Direct evidence for the source of uranium in the Baiyanghe deposit from accessory mineral alteration in the Yangzhuang granite porphyry, Xinjiang Province, northwest China

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ABSTRACT

Circumstantial evidence for the sources of uranium in ore deposits may be drawn from the study of deposit geochemistry and mineralogy. However, direct evidence supporting uranium leaching from source rocks has rarely been found. This study investigates the source of uranium in the Baiyanghe deposit in the Xiemisitai Mountains, northwest China. The main uranium ore bodies occur as fracture-fillings along contact zones between the Yangzhuang granite porphyry and the Devonian volcanic rocks. Zircon, thorite, columbite-(Mn), and bastnäsite are the dominant accessory minerals that host uranium in the granite porphyry. In situ columbite-(Mn) LA-ICP-MS U-Pb dating yields a weighted mean 206Pb/238U age of 310 ± 4 Ma, suggesting that the Yangzhuang granite porphyry was emplaced during the Late Carboniferous. Backscattered electron (BSE) images reveal that various degrees of alteration of these same accessory minerals may be observed in the granite porphyry, and the altered domains of these minerals have lower BSE intensities compared to the unaltered domains. Results indicate that the altered domains of zircon grains have lower concentrations of Zr, Si, and U, and higher concentrations of Y, Fe, Ca, and P relative to the unaltered domains, and the altered domains of columbite-(Mn) grains are enriched in Ti and Fe and are depleted in Nb, Ta, Mn, U, and Zr. The altered domains of thorite grains have higher concentrations of Zr, Fe, Ca, Nb, and P, and lower Th and U compared to those of the relict domains. The petrochemical data indicate that the granite porphyry experienced losses in U, Be, F, Ba, Sr, Pb, Zr, Mo, Nb, Ta, and Hf during alteration. These results suggest that the past-magmatic hydrothermal fluids might be responsible for the mobilization of uranium form minerals in the granite porphyry. It is concluded that U-bearing accessory minerals in the granite porphyry were the primary source of uranium, and that post-magmatic hydrothermal processes caused remobilization and significant localized enrichment of the uranium to form high-grade ores as fracture-fillings along its contacts.

Keywords: U-bearing accessory minerals, hydrothermal alteration, element maps, uranium source, Yangzhuang granite porphyry, Baiyanghe volcanic deposit

INTRODUCTION

Uranium deposits may be divided into diverse types (i.e., sandstone, vein, volcanic, unconformity, metasomatic, and phosphorite) based on the sources and the environment of formation for uranium ore minerals (Dahlkamp 1993). However, the majority of deposits are of post-magmatic hydrothermal origin (Cuney and Kyser 2008; Hu et al. 2008; Nash 2010; Cuney 2014). In many examples of secondary-enrichment researchers have proposed regions (or rocks) that may represent the sources of uranium in the deposits, but much of the evidence is circumstantial and based on the deposit geochemistry and mineralogy (e.g., Cuney and Mathieu 2000; Hecht and Cuney 2000; Mathieu et al. 2001; Chabiron et al. 2003; Tartèse et al. 2013; Christiansen et al. 2015; Bonnetti et al. 2017). Few studies provide direct evidence supporting uranium leaching from minerals in the source rocks (e.g., McGlone et al. 2016). In granitoids, uranium is mainly hosted in accessory phases such as uraninite, zircon, thorite, allanite, and monazite (Page 1982; Cuney and Friedrich 1987; Bea 1996; Förster 1999; Cuney 2009, 2014). Therefore, microscale leaching of uranium from primary U-bearing phases may be a key step in the formation of hydrothermal uranium deposits (Nasdala et al. 2010; Seydoux-Guillaume et al. 2015; McGlone et al. 2016).

The Baiyanghe deposit, located in the Xiemisitai Mountains, northwest China (Fig. 1), is the largest volcanogenic beryllium deposit in Asia (Li et al. 2015) and provides an opportunity to investigate the source of uranium in ore deposits. In the Baiyanghe deposit, a series of uranium occurrences are spatially but not temporally associated with the Yangzhuang granite porphyry (Fig. 2a, Ma et al. 2010; Li et al. 2015; Zhang et al. 2019). The uranium-beryllium ore bodies mainly occur as fracture-fillings along contact zones between the Yangzhuang granite porphyry and the Devonian volcanic rocks (Wang et al. 2012; Li et al. 2015). The Yangzhuang granite porphyry formed...