

## Giant Mineral Deposits and Their Geodynamic Setting in the Lanping Basin, Yunnan, China

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**Abstract** There are giant mineral deposits, including the Jinding Zn-Pb and Baiyangping Ag-Co-Cu, and other important mineral deposits (e.g., Baiyangchang Ag-Cu, Jinman Cu deposits, etc.) in the Lanping Mesozoic-Cenozoic Basin, Yunnan Province, China. The tabular ore-bodies and some veins hosted in terrestrial clastic rocks of the Mesozoic-Cenozoic age and no outcropping of igneous rocks in the giant deposits lead to the proposal of syngenetic origin, but the giant mineral deposits are not stratabound (e.g. MVT, sandstone- and Sedex-type). They formed in a continental red basin with intense crust movement. The mineralization is controlled by structures and lithology and occurs in different strata, and no sedimentary nature and no exhalative sediments are identified in the deposits. The deposits show some relations with organic matter (now asphalt and petroleum) and evaporates (gypsum). The middle-low-temperature (mainly 110°C to 280°C) mineralization took place at a depth of about 0.9 km to 3.1 km during the early Himalayan (58 to 67 Ma). The salinity of ore-forming fluids is surprisingly low (1.6% to 18.0 wt% (NaCl)<sub>eq</sub>). Affected by the collision of the Indian and Eurasian plates, the mantle is disturbed under the Lanping Basin. The large-scale mineralization is closely linked with the geodynamics of the crust movement, the mantle and mantle-flux upwelling and igneous activity. Giant mineral deposits and their geodynamic setting are unique in the Lanping Basin.

**Key words:** giant Jinding Zn-Pb deposit, giant Baiyangping Ag-Co-Cu deposit, ore geology, geodynamic setting, Lanping Basin, Yunnan Province, China

### 1 Introduction

The Lanping Basin in northwestern Yunnan, China, located in the eastern part of the Qinghai-Xizang (Tibet) Plateau, is much concerned for giant mineral deposits (Fig. 1). The giant Jinding Zn-Pb Deposit is the largest so far discovered in China, and also the youngest and the only giant Zn-Pb deposit hosted in continental sedimentary sequences in the world. The giant Baiyangping Ag-Co-Cu Deposit is discovered 30 km north of Jinding recently. There are also the middle-scale Jinman Cu Deposit and large-scale Baiyangchang Ag-Cu Deposit in the Lanping Basin (Fig. 1). The Lanping Basin is very important with giant deposits. The Jinding Deposit was found in 1960 and the exploration had been completed in 1984, and its genesis is a subject of debate, including stratabound sedimentary (Shi et al., 1983; Luo and Yang, 1994; Ning and Kyle, 1997; Hu et al., 1998; Kyle and Ning, 2002), exhalative sediment (Zhao, 1989a), and epigenetic origin (Wu et al., 1989; Gao, 1989; Hu, 1989; Xue et al., 2000, 2002c, 2003). The tabular orebodies hosted in Mesozoic-Cenozoic terrestrial clastic sequences and no outcropping of igneous rock in the ore district leads to the proposal of syngenetic origin. Many features, however, distinguish the deposits from other sediment-hosted deposits, such as MVT, sandstone type

and Sedex-type Zn-Pb deposits (Ncube and Amstutz, 1981; Sangster, 1990). The giant deposit in the Lanping Basin probably represents a new type of sediment-hosted deposits (Ning and Kyle, 1997; Xue et al., 2000, 2002c, 2003; Kyle and Ning, 2002). What is the geodynamic setting of these giant deposits? The basic ore geology and geodynamics of the Lanping Basin are revealed in this paper.

### 2 Giant Mineral Deposits

#### 2.1 Giant Jinding Zn-Pb Deposit

In the Jinding ore district (Fig. 2a), Mesozoic-Cenozoic sediments, westward thrusting, doming and dome breakage developed successively (Xue et al., 2002b, 2002c), and Zn-Pb mineralization accompanied the Jinding dome (Xue et al., 2003). The orebodies are usually tabular or vein in shape, which are mainly hosted in terrestrial clastic sequences of the Lower Cretaceous and controlled by a structure (thrust and dome)-lithologic trap (Xue et al., 2002c). No syngenetic features and no hydrothermal sediments that usually occur in Sedex-type Zn-Pb deposits could be found (Table 1). The cement texture is a typical ore texture resulted from sulfide minerals replacing the cement in the clastic rocks with high permeability. The assemblage of quartz + celestite + barite + sphalerite +

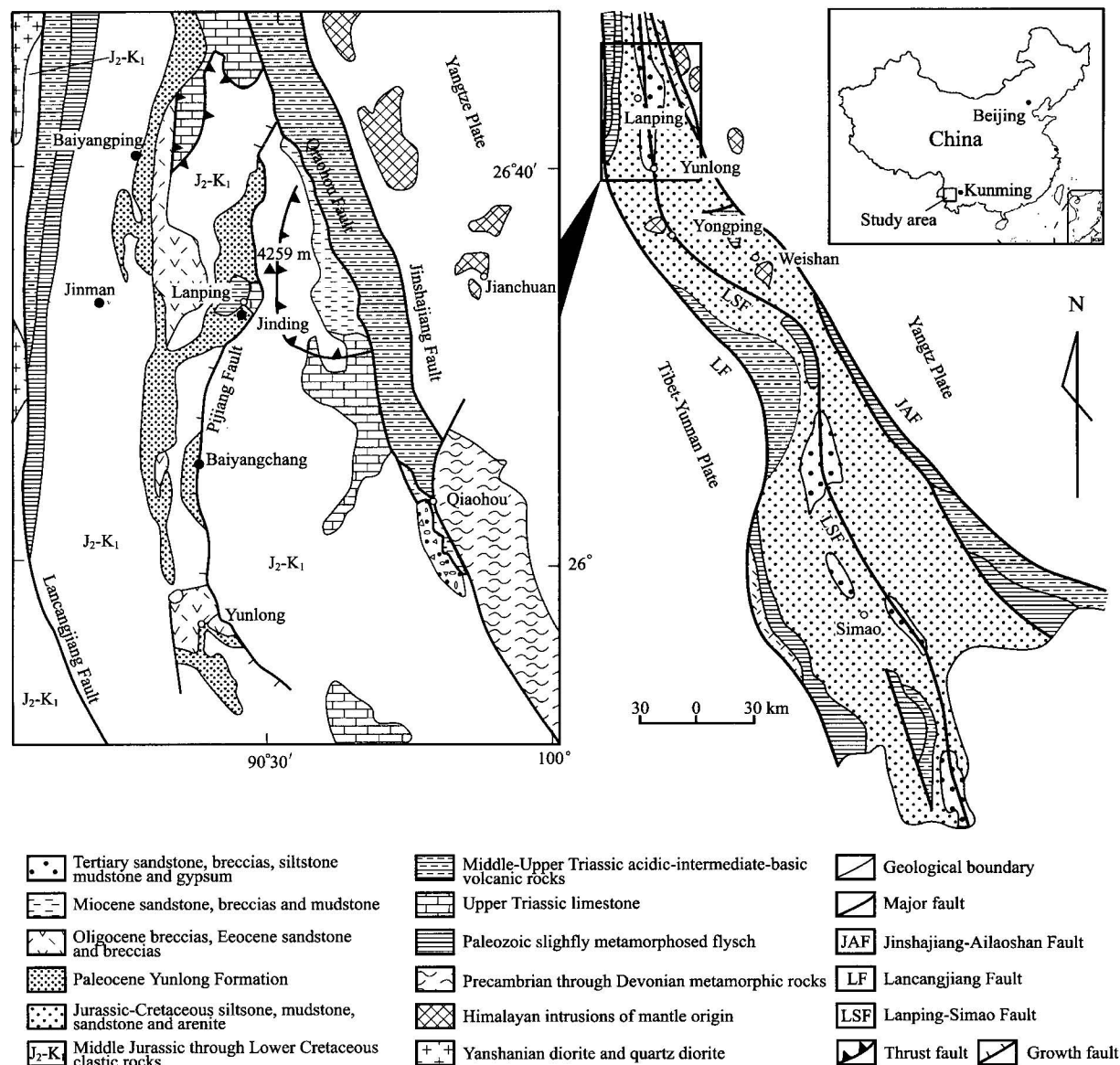


Fig. 1. Simple map of geology, tectonics and mineral deposits of the Lanping Basin, Yunnan Province, China.

galena + pyrite formed into the main ore bodies during the major ore-forming stage. The deposit zonation differs from that of in Sedex-type Zn-Pb deposits, suggesting a different ore-forming mechanism (Xue et al., 2002c). The metallogenic temperatures are in the range of 110°C to 150°C, the ore-forming fluid salinity is medium to low, and metallogenic depth has been estimated to be 0.9 to 1.5 km (Xue et al., 2002b, 2002c).

## 2.2 Giant Baiyangping Ag-Co-Cu Deposit

In the Baiyangping ore district (Fig. 2b), the ore bodies are distinctly controlled by extensive fractured zone, and occur as vein in sandstones and siltstones of Jurassic-Cretaceous sequences. The mineralization is characterized by hydrothermal replacement and space-filling in fractured

rocks (Xue et al., 2001). The ore mineralogy is very complex, the major Cu-bearing minerals are of the apthionite-tennantite series and the major Co-bearing minerals are of the cobaltite-Co-bearing arsenopyrite series (Table 1). The gangue minerals are mainly quartz, celestite, calcite, barite, and so on. The assemblage of quartz + celestite + barite + calcite + apthionite + tennantite + cobaltite + Co-bearing arsenopyrite formed during the main metallogenic stage, and in the assemblage, the quartz is the product of the early intensive silicification, the celestite and the barite are medium-grained automorphic, and the sulfide minerals are fine-grained xenomorphic. The homogenization temperatures of the fluid inclusions in the calcites of the main stage range from 190°C to 320°C (Xue et al., 2001).

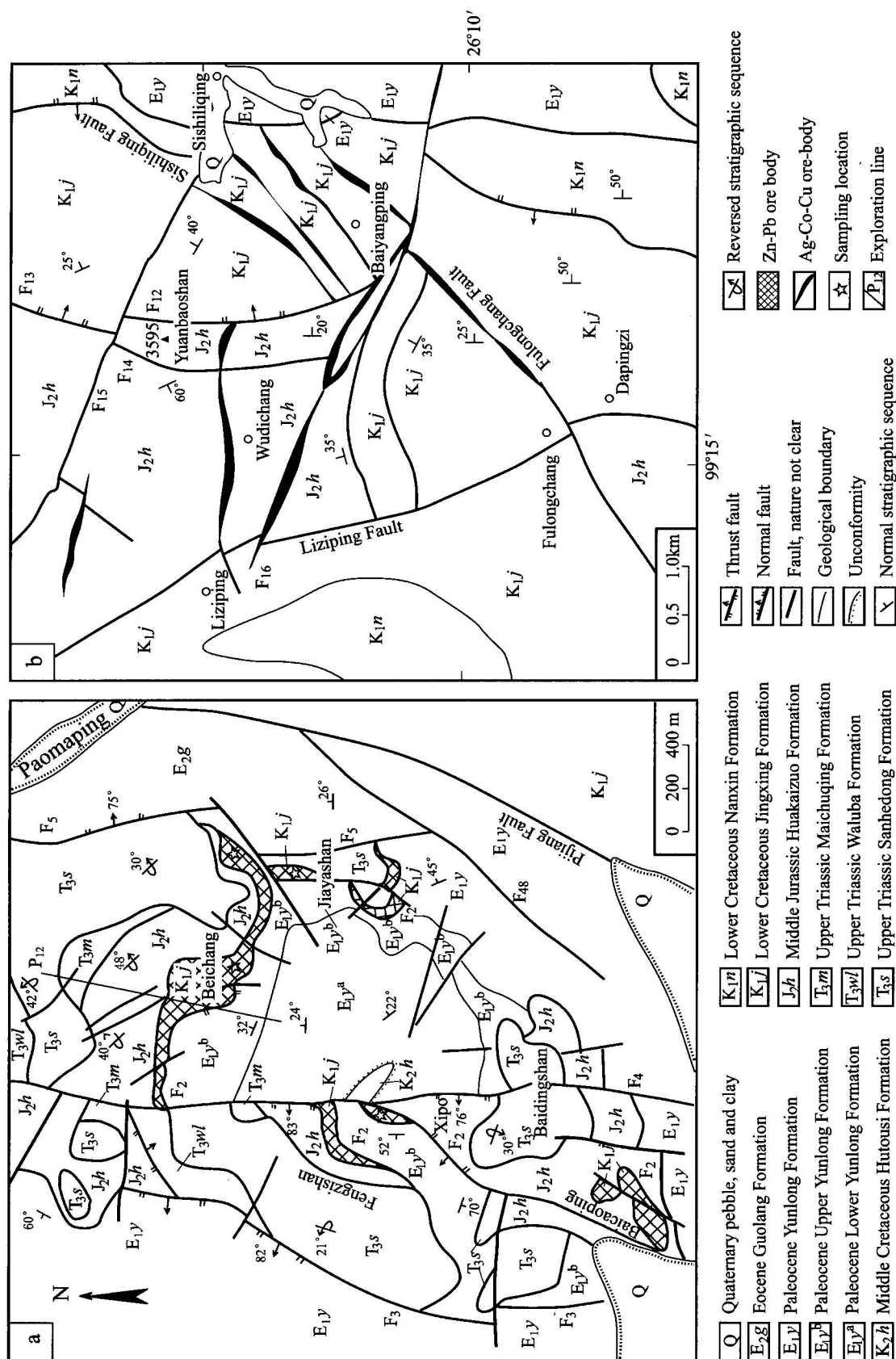


Fig. 2. Geological maps of the giant Jinding Zn-Pb deposit (a) and Baiyangping Ag-Co-Cu deposit (b), Lanping County, Yunnan.

Table 1 Basic geological features of important mineral deposits in the Lanping Basin, Yunnan

Mineral deposit	Jinding Zn-Pb Deposit	Baiyanggang Ag-Co-Cu Deposit	Jinman Cu Deposit	Baiyangchang Ag-Cu Deposit
Regional setting	Red continental basin with intense crust movements	Red continental basin with intense crust movements	Red continental basin with intense crust movements	Red continental basin with intense crust movements
Structure location	Lanping-Simao Fault zone	Lanping-Simao Fault zone	Lancangjiang Fault zone	Lanping-Simao Fault zone
Age of host rocks	Lower Cretaceous, Paleocene, Middle Jurassic	Lower Cretaceous, Middle Jurassic	Middle-Upper Jurassic	Lower-Middle Cretaceous, Upper Jurassic Paleocene
Host lithology	Fine sandstone, breccia, siltstone	Sandstone and siltstone	Fine sandstone and siltstone	Sandstone and sandy conglomerate
Organic association	Petroleum and asphalt in ores and hosts	Petroleum and asphalt in ores and hosts	Asphalt in ores	Yes (?)
Evaporate association	Close	Close	Yes, not close	Yes, close
Exhalative rock, igneous rock	No	No	No	No
Mineralization age	67 Ma (Re-Os dating) <sup>1)</sup>	62 Ma ( <sup>39</sup> Ar- <sup>40</sup> Ar dating) <sup>1)</sup>	58 Ma ( <sup>39</sup> Ar- <sup>40</sup> Ar dating) <sup>2)</sup>	Probably later than the Jinding Deposit
Orebody	Tabular, dissemination, some veins	Vein, stockwork alteration body	Vein, stockwork body	Lens, stockwork body
Alteration	Hanging-wall silicification, celestite, carbonation	Silicification, celestite and carbonation	Silicification, carbonation	Barite, carbonation
Metals	Zn, Pb, Cd, Tl, Ag, Sr, FeS <sub>2</sub>	Ag, Co, Cu, Zn, Pb, Ni	Cu, Co	Ag, Cu, Zn, Pb
Size	Zn+Pb>15 Mt, Cd 170000 t, Tl 8167 t	Ag 7336 t, Co 1892 t, Cu 530000 t	Cu 300000 t	Ag 1300 t, Cu 200000t,
Average grade	Zn 6.08%, Pb 1.29%	Ag 305.8 g/t, Co 0.074%, Cu 1.85%	Cu 2.04%	Ag 141 g/t, Cu 1.01%
Mineralogy	Sphalerite, galena, pyrite, celestite	Freibergite, cobaltite, Co-arsenotryrite	Tetrahedrite, bornite, chalcocopyrite, chalcocite	Argentite, freibergite, chalcocopyrite
Ore texture	Fine-grained, replacement, space-filling	Fine-grained, replacement, space-filling	Medium-grained, replacement, space-filling	Medium-grained, replacement, space-filling
Homogenization temperature	54C-309 °C, mainly 110-150°C	96-320°C, mainly 130-210°C	150-286°C	204-233°C <sup>3)</sup>
Mineralization depth	0.9-1.5 km	1.8-3.1 km <sup>4)</sup>	1.2-2.4 km <sup>4)</sup>	?
Salinity of ore fluid	1.6 to 18.0 wt% (NaCl) <sub>eq</sub> peak at 4.5%	3.0 to 6.4 wt% (NaCl) <sub>eq</sub> Peak at 5.7 wt% <sup>4)</sup>	7.0 to 14.4 wt% (NaCl) <sub>eq</sub> Peak at 9.6 wt%	?
Mineralization control	Thrust-dome-lithologic trap	Faults and fracture zone	Faults and fracture zone in bed	Faults and fracture zone in bed

Notes: 1) after Xue et al., 2003; 2) After Liu Jiajun (pers. comm.); 3) decrepitation temperatures; 4) after Xu and Mo, 2000

### 2.3 Basic features of mineral deposits

The basic natures of important deposits in the Lanping Basin are shown in Table 1. On the whole, the deposits occur in Mesozoic-Cenozoic sedimentary red beds and no outcropping of igneous rocks are found in the ore district, and syngenetic/sedimentary metallogenic natures have not been identified yet. The mineralization is controlled by structures and lithology, and the ore body occurs in different strata and is not stratabound. The deposit has complex metal composition and shows some relation with the organic matter (asphalt and petroleum) and evaporates (gypsum). The middle-low-temperature (110°C to 280°C) mineralization took place at the depth of about 0.9 km to 3.1 km during the early Himalayan (58 Ma to 67 Ma). If we noticed that the ore-hosting sequences contain extensive evaporates, the salinity of ore-forming fluid must be considered surprisingly low. Mineral deposits in the Lanping Basin, represented by Jinding, are unique.

### 3 Geodynamic Setting of Giant Mineral Deposits

The Lanping Basin is the northern part of the Mesozoic-Cenozoic Lanping-Simao Basin, which is tectonically situated in the Qamdo-Simao micro-plate between the Lancangjiang and Jinshajiang-Ailaoshan tectonic belts, and to the east it is linked with the Yangtze Plate, and to the west, the Tibet-Yunnan Plate (Fig. 1). The basin is a small landmass in the Paleotethys during the Proterozoic through the Early Paleozoic. The ocean disappeared at the end of the Caledonian and a stable landmass developed. The landmass rifted along the Lancangjiang and Jinshajiang belts during the Late Paleozoic, the Lanping basin was a micro-plate between the Yangtze and Tibet-Yunnan plates. The Paleotethys closed in the Late Permian or Early Triassic and the basin became a part of Laurasia. On the Paleotethys basement, the Mesozoic-Cenozoic Lanping Basin developed with marine and terrestrial carbonates, volcanic rocks, and clastic rocks, and there are several terrestrial gypsum-salt sequences and sedimentary gaps in the basin stratigraphic column. The tectonic evolution of the Lanping Basin shows the stages as a Indosinian rift basin, Yanshanian depression basin and Himalayan pull-apart basin (Xue et al., 2002a).

The main faults in the basin (Fig. 1), such as Jinshanjiang-Ailaoshan Fault, Lancangjiang Fault and Lanping-Simao Fault, cut deeply into the lower crust and upper mantle (Yin et al., 1990; Jin et al., 2003). The Lanping-Simao syn-sedimentary fault controls Tertiary basins and acted the strongest in the Cenozoic. Some blind E-W-trending structures are also recognized by remote

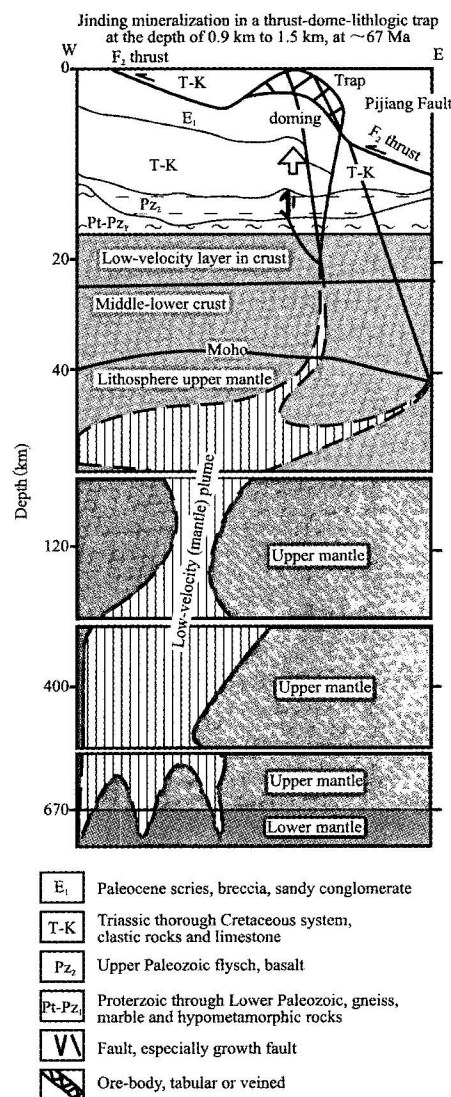


Fig. 3. Deep geodynamic setting of giant mineral deposits in the Lanping Basin, Yunnan Province, China.

(drawing according the deep geophysical data of Bian, 2000)

sensing, gravity and aeromagnetic survey (Xue et al., 2002a). According to the remote sensing interpretation, some annular structures occur at the cross of NNW- and E-W-trending structures, and this may suggest some thermal bodies or intrusive in the depth.

Magmatic rocks of the Upper Paleozoic through Cenozoic can be seen along the margin of the Lanping Basin, and Himalayan igneous rocks frequently occur also inside the basin, such as the Zaojiaochang intrusive and Xiquechang intrusive in Yunlong County, Zhuopan intrusive and Huanglianpu intrusive in Yongping County, Weishan intrusive in Weishan County. A gravity survey and remote sensing data indicate a blind Himalayan intrusive under Baicaoping in the Jinding ore district



(Zhang et al., 2000). These igneous rocks distribute along the Lanping-Simao Fault, and the lithology includes quartz syenite, beschtuite, granite-porphyry, assyntite and essexite and the volcanic rocks are alkaline basalt and trachyte. The isotope ages of these Cenozoic magmatic rocks range from 23 Ma to 68 Ma (55 age data of Rb-Sr and U-Pb dating with feldspar, mica, zircon or whole rock samples, Xue et al., 2003). Geochemical studies (e.g. initial  $^{87}\text{Sr}/^{86}\text{Sr}=0.7046$  to  $0.7084$ ) show that these Cenozoic magmatic rocks are of mantle origin, and many mantle-derived nodules have been found in these igneous rocks (Lü and Qian, 1999). These igneous rocks contain higher Pb (e.g. 119 ppm in syenite and 62 ppm in trachyte) and Zn (e.g. 110 ppm in trachyte) than the Clarke values in corresponding rocks, and the Cenozoic magma or thermal fluid, originating from the mantle in the Lanping Basin, is rich in metallogenic elements (Bian, 2000).

Deep geophysics studies on the Lanping Basin indicate that there are some lens-shaped high-temperature bodies in the crust with low velocity, which could be the magma chamber or the like. Besides, there are distinct rises of the asthenosphere up to 15 km to 20 km (Bian, 2000). Thermal metamorphism develops along the Lanping-Simao Fault zone, e.g., at Wuliangshan area, which could result from both deep faulting and heat-flow upwelling along the faults (Luo and Yang, 1994), and its age is recently determined to be 31 Ma to 24 Ma (K-Ar dating with sericite, Jue et al., 1998).

Sulfide Pb isotopic compositions of the giant Jinding Deposit suggest mantle source metal (Zhao, 1989b; Zhou and Zhou, 1992; Zhang, 1993; Zhang et al., 2002). Mantle fluid is inferred in the mineralization of the Jinding and Baiyangping deposits (Yin et al., 1990; Wang and Li, 1991; Xue et al., 2000). A  $\text{CO}_2$ -rich mantle ore-forming fluid has been found in the inclusions of the Jinding and Baiyangping deposits recently (Xue et al., 2002b). Inert gas isotope studies reveal mantle helium of about 2.0% to 32.6%, mantle neon of about 53% and considerable amount of mantle xenon in the Jinding and Baiyangping ore-forming fluid of the major ore stage (Xue et al., 2003).

Thermal springs are developed and earthquake frequently occur in the Lanping Basin now (Xue et al., 2002a). The faults that control the origination, development and evolution of the Lanping Basin still have a long-term activation.

To sum up, controlled by the India-Eurasia collision, strong deep fault activity and magmatism, turbulence and upwelling of mantle fluid, discordances in the stratigraphic column, as well as the interaction between the crust and the mantle within the continental plate, are the basic geological settings of the Lanping Basin. The basin has an obvious dynamics of mantle connection. This kind of geodynamics

is favorable for the material and power exchange to result in intense mineralization.

## 4 Conclusions

There are giant mineral deposits, including the Jinding, Baiyangping and other mineral deposits (e.g. Baiyangchang, Jinman, etc.) in the red Mesozoic-Cenozoic Lanping Basin. The giant mineral deposits are not stratabound (e.g. MVT, SST and Sedex-type) though they are hosted in sedimentary rocks. Affected by the Indian-Eurasian collision, the mantle is disturbed under the Lanping Basin. The large-scale mineralization is closely linked with the geodynamics of the crustal movement, the mantle fluid upwelling and igneous activity (Fig. 3).

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