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Research Advances

A New Discovery of Early Carboniferous Gabbros in the Southern Chinese Altai: Evidence for Ridge Subduction

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Objective

The Chinese Altai as a key part of the Central Asian Orogenic Belt is characterized by numerous outcrops of Paleozoic granitoids and minor mafic plutons (Fig. 1a). It is widely accepted that Devonian ridge subduction played an important role in the tectonic evolution of the Chinese Altai. However, Carboniferous magmatism related to ridge subduction has received little attention. Moreover, previous studies concentrated mainly on an intermediate-felsic large batholith, with little attention to mafic intrusion. Here, we present, for the first time, LA-ICP-MS zircon U-Pb dating and whole-rock geochemical data for the Kezijiaer gabbros from the southern Chinese Altai, aiming to elucidate their emplacement age, petrogenesis and tectonic setting. Based on this study, together with previous available data, we argue that Early Carboniferous ridge subduction also exerted a critical influence on the tectonic evolutionary history of the Chinese Altai in the Paleozoic.

Methods

Zircon U-Pb isotopic dating by LA-ICP-MS was carried out at the Key Laboratory for the Study of Focused Magmatism and Giant Ore Deposits, MLR, Xi'an Center of Geological Survey, CGS, using a Geolas 200M system equipped with a 193 nm ArF-excimer laser. Zircon 91500, GJ-1 and NIST610 were used as the reference materials for the U-Pb dating and to optimize the instrument.

Whole-rock geochemical analyses were performed using X-ray fluorescence (XRF) and inductively coupled-plasma mass spectrometry (ICP-MS) at Chang'an University (China), with analytical errors for most elements generally less than 3 wt.%. Values of Loss on ignition (LOI) were measured using an electronic analytical balance at constant temperature of around 1000°C.

Results

The gabbroic plutons in this study are located in the Kezijiaer area, southern Chinese Altai (88°24′40″E, 47°27′00″N). Detailed geological mapping revealed that these plutons occupy about an area of ~300 m^2 (seven large-scale bodies) and intrude into Proterozoic metamorphosed strata and Silurian granites.

Zircon crystals from the Kezijiaer gabbros are prismatic, transparent to translucent and subhedral. They are 200–60 μm long and 100–50 μm wide, with length/width ratios ranging from 4:1 to 2:1. In CL images (Fig. 1b), the zircons with high Th/U ratios (0.4–0.9) are characterized by remarkable oscillatory zoning, suggesting an origin from the magma source. Analyses of 27 zircon grains yielded $^{206}Pb/^{238}U$ ages ranging from 363 Ma to 340 Ma, with a weighted mean age of 348±3 Ma (MSWD=0.46; Fig. 1b). The dating result was interpreted as the crystallization age of the Kezijiaer gabbros.

Geochemically, the Kezijiaer gabbroic samples are characterized by a limited range of SiO_2 content (46.1–47.4 wt%), high MgO (6.65–8.11 wt%), TiO_2 (1.43–1.92 wt%) and CaO (8.99–15.1 wt%), and low K_2O (0.30–0.88 wt%), with relatively high Na_2O/K_2O ratios (2.04–10.10, average 3.67) and $Mg^{\#}$ values (53–57), displaying a trend of subalkaline tholeiitic compositions. Moreover, they have high Ni (60.5–97.7 ppm), Co (40.7–49.6 ppm), Cr (195–269 ppm) and Sr (227–452 ppm) abundances, and display relatively flat chondrite-normalized REE patterns ($(La/Yb)_N$ = 1.5–2.0, $(La/Sm)_N$ = 0.9–1.2 and $(Gd/Yb)_N$ = 1.3–1.7) with negative to positive weak Eu anomalies (δEu = 0.77–1.08). As well, the Kezijiaer gabbros exhibit a significant enrichment of large ion lithophile elements (such as Rb, Ba, Th and U) relative to the high-field strength elements, in particular Nb and Ta troughs, similar to those in subduction zone magmatism.

It is noted that the gabbroic samples in this study exhibit relatively high Nb/Ta (14.2–19.6), Zr/Hf (32.1–38.5) and Ti/V (22.1–32.4) values. These features show that the gabbros share geochemical signatures of both IAB and MORB, as manifested by the discrimination diagrams (Fig. 1c, d). Furthermore, they have low La/Sm (1.3–1.9), Sm/Yb (1.3–1.6) and Hf/Sm (0.7–1.0), coupled with high Th/La (0.1–0.3), suggesting that the Kezijiaer gabbros mainly originated from partial melting of a spinel-lherzolite mantle wedge metasomatized by subduction-related fluids and sediment melts with an input of asthenospheric components. Besides, they display relatively low Rb/Sr (0.1–0.3) and La/Sm (1.3–1.9), as

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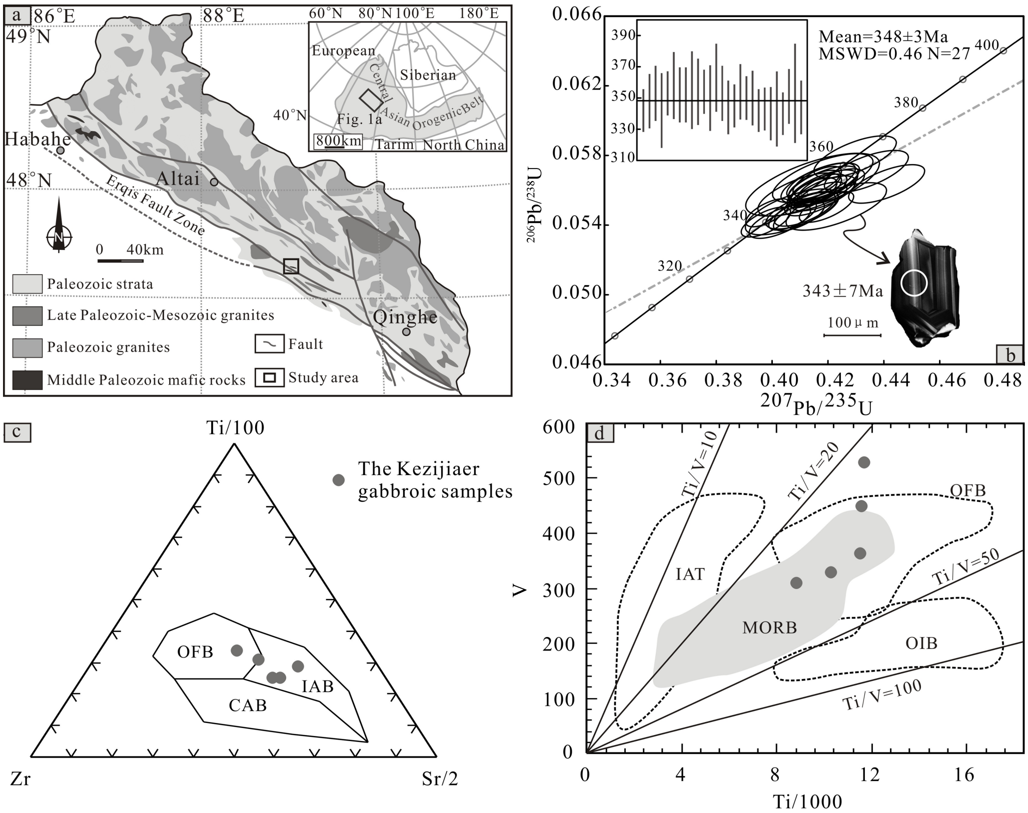

Fig. 1. (a) Simplified geological map of the Chinese Altai; (b) zircon U-Pb ages; (c) Ti/100-Zr-Sr/2 and (d) V-Ti/1000 discrimination diagrams of the Kezijiaer gabbros.

well as high Ti/Y (305–468) ratios, precluding the possibility that the magmas were markedly contaminated by crust-derived materials. In contrast, based on the correlation of MgO with other major elements, the results reveal that a pronounced fractionation of olivine and clinopyroxene has taken place.

Conclusions

(1) LA-ICP-MS zircon U-Pb dating results indicate that the southern Chinese Altai Kezijiaer gabbros with a crystallization age of 348±3Ma (MSWD=0.46) were emplaced in the Early Carboniferous.

(2) The Kezijiaer gabbros originated mainly from partial melting of a spinel-lherzolite mantle wedge that had been metasomatized by subduction-related fluids and sediment melts with input of asthenospheric components.

(3) Taking into account regional geology and published data, we argue that an Early Carboniferous ridge subduction regime responsible for the Kezijiaer gabbros might have also exerted a crucial role in the tectonic evolutionary processes of the Chinese Altai in the Paleozoic. Moreover, massive Devonian magmatic rocks related to ridge subduction have been reported in this region (Cai et al., 2010; Jiang et al., 2010), and thus we conclude that the Devonian ridge subduction most likely continued into the Early Carboniferous. This represents the first discovery in this area.

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