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Petrogenesis of the Kuangshancun and Hongshan intrusive complexes from the Handan–Xingtai district: Implications for iron mineralization associated with Mesozoic magmatism in the North China Craton

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ABSTRACT

The Handan–Xingtai district in eastern China exposes numerous late Mesozoic intrusions. Among these, the Kuangshancun intrusive complex is one of the major ore-related intrusions whereas the Hongshan complex is barren, although both intrusions display similar geochemical characteristics. The Kuangshancun complex consists of diorite and monzonite, with zircon LA-ICP-MS U–Pb age of 133.7 ± 1 Ma. The Hongshan complex mainly consists of syenite and shows zircon U–Pb age of 134.5 ± 1 Ma. The mineral chemistry of plagioclase from both complexes reveals normal zoning, consistent with the fractional crystallization process. Rocks of the Kuangshancun complex show SiO_2 in the range of 58.92–63.84 wt.%, Na_2O of 4.63–8.81 wt.%, and Al_2O_3 of 16.14–18.18 wt.%, together high Sr/Y (14–54) and high La_N/Yb_N (8.30–16.18) ratios. They show enrichment in LREE and depletion in HREE and HFSE, with no remarkable Eu anomalies, similar to the features of adakites. The whole rock initial $^{87}Sr/^{86}Sr$ ratios range from 0.706661 to 0.706722 and ε_{Nd} (t = 134 Ma) between −15.26 and −15.12, which are consistent with zircon $^{176}Hf/^{177}Hf$ ratios of 0.281940–0.282059 and ε_{Hf} (t) values of −27.0 to −22.7. Samples of the Hongshan complex show SiO_2 in the range of 56.57–68.16 wt.%, high Sr/Y (19–112) and high La_N/Yb_N (11.39–16.82) ratios. The zircon ε_{Hf} (t) values are in the range of −15.9 to −12.8 and ε_{Nd} (t = 134 Ma) is between −9.82 and −8.62. The Kuangshancun complex was derived through partial melting of an enriched lithospheric mantle contaminated by lower continental crust components. The Hongshan complex was also derived from the EM I-like mantle source. However, the calculated zircon Ce^{4+}/Ce^{3+} and Eu/Eu^* ratios indicate that the source magma of the Kuangshancun complex were characterized by higher oxygen fugacity as compared to that the Hongshan complex. The high oxidation states and high water contents are considered as possible key factors that led to the iron mineralization in the Kuangshancun and other intrusions in the Handan–Xingtai district.

1. Introduction

Recent studies in the eastern part of the North China Craton (NCC) have revealed several intermediate to felsic intrusions, many of which are genetically associated with Fe–Cu polymetallic mineralization (Wang et al., 2004a, 2006a, 2007; Li et al., 2008, 2009, 2010, 2013a; Shen et al., 2013). These rocks are characterized by high Sr, low heavy rare earth elements (HREEs) and Y contents and resultant high Sr/Y ratios. The key geochemical signatures, such as high Sr/Y and La/Yb ratios are widely used as the diagnostic criteria for adakites. Thus, petrogenesis of these high Sr/Y "adakitic" rocks is crucial for a better understanding of the genetic relationship between the Mesozoic magmatism and Cu–Fe mineralization in eastern China.

The Handan–Xingtai district is located within the Trans-North China Orogen, a major Paleoproterozoic suture zone that welds the Western and Eastern Blocks of the NCC (Zhao and Zhai, 2013; Santosh et al., 2013; Yang and Santosh, 2015) (Fig. 1). This region is one of the important iron ore fields in China. The Handan–Xingtai skarn-type iron deposits have been widely regarded as products of contact metamorphism between the Mesozoic dioritic to granitoid intrusions and the surrounding Ordovician marine carbonate rocks (Niu et al., 1995; Zheng et al., 2007a,b, 2007c). Thus,

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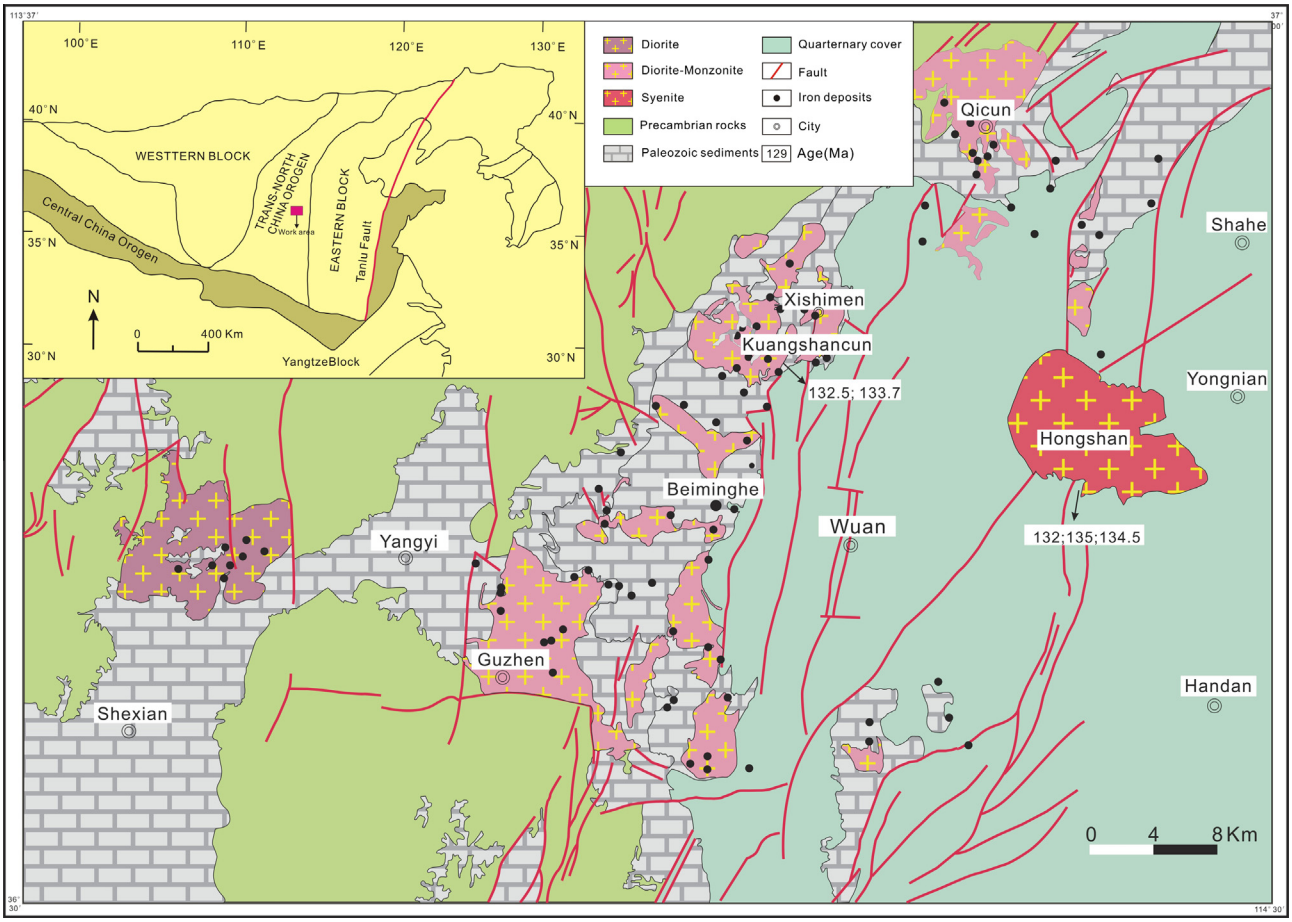

Fig. 1. Geological map showing the distribution of the intrusive complexes in Handan–Xingtai district (modified after Chen et al. (2004) and Zhao and Zhai (2013)). The age of Kuangshancun complex cited from Chen et al. (2004) and this study. The ages of Hongshan complex are cited from Zhou and Chen (2005), Chen et al. (2004) and; this study.

information on the age and evolution of the intrusions provides insights into the origin of magmatism and its relation with ore mineralization. Although the intrusions in the Handan–Xingtai district have been investigated in several studies, their petrogenesis and ore-forming mechanisms remain controversial. Huang and Xue (1990) suggested that the intrusions of Handan–Xingtai district were cogenetic and that the Hongshan syenites were formed by fractional crystallization of the Xishu–Wu'an monzonitic rocks. Chen et al. (2004, 2005, 2006, 2008, 2013) proposed that the Mesozoic magmatic rocks in the southern Taihang Mountains resulted from mixing between mantle-derived mafic magmas and Archean lower crustal components. However, Wang et al. (2006b) emphasized that the gabbroic rocks in this region formed from an enriched mantle source metasomatized by SiO_2-rich melts derived from subducted Paleoproterozoic crustal materials. In contrast, Xu et al. (2009) argued that the parental magma of the Fushan high-Mg# diorite in the Handan–Xingtai district was derived from partial melting of a delaminated lower continental crust followed by variable melt–peridotite interactions. Thus, the origin of the intrusive rocks in the Handan–Xingtai district and its impact implications on the iron mineralization process remain unresolved.

In this paper, we perform a comparative study on the ore-bearing and ore-barren intrusions based on mineralogical, geochemical, geochronological, and whole-rock Sr–Nd and zircon Hf isotope data from the Kuangshancun ore-bearing intrusive complex and the Hongshan ore-barren syenites in the Handan–Xingtai district (Fig. 1).

2. Geological setting

The Handan–Xingtai district, one of the largest concentrations of iron skarn deposits in China (Zhao et al., 2004; Zhang et al., 2014a), is located in the western margin of the eastern North China Craton (NCC) along the Trans-North China Orogen (TNCO) (Fig. 1). The major lithological units of this region and surrounding areas comprise early Precambrian metamorphic basement that are unconformably overlain by Phanerozoic sedimentary sequences. The basement mainly consists of the Archean Zanhuang Groups that is dominantly composed of TTG (tonalite–trondhjemite–granodiorite) gneisses and amphibolites, marble and banded iron formation (BIF) (Zhao et al., 2005; Zhai and Santosh, 2011). The major magmatic phases in the region are dominated by intermediate-mafic and alkaline intrusive complexes emplaced in the middle and late Mesozoic, with a surface area of 300 km^2 (Niu et al., 1995; Huang and Xue, 1990; Zheng et al., 2007b). The intrusion of the magmatic units into the Ordovician carbonate sedimentary rocks have resulted in contact metamorphism, generating many skarn-type iron deposits that are mainly distributed in the Handan and Xingtai districts. Among these, the Kuangshancun skarn iron deposit (also called as Xishimen ore deposit) with an iron reserve of more than 110 million tons, is closely related to the Kuangshancun intrusive complex whereas the nearby Hongshan complex is an ore-barren intrusion.

The Kuangshancun complex is emplaced into the Middle Ordovician limestone and dolomite, with an exposed area of 35 km^2. The dominant rocks are monzonite and diorite. The