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Mineralogy, geochemistry and ore genesis of the Dawan uranium deposit in southern Hunan Province, South China

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ABSTRACT

The Dawan deposit in southern Hunan Province is one of the large-scale metasedimentary rock-hosted uranium deposits in China. Uranium orebodies occur mainly as big vein type and disseminated veinlet type, and are chiefly hosted within the Cambrian metasedimentary rocks, but some small ore veins can extend into the Jurassic Jinjiling granites. The dominant uranium ore minerals include pitchblende and coffinite. Coffinite often replaces and rims the pre-existing pyrite, and pitchblende occurs as veinlets and disseminated grains filled the fracture zones of metasedimentary rocks. It is suggested that the coffinite was most likely formed by initial reduction of U^{6+} to U^{4+} by pyrite from an oxidized Si-rich fluid at an early mineralization stage, whereas the pitchblende may have formed at a later stage in a relatively reduced and Si-poor fluid. Chlorite alteration is widespread and is inter-grown with pitchblende in ores. Electron microprobe analysis reveals that the chlorite belongs to Mg-rich clinochlore, which is different to the Fe-rich chlorite in most granite-hosted and volcanic rock-hosted uranium deposits in South China. The hydrothermal alteration temperatures were estimated to be 189–227 °C according to chlorite geothermometer. The ores show similar trace element characteristics to those of metasedimentary wall-rocks, but different from those of the Jinjiling granites. Negative Ce anomalies of the ores indicate an oxidized hydrothermal fluid, which was most likely derived from circulated meteoric water. The $\varepsilon_{Nd}(t)$ values of the ores are lower than those of the Jinjiling granites, but fall into the range of the basement strata. Sulfur isotopic compositions of hydrothermal pyrites vary from −9.5‰ to −7.7‰, similar to those from the wall-rocks, which implies that the sulfur in ore-forming fluids was mainly derived from diagenetic sulfur in the sedimentary strata. Pyrite in ores shows highly radiogenic lead isotopic compositions ($^{206}Pb/^{204}Pb$ = 19.684–89.234 and $^{207}Pb/^{204}Pb$ = 15.722–19.683). In a plot of $^{206}Pb/^{204}Pb$ vs. $^{207}Pb/^{204}Pb$, the data show a good linear array and yield an isochron age of 479 ± 69 Ma (MSWD = 1.6), which is much older than the granites but relatively close to the age of the host metasedimentary strata, indicating that the uranium source was probably derived from the wall-rock strata. It is suggested that the Dawan deposit is a hydrothermally reworked uranium deposit (referred to as the carbonaceous-siliceous-pelitic rock type by many Chinese geologists) with a close relationship with the host metasedimentary rocks. The Dawan deposit has no genetic relationship to the Jinjiling granite, contrary to what was previously suggested, and therefore the exploration in this area should focus on the conjunct occurrence of the Cambrian metasedimentary rocks rich in organic carbon and pyrite and the tectonic faulting which fractured and brecciated the strata.

1. Introduction

South China is rich in vein-type hydrothermal uranium deposits, which have provided the major sources of uranium for the country in the past several decades. These deposits are hosted by three types of rocks: granitic, volcanic, and carbonaceous-siliceous-pelitic sedimentary rocks. The ages of the host rocks are highly variable, mostly ranging from Precambrian to Jurassic, but the main uranium mineralization ages are Cretaceous to Tertiary (see reviews by Min, 1995; Hu et al., 2008). Hu et al. (2008) proposed a genetic model for these vein-type uranium deposits in South China, in which formation of the veins was suggested to be related to Cretaceous–Tertiary crustal extension and associated magmatism. However, many aspects of the genesis of these uranium deposits in South China remain unresolved, especially for the origin of the ore-forming fluids, the uranium sources and the mineralization processes. The ore-forming fluids can be of various types including connate, diagenetic brines, meteoric waters, and mantle-derived fluids (Beijing Institute of Uranium Geology, 1982; Deng et al., 2003; Derome et al., 2005; Du, 1982; Du and Wang, 1984; Hu et al., 2008, 2009; Jiang et al., 2006; Ling, 2011; Mercadier et al., 2012; Min, 1995; Pal et al., 2010;

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Richard et al., 2011; Skirrow et al., 2009; Wang and Liu, 1987). The uranium in the ore-forming fluids of the uranium deposits in South China can be extracted from granites, volcanic rocks and sedimentary rocks (Hu et al., 1993, 2008; Min, 1995; Min et al., 1999; Wang and Liu, 1987; Zhang and Zhang, 1991; Zhang et al., 2003; Zhao et al., 2011), and deposition of the uranium minerals may be caused by changes in Eh, pH, pressure and temperature (Beijing Institute of Uranium Geology, 1982; Zhang and Zhang, 1991; Zheng et al., 1986, 1996). Thus, detailed geology and geochemistry studies on individual deposits are needed in order to evaluate ore genesis and to guide further exploration of uranium deposits in South China.

The Dawan uranium deposit is one of the large-scale deposits in South China, with >3000 t uranium resources. This deposit is located in Lanshan Country, southern Hunan Province, South China. Orebodies are hosted by Cambrian metasedimentary rocks and can be classified into the carbonaceous-siliceous-pelitic rock type uranium deposits (Min, 1995). The deposit is also located close to the Jurassic Jinjiling A-type granites, which have obviously higher U contents (8–16 ppm, Fu et al., 2005) than the average upper continental crust (2.7 ppm, Rudnick and Gao, 2003). Therefore, some researchers suggested that the uranium mineralization might have a genetic relationship to the Jinjiling granites (China Nuclear Geological Bureau, 2005; Yang, 2011). Previous and on-going explorations have mainly been carried out along the boundary of the granitic body with country sedimentary rocks. A lot of studies have focused on geochemistry and petrogenesis of the Jinjiling granites (Fu et al., 2004, 2005; Huang et al., 2011; Jiang et al., 2009; Zhang et al., 2001). The ore genesis and mineralization processes of the Dawan deposit, however, are poorly understood. The mineralization age (~80 Ma, China Nuclear Geological Bureau, 2005) is obviously younger than the emplacement age of the Jinjiling granites (~156 Ma, Fu et al., 2004). What effects did the metasedimentary strata and the Jinjiling granites have in the ore formation? In this paper, we present mineral compositions, trace element concentrations and Nd–Sr–S–Pb isotopic data for the ores and host rocks in the Dawan deposit. The aim of this study is to constrain the sources of uranium and mineralization processes and to establish the genetic model of this deposit. This approach will be used to guide on-going exploration in this area.

2. Geological settings

The Dawan uranium deposit is located south-west of and adjacent to the Jinjiling granites (a part of the Jiuyishan batholith). The Jiuyishan is a composite granitic batholith, with a total outcrop area of more than 1300 km^2, and is composed of Devonian Xuehuading granites, Jurassic Jinjiling and Shaziling granites and Jurassic Xishan granitic intrusive and volcanic complex (Fig. 1). The Jiuyishan batholith is located in the western part of the Nanling Mountain Region, which contains abundant Mesozoic granites and the most important W–Sn, Nb–Ta and U deposits in South China.

The Jinjiling granitic body has an outcrop area of 390 km^2. It was emplaced into Neoproterozoic Sinian and Cambrian metamorphic rocks at 153–156 Ma (zircon U–Pb dating, Fu et al., 2004; Huang et al., 2011). The Jinjiling granites consist mainly of syeno-granite and alkali-feldspar granite with alkali feldspar (46–57%), plagioclase (2–16%), quartz (31–42%) and biotite (3–7%). Recently, the Jinjiling granites have been considered as A-type granite (Fu et al., 2005; Huang et al., 2011; Jiang et al., 2009) and were probably generated by partial melting of granulitized Paleo-proterozoic metamorphic basement in the lower crust (Huang et al., 2011; Jiang et al., 2009). U contents of the Jinjiling granites vary from 8–16 ppm (Fu et al., 2005; Jiang et al., 2009), about 3–5 times higher than the average upper continental crust (2.7 ppm, Rudnick and Gao, 2003).

The studied area is located in the Cathaysian Block. The basement of the southern Hunan consists of the Paleo- to Meso-proterozoic metamorphic rocks. The basement was overlain by the Neoproteozoic to

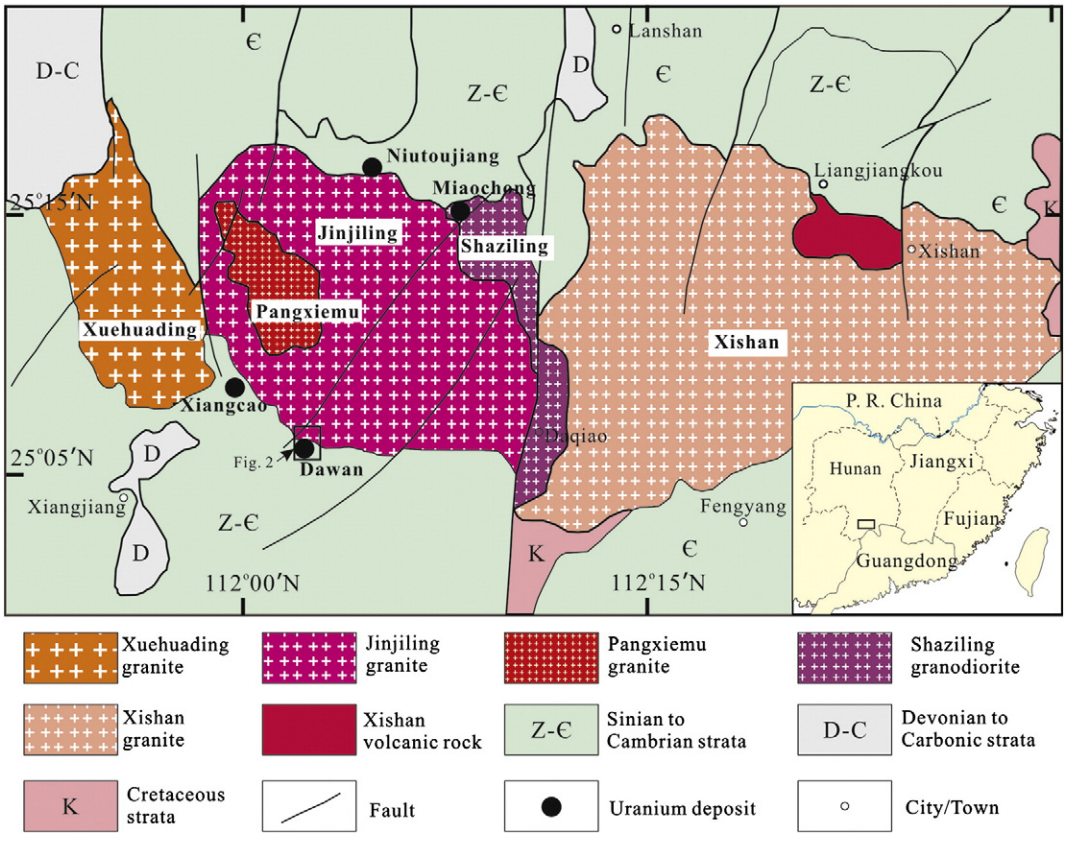

Fig. 1. Simplified geological map of the Jinjiling granites and the Dawan uranium deposit.