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Petrogenesis of Jurassic granitoids at the northeastern margin of the North China Craton: New geochemical and geochronological constraints on subduction of the Paleo-Pacific Plate

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ABSTRACT

At the junction between the North China Craton (NCC) and the Central Asian Orogenic Belt (CAOB), northern Liaoning province, NE China, there are widespread Jurassic igneous rocks. The tectonic setting and petrogenesis of these rocks are unresolved. Zircon U–Pb dating, whole-rock geochemistry, and Hf isotopic compositions of Jurassic granitoids were investigated to constrain their ages and petrogenesis in order to understand the tectonic evolution of the Paleo-Pacific Ocean along the northeastern margin of the NCC. Geochronological data indicate that magmatism occurred between the early and late Jurassic (180–156 Ma). Despite the wide range in ages of the intrusions, Jurassic granitoids were likely derived from a similar or common source, as inferred from their geochemical and Hf isotopic characteristics. Compared to the island arc andesite-dacite-rhyolite series, the Jurassic granitoids are characterized by higher SiO_2, Al_2O_3, and Sr contents, and lower MgO, FeO_T, Y, and Yb contents, indicating that the primary magmas show typical characteristics of adakitic magmas derived from partial melting of thickened lower crust. These findings, combined with their $\varepsilon_{Hf}(t)$ values (+1.4 to +5.4) and two-stage model ages (1515–1165 Ma), indicate the primary magmas originated from partial melting of juvenile crustal material accreted during the Mesoproterozoic. They are enriched in large-ion lithophile elements (e.g., Rb, K, Th, Ba, and U) and light rare-earth elements (REE), and depleted in high-field-strength elements (e.g., Nb, Ta, Ti, and P) and heavy REE. Based on these findings and previous studies, we suggest that the Jurassic adakitic granitoids (180–156 Ma) were formed in an active continental margin and compressive tectonic setting, related to subduction of the Paleo-Pacific Plate.

1. Introduction

Tectonically, NE China is located between the northern margin of the North China Craton (NCC) and the eastern segment of the Central Asian Orogenic Belt (CAOB). During the Paleozoic, the region experienced the evolution and final closure of the Paleo-Asian Ocean, and the amalgamation of the NCC with multiple micro-continental massifs including, from west to east, the Erguna, Xing'an, Songliao, Jiamusi, and Khanka blocks (Fig. 1a; Li, 2006; Liu et al., 2017; Wu et al., 2007; Xu et al., 2009; Zhou et al., 2009, Zhou et al., 2011a; Zhou et al., 2011b, 2011c; Zhou and Li, 2017). During the Mesozoic, NE China was above the subduction zone of the circum-Pacific tectonic regime (Sun et al., 2005; Wang et al., 2017; Wu et al., 2007; Xu et al., 2009, 2013; Zhou et al., 2009). It is generally considered that Jurassic magmatism in NE China was related to subduction of the Paleo-Pacific Plate beneath the Eurasian continent (Ge et al., 2005; Wang et al., 2006a, 2015a; Wu et al., 2011; Zhang et al., 2008, Zhang et al., 2010a,b), although far-field effects of collision related to closure of the Mongol–Okhotsk Ocean cannot be precluded, especially in the Great Xing'an Range (Pei et al., 2011; Tang et al., 2016; Wang et al., 2015b; Xu et al., 2013b; Zhang et al., 2016).

Jurassic magmatism was widespread and intensive in northern Liaoning Province, which is located at the junction between the NCC and CAOB (JBGMR, 2004; LBGMR, 2016; Liu et al., 2016; Wang et al., 2013, 2014; Wu et al., 2011; Zhang et al., 2016). This region is therefore important in terms of understanding the processes of subduction of the Paleo-Pacific Plate. However, the tectonic setting and petrogenesis of these Jurassic igneous rocks remain unresolved. Here we present new

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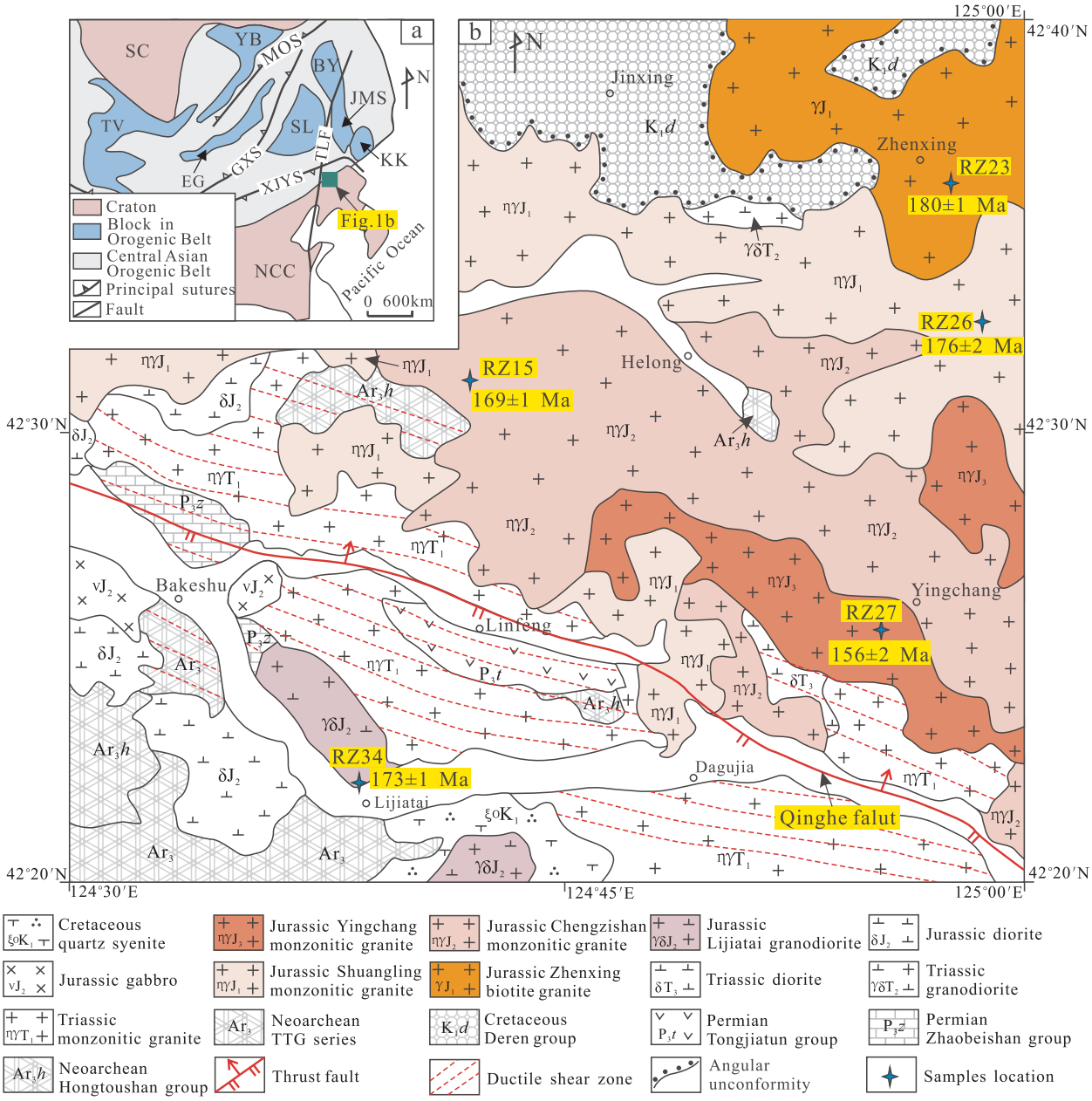

Fig. 1. Maps showing: (a) the main tectonic subdivisions of East Asia (modified after Zhou et al. 2009); and (b) a simplified geological map of the study area, including the locations and ages of the Jurassic granitoids discussed here. SC, Siberia Craton; NCC, North China Craton; TV, Tuva–Mongolia massif; YB, Yablanov massif; EG, Erguna massif; SL, Songliao massif; BY, Bureya massif; JMS, Jiamusi massif; KK, Khanka massif; MOS, Mongol–Okhotsk suture; GXS, Great Xing'an suture; XJYS, Xar Moron–Jilin–Yanji suture; TLF, Tan–Lu fault.

zircon U–Pb ages, whole-rock geochemistry, and Hf isotopic compositions of the Jurassic granitoids, with the aim of gaining insights into their petrogenesis and tectonic setting, and the tectonic evolution of the Paleo-Pacific Ocean.

2. Geological background

Jurassic magmatic events have recently been found to be widespread in NE China, not only on the northern margin of the NCC and its northern continental accretionary belt (Gao et al., 2004; Ma and Zheng, 2009; Wu et al., 2006a, 2011; Yang and Li, 2008; Zhang et al., 2007, 2014, 2016; Zheng et al., 2004), but also in eastern Heilongjiang and Jilin provinces (Xu et al., 2013a), the Great Xing'an Range (Meng et al., 2011; Wang et al., 2006a; Xu et al., 2013a; Ying et al., 2010; Zhang et al., 2010a,b), and the Lesser Xing'an–Zhangguangcai Ranges (Xu et al., 2013b; Yu et al., 2012).

The study area is located at the junction between the eastern segment of the CAOB and the northeastern margin of the NCC. The Qinghe Fault (QHF), which marks the boundary between the NCC and the CAOB, transects the study area (Liu et al., 2017). Triassic and earlier rocks on both sides of the QHF have experienced intensive ductile deformation, whereas Jurassic and later rocks were not influenced by this deformation (Liu et al., 2016). The CAOB lies to the north of the QHF, and the NCC to the south. The northern area of the QHF contains the Lower Cretaceous Deren Formation, which is dominated by terrigenous clastic rocks and intermediate–acid volcanic rocks; the late Permian Zhaobeishan Formation, dominated by marbles and granulites; the late Permian Tongjiatun Formation, dominated by weakly metamorphosed andesites; and the Neoarchean Hongtoushan Formation, which contains supracrustal rocks including amphibolites, granulites, and magnetite-bearing quartzites (Fig. 1b). The region south of the QHF contains massive Neoarchean tonalite–trondhjemite–granodiorite (TTG) gneisses