

## Monogenetic cones of Klyuchevskaya group of volcanoes (Kamchatka, Russia)

Olga Girina<sup>1</sup>, Vladimir Ladygin<sup>2</sup>

<sup>1</sup>*Institute of Volcanology and Seismology FEB RAS,  
Petropavlovsk-Kamchatsky 683006, Russia. girina@kscnet.ru*

<sup>2</sup>*Lomonosov Moscow State University, Faculty of Geology,  
Moscow, 119991, Russia.*

**Keywords:** monogenetic cones, Klyuchevskaya volcanic group, Kamchatka

The Klyuchevskaya group of volcanoes (KGV) is the center of the most active volcanism not only in Kamchatka, but also in the world, due to the location this group in the subduction zone at the intersection of the Aleutian and Kuril-Kamchatka volcanic arcs. The evolution of volcanic arcs, the unevenness of subduction processes led to the formation of the block structure of the KGV, the revival of faults in certain directions at different eras, the contiguity of fault zones, and the long-term volcanic activity of the region (The deep structure..., 1976; Ivanov et al., 2001). Of the 13 volcanoes of the group, four are active; on the slopes of three volcanoes (Klyuchevskoy, Tolbachik and Tolbachinsky Dol, Ushkovsky) monogenic cones are widespread.

The hypothesis of the existence of a common magma chamber for all KGV, as well as independent magma chambers for each of these volcanoes, was first presented in the works of G.S. Gorshkov (1956) and B.I. Piip (1956). Magma chambers and cameras of the KGV volcanoes continue to be studied by geophysical and geological methods.

A generalized schematic tectonic map of the KGV is shown in the work (Girina, 2016). This scheme of principal fault zones in the area of the KGV was created on the basis of the analysis of a set of various published materials and numerous satellite data of middle and high resolution (MODIS, SRTM, Aster, Landsat, Meteor-M, Kanopus-B and the others), as well as on the author's studies of the volcanoes of the Klyuchevskaya group. It is shown that the faults ever formed here are long-lived and their activation is associated with certain stages of the evolution of the KGV. The formation of all stratovolcanoes of KGV mainly happens owing to deep faults (1-3 on Fig. 2 from (Girina, 2016)) of the northwest, northeast and west-northwest directions. Regional zones of monogenic cones of the KGV, identified by B.I. Piip (1956), in the area of Ushkovsky, Tolbachik, and Klyuchevskoy volcanoes, are associated with the deep fault zones of the northwestern and northeastern directions. For example, one of these zones (6 on Fig. 2 from

(Girina, 2016)) extends to the southeast and east slopes of Klyuchevskoy; according to B.I. Piip (1956), this fault zone was the reason for the beginning of the formation of Plosky Tolbachik volcano and the existence of a lava lake in its crater. It is characteristic, that the monogenic cones associated with this fault zone, break through the deposits of the andesitic volcanoes Zimina and Bezymianny. The fissure zone of north-north-eastern direction in the central part of the KGV is well expressed on the Tolbachinsky Dol and on the south-western slope of Ushkovsky volcano (7 on Fig. 2 from (Girina, 2016)). For example, on such of a fault the breakthrough of 50th anniversary of the IVS FEB RAS was formed on Tolbachinsky Dol in 2012-2013 (Girina, 2016). Another fissure zone (8 on Fig. 2 from (Girina, 2016)), on which young monogenic cones are planted, is well manifested on the Tolbachinsky Dol. For example, the Severny Proryv of 1975 was formed on such fissure. Probably, the activation of faults 7 and 8 on the Tolbachinsky Dol affected the fault zone 6 (Girina, 2016), which more than once led to the disappearance of the lava lake after the formation of the collapse caldera at the top of Plosky Tolbachik volcano (Piip, 1956).

Rocks erupted by volcanoes and their monogenic cones of the KGV refer to the basalt-andesite-basalt formation (Ermakov, 1977), associated with extension zones and magma sources confined to the upper and middle mantle (Ivanov et al., 2001; Large Tolbachik..., 1984).

According to the petrochemical characteristics, the rocks of monogenic cones are divided into the following subtypes: magnesian basalts (Ushkovsky, Klyuchevskoy, Tolbachinsky Dol); high aluminous basalts (Klyuchevskoy, Tolbachinsky Dol); aluminous basaltic andesite, magnesian basaltic andesites (Klyuchevskoy) (Large Tolbachik..., 1984; Popolitov, Volynets, 1981; Volynets et al., 1976). The rocks of monogenic cones of Ushkovsky volcano are the most ancient rocks (pre-Holocene), and the cones of Klyuchevskoy and Tolbachinsky Dol - Holocene (Ponomareva et al., 2007).

The magnetic properties of the lavas of monogenic cones of Tolbachinsky Dol and Klyuchevskoy volcano were studied using the Kappameter (KT-6) field device (SatisGeo) (Girina, Bagenov, 2014, 2015). On Tolbachinsky Dol was studied a value of the magnetic susceptibility of lavas eruptions on 1975, 1941, 1000-1500 years ago (Kleshnya cone), and 1500-2000 years ago (lavas Maguskin field) (age of old lavas according of "Large Tolbachik...", 1984). On Klyuchevskoy volcano was studied a value of the magnetic susceptibility of lavas eruptions on 1945 (Zavaritsky), 1946 (Apakhonchich), 1956 (Kryzhanovsky). Lavas of Tolbachinsky Dol are

magnesian basalts (eruptions on 1941, and 1975), and aluminous basalts (eruptions of Kleshnya, and Maguskin field); lavas of Klyuchevskoy volcano are aluminous basalts (Girina, Bagenov, 2014, 2015; Large Tolbachik..., 1984).

The range of changes of the magnetic susceptibility value of the studied basalts of Tolbachinsky Dol is from 3 to  $38 \cdot 10^{-3}$  SI units (Fig. 1).

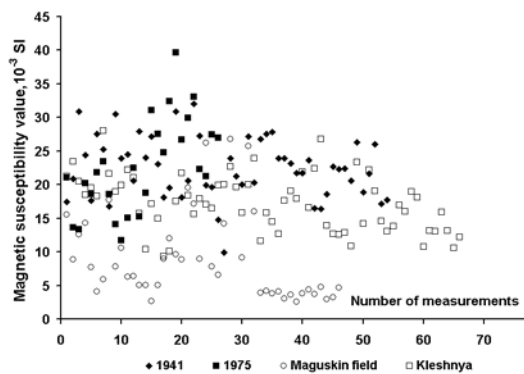


Fig. 1 – The value of magnetic susceptibility of the studied lavas of Tolbachinsky Dol.

The range of changes of the magnetic susceptibility value of the studied basalts of Klyuchevskoy volcano varies from 10 to  $52 \cdot 10^{-3}$  SI units (Fig. 2).

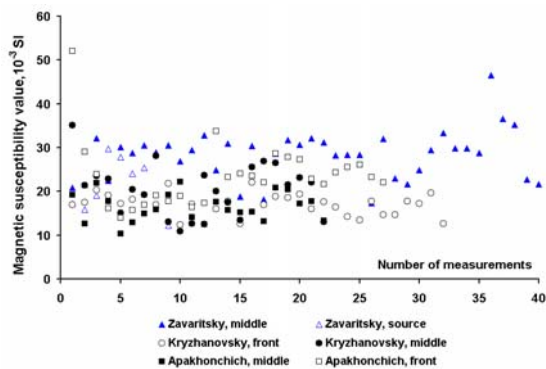


Fig. 2 – The value of magnetic susceptibility of the studied lavas of Klyuchevskoy volcano.

Magnesian basalts have higher magnetic susceptibility parameters compared to aluminous (the higher the MgO content in the rock, the higher the magnetic susceptibility of the rocks). Lavas of the Tolbachinsky Dol of eruptions on 1941 and 1975 have the highest average values of magnetic susceptibility, lavas of the Maguskin field - the lowest.

Although lavas are similar in petrographic characteristics, the magnetic susceptibility values of basalts of lava flows of the Zavaritsky cone is somewhat higher relative to other studied rocks due

to their larger quantity of phenocrysts of dark-colored minerals.

## References

- Ivanov B.V., Popruzhenko S.V., Aprelkov S.E., 2001. The deep structure of the Central Kamchatka Depression and the structural position of volcanoes. Geodynamics and volcanism of the Kuril-Kamchatka Island arc system. Petropavlovsk-Kamchatsky: IVGG FEB RAS. 45–57.
- Ermakov V.A., 1977. Formational dissection of Quaternary volcanic rocks. Moscow: Nedra, 224.
- Girina O.A., 2016. Satellite high-resolution data to clarify the position of fault zones within Klyuchevskaya volcanic group of Kamchatka. *Sovremennye problemy distantsionnogo zondirovaniya Zemli iz kosmosa* 13/6: 148–156. doi: 10.21046/2070-7401-2016-13-6-148-156
- Girina O.A., Bagenov E.V., 2014. About magnetic properties of Tolbachinsky Dol basalts, Kamchatka. *Educatio*, 3/7: 52-54. [https://edu-science.ru/wp-content/uploads/2016/03/edu\\_3\\_p7\\_4-63.pdf](https://edu-science.ru/wp-content/uploads/2016/03/edu_3_p7_4-63.pdf)
- Girina O.A., Bagenov E.V., 2015. Magnetic properties of Klyuchevskoy volcano basalts. *Evraziiskoe nauchnoe ob'edinenie* 2/5(5): 175–177. <https://elibrary.ru/item.asp?id=23527972>
- Gorshkov G.S., 1956. On the depth of the magma chamber of Klyuchevskoy volcano. *Doklady AN SSSR* 106/ 4: 703–705.
- Large Tolbachik Fissure Eruption (1975–1976, Kamchatka) / Ed. S.A. Fedotov. 1984. Moscow: Nauka, 637.
- Piip B.L., 1956. Klyuchevskaya sopka and its eruptions in 1944-1945, and last. Moscow: AN SSSR, 312.
- Ponomareva V., Kyle P., Pevzner M. et al., 2007. Holocene eruptive history of Shiveluch Volcano, Kamchatka Peninsula, Russia. *Volcanism and Subduction: the Kamchatka Region*. Washington: AGU: 263–282.
- Popolitov E.I., Volynets O.N., 1981. Geochemical features of Quaternary volcanism of the Kuril-Kamchatka Island arc and some issues of petrogenesis. Moscow: Nauka, 182 p.
- The deep structure, seismicity and modern activities of the Klyuchevskaya group of volcanoes / Ed. B.V. Ivanov, S.T. Balesta, 1976. Vladivostok: FESC AN SSSR, 148.
- Volynets O.N., Ermakov V.A., Kirsanov I.T., Dubik Yu.M., 1976. Petrochemical types of Quaternary basalts of Kamchatka and their geological position. *Bulletin of Volcanological station* 52: 115–126.