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Petrology and geochemistry of the early Mesozoic pyroxene andesites in the Maixiu Area, West Qinling, China: Products of subduction or syn-collision?

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ABSTRACT

The Qinling–Dabie–Sulu Orogen is dotted with Mesozoic igneous rocks and its exact tectonic origin is still controversial, especially the precise timing of initial collision between the North China Block (NCB) and the Yangtze Block (YB) and the subsequent closure of the Paleo-Tethys Ocean in Qinling, China. This paper presents geochronological and geochemical data for pyroxene andesites in Maixiu area, West Qinling. Laser fusion $^{40}Ar/^{39}Ar$ dating for matrix glass yields an isochron age of 234 ± 3 Ma. The Maixiu pyroxene andesites (MPAs) display a hyalopilitic texture, and the predominant phenocryst phases are plagioclase, orthopyroxene and clinopyroxene. Orthopyroxene generally displays delicately normal zoning, whereas some clinopyroxene grains exhibit reverse zonings. Textural relations indicate that magma mixing plays a key role for the genesis of the MPAs. The MPAs, with 53.75–57.29 wt.% SiO_2, 0.6–0.82 wt.% TiO_2 and 48–72 Mg#, are characterized by high magnesium contents in some samples. The MPAs display enriched light rare earth elements (LREEs) and relatively high $(La/Yb)_N$ ratios (5–9). Clinopyroxene phenocrysts are depleted in some HFSE (e.g., Nb, Zr, Hf, and Ti) and some LILE (i.e., Ba, K and Sr), and are enriched in some other HFSE (e.g., Th and U), REE (e.g., Nd and Sm) and some other LILE (e.g., Rb and Pb). The MPAs have uniformly low $\varepsilon_{Nd}(t)$ values (−7.74 to −9.27) and high $(^{87}Sr/^{86}Sr)_t$ ratios (0.70788 to 0.71225), implying a continental rather than oceanic type magma source. Based on data for clinopyroxene phenocrysts, we estimate a temperature range of 956 to 1087 °C with the mean value of 1032 ± 39 °C (1σ), and a pressure range from 5.9 to 13.6 kbar with an average of 9.8 ± 1.9 kbar (1σ). We conclude that the petrogenesis of the MPAs in West Qinling Orogen may have involved magma mixing between melts derived from the sedimentary cover of the northward-subducting A'nyemaqen–Mianlue oceanic slab and peridotite-derived basaltic melts from the overriding mantle wedge during the initial collision stage between the NCB and the YB.

1. Introduction

Andesite is the second most common volcanic rock type on Earth and provides abundant information about the interaction between the mantle and crust in the subduction zones (Grove and Kinzler, 1986). However, the petrogenesis of subduction-related andesite petrogenesis is being debated (Boettcher, 1973; Grove and Kinzler, 1986; Reubi and Blundy, 2009; Tatsumi and Eggins, 1995; Thorpe, 1982), since andesite can form via different processes, such as (1) magma mixing between felsic and mafic/ultramafic melt (Reubi and Blundy, 2009; Streck et al., 2007); (2) fractional melting or assimilation fractional crystallization (AFC) from basaltic composition (Gill, 1981; Graham and Cole, 1991; Tiepolo et al., 2011); (3) partial melting of the hydrated mantle wedge peridotite (Kelemen, 1995). In particular, the fluid dehydration from water-bearing minerals (such as carpholites, amphiboles, and chlorites), plays a key role in the genesis of arc andesite, which are enriched in large ion lithophile elements (LILE) and light rare earth elements (LREE), and depletion of high field strength elements (HFSE) (Chiaradia et al., 2011). Moreover, andesites and coeval basalt–dacite–rhyolite volcanic suites can serve as excellent proxies for the paleotectonic and paleogeographical reconstruction, especially in ancient orogens that underwent multiple deformation stages (Bailey, 1981).

Stretching across the central part of China, the Qinling–Dabie–Sulu Orogen (Central Orogen) marks the final amalgamation of the North China Block (NCB) and Yangtze Block (YB) (Fig. 1A and B). It is generally accepted that the Qinling Orogenic belt can be divided into two parts along the Baoji–Chengdu railway (Meng and Zhang, 2000; Zhang et al., 2001, 2007; Fig. 1C), namely the East Qinling Orogenic Belt and the West Qinling Orogenic Belt. During the past four decades, much research was done in the eastern part of this orogen (Dong et al., 2011;

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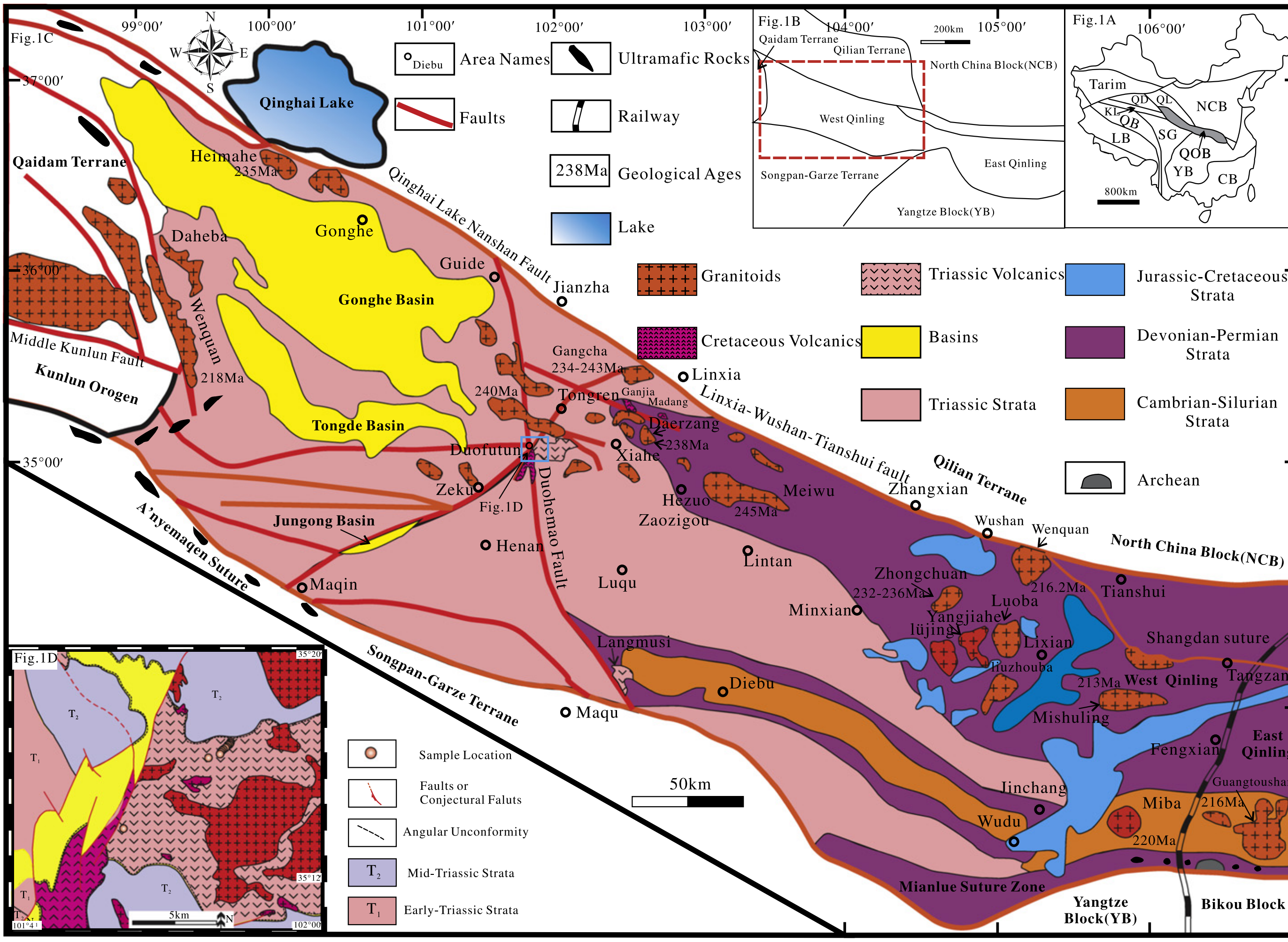

Fig. 1. A and B. Subdivision of the major tectonic units in China showing the location of the Qinling Orogenic Belt. C. Simplified regional geological map of the West Qinling, showing distribution of the Mesozoic granitoids in the West Qinling Orogen (modified from Feng et al., 2002; Zhang et al., 2006, 2007). Abbreviations in Fig. 1A: CB: Cathaysia Block; KL: Kunlun; LB: Lhasa Block; NCB: North China Block; QB: Qiangtang Block; QD: Qaidam; QL: Qilian; QOB: Qinling Orogenic Belt; YB: Yangtze Block. Pluton names and age data sources in Fig. 1C: Wenquan (218 Ma) and Heimahe (235 Ma) are from Zhang et al. (2006); Zhongchuan (232–236 Ma) is from Zhu et al. (in press); Daerzang (238 Ma) and Meiwu (245 Ma) are from Jin et al. (2005); Tongren (240 Ma) are from Feng et al. (2002); Guangtoushan (216 Ma) is from Sun et al. (2000); Miba (220 Ma) is from Sun et al. (2002); Mishuling (213 Ma) is from Qin et al. (2009); Wenquan (216.2 Ma) is from Zhu et al. (2011); and Gangcha (234–243 Ma) is from Guo et al. (2011, 2012) and Luo et al. (2012). D. Geological map of the Maixiu area, West Qinling.

Li et al., 1978; Mattauer et al., 1985). However, knowledge on the western counterpart is still cryptic till now (Zheng et al., 2010), and this largely restricts our understanding of the general geological evolution of the entire orogen. Specifically, the precise time of tectonic transition from the Mianlue Paleo-ocean's northward subduction to the Yangtze Block–North China Block collision is still debated due to a lack of geochronological data. For example, several authors considered the early Indosinian granitoids in the Central Orogen as products of a post-collisional regime (Luo et al., 2012; Zhang et al., 2006). However, Jin et al. (2005) and Guo et al. (2011, 2012) contended that the coeval adakite-like granitoids occurring in the same tectonic unit (Fig. 1) are consistent with an active destructive margin regime during the early Indosinian in West Qinling.

Here, we report, the geochronology, mineral chemistry, whole-rock major-trace element chemistry, and Sr–Nd isotopic data to constrain the timing of volcanism and petrogenesis of the Mesozoic volcanic rocks from the Maixiu area, West Qinling. Our main objective is to develop a paleotectonic model that is consistent with the coeval intrusive rocks in the same regions (e.g. Gangcha complex and Daerzang pluton; Fig. 1).

2. Geological background

West Qinling is the westward extension of East Qinling and is bounded by Qilian terrane to the north, Qaidam terrane to the west, and the Songpan–Garzê terrane to the south (Ratschbacher et al., 2003; Zhang et al., 2001; Zheng et al., 2010) (Fig. 1 A and B), Moreover, the A'nimaque–Mianlue suture zone along the southern margin of West Qinling is interpreted to represent a fossil ocean, belonging to one branch of the Paleo-Tethys, and extends to the Buqingshan–A'nimaque paleo-ocean in the Eastern Kunlun Orogen.

West Qinling is interpreted to be a microcontinental block that originally split from the NCB, migrated towards the northern YB during the Meso-Neoproterozoic, and then collided with the NCB during the Triassic (Dong et al., 2011; Meng et al., 2005; Zheng et al., 2010). As the main component of the Foping metamorphic terrane, the oldest exposed crystalline basement in West Qinling is the Qinling Group, which predominantly consists of gneisses, amphibolites and marbles, with U–Pb ages ranging from 2172 to 2267 Ma (Dong et al., 2011; Meng and Zhang, 2000). However, the well exposed stratigraphic sequence in our study area is the Upper Permian Maomaolong