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Geodynamic setting of Mesozoic magmatism in NE China and surrounding regions: Perspectives from spatio-temporal distribution patterns of ore deposits

He-gen Ouyang [a,*], Jing-wen Mao [a], M. Santosh [b,c], Jie Zhou [d], Zhen-hua Zhou [a], Yue Wu [e], Lin Hou [b,f]

[a] MLR Key Laboratory of Metallogeny and Mineral Assessment, Institute of Mineral Resources, Chinese Academy of Geological Sciences, Beijing 100037, PR China
[b] School of Earth Science and Resources, China University of Geosciences, Beijing 100083, PR China
[c] Faculty of Science, Kochi University, Kochi 780-8520, Japan
[d] China Science Publishing & Media Ltd.(CSPM), Beijing 100717, PR China
[e] Department of Geochemistry, Yangtze University, Wuhan 430100, PR China
[f] Chengdu Institute of Geology and Mineral Resources, Chengdu 610000, PR China

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ABSTRACT

North-eastern China and surrounding regions host some of the best examples of Phanerozoic juvenile crust on the globe. However, the Mesozoic tectonic setting and geodynamic processes in this region remain debated. Here we attempt a systematic analysis of the spatio-temporal distribution patterns of ore deposits in NE China and surrounding regions to constrain the geodynamic milieu. From an evaluation of the available geochronological data, we identify five distinct stages of ore formation: 240–205 Ma, 190–165 Ma, 155–145 Ma, 140–120 Ma, and 115–100 Ma. The Triassic (240–205 Ma) magmatism and associated mineralisation occurred during in a post-collisional tectonic setting involving the closure of the Paleo-Asian Ocean. The Early-Mid Jurassic (190–165 Ma) events are related to the subduction of the Paleo-Pacific Ocean in the eastern Asian continental margin, whereas in the Erguna block, these are associated with the subduction of the Mongol–Okhotsk Ocean. From 155 to 120 Ma, large-scale continental extension occurred in NE China and surrounding regions. However, the Late Jurassic magmatism and mineralisation events in these areas evolved in a post-orogenic extensional environment of the Mongol–Okhotsk Ocean subduction system. The early stage of the Early Cretaceous events occurred under the combined effects of the closure of the Mongol–Okhotsk Ocean and the subduction of the Paleo-Pacific Ocean. The widespread extension ceased during the late phase of Early Cretaceous (115–100 Ma), following the rapid tectonic changes resulting from the Paleo-Pacific Oceanic plate reconfiguration.

1. Introduction

Ore deposits of economic significance are heterogeneously, but not randomly, distributed in time and space, and their genesis has been correlated to specific conditions and tectonic environments (Groves and Bierlein, 2007; Bierlein et al., 2009). The nature, timing of formation and distribution of ore deposits on the globe are intrinsically linked with the geodynamic evolution of the Earth (Groves and Bierlein, 2007; Mao et al., 2013; Zhai and Santosh, 2013). Thus, the spatio-temporal distribution patterns of diverse mineral deposits offer important clues to reconstruct the tectonic settings (e.g., Hu and Zhou, 2012; Mao et al., 2011, 2013; Pirajno et al., 2011; Zoheir, 2012; Goldfarb et al., 2013; Li and Santosh, 2013) and to constrain the geodynamic processes during the evolution of the Earth (e.g., Kesler, 1997; Wan et al., 2011).

NE China is the easternmost segment of the Central Asian Orogenic Belt (CAOB), the largest Phanerozoic accretionary belt in the globe with some of the best preserved examples for the production of juvenile crust (Wu et al., 2003). This region is characterised by voluminous magmatic rocks exposed over an area of ca. 200,000 km^2 (Wu et al., 2011). Most of these rocks were emplaced during the Jurassic to Early Cretaceous (190–115 Ma), and some of them during the Paleozoic (Zhang et al., 2010a; Wu et al., 2011). During the Mesozoic, the eastern part of CAOB was tectonically linked to the Mongol–Okhotsk Ocean closure and the subduction of the Paleo-Pacific Ocean (Maruyama et al., 1997; Dmitry et al., 2010; Donskaya et al., 2012). Because of this complex plate-tectonic regime, the corresponding geodynamic settings of the Mesozoic igneous rocks in the eastern part of the CAOB are ambiguous, especially from the Jurassic to Early Cretaceous.

* Corresponding author. Address: 26 Baiwanzhuang Street, Xicheng District, Institute of Mineral Resources, Chinese Academy of Geological Sciences, Beijing 100083, PR China. Tel.: +86 10 82321153.
E-mail addresses: oyhg1984@163.com (H.-g. Ouyang), jingwenmao@263.net (J.-w. Mao), msantosh.gr@gmail.com (M. Santosh).

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Although several investigations have been carried out on these Mesozoic magmatic suites in NE China, there is no consensus yet regarding the geodynamic mechanism by which such voluminous and diverse magmas were generated. Among the models proposed to explain the driving force for magmatism, are: (1) mantle plume (e.g., Lin et al., 1998; Pirajno et al., 2009); (2) intra-continental extensional orogeny, unrelated to the Paleo-Pacific Ocean subduction (e.g., Shao et al., 2001); (3) the closure of the Mongol–Okhotsk Ocean and subsequent orogenic collapse (e.g., Fan et al., 2003; Meng, 2003; Ying et al., 2010), possibly aided by mantle plume activity (e.g., Ying et al., 2010); (4) westward subduction of the Paleo-Pacific Oceanic plate, leading to large scale delamination (e.g., Wu et al., 2005a,b; Zhang et al., 2010a, 2011a; Pei et al., 2011a; Yu et al., 2012; Guo et al., 2013); and (5) compositional effects of the closure of the Mongol–Okhotsk Ocean and the subduction of the Paleo-Pacific Oceanic plate (e.g., Wang et al., 2002, 2006a, 2012c; Mao et al., 2003a, 2005; Wu et al., 2011; Li et al., 2012c).

In contrast to earlier studies, which focused on the regional geology, petrochemistry and geochronology, here we employ the spatio-temporal distribution of diverse ore deposits across NE China and surrounding regions, in conjunction with conventional tectonic and petrogenetic data, to review the metallogenic framework in NE China and surrounding regions. We then evaluate the geodynamic mechanism of formation of the Mesozoic igneous rocks and related ore deposits in these areas.

2. Geological background

The NE China and surrounding regions in this study are composed of a Paleozoic orogenic collage (i.e., the Xing'an-Monglolia Orogenic Belt (XMOB)), which forms part of the eastern segment of the CAOB (Sengör et al., 1993), and northeastern part of the eastern block of the North China Craton (NCC) in the north (see Fig. 1).

2.1. The Xing'an-Mongolia Orogenic Belt (XMOB)

The XMOB, located between the Siberian and the North China Cratons, comprises a series of micro-continents (Sengör et al., 1993; Xiao et al., 2003), separated from the NCC by the Chifeng–Kaiyuan fault belt in the south (Fig. 1) and from the Siberian plate by the Mongol–Okhotsk suture zone in the north. This orogenic belt is composed of the Erguna and Xing'an blocks in the northwest, the Songliao block in the central part, the Liaoyuan terrane in the south, and the Jiamusi block and Nadanhada terrane in the east (Fig. 1), and is mainly formed from the progressive subduction of the Paleo-Asian Ocean and the amalgamation of different terranes derived from multiple sources (Zhou and Wilde, 2012; Zheng et al., 2012). Although the timing and mechanism of amalgamation of the micro-continents still remains controversial, it has been proposed that the Erguna block collided with the Xing'an block during the Early Paleozoic (Zhang and Tang, 1989; Ge et al., 2005a). The Songliao block was then accreted to the Xing'an–Erguna composite block along the Hegenshan–Heihe suture in the Late Devonian to Early Carboniferous (Robinson et al., 1999; Chen et al., 2000; Wu et al., 2002). Final closure of the Paleo-Pacific Ocean occurred during the Late Permian to the Early Triassic along the Solonker–Xar Moron–Changchun suture (Xiao et al., 2003; Xu et al., 2009; Wu et al., 2011). Subsequently, regional extension developed in the late Paleozoic (Wu et al., 2002; Meng et al., 2011a). During the Mesozoic period, the XMOB was affected by the widespread emplacement of Late Mesozoic volcanic and granitic rocks (Lin et al., 2004; Ge et al., 2005a; Zhang et al., 2010a; Wu et al., 2011). The Mesozoic granitoids and volcanic rocks, along with those of the Paleozoic age, in this region, show positive $\varepsilon_{Nd}(t)$ values and young Nd model ages (Wu et al., 2002, 2003; Zhang et al., 2008; Guo et al., 2010), representing significant Phanerozoic crust growth (Xiao et al., 2003; Wu et al., 2003, 2011; Zhang et al., 2008, 2010a).

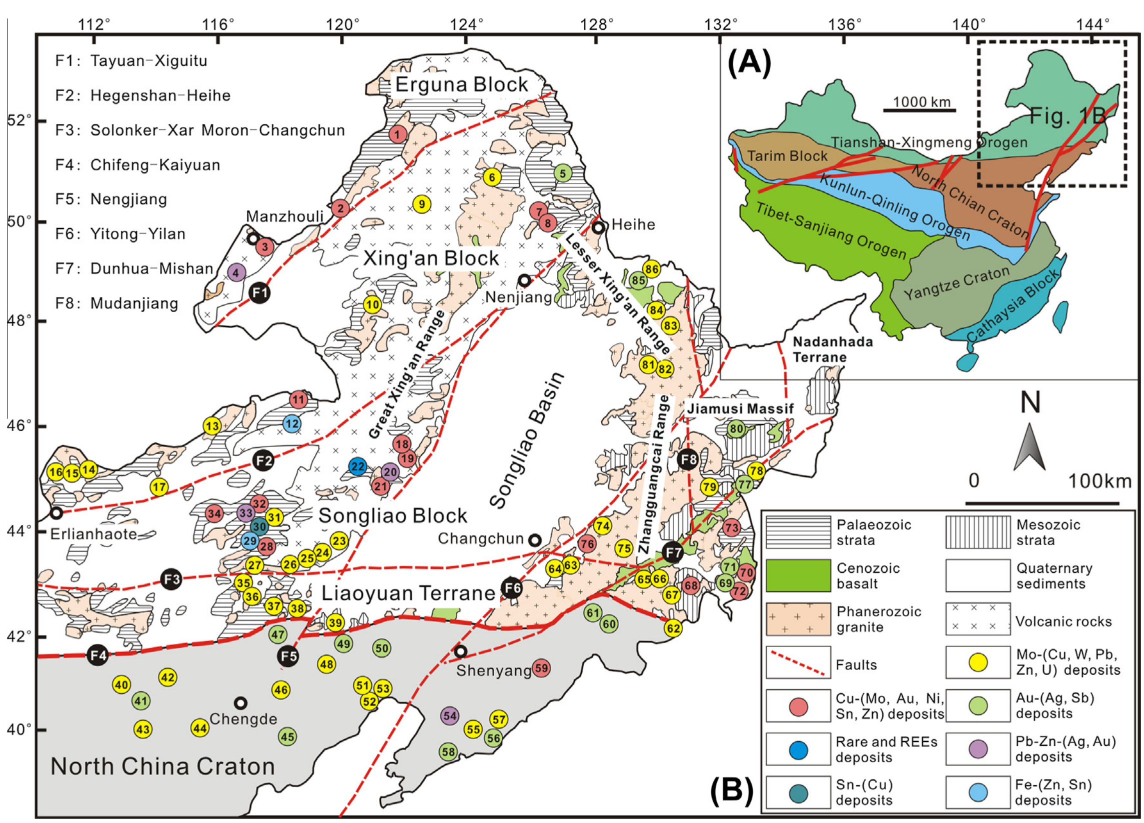

Fig. 1. (A) Geotectonic division of China (after from Mao et al. (2011)); (B) Geological map of NE China and surrounding regions (modified from Zeng et al. (2012)), showing the distribution of different types of major Mesozoic ore deposits. Data sources and deposit numbers are listed in Table 1.