze elements with atom number from 5-boron (B) to 92-uranium (U). The specifications of H9000NAR: point resolution-0.18nm; lattice resolution-0.1nm; the minimum beam spot-0.8nm. For the TEM has no reference materials, the result cannot show the mass percentage content of the particles. During the observation, the beam spot is <0.2μm in diameter.

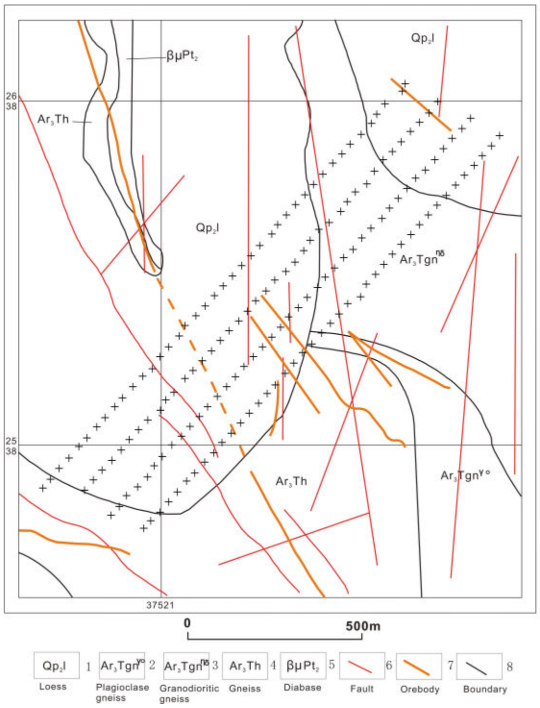

Figure 1 Sampling points and simplified geological-tectonic map in Shenjiayao gold deposit.

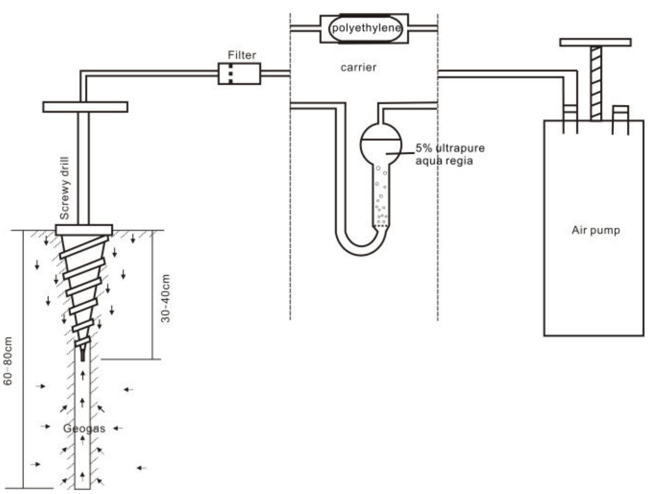

Figure 2 The Equipments and flow chart of collecting the geogas

Results

Spatial distribution

Results of the first geogas prospecting in the Shenjiayao gold deposit is exhibited in Figure 3-5. The W spatial distribution is similar to Au spatial distribution. In the southwestern part of the study area there are significant geochemical anomalies—Au content increasing from outside to inside, which generally reflects the deep ore body in the theory of exploration geochemistry. Several geochemical anomalies occur from southwestern to northeastern part, not as strong as in the southwestern part, but concentration centers are clear in spatial distribution maps. Southwestern Au anomaly is located on the Southwestern side of the gold ore body, not just on the ore body in Figure 3. One reason is probably that the largest 01 bearing gold crushed belt has an inclination of 265°, ore body extending over 1km along the inclination, where the geogas carrying ore-forming and related elements vertically passes through the ore body and then these elements are unloaded on the surface. The other reason is likely that Au is richer in the deep than in the shallow, therefore geochemical anamolies are situated on the vitical projection position—anamolies are on the southwestern side of the orebody in Figure 3. In the middle part of Figure 3, Au anamolies are located on the orebody. There is an Au concentration cneter on the cross between the orebody and fault where geogas can transport easily. In the northeastern part of the Figure 3, Au anamolies are also on the southwestern side of the ore body. Because of the lack of geological information, the auther indicates the reasons resulting in the deflection of the anamolies are similar to those on the southwest, related to the occurrence and enrichment of the ore body. W (Figure 4) shows similar spatial distribution compared with Au. However, Au spatial distribution in the 5% ultrapure aqua regia carrier in the Shenjiayao gold deposit is a little different from it in the polyethylene carrier (Figure 5). It is indicated that 5% ultrapure aqua regia and polyethylene have different capture ability for Au, and polyethylene carrier is more appropriate to apply to explore gold deposit.

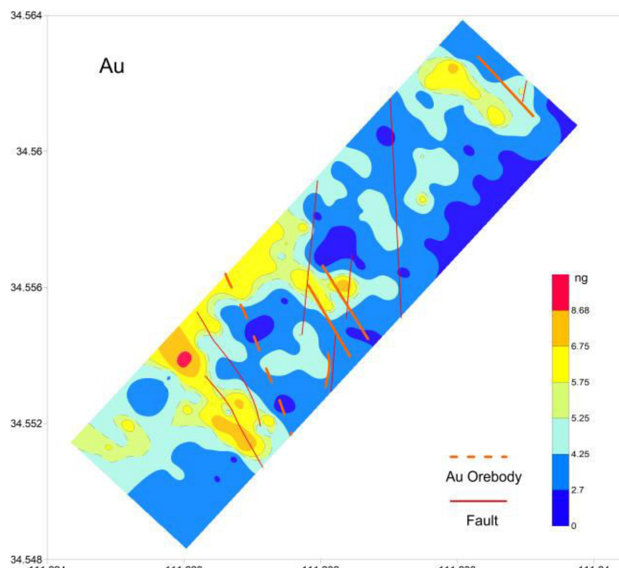

Figure 3 Au spatial distribution chart in the polyethylene carrier in the Shenjiayao gold deposit

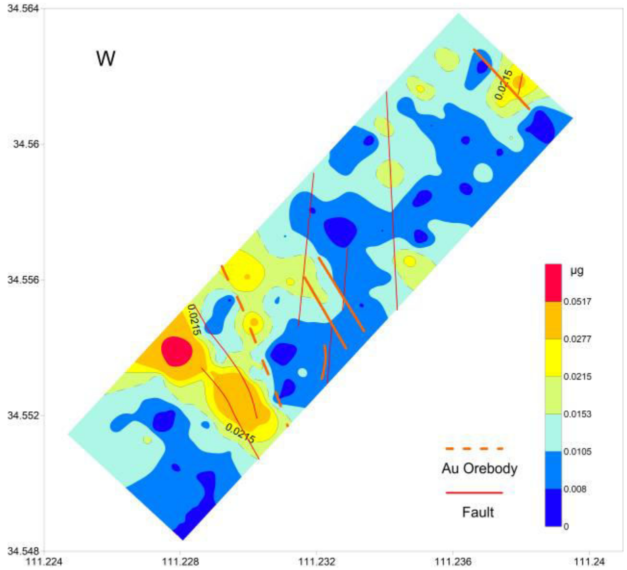

Figure 4 W spatial distribution chart in the polyethylene carrier in the Shenjiayao gold deposit

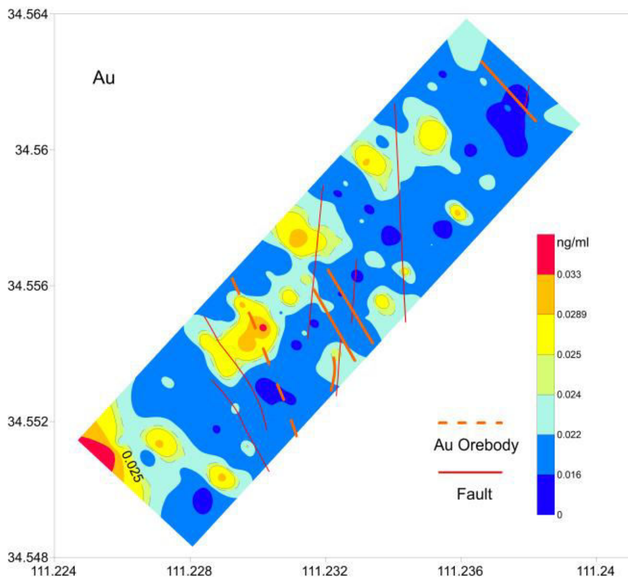

Figure 5 Au spatial distribution chart in the 5% ultrapure aqua regia carrier in the Shenjiayao gold deposit

Nanoparticles in the geogas

Characteristics of nanoparticles in the geogas are listed in Table 1

Single nanoparticle in the geogas at Shenjiayao gold deposit is several to tens of nanometers in diameter. Sphere, granule and polygon are common shapes. Some nanoparticles exhibit separate, and some form an assemblage. Nanoparticles with inner ordered structure are observed in the geogas.Nanoparticles vary in their composition: (1) Native Cu nanoparticles represent the single component ones; (2) Au is the major element with Cu and Pb. There are complex nanoparticles like Cu-Au(Figure 6), Cu-Pb-Au nanoparticles; (3)Nanoparticles include ore-forming elements and Ti.

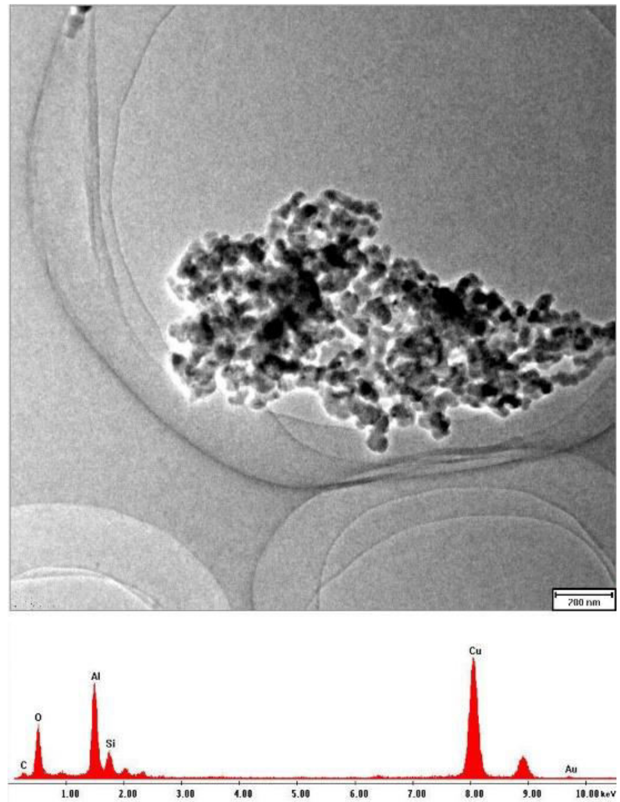

Figure 6 Cu-Au nanoparticles in the geogas in the Shenjiayao gold deposit.

Table 1 The forms and composition of nanoparticles in geogas in the Shenjiayao gold deposit

shape	sphere, ellipsoid, polygon,
size	several to hundreds of nm
Inner structure	ordered structure
composition	Cu-Au、Cu-Pb-Au、Cu、Cu-Ti-Fe-Mo、Cu-Fe、Cu-Fe-Zn-Ti-V、Mn-Fe、Cu-Ti、Fe-Zn
assemblage	single or fascicled sphere, unregularly sphere, mesh granule

Conclusions

Spatical distributions of Ore-forming and related elements can be used to reflect the deep concealed deposit, which are macro appearances of geochemical anomalies using geogas prospecting for concealed gold deposit, while the observed Au-bearing nanoparticles are the micro evidences. Wtat is more, there are significant correclation between Au and W, Ag and Hg no matter in the geogas or in the ores.It can be indicated that elements in the geogas inherit the characteristics of them in ores, which means that the geochemical anamolies in the geogas come from ore bodies. In Shenjiayao gold deposit, Macro appearance and micro evidence of geochemical anamolies using geogas prospecting for concealed gold deposit show that it is effective to apply geogas prospecting to explore gold deposit in loess covered area.

Acknowledgments

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