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Geochemistry of picrites and associated lavas of a Devonian island arc in the northern Junggar terrane, Xinjiang (NW China): Implications for petrogenesis, arc mantle sources and tectonic setting

Zhaochong Zhang [a,*], Jingwen Mao [b], Jinhong Cai [a], Timothy M. Kusky [c], Gang Zhou [d], Shenghao Yan [b], Li Zhao [a]

[a] State Key Laboratory of Geological Processes and Mineral Resources, China University of Geosciences, Beijing 100083, China
[b] Institute of Mineral Resources, Chinese Academy of Geological Sciences, Beijing 100037, China
[c] Department of Earth and Atmospheric Sciences, 3507 Laclede Avenue, St. Louis, MO 63103-2010, USA
[d] No. 4 Geological Party, Xinjiang Bureau of Geology and Mineral Resources, Altay, 836500, China

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ABSTRACT

The Junggar terrane in China's Xinjiang Province sits adjacent to the Siberian craton and Kazakhstan block. A nearly 100-m thick series of high-Mg lava flows is found in a Devonian arc in the Junggar terrane. The highly porphyritic high-Mg lavas are stratigraphically in the lower part of the Middle Devonian Beitashan Formation, and are overlain by basalts and andesites. Based on the chemistry and phenocryst contents, the high-Mg lavas are classified into picrites and ankaramites. The former are characterized by a large amount of olivine phenocrysts (Fo 79–82) with minor clinopyroxene ($En_{44-50}Fs_{1-10}Wo_{44-48}$) and rare chrome spinel with Cr# (Cr/Cr+Al) values between 0.63 and 0.86, whereas clinopyroxene phenocrysts are dominant in ankaramite. The groundmass in the picrites and ankaramites consists of plagioclase, clinopyroxene, and Ti-magnetite. Glass is not preserved, but minor metal sulfides are present. Based on olivine-melt equilibrium, the primitive magmas had approximately 9 wt.% MgO, and the high-Mg lavas contain accumulated olivine (picrites) and clinopyroxene+olivine (ankaramites). All lavas have similar primitive mantle normalized trace element patterns, characterized by negative Nb, Ta and Ti anomalies, as typical for island arc volcanic rocks. These relationships suggest that the rock suites are co-magmatic. The Zr/Nb ratios (23–66) of the picrites and basalts resemble MORBs (10–66), suggesting MORB-like sources for the picrites. The picritic rocks have slightly LREE-enriched patterns with $(La/Yb)_n$ ranging from 1.6 to 3.5 and $(La/Sm)_n$ from 1.2 to 2.1. In contrast, basaltic rocks have flat to slightly LREE-enriched patterns with $(La/Yb)_n$ ranging from 1.2 to 5.7 and $(La/Sm)_n$ from 0.8 to 2.5, whereas andesitic rocks have modestly LREE-enriched patterns with $(La/Yb)_n$ ranging from 2.8 to 9.1 and $(La/Sm)_n$ from 1.7 to 2.9. The REE patterns for all rocks do not exhibit Eu anomalies. The rocks have similar $(^{87}Sr/^{86}Sr)_t$ (0.7033–0.7043, t=385 Ma) and $\varepsilon_{Nd}(t)$ values (6.4–7.3), overlapping with the present day island arc field. Consequently, primary magmas were most likely generated in N-MORB-type mantle, which was modified by the addition of a fluid component derived from altered subducted oceanic crust as indicated by elevated Sr/Nd and low Th/Yb ratios. REE modelling suggests that the primary magmas were derived from garnet–spinel transition zone mantle.

1. Introduction

Volcanic arc rocks can provide much information for understanding crustal and mantle processes. Unmodified primary magmas are especially important, as they can provide key constraints on the compositional and thermal structure of sub-arc mantles via geothermometry, geobarometry and experimental data (Myers and Johnston, 1996; Hirschmann et al., 2000; Falloon and Danyushevsky, 2000). Primary melts also offer a baseline for estimating the extent of fractionation required to generate arc and, ultimately, continental crust.

Picrites are characterized by MgO contents of more than 12 wt.%, SiO_2 contents lower than 45 wt.% and less than 3 wt.% alkalies (Le Bas, 2000). Picrites may be formed in different tectonic environments, including large igneous provinces (LIP), close to rift systems (e.g., West Greenland; Larsen and Pedersen, 2000), at mid-ocean ridges (e.g., Perfit et al., 1996), and in island arcs. However, the few occurrences from arcs reported in the literature are all confined to intra-oceanic subduction regimes. Island arc picrites are only reported from the Aleutians (e.g. Nye and Reid, 1986), the Lesser Antilles (e.g. Woodland et al., 2002), Kamchatka (e.g. Kamenetsky et al., 1995), Japan (e.g.

* Corresponding author.
E-mail address: zczhang@cugb.edu.cn (Z. Zhang).

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Yamamoto, 1988; Ninomiya and Arai, 1993), Vanuatu (e.g. Eggins, 1993; Peate et al., 1997) and from the Solomon Islands (e.g. Cox and Bell, 1972; Ramsay et al., 1984; Schuth et al., 2004). It is not fully understood as to whether the parental magmas in island arcs are of picritic or basaltic composition. Based on a study of island arc volcanic rocks from Grenada, Lesser Antilles, Woodland et al. (2002) proposed that subduction-related picritic magmas can be parental magmas of associated basalts. In contrast to this model, other examples of subduction-related picrites appear to be linked to anomalous thermal regimes such as those in Vanuatu which are linked to the subduction of a complexly fractured part (d'Entrecasteaux fracture zone) of the Indian–Australian plate beneath Vanuatu (e.g., Peate et al., 1997).

Recently, we recognized a nearly 100-m thick succession of picritic lava flows from the Devonian Beitashan Formation (Fm.) in the Junggar terrane, which lies in the middle of the Central Asian orogenic belt (CAOB), bordered on the north by the Siberian craton and on the south by the North China–Tarim cratonic block (Fig. 1a). Although some researchers suggested the volcanic rocks from the Beitashan Fm. formed in a rift setting (e.g., Wei and Ni, 1990; Han, 1991), we support the alternative view (Yu et al., 1993; He et al., 1994) that they formed in an arc setting. In this paper we report the first major element, trace element, and Sr–Nd isotopic geochemical data for whole rocks from these lavas, with the aim of providing constraints on mantle source characteristics and tectonic implications.

2. Geological setting

The Junggar terrane is bounded between the Siberian craton, the Kazakhstan block, and the Tianshan Range (Fig. 1b). The Irtysh fault (Fig. 1c) marks the boundary between the Caledonian Altay orogenic

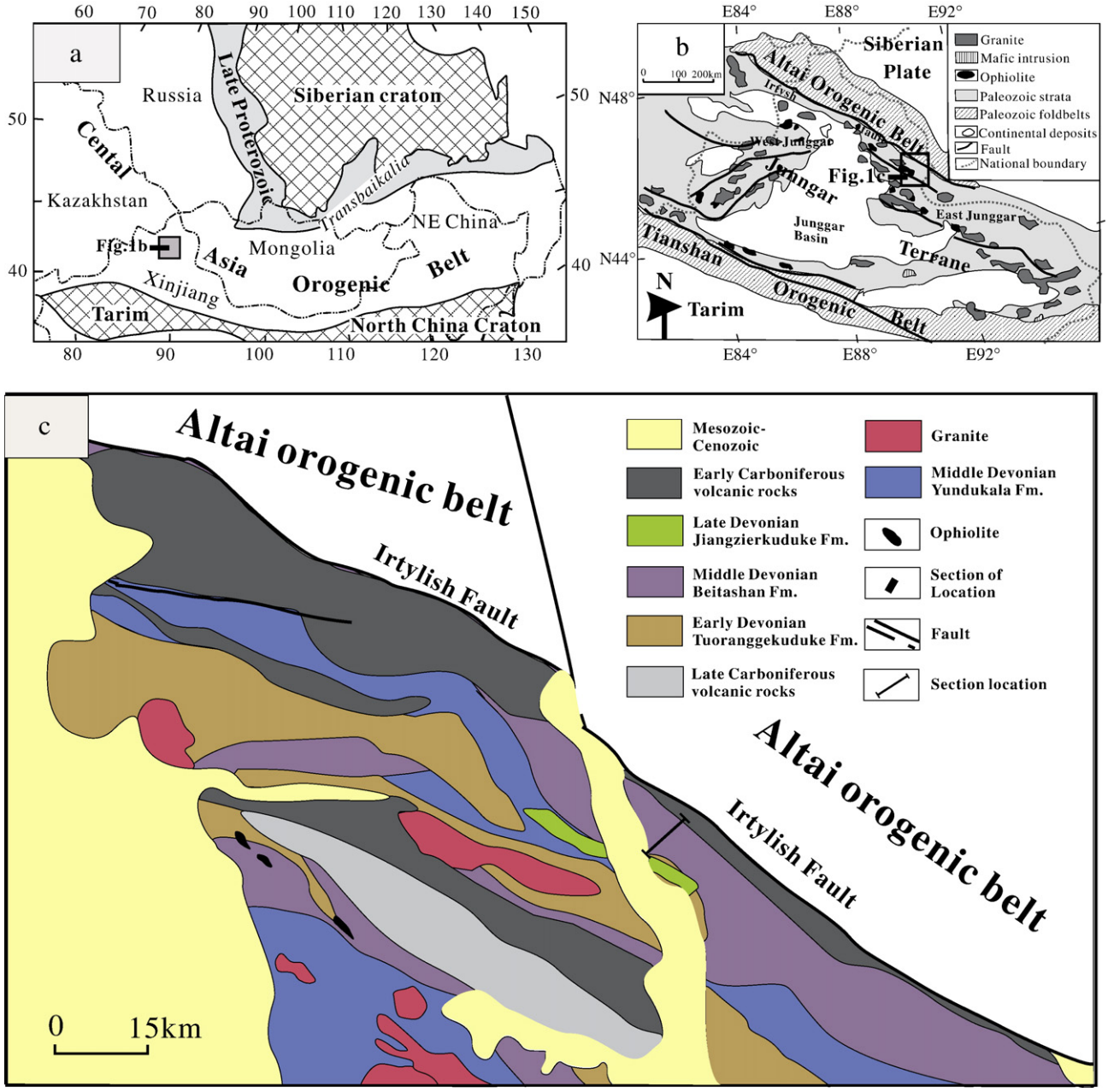

Fig. 1. (a) Relationship of study area with the Central Asia Orogenic Belt (modified from Jahn et al., 2000); (b) Simplified geological map of the Junggar terrane in northern Xinjiang (modified from Chen and Jahn, 2004); (c) Distribution of Palaeozoic volcanic rocks in the East Junggar terrane. The geology of the Altay orogenic belt to the north of the Irtysh Fault is not shown.