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Underplating generated A- and I-type granitoids of the East Junggar from the lower and the upper oceanic crust with mixing of mafic magma: Insights from integrated zircon U–Pb ages, petrography, geochemistry and Nd–Sr–Hf isotopes

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ABSTRACT

Whole rock major and trace element, Nd–Sr and zircon Hf isotopic compositions and secondary-ion mass spectrometry zircon U–Pb ages of eleven granitoid intrusions and dioritic rocks from the East Junggar (NW China) were analyzed in this study. The East Junggar granitoids were emplaced during terminal Early to Late Carboniferous (325–301 Ma) following volcanic eruption of the Batamayi Formation. Zircons from the East Junggar granitoids yielded 210 concordant $^{206}Pb/^{238}U$ ages which are all younger than 334 Ma and exhibit $\varepsilon_{Hf}(t)$ values distinctly higher than Devonian arc volcanic-rocks. Seismic P-wave velocities of deep crust of the East Junggar proper resemble those of oceanic crust (OC). These characteristics suggest absence of volcanic rock and volcano-sedimentary rock of Devonian and Early Carboniferous from the source region. The East Junggar granitoids show $\varepsilon_{Nd}(t)$ and initial $^{87}Sr/^{86}Sr$ values substantially overlapping those of the Armantai ophiolite in the area. The Early Paleozoic OC with seamount-like composition as the Zhaheba–Armantai ophiolites remained in the lower crust and formed main source rock of the East Junggar granitoids. Based on petrography and geochemistry, the East Junggar granitoids are classified into peralkaline A-type in the northern subarea, I-type (I_1 and I_2 subgroups) mainly in the north and A-type in the south of the southern subarea. The perthitic or argillated core and oligoclasic rim with an argillated boundary of feldspar phenocrysts and inclusion of perthites or its overgrowth by matrix plagioclase, in the monzogranites (northern subarea), suggest mixing of peralkaline granitic magma with mafic magma. In the north of the southern subarea, the presence of magmatic microdioritic enclaves (MMEs) in the I_1 subgroup granitoids, transfer of plagioclase phenocrysts and hornblendes between host granodiorite and the MME across the boundary and a prominent resorption surface in the plagioclase phenocrysts indicate mixing of crustal magma (I_2 subgroup granitoids) with mafic magma. Magma mixing shifted $(^{87}Sr/^{86}Sr)_i$ of the I_1 subgroup granitoids towards the mantle array. Two generations of hornblende with zonal distribution and similar mineral and geochemical compositions of quartz monzodiorite and hosted MME with unfractionated rare earth elements (REE) suggest extended magma mixing with onset probably at or near source region. These observations imply concurrency of mantle input and the crustal melting and, hence, a causal relationship between underplating/intraplating and the lower OC/upper OC melting. The I-type granitoids experienced plagioclase and hornblende fractionations, whereas fractionated phases of the two groups of A-type granites were alkali feldspar and albite–oligoclase with significant involvement of F^--rich fluid. Granodioritic parent magmas of the I_2 subgroup granitoids stemmed from the hydrous upper OC. Parent magmas of the two A-type groups possess syenogranitic or quartz syenitic compositions. The peralkaline A-type granites stemmed from the lower OC, whereas the A-type granites from dehydrated upper OC left behind after extensive partial melting and extraction of I-type granitoids. Based on comparison in the ternary system Mg_2SiO_4–$CaAl_2SiO_6$–SiO_2, most of the Batamayi volcanic rocks with affinity to ocean-island basalts were derived from asthenospheric upwelling. The gabbro–dioritic rocks with higher light to heavy REE ratios stemmed from metasomatized lithospheric mantle. Both of the above mafic rocks contain subducted slab component.

Loci of ponding of mafic magma and crustal melting migrated upward and southeastward from the lower OC in the northern subarea (yielding the peralkaline A-type granites) to the upper OC in the southern subarea. The latter evolved from hydrous (yielding the I-type granitoids in the north of the subarea) to dehydrated (yielding the A-type granites in the south of the subarea). Sequence of these events resulted in increasingly-later formation of the East Junggar granitoids southeastwards with an age span of ~20 Ma. Minor contribution from Late Paleozoic

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OC to the source of the southern granitoid subarea caused the latter showing distinctly higher $\varepsilon_{Nd}(t)$ than the northern subarea. In conclusion, underplating caused OC remelting which, together with significant magma mixing, produced the East Junggar granitoids in a non-subduction zone environment.

1. Introduction

Granitoids of the East Junggar and West Junggar are exclusively A- and I-types with notable absence of S-type and exhibit high positive $\varepsilon_{Nd}(t)$, low initial $^{87}Sr/^{86}Sr$ and young depleted-mantle model ages (<1 Ga) (e.g., Chen and Arakawa, 2005; Chen and Jahn, 2004; Geng et al., 2009; Han et al., 1997; Liu, 1990, 1991, 1993; Tang et al., 2010) suggesting significant addition of juvenile material. Han et al. (1997) considered that A-type granites of Ulungur, the East Junggar, represent residual magma from basic magma after extensive fractional crystallization. Chen and Jahn (2004) concluded that Paleozoic granitoids of the West Junggar and East Junggar were derived from buried oceanic crust (OC) and arc complex of Early Paleozoic. In summary, OC, island arc volcanic rock and freshly mantle-derived materials constitute three candidates of source rock of the East Junggar granitoids that remain unresolved. Second, geodynamic mechanisms that generated granitoids of the areas are in dispute. Most workers considered that the Junggar granitoids were post-collisional or formed under extensional regime (e.g., Chen and Arakawa, 2005; Han et al., 1997). However, other workers believed that ridge subduction continued to the Late Carboniferous producing granitoids and dioritic rocks (329–296 Ma) (Geng et al., 2009) and adakites and high-Mg diorites (Tang et al., 2010) in the West Junggar.

The Junggar terrains and the Chinese Altay on the north are respectively oceanic realm and continental arc that are typical of the Central Asian Orogenic Belt (CAOB). Liu et al. (2012) showed that voluminous granitoids of the Chinese Altay were derived dominantly from detrital materials eroded from juvenile rocks of the Caledonian province and Tuva–Mongol microcontinental block and inherit primitive Nd–Sr–Hf isotopic compositions of the latter. Eastwards, the East Junggar extends to the Inner Mongolia and Northeast China where widespread granitoids

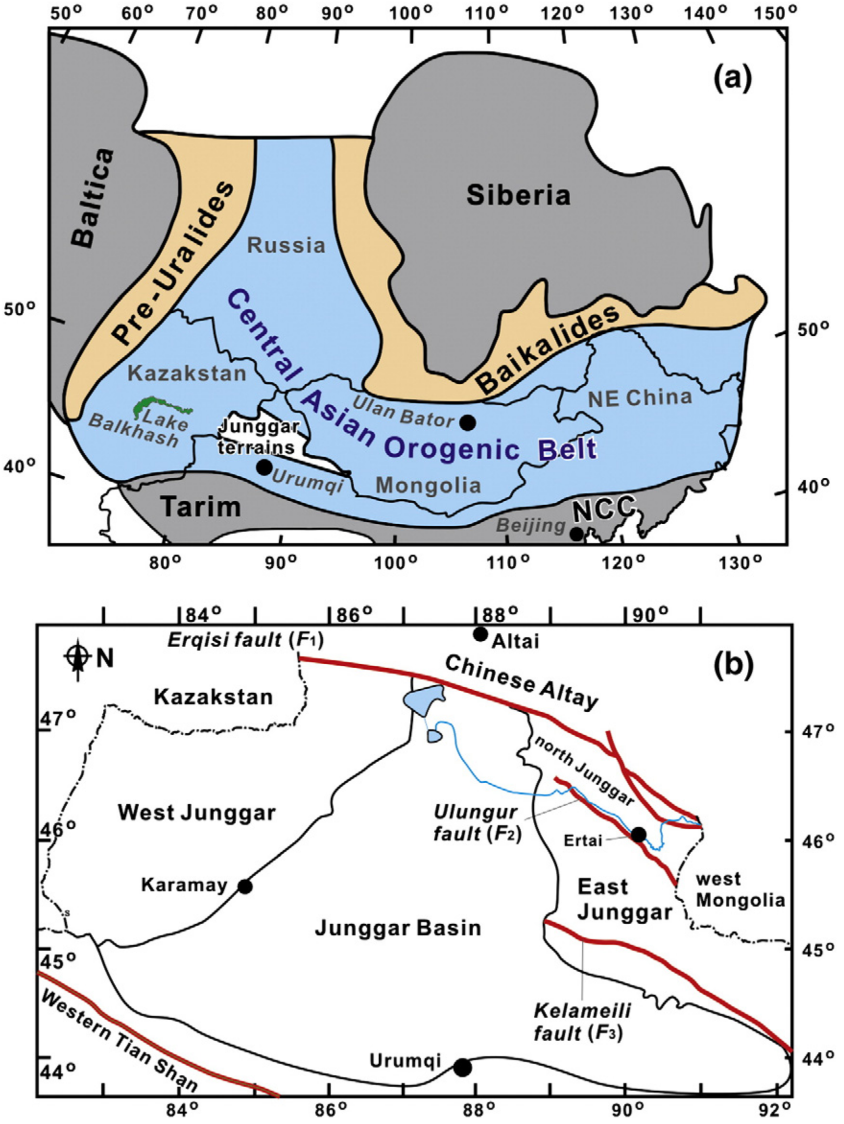

Fig. 1. (a) Location of the Junggar terrains in the Central Asian Orogenic Belt. (b) Distribution of the West Junggar, Junggar Basin and East Junggar and division of the East Junggar into north Junggar and East Junggar proper with fault F_2 as boundary.