Magmatic Gold Mineralization in the Western Qinling Orogenic Belt: Geology and Metallogenesis of the Baguamiao, Liba and Xiaogouli Gold Deposits

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Abstract The superlarge Baguamiao, large Liba and Xiaogouli gold deposits represent three typical gold deposits different from the Carlin type in the western Qinling Orogenic Belt. Based on Ar-Ar dating of quartz from ores, U-Pb dating of single zircon from granite, tracing of H and O isotopes and studies on the mineralogy and texture of spots and bleached alteration developed in wall rocks, this paper focuses the relations between gold deposits and granite to clarify the origin of gold deposits and the metallogenesis in the tectonic evolution of the Qinling Orogenic Belt. The comprehensive studies show that the age of the granite (148.1–244 Ma) is identical with that of the gold deposits (131.91–232.56 Ma). It is suggested that the granite has close temporal, spatial and genetic relationship with the gold deposits. The granite provides a heat source, water source and considerable amount of ore-forming material. Finally, it is concluded that the orogenesis by collision, emplacement of the granite and positioning of the gold deposits represent a successive process. Both the granite and gold deposits resulted from the syn-orogeny and post-orogeny tectonic evolution.

Key words: Western Qinling Orogenic Belt, Baguamiao Gold Deposit, Liba Gold Deposit, Xiaogouli Gold Deposit, granite

1 Introduction

The Western Qinling Orogenic Belt abuts the North China Platform along the Shangzhou-Danfeng Suture (F₁) in the north and neighbors the Yangtze Platform along the Mianxian-Lueyang Suture (F₂) to the south (Fig. 1) (Zhang et al., 1996). In the Paleozoic the three tectonic units corresponded to the active continental margin of the southern margin of the North China Plate, passive continental margin of the northern margin of the Yangtze Plate and the Qinling micro-plate, respectively. Strata there are composed of a set of Devonian epimetamorphic clastic rocks-carbonates. The unaltered intrusives are mainly Indosinian-Yanshanian granites. A series of gold deposits and Pb-Zn deposits (Fig. 1) are concentrated in the Devonian clastic rocks-carbonates in northern part of the southern Qinling Fold Belt between the Shangzhou-Danfeng Suture (F₁) and Lintan-Zhenan Fault (F₂). Gold deposits used to be ascribed to the Carlin type (Zhang, 1998a and b; Zhao, 1999) because of some similarities to the Carlin type. Different from the Carlin type, the superlarge Baguamiao Gold Deposit, large Liba Gold Deposit and Xiaogouli Gold Deposit are characterized by easily-separated coarse gold grains and close relation to granite and dykes. Accordingly, started with the mineralogy and texture of spots and alteration, based on geology and geochemistry, and combined with Ar-Ar dating of quartz from ores and U-Pb dating of single zircon from granite as well stable isotopes, this paper aims at revealing the relationship between gold deposits and granite to clarify the metallogenesis in the tectonic evolution of the orogen.

2 Geology of Typical Gold Deposits

The Baguamiao Gold Deposit is located 35 km northeast of Fengxian County, west of the Fengxian-Taibai Ore Field. Strata there are composed of spotted ankerite-sericite phyllite, calcareous chlorite phyllite, sillicalite and epizonal fine clasolite of the Mid-Upper Devonian Xinghongpu Formation. Ore-bearing rocks are characteristic of brittle-ductile shearing deformation and mylonitization, forming the Changgou-Erlihe Brittle-ductile Shear Zone (Fang et al., 2000; Feng et al., 2003a and b). Faults strike mainly northwest and northeast. The Xiba Granite intruded in the southeast. Dykes were emplaced in the mine. There exist NW-trending quartz veins and NE-trending quartz veins. The former with Au content of less than 3 ppm is controlled by the brittle-ductile shear zone; the latter with Au content of more than 3 ppm cuts the former. Ore bodies structurally
are controlled as dissemination, veinlet, stockwork, lumpy and band. Because of intensive alteration, the ores are usually light-colored. Alteration there is mainly characterized by silicification, ankeritization, sericitization, and pyritization. Gold in grain size ranges from 0.005 mm to 0.7 mm, up to 1.2 mm at most (Fang et al., 2000; Feng et al., 2003a).

The Liba Gold Deposit is located in the eastern part of the Lixian-Minxian Ore Field (Fig. 1). The exposed strata there are composed of spotted slate, and silstone of the Middle Devonian Shujiaba Formation. The Zhongchuan Granite is 2 km southwest of the mine. Coeval dikes, mainly plagi-ampithe lamprophyre, diorite, plagio-apatite and granite, as the important indicator of mineralization, are well developed in and around the mine. Faults are developed dominantly striking north-west and north-east. Orebodies are confined to NW-trending faults and are composed of bleached altered slate and silstone. The alteration is characterized by pyritization, carbonatization, silicification and sericitization related to Au mineralization. Sulfides, being less than 10%, are composed of pyrite and minor sphalerite, galena, arsenopyrite and pyrrhotine (Huang, 2000; Feng et al., 2003b).

The Xiaogouli Gold Deposit is located 40 km west of Chengxian (Fig. 1). The exposed strata there are sericite phyllite, calc-silicicites, and limestone of the Middle Devonian Xihanshui Formation. Faults are developed well, mainly trending northwest and northeast, controlling the distribution of Au quartz lode and granite dikes. The Dashan Granite intruded 800 m southeast of the mine. Dikes are developed well in dominance of granite, lamprophyre and diorite dikes within and around the mine, always constituting the footwall and hanging wall of orebodies. Its metallogenic characteristics is similar to some gold deposits related to quartz veins in the Jiaoqong area and Xiaoguiling area (Deng et al., 2003; Du et al., 2003). Controlled by fractures, the orebodies are shaped as lens and veins with strike similar to the strata or crossing the strata at a gentle angle. Visible coarse gold grains can be identified in quartz veins. From a sample weighing 150 g, 214 gold grains weighing 435.17 mg were once separated. Gold is shaped as irregularly granule, sheets, breccia, spherules, rods and dendrites. Gold grains with fine crystal planes are generally 1.6 – 2.9 mm in diameter. Alteration is developed in bleached zones including silicification, sericitization, albitionization, chloritization, arsenopyritization, pyritization, etc. A great amount of pyrite, arsenopyrite, freibergite, sulfides, sericite, chlorite and kaolinite are present in bleached alteration zones (Feng et al., 2002).

3 Spatial Constraint of Granite on Gold Deposits

Gold deposits in the Fengxian-Lixian region have a close spatial relationship with magmatic intrusives, about 0.8 – 3 km away. In Lixian, gold deposits and occurrences are distributed around the Zhongchuan Granite. The Baguamiao, Liba and Xiaogouli gold deposits are located close to the Xiba Granite, Zhongchuan Granite and Dahan Granite respectively. In addition, the Anjiacha and Maanqiao gold deposits are located near the Caoguan Granite and Xianggou Granite respectively. Granite and diorite dikes intruded within and around the gold deposits. Bleached altered zones with higher Au contents are well
developed beside dikes. Granitic dikes or veins are often distributed in clusters or groups as footwall or hanging wall of orebodies. Wall rocks beside dikes are intensively altered to be economic ores.

Spots are extensively developed in wall rocks and are composed of pyrite, pyrrhotite, limonite, arsenopyrite, chlorite, quartz, sericite, biotite, cordierite, andalusite, tourmaline and carbonates. Thermal metamorphic contact is developed around the Zhongchuan Granite with change through andalusite, chiastolite, cordierite and biotite→cordierite, biotite and quartz→biotite, quartz and muscovite→sericite, chlorite and quartz outward. There exist four types of spots in wall rocks of the Baguamiao Gold Deposit, that is tourmaline+pyrrhotite+pyrite (carbonate) spot, mica spot, bitite+chlorite+quartz+carbonate+pyrrhotite spot, and ankerite spot. Spots identified in wall rocks of the Xiaogouli Deposit are mineralogically divided into five types: ankerite spot, chlorite spot, pyrite spot, composite spot (Pyrite, ankerite, quartz, chlorite, limonite) and limonite spot. The common mineral assemblage is quartz+biotite+pyrite+cordierite. Within spots, mineral assemblage of spots changes from pyrite+quartz through chlorite to biotite form its core to rim. If metasomatism is intense enough to make spots totally filled with pyrite, the altered rocks are highly mineralized. The location of gold deposits lies on the transition from biotite+chlorite+quartz spots to sericite+quartz+pyrite spots. From gold deposits to the periphery of a granite, minerals of spots intend to change from pyrite, quartz and carbonate→chlorite, carbonate and sericite→biotite, andalusite and cordierite. Thus, the mineralogy and structure of spots indicate that the spots represent a thermal metamorphism and inhomogeneous metasomatism of hydrothermal solution. It is suggested that granitic intrusives acted as a heat source to heat and drive fluid to ascend at depth.

4 Ages of Gold Deposits and Granite

Ideal plateau ages and isochron ages were obtained by dating quartz from ores. The Au-bearing quartz of the Xiaogouli Gold Deposit yielded a plateau age of 197.45±1.13 Ma and isochron age of 193.24±0.93 Ma (Table 1). A single zircon from the Dazhan Granite was dated 201.4±0.9 Ma by the U-Pb method. Accordingly, It is suggested that the gold deposits are similar to those in the Xiaojinling area (Li et al., 2002) and the mineralization is contemporaneous with granite or a little later.

Gold-bearing quartz from the No.5 orebody in the Liba Gold Deposit was dated at the Ar-Ar plateau age of 210.6±1.26 Ma and isochron age of 205.0±3.53 Ma. While the dating of fluid inclusions of pyrite yielded a Rb-Sr age of 171.6 Ma (Wang et al., 1996) and galena yielded a Pb-Pb age of 171.6 Ma (Huang, 2000). Thus it is assumed that the Liba Gold Deposit was formed at 210–171.6 Ma, i.e., late Indosinian-early Yanshanian. In addition, the Zhongchuan complex granitic intrusive with intrusion activities of five stages in three phases was dated at K-Ar ages of 177–229 Ma. The U-Pb dating of single zircon from a granitic dyke around the mine yielded an age of 166.5 Ma.

The superlarge Baguamiao Gold Deposit is characteristic of multi-phase mineralization. The dating of northwest-trending quartz veins confined to a ductile shear zone yielded an Ar-Ar plateau age 232.58±1.59 Ma and Ar-Ar isochron age of 222.14±3.45 Ma of the Indosinian epoch (Triassic), while the northeast-trending quartz vein was dated with the Ar-Ar method at a plateau age of

<table>
<thead>
<tr>
<th>Mines</th>
<th>Lithology</th>
<th>Ages (Ma)</th>
<th>Dating methods</th>
<th>Intrusives</th>
<th>Ages (Ma)</th>
<th>Dating methods</th>
</tr>
</thead>
<tbody>
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<td>131.9±0.98</td>
<td>Ar-Ar pateau age</td>
<td>quartz diorite</td>
<td>200–220</td>
<td>zircon Th-Pb</td>
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<td></td>
<td>NE-trending quartz vein</td>
<td>129.4±0.35</td>
<td>Ar-Ar isochron age</td>
<td>quartz diorite</td>
<td>244</td>
<td>apatite U-Th-Pb</td>
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<td>232.56±1.59</td>
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<td>biotite K-Ar</td>
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<td></td>
<td></td>
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<td>biotite K-Ar</td>
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<td></td>
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<td>198.1</td>
<td>biotite K-Ar</td>
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<tr>
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<td>197.45±1.13</td>
<td>Ar-Ar pateau age</td>
<td>Dashan granite</td>
<td>201.4</td>
<td>zircon U-Pb</td>
</tr>
<tr>
<td></td>
<td>quartz of orebody</td>
<td>193.24±0.93</td>
<td>Ar-Ar isochron age</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>quartz vein</td>
<td>210.6±0.26</td>
<td>Ar-Ar pateau age</td>
<td>granite</td>
<td>166.5</td>
<td>zircon U-Pb</td>
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<td></td>
<td>quartz vein</td>
<td>205.0±2.53</td>
<td>Ar-Ar isochron age</td>
<td>meso-grained granodiorite</td>
<td>196</td>
<td>biotite K-Ar</td>
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<tr>
<td></td>
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<td>171.6</td>
<td>Rh-Sr, fluid inclusion</td>
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<td>188–229</td>
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<td></td>
<td>galena of ore</td>
<td>184</td>
<td>Pb-Pb</td>
<td>biotite granite</td>
<td>184–199</td>
<td>biotite K-Ar</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>fine-grained biotite granite</td>
<td>177–218</td>
<td>biotite K-Ar</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>meso-grained biotite granite</td>
<td>179</td>
<td>biotite K-Ar</td>
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</table>
131.91±0.98 Ma and isochron age of 129.45±0.35 Ma of the Yanshanian epoch (Jurassic). The Xiba Granite is a complex of multi-phase intrusion. The early quartz diorite is dated with the U-Th-Pb method of zircon and apatite at 220–244 Ma and the late biotite granite is dated with the K- Ar method of biotite at 148.1–179.5 Ma. It is evident that the gold deposits were formed at 131.91±0.98 Ma to 232.56±1.59 Ma, e.g. quartz from the Shangjiaogou Gold Deposit was dated with Ar-Ar method at a plateau age of 160.59±0.65 Ma and isochron age of 160.00±0.85 Ma. Intrusives in the western Qinling Orogenic Belt were emplaced at 166.5 Ma to 244 Ma. Granite and gold mineralization having close connection in time resulted from the same syn-orogenic or post-orogenic event. The multi-epoch metallization is related to a multi-epoch intrusion of granite. Especially, the superlarge Baguamiao and large Liba gold deposit at least underwent a Indoasian metatization and Yanshanian metatization. Zhu (1995) classified magmatic activities into four stages: 470–570 Ma, 309–360 Ma, 214–190 Ma, and 95–105 Ma. The intrusives of the first stage were migmatized and have no relation to Au mineralization. The intrusives of the second stage were intruded syn-orogenically and were slightly migmatized. No gold deposits were discovered around them. Granite and granodiorite of the third and fourth stages emplaced syn-orogenically and post-orogenically are related to Au mineralization. Most gold deposits have spatial, temporal and genetic relation to them. As a general rule, gold deposits in Shaanxi, Gansu and Henan Provinces are located within 3 km away from the last two types of intrusives. Therefore, the last two magmatic stages can be also regarded as two metallization stages.

5 Genetic Relationship between Gold Deposits and Granite

According to H and O isotope analysis of 31 samples and calculation of isotopic fractionation function (1000lnε=3.38×10^6t^2−3.4, Clayton, 1972), δD values of the Baguamiao Gold Deposit range from −86‰ to −73‰, averaging −79.89‰, and δ18O from 5.03‰ to 13.34‰, averaging 11.01‰. The Liba Gold Deposit gained δD values ranging from −74‰ to −83‰, averaging −79.88‰, and δ18O values from 9.51‰ to 11.72‰, averaging 10.66‰. The Xiaogouli Gold Deposit obtained δD values ranging from −58‰ to −77‰, averaging −69.2‰ and δ18O ranging from 8.15‰ to 12.82‰, averaging 10.72‰. On the δD-δ18O diagram (Fig. 2), these data are plotted near the field of magmatic water, which indicates that fluids were derived from magmatism and meteoric water.

The alteration is characterized by bleached zones where silicification, sericitization, carbonitization and pyritization are intense enough to be mineralized with the intrusion of granites, e.g. an anomaly halo of Pb, Zn, Ag and Au was formed around the Xianggou Granite near the Ma’anqiao Gold Deposit. Granite stocks or dikes have high Au content up to 240 ppb (Table 2). Pyrite, galena and chalcopyrite veinlets exist within some intrusives. The Daxian Granite has a gold content of 1.7 ppb at its center and 6.3 ppb in its periphery. From the center to the dikes around granite, the Au content intends to increase.

According to Wang et al. (1996), pyrite in spot is one of the main gold-carrying minerals. Gold grains carried by pyrites account to 40.8%, while gold grains carried by pyrites of spots account to 6.9%. A transmission electron microscope analysis indicates that pyrite in spot contains sub-microscopic gold with a grain size of 0.02–0.16μm, which precipitates on crystal planes or on the edge of crystals. Gold grains also exist in the interstice among

![Fig. 2. δ18O-δD diagram of the Baguamiao, Liba and Xiaogouli gold deposits.](image)

### Table 2 Trace element contents of intrusives within or around the gold deposits (Au: ppb; others: ppm)

<table>
<thead>
<tr>
<th>Mine</th>
<th>Lithology</th>
<th>Samples</th>
<th>Au (ppb)</th>
<th>Ag (ppb)</th>
<th>Cu (ppb)</th>
<th>Pb (ppb)</th>
<th>Zn (ppb)</th>
<th>As (ppb)</th>
<th>Sb (ppb)</th>
<th>Bi (ppb)</th>
<th>Hg (ppb)</th>
<th>W (ppm)</th>
<th>Mo (ppm)</th>
<th>Sn (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baguamiao</td>
<td>Dikes</td>
<td>5</td>
<td>20.80</td>
<td>0.08</td>
<td>9.67</td>
<td>28.33</td>
<td>90.67</td>
<td>46.33</td>
<td>2.40</td>
<td>0.29</td>
<td>0.04</td>
<td>1.90</td>
<td>0.60</td>
<td>2.70</td>
</tr>
<tr>
<td>Xiaogouli</td>
<td>Dikes</td>
<td>8</td>
<td>33.25</td>
<td>0.24</td>
<td>30.25</td>
<td>49.13</td>
<td>194.13</td>
<td>60.09</td>
<td>10.36</td>
<td>0.79</td>
<td>0.09</td>
<td>2.96</td>
<td>1.38</td>
<td>2.29</td>
</tr>
<tr>
<td>Liba</td>
<td>Dikes</td>
<td>3</td>
<td>3.85</td>
<td>0.07</td>
<td>24.00</td>
<td>36.50</td>
<td>80.50</td>
<td>1.65</td>
<td>1.07</td>
<td>0.43</td>
<td>0.06</td>
<td>1.95</td>
<td>0.55</td>
<td>2.20</td>
</tr>
<tr>
<td>Zhongchuan Granite</td>
<td>Dikes</td>
<td>5</td>
<td>57.75</td>
<td>0.37</td>
<td>48.50</td>
<td>56.75</td>
<td>167.75</td>
<td>72.00</td>
<td>9.20</td>
<td>0.29</td>
<td>0.04</td>
<td>2.48</td>
<td>1.18</td>
<td>5.25</td>
</tr>
</tbody>
</table>

- 0 – Baguamiao Gold Deposit; □ – Liba Gold Deposit; △ – Xiaogouli Gold Deposit
quartz, sericite and arsenopyrite. A comprehensive study shows that granite provides considerable amount of ore-forming materials.

6 Conclusions

From the above-mentioned studies, the following conclusions can be drawn:

(1) Some gold deposits in the Western Qinling Orogenic Belt, such as the Baguamiao, Liba and Xiaogouli gold deposits with easily-separated coarse grains of gold particles and close to bleached alteration is different from the Carlin type in geology and geochemistry.

(2) Gold deposits are distributed around granites. Granitic intrusives offer a thermal source. The mineralogy and texture of spots developed in wall rocks indicate that the spots resulted from thermal metamorphism and fluid metasomatism.

(3) Granite stocks and dikes have higher Au contents, and even were mineralized. Granite supplies a considerable amount of ore-forming material. In addition, it is proposed that the hydrothermal solution was derived from magmatism.

(4) The age of granites (148.1–244 Ma) is identical with that of the gold deposits (131.91–232.56 Ma). The orogeny by collision, emplacement of granites and positioning of gold deposits represent a united successive process. Both granite and gold deposits formed in the Indo-Russian-Yanshanian epoch result from a syn-orogenic and post-orogenic tectonic evolution.

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References