STEPHY Publishers

Global Scientific Research in Environmental Science

Review Article

The Tefroid Deposits on an Active Stratovolkano Bezymianny (Kamchatka)

PK Skuf'in*

Geological Institute, Kola Science Centre, RAS, Apatity, Russia

Abstract

The article highlights the results of a study of volcanic processes on the large active stratovolcano Bezymyanny, located on the Eastern mountain range of Kamchatka, in the Klyuchevskoy group of Holocene volcanoes. It is one of the most active volcanoes in the world, characterized by continuous short-term explosive eruptions with powerful outbursts of ash material, accompanied by lava flows and the formation of extrusions. Among Russian and foreign volcanologists, this volcano became world famous on March 30, 1956, when a catastrophic eruption occurred, which in geological literature was called a "directed explosion" or "an eruption of the Bezymyanny type." In addition to volcanic structures, peculiar volcanic-sedimentary deposits of the volcano were also investigated, represented by the so-called tefroids, which are the product of the movement and washing of volcanic-clastic material of eruptions. Modern volcanological expeditions in Kamchatka and the Kuril Islands have made it possible to prove not only the synchronicity of the forming tefroid accumulations with volcanism, but also the extensive distribution of these rocks, which often prevail over volcanoterrigenous sediments. In all the modern volcanic regions studied in detail, a wide development of tefroid formations has been established. By age, tefroids develop from the early Precambrian to the present day. On the slopes of the volcano and in the area of development of dry streams, there is a constant movement of fine-grained material to the foot of the volcano. These freely moving material in the process of movement are sorted by size, roundness and form well-sustained thick tefroid layers. The volcano stands half submerged in these geologically instantaneously deposited tefroid strata.

Keywords: Kamchatka, Stratovolcano bezymianny, Tefroids, Extrusion, Decompression, Pyroclasticmaterial, Eruption

Introduction

Volcano Bezymyanny is a large active stratovolcano on the Eastern mountain range of Kamchatka, 350km northeast of Petropavlovsk-Kamchatsky and 40km from the village of Ust-Kamchatsk. It is one of the most active volcanoes in the world, which is characterized by continuous short-term explosive eruptions with powerful outbursts of ash material, accompanied by lava flows and the formation of extrusions.[1-9] The last strong eruption occurred on March 15, 2019, when the giant threw out a column of ash more than 15km high, which was not accompanied by a catastrophic fall of ash material.

The height of the volcano is 2882m (up to 1956-3075m); the volcanic edifice includes a young active stratovolcano and the remains of an old volcano destroyed by the 1956 eruption, in the place of which a crater 1.3x2.8km in size was formed. The large volcanic Dome Novy continues to grow in the crater; on the body of this dome, as well as on the slopes of the volcano itself, many extrusive structures of various shapes and sizes (domes, large obelisks, etc.) were formed. Among Russian and foreign volcanologists, this volcano became world famous on March 30, 1956, when a catastrophic eruption occurred, which in geological literature was called a "directed explosion" or "an eruption of the Bezymyanny type".[10]

Eruption 1955-1956 was the first in this area since 1697 and occurred, according to tephrochronological studies, after a 1000-year dormant period.2 Before the eruption, the volcano had the shape of a regular cone 3085 m high (an andesitic stratovolcano, complicated by numerous side extrusive domes). The eruption began on October 22, 1955 after 23days of continuous earthquakes. Until

Quick Response Code:

***Corresponding author:** PK Skuf'in, Geological Institute, Kola Science Centre, RAS, Apatity, Russia

Received: 01 April, 2021 **Published:** 16 April, 2021

Citation: PK Skuf'in. The Tefroid Deposits on an Active Stratovolkano Bezymianny (Kamchatka). *Glob Scient Res Env Sci*. 2021;1(3):1–4. DOI: 10.53902/GSRES.2021.01.000513

March 30, 1956, the eruption was of a moderate, Vulcan character (pre-culmination stage). At the top of the volcano, a crater with a diameter of 800m was formed, from which there were frequent emissions of ash to an altitude of 7km. In November, the squeezing out of a powerful extrusive viscous lava dome–the Novy Dome–began in the crater. This caused a strong swelling (more than 100m) of the eastern slope of the volcano. The slope eventually collapsed, and on March 30, 1956, a global event began –a catastrophic eruption (culmination stage). The collapse was immediately followed by a colossal directional explosion caused by the immense pressure of the erupting extrusive lava.

The material ejected from the explosion caused a "pyroclastic wave" (turbulent flow of a hot mixture of gas and pyroclastics). Its speed reached 60m/s, the temperature exceeded 300°C. Pyroclastic flows up to 30km long descended along the slope. As a result of the explosion, a horseshoe-shaped crater with a diameter of ~1.3km appeared inside the volcano (Figure 1). On the eastern slope, a cover of specific pyroclastic deposits (directional blast deposits) has developed. After the paroxysm, the extrusive dome of viscous lava (Novy Dome) continues to squeeze out in the crater, the formation of which continues to the present time (post-culmination stage).

Continuous (since 1956) extrusive eruptions of andesitic lava in the crater forming the Novy Dome occurred as protrusions of rigid blocks and were accompanied by explosions of varying strength and incandescent avalanches of andesitic lavoclastic material. In the early years of the formation of the the Novy Dome, continuous eruptions were observed on the volcano, with extrusion blocks and obelisks being squeezed out in a solid state. Subsequently, the growth of the dome became discontinuous, and along with rigid blocks, viscous extrusions began to be squeezed out in 1977. Currently, the material from these extrusions has nearly filled the 1956 crater(Figure 2).

On Bezymyanny volcano, a multistage process of formation of volcanic domes of different sizes and ages is constantly going on. The formation process of each dome is also multi-stage and is accompanied by constant emissions of volcano-clastic material of various shapes and sizes(Figure 3). Eruptions often emit blocky material and large blocks of extrusive lava several m3 in size up to 0.5km from the extrusion dome (Figure 4). In the extrusive type of eruption, medium-acid lava is in a viscous or already solidified state and penetrates into the upper parts of volcanic apparatus, filling craters and cracks of various scales within the volcanic edifice, forming extrusive domes, as well as ring and conical dikes.7At the same time, lava has a massive, and sometimes a clearly pronounced fluid and banded texture, oriented in the direction of movement of the extrusion masses. The fragility and rapid destruction of igneous andesites are characteristic. Samples of well-crystallized rocks, which make up the material for lavoclastic flows, are crumbled with a light blow of a geological hammer into gruss, which is similar in dimension to the grains of the minerals composing andesites.

The rapid destruction of extrusive lavas (Figures 4&5) is explained not only by decompaction by means of "removal of hidden deep stresses",6 but also by the widespread argillization of volcanic material; at the same time, metastable volcanic glass, the amount of which in extrusive andesites, reaches 30–40%, is the first to undergo argillization. In the andesites of the Bezymyanny volcano, volcanic glass is replaced by clay minerals and opal; therefore, the fragile framework of mineral grains in the clay matrix disintegrates at the slightest mechanical impact.

As a result, both the NovyDome and the Bezymyanny volcano itself stand as if immersed in this loose sand and gravel material, which is picked up by temporary streams, washed into deep ravines of many meters depth and is carried away by the Sukha Khapitsa river system in masses. On the slopes of the volcano, there is a constant movement of fine-grained lavoclastic material to the foot of the volcanic edifice. This diverse material is graded by size, rounded and formed into well-aged sediments of reclaimed lavoclastic rocks–tefroids.

Thus, the volcano is currently in an active phase of activity. The formation of the domes is accompanied by weak and moderate explosive eruptions of varying strength (1-2times a year), with the ejection of clouds of volcanic ash and the formation of incandescent avalanches on the slopes, with the formation of small small-block lavoclastic flows up to 12km long. The active formation of numerous extrusive structures of various sizes took place not only on the volcano itself, but also in its vicinity. At the same time, the formation of fairly large domes was characterized by prolonged active volcanic activity, up to the final formation of the morphological appearance of these volcanic structures. An example of a large young extrusion dome Lohmaty is typical. The chaotic structure of the dome's surface, the presence of numerous extrusion blocks and obelisks of different sizes gives the impression of the newest age of this dome (Figure 6). At the same time, examples of more ancient extrusive structures can be observed in the vicinity of Bezymyanny volcano. The largest ancient extrusion is the Plotiná dome (Figure 7). Endlessly inventive nature gives us the opportunity to observe a whole collection of bizarre volcanic structures. On the ancient volcanic dome of Plotiná, in the process of its formation, a small extrusive dome of a smaller size with an ideal spherical shape was formed (Figure 8).

Let's consider a somewhat broader a problem of formation of the so-called tefroid rocks (tefroids)–a kind of volcanogenic-sedimentary formations arising from the movement and washing of erupted volcaniclastic material. Fragments of pyroclastics are incorporated into tefroids during synvolcanic outbursts of volcanic ash and during the destruction of lava extrusion structures. It is characteristic that the degree of roundness of tefroids is approximately the same both in the thickness of the tefroid horizons and in the area of their development. In tefroids, volcanoclastic material is partly represented by rounded and semi-rounded fragments of volcanic glass, while in tuffite sandstones, volcanic glass undergoes decomposition.[7] Originally, tefroids included rocks formed only by rounded and graded tephra. Subsequently, any rounded and sorted volcanoclastic material began to be referred to as tefroids: blocky boulders of lavoclastic flows, clastic material of extrusive domes and individual extrusive obelisks, tephra of pyroclastic flows, and

other products of eruptions. Modern studies in Kamchatka and the Kuril Islands have shown the synchronicity of the formation of tefroids and the process of volcanism, as well as the wide distribution of these rocks and their predominance over volcanogenic-terrigenous rocks. By age, tefroids develop from the early Precambrian to the present day.

A typical example of deposits of lavoclastic tefroid rocks is their formation during the movement and washing of large pyroclastic ejections on the Japanese volcano Taketomi.[7] Within a month, the volcano erupted about 100million tons of pyroclastics, partially deposited on the shores of the Sea of Okhotsk. After 40years, these sediments washed by the sea surf formed the coastal horizon of tefroid psammites with a thickness of more than 5m. Observations in areas of recent volcanism indicate the extreme rapidity of the processes of formation of volcanic extrusive structures, the discrete nature of their manifestation and rapid destruction during weathering. In particular, in the Okhotsk-Chukotka volcanic belt, there are cases[3] when several large stratigraphic units with completely identical organic remains were distinguished in powerful series of tefroid accumulations.

According to R.L. Smith and R.A. Bailey,[6] large volumes (200-2000km^3) of lavoclastic and extrusive masses of acidic caldera accumulations can form geologically instantly–in less than 10years. The total volume of felsic volcanics deposited within only one Pegtymel volcano-tectonic caldera structure is estimated at 40,000km^3, of which at least 70% are thick bodies of felsic extrusive rocks, the formation of which could have occurred in the interval of 150-1500years.

Conclusion

Summarizing the factual material cited, I would like to note that when I studied Volcano Bezymianny, I was, first of all, delighted with the magnificent and general volcanic forms of this volcano area. However, in addition to the different volcanic structures, any attentive observer will immediately be struck by the amazing variety of forms and features of the manifestation of volcanic activity on this volcano. Numerous examples of this diversity amaze the observer from the first stages of the study. The characteristic features and details of these processes usually elude the attention of venerable authors of monographs on volcanology. In addition, it, however, only partially affects the problem of the formation of modern and ancienttefroid deposits. These notes touch upon this problem only fragmentarily.

Acknowledgments

None.

Funding

None.

Conflicts of Interest

Author declares that there is no conflict of interest.

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Figure 1: Formation of the Novy Dome in the crater of Bezymyanny volcano (Photo from a helicopter).

Figure 2: Eastern slope of Bezymyanny volcano. Rising clouds of gas are visible above the Novy Dome. The foot of the dome is covered with the newest deposits of volcanoclastic material – the product of the rapid destruction of the penetrating extrusions.

Figure 3: Large blocks of extrusive lava and coarse-clastic material ejected during local explosions at Novy Dome.

Figure 4: An extrusive lava block ejected during the formation of dome Novy. Traces of decompression are visible.

Figure 5: The formation of sand and gravel tefroid deposits during decompression of clastic material of extrusive emissions.

Figure 6: Young extrusive dome Lohmaty on the eastern slope of Bezymyanny volcano.

Figure 7: Ancient extrusive dome of Plotiná at the foot of the eastern slope of Bezymyanny volcano.

Figure 8: Extrusive dome of regular spherical shape, a fragment of the ancient dome of Plotiná.