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Zircon U–Pb age and Sr–Nd–Hf isotope geochemistry of Permian granodiorite and associated gabbro in the Songliao Block, NE China and implications for growth of juvenile crust

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ABSTRACT

Post-orogenic granitic and associated mafic rocks from northeastern (NE) China consist of granodiorite and gabbro intrusions. We report here upon new U–Pb zircon ages, geochemical data and Sr–Nd–Hf isotopic data for these rocks. LA-ICP-MS U–Pb zircon analysis yields an age of 262.8 ± 1.0 Ma for the granitic rocks, and a uniform age of 262.1 ± 0.7 Ma for the gabbro. Most of the granitic and mafic rocks are characterised by low $K_2O + Na_2O$, and pertain to the subalkaline series in the total alkali–silica diagram. The granodiorite samples show low $(^{87}Sr/^{86}Sr)_i$ ranging from 0.700 to 0.705, positive $\varepsilon_{Nd}(t)$ values from +0.3 to +0.8, and large variation in $\varepsilon_{Hf}(t)$ values of between −4.0 and +2.5, indicating that both newly underplated basalt (70–80%) and ancient lower crustal sources (20–30%) contributed to their origin. Furthermore, positive $\varepsilon_{Hf}(t)$ values with two-stage model ages (T_{DM2}) of 1123–1260 Ma, together with Nd model ages (960–1000 Ma), suggest an important episode of crustal growth during the Meso-Neoproterozoic beneath the Songliao Block. In contrast, the investigated gabbro is characterised by relatively high $(^{87}Sr/^{86}Sr)_i$ ratios (0.707–0.708), negative $\varepsilon_{Nd}(t)$ (−5.9 to −5.3) and $\varepsilon_{Hf}(t)$ values (−5.0 to −2.3), implying that this was derived from an enriched mantle source. The geochemical data indicate that the granitic magmas underwent separation of clinopyroxene, hornblende, K-feldspar, plagioclase, Ti-bearing phases (e.g., rutile, ilmenite, titanite), apatite and zircon during their evolution. Whereas the gabbro is characterised by low MgO (2.92–3.92 wt.%), Mg# (35–41) and compatible elements content, such as Cr (10–68 ppm), Co (16–31 ppm) and Ni (5.7–33 ppm), features of a more evolved mafic magma. There is no evidence that the granitic and mafic rocks were affected by crustal contamination during emplacement. Our interpretation is that the two coeval intrusive suites were both formed in a post-orogenic extensional setting, related to lithospheric delamination or 'collapse' of the Central Asian Orogenic Belt (CAOB) (Xingmeng orogenic Belt in China).

1. Introduction

Phanerozoic granites are widespread (~3×10^5 km^2, Wu et al., 2007a) throughout northeastern China (NE China). Recent studies indicate that many of these granites contain a large proportion of juvenile crustal material, thus suggesting that the Phanerozoic was an extensive period of crustal growth for this part of the world (Wu et al., 2000a; Chen et al., 2000; Zhao et al., 2000; Jahn et al., 2000a,b; Wu et al., 2001, 2002; Chen and Jahn, 2002; Jahn, 2002; Wu et al., 2003a,b; Cheng et al., 2006; Ge et al., 2007; Wu et al., 2007a). It is precisely because of the special significance of this part of Asia to models of global crustal growth that systematic isotopic and petrogenetic studies of all of the Phanerozoic granitic intrusions in NE China is needed.

NE China is generally regarded to form part of the Hercynian Fold belt; as such, most of the granites present in NE China were traditionally considered to be of Late Palaeozoic (or Hercynian) age (Wu et al., 2000a). Recent investigations, however, have indicated that in fact these intrusions were mainly formed during the early Mesozoic (Wu et al., 2000a, 2007a), and further, that 'true' Late Palaeozoic granitoid rocks are rare, being distributed only in the Jiamusi Block in the east and in the Great Xing'an Range in the west (Fig. 1a) (Wu et al., 2000b, 2001, 2002). In the Songliao Block (Fig. 1a), Late Palaeozoic granites have not yet been recorded. Accordingly, in order to further understand the spatio–temporal relationships of the voluminous granitic rocks in NE China, precise geochronological and geochemical data are required.

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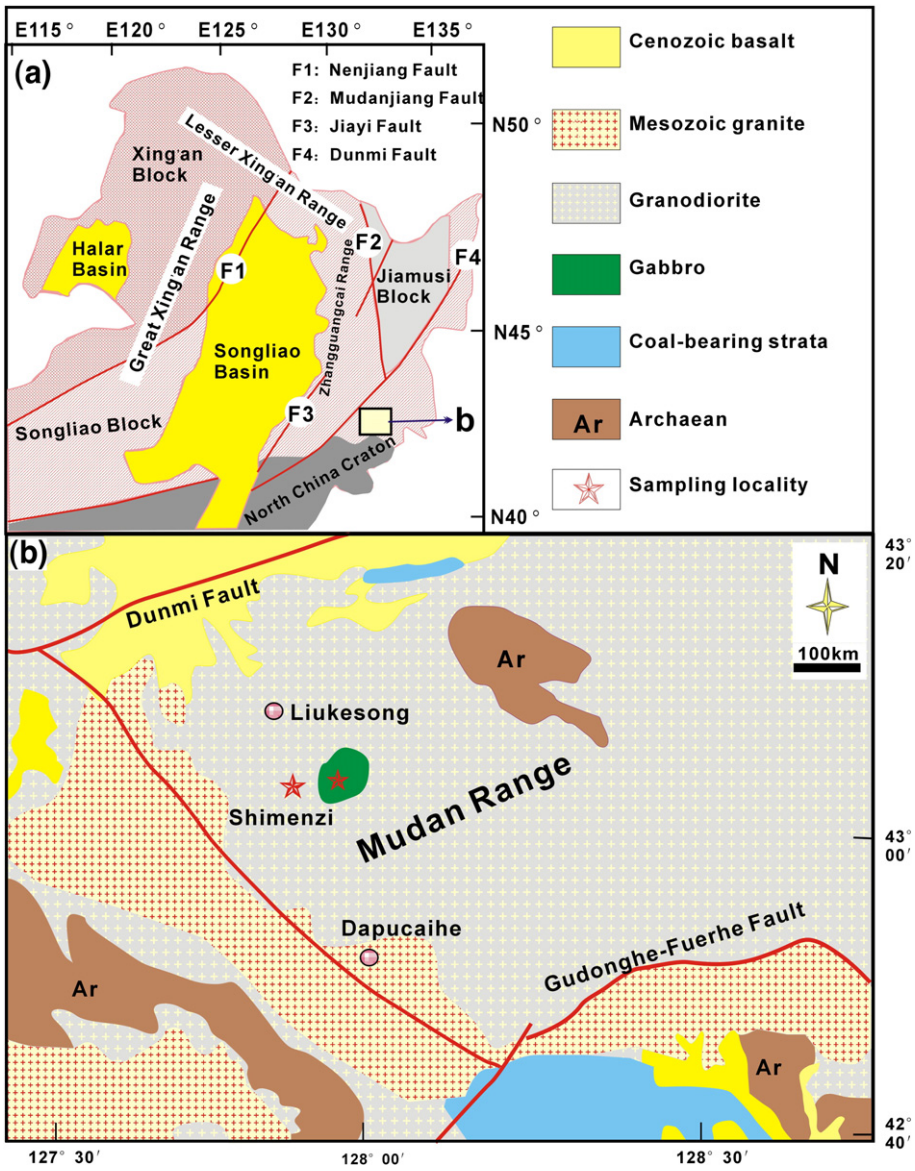

Fig. 1. (a) Tectonic divisions of NE China (cited from Wu et al., 2002). (b) Geological map of the study area that includes the sampling localities for the granodiorite and gabbro samples.

For a long time, the existence of Late Palaeozoic, mafic magmatism in the east of the Jilin and Heilongjiang provinces has proven controversial. For example, the mafic–ultramafic intrusions distributed at Hongqiling and Piaohechuan (Cu–Ni deposits), in the east of the Jilin Province, had been considered to have been emplaced during the Late Palaeozoic (Qin, 1995); more precise geochronology, however, now suggests that they are the results of Indosinian magmatism (Wu et al., 2004a). Although, some researchers have documented, recently, the presence of Late Palaeozoic mafic magmatic activity in the area of Yanbian, eastern Jilin Province in the Chinese literature (e.g., Sun et al., 2008; Zhao et al., 2008), the source features and petrogenesis of these mafic rocks have not yet been regarded.

Accordingly, this study provides good opportunity to further document the ages, and the chemical and isotopic characteristics of Late Palaeozoic granodiorite and associated gabbro in NE China; herein we undertake a systematic isotopic and geochemical investigation of representative intrusions from the Songliao Block. Moreover, in this paper, we report new ages and Sr–Nd–Hf isotopic data to constrain their petrogenesis and use this data to discuss their implications for crustal growth in NE China during the Phanerozoic.

2. Geological setting and petrology

NE China is divided by the Nenjiang (F1) and Mudanjiang (F2) Faults (Fig. 1a) into three microcontinental blocks (i.e., the Jiamusi Block in the east, Songliao Block in the centre and Xing'an Block in the northwest) (Ye et al., 1994). The Jiamusi Block is mainly composed of two sequences of Precambrian metamorphic rocks: the Mashan and Heilongjiang Groups (Wu et al., 2003a,b). The Mashan Group, that has been metamorphosed at granulite facies conditions (Wilde et al., 2000), comprises granulite, marble, graphitic schist, together with gneiss and garnet-bearing granite. By contrast, the Heilongjiang Group, exposed along the Mudanjiang Fault (F2) between the Jiamusi and Songliao Blocks (Fig.1a), is characterised by highly deformed blueschist facies rocks, including glaucophane schist, marble and chert (Wu et al., 2003a,b). The Songliao Block consists of the Lesser Xing'an Range in the north, the Songliao sedimentary basin in the centre and the Zhangguangcai Range in the east (Fig. 1a). Voluminous Phanerozoic granitic rocks are widespread throughout the Block, intruding both mountainous regions (JBGMR, 1988; IMBGMR, 1990; HBGMR, 1993) and beneath the Songliao basins (Wu et al., 2001).