The formation of a mantle-branch structure in western Shandong and its constraints on gold mineralization

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Abstract. On the basis of regional strata, magmatic activity, ring and radial faults, gently dipping detachments, geophysical information and isotopic age, this paper discusses the characteristics of mantle-branch structure in western Shandong. According to the characteristics of ore-control structures, gold deposits in the Luxi mantle-branch structure are divided into ductile shear zone type and detachment-slip layer type deposits. The detachment-slip layers type deposit, including the Guilaizhuang gold deposit and Mofanggou gold deposit are significant economic types. The $\delta^{34}S$ values of pyrite associated with gold mineralization exhibit a narrow range of -0.71 to 2.99‰, implying that the sulfur was probably derived from the mantle or magma, whereas the $\delta^{18}O_{fluid}$ and δD values suggest that the ore-forming fluids of the gold deposits mixed with meteoric water in the shallow level.

Keywords. Western Shandong, mantle-branch structure, gold deposits, zircon SHRIMP U-Pb dating, stable isotope

1 Introduction

The western Shandong (Luxi) region, located in the southeastern edge of the North China Craton and separated by the Tanlu fault from the Jiaodong gold province (the largest gold producing area in China) has drawn attention for its unique geological characteristics and abundant mineral resources in the last ten years (Yu, 2001; Niu et al. 2004). Although the geology has been well studied, the evolution of geology and the structural controls mineralization are still open to debate. On the basis of the setting of ore-formation and the characteristics of geochemistry, this paper discusses the formation of a mantle-branch structure in western Shandong and its constraints to the gold mineralization.

2 Characteristics of the mantle- structure in western Shandong

2.1 Occurrence of regional strata

Similar to other areas in the interior of the North China Craton, the strata of the Luxi region consist of Archean and Paleoproterozoic basement, and Meso- Neoproterozoic and Paleozoic cover strata. Regionally, they are characterized by a circulas distribution with Taian-Pingyi as a center. The center comprises a well-developed magmatic and metamorphic complex, which is surrounded by Paleozoic cover strata. This suggests an extensional tectonic setting, with the basement uplifted and the cover strata detached outwards in the Luxi region (Fig. 1).

2.2 Extensive magmatic activity

The Luxi terrane contains well developed Mesozoic mantle-derived magmatic rocks, including intrusives, potash-rich volcanics and lamprophyres. The intrusive rocks, with extensive distribution but relatively small size, are variable in lithology. According to lithological assemblages, they can be subdivided into: (1) monzodiorite porphyry– monzonite porphyry, syenite porphyry assemblage, (2) pyroxenite– monzodiorite– syenite assemblage, (3) olivine gabbro– pyroxene diorite(amphibole diorite)-quartz monzonite assemblage, (4) diorite (porphyry)-quartz monzodiorite(porphyry)- granite (porphyry) assemblage, (5) carbonatite.

Strontium and Nd isotopic compositions of Mesozoic potash-rich volcanic rocks, lamprophyres and carbonatite in Luxi and its adjacent area share similar characteristics, such as $^{87}Sr/^{86}Sr$ values of potash-rich volcanic rocks in Mengyin Basin from 0.708715 to 0.711418–ε_{Nd} from -11.47 to -17.54, ε_{Nd} of lamprophyres from -11.57 to -19.64 (Qiu et al. 2001). $^{87}Sr/^{86}Sr$ ratios of Luxi carbonatite vary from 0.70998 to 0.71048–ε_{Nd} from -14.1 to -16.7 (Chu et al., 1997;Yin et al. 2001). All higher $^{87}Sr/^{86}Sr$ ratios and lower ε_{Nd} values reflect that these rocks have the characteristics of crustal material, but potash-rich volcanic rocks and lamprophyres in the Mengyin Basin exist mantle xenoliths as chrome-diopside and chrome- phlogopite, which shows mantle genesis of these rocks.

2.3 Radial and ringed fault systems

Faults in western Shandong are generally distributed in concentric ring and radial shapes outward from the Xinzhai- Sishui- Pingyi- Mengyin area in the central part of the area. The concentric ring faults may be divided into three basically complete ring structures from the inner part outward: (1) the Feicheng-Yiyuan-Linyi-Qufu ring fault, (2) the Juye-Liangshan-Jinan-Zibo ring tectonic belt, and (3) the Matouji- Fanxian- Liaocheng-Huantai ring fault.

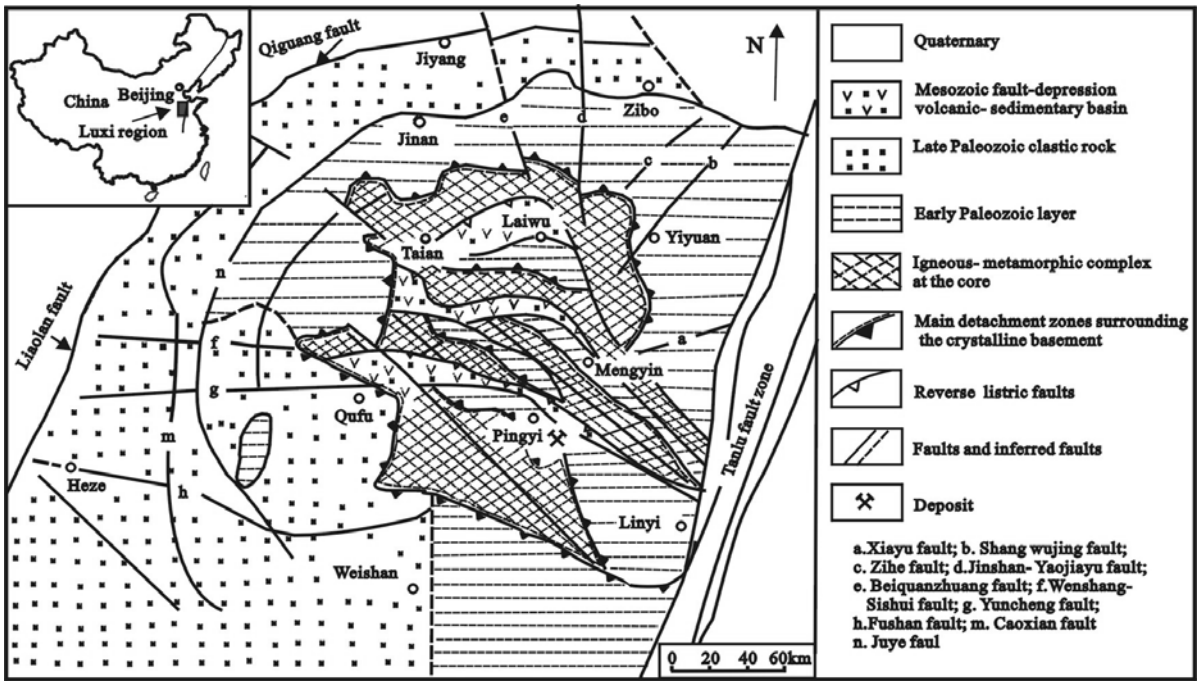

Figure 1: Tectonic sketch map of western Shandong

The radial faults comprise mainly the Nishan, Yuncheng, Wenshang- Sishui, Feicheng, Wenzu, Jinshan-Yaojiayu and Shangwujing faults. The faults generally dip steeply and show the tensile character. The intersection of the radial and concentric ring faults indicates that they are the product of the same stress field and the same tectonic phase. Generally, these radial and ringed faults occur in the early uplift of mantle-branch structure, and reflect a relatively small vertical relief of uplift.

2.4 Geophysical evidences for the Mesozoic mantle-branch structure

Three-dimensional velocity images from seismic tomography demonstrate that high-velocity blocks (Vp is more than 8.3Km/s) exist in the upper part of the mantle whose Vp is 7.8 ~ 8.0Km/s (Lu et al. 2000). A structural profile of crust-mantle from Beijing to Okinawa shows two mantle upwelling areas whose Vs is lesser than 4.2 ~ 4.3 km/s (Feng et al. 1996). They correspond to two sub-mantle plumes, one situated in the Okinawa ocean trough, and the other the North China sub- mantle plume with the Bozhong region as a center (Niu et al, 2002). The Luxi mantle-branch structure is a second-order unit of the Bozhong sub- mantle plume. Synthetic outcomes from man-made seismic exploration and geodesic electrical sounding further show that upper mantle obviously uplifts around Linyi in the Luxi mantle-branch structure.

2.5 Units of the Luxi mantle-branch structure

The mantle-branch structure — a third-order unit of a mantle plume, is a complex structure developed in shallow lithosphere during multiple evolution of mantle plume (Maruyama, 1994). The mantle-branch structure is generally composed of three units: magmatic and metamorphic complex, surrounding detachment-slip layers, and overlap fault volcanic basin, which are related each other.

2.6 Evolution of the Mesozoic mantle- branch structure

According to the ages of Mesozoic magmatic rocks, magmatic activity can be divided into two stages, one is in early Jurassic epoch, when the Tongshi alkali complex rock body formed, dated at 175.7±3.8Ma by the $^{206}Pb/^{238}U$ weighted mean age; the other is in early Cretaceous epoch, ranging from 110Ma to 130Ma, when Jinan, Guodian, Tongjin, and Laiwu rock masses formed. Statistics (n=95) from the ages of these rocks by K-Ar or $^{40}Ar/^{39}Ar$ dating show that most data cluster between 132Ma and 110Ma (Lin et al., 1996; Qiu et al., 2001). Thus, it is inferred that the activities of Mesozoic mantle-branch structure in western Shandong have two peak periods: early Jurassic epoch and early Cretaceous epoch, with the latter more extensive. This is consistent with the viewpoint that the early Cretaceous epoch represents the climax of a global mantle plume (Larson, 1991). In the light of extensive Neocene volcanism in the Bohai region (Gu et al. 2000),

the Luxi mantle-branch structure has undergone three active periods and three inactive periods since Mesozoic-Cenozoic era. This suggests that the lithosphere of eastern China has undergone a process of uplift-fallback since the Mesozoic-Cenozoic era.

3 Genesis of gold deposits in the mantle-branch structure

3.1 Types of gold deposits

There are numerous gold deposits or occurrences in the Luxi mantle-branch structure. Although the characteristics of gold deposits are different, all of them occur in two tectonic units of the Luxi mantle-branch structure (the magmatic- metamorphic complex core and detachment-slip layers). According to the characteristics of the ore-controlling structure, gold deposits in the Luxi mantle-branch structure are divided into two types, that is, ductile shear zone type and detachment-slip layer type. The former, which comprised Huamawan, Yuejiazhuang and Buwa gold deposits (or occurrences), occur along NW-trending ductile shear zone, and are temporally and spatially related to Mesozoic intrusive rocks, and the latter, including Guilaizhuang gold deposit and Mofanggou gold deposit with total gold reserves of 45 tons, constitute the main gold deposits in western Shandong.

3.2 Geochemistry of detachment-slip layer type gold deposits

$\delta^{34}S$ values of pyrite from silicified and carbonatized monzodiorite porphyry, igneous breccia and mineralized dolostone of the Guilaizhuang and Mofanggou gold deposits range from -0.71 to 2.99‰ (Lin et al. 1997), close to those of the mantle sulfur, suggesting a mantle or magma source of sulfur in the ores. The δD values of detachment-slip layer type gold deposits in western Shandong range from –48 to –70‰, and the $\delta^{18}O_{fluid}$ values of ore fluids of the Guilaizhuang gold deposit vary from –1.13‰ to +5.07‰, being notably deviated from the $\delta^{18}O_{fluid}$ range (5.5 to 9.5‰) of magmatic water, which suggest that the ore-forming fluids of the gold deposits mixed with meteoric water.

3.3 A proposed gold mineralization model

A proposed gold mineralization model is as follows. The NW-trending steeply dipping ductile shear belt cuts deep-seated pyrolite of the mantle sub- plume beneath North China, resulting in decompression to form anatectic magma. The magmatic complex was emplaced at the main detachment between Cambrian carbonate rocks and Neoarchean granodiorite or Paleoproterozoic monzogranite. The magmatic hydrothermal fluids and Au-rich ore-forming fluids migrated upward along the detachment zone and deposited gold on the ductile shear belt and detachment-slip layers.

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References

Chu T, Shen W (1997) Isotopic geochemistry of apatite from carbonatite in central Shandong. Acta Mineralogica Sinica, 17, No 1: 82-85

Feng F, Song L (1996) Mantle diapir tectonics: thermo-dynamic analysis of circum-western Pacific Basins. Earth Science, 21, No 4: 383-394

Gu L, Dai T, Fan W (2000) Mesozoic-Cenozoic volcanism and the significance of deep processes in the Bohai region. Geotectonica et Metallogenia, 24, No1: 9-17

Larson R L (1991) Latest pulse of earth, evidence for a mid-Cretaceous superplume. Geology, 19: 547-550

Lin J, Tan D, Jin Y (1996) $^{40}Ar/^{39}Ar$ ages of Mesozoic igneous activities in western Shandong. Acta Petrologica et Mineralogical, 15, No 3: 213-220

Lin J, Tan D, Yu X, Li B, Li Y, Xu W (1997) Genesis of Guilaizhuang gold deposit of western Shandong. Shandong Science and Technology press, Jinan: 1-160

Lu F, Zheng J, Li W, Chen M., Cheng Z (2000) The main evolution pattern of Phanerozoic mantle in the eastern China:the "Mushroom cloud" model. Earth Science Frontiers, 7, No. 1: 97-107

Maruyama, S (1994) Plume tectonics. Geol. Soc. Japan, 100, No.1: 24-49

Niu S, Hu H, Mao J, Sun A, Xu C, Hou Q (2004). Structure in wester Shandong and its genetic mechanism. Geology in China, 31, No.1: 34-39

Qiu J, Xu X, Luo Q (2001). Potash-rich volcanic rocks and lamprophyres in western Shandong province: ^{40}Ar-^{39}Ar dating and source tracing. Chinese Science Bulletin, 46, No.18: 1500-1508

Yin J, Zhou X (2001) Characterization of trace elements and Sr, Nd isotopes of carbonatites in the western Shandong province. Bulletin of Mineralogy, Petrology and Geochemistry, 20, No. 4: 09-314

Yu X (2001) Ore-froming series and model of Tongshi Gold field in Pingyi, Shandong province. Geology of Shandong, 17, No.3-4: 5 9-64