Neoproterozoic mafic to felsic magmatism of the Longmenshan Thrust Belt, western Yangtze Block: from supra-subduction to extensional settings

Li Yabo[1], Inna Safonova[2, 3], Alexandra Gurova[2, 3], Gan Baoping[1]

[1] *Southwest Jiaotong University, Chengdu, Sichuan, China*

[2] *Novosibirsk State University, Novosibirsk, Russia*

[3] *Institute of Geology and Mineralogy SB RAS, Russia*

The Longmenshan Thrust Belt (LTB) is located in the western margin of the Yangtze Block, at the junction zone between the Sichuan Basin and Songpan-Ganze terrane. The western Yangtze Block, a core of the South China Craton, consists of Proterozoic mafic-ultramafic plutons and granitoids intrusions, Paleozoic volcanogenic-sedimentary formations linked to the evolution of the Tethys Ocean, and Mesozoic continental sedimentary cover. The LTB is dominated by Neoproterozoic granitoids and mafic dikes and early-middle Paleozoic volcanogenic-sedimentary units. It has a complicated thrust-nappe structure that formed in Mesozoic to Cenozoic time during the early Mesozoic orogeny, late Mesozoic post orogenic extension and Cenozoic duplexing (Xue et al., 2022). The LTB is characterized by multiple NE trending faults zones and is a tectonically and seismically active area. Previous U-Pb geochronological data show that the Neoproterozoic magmatism of the western Yangtze Block during ca. 910-730 Ma (Xiong et al., 2023). We studied Neoproterozoic mafic to felsic plutonic intrusions and dikes exposed in the southern part of the LFB, near Ya'an City of the Tianquan County, Sichuan Province. The study area is located within the Xianshuihe fault zone and its stratigraphy also includes Ordovician carbonates, siliciclastic rocks (conglomerate, sandstone, siltstone and mudstone), chert, and Silurian siliciclastic rocks (sandstone, siltstone, mudstone shale), and subordinate Mesozoic sedimentary strata. We sampled plutonic magmatic rocks, gabbroids and granitoids, exposed along the Da and Laba rivers. The gabbros typically occur as separate stocks and dikes cutting the grantioids. The sampled rocks were studied for U-Pb ages, major and trace element composition, Hf-in-zircon and whole-rock Nd isotopes.

According to the TAS classification, the samples are gabbro and monzogabbro, gabbrodiorite and monzodiorite, diorite and monzonite. The gabbroids are high-Ti and low-Ti. We separated zircons from high-Ti monzogabbro and monzodiorite and low-Ti gabbro, gabbrodiorite, diorite, and monzonite and performed their U-Pb dating. The low-Ti gabbro, gabbrodiorite, diorite and monzonite yielded mean U-Pb zircon ages of 816 ± 3, 813 ± 3, 809 ± 3 and 807 ± 3 Ma. The two high-Ti gabbroids yielded similar weighted mean ages of 787 ± 3 and 783 ± 3 Ma.

The groups of gabbroids (gabbro, gabbrodiorite, monzodiorite) and granitoids (diorite and monzonite) are characterized by variable compositions each. The low-Ti gabbroids show the lower concentrations of TiO_2 = 1.0-1.5 wt.% and FeO = 7.2-8.8 wt.% compared to the high-Ti gabbros (TiO_2 = 2.0-3.4, FeO = 11.5-11.9 wt.%). The granitoids can be divided into low-Si diorites (including monzodiorite) and "normal" diorites including monzonite. The low-silica diorites are characterized by higher concentrations of FeO (6.4-9.3 wt.%), MgO (2.7-5.7 wt.%) and CaO (5.2-6.9 wt.%) compared to the diorites (FeO = 5.2-7.3, MgO = 2.3-2.7, CaO = 2.7-4.5 wt.%). According to the alkalis-FeO-MgO classification, the subalkaline samples belong to the calc-alkaline series. In the low-Ti rocks, the concentrations of CaO and FeO decrease with increasing SiO_2 suggesting fractionation of olivine or orthopyroxene and clinopyroxenes. Such a correlation is not observed in the high-Ti gabbro indicating that the crystalline differentiation was not hardly responsible for the observed compositional variations.

The high-Ti gabbro are more enriched in the rare-earth elements (REE) compared to the low-Ti gabbro (ΣREE = 157 vs 88). They are typically enriched in light REE (LREE; La/Yb_N = 3.0-9.7), show a notable differentiation of heavy REE (HREE; Gd/Yb_N = 1.5-2.7) and have Zr/Nb ratios spanning 8.7-27.0. They are weakly depleted in Nb (Nb/Th_N = 0.3-1.0, Nb/La_N = 0.3-0.9). The low-Ti gabbroids are also enriched in LREE (La/Yb_N = 2.6-9.4), are characterized by moderately differentiated HREE (Gd/Yb_N = 1.3-2.2), but have higher Zr/Nb ratios (19-34). They are also depleted in Nb, but to a higher degree (Nb/Th_N = 0.2-0.3, Nb/La_N = 0.2-0.5) that is typical of suprasubduction igneous rocks (Pearce, 1982).

The low-silica diorites are also enriched in rare elements (La/Yb_N = 2.9-10.7) and have differentiated HREE (Gd/Yb_N = 1.0-2.5) and moderate Zr/Nb (18-33). The rocks are also depleted in Nb (Nb/Th_N = 0.2-0.6, Nb/La_N = 0.3-0.4). The diorites have similar features, but higher Zr/Nb (23-48) suggesting more evolved character. They are also enriched in LREE, moderately differentiated in HREE (La/Yb_N = 3.0-6.0, Gd/Yb_N = 1.6-1.8) and depleted in Nb (Nb/Th_N = 0.2-0.4, Nb/La_N = 0.3-0.4).

All groups are characterized by positive εNd(t) values: 3.9-6.0 for the high-Ti gabbros, 3.1-4.3 for the low-Ti gabbroids, 4.3-4.4 for the low-silica diorites and 1.9 for diorite. The zircons from a low-Ti gabbro, low-silica diorite and diorite yielded positive εHf(t) values of 10.3, 11.2 and 11.1, respectively.

Thus, the Tianquan study area of the Longmenshan thrust belt obviously hosts at least two magmatic series of rocks: an older calc-alkaline series (816 to 807 Ma) represented by low-Ti gabbroids and diorites and a younger alkaline series (787-783 Ma) of high-Ti gabbro and monzodiorite. The calc-alkaline igneous series was evolving during almost 10 myr through crystalline differentiation from gabbro to diorite suggesting one or more intermediate chambers. The plutonic rocks of this series are characterized by typical features of supra-subduction igneous rocks: wide ranges of concentrations of most major oxides, medium to low concentrations of TiO_2, enrichment of LREE, depletion in Nb-Ta. The parental melts were derived from mantle wedge juvenile mantle sources (εNd(t) = +1.9-4.4; εHf(t) = +1.9-4.4), possibly, lherzolite or harzburgite (Gd/Yb_N = 1.3-2.2). They could be emplaced in a tectonic setting of a young active continental margin or evolved/mature island arc. The parental melts of the younger high-Ti gabbroids could be formed by mixing of enriched and depleted mantle sources (εNd(t) = +3.9-6.0) in an extensional tectonic setting. The extension was probably provided by active margin rifting or intra-arc rifting that has been fixed before in the western Yangtze for the 790-780 Ma time period (Wu et al., 2024).

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