1 Introduction

The SinoProbe, a deep exploration and multidisciplinary earth science research program in China, has successfully conducted scientific deep (2012 m length) drilling, named ZK01 in the Zhuanqiao district of the Luzong Basin (holes point coordinate: 117° 28′ 45.47″ E, 31° 0′ 4.09″ N). Scientific deep drilling named ZK01 of Zhuanqiao lies in the centre of Luzong Basin, 15 km east of Huangmeijian Pluton. Thorium and uranium mineralization is found in the first place in syenite-monzonite at 1.5~1.9 Km depth of ZK01.

Recently, a large amount of geophysical and geological work has referred to the presence of large syenite-monzonite intrusions at depth of Luzong basin (Lu et al. 2013), which Zhang et al. (2010) proposed are related to iron mineralization. The Luzong OCA has attracted geologists’ and mineralogists’ attention again in regard to the petrogenesis and mineralization associated with widely existed syenites. However, syenites and related mineralization are still poorly understood.

2 Petrology and Alteration Characteristic

The drill core from the ZK01 can be divided into 4 parts from the top to bottom: (1) the Quaternary gravels (0~17m) belonging to Lower Cretaceous Zhuanqiao Formation, clasts mainly composed of trachyandesite, (2) volcanic-sedimentary rocks of Zhuanqiao Formation (17~1488 m) mainly including trachyandesite and pyroxene-trachyandesite, (3) syenite (1488~1848m), and (4) monzonite (1848~2011.95m).

Alterations associated with uranium and thorium mineralization are the albitionization, tourmalinization, anhydrite and other high-temperature hydrothermal alteration. According to the alteration and mineralization assemblage, mineralization can be divided into five stages, i.e. anhydrite-tourmaline veins at stage I, uranium-thorium mineralization at stage II, magnetite mineralization at stage III, sulfide-sulphate stage IV, and quartz-calcite-sulphide at stage V. Uranium and thorium mineralization was found at stage II and III. The results indicated that thorium and uranium have two occurrences in the deposit, including independent thorium minerals, isomorphic form existing in uranium minerals, and micro-isomorphic form lying in accessory minerals. Independent uranium and thorium minerals occur as the euhedral crystal within albite, and often associated with zircon in space, or are dispersed in rutile, apatite, anhydrite and other hydrothermal alteration minerals as fine particles.

3 Geochemistry and Chronology

Trachyandesite (131.29 ± 0.85 Ma), syenite (130.95 ± 0.56 Ma) and monzonite (130.88 ± 0.41 Ma) from ZK01 form almost at the same time, which were emplaced slightly earlier than the A-type intrusions. The $\varepsilon$Hf(t) values of trachyandesite, syenite and monzonite range from -12.9 to -7.6, from -10.1 to -6.5, and from -11.1 to -3.4, respectively, which suggest that igneous rocks in ZK01 were derived from enriched mantle with heavy contaminated by continental material.

Major and trace elements suggest these igneous rocks in ZK01 are characterized by high content of potassium (K2O averaged at 3.7%), rich alkali (K2O+Na2O averaged at 8.4%) and LREE and depleted strong incompatible elements, and belongs to shoshonite series. Weak negative Eu anomalies that the values of Eu/Eu* are 0.63~1.28 in syenites and 0.74~0.88 in monzonites characterize the deep rocks, whereas a larger range with more significant negative Eu anomalies (Eu/Eu* values of 0.26~1.24) is present in A-type granites, suggesting A-type granites are more fractioned in plagioclase. Based on these mineralogical and geochemical characteristics, we conclude that deep rock is a fractionated I-type granite.

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4 Fluid Inclusions

Three types of fluid inclusions including liquid-rich (I), gas-rich (II) and daughter mineral-bearing (III) fluid inclusions, respectively, have been observed. The daughter minerals mainly include halite and sylvite. The fluid inclusions of stage I are characterized by high temperatures (540–560°C at Peak) and low to high salinity (65–70% and 0–5% NaCl eq. at Peak). The fluid inclusions of stage II exhibit medium to high temperatures (320–340°C at peak) and low to high salinity (0–5% NaCl eq. at peak). The fluid inclusions of stage III have medium temperatures (380–400°C at peak) and medium to high salinity (0–5% NaCl eq. at peak). The fluid inclusions of stage IV have medium temperatures (240–260°C at peak) and medium to high salinity (0–5% NaCl eq. at peak). The fluid inclusions of stage V have medium temperatures (160–180°C at Peak) and medium to high salinity (0–5% NaCl eq. at peak). Boiling are occurred in fluid evolution repeatedly, which cause the change of physical and chemical state that change may be one of the major factors leading to migration and mineral precipitation.

5 Genesis and Prospecting

The characteristic of mineralization, alteration and fluid inclusions reveal a high temperature mineralization style of uraninite deposits when it was in the basin deep rock. Combined with those of uranium deposits (occurrences) nearby, two phases of mineralizations at least have been recognized in Luzong basin. The first phase was alkalic metasomatic type mineralization and the second was fluorite-hydromuscovite type mineralization. Uranium mineralization might be a typical volcanic-subvolcanic hydrothermal uranium deposits associated with Mesozoic volcanic activity.

Recently, geophysical work reveals the presence of large syenite and monzonite intrusions at depth in the Luzong basin (Dong et al. 2011). With the discovery of the Nihe large Fe-S deposit at a depth of over 700 m (Lu et al. 2013) and iron deposits are discovered in the 900–1400m depth or deeper in the southwest of Luohoe deposit, more and more works have given a strong evidence that deep rocks have enormous mineral potential. Syenite-monzonite with magnetite veins are also found in 500m depth of Longqiao iron deposit, 300 m depth of Luohoe iron deposit and 500m depth of Hejia-Xiaoling pyrite deposit. Zhang et al proposed that volcanic and deep magmatic rocks, and ore-formations, portray a vertical zoning in the basin (Zhang et al. 2010). The volcanic and sub-volcanic rocks are present in the upper part (Zhang et al. 2010). In the lower part, gabbro-monzonite-syenite complex rocks occur, which means beneath the volcanic-sedimentary layer there is a series of high-temperature alteration pyroxenite and anhydrite rocks (Zhang et al. 2010), which share the same character with the uranium and thorium mineralization in ZK01.

Moreover, comprehensive interpretation of seismic reflection characteristics, electric differences, gravity and magnetic anomalies shows that a “mantle uplift” exists right beneath the Middle–Lower Yangtze (or Changjiang) River Valley metallogenic belt (Dong et al. 2011) and the NNE- to NE-striking Tanlu fault system is considered to be the basin-controlling structure providing the channel for mantle fluid migration and magma upwelling (Dong et al. 2011). One of the most typical faults is the Luohe fault in the Luzong volcanic OCA (Dong et al. 2011). The Luohe fault, located at the northwestern margin of the Luzong basin, dips to the southeast and cuts through the MOHO at depth (Dong et al. 2011), controlling the distribution of volcanic rocks in the Early Cretaceous, and playing a vital role as the channel of mantle-fluid migration and magma upwelling at depth in the Luzong volcanic basin. We suggest that both iron and uranium mineralization can derived from deep resource from the magma, most likely resulting from the partial melting of an alkali basalt along the Luohe fault. The deep and centre of Luzong Basin might exist prospecting potential of thorium and uranium.

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References

