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Petrogenesis of Late Paleozoic volcanics from the Zhaheba depression, East Junggar: Insights into collisional event in an accretionary orogen of Central Asia

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ABSTRACT

The Carboniferous to Permian period marks an important transition from accretion to collision in the East Junggar terrane, NW China. Field and Well Fuqian-1 well core data from the Zhaheba depression provide a better window for understanding the magmatic process during this period and its implications for the continental growth of Central Asia. Field investigations reveal structural features characterized by NE–SW compression, with lithology composed of basic and intermediate-felsic volcanic rocks and pyroclastic rocks. The core samples from Well Fuqian-1 show dominantly basalt, basaltic andesite, dacite and minor pyroclastic rocks. We report zircon SHRIMP U–Pb ages of 276.0–279.8 Ma from rhyolites and zircon LA–ICP-MS U–Pb ages of 315.4–317.4 Ma from dacite and basaltic andesite. Our data suggest that the volcanic rocks from surface exposures and the well cores of Well Fuqian-1 formed in the Early Permian and the Late Carboniferous, respectively. The Late Carboniferous mafic rocks have geochemical characteristics similar to the intercalated Early Permian felsic rocks. The mafic rocks show low initial $^{87}Sr/^{86}Sr$ (0.703162–0.703783) and high $\varepsilon_{Nd}(t)$ (5.5–7.5), enrichment in LREE and some LILEs (such as Rb and Th) as well as HFSEs (such as Zr, Y), and depletion in Nb, Ta and Ti. Furthermore, they also display lower Sm/Th (1.6–8.4) and higher Th/Y (0.03–0.12) ratios than those of MORB, and variable Th/Zr (0.004–0.016), Ba/Th (61–839), Ba/La (6.13–48.77) and Ba/Nb (10–101) ratios. The geochemical data suggest that these rocks were derived dominantly from a 5–10% partial melting of a mainly garnet-rich with minor spinel-bearing lherzolite mantle source metasomatized by slab-derived fluids. The felsic rocks are rich in silica (SiO_2 = 57.43–78.07%) and alkalis ($K_2O + Na_2O$ = 5.33–9.28%) and possess high TFe_2O_3 (0.70–6.95%) contents and Ga/Al ratios, and low CaO (0.18–5.11%) and MgO (0.13–2.02%) contents. They represent typical high–medium-K calc-alkaline A-type rhyolite with enrichment of LREE and HFSE (Zr, Hf) and depletion of Ba, Sr, Eu, Nb and Ta. These rocks display high $\varepsilon_{Nd}(t)$ (6.9–7.3) and $\varepsilon_{Hf}(t)$ (10.3–14.6) values and young crustal model ages (348–557 Ma). Integrating regional geological data from the East Junggar terrane and the available data from the proximal ophiolite belt, we propose that an arc–arc or arc–continent post-collisional setting in the Zhaheba area commenced at ca. 317 Ma. The Late Carboniferous–Early Permian felsic and mafic magmas were derived from the partial melting of the juvenile mafic lower crust and subcontinental lithospheric mantle metasomatized by pre-Carboniferous subduction-related fluids through asthenospheric upwelling. This post-collisional event suggests that vertical accretion played an important role not only in the Late Carboniferous–Early Permian continental growth of the East Junggar, but also in the final evolutionary phase of the accretionary orogen.

1. Introduction

The Central Asian Orogenic Belt (CAOB), also known as the Altaids or Altaid collage (Şengör et al., 1993), was considered in earlier studies to have resulted from the oceanward growth of a single and laterally extensive island arc (Şengör and Natal'in, 1996; Şengör et al., 1993). More recent studies identify successive accretion of oceanic islands, seamounts, accretionary wedges and microcontinents from the Neoproterozoic to Late Paleozoic in the CAOB (Buslov et al., 2001; Glorie et al., 2011; Kröner et al., 2011; Metcalfe, 2013; Rojas-Agramonte et al., 2011; Safonova et al., 2011; Windley et al., 2007; Xiao et al., 2010). Voluminous Paleozoic I- or A-type granitoids derived from juvenile sources were also emplaced (B.F. Han et al., 2006, 2010; Chen and Jahn, 2004; Chen et al., 2010; Jahn et al., 2000; Su et al.,

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2012; Yang et al., 2011), revealing a complex combination of subduction–accretion processes and late-stage extension (Coleman, 1989; Jahn et al., 2000; Kovalenko et al., 2004; Şengör et al., 1993; Xiao et al., 2011). However, a coeval similar phenomenon of compressional deformation in the same direction, accompanied by foreland sedimentation, in the northern Xinjiang region seems to indicate collisional orogenesis in the Late Carboniferous (Li and Poliyangsiji, 2001). Therefore, an understanding of the tectonic milieu and its transition is not only critical to reconstruct the geological history of the CAOB, but also has important implications for the continental growth of Central Asia.

The Junggar terrane is an important tectonic unit of the Central Asian Paleozoic accretionary and collisional orogenic belt between Siberian and Kazakhstan–Junggar plates (Fig. 1a). It is traditionally divided into the Junggar Basin, West Junggar terrane and East Junggar terrane (Fig. 1b). The West Junggar terrane is made up of Paleozoic accretionary complexes with NE–SW trending faults in the south and volcanic arcs with E–W trending faults and fault-bounded blocks in the north

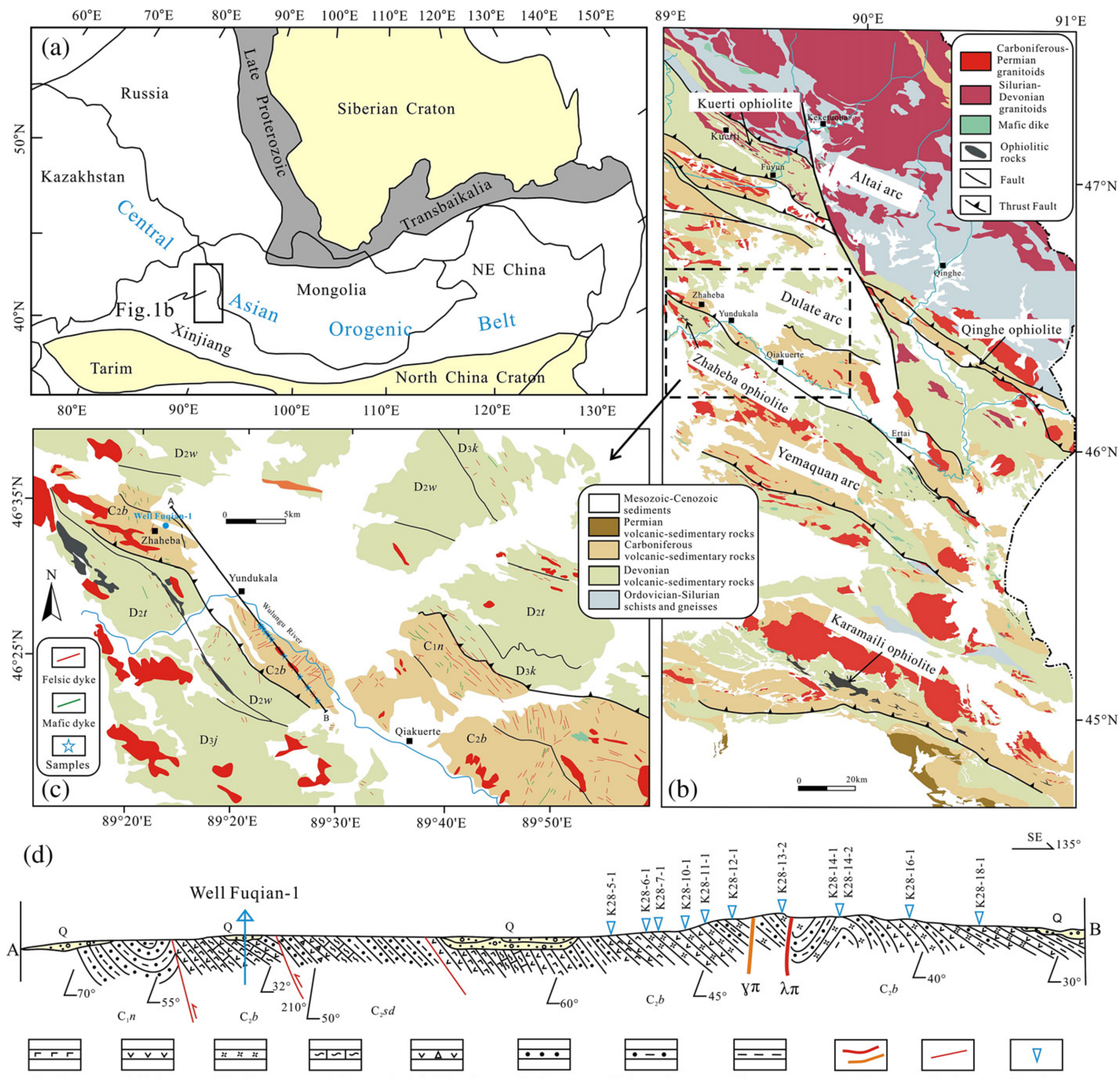

Fig. 1. (a) Relationship of the study area with the Central Asian Orogenic Belt (modified after Han et al., 2010; Jahn et al., 2004; Windley et al., 2007). (b) Geological map of the East Junggar terrane and adjacent Altai in northern Xinjiang (modified after BGMRXUAR, 1993). (c) Geological map of the Zhaheba depression showing the locality of Well Fuqian-1 and geological cross-section AB and sample distribution from the Zhaheba area (modified after BGMRXUAR, 1993). D_{2t}—Middle Devonian Tuoranggekuduke Formation; D_{2w}—Middle Devonian Yundukala Formation; D_{3k}—Upper Devonian Kaxiweng Formation; D_{3j}—Upper Devonian Jiangzierkuduke Formation; C_1n—Lower Carboniferous Nanmingshui Formation; C_2b—Upper Carboniferous Batamayineishan Formation; C_2sd—Upper Carboniferous Sudukuke Formation; (d) Detailed geological cross-section AB of the Yundukala area of the Zhaheba depression in the East Junggar terrane.