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Zircon U–Pb and molybdenite Re–Os dating of the Chalukou porphyry Mo deposit in the northern Great Xing'an Range, China and its geological significance

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ABSTRACT

The newly discovered Chalukou giant porphyry Mo deposit, located in the northern Great Xing'an Range, is the biggest Mo deposit in northeast China. The Chalukou Mo deposit occurs in an intermediate-acid complex and Jurassic volcano-sedimentary rocks, of which granite porphyry, quartz porphyry, and fine-grained granite are closely associated with Mo mineralization. However, the ages of the igneous rocks and Mo mineralization are poorly constrained. In this paper, we report precise in situ LA-ICP-MS zircon U–Pb dates for the monzogranite, granite porphyry, quartz porphyry, fine grained granite, rhyolite porphyry, diorite porphyry, and andesite porphyry in the Chalukou deposit, corresponding with ages of 162 ± 2 Ma, 149 ± 5 Ma, 148 ± 2 Ma, 148 ± 1 Ma, 137 ± 3 Ma, 133 ± 2 Ma, and 132 ± 2 Ma, respectively. Analyses of six molybdenite samples yielded a Re–Os isochron age of 148 ± 1 Ma. These data indicate that the sequence of the magmatic activity in the Chalukou deposit ranges from Jurassic volcano-sedimentary rocks and monzogranite, through late Jurassic granite porphyry, quartz porphyry, and fine-grained granite, to early Cretaceous rhyolite porphyry, diorite porphyry, and andesite porphyry. The Chalukou porphyry Mo deposit was formed in the late Jurassic, and occurred in a transitional tectonic setting from compression to extension caused by subduction of the Paleo-Pacific oceanic plate.

1. Introduction

The Great Xing'an Range area is located on the southern margin of the Siberia Plate, a region with strong superposition of the Paleozoic Paleoasian tectonic-metallogenic domain and the Mesozoic Western Pacific marginal tectonic-metallogenic domain. Most deposits found to date are closely associated with the Mesozoic magmatic hydrothermal activity, and the deposit types are mainly porphyry, skarn, hydrothermal veins, and epithermal deposits (Zhao and Zhang, 1997; Liu et al., 2004; Chen et al., 2007). The Mesozoic granite and volcanic rocks are widely distributed in the Great Xing'an Range (Sengör and Natal'in, 1996). The degree of exploration is relatively high in the southern segment of the Great Xing'an Range, with Pb–Zn, Ag, Cu, Sn, and rare earth element (REE) deposits. Several large mineral deposits have been discovered, including the Dajin polymetallic tin deposit (Chu et al., 2002), Huanggang Fe–Sn deposit (Zhou et al., 2010), Bairendaba Ag–Pb–Zn deposit (Liu et al., 2010a), and Baerzhe REE deposit (Niu et al., 2008). Large deposits discovered in the Manzhouli area of the northern segment include the Wunugetushan Cu–Mo deposit (Qin et al., 1999; Li et al., 2007), Jiawula Ag–Pb–Zn deposit (Zhai et al., 2010), Chaganbulagen Ag–Pb–Zn deposit (Wu et al., 2010), and Erentaolegai Ag–Mn deposit (Wu et al., 2010). Overall, a few large or medium deposits have been discovered in the majority of the northern segment, and the mineralization age of the Duobaoshan porphyry Cu–Mo deposit discovered in the 1950s is Early Paleozoic (Liu et al., 2010b, 2012). The scale and number of deposits found in the northern segment of the Great Xing'an Range are far less than those of the southern segment. For a long time, this area was primarily exploited for hydrothermal vein-type Pb–Zn–Ag deposits and epithermal Au deposits. However, the discovery of the Chalukou giant Mo deposit indicates that this area has a strong potential for porphyry molybdenum mineralization. The Chalukou porphyry Mo deposit was discovered in 2005, and the explored industrial Mo resource is about 1.78 Mt with an average grade of 0.09%; the resource of marginal Mo ore is 0.68 Mt with an average grade of 0.05%; the Pb + Zn is about 0.37 Mt with an average grade of 1.27%; and the amount of associated Ag is about 814 t with an average grade of 2 g/t (JMIC, 2010, 2011). Update, the Chalukou giant porphyry Mo deposit is the largest Mo deposit in northeast China.

The current research of the Chalukou deposit is only limited to descriptions of the geological features, such as scale,

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mineralization type, orebody morphology (Lü et al., 2010; Liu et al., 2011). Re–Os isotopic dating of eight molybdenite samples yielded an isochron age of 147 Ma (Nie et al., 2011). The mineralization of the Chalukou Mo deposit is proposed to be related to an intermediate-acid complex in the area, but there is a gap in the published research concerning the age of intrusive and subvolcanic rocks for different periods. Based on observation and analysis of the relationship between the orebodies of the Chalukou deposit and the related porphyry and all types of wall-rocks, this study selected intrusive and subvolcanic rocks of the Chalukou deposit for the LA-ICP-MS (Laser Ablation Multicollector inductively Coupled Plasma Mass Spectrometry) zircon U–Pb dating, and dated the related ores with molybdenite Re–Os method so as to eliminate the rock- and ore-forming age framework and integrate the mineralization with its corresponding tectonic setting.

2. Geological setting

The Xing'an–Mongolia orogenic belt, which is east of the Paleoasian or Central Asian orogenic belt and between the Siberia Craton and the North China Craton, is composed of a series of micro-continental blocks (Sengör et al., 1993; Jahn et al., 2000; Jahn, 2004; Li, 2006; Wu et al., 2012). The Xing'an–Mongolia orogenic belt and the southern North China Craton are separated by the Chifeng-Kaiyuan fault. The Tayuan-Xiguitu, Hegenshan-Heihe, and Jiamusi-Mudanjiang faults separate the Xing'an–Mongolia orogenic belt from northwest to southeast into the Argun, Xing'an, Songliao, and Jiamusi blocks (Wu et al., 2007)(Fig. 1a). Located mainly on the Xing'an and Argun blocks, the Great Xing'an Range area is known for large outcropping Mesozoic granite and volcanic rocks (Fan et al., 2003; Ge et al., 2005a, 2007; Wang et al., 2006; Zhang et al., 2008) and is divided into southern and northern segments with the border at N47°20′ (Zhao et al., 1989)(Fig. 1b).

During the Phanerozoic, northeastern China underwent a complex history, highlighted by multiple stages of accretion and collision, although the time and manner of the amalgamation of the micro-continents still remains controversial (Zhang et al., 2010). Studies on the Early Ordovician post-collisional granite and ophiolite suite distributed along the Tayuan-Xiguitu fault suggest the Xing'an block collided and merged with the Argun block along the Tayuan-Xiguitu fault in the Early Paleozoic (Yan et al., 1989; Zhang and Tang, 1989; Li, 1991; Ge et al., 2005b), and the Songliao block merged with the mentioned joint block along the Hegenshan-Heihe fault in the Late Devonian-Early Carboniferous age (Hong et al., 1994; Chen et al., 2000; Sun et al., 2001; Wu et al., 2002; Zhou et al., 2005). In the Late Paleozoic, massive extension activity seems to have occurred in this area (Tang, 1990). In the Early Mesozoic, the Jiamusi block merged with the composite block inside the Xing'an–Mongolia orogenic belt along the Mudanjiang fault (Ge et al., 2005a, 2007).

The strata outcropped in the northern area of the Great Xing'an Range are mainly as metamorphic rocks in the Paleoproterozoic Xinghuadukou Group, which constitutes the Precambrian crystalline basement; shallow metamorphic rocks in the Neoproterozoic Jiageda Group; the Cambrian, Ordovician, Silurian, Devonian, Carboniferous, and Permian clastic and carbonate rocks in Paleozoic cover sequence; the Jurassic, Cretaceous volcaniclastic rocks and a coal-bearing seams. The intrusive rocks in the area were mainly formed in the late Paleozoic and Mesozoic with a small amount in the early Paleozoic. Early Paleozoic magmatic activity mainly occurred in the Mohe, Tahe, and Duobaoshan area of Nenjiang County (Ge et al., 2005b; Wu et al., 2005, 2012; Liu et al., 2012). Basic-ultrabasic rocks were mainly formed in the Late Paleozoic and mostly developed along the boundaries between the blocks. Massive intermediate-acidic intrusive rocks were developed in the Late Paleozoic and Mesozoic (Liu et al., 2004). The Great Xing'an Range area was mainly affected by NS-trending compression between the Siberia Craton and the North China Craton prior to the Early Jurassic, and it formed a series of fold belts and deep faults along the margin of two ancient continents that are mainly EW-trending and then NE-trending. After the Mid-Late Jurassic, the main influence was the oblique subduction to northwest of the Pacific

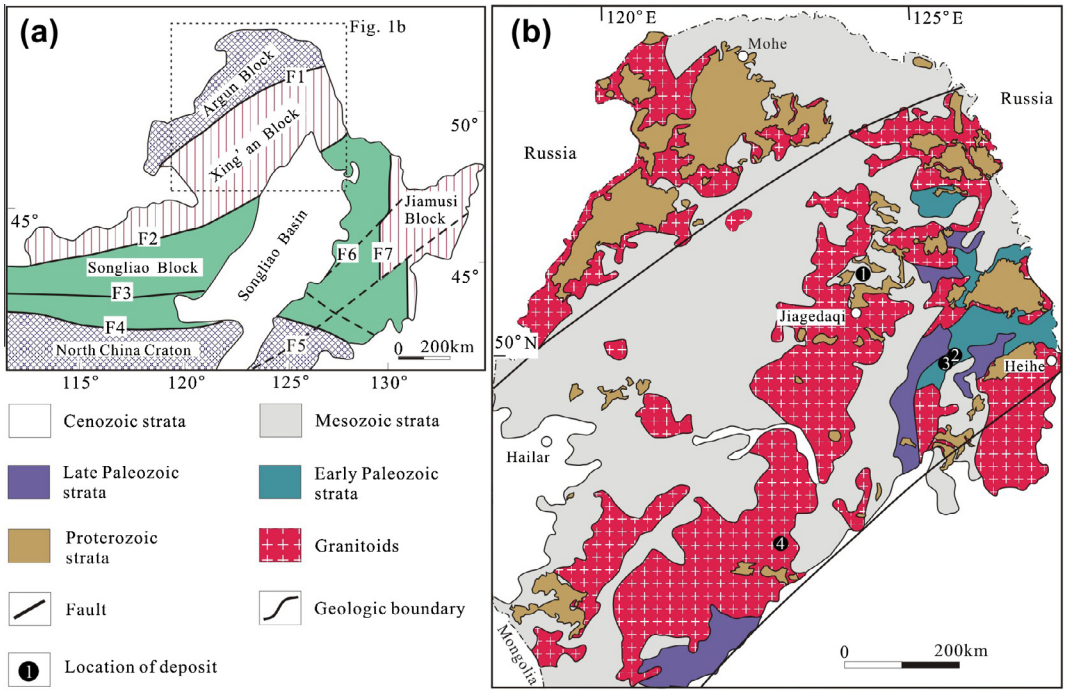

Fig. 1. Geotectonic units (Fig. 1a after Zhang et al., 2010) and sketch regional geological map (Fig. 1b after IMBGMR, 1991; HBGMR, 1993; SIGMR, 2005) of the northern Great Xing'an Range. F1, Tayuan-Xiguitu Fault; F2, Hegenshan-Heihe Fault; F3, Xilamulun-Changchun Fault; F4, Chifeng-Kaiyuan Fault; F5, Dunhua-Mishan Fault; F6, Yilan-Yitong Fault; F7, Jiamusi-Mudanjiang Fault; ❶, Chalukou Mo deposit; ❷, Duobaoshan Cu–Mo deposit; ❸, Tongshan Cu deposit; ❹, Taipinggou Mo deposit.