Composition, sources and differentiation mechanisms of magmas of Changbaishan Tianchi volcano (China-North Korea)

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In the Late Cenozoic, a large intraplate volcanic province was formed in the eastern part of the Asian continent. The province extends over a territory of 2500 x 2500 km2 and its structure is defined by a number of autonomously evolving volcanic areas. Although these areas are spatially and structurally separated, their volcanic products are similar (these are predominantly lavas of elevated alkalinity), as also are the types of eruptions (predominantly fissure eruptions). The remarkable Changbaishan Tianchi volcanic area at the boundary between China and North Korea hosts four large stratovolcanoes, which differ from other volcanic edifices in the province not only by their shapes but also the composition of their rocks (which vary from basalt to rhyolite) and also in having widespread pyroclastic rocks: pumice, tuff, and ignimbrite. The most widely known volcano is Changbaishan Tianchi (known as Pektusan in Korea), which is made up mostly of trachyte and pantellerite.

We utilized our original geochemical data on rocks sampled during our fieldwork to estimate the composition of the parental magmas of Changbaishan Tianchi volcano and to get insight into the circumstances and mechanisms of their differentiation.

The geological evolution of Changbaishan Tianchi volcano comprises the following major stages: origin of the shield platform at 4.5 Ma (Liu *et al.*, 1998) and the formation of the volcanic cone and its caldera evolutionary stage, which ended with a catastrophic eruption at 939-946 A.D. (Wei *et al.*, 2013). Changbaishan Tianchi volcano is still active, a number of its historic eruptions were documented, the latest of which occurred approximately a century ago in 1903 (Wei *et al.*, 2013).

The rocks of the shield basement of Changbaishan Tianchi volcano vary from basalt to trachyandesite and typically contain the olivine-clinopyroxene-plagioclase assemblage. The cone of the volcano consists mostly of pyroclastic rocks of trachyte, comendite, and pantellerite composition that typically contain anorthoclase, quartz, clinopyroxene, and fayalite. The accessory minerals are ilmenite, titanomagnetite, and apatite. The slopes of the volcano are intruded by necks and dikes of alkali basalt, trachybasalt, and trachybasaltic andesite. Pantellerite vitrophyre bodies are exposed in the slopes around the caldera. The pyroclastic material of Changbaishan Tianchi volcano consists of trachybasaltic andesite bombs, which occur near basalt diatremes, and acid pumice, which compose the pyroclastic mantle on the slopes.

In the alkalis vs. silica diagram, the fields of the mafic and acid products are clearly separated from one another, thus accentuating the bimodal character of the magmatic rocks.

The lavas composing the shield platform of Changbaishan Tianchi volcano are weakly differentiated mafic rocks whose geochemical characteristics are generally similar. The rocks are characterized by low REE concentrations, with LREE strongly dominating over HREE ($(La/Yb)_N = 34 – 38$). All of the rocks show weakly pronounced positive Eu anomalies, are enriched in Ba (up to 810 ppm in the basalt and trachybasalt, up to 2800 ppm in the trachybasaltic andesite, and up to 2960 ppm in the trachyandesite) and depleted in U.

We have examined the distribution of trace elements in the trachybasaltic andesite, trachyte, trachydacite, and rhyolite from the cone of Changbaishan Tianchi volcano. The trachybasaltic andesite exhibits fairly steeply inclined REE patterns ($(La/Yb)_N = 19 – 23$) at relatively low REE concentrations. The trachybasaltic andesite is enriched in Ba (up to 800 ppm) and depleted in Th and U, whose concentrations are no higher than 100 ppm. The geochemistry of these rocks is similar to the geochemistry of the rocks composing the shield platform. All silicic rocks composing the cone of the volcano have conformable normalized trace-element patterns, and their $(La/Yb)_N = 15 – 23$. The rocks show negative Eu anomalies, whose 'depths' are different for the trachyte, trachydacite, and rhyolite. The REE concentrations of thee rocks are high and reach 1000 ppm. The silicic rocks are also noted for high Zr (up to 2340 ppm) and low Ba (usually <100 ppm) and Sr (no higher than 20 ppm) concentrations.

Geochemical data on rocks of Changbaishan Tianchi volcano reveal the following tendencies. The distribution of trace elements in basaltoid from this volcano is similar to that in OIB. The Changbaishan Tianchi basaltoids differs from the latter only in bearing higher concentrations of trace elements and REE. In the rock sequence from the basalt to pantellerite, the concentrations of REE (except Eu) and Zr increase, and those of Ba, Sr, and Eu decrease.

The Zr, Y, Ta, Hf, Th, and Rb concentrations in rocks of both the shield and the cone of the volcano were determined to be positively correlated with Nb, as also are REE (both HREE and LREE). This distribution of trace elements suggests that crystal fractionation played a leading role in producing the whole spectrum of rocks composing Changbaishan Tianchi volcano.

In order to estimate the sources from which the parental magmas of the volcano were derived, we used paired ratios of the most incompatible elements (Th/Yb – Ta/Yb, Zr/Nb – Nb/Th), because these ratios are only insignificantly modified in the course of magmatic differentiation. It was determined that data points of the Changbaishan Tianchi volcanic rocks generally (regardless of the petrographic compositions) compose a fairly compact group not far from the field of the OIB-type source. These common features of the rocks suggest that the composition of the magma source was highly homogeneous for the whole petrographic series of volcanic rocks.

The aforementioned geochemical patterns of the rocks indicate that the parental magmas were basalt of elevated alkalinity. The geochemistry of these melts is practically identical with that of OIB. Because of this, the magma source of Changbaishan Tianchi volcano should be compared with the mantle of close to the mantle of oceanic islands and generally to the magma source of the Late Cenozoic volcanic province in East Asia, i.e., with the mantle related to mantle plumes.

Liu, R., Fan, Q., Zheng, X., Zhang, M., Li, N. (1998): Sci in China (Series D), 41/4: 382–389.

Wei, H.Q., Liu, G.M., Gill, J. (2013): Bull Volcanol, 75/4:706–719.