Low-Sulfidation Epithermal Gold Deposits in East China: Characteristics, Types, and Setting

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Abstract: We preliminarily describe the basic characteristics of the low-sulfidation epithermal gold deposits in East China. It can be divided into granite- and alkaline rock-related types. These gold deposits are structurally controlled by caldera, craters, diatremes and related faults, hosted in volcanic rocks, and characterized by alterations of adularia, chalcedony, quartz, sericite and calcite assemblages. The ore-forming ages are within three pulses of 180-188Ma, 135-141Ma, and ca. 120Ma, which are geodynamically corresponding the collision orogenic process between North China and Yangtze cratons, transformation of the tectonic regime, and delamination of the lithosphere, respectively

1 Introduction

Lindgren (1922) defined the epithermal environment as being shallow in depth, typically hosting deposits of Au, Ag, and base metals plus Hg, Sb, S, kaolinite, alunite, and silica. Two contrasting styles of hydrothermal systems comprising low- and high-sulfidation exist within the epithermal environment, and both are well known from the study of active examples (e.g., Henley and Ellis, 1983). The two-epithermal gold deposit styles of contrasting alteration and ore assemblages form within these distinctly different systems in somewhat contrasting volcanic settings (Hedenquist et al., 2000).

In the past twenty years, a lot of epithermal gold deposits have been recognized or discovered in East China, a part of the Circum-Pacific tectonic-metallogenic belt and Tianshan-Altay, a part of Altaid tectonic-metallogenic belt. Up to now, we know a dozen of epithermal gold deposits in East China. But except for the Zijinshan in Fujian province (So, 1998), and Chinguashih in Taiwan (White, 1991), the others are not reported in international community. The Zijinshan, Tiantoushan and Chiguashi are high sulfidation type, the others are low sulfidation. This paper preliminarily describes the basic characteristics of the low sulfidation style of the epithermal gold deposits in East China and eliminates their forming setting.

2 Spatial and temporal distribution of the epithermal Au deposits in East China

Low-sulfidation gold deposits in China are geographically distributed from northeastern, north and south China, and geologically span Xinmeng foldbelt, North China craton, Yangtze craton, and South China fold belt from north to south (Fig. 1). These deposits are genetically associated with Mesozoic volcanic activities and the metallogenic age ranges from 188 Ma to 95Ma with a pulse of ca. 120 Ma.

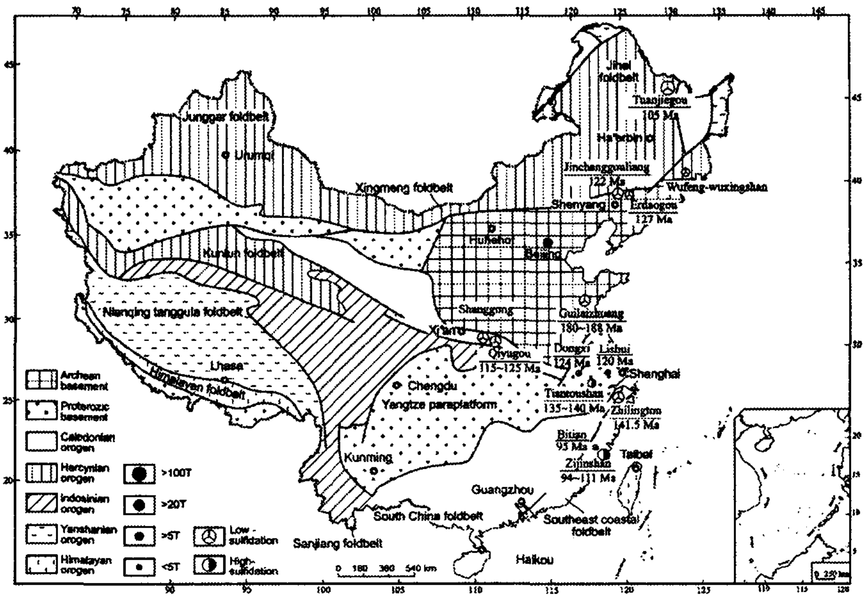

Fig. 1 Sketch map showing the major tectonic units and distribution of epithermal gold deposits in East China.

3 Characters of low-sulfidation epithermal Au Deposits

We put the low sulfidation gold deposits and their dating ages in the Fig. 1 and summary their individual characteristics in Table 1. These gold deposits are structurally controlled by caldera, craters, diatremes and related faults. Some of them are hosted in the porphyry and adjourned country rocks surrounding either volcanic caters or porphyry (e.g. the Duanjirgou). Andesitic, rhyolite, tuff, and volcanic conglomerate occur around the subvolcanic stock or crater or caldera. The mineralization occurs as veins, stockwork and breccia pipes and are generally controlled by varied-trending faults and fractures, particularly ring- and radiometric shape fracture systems. Gold ore in low-sulfidation deposits is commonly associated with quartz, adularia, sericite, calcite and chlorite as the major gangue minerals. The alteration halos around mineralization, particularly in vein-controlled mineralization, include a variety of temperature-sensitive clay minerals. Except for quartz, chalcedony, sericite, and calcite, there are wall-alteration assemblages comprising albite, opal, epidote, chlorite, zeolite, pyrite, and rare kaolinite. Low-sulfidation gold deposits are affiliated with wide range of rock types, from alkalic to calc-alkalic (Silitoe, 1993). In light of the related magmatic rocks, the low-sulfidation gold deposits can be divided into granitoid porphyry- and alkaline rock-related. The latter one is frequently tellurium-rich deposit (Jensen and Barton, 2000). We describe several representing deposits as following:

3.1 Wufeng – Wuxing deposit

It is located in Yanji basin, the eastmost part of the Xingmeng foldbelt and closed to the boundary between China and Korea. The host rocks in the ore district are Upper Jurassic andesitic lava and conglomerate, and Lower Cretaceous terrestrial sedimentary rocks. An alkaline granite stock is exposed in the northeast portion of the district. The gold orebodies are hosted in both volcanic rocks in southwest and alkaline granite stock in northeast, which are named as the Wufeng and Wuxing, respectively. All mineralization developed along NW- and NE-trending groups of faults. The two groups of ore-hosted faults cross at the Wufeng and formed the largest orebody in the mine with 2km long by 3-8 meters wide. The orebodies are composed of veins, stockwork and disseminated ores comprising dense tiny adularia-sericite-calcite-quartz, fluorite-calcite-quartz, chalcedony veins. A big halo of the alteration occurs around the ore veins or orebodies. The ore minerals are calaverite, eletrum, native gold, native silver, argentite, pyrite, magnetite, sphalerite, galena, hematite, chalcopyrite, tetrahedrite, and cinnabar. The gangue minerals contain opal, chalcedony, calcite, quartz, fluorite, sericite and kaolinite. Its reserve is ca. 5 tons with averaging grade of 6 g/t. Feng (1998) obtained the homogenization temperature of 100 - 180°C and salinity of 0.5 to 5.0 wt% NaCl equiv. The sulfur isotope of pyrites range from 1.0‰ to 2.6‰ averaging 1.7‰, and carbon isotope of calcite from –6.9‰ to –9.4‰, reflecting a mantle source (Feng, 1998). But δD and $\delta^{18}O$ of fluid inclusion indicate a dominant meteoritic source.

3.2 Guilaizhuang gold deposit

It is located in west Shandong province and west to the regional Tan-Lu shear fault group. The Guilaizhuang gold deposit and the other mineralized occurrences are distributed in the Tongshi sub-volcanic complex exposed ca. 30 km^2 consisting of early stage diorite porphyry and late stage monozite-syenite porphyry, which is root of the volcanic caldera. This complex dated to be 188.4±1.6Ma with Ar-Ar method for amphibole (Lin et al., 1997) intruded the Neoarchean biotite plagioclase gneiss and Cambrian clastic rocks and carbonate, commonly along their boundary. The ring and radiometric fractures around the caldera developed and some of them were changed to breccia pipes, which definitely host the gold mineralization. All the breccia comprising porphyry, gneiss, quartzite, and dolomite have been altered to be ores, which are accompanied by strong alterations of quartz-adularia-sericite-hydromica, fluorite and calcite. Minor skarn gold mineralization occurs along the contact between the stock and Cambrian dolomite. In the gold ores except for eletrum, native gold, and native silver there is a plenty of tellurim minerals comprising calaverite, altaite, tellubismuth magnolite, hessite, melonite as well as pyrite, pyrrhotite, marcasite, chalcopyrite, native copper, galena, and sphelarite. The gangue minerals are opal, chalcedony, quartz, sericite, carbonate and fluorite.

Fluid inclusion homogenization temperatures range from 120 to 270°C and the salinities are 4-10 wt% NaCl equiv. Sulfur isotopes of the ores indicate that sulfur is derived from mixture of mantle and crust, dominated in mantle (Lin et al., 1997). Lead isotope is also consistent with sulfur isotope. Oxygen and hydrogen isotopes suggest that both magmatic fluid and meteorite be involved in ore-forming process.

3.3 Qiyugou gold deposit

The Qiyugou gold deposits (40 t Au) is situated in the eastern part of the Xiong'ershan Mountanis and is 5km southeast of the Mesozoic Huashani granite pluton. The gold mineralization is hosted in a series of cryptoexplosion breccia pipes. In the area of the Qiyugou gold deposit, 38 such breccia pipes and many small porphyries are distributed along NW-and NE-striking faults. ^{40}Ar-^{39}Ar age of 115-125Ma was obtained by Wang et al (2001) with dating K-feldspar in the gold ore, which is slightly younger than the Rb-Sr isochronal (127Ma) of the Huashan pluton (Shao and Luan, 1989)

The Qiyugou gold deposit is chiefly composed of six auriferous breccia pipes. These breccia pipes are elliptical or spindle in shape, with exposed aeras of 0.01 to 0.03km^2, and vertical depths of >660m. The breccias range from 1cm to several meters in diameter. Breccias have complex compositions, with gneissic fragments in the pipe margins and in the upper part of the pipes, and andesiyic porphyry clasts in the inner part of the pipes. In the lower part s of the pipes, andesitic constitutes are cataclatic.

Three stages of hydrothermal activity are recognlzed at the Qiyugou gold deposits (Luan et al.1988; Shao and Luan 1989). The first is a greisen-like event characterized by quartz-pyrite, pyrite-mica-chalcocite, and quartz-mica-pyrite assemblages. The second, and main ore stage, is enriched in gold, base metal sulfide minerals, and quartz. It is also included deposition of K-feldspar, hastingsite, and lesser tetradymite. The third stage is defined by quartz-calcite-pyrite veinlets. Fluid inclusion homogenization temperatures for the three stages are 433-331, 338-240, and 200-174°C, respectively (Shao and Luan 1989). Gold mineralization is strictly contained in the altered breccia pipes. The upper part of the pipes, the matrices of the breccias, and well-developed small fractures are favorable sites for gold deposition. Intense K-feldspar-quartz-pyrite alteration is closely associated with gold mineralization.

The $\delta^{34}S$ values for sulfide minerals in the Qiyugou deposit are -1.8 to +2.7 per mil for pyrite, -2.3 to -1.0 per mil for chalcopyrite, and -3.5 to -2.1 per mil for galena (Shao and Luan 1989; Ren and Li 1996). Ren and Li (1996) also reported fluid inclusion waters with $\delta^{18}O$ and δD values, respectively, of 1.4 to 7.0 and -52 to -74 per mil for gold-bearing quartz. These isotopic data were suggested to reflect a relationship of mineralization to magmatism.

3.4 Bitian gold deposit

The Bitian is one component of the epithermal gold system in the Zijinshan ore district, composed of porphyry Cu (Zhongliao deposit), high-suldafication epithermal Au-Cu (the Zijinshan deposit), and low-sulfidation Au (Zhang et al., 2003). But unlike the Zijinshan, a typical high-sulfidation deposit, it is a low-sulfidation epithermal gold deposit (So et al., 1998). It is 3 km west to the Zijinshan mine (Huang et al., 1996) and shares the same geological setting with the latter. The Zijinshan ore district is located within Bitian-Shanghang NE-trending Cretaceous faulting basin with basement of Neoproterozoic metaclastic rocks and cover of Cretaceous dacite, trachytic andesite, tuff and rhyolite. The Bitian gold deposit occurs at the southwestmost of the basin and is hosted by the volcanic rocks, which gradually change to the granodiorite porphyry downward (Zhang et al., 2001). The gold-copper mineralization occur along silicification fractures and cryptoexplosion breccia pipes frequently located at the cross-positions of NE- and NW-trending fractures, extending downward to the buried granodiorite pluton. The mineralization shows zoning with copper at lower and gold at upper portion. The hosted rocks for the mineralization have been strongly altered to chalcedony, adularia and sericite. And the alteration also reflects zoning, i.e. on the whole, chalcedony, quartz, adularia, sericite, chlorite, carbonate, and clay minerals comprising hydromica and kaolinite from the ore veins outward (Huang et al., 1996). The ore minerals in the ores are pyrite, chalcopyrite, bonite, native gold, and minor argentite, galena, sphelarite, native silver, electrum. The gangue minerals are quartz, chalcedony, sericite, hydromica, adularia, and minor siderite and barite.

Compared with the Zhongliao and Zijinshan, the Bitian is far from the Cretaceous granite stock. Correspondingly its both homogenization temperatures (126-269°C) and salinity (0.9-5.0% NaCl equiv) of fluid inclusions are lower than those of the Zhongliao porphyr copper deposit (420 - 660°C and 10.5-68.5% NaCl equiv for K-feldspar-biotite zone and 260-440°C and 4.5-44.0% NaCl equiv for sericite-quartz zone), and the Zijinshan high-sulfidation gold deposit (220-400°C and 3.9-15.2% NaCl equiv for sericite-quartz zone and 120-400°C and 0.9-20.9% NaCl equiv for quartz-alunite zone) (Zhang et al., 2003). It is obvious that more meteorite was involving in ore-forming system from porphyry copper, high-sulfidation to low-sulfidation gold deposits just as Hedenquist and Lowenstern (1994) proposed.

4 Geodynamic Setting for the epithermal gold deposits

Hedenquist et al (2000) reviewed the epithermal gold deposits over the world. He found the almost deposits are located in circum-Pacific island arc and continental margins. It is obvious that these epithermal deposits are genetically associated with the subduction of the pacific plate. Although China continental is also a part of the circum-Pacific belt, it is far from the Pacific, even far from the Japan Island arc.

The ages of the epithermal deposits comprising both low- and high-sulfidation mainly range from 140Ma to 94Ma with a pulse of ca. 120Ma. There exceptional are the Guilaizhuang of 180-188Ma, Tiantoushan of 135-140Ma, and Zhilingtou of 141.5±5Ma. These age distributions are absolutely consistent with the orogenic gold deposits (Hart et al., 2002; Mao et al., 2002a, b; Qiu et al., 2002) and the other metallic deposits in East China. There is three pulse of metallogenic ages in Mesozoic, i.e. 190-160Ma, 135-140Ma, and ca. 120Ma in East China. Their corresponding geodynamic settings are proposed to be the collision orogenic process between North China and Yangtze cratons, transformation of the tectonic regime, and delamination of the lithosphere, respectively, in light of the analyzing the Mesozoic geodynamic evolution in the East China.

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