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Noble Gas Isotope and Silicon Isotope Trace the Crust-mantle Effect in the Ore-Forming Process: Example as Alkali-Rich Porphyry Polymetallic Depoists in Western Yunnan, China

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1 Introduction

Influenced by India-Eurasia continental subduction and collision, Sanjiang area widely developes Cenozoic magmatic activity between the west margin of Yangtze platform and the southeast margin of Qinghai-Tibet Plateau. A large number of alkaline-rich porphyry and polymetallic deposits distribute along the Jingshajiang-Ailaoshan–Honghe faults zone. There are typical ore deposits, such as, Machangqing Cu-Mo-Au deposit in Xiangyun, Beiya Pb-Au deposit in Heqing, Yaoan Pb-Ag-Au deposit in Heqing, Jinding Pb-Zn deposit in Lanping and Laowangzhai Au deposit in Zhenyuan.

The genesis of alkali-rich porphyry polymetallic deposits has been highly researched by previous authors in western Yunnan, but the ideas on genetic mechanism of these deposits are still diverse, such as rift tectonics genetic model (Zhang et al., 1987), lithospheric thickening model (Chung et al., 1998), fracture strike-slip-extension model (Lv and Qian, 2000; Hou et al., 2003) and plate subduction model (Liu et al., 2000; Hou et al., 2004). Hou et al. (2008) and Mo et al. (2009) studied and confirmed the existence of crust-mantle transition zone, suggesting that the Cenozoic shoshonite series magma was derived from crust-mantle transition zone, however, the formation mechanism of the deposits had not been given in detail. Noble gas isotope has the characteristics of stable chemical activity and low content in the geological body, and the content or the variation of noble gas isotopic composition is more sensitive than that of any other element in the geological process, so noble gas isotope is the good tracer for the origin of ore- forming fluid and the metallogenetic and petrogenetic processes (Harrison et al., 1999; Cécile et al., 2005; Sun et al., 2006; Ye et al., 2007). Furthermore, it is highly regarded that the silicon isotope analysis method is gradually applied in the geological research. It can all get a significant effect that silicon isotope analysis methods were applied to solve the cause problem of some lead-zinc deposits(Jiang et al., 1992a), the characteristics of silicon isotopic compositions was the tracer for the source of silica in Precambrian magnet quartzite with ore-bearing formations(Jiang et al., 1992b) and applied directly to the sedimentary facies analysis (Song et al., 1989). Through the research of noble gas isotope of fluid inclusions in ore minerals and silicon isotope in rock mass and vein, the author reveals the mantle fluid metasomatism and crust-mantle mixing characteristics in the course of metallogenesis of alkali-rich porphyry polymetallic deposits in western Yunnan.

2 Geologic Characteristics of Deposits

Alkali-rich porphyry polymetallic deposits are controlled by structures and developed as veins or disseminated veinlets in porphyry bodies, in sedimentary wall rocks and in the contact zones between porphyry bodies and sedimentary wall rocks in western Yunnan. The ore minerals are mainly Mo minerals, Cu-Mo minerals, Pb-Zn-Fe minerals and Au-Ag minerals, which present a series of high temperature→ low temperature metallogenic effects from rock mass→ contact zones → sedimentary wall rocks (Liu et al., 2006). Wall rock alterations of the ore deposits are mainly silication, beresitization, epidotization, chloritization and ferritization. Accompanying with intensive silicification and hematitization, skarnization develops in the carbonate part of Beiya rock. The potash alteration in alkali-rich

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porphyry mainly shows as metasomatic K-feldspathization and sericitization. Pb and Ag are mainly ore mineralized products in K-rich syenite porphyry, Cu (Mo) and Au are mainly ore mineralized products in K-rich and acidulous masanophyre-granodiorite porphyry. The relationship between alkali-rich porphyry and Au-mineralization has been studied (Zeng et al., 1999). Meanwhile, petrogenesis and metallogensis are strongly controlled by tectonism. As the first level structure, Jinshajiang-Ailaoshan deep faults are the pathway through which ore-forming materials and fluids from mantle or deep crust migrate. Secondary fold belts, intersections between faults and anticline, tectonic fissures in igneous rocks, contact zones and fracture zones of flexure between layers are ore-bearing structures in some extent. By the effect of fluids, sedimentary wall rocks can probably provide a part of minerals which are not the main source of metallogenic materials. However, alkaline-rich magma migrating upward along deep faults and ore-forming fluids accompanying with it are derived from upper mantle and are the major ore-forming material source of alkaline-rich porphyry deposits in western Yunnan.

There are four symptomatic minerals related with the petrogenesis of alkaline-rich magma and fluid effect in deposits: the primary feldspar phenocrysts in alkaline-rich magma diagenesis; the silicific quartz which is the production of silica-rich ore-forming fluids metasomatizing wall rocks in the petrogenetic process of the alkaline-rich magma; the hemimorphite which is closely associated with residual galena in the altered ore bodies of Beiya rock and may be water-rich secondary-Zn silicate minerals in the effect of silica-rich ore-forming fluids replacing original sphalerite; the uvarovitic garnet which is formed by skarnization and is the deutergenic product in Beiya rock.

3 Discussions and Conclusions

(1) In western Yunnan, He-isotope compositions in fluid inclusions vary widely. $^{3}He/^{4}He$ ratios vary mainly in the range of 0.1608~3.47Ra and are much higher than the crustal eigenvalue but slightly lower than the mantle eigenvalue, which indicates that He-isotope compositions have the characteristics of crust-mantle transition or crust-mantle mixing.

(2) In the research area, Ne-isotope compositions of fluid inclusions vary also widely. $^{20}Ne/^{22}Ne$ ratios are mainly in the range of 9.816~12.64 which is higher than the Ne-isotope compositions of the crust and those of the saturated atmosphere but closer to those of mantle fluids; $^{21}Ne/^{22}Ne$ values change in the range of 0.0267~0.0481which is significantly lower than the Ne-isotope compositions of the saturated atmosphere and the crust but closer to those of the mantle. It indicates that mineral inclusions are significantly effected by crustal fluids or groundwater in the process of formation.

(3) $^{40}Ar/^{36}Ar$ ratios of fluid inclusions vary from 307.5 to 681.7 $^{38}Ar/^{36}Ar$ ratios vary in the range of 0.1769 ~ 0.2132; they are higher than Air ratio but lower than MORB ratio, which shows that Ar in mantle fluids is more easily to be mixed with crust and groundwater.

(4) Xe-isotope compositions of fluid inclusions in western Yunnan vary widely. $^{128\sim136}Xe/^{130}Xe$ ratios of most samples are higher than air ratio or closer to air ratio, which indicates that Xe-isotopes are surplus compared with air ratio. ^{129}Xe excess and ^{136}Xe excess both reflect that the ore-forming fluids in western Yunnan contain Xe from mantle.

(5) $\delta^{30}Si$ values of silicon-rich ore-forming fluids vary in the range of -2.4‰~ -0.1‰, the silicon isotopic compositions have the negative characteristics with little isotope kinetic fractionation and have the nature of original mantle fluids; While $\delta^{30}Si$ values of alkali-rich porphyry range from 0.0‰ to 0.4‰ and are different from lunar rock's and meteorite's, the silicon isotopic compositions have positive characteristics with drastic isotope kinetic fractionation, which reflects that there exists alkali-rich porphyry derived from the metasomatic enriched mantle and silicon-rich ore-forming fluids derived from the original mantle source area. Silicon-rich ore-forming fluids metasomatize alkali-rich porphyry and wall rocks accompanying the petrogenetic process of alkali-rich magma, which is the fact that mantle fluid metasomatism is a continuation of mineralization in crust.

Noble gas isotope compositions of fluid inclusions and silicon isotope compositions of minerals relating to mineralization and rocks as mentioned above show that the ore-bearing fluids have a mantle-derived characteristics and a strong crustal fluid or material mixing characteristics in western Yunnan and the ore-forming materials of polymetallic deposits are mainly derived from differentiation products of enriched mantle formed by mantle metasomatism. These products are silicon-rich ore-forming fluids and alkali-rich magma, which carried ore-forming materials into crust along deep faults and mixed with rocks accompanying with silicon-rich ore-forming fluids replacing alkali-rich porphyry and the wall rocks in the course of alkali-rich magmatism. It is this fluid effect that plays an important role in Cenozoic large-super large polymetallic deposits in western Yunnan, China.

Key words: Noble gas isotope, Silicon isotope, Crust-mantle mixing, Mantle-fluid effect, Alkali-rich porphyry polymetallic deposits, Western Yunnan

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