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Editorial

Introduction to the 2012–2013 Tolbachik eruption special issue

The Tolbachik volcanic complex in central Kamchatka holds a special place in global volcanological studies. It is one of 4 areas of extensive historic volcanic activity in the northern part of the Central Kamchatka Depression (the others being Klyuchevskoy, Bezymianny, Shiveluch), and is part of the Klyuchevskoy volcanic group, which is one of the most active areas of volcanism on Earth. Tolbachik is especially well-known due largely to the massive 1975–1976 eruption that became known as the Great Tolbachik Fissure eruption (GTFE; Fedotov, 1983; Fedotov et al., 1984). This was one of the first eruptions in Russia to be predicted based on precursory seismic activity, based on M5 earthquakes approximately one week before the eruption started, and was intensively studied during its course by a large number of Russian scientists. A summary of those studies was published, first in Russian and then in English, and it became widely read for many reasons. One in particular is that the eruption was somewhat unusual for a subduction zone setting; although many subduction zone stratovolcanoes have associated basaltic tephra cone-lava fields, this was the first such Hawaiian-style eruption to be widely observed. After the end of the eruption in 1976, the complex showed no signs of activity until 27 November 2012, when increased seismic activity was registered by the Kamchatka Branch of the Russian Geophysical Survey and a red glow from the eruption site was first noticed through the snowstorm haze. This prompted them, and then the Kamchatka Volcanic Emergency Response Team (KVERT) to issue an alert that activity was coming from the south flank of Plosky Tolbachik volcano, the younger of two volcanic edifices (the older is Ostry Tolbachik) that together make up the bulk of the complex along with tephra cone-lava fields that lie along a NE–SW fissure zone that transects Plosky Tolbachik. The new eruption lasted for more than 250 days and, like the 1975–1976 eruption, was dominated by Hawaiian-style activity. With the start of the eruption coinciding with the onset of winter months in Kamchatka, field observations, while virtually continuous, were also not as numerous as those that documented the GTFE 36 years previously. Nonetheless the Institute of Volcanology and Seismology (IVS) in Petropavlovsk-Kamchatsky provided almost continuous field-based coverage throughout the eruption. Many of the research projects begun during the eruption comprise international teams of scientists who were able to partner with IVS through international funding, particularly through the United States National Science Foundation and the National Geographic Committee for Research.

This special issue represents the first collection of detailed scientific studies resulting from syn-eruption observations and subsequent sample collection. The issue includes two special review papers. The first, by Churikova et al. summarizes all previously published petrological, geochemical, and geochronologic data on the Tolbachik volcanic massif prior to the 2012–2013 eruption and provides a clear framework for the new research results. The second, by Belousov et al., gives a detailed chronology for the 2012–2013 eruption and sets the stage for many of the other, more specific studies. While a number of studies on the physical volcanology of the eruption are ongoing, the review paper by Belousov et al. also presents the general volcanology of the eruption, and is supplemented by documentation of unique lava–snow interactions by Edwards et al. Of the 13 remaining papers, a large number focus on petrological and geochemical studies of this unique petrotectonic setting, while others focus on geophysical studies (seismicity, geodesy), remote sensing and physical volcanology.

Seven different studies use geophysical and/or remote sensing techniques to provide broader-scale constraints on the Tolbachik volcanic system, including studies utilizing seismicity (3 total), ground deformation, radar interferometry, infrasound and remote sensing of aerosols. Kugaenko et al. presented data on seismicity and ground deformation from global positioning satellites (GPS) of the area around Tolbachik volcano before the 2012–13 eruption. Importantly, this paper shows that subtle but statistically significant seismic unrest under the volcano started at least 4–5 months before the eruption onset. Simultaneously with the elevated seismicity, GPS stations from distances up to 60 km from the volcano started to register ground deformation associated with magma migration. Senyukov et al. present a detailed analysis of the precursory seismic swarm as well as seismicity that accompanied the 2012–13 eruption. They infer that the erupted magma ascended from a storage zone located under the volcano at depths less than 10 km, and show that opening of the eruption fissure probably occurred in two episodes separated by approximately 3 h of decreased seismic activity. They also put the seismicity from the 2012–13 eruption in historical context by comparison with the data on seismicity of the 1975–76 GTFE eruption. Caudron et al. processed seismic data for the entire Klyuchevskoy volcano group using the Seismic Amplitude Ratio Analysis (SARA) method to show that clear seismic migration started about 20 hours before the reported eruption onset (05:15 UTC, 27 November 2012). This result is important because the initial vertical migration of magma under Plosky Tolbachik volcano changed at shallower depth to sub-lateral migration towards the eruptive vents. Lundgren et al. used data of satellite interferometric synthetic aperture radar (InSAR) to compute relative displacement images (interferograms) spanning the 2012–13 eruption. The data constrain a shallow, distributed dike model with a maximum opening of 6–8 m. The distribution of the dike opening and its correspondence with co-diking seismicity suggest that the dike propagated radially from Tolbachik's central conduit. Albert et al. use analysis of local and regional infrasound signals from the eruption to document the bursting of large gas bubbles on the surface of the intra-crater lava pond. These data allow for estimation of the radii of individual slug bursts (mean about 3.5 m) and their mass

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emissions (up to about 3000 kg). Melnikov et al. present an integrated study of the initial stages of the eruption using a combination of petrological and remote sensing data, based on interpretation of infrared images from the scanning radiometer VIIRS Suomi NPP, and provide the first estimates for the timing of the Naboko vent opening, which was poorly known due to the bad weather conditions during the first three days of the eruption. The final remote sensing contribution, by Telling et al., uses multi-sensor satellite data to evaluate volcanic activity, SO_2 emissions and heat flux for the 2012–2013 eruption. The eruption produced a total of ~200 kt of SO_2 during the 9-month eruption, and this study identified a 55-day cycle potentially attributable to the eruptive behavior.

The rest 6 contributions are dedicated to the various aspects of the composition of volcanic products of the Tolbachik complex and its associated fissure zones: petrology, mineralogy, geochemistry, studies of volatiles, fumarolic gases, native metals and petrogenetic modeling. The research paper by Churikova et al. is a comprehensive study of the history and geochemical evolution of the Tolbachik volcanic massif from Late Pleistocene times, previously unstudied. With the new geological, petrographical, geochemical and geochronological data the authors demonstrate that fractional crystallization under different water conditions and in a variably depleted upper mantle source are reasonable processes to explain all observed variations in rocks within the Tolbachik volcanic massif. Portnyagin et al. present new high-quality data on major and trace element compositions and on Sr–Nd–Pb (double spike) and O isotope compositions for Late Holocene rocks from the Tolbachik volcanic field. They constrain the composition of primary Tolbachik magmas and their melting conditions, as well as processes that influence the chemical evolution of magmas. They argue that complex, open-system Recharge-Evacuation-Fractional Crystallization (REFC) is responsible for the observed diversity of products, including the unusual high-K basaltic trachyandesites of the 2012–13 eruption. Volynets et al. present a detailed study of the 2012–13 eruption products collected systematically throughout the eruption as part of the syn-eruption monitoring effort. The paper contains a time-bounded dataset of major and trace element chemistry of volcanic rocks, allowing for assessment of compositional variations of lava and tephra over the course of the eruption. These authors also provide the results of the geochemical modeling; they explain the initial change in geochemistry by fractional crystallization in the magma storage zone and show that the newly erupted material has been derived from remnant high-Al magma from the 1975–76 Southern Breakthrough eruption with only slight amounts of cooling during the intervening 36 years. Plechov et al. report compositions for bulk rock samples, minerals, glasses and melt inclusions, as well as a detailed petrography study of the eruption products. They evaluate volatile content and saturation conditions, and argue that the 2012–13 Tolbachik magmas appear to derive from an unusually H_2O-poor and K_2O-rich basaltic parent. The two final geochemical papers are dedicated to the native metals found in the products of the eruption. Simakin et al. present analyses of minerals, aerosols and melt inclusions in olivine and clinopyroxene phenocrysts, and make estimates of oxygen fugacity and pressure in the magmatic source region. They relate the discovery of the native Ni and PGEs in the aerosols of the Tolbachik 2012–2013 eruption to the influence of CO_2–CO-rich fluids at or near magma generation depths. Chaplygin et al. provide a thorough study of native gold occurrences from the 1975–76 and 2012–13 Tolbachik eruptions and show that gas transport reactions may be the main mechanism for the native Au precipitation.

As Guest editors, we would like to thank all authors and coauthors of this issue for their hard work on preparing and improving their manuscripts and meeting all the deadlines. Critical reviews, provided by the scientists from virtually all over the world, have an incredible value and are greatly appreciated. Authors of many contributions of this special issue are not native English-speakers, and we are grateful to all reviewers and editors who made thorough and detailed comments and therefore helped a lot in refining the initial versions of the articles. Lionel Wilson, Emily Wan, Timothy Horscroft, Banupriya Mahesh and other members of Elsevier staff and Journal of Volcanology and Geothermal Research editorial office are specially thanked for their continuous support and efforts that made the process of the SI preparation smooth and easy.

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