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Petrogenesis of the Dengzhazi A-type pluton from the Taihang–Yanshan Mesozoic orogenic belts, North China Craton

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ABSTRACT

The voluminous Mesozoic monzonitic to monzogranitic rocks in the north China craton (NCC) mostly show high-K calc-alkaline and I-type granitoids features. The Dengzhazi granitic pluton, however, shows features typical of A-type granites. The A-type pluton was emplaced in the Taihang–Yanshan orogenic belts of the northern margin of the NCC, with zircon U–Pb ages of around 140 Ma. The Dengzhazi A-type granites are characterized by high SiO_2 (70.2–77.7 wt.%), $K_2O + Na_2O$, Zr, Nb, Ga, Zn, and Y contents as well as high Ga/Al ratios, and extremely low CaO, Ba, Sr. In addition, they show high zircon saturation temperatures (870–950 °C), low water and low oxygen fugacity. All these features are consistent with the A-type affinity of the pluton.

In situ Hf isotopic analyses for the dated zircons show relatively small range of $\varepsilon_{Hf}(t)$ (−13 to −17). They also have homogeneous initial Nd isotopic compositions with $\varepsilon_{Nd}(t)$ ranging from −15.1 to −16.3. The Hf and Nd isotopic data suggest that the Dengzhazi A-type granites originated from a homogeneous crustal source, probably the Archean mafic-intermediate granulites. Taking into account the high temperatures, the low H_2O and fO_2 of the magma system, we believe that partial melting of the granulites should have been triggered by underplating of mantle-derived magmas at the base of the mafic lower crust in an extensional regime. The Dengzhazi A-type granite is the oldest pluton of the Taihang–Yanshan Mesozoic magma belts, signifying the commencement of extensive underplating of mafic magmas, and thus of lithospheric thinning in the northern NCC.

1. Introduction

A-type granite is a minor group with distinctive compositional features in the family of granites. It was first proposed by Loiselle and Wones (1979) to characterize "mildly alkaline rocks" with higher ($K_2O + Na_2O$) than typical "calc-alkaline" (I-type) rocks. A-type granites are usually characterized by high $Fe_{total}/(Fe_{total} + Mg)$, $K_2O + Na_2O$ and higher Ga/Al ratios, and are rich in high field strength elements such as Zr, Nb, Ta and REE (except Eu), but low in CaO, Ba and Sr (Collins et al., 1982; Whalen et al., 1987). Minimum magma liquidus temperature may be >900 °C (Clemens et al., 1986; Creaser and White, 1991). A-type granites are further divided into aluminous and alkaline sub-groups based on the relative contents of $Na_2O + K_2O$, Al_2O_3 and CaO, or the presence or absence of alkali mafic minerals (e.g., King et al., 1997). Recently, reduced and oxidized sub-groups were emphasized by some researchers, which could reflect different oxygen fugacity conditions and water contents of magma sources (e.g., Frost and Frost, 1997; Dall'Agnol and Oliveira, 2007; Wang, 2009).

The origin of A-type granites remains a subject of considerable debate. Some researchers proposed that A-type granites are derived from melting of tonalitic or more felsic crust (e.g., Clemens et al., 1986; Creaser and White, 1991; Patiño Douce, 1997) or mafic lower crust (Bédard, 1990; Frost and Frost, 1997; Frost et al., 1999; Wang, 2009), while others suggest that they are derivatives of mantle-derived basalts through fractionation (e.g., Turner et al., 1992; Litvinovsky et al., 2002; Mushkin et al., 2003), or a combination of crustal and mantle sources (Kerr and Fryer, 1993; Mingram et al., 2000; Wu et al., 2002; Yang et al., 2006). A-type granites occur world-wide throughout geological time in a variety of tectonic settings and do not necessarily indicate an anorogenic or rifting environment (Whalen et al., 1987).

In this paper, we present petrological data, zircon U–Pb age, zircon *in situ* Hf isotope, whole-rock chemical and Nd–Sr isotopes for a Mesozoic A-type granite in the northern margin of the North China Craton, to constrain the source and petrogenesis of the A-type pluton.

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2. Geological setting and sample descriptions

The North China Craton (NCC) is located in the eastern part of the Euro-Asian continent, which is one of the oldest continental nuclei in the world (Liu et al., 1992; Wu et al., 2008). The NCC was stabilized in Paleo-Proterozoic times, and the basement rocks of it is expected to be dominated by TTG gneisses and mediate to mafic granulites/amphibolites (e.g., Jahn et al., 1987; Guo and Zhai, 2001; Liu et al., 2000). A giant south-north gravity lineament (NSGL; Fig. 1a) based on geophysical data divides the craton into two distinct tectonic domains (Ma, 1989). However, the eastern part of the NCC was reactivated during the period of Jurassic and Cretaceous (Yanshanian) time as indicated by the high heat flow, the presence of voluminous magmatic rocks and the development of sedimentary basins, due probably to lithosphere thinning (Menzies et al., 1993; Griffin et al., 1998; Fan et al., 2000; Zheng et al., 2001; Xu, 2001; Gao et al., 2002). The Mesozoic magmatic rocks are composed mainly of intermediate to felsic rocks, and subordinate coeval mafic plutons/basalts, with zircon U–Pb ages mainly in the period of 180–117 Ma (e.g., Davis et al., 1998; Wang et al., 1998; Yang et al., 2004, 2008; Chen et al., 2005; Wu et al., 2005a,b; Zhou and Chen, 2006). The intermediate to felsic rocks contain plutons of quartz diorite, monzodiorite, quartz monzonite and monzogranite, in which mafic microgranular enclaves (MMEs)

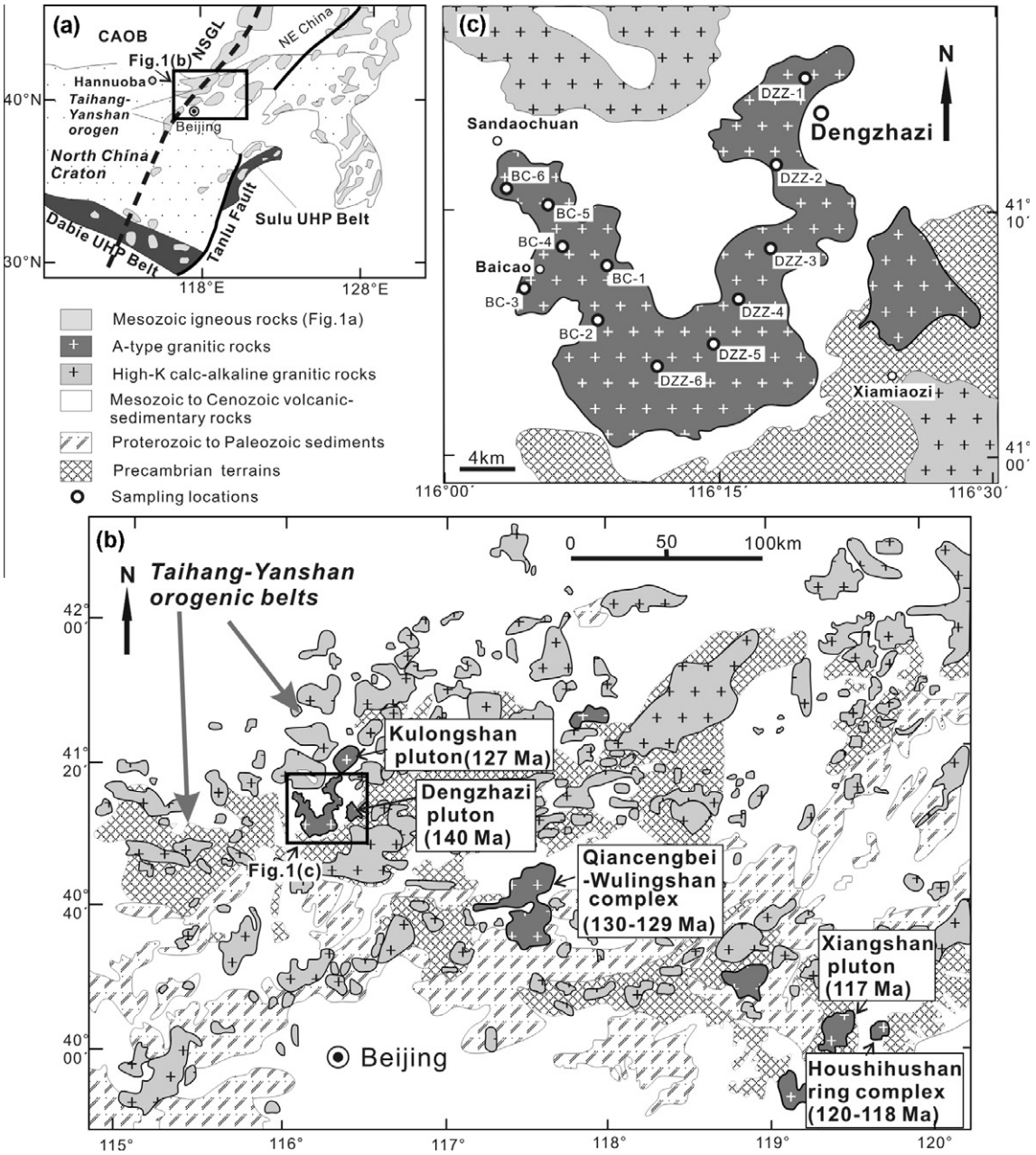

Fig. 1. (a) Sketch geological map of the North China Craton (NCC), in which study area is shown. NSGL, north–south gravity lineament; UHP, ultrahigh pressure; CAOB, Central Asian Orogenic Belts. (b) Geological map showing the distribution of the Mesozoic magmas in the Taihang–Yanshan orogenic belts, in which A-type granitic rocks were shown (modified after Yang et al., 2008). The age data of the Houshihushan ring complex, Xiangshan complex and Qiancengbei-Wulingshan complex are from Yang et al. (2008); the age data of the Kulongshan pluton is from Sun and Yang (2009). (c) Map of the Dengzhazi granitic pluton that intruded into the Archean terrain and the Jurassic volcanic rocks. Also shown are sampling localities.