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Time Sequence of Himalayan Endogenetic Mineralization on the East Side of the Qinghai-Tibet Plateau

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Abstract Among the endogenetic deposits in the Sanjiang area and at the west margin of the Yangtze platform, Himalayan deposits are the most important and contribute a large proportion of the resources of superlarge deposits. Among the controlled resources of this region, 84% of copper resources, 67% of Pb-Zn, 31% of Ag, 77% of gold and 24% of tin come from Himalayan deposits on the east side of the Qinghai-Tibet plateau. Himalayan endogenetic mineralization shows a relatively complete sequence evolution in the Sanjiang area and on the west margin of the Yangtze platform. Mineralization is manifested by gold deposits related to K-rich lamprophyre, REE deposits related to alkalic complexes and Cu-Au-polymetallic deposits related to alkaline porphyry. Six sequences of mineralization evolution since 65 Ma B.P. in the Sanjiang area and on the west side of the Yangtze platform can be recognized. Himalayan endogenetic mineralization on the east side of the Qinghai-Tibet plateau reached its peak before the Oligocene, corresponding to episodes I and II of the intracontinental orogenic cycle. Afterwards, mineralization waned obviously.

Key words: time sequence, Himalayan endogenetic deposits, Qinghai-Tibet plateau

1 Geological Setting

The east side of the Qinghai-Tibet Plateau refers to the drainage areas of the Nujiang, Lancang, Jinsha, Dadu and Honghe rivers, located to the west of 102°E longitude, and tectonically includes the Sanjiang (means three rivers, i.e., the Nujiang, Lancang and Jinsha rivers) fold system of the Tethys tectonic domain and the west margin of the Yangtze platform. This region is a Himalayan intracontinental orogenic belt formed by the collision of the Indian plate and the Eurasian plate. Although the Sanjiang fold system, the west margin of the Yangtze platform and the Qinghai-Tibet Plateau all underwent intracontinental deformation with the consuming of the Neo-Tethys, the tectonic features of the Sanjiang fold system and the west margin of the Yangtze platform are quite different from those of the Himalayas and the north side of the Qinghai-Tibet plateau. For example:

The Cenozoic deformation of the Sanjiang fold system and the west margin of the Yangtze platform was caused by large-scale strike slip or thrusting, different from the arc-trench-basin process and wedging nappe mechanism that is characteristic of the Himalayan collision zone, and their accretion thickness is only 1/2 to 4/5 that of the Qinghai-Tibet Plateau.

(2) The Qinghai-Tibet Plateau was folded mainly in the Miocene, while the Sanjiang area and the west margin of the Yangtze platform were intracontinentally deformed first and mainly between the middle and late Eocene and secondly at the end of the Oligocene. The Miocene tectonic stress field was rather stable.

(3) The representative igneous rocks of the Himalayan area are typical ophiolites and arc volcanic rocks of Late Cretaceous to Eogene age; while those of the Sanjiang area and the west margin of the Yangtze platform are polyphase porphyry, alkalic rocks, mantle-derived K-rich lamprophyre and so on, which are distributed linearly or as a hot-spot chain, showing a larger intensity and scope of igneous activity than in the Himalayan area (Wang Chengshan et al., 1999).

(4) The Cenozoic ultra-metamorphism and migmatization in the Himalayan area were far stronger than in the Sanjiang area and on the west margin of the Yangtze platform.

(5) The oceanic basin deposition in the Sanjiang area and on the west margin of the Yangtze platform had ended in the Late Triassic, much earlier than the forearc sedimentation and mélange accumulation of the New-Tethys in the Himalayan area. Foreland molasse formations are well developed in the above two areas; however, very thick salt-formations formed under dry and hot conditions are more characteristic of the Sanjiang area and the west margin of the Yangtze platform. Such a difference in sedimentary environment contributed different conditions for mineralization (Lou et al., 1995; Wang Liquan et al., 1999).

(6) The Himalayan intracontinental orogeny at the east side of the Qinghai-Tibet plateau originated and developed on a complex and varied basement, including stable platform basement and platform-margin, depressions as well as active spreading zones, arcs and metamorphosed terrains of the Palaeo-Tethys, showing far more diverse and stronger mineralization in the Sanjiang area and on the west margin of the Yangtze platform than in the Himalayan area and on the north side of the Qinghai-Tibet plateau (Wang Denghong et al., 1998a, 1998b; Xiao et al., 1998).

2 Time Sequence of Himalayan Endogenetic Mineralization

Based on a comprehensive analysis of tectonic episodes, magmatic-volcanic activity, metamorphism, deformation and endogenetic mineralization, six sequences of mineralization evolution since 65 Ma B.P. in the Sanjiang area and on the west side of the Yangtze platform can be distinguished. Different sequences have different features of mineralization:

Sequence 1: from Palaeocene to early Eocene (corresponding to Danian–Ypresian). It is characterized by mineralization related to crust-derived granitic magma, distributed in the Binlangjiang area on the west side of Nujiang, which evolved from the late Yanshanian and belongs to the westernmost branch of the West Yunnan-Southeast Asia tin metallogenic belt (from Tengchong in Yunnan to Puji in Thailand). There exist three super-units and eight units of granitoids, aged at 59.8–51.1 Ma. Among the deposits, large tin deposits such as the Lailishan deposit are related to biotite-K-feldspar granite of early Eocene age, and small Nb-Ta-REE deposits such as the Dayangtian and Baihuanan deposits are related to muscovite-albite granite of terminal Eocene age. Paired metamorphic belts exist on the boundary of China and Burma, where the famous jadeite deposits in Burma occur within high-pressure metamorphic belts, while the above-mentioned Sn-REE-bearing granites in Yunnan occur within a high-temperature belt.

Sequence 2: from middle Eocene to late Eocene (corresponding to Bartonian–Priabonian). It is the major episode (Episode I) of the Himalayan movement in the Sanjiang region, with strong mineralization along the Jinshajiang-Ailaoshan fault, especially in the Lanping basin. On the east margin of the Lanping basin, the superlarge Jinding Pb-Zn deposit formed under the control of the Pijiang contemporaneous fault and because of the integration of the following three special geological factors: (1) sandstone and brecciola of fluviolacustrine delta facies at the fore-slump, acting as two kinds of host rocks; (2) a huge zone of weakness between the autochthonous system (dome) and the allochthonous system (nappe-overturned anticline); (3) lacustrine sediments controlled by contemporaneous faults, with a long history of primary enrichment of ore materials leached from basement rocks by hydrothermal solution from the beginning of the Palaeocene to the mineralization peak in the Eocene.

Sequence 3: from late Eocene to Oligocene (corresponding to Priabonian–Chattian). This is the most important stage of mantle-source and mantle-crust-mixing source mineralization in the Sanjiang area and on the west margin of the Yangtze platform, and tectonically between Episode I and Episode II of the Himalayan movement. Mineralization is manifested by gold deposits related to K-rich lamprophyre, REE deposits related to alkalic complexes and Cu-Au-polymetallic deposits related to subalkaline porphyry. These deposits are concentrated spatially in the Ailaoshan, Mianning-Dechang, Zaduo-Jiangda-Mangkang and Yanyuan-Heqing-Jinping metallogenic belts respectively.

There are more than 100 hypabyssal porphyry bodies on the east side of the Qinghai-Tibet plateau, and mineralization is best developed in quartz monzoniteporphyry, monzonitic granite porphyry and orthoclase porphyry. Different rock groups show different metallogenic specialization. For example, the eastern Tibet-southern Qinghai area is dominated by copper mineralization of porphyry type and skarn type and characterized by deeply seated intrusives and large deposits; the Heqing-Chuxiong-Yanyuan area is dominated by Au-Pb-Zn deposits with subordinate Cu-Ag deposits, and characterized by medium-sized deposits; the Jinping area is characterized by small Cu-Mo deposits. Although the isotopic ages of the porphyries range from 16.5 to 67.9 Ma, mineralized rocks formed concentrated at 33–36.3 Ma (exceptionally at 41–52.76 Ma) in western Yunnan, at 32.2–34.6 Ma in western Sichuan, at 34.9–43.2 Ma (exceptionally at 43.5–57.9 Ma) in eastern Tibet, and at 33.9–49.4 Ma (exceptionally at 22 Ma) in southern Qinghai. The Yulong superlarge porphyry copper deposit in Tibet formed relatively early.

Gold deposits related to K-rich lamprophyres occur within the Ailaoshan ductile shear zone. Mineralization of this stage continued from the Indosinian (silica alteration type, Jinchang deposit in Mojiang) and Yanshanian (sericite alteration type, Kudumu in Zhenyuan), including the carbonate alteration type such as the Laowangzhai gold deposit in Zhenyuan and quartz vein type such as the Daping gold deposit in Yuanyang. The gold-bearing K-rich lamprophyre has isotope ages of 35.6–43 Ma and exceptionally may have continued to 28.21 Ma.

Alkalic complexes are distributed at Yongping, Mianning, Dechang and some other areas and host two types of REE deposits: one is disseminated-veinlet bastnaesite deposits such as the Maoniuping deposit in Mianning, which are hosted within alkali pegmatite, calcite carbonatite, and aegirine alkali granite; the other is fluorite-barite-barytocelestite bastnaesite deposits such as the Daluxiang deposit in Dechang, which are hosted within aegirine-augite syenite. Alkalic rocks and related mineralization have isotope ages of 27.8–40.3 Ma, which are the same as those of K-rich lamprophyres but relatively concentrated as compared with those of porphyries.

Sequence 4: between Oligocene and Miocene (i.e. between Chattian and Aquitanian). During this period, the Sanjiang area suffered Episode II of the Himalayan movement. The Ailaoshan and Gaoligongshan metamorphic terrains were subjected to superimposed migmatization and mylonitization, resulting in appearance of swarms of granite pegmatite dykes and quartz veins and forming top-grade gems and jades. Gems and Jades are relatively concentrated in the Honghe-Jinping area and in the Huang Lien Son area of Vietnam and dominated by ruby and sapphire of corundum type and aquamarine of beryl type. The ages of ore-bearing pegmatites are 25.6 to 28.7 Ma.

Sequence 5: Neogene (from Miocene to Pliocene, including Aquitanian and Pliocene). Different from the Himalayas where there occurred strong orogeny, the Sanjiang area and the west margin of the Yangtze platform are marked by downfaulted intermontane basins and exogenetic mineral deposits such as lignite, diatomite, kaolin and germanium deposits. Three types of endogenetic mineralization have been discriminated.

The first is large and medium-sized deposits distributed on the west and south sides of the Lanping basin, along linear thrust zones and interlayer gliding fault zones. There are many high-grade deposits with complicated compositions, such as the Baiyangping polymetallic silver deposit, Yongping Cu-Co deposit, Bijiashan Sb deposit, Zhacun gold deposit and Shihuangchang As deposit. The highest horizon of the host rocks is the Oligocene Baoxiangsi Formation but isotopic age data about the mineralization are lacking.

The second is quartz vein type gold deposits hosted by ductile shear zones, mylonitized zones and interlayer-décollement zones along the Xianshuihe fault and Jinpingshan fault, such as the Huangjinping gold deposit in Kangding and the Pusagang gold deposit in Shimian. Although many occurrences of this kind of mineralization with high grades have been found, their sizes are usually small. The isotopic ages of mineralization are 15.4–26.9 Ma.

The third type is W-Sn-polymetal-REE mineralization occurrences related to the Zheduoshan granite in Sichuan, which is dated at 9.9–15 Ma. Its strength of mineralization is far less than that of the crust-derived granite of Sequence 1.

Sequence 6: Quaternary (Pleistocene to Holocene). This is the main uplift stage of the Qinghai-Tibet plateau. During this period, tectono-magmatic activity in the Sanjiang area and on the west margin of the Yangtze platform was displayed by intermediate-basic volcanic eruptions of central type, which began from the Pliocene and clustered as hotspots. A total of 19 groups of volcanic cones and 79 modern active hot springs are distributed at Tengchong and cover an area of 724 km^2. Volcanic rocks are dominated by basalt and andesite, which can be divided into two cycles, four stages (N_2, Q_1, Q_3, and Q_4) and ten sub-stages of eruption. The only endogenetic deposit is the Lianghe gold deposit of modern hot spring type in Tengchong. Trachytes and alkalic volcanic pipes of this sequence exist in Jianchuan, Yongde, Maguan, Pingbian and other areas, but no economic deposit has been discovered now.

3 Conclusions

(1) Himalayan endogenetic mineralization shows a relatively complete sequence evolution in the Sanjiang area and on the west margin of the Yangtze platform. On the one hand, the mineralization inherited the evolution of gold deposits hosted in Indosinian and Yanshanian ductile shear zones (e.g. those in Ailaoshan) and W-Sn deposits related to crustal granites (e.g. those in Tengchong); on the other hand, some major kinds of mineralization were newly born. The most important examples are stratabound polymetallic deposits (e.g. Jinding of Lanping) formed by hydrothermal fluids within basins, porphyry Cu-Au deposits related to the mantle-crust mixing source (e.g. Yulong of Jomda) REE deposits hosted in mantle-derived alkalic rocks (e.g. Maoniuping of Mianning) gem deposits in ultra-metamorphic zones (e.g. Yuanyang).

(2) Himalayan endogenetic mineralization on the east side of the Qinghai-Tibet Plateau reached its culmination before the Oligocene, corresponding to Episodes I and II of the intracontinental orogenic cycle. Afterwards, mineralization waned obviously.

(3) The distribution of the Himalayan endogenetic metallogenetic belts was controlled by tectono-magmatic belts and the endogenetic mineral deposits are concentrated between latitudes 24° and 32° N, where the thickness of the crust is about 40 to 60 km. Most of the mineral deposits related to the mantle source and mantle-crust-mixing source just originated from an abnormal mantle with a *P*-wave velocity of 7.76–7.84 km/sec in the deep crust. An intracrustal low-velocity zone, 8–12 km thick, exists at depths of 7–21 km, with a *P*-wave velocity of 5.54–5.84 km/sec.

(4) Among the endogenetic deposits in the Sanjiang area and at the west margin of the Yangtze platform, Himalayan deposits are the most important and contribute a large proportion of the resources of superlarge deposits. Among the controlled resources of this region, 84% of copper resources come from Himalayan copper deposits, of which 64% from superlarge deposits; 67% of Pb-Zn from Himalayan Pb-Zn deposits, of which 64% from superlarge deposits, 31% of Ag from Himalayan Ag deposits, of which 10% from superlarge deposits; 77% of gold from Himalayan deposits, of which 56% from superlarge deposits; 24% of tin from Himalayan deposits but there are no superlarge deposits. So, the Himalayan endogenetic mineralization played a very important role in this region, showing a high degree of enrichment of mineralization in favourable sections of this region, i.e., the east side of the Qinghai-Tibet plateau.

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