

## The 2012-2013 Fissure Tolbachik Eruption, Kamchatka

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### Summary

This work presents the results of morphometric and geological investigations of the 2012-2013 Fissure Tolbachik Eruption (FTE 2012-2013).

It was revealed that FTE 2012-2013 was primarily effusive. The volume of pyroclastic deposits is not more than 0.1 km<sup>3</sup> in 1.5 km from the new fissures area. The largest lava discharge was in the first two days (440 m<sup>3</sup>/sec), when there was a maximum amount of active lava vents along the whole new fissures. In the following two weeks the lava discharge decreased (140 m<sup>3</sup>/sec at the average). From the second part of December 2012 to June 2013 the lava discharge was close to 18 m<sup>3</sup>/sec. From November 27, 2012 (the beginning of the eruption) to June 5, 2013 the erupted lava covered over 35.23 km<sup>2</sup>, its volume was 0.52 km<sup>3</sup>. According to the author's preliminary estimations the total volume of lava deposits at the end of the eruption (September 17, 2013) comprises 0.55-0.65 km<sup>3</sup>.

The rocks from the November 2012 -January 2013 eruption significantly differ from the earlier studied rocks from the Tolbachinskiy Dale. The most evident sign is higher values of alkalis and TiO<sub>2</sub> concentrations. Among the eruptive products there are non-typical accessory minerals: garnet, moissanite, corundum diamonds and native Al, Fe and Cu. The pillow lava formation in subaerial conditions was observed for the first time. The 2012-2013 Fissure Tolbachik Eruption is the unique among all earlier studied eruptions at the Tolbachinskiy Dale.

## 1. The description of the eruption

On November 27, 2012 according to seismic data, the new eruption has started in the Tolbachinskiy Dale territory, at the south part of Plosky Tolbachik Volcano basement. Due to bad weather conditions it was not possible to observe the eruption till November 29, 2012. The first heliborne photography of lava flows from the new eruption was made that day. Later aerial photography of FTE 2012-2013 area were carried out on December 13, 2012 and June 5, 2013. Based on processing of these photographic material, and EO-1 satellite images from March 6, 2013, and the previous aerial photographs from September 19, 1987 precise quantitative data on eruptive products were obtained and lava flows were mapped by DVIGALO *et al.* (2014). Volcanological interpretation of high resolution aerial photographs allowed to reconstruct the history of the eruption. During the first two days the eruption of volcanic products mainly occurred from the group of vents located at the heights from 1737 m to 2239 m. The most productive of them (the lowest) were named after the famous volcanologist Igor Menyaylov GORDEEV *et al.* (2013). The average lava discharge ( $440 \text{ m}^3/\text{sec}$ ) during the first two days was estimated by the eruptive products volume on November 29, 2012. In the following days the lava discharge decreased and from November 29 to December 13 its average values comprised  $140 \text{ m}^3/\text{sec}$  DVIGALO *et al.* (2014). It should be noted that on November 28 the NNE ash fall was observed up to 100 km from the center of the eruption, AIRS satellite images showed a huge ( $5 \cdot 10^4$  tons) emission of sulphur dioxide GORDEEV *et al.* (2013).

On December 1, 2012 the Menyaylov Vents ceased their activity. Effusive activity was located downslope (1600-1700 m). By November 29, 2012 the liquid lava fountaining was observed here by SAMOYLENKO *et al.* (2012) from a new eruptive fissure in the SW sector of the Krasny Cone. On December 13, 2012 small (the total volume  $0.008 \text{ km}^3$ ) cinder cones named after Sophya Naboko were formed in this fissure place and also to the north of the Krasny Cone GORDEEV *et al.* (2013). From the second part of December 2012 to June 2013 the lava discharge comprised over  $18 \text{ m}^3/\text{sec}$  DVIGALO *et al.* (2014). Based on this value, and the estimated by June 5, 2013 lava volume ( $0.52 \text{ km}^3$ ) author can assume that the total volume of FTE 2012-2013 lava by the end of the eruption (September 17, 2013) comprised no more than  $0.69 \text{ km}^2$ . As far as the field works of KUGAYENKO *et al.* (2013) give evidence on relative decrease of eruption activity in the last months, the most probable value for the total lava volume is  $0.55\text{-}0.65 \text{ km}^3$ .

## 2. The eruptive products composition

According to GORDEEV *et al.* (2013) the eruptive rocks are high-Al basaltic trachyandesites. The content of SiO<sub>2</sub>, TiO<sub>2</sub>, and also K<sub>2</sub>O+Na<sub>2</sub>O is the highest among all other investigated rocks from the previous fissure eruptions at the Tolbachinskiy Dale. The most silicic (to 55% SiO<sub>2</sub>) and richest in alkalis (to 6.7% K<sub>2</sub>O+Na<sub>2</sub>O) rocks were erupted during the first two days. In the following days the SiO<sub>2</sub> and alkalis content decreased by ~2% and ~0.5% respectively, the K<sub>2</sub>O/MgO ratio also decreased but the content of MgO, TiO<sub>2</sub>, and Mg# increased. VOLYNETS *et al.* (2013) revealed that the concentrations of REEs and other incompatible microelements in rocks erupted from the Menyaylov Vents are rather more high, at that all rocks of FTE 2012-2013 have identical elemental ratios. This identity suggests that all erupted rocks have been derived from one and the same magma melt but their compositional variations resulted from fractionation processes. It's interesting that the chemical composition of FTE 2012-2013 rocks is close in major elements, microelements and REEs content to the rocks have been found on Ushkovsky and Krestovsky Volcanoes, which are located 40 km to the NNE of the Tolbachinskiy Dale, VOLYNETS *et al.* (2013).

## 3. Non-typical accessory minerals

An interesting scientific discovery among FTE 2012-2013 accessory minerals is diamond crystals. Most of the found diamond crystals were extracted from two lava samples. On December 4, 2012 these samples were collected from the area of the west part of the lava flows field. In the beginning of February, 2013 one more diamond crystal was found in ashes sampled 100 m from the Naboko Cones GORDEEV *et al.* (2014).

The total amount of diamond crystals up to 0.7 mm in size was over 700. Most of them are greenish in colour. Four of them are colourless. They are mostly have the shape of combinations of cube and octahedron, and sometimes rhombic-dodecahedron shape. Twin by the plane {111} crystals and crystal-jams also were found. There are numerous etch pits at the surface of diamonds. Single grains of moissanite, garnet, corundum and native Fe, Al and Cu were extracted from these samples ANIKIN *et al.* (2013).

#### 4. The probable explanation for this eruption characteristic features

The comparative analysis of the 2012-2013 Fissure Tolbachik Eruption (FTE) and the 1975-1976 Great Tolbachik Fissure Eruption (GFTE) allows to reveal some characteristic features for the new eruption. Among these are: the onrush of eruptive process (FTE began 15 hour after seismic precursor, whereas GFEE began 10 days after swarm of volcanic earthquakes GORDEEV *et al.* (2013)), the absence of continuous initial explosive phase and also more close location of eruption zone. The basement of Plosky Tolbachik Volcano was not involved in FTE 2012-2013, at that several days before the GFTE there was a bit of crystal-lapilli and Pele's hair ejected from its summit pit crater, and by the end of the eruption due to the subsidence the volume of the pit crater increased from 0.022 km<sup>3</sup> to 0.347 km<sup>3</sup> DVIGALO *et al.* (1984). Nevertheless, it should be noted that a swarm of earthquakes 1-10 hours before the eruption was registered in 3-5 km from Menyaylov Vents in the SE sector of the Plosky Tolbachik basement YERMAKOV *et al.* (2013). On November 27, 2012 at 5:15 UTC a strong earthquake ( $K_s > 9$ ), evidencing the beginning of the eruption, occurred in the area of Menyaylov Vents. In the result of the earthquake a zone 300 m wide, more than 2000 m long of new open-joint fissures was formed. The obvious depth of these fissures is up to 60 m. The combination of rather non-explosive lava effusion (the explosive coefficient 3%) and a huge emission of gases (SO<sub>2</sub>) during FTE 2012-2013 is paradoxical. Apparently, the segregation of the considerable part of the magma gas component occurred underground. The author assumes that the initial penetration of magma from the deep depth occurred apart from the eruption zone into a weak near-surface horizon. The decrease of the pressure at magma rising causes degassing. The gas segregation could occur into empty magma reservoir in the basement of Plosky Tolbachik Volcano. The avalanche increase of the gas pressure caused lateral movement of the degassing magma melt along the weak horizon. The mechanism of the November 27, 2012 at 5:15 UTC earthquake and the fissures formation is a powerful fluid hammer DVIGALO *et al.* (2014). The shock wave front pressure is proved to be enough for diamonds formation. The gas pressure during the first two days resulted in a huge lava discharge. On November 28, 2012 expanding gas reached the Menyaylov Vents and its emission into the atmosphere and an ash formation occurred. The field researchers observed further variable flowing at weak explosive activity that is also probably resulted from the gases

escape as magma rises toward the surface. At that rather constant values for the average discharge ( $18 \text{ m}^3/\text{sec}$ ) agree with the rate of magma arrival from the deep source. As to non-typical for subaerial eruptions pillow lava then the process of its formation is similar to submarine. Obligatory for this process fast-cooling of the lava crust occurred due to the contact with the cold (about  $-40^\circ \text{ C}$ ) winter air.

#### References

- ANIKIN L. P., SOKORENKO A. V., OVSYANNIKOV A. A., SIDOROV YE. G., DUNIN-BARKOVSKY R. L., ANTONOV A. V., CHUBAROV V. M. (2013) – Discovery of Diamonds in the Lavas of the 2012-2013 Tolbachik Eruption. In GORDEEV E. I. (Eds.), *Proceedings of the Regional Conference "Volcanism and related processes" (29-30 March 2013)*, 20-23 (in Russian).
- DVGALO V. N., CHIRKOV A. M. & FEDOTOV S. A. (1984) – New Summit Caldera of Ploskiy Tolbachik volcano. In FEDOTOV S. A. (Eds.), *Large Tolbachik Fissure Eruption*. "Science" Publ., Moscow, 75-83 (in Russian).
- DVGALO V. N., SVIRID I. YU. & SHEVCHENKO A. V. (2014) – First Quantitative Estimates of Parameters of the 2012-2013 Tolbachik Fissure Eruption by the Data of Aerial Photogrammetric Observing. *Journal of Volcanology and Seismology*, 8 (4), Article in Press.
- GORDEEV E. I., MURAVYOV YA. D., SAMOYLENKO S. B., VOLYNETS A. O., MELNIKOV D. V., DVGALO V. N. & MELEKESTSEV I. V. (2013) – First Results from the 2012-2013 Tolbachik Fissure Eruption. *Bulletin of the Volcanological Society of Japan*, 58 (2), CD-BOOK, SP1-SP8.
- GORDEEV E. I., KARPOV G. A., ANIKIN L. P., KRIVOVICHEV S. V., FILATOV S. K., ANTONOV A.V. & OVSYANNIKOV A. A. (2014) – Diamonds in Lavas of the Tolbachik Fissure Eruption in Kamchatka. *Doklady Earth Sciences*, 454 (1), 47–49.
- KUGAYENKO YU. A., FIRSTOV P. P., VOROPAYEV P. V., MAKHMUDOV YE. R., MAKAROV YE. O. & KONOVALOVA A. A. (2013) – Integrated Geophysical Expedition in the area of the 2012-2013 Tolbachik Fissure Eruption, Kamchatka. *KRAESC Bulletin Earth Sciences*, 22 (2), 225-231 (in Russian).
- SAMOYLENKO S. B., MELNIKOV D. V., MAGUS'KIN M. A. & OVSYANNIKOV A. A. (2012) – Beginning of the New Fissure Tolbachik Eruption in 2012. *KRAESC Bulletin Earth Sciences*, 20 (2), 20-22 (in Russian).
- VOLYNETS A. O., MELNIKOV D. V. & YAKUSHEV A. I. (2013) – First Data on Composition of the Volcanic Rocks of the IVS 50th Anniversary Fissure Tolbachik Eruption (Kamchatka). *Doklady Earth Sciences*, 452 (1), 953–957.
- YERMAKOV V. A., GONTOVAYA L. I. & SENYUKOV S. L. (2013) – Preliminary model of the New Tolbachik Eruption obtained by the complex geological and geophysical data In GORDEEV E. I. (Eds.), *Proceedings of the Regional Conference "Volcanism and related processes" (29-30 March 2013)*, 63-72 (in Russian).