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Introduction of sub-lithospheric component into melted lithospheric base by propagating crack: Case study of migrated Quaternary volcanoes in Wudalianchi, China

Irina Chuvashova (1,2) and Yi-min Sun (3)

(1) Institute of the Earth's Crust of Russian Academy of Science, Siberian Branch, Irkutsk, 664033 Russia, (2) Irkutsk State University, Irkutsk, 664003 Russia, (3) Institute of Volcano and Mineral Spring, Heilongjiang Academy of Science, Wudalianchi, Heilongjiang, 164155, China

From a long-lasted discussion on origin of mantle magmatism (i.e. Foulger, 2010), it follows that magmatic sources might belong to: (1) a plume, starting from the lower thermal boundary layer of the mantle, (2) a counter-flow from the lower mantle after an avalanche of slab material from the transition layer, (3) a melting anomaly of a domain that extends above the transition layer at depths of 200–410 km, (4) a melting anomaly of a domain that occurs beneath the lithosphere at depths of 50–200 km, (5) a melting anomaly of the lithospheric base, activated due to its extension, and (6) a melting anomaly of the crust–mantle boundary originated through delamination of an orogenic root in compressional conditions. In this study, we present geological and geochemical evidence on the Quaternary volcanism related to the shallow melting anomaly at the lithospheric base.

Eruptions of potassic liquids at the northern terminus of the Songliao basin, subsided from the Middle Jurassic to Paleogene, are limited to the Wudalianchi zone that is exhibited by the 230-km long north-south chain of late Cenozoic volcanic fields: Erkeshan – Wudalianchi – Keluo – Xiaogulihe. Contemporaneous eruptions of potassic-sodic melts are distributed at the western and eastern flanks of this zone, in the Nuominhe and Wuyiling volcanic fields, respectively. The melting anomaly is marked by local decreasing S-wave velocities at a depth of 100 km (Rasskazov et al., 2014). Lithospheric control of the potassic volcanism is emphasized by decreasing thickness of the crust up to 33.5 km (Wang, Chen, 2005).

In the Wudalianchi field, volcanism commenced at ca. 2.3 Ma and episodically rejuvenated until AD1720–1721 (Guide book ..., 2010). From comparative geochemical study of volcanic rocks from the Wudalianchi zone and Nuominhe volcanic field, the volcanism was examined to be provided by melting of the heterogeneous lithospheric base, material of which was mixed with a common sub-lithospheric component. Due to mutual convergence of trends, obtained in the diagrams of initial (87Sr/86Sr) versus 1/Sr and initial (87Sr/86Sr) versus 206Pb/204Pb, the common sub-lithospheric composition of volcanic rocks was defined at the initial values (87Sr/86Sr) = 0.7052 and 206Pb/204Pb = 17.5. From model calculations, the erupted liquids were examined as generated through melting of the lithospheric material with minor sub-lithospheric admixture, which did not exceed 9 % (Chuvashova et al., 2009; Rasskazov et al., 2014).

In terms of space-time activity and variations of rock compositions obtained on basis of the new representative sampling, we distinguish three groups of the Wudalianchi volcanoes: north-western (Northern and Southern Gelaquishan), central (Wohushan, Bijiashan, Laoheishan, Huoshaoshan), and eastern (Yaoquanshan, Weishan, Western and Eastern Jiaodebushan, Xiaogoshan, Western and Eastern Longmenshan, and Molabushan). Randomly distributed rocks of the north-western and eastern groups, as well as the Erkeshan volcanoes, we examine as a result of background volcanic activity. These rocks show a limited range of compositions dominated by lithospheric material: SiO_2 51–55 wt.%, K2O 5–6 wt.%, CaO 5.3–6.8 wt.%, MgO 5.3–7.0 wt.%, CaO/Al2O_3 0.35–0.45, and CaO/Sr 31–45. On the contrary, the central group of the Wudalianchi volcanoes reveals persistent northeastward shift of eruptions along the volcanic line Wohushan – Bijiashan – Laoheishan – Huoshaoshan in the past 1.3 Ma. Initial rocks from the Wohushan volcano are compositionally close to rocks of background activity. Over time, the compositions of rocks from the migrated volcanoes have changed due to admixture of the sub-lithospheric component with decreasing SiO_2 to 49 wt.%, K2O to 3.2 wt .% and increasing CaO to 8.1 wt.%, MgO to 8.3 wt.%, CaO/Al2O_3 to 0.65, CaO/Sr to 65.

We infer that the background eruptions in the Wudalianchi and Erkeshan volcanic fields were due to overall melting at the base of the heterogeneous lithospheric mantle beneath the northern Songliao basin and that admixture of the common sub-lithospheric component was locally introduced into the melted region by mechanism of propagating crack.

This study is based on analytical data obtained for volcanic rocks in the Chinese-Russian Wudalianchi–Baikal

Research Center on recent volcanism and environment. Major oxides were determined by "wet chemistry" at the Institute of the Earth's Crust SB RAS, Irkutsk. Trace-elements were measured by ICP–MS technique using mass-spectrometer Agilent 7500ce of the Center for collective use "Microanalysis" (Limnological Institute of SB RAS, Irkutsk) and Nd, Pb, and Sr isotopes by TIMS technique using mass-spectrometer Finnigan MAT 262 of the Center for collective use "Geodynamics and geochronology" (Institute of the Earth's Crust SB RAS). The work was supported by the RFBR grant № 16-05-00774.

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