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Metallogenic Features and Metalogenic Model of Laterite Gold Deposits in Southern China

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Abstract The modern laterite gold deposits in southern China, which belong to reworked laterite deposits, can be further divided into three subclasses and seven types. Their geological features, ore-forming conditions and regularities are discussed. A geologic-geochemical metallogenic model for laterite gold deposits has been established.

Key words: laterite gold deposit, geological feature, ore-forming condition, metallogenic model, southern China

1 Deposit Types and Their Geological Features

1.1 Types of mineral deposits

Laterite gold deposits occurred in red weathering crust where gold in geological bodies is motivated and transferred under laterilization and then precipitated to form gold deposits (Ma and Guan, 1997). Since the late 1980s, the following laterite gold deposits have been discovered consequently in southern China such as the Shewushan, Longxingzhai, Dafan, Wangjiafang, Longtang, Xiajia, Badu, Laowanchang, Shengjingguan, Maiwoba, and Beiya deposits, which are all reworked laterite gold deposits and belong to the modern laterite ones.

These reworked laterite gold deposits can be further divided into three subclasses and seven types (Chen and Yang, 1998): leaching-accumulated type deposits occurring in old interstratified tectonic belts (Shewushan type and Longxingzhai type), leaching-accumulated type deposits at rock contact belts (Dafan type, Beiya type and Baise type) and leaching-accumulated type deposits in karst depression areas (Laowanchang type and Zhenxu type) (Table 1).

1.2 Geological features of deposits

The section of red weathering crust is as follows (from top to bottom): surface laterite—hard crust zone—reticular pattern laterite (iron plate)—varicolored clay zone—sapropelite—base rock (Table 2). The most developed one is Shewushan type and the next one is Dafan type. The zoning of red weathering crust in the Longxingzhai type deposits is not obvious, and the weathering crust sections of other type deposits are not well developed with low maturity. The red weathering crust of Shewushan and Dafan types belongs to intensity—subintensity Al-riched weathering one, and the others are medium intensity—subintensity Al-riched weathering one (Wang et al., 1996).

Gold orebodies occur mainly in varicolored clay zones of red weathering crust. In the Laowanchang type and Zhenxu type deposits, gold mineralization is distributed on the whole section of weathering crust. The orebodies normally have stratiform, bedded, lens-shaped, sack-like and irregular forms. The deposits have different sizes: the Shewushan, Laowanchang and Beiya types are medium-large or large-sized one and the others have medium-small sizes, but the Zhenxu type deposits are mainly small ones or mineralized occurrences.

The ore minerals consist mainly of clay group minerals, including kaolin, illite, montmorillonite and hydrokaolin and secondarily of limonite, goethite, hematite, pyrolusite, hydrargillite, romeite, quartz, calcite, barite, carbon, and chlorite. There are also small amounts of fragments of ferralitic rock, silica rock, limestone etc. These minerals often exist as ferralite, nodule, ferreous nodule, Mn-nodule or ferromanganese rock fragments and one could observe bertillon structure inside manganese nodules. Romeite,

Table 1 Types of reworked laterite gold deposits in southern China

Classification		Tectonic position	Source of gold	Occurrence state of gold	Mineralization	Cases
Subclass	Deposit type					
Leaching-accumulated at palaeotectonic belt	Shewushan	Palaeopseudo-conformity, unconformity, old fault belt	Fine-disseminated gold deposit	Sub-microscopic	(1)+(2)	Shewushan, Maiwoba, Longtang and Shengjingguan
	Longxingzhai	Stratohorizon (D_2, D_1, C, P)	Seabed eruptive sedimentary type Mn, Pb, Zn, Ag, Au deposits	Sub-microscopic, fine (<0.1 mm), and granular (0.25–1 mm), dendroid	(3) (2) (4)	Longxingzhai, Xinmin
Leaching-accumulated at rock contact belt	Dafan	Contact belt of granite-diorite-porphyroid	Skarn-hydrothermal polymetallic Ag, Au ore	Sub-microscopic	(5) (2) (4)	Dafen Hutang
	Beiya	Contact belt of orthophyroid	Porphyry-skarn-hydrothermal Pb, Zn, Ag, Au Gossan ore	Microscopic irregular granular, sheet, dendroid, tadpole-like	(5) (1)+(2) (4)	Beiya, Laojiezi, Yinchangpingzi
	Baise	Contact belt of diabasoid	Carlin-type Au, Q-vein Au, Au-bearing diabase	Sub-microscopic	(7)+(1)	Badu, Shijia, Zhuchang, Caijiawan and Baping
Leach-acumulated in karst depression	Laowanchang	Karst-depression	Carlin-type Au	Sub-microscopic	(1)+(6)+(2)	Laowanchang
	Zhenxu	Karst-depression	Q-calcite veinlet Au	Irregular, particles, dendroid, acicular, crusty, euhedral crystal, 0.06–6 mm,	(1)+(6) +(7)+(8)	Zhenxu, Xiajia, Jiaoman, Longzhen and Niuping

Notes: (1) epithermal; (2) leaching-accumulated laterization; (3) seabed eruptive sedimentary; (4) ore-cap supergene oxidation, leach-accumulated enrichment; (5) contact-metasomatic-hydrothermal; (6) collapse-colluviation; (7) residual and leached accumulated laterization; (8) flood and talus deposition

Table 2 Profile zoning of weathering crust in Shewushan type laterite gold deposits

Comprehensive profile	Shewushan	Wangjiafang	Taoxu
Surface laterite	Surface laterite	Surface laterite	Surface laterite
Hard crust	Silica cap, silica fragments Fe-mangnese fragments	Silica cap, silicarock fragments	Ferralite subparticle
Reticular pattern laterite	Reticular pattern laterite	Reticular pattern laterite	Reticular pattern laterite
Iron pan	Iron pan		
Varicolored clay zone	Top: light colour clay bottom: brown clay	Varicolored (red, black) zlay zone	Brown, varicoloured clay layer
Sapropelite	Grey clay zone with weathering residual texture		Sapropelite (semi-weathered dolomite)
Base rock	Lower Palaeozoic and Mesozoic carbonate rock, detrital rock (with Carlin-type Au ore)	Lower Permian fine-detrital rock (with Carlin-type Au ore)	base rock (D_2d calcareous dolomite, with Au mineralization)

brown in colour with rounded and subrounded shape, is a typical mineral of Zhenxu type gold deposits. Calcite and quartz have rounded and subangular shape. The precious metallic mineral is native gold. The major chemical compositions are SiO_2, Al_2O_3 and Fe_2O_3, with a small amount of other oxides in deposits of different types. For example, the Shewushan type has a high content of K_2O, but the Baise type and Zhenxu type have high contents of TiO_2 and CaO respectively. These reflect some characteristics of source gold ore-bodies. For example, the source of Baise type gold deposits is near a contact belt of diabase and its TiO_2 content is higher than that of other deposits after lateritation; the source of Zhenxu type deposits is a Au(Sb)-bearing calcite vein located in limestone and the CaO content is higher than that of other deposits after lateritation. The major useful components of ore is gold, yet the grades of Shewushan, Baise, Dafan, Longxingzhai and Beiya type deposits are relatively low averaging from 1.0×10^{-6} to 2.0×10^{-6}; Zhenxu and Laowanchang type deposits are relatively rich in gold compared with other deposits. The Zhengxu deposit has a grade varing from 1.0×10^{-6} to 5.0×10^{-6}, or up to 15×10^{-6} and 37×10^{-6}, Laowanchang type deposits have grades ranging from 4.1×10^{-6} to 5×10^{-6}, or even greater than 40×10^{-6}. The gold in ore appears in sub-microscopic state. There are some naked gold particles, powdery gold and microscopic gold in Longxingzhai and Beiya type deposits. The gold of Zhenxu type deposits is different, existing as gold particles. The gold-bearing mineral has a high Au content with the index normally greater than 900. The ore mainly has pelitic and slit-pelitie textures. Earthy structure is dominant and there are also reticulate, residual-ripple, brecciated residual-brecciated and porous structures.

2 Ore-Controlling Conditions and Metallogenic Regularity

2.1 Tectono-magmatic setting and metallogeny

The relationship between tectono—magma activity and metallogeny can be showed in two aspects: (1) tectono-magmatic activity controls evidently the primary gold mineralization, and further dominates the type of laterite gold deposits; (2) neotectonism controls the distribution of laterite gold deposits by restricting the development of modern geomorphy.

2.2 Controlling factors of gold orebody sources

This can be presented in three aspects: (1) the type of orebody sources dominates the type of laterite gold deposits; (2) the size and the grade of original orebodies affect the laterite gold deposits; large gold orebodies are favourable for forming large scale laterite gold deposits and higher gold content in the gold body source is also favourable for forming high-grade laterite gold deposits; (3) occurrence of gold body source controls the size of deposits: a flatter original gold orebody is advantageous for forming a large-sized laterite gold deposit, on the contrary, steep occurrence forming a small-scale deposit.

2.3 Relationship between palaeoclimate and laterite gold deposits

Laterite gold deposits are formed under the climate condition of tropical and subtropical arid-humid alternation. The humid tropical-subtropical environment in the Quaternary especially in the Pleistocene in southern China is most advantageous for forming red weathering crust and laterite gold deposits.

2.3 Geomorphic conditions

(1) So far the laterite gold deposits in southern China were discovered only in mountain areas of western Yunnan, the Yungui plateau and hills and plain areas in central and southern China. (2) In the mountain area of western Yunnan, laterite gold deposits are distributed mainly in hill belts of intermountain basins. The laterite gold deposits in the Yungui plateau to the east of the Yuanjiang River are located in hills belts, occurring mainly on the denudational plain formed by neotectonism. (3) Laterite gold deposits in central and southern China are distributed mainly in foreland hills, low hills and peneplain ground. (4) Karst depression leaching-accumulated—illuviated type gold deposits occur in karst depressions, funnels and caves.

2.4 Time-space distribution features

(1) Metallogenic time: The laterite gold deposits in the middle-lower reaches of the Yangtze River and southern China belong basically to the Pleistocene epoch and mainly formed in the middle Pleistocene. The reticulate pattern of laterite could be found in Shewushan type, Dafan type and Longxingzhai type deposits. These indicate that the main parts of these deposits should be the products of the middle Pleistocene epoch. Laterite in the Yungui plateau was formed from the early Pleistocene to middle-late Pleistocene, so the laterite gold deposits belong to the middle-late Pleistocene. (2) Space distribution: The Shewushan deposit is the northmost part of the discovered laterite gold deposits so far, at about 30°W. Quaternary laterite especially reticulate laterite with high maturity in southern China is developed mainly to the south of 31°N, so it is believed that the distribution area of modern laterite gold deposits of southern China is from 31°N southwards to the Hainan Island, which is a tropical land where there occur the Wenchang and Qionghai laterite bauxite deposits, thus providing a favourable palaeoclimate condition for forming laterite gold deposits.

Besides, the distribution of laterite gold deposits has an intimate relation to the location of original gold orebody source. In the area where Carlin type gold deposits are developed, for example, the neighbouring area among Yunnan, Guizhou, and Guangxi provinces, central and southwest Guangxi, west Jiangxi, south-east Hubei province, these areas are mainly distribution zones of Shewushan, Laowanchang , and Baise types gold deposits. Zhenxu type deposits are dominated in central, west and northwest Guangxi where there developed Jiaoman type gold deposits.

2.5 Ore enrichment regularity

(1) The position near gold orebody source is one of the macroscopic marks of enriched part of laterite gold deposits. (2) Gold mineralization is concentratedly on varicoloured clay zones above and near the water-table, normally in the varicolored clay zones under the reticular layers and iron pans. If no reticular laterite or iron plate exists, deposits occurred also in such zones. (3) If there are kaolinite layers under the reticular laterite, then the thicker the kaolin layer, the thicker and higher grade the gold orebody. (4) The grade of blocky ore is higher than that of earthy ore in Shewushan type and Baise type deposits; gold is enriched in ore with weak silication; clay-ore containing red-brown limonite-quartz veinlets have higher grade; yellow-brown or dark brown ore is richer in gold than purple one. (5) Mineralization is distributed on the whole laterite section, becoming richer from top to bottom for Laowanchang and Zhenxu type deposits. (6) Zhenxu type gold deposits have the following enrichment features: 1) peak forest depression and karst depression are favourable for gold enrichment, on the contrary, hillside valleies are not good for gold enrichment; 2) in the lower part of peak forest depression and in solution grooves, gold is relatively rich; 3) in the area along the section, the middle-lower part has high gold content with large gold particles appearing mainly in the top part. 4) the more romeite in ore, the stronger the gold mineralization and the thicker the orebody. (7) Occasionally, there is gold mineralization in sapropelite zones.

3 Metallogenic Model

The geologic-geochemical metallogenic model of laterite gold deposits in southern China is as follows (Fig. 1):

(1) The section of gold-bearing red weathering crust (from top to bottom): surface laterite—hard crust zone—reticular laterite—varicolored clay zone—sapropelite zone—base rock. The varicolored clay zone is an important host layer of gold orebody.

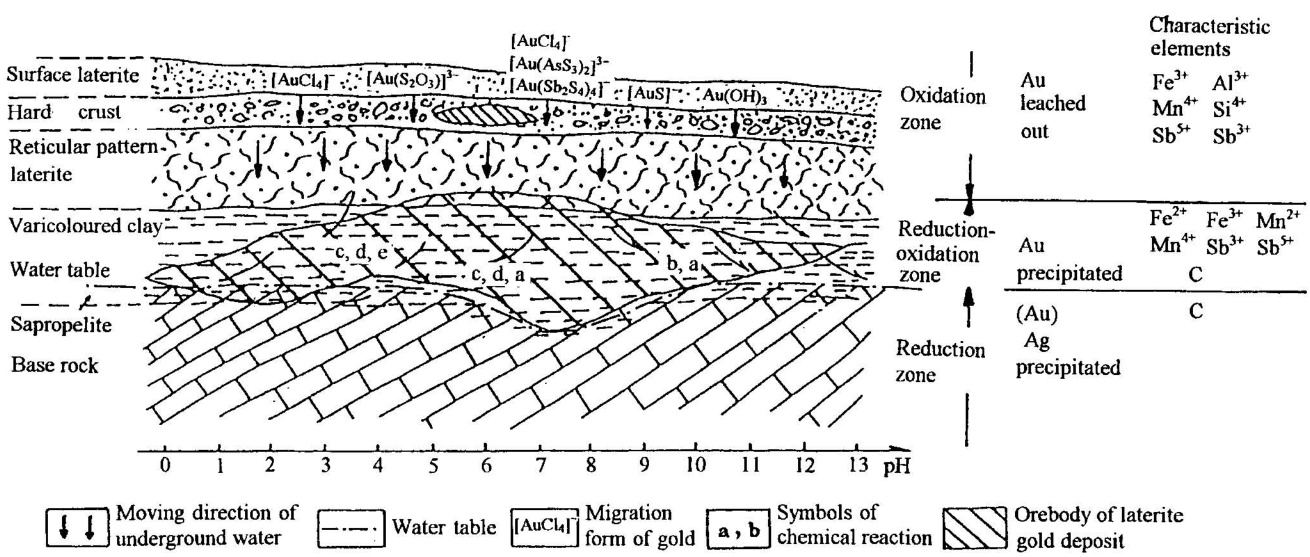

Fig. 1. Metallogenic model of laterite gold deposits in southern China.

1. Moving direction of underground water; 2. water table; 3. migration form of gold; 4. symbol of chemical reaction; 5. orebody of laterite gold deposit; 6. base rock (carbonate rock). a: $[AuCl_4]^- + 3Fe^{2+} + 6H_2O \rightarrow Au^0 + 3FeO(OH) + 4Cl^- + 9H^+$ (Shewushan, Baise, Longxingzhai, Dafan, Beiya and Zhenxu types etc.); b: $3[Au(S_2O_3)_2]^{3-} + Fe^{2+} + 4H_2O \rightarrow Au^0 + FeO(OH) + 5H^+ + 2SO_4^{2-} + 2HS^-$ (Shewushan, Laowanchang, Baise, Longxingzhai, Beiya and Dafan types etc.); c: $3Au(OH)_3 + H^+ + 2Mn^{2+} \rightarrow 4Au^0 + 3MnO_2 + 6H_s$ (Zhenxu types); d: $[Au(Sb_2S_4)]^- + 2Fe^{2+} + 5H_2O + 7O_2 \rightarrow Au^0 + 2FeO(OH) + Sb_2O_5 + 4H_2SO_3$ (Zhenxu, Shewushan, Laowanchang types); e: $[AuS]^- + Fe^{2+} + 2H_2O \rightarrow Au^0 + FeO(OH) + S + 3H^+$ (Shewushan, Baise, Zhenxu, Longxingzhai and Dafan types).

(2) There are several kinds of mineralizations in the source gold orebodies: fine disseminated type, Au(Sb)-bearing Quartz-calcite vein type, Fe, Mn, Pb, Zn, Ag, Au mineralization of submarine eruption sedimentary type, Au(Ag)-polymetallic contact metasomatic(skarn)—hydrothermal type, porphyry-skarn—hydrothermal Pb-Zn-Ag-Au mineralization and mineralization of gossan type.

(3) Lateritization took place under the climate condition of tropical-subtropical arid-humid alternation in southern China, where hills, peneplain and karst depressions are developed in the Quaternary, especially in the Pleistocene. In the same period, the gold in gold-bearing geological bodies located at certain tectonic positions were motivated and transferred as Au-Cl complex and Au-S complex or in colloid-absorbed form in fluids with certain pH, Eh values.

(4) Gold penetrated and migrated from surface to bottom in red weathering crust and gold-bearing solutions gradually changed their moving directions to be horizontal near the water table. At this time, Eh and pH values of solutions were changed, gold was precipitated and enriched under the interaction of reducing agents (Fe^{2+} and Mn^{2+}) and absorptive agents of Fe-Mn oxides colloid, and clay group minerals. The reaction equations are showed in Fig. 1. Gold was precipitated and enriched in varicoloured clay zones above the water table and nearby as stratiform, bedded-like, lens-shape and sack-like orebodies.

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