Control of volcanism in Asia by transtensional zones: change of sources at a lithosphere–asthenosphere boundary layer in the Wudalianchi field, China

Sergei Rasskazov[1,2], Irina Chuvashova[1,2], Yi-min Sun[3], Chen Yang[3], Zhenhua Xie[3], Zhenxing Fang[3], Jinghua Wang[3], Tatiana Yasnygina[1] and Tatiana Chikisheva[1,2]

[1] Institute of the Earth's Crust of Russian Academy of Science, Siberian Branch, Irkutsk, 664033 Russia, rassk@crust.irk.ru
[2]Irkutsk State University, Irkutsk, 664003 Russia
[3] Institute of Volcano and Mineral Spring, Heilongjiang Academy of Science, Wudalianchi, Heilongjiang, 164155, China

Keywords: Potassic rocks, transtension.

Transtension is a system of stresses that tends to cause oblique extension, i.e., combined extension and strike slip (Neuendorf et al, 2011). Syn-volcanic transtensional deformations of the lithosphere may provide two possible scenarios for control of magmatic processes. One assumes ascending sub-lithospheric melts, which mark the permeable lithosphere in transtension area without melting lithospheric material. Products of volcanic eruptions in such a zone show only sub-lithospheric mantle material. Components of magmatic liquids do not reveal any connection to a lithospheric structure. Another scenario yields a direct control of melting in lithospheric sources in evolving transtensional structure. In this case, spatial-temporal change of lithospheric and sub-lithospheric components is a direct indication of the evolving transtensional zone.

Activity of echelon volcanic fields, controlled by north-south or west-east transtensional structures, is indicative for specific tectonically active areas of Asia. For instance, volcanism is characteristic of transtensional segments of the Baikal Rift Zone. In the north-south Kamar segment, volcanism is constrained between 18 and 12 Ma, in the west-east Muya-Udokan segment, it was displayed in the Udokan volcanic field in the last 14 Ma, and in the north-south Tsipa-Muyakan segment in the Vitim volcanic field in the range of 16.0-0.6 Ma (Rasskazov et al., 2013). A transtension of the lithosphere is well pronounced also in the Eastern Hangay area, Central Mongolia. To the south of this ridge, in Valley of Lakes, en echelon character of west-east volcanic structures was exhibited at 32-31 Ma. At the ridge and north of it, volcanism occurred in west-east left-lateral transtensional segments in the time interval from 17.0 to 8.0 Ma. Between the Eastern and Central Hangay, the right-lateral north-south Chulutyn transtensional segment was reactivated in the range of 9.6-2.1 Ma (Rasskazov et al., 2012). There are non-volcanic transtensional segments (such as Rel-Verkhniyangarsk in the Baikal Rift Zone). Some seismically active strike slips (e.g., Bolnay) have no effect on the configuration of volcanic fields and might reflect shallow displacement of crustal tectonic blocks.

Lateral movements widely developed along north-south faults in East Asia (e.g., Tan-lu, Sakhalin-Hokkaido, Tsushima, Central Sikhote-Alin). Right- and left-lateral displacements in some of these faults, however, are controversial (Jolivet et al, 1994.; Rasskazov et al., 1998; Gilder et al., 1999; Zhang et al., 2003). In this paper, we present arguments in favor of common transtensional nature of lithospheric-derived melting anomaly of the Wudalianchi volcanic zones that extends north-south over 230 km at the northern circuit of the Songliao basin, Northeast China.

The basin subsided from the Middle Jurassic to Paleogene. Potassic rocks from the Wudalianchi zone, dated back to the Pliocene and Quaternary (Guide book…, 2010; Zhao et al., 2014), show stepwise widening of K_2O contents along this zone from the Erkeshan volcanic field (5.6-5.8 wt%) through Wudalianchi (3.2-6.0 wt.%) and Keluo (4.0-7.0 wt.%) to the Xaogulihe volcanic field (2.0-9.5 wt%). In the Quaternary rocks from Wudalianchi, K_2O concentrations range from 4.8 to 6.0 wt% with its relative decrease in rocks at the beginning and end of volcanic evolution. Initial lava flows with K_2O contents 3.9-5.2 wt% erupted along the Laoshantou – Old Gelaqiushan north-south locus from 2.5 to 2.0 Ma and in the final cone of the Huoshaoshan volcano, erupted in 1721, dropped to 3.2 wt%.

Volcanism displays background activity, irregular in time and space, and propagating activity, characterized by temporal shift of volcanic edifices. Background eruptions occurred between 1.3 and 0.8 Ma at the South Gelaqiushan volcano and along the west-east locus of the Lianhuashan, Yaoquanshan, West Jaodebushan, West Longmenshan volcanoes. In the last 0.6 Ma, three groups of volcanoes erupted: Western (North Gelaqiushan, Lianhuashan, Jianshan-Jiamshanzi), Central (Wohushan, Bijiashan, Laoheishan, Huoshaoshan), and Eastern (Weishan, East Jaodebushan, Xiaogoshan, West and

East Longmenshan, Molabushan). Background eruptions continued in the Western and Eastern groups, whereas the Central group displayed stepwise shift of activity from the southwest to the northeast. Such a regular volcanic evolution was accompanied with a relative reduction of K_2O abundances in final eruption products of the Huoshaoshan volcano.

From a comparative analysis of K_2O, other major oxides, and trace elements in rocks of early and late eruption phases in the Central group of volcanoes, we infer that rocks were compositionally almost similar to the background ones in edifices of the first volcano (Wohushan), were partially close to the background rocks and partly differed from them in edifices of the second and third volcanoes (Bijiashan, Laoheishan), and were significantly different from the background rocks in the cone of the fourth volcano (Huoshaoshan).

We suggest that magma generation under the Wudalianchi volcanic field was controlled by developing transtension of a layer at the base of the lithosphere that divided and shielded sources of underlying homogeneous sub-lithospheric convective mantle and the overlying enriched heterogeneous lithosphere. The sub-lithospheric magma source had $^{87}Sr/^{86}Sr$ = 0.7052 (Rasskazov et al., 2011), sources of the boundary shielding layer the same and lower Sr-isotopic ratios, and sources of the overlying region the same and higher ones. The development of transtension governed time and space of locally introduced convective mantle component through the boundary shielding layer on background of melting enriched mantle material above the latter.

The 2.5–2.0 Ma local eruptions of sub-lithospheric liquids, derived from the axial part of the north-south zone of transtension, were followed with the 1.3–0.8 Ma background melts from a wider transtensional segment of the enriched lithospheric region. Afterwards, in the past 0.6 Ma, background melting of the enriched lithosphere sharply outlined edge portions of the transtensional segment, whereas simultaneous local sub-lithospheric melting propagated along a crack originated within the boundary shielding layer due to concentrating tectonic forces at the central portion of the transtensional segment.

Acknowledgements

This presentation was prepared in the Chinese-Russian Wudalianchi-Baikal Research Center on recent volcanism and environment.

References

Guide book for field mission to Wudalianchi National Park, China, 2010. Prepared by Wudalianchi National Park and Nature Management Committee Heilongjiang province, 50 p.

Gilder, S.A., Leloup, P.H., Courtillot, V., Chen, Y., Coe, R.S., Zhao, X., Xiao, W., Halim, N., Cogné, J-P., and Zhu, R., 1999. Tectonic evolution of the Tancheng-Lujiang (Tan-Lu) fault via Middle Triassic to Early Cenozoic paleomagnatic data, Journ. Geophys. Res. 104: 15365–15390.

Jolivet, L., Tamaki, K., Fournier, M., 1994. Japan Sea opening history and mechanism: A synthesis. J. Geophys. Res. 99: 22 237–22 259.

Neuendorf K.K.E., Mehl J.P., Jr., Jackson J.A. Glossary of geology. Fifth edition, revised. American Geosciences Institute, Alexandria, Virginia, 2011. 783 p.

Rasskazov, S.V., Logatchev, N.A., Ivanov, A.V., 1998. Correlation of Late Cenozoic tectonic and magmatic events of the Baikal Rift System with the events in the south-east of the Eurasian Plate. Geotectonics (4), 25–40.

Rasskazov, S.V., Chuvashova, I.S., Liu, J., Meng, F., Yasnygina, T.A., Fefelov, N.N., Saranina, E.V., 2011. Proportions of lithospheric and asthenospheric components in Late Cenozoic K and K–Na lavas in Heilongjiang Province, Northeastern China. Petrology 19: 568–600.

Rasskazov, S.V., Chuvashova, I.S., Yasnygina, T.A., Fefelov, N.N., Saranina, E.V., 2012. Potassic and potassic–sodic volcanic series in the Cenozoic of Asia. Novosibirsk Academic Publishing House "GEO", 351 p.

Rasskazov, S.V., Yasnygina, T.A., Chuvashova, I.S., Mikheeva, E.A., Snopkov, S.V., 2013. The Kultuk Volcano: spatial-temporal change of magmatic sources at the western terminus of the South Baikal basin between 18 and 12 Ma. Geodynamics & Tectonophysics 4: 135–168. doi: 10.5800 / GT2013420095.

Zhang, Y. Q.; Shi, W.; Dong, S. W., 2003. Strike-slip and extensional tectonics of the Tan-Lu fault zone (eastern China) from the Cretaceous to Cenozoic. EGS - AGU - EUG Joint Assembly, Abstract #1949.

Zhao Y-W., Li Ni., Fan Q-C., Zou H., Xu Y-G., 2014. Two episodes of volcanism in the Wudalianchi volcanic belt, NE China: Evidence for tectonic controls on volcanic activities. Journal of Volcanology and Geothermal Research 285: 170–179. dx.doi.org/10.1016/j.jvolgeores.2014.08.016.