Alteration, Fluid Inclusions and Isotope Composition of the Xindigou and the Maoduqing Gold Deposits in Daqingshan Mt., Inner Mongolia, China

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Introduction. Gold deposits in Wulashan-Daqingshan area of Innermongolia can be divided into three types (Xu et al., 1999; Hu et al., 2002): (1) the quartz-vein-altered rock type related to ductile shear zones; (2) the altered-quartz vein type within fractured quartz diorites; and (3) the veinlet-disseminated type in carbonate formation of Proterozoic strata. The former two types are actually orogenic gold deposits according to Groves et al.(1998) and Goldfarb et al.(2001). This study is focused on two newly found orogenic gold deposits, the Xindigou and the Moduqing in eastern Daqingshan area, mainly by alteration and fluid inclusions.

Ore Geology. The Xindigou gold deposit, located 70km northeast of Huhuhot, occurs in the Liushugou formation of the Upper Archean Sertungshan Group (Fig.1). The petrology of the Liushugou formation consists of metamorphic basic and acid volcanic rocks, which include chlorite schist, chlorite-sericite-quartz schist and sericite-quartz schist. These rocks had become mylonite and phyllonite. The ore bodies occurs as banded or lenticular which were folded as the strata, striking 330° ~150° and dipping SWW with dip angle 45°. The length of single ore body is more than 300m and the width 1~25m, with average grades of 2.01~4. 49 × 10⁻⁶ (Wang et al., 2004; Zheng et al.,2005).

The Maoduqing gold deposit, located 20km north of Huhuhot, occurs also in the Liushugou formation of the Upper Archean Sertungshan Group. The petrology of the mine area consists of biotite-muscovite-quartz schist, chlorite schist and dolomite marble. The ore bodies occur between schist and marble layers and are controlled by the foot wall of a reverse fault, striking 295° and dipping 25° with dip angle 30° ~50°. The length of single ore body is more than 150m, with average width 14m, and the average grades are 2.07 × 10⁻⁶ (Kang, 2000; Yang, 2003). The main ore minerals are native gold, pyrite, chalcopyrite, galena, sphalerite, magnetite and hematite, and the wallrock alteration were dominated by silicification, pyritization and sericitization.

The main ore minerals of both deposits are native gold, pyrite, chalcopyrite, galena, sphalerite, magnetite and hematite, and the wallrock alteration were dominated by silicification, pyritization and sericitization. The mineralizing stages can be identified in three: (I) early pyritization-sericitization-silicification stage; (II) disseminated pyrite-mylonitization-eye ball quartz stage; and (III) tiny veinlets of pyrite and quartz stage.

Wallrock Alteration. The typical tectonic-altered rocks in the Xindigou and the Maoduqing gold deposits are as follows.

Phyllonitized quartz-(chlorite)-sericite-schist consists of cataclastic-augen quartz (0.1~0.5mm, 8~10%), granule recrystallized quartz (0.01~0.05mm, 30%), sericite (30~50%), chlorite (0~20%), cataclastic oligoclase or microcline (<5%) and relict volcanic clast or debris (<5%), with lepidoblastic texture, rotary texture and schistose structure.

Mylonitized chlorite-quartz-schist consists of lenticular-augen quartz (20%), fine recrystallized quartz (30%), cataclastic oligoclase (20%), chlorite (25%) and small amounts of muscovite, sericite, calcite and essonite, with lepid-granoblastic texture, mylonitic texture and schistose structure.

Sericite-chlorite-(feldspar)-quartz mylonite consists of flour quartz (0.03~0.1mm, 30%), cataclastic-augen quartz (0.2~0.5mm, 20%), chlorite (20%), sericite (15%), dessimated pyrite and calcite, with mylonitic texture and augen structure.

Pyrite-sericite-(feldspar)-quartz mylonite consists of lenticular-augen quartz (0.2~0.5mm, 40%), fine recrystallized quartz (0.01~0.05mm, 20%), sericite(30%), chlorite (<5~10%), pyrite...
(5%) and calcite (<5%), with lepido-granoblastic texture and schistose structure. Pyrite occurs as tiny veils or disseminated, with small amounts of chalcopyrite.

![Regional geologic sketch map of Xindigou and Maoduqing gold deposits.](image)

Rare earth element analysis of altered rocks was carried out in Geology Research Center of Nuclear Industry. The instrument for measurement is ELEMENT type Inductively coupled plasma-mass spectrometry (ICP-MS) made by Finnigan MAT, with 300 of resolving power and 1.25kw of RF power. The laboratory conditions are: 0.85L/min of sample gas current velocity, 0.83L/min of supplementary gas current velocity and 12.0L/min of cooling gas current velocity. The results are as follows.

1. The total contents of REE ($\Sigma$REE) in main altered rocks of the Maoduqing and the Xindigou gold deposit range from $44.9\times10^{-6}$ to $155.4\times10^{-6}$, which are resemble to those of original mid-basic volcanic rocks, indicating that no obvious changes have happened during hydrothermal wallrock alteration.

2. The ratios of light REE to heavy REE (LREE/HREE) are 7.0~26.1, showing that the altered rocks are rich in light rare earth elements and appear right decline of curves in REE pattern model grams (Fig. 2). The fractionation in LREE exists, with 2.2~6.1 of $(La/Sm)_N$, while that in HREE is not obvious, with 1.8~1.0 of $(Gd/Yb)_N$. These characteristics are also similar to original intermediate-basic volcanic rocks.

3. Abnormity of Eu is not clear in the altered rock samples of the Maoduqing and the Xindigou, with 0.6~1.2 of $\delta$Eu. The $\delta$Ce(0.8~1.0) is also unclear. Those reflect the features of original intermediate-basic volcanic rocks.
Fluid Inclusions and Isotope Composition. Fluid inclusion study has been done for the Maoduqing and the Xindigou gold deposits. Because late tectonic events were frequent, microfractures are developed and most primary fluid inclusions were broken. In some samples, primary fluid inclusions (Roedder, 1984) can be found and may be divided into three types: 1) CO₂-rich inclusions (L₂H₂O-L CO₂ or L₂H₂O-V CO₂), which consists of liquid H₂O and liquid CO₂ (with 50-80% of CO₂ / H₂O); 2) aqueous inclusions, which consists of a liquid H₂O phase and a vapor phase, with more than 90% of L/V; 3) CO₂ inclusions, which consists of a liquid CO₂ phase and a gas CO₂ phase, or only a liquid phase under the room temperatures. These carbonic inclusions are usually found in place where mylonitization was intensive and occur vertically to the long axis of lenticular quartz.

The first type of fluid inclusions is the main sort in the Maoduqing gold deposit, but the size of those inclusions are small (less than 2 µ.). Wang et al. (2004) gained 278-323 °C of homogenization temperatures. CO₂ inclusions may be dominant in some samples and the melting temperatures (tₘ,H₂O) range from -57.5 to -56.5°C. They have two behaves when heating. For the first group, the homogenization temperatures (tₜ,H₂O) range from -20 to -10°C, and for the second group, tₜ,CO₂ range from -1.6 to +14.3°C. Laser Ramam microprobe analysis shows distinct CO₂ spectra peaks at Ramam shift 1386 cm⁻¹ and 1278 cm⁻¹ (Fig.3), and no CH₄, H₂O and other spectra peaks.
The values of δ¹⁸O_{snow} in vein quartz vary from 10.78~15.5‰, which are identical with other gold deposits of this area, such as the Wulashan gold deposit (11.36~12.89‰), the Donghuofang(12.5~12.9‰), and the Houshihua (12.5~13.2‰). The values of δD range from -60.3~102‰, which are also similar to the Wulashan and others. When the δ¹⁸O_{snow} are turned to δ¹⁸O_{H₂O} with Clayton formula (1972), most points projected in δ¹⁸O_{H₂O} -δD_{H₂O} coordinate diagram is under normal magmatic water region, but there is an oxygen-shift towards rain water. Hence, it is illustrated that the ore-forming fluid was related with magmatic activity and locally influenced by meteoric water.

The values of sulfide δ³⁴S for the Xindigou and the Maoduqing range from 1.46‰ to 5.45‰, which are also similar with other gold deposits of the Daqingshan area. The fact that δ³⁴S round 0 indicates that the ore sulfur would come from mantle or lower crust. However, from the Wulashan gold deposit to east, δ³⁴S sequencely changes from -7~14 (Wulashan), -0.5~6.2 (Houshihua, No.15), +0.02~+6.1 (Donghuofang), to+1.46~5.45‰(Xindigou and Maoduqing).

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