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Magmatism and tectonic evolution of the Chinese Altai, NW China: insights from the Paleozoic mafic and felsic intrusions

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The Chinese Altai, as a key segment of the Central Asian Orogenic Belt (CAOB), is dominated by variably deformed and metamorphosed sedimentary rocks, volcanic rocks and plutonic rocks. The plutonic rocks include extensive granites and relatively subordinate mafic intrusions. For instance, mafic dykes in the northwestern region (Habahe area) have an emplacement age of 375.5±4.8Ma and include gabbroic and doleritic dykes. The gabbroic dykes have chondrite-normalized REE patterns similar to N-MORB (La/YbN=0.86∼1.1), together with their high εNd(t) values (+7.6∼+8.1), indicating deriviation from a N-MORB-type depleted asthenospheric mantle. While the doleritic dykes resemble E-MORB (La/YbN= 1.12∼2.28) with relatively low εNd(t) values (+3.4-+5.4) and high initial 87Sr/86Sr ratios (0.7057-0.7060), suggesting derivation from a mantle wedge metasomatized by slab-derived fluids and/or melts. In contrast, mafic intrusions in the southeastern region (Keketuohai area) occur as a zoned intrusion with an emplacement age of 409±5 Ma, consisting of dunite, olivine gabbro, hornblende gabbro and pyroxene diorite. Their εNd(t) values (0 to +2.7) suggest that the parental magma was produced by partial melting of the lithospheric mantle under a high geothermal regime.

Zircon U-Pb ages demonstrate that voluminous granitoids were continuously emplaced over more than 30 % area of the Chinese Altai during the period from 447 Ma to 368 Ma with a climax at ca. 400 Ma. Positive εHf(t) values (0 to +9) of normal magmatic zircons suggest that the granitoid magmas were derived from juvenile sources. The extensive magmatism at ca. 400 Ma significantly changed the Hf isotopic composition of the magma source by substantial input of juvenile material in a relatively short period. Four representative large S-type granitic intrusions were emplaced from 419 to 393 Ma, consistent with a period of intensive magmatic activities. The S-type granitic magmas were generated by dehydration melting of newly accreted materials, which were possibly brought to at least middle crustal depth by subduction-related activities in an active continental margin. In contrast, Carboniferous rocks were relatively minor and some granodioritic intrusions in the northwestern region have 313±5 Ma emplacement age. They are characterized by distinctively low total REE contents (67-187 ppm) without pronounced negative Eu anomalies and mantle-like whole-rock Nd-Sr isotopic compositions (εNd(t)=+2.5 to +4.5; (87Sr/86Sr)i =0.7038 to 0.7048) and zircon εHf(t) values (+5.93 to +12.9), implying that parental magma was probably derived from an oceanic lithospheric mantle.

Magmatism was active continuously from the Early to Middle Paleozoic, and the strongest magmatic activity took place in the Devonian. Mafic and felsic rocks mostly have positive zircon εHf(t) values, and show a dramatic change in zircon Hf isotope compositions at ca. 400 Ma, suggesting significant contributions from mantle-derived juvenile materials to the crust. These findings, together with the occurrence of chemically distinctive igneous rocks and the high-T metamorphism, can be collectively accounted for by ridge-trench interaction during the accretionary orogenic process. In contrast, Carboniferous magmatism represents an important transitional episode from subduction-related regime to post-orogenic extension.