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Timing and origin of Mesozoic magmatism and metallogeny in the Wutai-Hengshan region: Implications for destruction of the North China Craton

Ju-Quan Zhang [a,b], Sheng-Rong Li [a,*], M. Santosh [a], Qing Li [a], Si-Da Niu [a], Zeng-Da Li [a], Xue-Ge Zhang [a], Li-Bin Jia [a]

[a] School of Earth Sciences and Resources, China University of Geosciences Beijing, 29 Xueyuan Road, Beijing 100083, China
[b] School of Gemology and Materials Technology, Shijiazhuang University of Economics, 136 Huaianxi Road, Shijiazhuang 050031, Hebei Province, China

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ABSTRACT

The Wutai-Hengshan region in the northwestern domain of Taihang Mountains (TM) occurs along the Trans-North China Orogen (TNCO) that amalgamates the Western and Eastern Blocks of the North China Craton (NCC). The metamorphic basement in the region is composed of ca. 2.5 Ga granite-greenstone belts within which the Mesozoic magmatic suites are widely emplaced, associated with polymetallic mineralization. The timing, origin and evolution of the magmatic rocks in the Wutai-Hengshan region provide important clues to evaluate the timing, mechanism and process of the destruction of the NCC. In this study, we report new zircon U–Pb and in-situ Hf isotopic data on some of the Mesozoic intrusions associated with Au–Ag–Cu–Mo mineralization from this region. The results show that magmatism and metallogeny in the Yixingzhai and Boqiang-Gengzhuang mining regions occurred during 142–130 Ma, starting with felsic granite porphyry with Mo–Cu mineralization, and intermediate magma associated with gold mineralization. The emplacement of magma and mineralization in Diaoquan mining region occurred about 132–130 Ma, with the intermediate magma emplaced earlier than felsic magma. The in-situ Hf isotopic data indicate that most of the felsic magma was produced by partial melting of the lower crust, and that the intermediate magma witnessed intrusion of mafic magma derived from mantle with magma mixing in different proportion. The process of crystallization differentiation played an important role in the formation of Diaoquan complex intrusion.

The magmatism and metallogeny in the Wutai-Hengshan region were coeval with the craton destruction of the NCC. The Mesozoic magmatism and metallogeny in this region during 142–130 Ma contributed to the destruction of the stable cratonic architecture of the NCC. The mafic lower crust was modified by magma derived from mantle during this process. The regional geodynamics associated with these processes are correlated to the subduction of the paleo-Pacific oceanic lithosphere.

1. Introduction

It has been widely accepted that the Precambrian architecture of the North China Craton (NCC) has been partly destroyed during Mesozoic and Cenozoic (e.g. Menzies et al., 1993; Griffin et al., 1998; Xu, 2001; Wu et al., 2003, 2005, 2006; Yang et al., 2007; Zheng et al., 2007; Chen et al., 2008a; Chen, 2010). Numerous petrological, geochemical and geophysical studies have shown that the eastern part of NCC lost 60–100 km thick old sub-continental lithospheric mantle (Menzies et al., 1993; Griffin et al., 1998; Fan et al., 2000; Xu, 2001; Gao et al., 2002), the features resulting from which are manifested as abundant volcanism, extensive structural deformation, high surface heat flow, and low seismic wave velocities in the upper mantle (Chen, 2010; Chen et al., 2008b; Yang et al., 2007; Zheng et al., 2007; Wu et al., 2005; Gao et al., 2002; Xu, 2001; Griffin et al., 1998; Menzies et al., 1993). The mechanism and timing of craton destruction in the NCC are topics of debate. Delamination (Deng et al., 2004, 2007; Wu et al., 2003), and thermo-mechanical and chemical erosion (Xu, 2001; Zhang et al., 2002; Xu et al., 2003, 2004) are among the major models proposed to explain the process of destruction. Some workers suggest that the destruction processes continued for more than 100 million years (e.g., Xu et al., 2009), whereas others proposed that the major

* Corresponding author.
E-mail address: lisr@cugb.edu.cn (S.-R. Li).

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phase of destruction took place during the Jurassic (e.g., Gao et al., 2004) or Cretaceous (e.g., Wu et al., 2005; Zhu et al., 2012) within a short period.

Magmatism and related metallic mineralization are keys to evaluate geodynamic processes (e.g., Menzies et al., 1993; Deng et al., 2004; Hou et al., 2004; Mao et al., 2005; Mo et al., 2006; Luo et al., 2006; Pirajno et al., 2011; Zhang et al., 2011; Dharma Rao et al., 2012; Chen et al., 2007; Hu et al., 2009; Li et al., 2013, 2014a, b; Zhai and Santosh, 2013), and have been used to probe the history of major changes in lithospheric architecture (e.g., Zhai et al., 2002; Zhu et al., 2009, 2012; Chen et al., 2009; Gao et al., 2009; Zhang et al., 2011). Inhomogeneous thinning of the lithosphere under the central NCC was inferred from detailed investigations of metallogeny in the Taihang Mountains (TM) in the central NCC by Li et al. (2013, 2014b). The Wutaishan-Hengshan region, located in the central part of the NCC, marks the transition zone between the thinned eastern cratonic lithosphere and the stable western lithosphere. Mesozoic intrusive and volcanic rocks are widely distributed in this region, and are associated with Au, Ag, Mo and Cu polymetallic mineralization, providing important targets for studying the destruction of the NCC.

In this paper, we present new felid observations, LA-ICP-MS zircon U–Pb chronology, and in-situ Hf isotope data from different intrusions in the Yixingzha gold, Boqiang-Gengzhuang Mo–Cu–Au and Diaoquan Ag–Cu deposits. Combined with previous dating and Hf isotope data from the eastern NCC, we discuss the timing, origin and geodynamic setting of magmatism and metallogeny in the Wutai-Hengshan region and their implications for the destruction of NCC.

2. Geological setting

The NCC is one of the fundamental Precambrian nuclei of Asia, traditionally divided into three segments as the Eastern Block, the Western Block and the Trans-North China Orogen (e.g. Zhao et al., 2002; Kröner et al., 2005; Kusky et al., 2003; Trap et al., 2009) (Fig. 1). The Trans-North China Orogen (TNCO) trending approximately N–S along the central part of the NCC defines a major Paleoproterozoic belt of subduction–accretion–collision along which the Western and Eastern Blocks were amalgamated (Zhao and Zhai, 2013; Yang and Santosh, 2014 and references therein). The Wutai-Hengshan region is located at the center of North China Craton (CNCC), along the Trans-North China Orogen (Fig. 1), to the west of the Taihang Mountains (TM). The Great Hinggan Range–Taihang Mountain gravity lineament (HTGL, e.g., Griffin et al., 1998) passes through eastern part of this region (Fig. 1c). The thickness of lithosphere in this region ranges from about 100–160 km, thinner than the Western Block but thicker than the Eastern Block.

The metamorphic basement formed during the Neoarchean to Paleoproterozoic, and is dominantly composed of ca. 2.5 Ga greenstone belt (Zhai and Santosh, 2011; Santosh, 2010), together with tonalite–trondhjemite–granodiorite (TTG) gneisses and granitoids of the Wutai, Hengshan and Fuping complexes in the TNCO (e.g., Zhao et al., 2001). The Wutai complex is composed mainly of greenschist facies mafic to felsic bimodal volcanic rocks, siliciclastic sedimentary rocks, VMS and BIF (Polat et al., 2005), intruded by the ca. 2.5 Ga TTG suites (Guan et al., 2002; Kusky and Li, 2003; Liu et al., 2004). The high-grade gneissic terranes of the Hengshan and Fuping Complex are located to the northwest and the southeast of Wutai complex. The Hengshan Complex is composed mainly of 2.7–2.5 Ga amphibolite to granulite facies orthogneisses (Zhao et al., 2002). The major rocks types in the Fuping Complex are TTG gneisses, mafic granulites, amphibolites, monzogranites and granodiorites (Zhao et al., 2002). Paleoproterozoic Hutuo group metasedimentary rocks cover the Wutai Complex with an angular unconformity in the southwest. The NCC witnessed a prolonged stage of quiescence during Mesoproterozoic to Mesozoic, with deposition of sedimentary cover rocks on the metamorphic basement. During Mesozoic, widespread tectonic and magmatic activity occurred, leading to hydrothermal mineralization and formation of volcanic-sedimentary basin.

The intensity of magmatism shows a gradual decrease from east to west. Volcanic rocks occur only in the eastern part of the Tanghe fault. The intrusive rocks can be divided into two groups. The first group is composed of hypabyssal rocks, which shows a close relationship with the Au–Ag–Cu–Mo–Fe–Mn mineralization in this region (Fig. 2), including quartz porphyrite, granite porphyrite, felsite, diorite, granodiorite, monzonite, and diorite pophyrite. The second group is represented by plutonic rocks, including biotite granite and adamellite. The several NW and NE faults are considered to be the channels of hypabyssal magma emplacement, and control the Mesozoic magmatism and mineralization (Fig. 2).

Gold mineralization is widely distributed in Wutaishan-Hengshan region, including the Neoarchean–Paleoproterozoic metamorphic Au deposits and Mesozoic magmatic hydrothermal Au deposits, with the latter being much larger than the former in

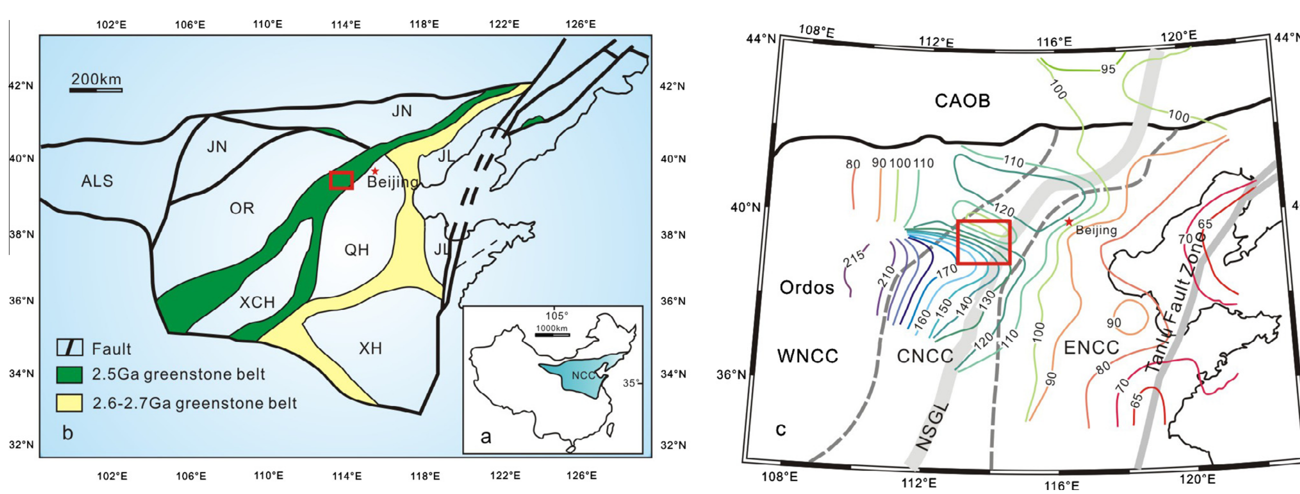

Fig. 1. a. The location of the North China Craton. (b) Tectonic map of the North China Craton (modified after Zhai and Santosh, 2011). (c) The distribution of lithosphere thickness beneath the NCC (after Zhu et al., 2011). The red box shows the study area.