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Parasitic Eruption of Klyuchevskoĭ Volcano (Predskazannyĭ Eruption, 1983)

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The dynamic development of a parasitic eruption of Klyuchevskoĭ Volcano is described. The outburst of magma occurred on March 8, 1983, from a vent on the eastern slope of the volcano, in its glacier belt, 2875 m above sea level. The eruption lasted 112 days.

Klyuchevskoĭ Volcano, the highest in Eurasia (4750 m), is one of the most active volcanoes in the Kuril-Kamchatka region. Between eruptions its summit crater displays continuous fumarolic activity occasionally interrupted by weak outbursts of ash and bombs.

According to Piĭ [12], Mount Klyuchevskoĭ is seated on the slopes of older volcanoes, Mount Blizhnyaya Ploskaya and Kamen'. There are outcrops of megaplagiophyric lavas at the base, which are exposed by the Erman Glacier on the northern flank. A symmetrical cone of Mount Klyuchevskoĭ is built up of alternating beds of basaltic lava and pyroclastic material clearly visible on the walls of the cirque and also on patches on the side clear on snow and ice. The cone retains its regular shape despite the erosive and gravitational processes occurring on its surface. Piĭp established that loose material predominated over lava flows in the cone structure. Parasitic (lateral) eruptions occur more often at Klyuchevskoĭ than at any other volcano and are its distinguishing feature (Figure 1).

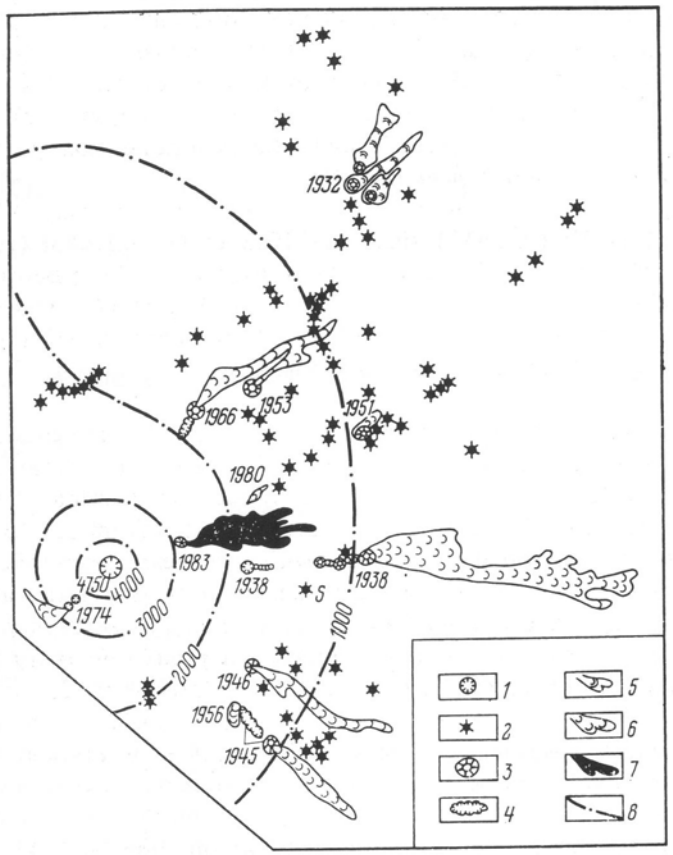

FIGURE 1 Schematic map of Klyuchevskoĭ parasitic eruptions. 1—Klyuchevskoĭ summit crater; 2—prehistoric eruptive centers; 3—cinder cones and lava flows of historic eruptions; 3—explosion craters; 5—lava flows of the Tuĭla group; 6—lava flows from other parasitic eruptions; 7—lava flows from Predskazannyĭeruption; 8—contour lines.

A precisely-dated parasitic eruption of Klyuchevskoĭ that produced three craters at heights from 450 to 500 m began on January 25, 1932, with the formation of an explosion crater which was named Kirgurich. Two and a half weeks later the explosive activity gave way to explosive-extrusive activity which ceased on May 25. Tuĭla, a second crater, opened in a month's time and was also active for four months; the dynamics of its eruptive activity was the same as that of Kirgurich.

Biokos', a third crater, was formed a week after the outburst at Tuĭla and it was active for a fairly brief period. The total volume of lava was estimated at 0.44 km³ [12]. A study of the spatial location of this group of parasitic eruptions and of the composition of their ejecta prompted some workers to relate it genetically to the areal rather than parasitic zone of Klyuchevskoĭ Volcano [4], [5].

Ten parasitic eruptions, which are briefly described below, have occurred at Klyuchevskoĭ since the 1932 event: Bilyukaĭ (1938); Yubileĭnyĭ (1945); Apakhonchich (1946); Bylinkina (1951); Belyankin (1953); Vernadskiĭ and Kryzhanovskiĭ (1956); Piĭp (1966); Named in Honor of the 4th National Volcanological Conference (FNVC) (1974); March 8 (1980); and Predskazannyĭ (1983).

The Bilyukaĭ eruption began on February 7, 1938, [11] and continued for 13 months. Higher upslope from the Bilyukaĭ cone several other cones were formed, 900 to 1800 m above sea level (Tiranus, Tretiĭ, Kozeĭ, and Propushchennyĭ), whose activity lasted from one to five months. The eruption of craters began with violent explosions followed by the extrusion of lava from the Bilyukaĭ, Tiranus, and Tretiĭ craters. Some time after the eruption had begun, a cone up to 200 m high was formed in the Bilyukaĭ crater. Its summit collapsed in February 1939 and the eruption ceased. Explosive activity intensified during the Bilyukaĭ eruption three times and was accompanied by lava extrusions. According to Naboko's estimates, the volume of erupted lava amounted to 0.24 km³ [11].

The Eruption of the Yubileĭnyĭ group began on June 19, 1945. The eruption occurred on the southeastern flank of the volcano, 1000 to 1450 m above sea level. A chain of craters extended for a distance of 2 km. Two lower craters, (Krasheninnikov and Zavaritskiĭ) were active until the eruption ceased on the night of July 6. The activity of the Krasheninnikov crater was explosive and of the lower Zavaritskiĭ crater, extrusive, Piĭp, who studied and described this eruption in great detail, estimated the volume of lava extruded at 0.03 km³ [12].

The Apakhonchich parasitic eruption began on October 23, 1946, and lasted about a month. Lava broke through from a cinder cone, about 100 m high, on the southeastern flank of Klyuchevskoĭ at a height of 1600 m. It flowed from a lower bocca at the base of the cone, in a

narrow stream 10 km long, and had a typical blocky surface. Its volume was estimated at 0.015 km³ [13].

The 1951 Bylinkina parasitic eruption occurred at a height of 950 m and continued for 10 days. It gave rise to a cinder cone from which a lava flow about 1 km long and 0.005 km³ in volume was extruded [13].

The Belyankin eruption begin on the night of June 12, 1953. In three days a cinder cone about 70 m high was formed, at an elevation of 1350 m, from which lava began to flow in several streams on June 16. The flow, about 6 km long was extruded from a lower bocca at the base of the cone. The eruption ceased on the morning of June 25. The volume of lava exceeded 0.01 km³ [13].

The Vernadskiĭ and Kryzhanovskiĭ parasitic eruptions occurred in July 1956, at a height of 1500 m, higher than the Yubileĭnyĭ group of 1945. The eruptive activity was very weak, extrusive, and continued for five days. The volume of the two lava flows was 0.004 km³ [13].

The next event occurred after a ten-year repose period, the longest interval between parasitic eruptions at Klyuchevskoĭ.

The Piĭp Eruption began on October 6, 1966, at the Klyuchevskoĭ northeastern flank, 2000 to 2100 m above sea level. The vents situated along a fissure were clearly identified by the type of their activity as explosive, explosive-extrusive, and extrusive. As their activity subsided and finally died down, the explosive craters detonated less frequently and the extrusion of laval became intermittent. The eruption lasted three months, and the volume of lava amounted to 0.1 km³ [10].

The eruption named in honor of the 4th National Volcanological Conference (FNVC) began on August 23, 1974, in the Bogdanovich Glacier area. It was the "highest" eruption in recorded history. Two craters were formed at different elevations. The upper one, 3600 m above sea level, displayed explosive activity, and the other, 200 m below, was extrusive. The eruption had three distinct phases: the first and the third phases were characterized by intense, and the second, by moderate activity. The eruption ceased in December 1974. The volume of ejected lava was not estimated [1], [7].

The March 8 eruption occurred in 1980 on the eastern flank of Klyuchevskoĭ at a height of 1800 m. A brief extrusive event (March 5 to 12), it was the weakest of all recorded parasitic eruptions at this volcano.

Several eruptive centers appeared along a 1000-m long fissure, and a narrow 1100-m long lava flow originated from four newly formed hornitoes, 10 to 2 m high. The volume of lava is estimated at 310 500 m³ [3], [9].

Prediction and study of the Predskazannyĭ eruption. On February 28, 1983, at 4 h 07 min GMT, an M = 3 earthquake with a focal depth of about 10 km, and an epicenter 3 km from the central crater, at an azimuth 70°, occurred on the northeastern flank of Klyuchevskoĭ. An earthquake swarm, which commenced in the same area immediately afterwards, preceded the eruption. Tokarev, head of the Eruption Prediction and Mechanism Laboratory. Institute of Volcanology, predicted a parasitic eruption between March 4 and 9, 1983 [14].

A field team was organized at the Institute of Volcanology in advance to investigate the site of the predicted eruption. Later the event was studied by a joint expedition (program director Fedotov, field group head Zharinov) which included teams of volcanologists, geodesists, glaciologists, and physicists.

Working under severe winter conditions of the Kamchatka Highland, the field group members were able to monitor the eruption. They made observations of the eruption dynamics; collected solid samples and determined their exact location, and the chronological sequence of their ejection; measured the temperature and viscosity of lava flows; made surface deformation measurements; conducted photogrammetric and aerial photographic surveys; made recordings of seismic and acoustic phenomena; and carried out glaciological studies.

SURFACE MORPHOLOGY OF THE AREA AND THE COURSE OF THE PREDSKAZANNYĬ ERUPTION

The eruption began on March 8, 1983, at a point on the eastern flank of the volcano where the steep (20–30°) summit part of the cone changes in inclination and gradually descends to the base at no more than 15°. Magma erupted at a height of 2875 m above sea level, along a fissure

about 200 m long which had opened along the margin between a "pseudomoraine" (ice-cemented loose deposits of volcanic and glacial origin) and the right side of one of the heads of the Kell' Glacier. The eruption must have begun as a subglacial event, because a pack of highly porous ash-filled ice is revealed at the base of the glacier exposed by the eruption.

Various glacial structures are a common features in the area of the eruption. They can be subdivided according to their surface morphology, inner structure, and evolution into three zones situated at different heights of the flank of the volcano.

The upper zone, at elevation of 2700 to 4500 m, is a belt about 50–60 m thick, composed of ice, pyroclastics, and thin lava flows. Occasional dykes and rocky ridges are exposed. Lower, at heights between 2200 and 2700 m, is the zone of "dead" and buried ice, with numerous moraine ridges cropping out, and the thickness of ice being 20–30 m. Still lower, at elevations under 700–800 m, is the zone of permafrost cut through by the upper reaches of "dry" rivers. The permafrost is about 100 m thick. All three zones are dissected by glaciers originating in sinks at elevations of 3000 to 4000 m, with tongues creeping far downslope. The ice thickness is 60–80 m in the glacier reservoirs but it does not exceed 50 m in the tongues.

The eruption center was confined to the boundary between the Kell' Glacier and the pseudomoraine. Lava gushed forth from the center continuously, evidently transported through a new radial dyke. The interaction between the lava and the glacier gave rise to hot water streams which cut a gorge in the ice providing a narrow channel for the lava flow moving downslope at a rate of 5 to 7 m/s. There were no marginal pressure ridges in the flow. During the initial phase of the eruption of lava discharge exceeded 25 m³/s. Traces of ash — a result of phreatic explosions - were visible on the southern wall of the glacial gorge (Figure 2). The explosions had been caused by the combined action of several factors: the intrusion of lava and lahars into the glacier, the collapse of glacial blocks onto the surface of the lava flow and the resulting rapid penetration of voluminous meltwater under the moving lava flow. Where lava came into contact with the glacier, water streams (with temperatures close to 50°C) cut a channel up to 20 m deep. The rate of the water discharge varied between 100 and 10 m³/s.

On March 18 the lava flow bifurcated. Its southern tongue reached a

FIGURE 2 Initial stage of Predskazannyĭ eruption. Lava flow within a glacial gorge on March 11, 1983. Photograph by Dvigalo.

rocky patch on the flank and became accessible for sampling† (Figure 3). The lava flow was about 1 km long and secondary bocche were noticed there for the first time. Lava continued to issue from one eruption center as before and flowed to the distant bocche along fissures which had formed within the new lava field (Figure 4).

On March 23, the 15th day of the eruption, the cinder cone 15 m high, open to the east, emerged at the outflow of lava in 12-hour time. Its southern side rested on the pseudomoraine, and on the north it was

† The aerial photographic surveys of the eruption made regularly by Dvigalo and Nesmachnyĭ will provide accurate estimates of the growing area and thickness of the lava field and, hence, will make it possible to calculate the changes of lava volume with time.

FIGURE 3 Formation of the lava field beginning on March 18, 1983. Photograph by Podtabachnyĭ.

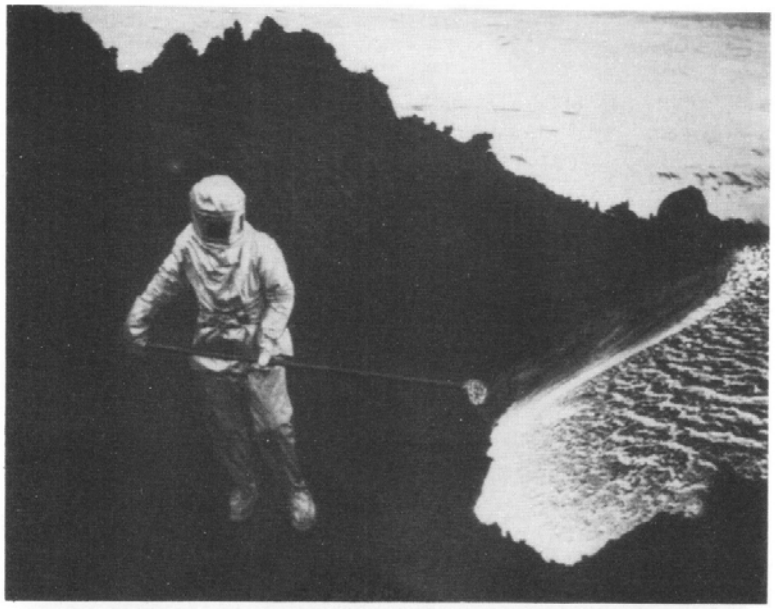

FIGURE 4 Lava bocca 1.5 km from the cinder cone. Photograph by Ivanchenko.

supported by the glacier. The glacier at the base of the cone was estimated to be 40 to 50 m thick. Cinders and porous volcanic bombs were ejected from the cone to a height of 40 m above the crater rim. Detonations occurred at intervals of 3 to 5 s. Burning gas (a blue flame like in a gas burner) was at times visible in the bocche on the flank. Lava was extruded to the surface from beneath the base of the cone and through the bocche (Figure 5). The viscosity of the lava at the vent was 1.5×10^5 P (measurements made by Panov, Slezin, and Storcheus); its surface temperature, measured with a *Promin'* pyrometer, did not exceed 1080°C.

On April 1 the lava level in the crater of the cinder cone rose and for several hours lava splashed out of it or overflowed its rim. Simultaneously bombs were hurled to a height of 100 m. Bombs up to 0.5 m across were thrown out mostly at an angle of 35–40° with respect to the horizon and to a height of up to 20 m. As a result, the cone acquired a regular shape. Lava continued to flow from the bocca on its side and

FIGURE 5 Lava field on March 28, 1983. Photograph by Podtabachnyĭ.

through the bocche in individual streams flowing across the lava field. The steams were 4 km long and were roughly 10 m wide; the height of the marginal pressure ridges was 2 to 3 m (Figure 6). The fronts of some of the streams moved at a rate of 300 to 400 m per day. At this point the

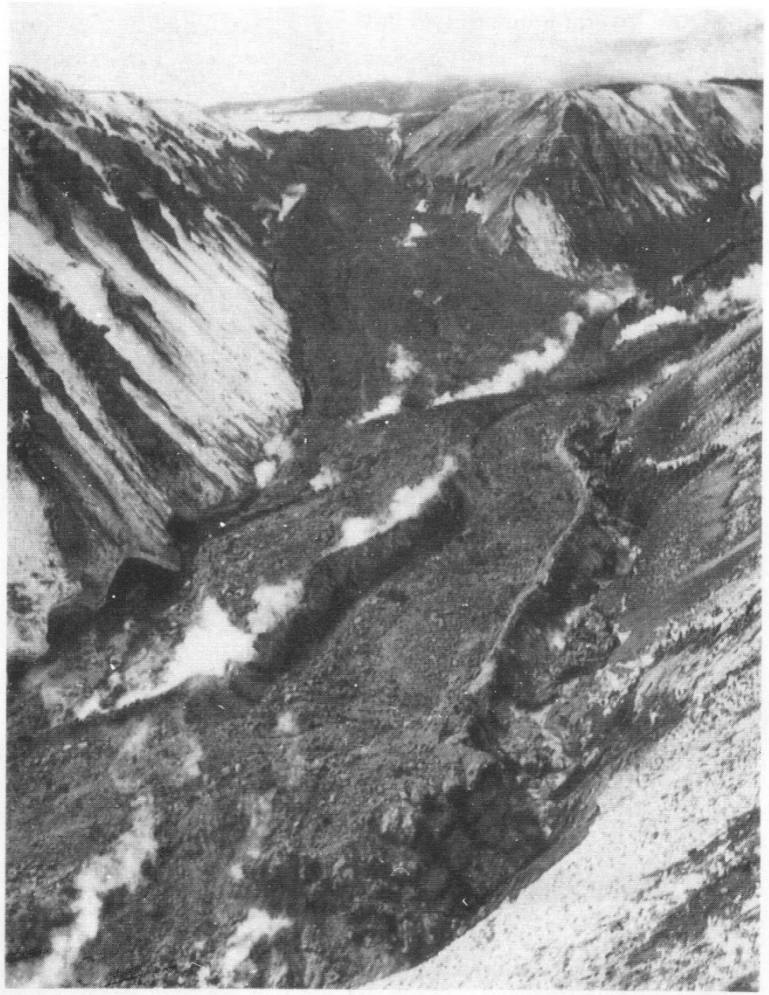

FIGURE 6 Lava flow 4 km from the main vent. Photograph by Smelov.

volume of the lava field began to increase primarily owing to the increment in thickness, which locally reached 50 m. A narrow fissure about 70 m long opened in the glacier above the base of the cinder cone.

On April 2 the cone crater consisted of two coalesced vents. The explosive activity of the cinder cone was intermittent: active periods

lasting from several hours to two days were interrupted by 3 or 4-day periods of repose. Noisy gas and vapour outbursts came as single events or in sequences of several explosions. A distinct pattern could be observed in the activity of the crater and lava bocca: the lava discharge increased when the explosive activity subsided and decreased as the activity intensified.

On April 12 the cinder cone had grown to 20 m and bombs were shot into the air continuously as high as 50 m (Figure 7).

FIGURE 7 View of the cinder cone on April 12, 1983. Photograph by Ivanchenko.

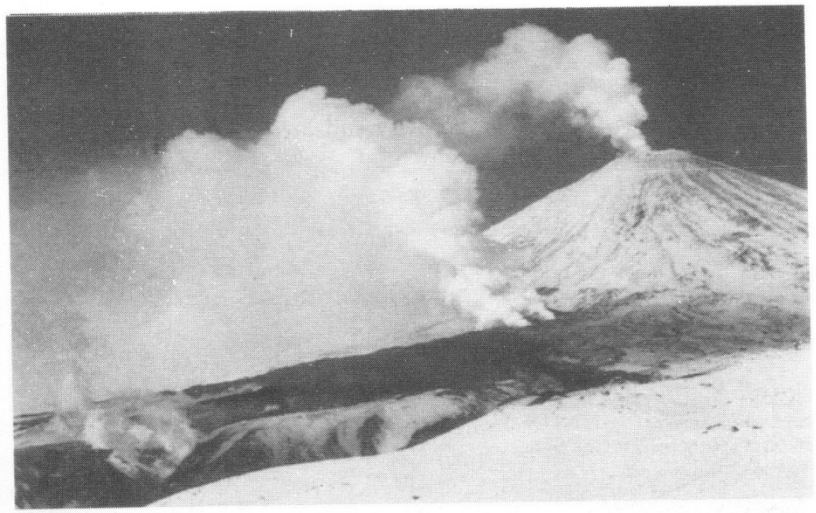

FIGURE 8 The main stage of the eruption. Photograph by Smelov.

On April 30 the eastern side of the cinder cone slumped and partially collapsed, but the lava flow of April 1 remained on it.

Extrusive activity continued at the same level. The lava field thickened intensively (Figure 8). There were 5 to 7 active bocche from which liquid lava was extruded forming lakes and pools on the lava field.

On May 5 lava began to issue from vents below the base of the cone. By that time the cone had regained its regular shape, and the pits on its flank had been smoothed over. Several bocche were active: the upper lave outflows were 400 to 500 m downslope from the base of the cone and the lower ones, about 2 km from the cone.

From March to the end of May the eruptive activity was on the whole stable, with insignificant changes in the lava charge (Figure 9).

In March, the intrusion of lava streams into the glacier led to the formation of several lahars which moved for more than 15 km toward the foot of the volcano. Jůdging by the fact that the sides of dry river valleys were overwashed, the maximum water discharge exceed 100 m^3/s. The snow cover more than 5 m thick, was removed from the floors of canyons, and the temporary channels became 2 to 3 m deeper.

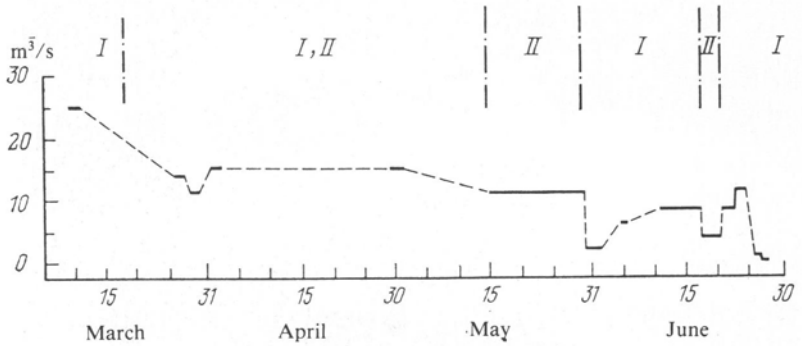

FIGURE 9 Changing lava discharge during the eruption. Solid line indicates lava discharge estimated by direct observations; dash line denotes inferred discharge; I—lava extrusion from beneath the cinder cone; II—extrusion of lava from bocche situated away from the cinder cone.

In April and May the water run-off was intermittent: the movement of the streams of lava across the lava field caused the main flow of melt-water to change its course accordingly, following them into one or another channel (Figure 10). The mean water discharge from the beginning of the eruption was 10 m^3/s, while the total volume of melted snow and ice exceeded 90 million m^3, or 80 million t of water. No hyaloclastite was formed in places where the lava came into contact with ice.

On May 28, the first changes in the eruption dynamics became apparent: the extrusive activity decreased abruptly and the lava discharge dropped to 5 m^3/s; the activity ceased in the bocche and the lava outflow shifted back to the base of the cinder cone. The depletion and closure of the lava bocche occurred gradually, from the lower to the upper ones.

On the morning of May 31 there were no signs of activity. At 19 h 15 min a gas-and-vapor column rose above the cone, followed by occasional powerful explosions and the hurling of bombs to heights of 150 to 200 m. At the outflow in the base of the cone, lava blisters, 2–3 m in diameter, swelled and burst from time to time, sputtering cinder.

At some points the lava level at the outflow dropped, revealing the opening of a narrow feeder, about 1.5 m wide, leading down beneath the base of the cone. In 15–20 min the lava would begin to rise quickly

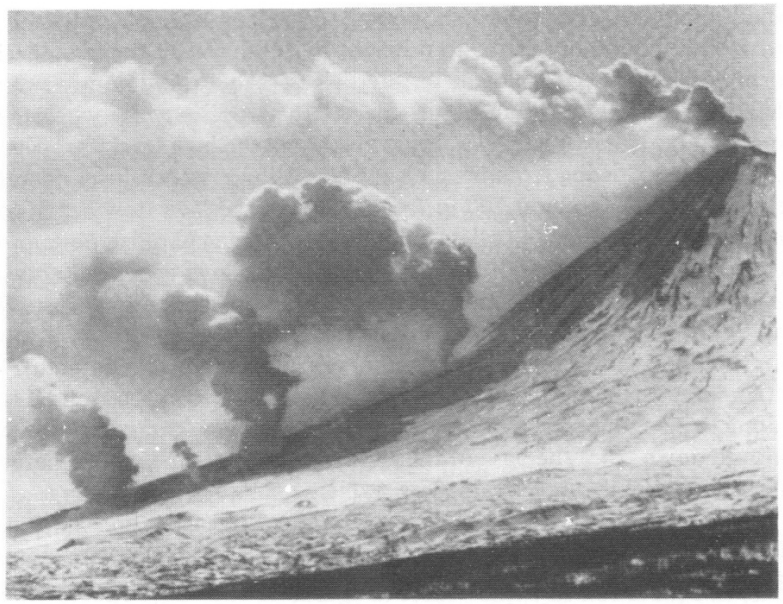

FIGURE 10 General view of Predskazannyĭ eruption during intense explosive activity. Photograph taken at the volcanological station in the town of Klyuchi by Smelov.

and regained its former level in 5 to 7 min. Such changes in the lava level at the outflow were observed several times that day.

On June 2 lava rose to the rim of the crater of the cinder cone for the second time and issued in two narrow streams for several hours. At the same time, two new bocche opened on its flnak. The upper one, a gas bocca, was situated 7 m below the crater rim, and the lower one, a lava bocca, at the base of the cone. The activity of the bocche was somehow correlated: when it intensified in the crater, the lava level dropped in the bocche, and vice versa. The lava spilling over the crater was more viscous than the lava issuing from the lower bocca.

On July 4 the lava again destroyed the eastern sector of the cinder cone as far down as the upper bocca. The ensuing lava-fall reached the lava field and was moving along its northern side.

By June 10 the pit on the cone had been smoothed as a result of the explosive activity, and the cone had once again acquired a regular shape, with a slope of 30 to 35° near the crater. When the lava level in

the vent rose to the crater rim, a continuous lava fountain followed, with the ejection of bombs to a height of 20 m. When the lava level dropped, explosions followed at intervals of 3 to 4 s and bombs were hurled to a height of 80 m. After June 10 the eruptive activity became more stable, there were fewer explosions, and the lava level dropped.

Lava was flowing from beneath the cone along the northern side of the lava field. At about 700 m from the vent, the lava flow began to meander and branch, but all its tongues were moving parallel, not more than 100 to 150 m apart. During this period the lava advanced about 2 km in the general direction. Marginal pressure ridges grew fast all along the flow. This activity continued till June 17.

On June 18 the canyon-like channel was blocked by a lava "dam," 100 m below the outflow. Above the "dam," the crust consolidated along the length of the flow and a new lava pipe was formed. The vent moved down from the base of the cone once more. The lava discharge decreased slightly and became less stable.

On June 19 the extrusion of lava continued from the bocca, 10 m from the cone. The discharge was intermittent and relatively slow: 3–4 m^3/s. At times the lava level at the outflow rose to 1.5 to 2 m in 5 to 7 min and the rate of discharge increased to 10–12 m^3/s. In many places lava spilled over the marginal pressure ridges, building them up in height and width. About 30 or 40 min later the lava discharge dropped to the former level. The morphology of the marginal ridges and the traces of fresh overwashes on them indicate repeated changes in the rate of the lava discharge (see Figure 6).

Meanwhile, the main channel of the lava flow had shifted southward and approached the axial line of the lava field. From that time on, the area of the lava field ceased to increase. Fresh lava moved only over the surface of the earlier lava streams.

On June 24 the bocca at the base of the cone resumed activity and the lava discharge became 7 m^3/s.

On June 26 the discharge dropped to 0.3–0.5 m^3/s. While the geometrical parameters of the channel remained the same, the speed of the lava flow fell to 1.3 cm/s, and apparent viscosity increased to 10^7 P. The lava at the vent had a "ribbed" surface typical of very viscous lava.

On June 27, at 14 h 15 min, the activity of the cinder cone and the extrusion of lava ceased. The eruption came to an end.

The 112-day Predskazannyĭ parasitic eruption was, in effect, purely extrusive, like the eruption of 1980. It was characterized by mild

explosive activity with occasional overwashes of lava, but not a single ejection of ash.

At the end of the eruption the cinder cone was 50 m high, 150 m across at the base, and had a volume of 300 000 m³. The vent was slightly deformed funnel-shaped 15 to 20 m in diameter at the top and 10 to 12 m at the bottom. The walls of the vent were smooth and fused, and their upper sections resembled glazed brickwork made up of lava fragments, 20 to 40 cm in size. The upper 20 m of the outside cone also looked like brickwork but it was not glazed. A lava surface with red glowing cracks in its crust was visible at the bottom of the vent. The depth from the vent opening to the lava surface was 50–60 m.

According to preliminary estimates, the volume of the extruded lava was 0.15 km³. Lava issued to the surface both from the main bocca beneath the base of the cone from the secondary bocche, flowing in numerous streams which often changed their course (Figure 11). The morphology of the lava field was determined by the lava flows pouring down the steep flank of the volcano. At outlets ropy lava occurred which graded into flat blocky lava, but for the most part it was of the cinder blocky type. The discharge at some vents was not even, but on the whole, it gradually decreased in the course of the eruption from about 25 m³/s at the beginning to 3–5 m³/s at the end. At the final stage it was low on the average, but increased up to 10–12 m³/s repeatedly for periods of less than one hour.

Fumarolic activity in the lava flows and the cinder cone during the Predskazannyĭ eruption was very mild and was mostly confined to the base of the cone.

The main feature of Predskazannyĭ was the formation of bocche from one eruptive vent which resulted in secondary lava extrusions far from the cone. On the whole, the eruption dynamics was fairly stable, exhibiting no abrupt changes.

However, three stages in the extrusive activity of Predskazannyĭ can be identified.

1) The initial stage, March 8 to 23: the formation of an eruptive center in a fissure inside the glacier; extrusion of lava and lava fountains, accompanied by fast destruction of the glacier; maximum lava discharge; phreatic explosions and lahars.

2) The main stage, March 24 to May 28: the formation of a cinder cone and bocche; continuous meandering of lava streams; the move-

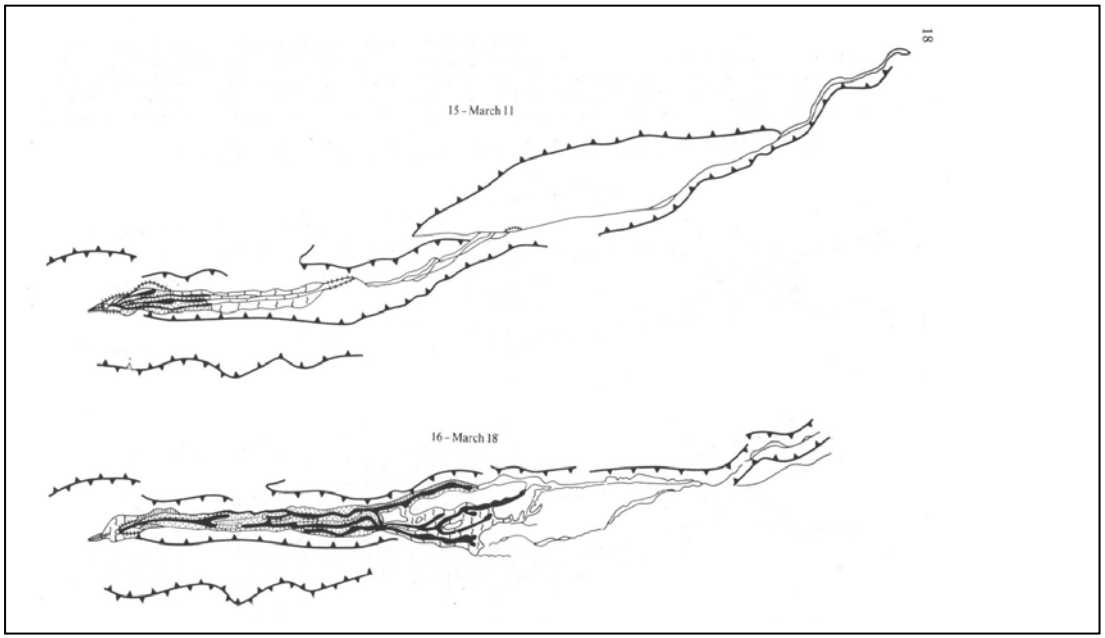

FIGURE 11 Evolution of Predskazannyĭ eruption. Schematic map compiled by Litasov from aerial photographic survey data of 1983. 1—scarps and ravines; 2—limits of glacial cirque; 3—glacier walls with undisplaced fissures; 4—glacier walls with fissures displaced along the marginal pressure ridges of the lava field; 5—lahars, mud flows, and rivers; 6—relics of the volcanic structure; 7—fissure at the base of the cinder cone; 8—cinder cone with a crater; 9—feeding fissure at the base of the cinder cone; 10—lava bocche, 11—lava flow with marginal pressure ridges; 12—moving lava flows; 13—cooling lava flows; 14—cooled lava flows.

ment of the main lava flow downslope and the formation and thickening of the lava field; a decrease in the lava discharge to half of what it was in the first stage; phreatic explosions and lahars.

3) The final stage, May 29 to June 27: the closing of the lava pipes; lava extrusion only from the bocche in the cinder cone; sharp changes in the lava discharge; the growing thickness of the upper section of the lava field; the first appearances of xenolith fragments and cognate inclusions on the lava surface.

In terms of the most common petrogenic oxides the volcanite composition corresponded to cal-calcalic aluminous basalts and remained constant at all stages of the eruption (SiO_2 = 53.04%; TiO_2 = 1.03%; Al_2O_3 = 18.13%; Fe_2O_3 = 3.01%; FeO = 5.25%; MnO = 0.17%; MgO = 5.22%; CaO = 8.18%; Na_2O = 3.40%; K_2O = 1.22%).

The lavas are dark-gray, almost black, of a porphyric texture whose paragenesis is similar to that of the rock-forming minerals of phenocrysts and of the groundmass. The phenocrysts are dominated by plagioclase (up to 12 percent); olivine is more common than clynopyroxene, and orthoyroxene is rare. The total amount of olivine and pyroxene phenocrysts in the lavas does not exceed 5 percent.

The composition of the rock-forming minerals in basalt ranges from basic andesine to bytownite in plagioclase, and from chrysolite to hyalosiderite in olivine. In clinopyroxene it corresponds to enstatite and augite, and in orthopyroxene to bronzite and hypersthene.

Any analysis of the specific features of the parasitic eruptions at Klyuchevskoĭ must include a description of the activity of its summit crater. Piĭp [13] devoted much attention to this question.

THE STATE OF THE KLYUCHEVSKOĬ SUMMIT CRATER IN 1983

Continuous monitoring from the seismic stations at Klyuchi, Apakhonchich, and Podkova, and at the site of the eruption revealed three phases in the activity of the summit crater of Klyuchevskoĭ Volcano.

Phase 1, January 8 to February 4, 1983, preceded the terminal eruption and was characterized by brief glowing above the crater and by mild cinder ejections.

Phase 2, February 5 to 28, 1983, was a period of mild explosive activity in the central crater. It was intermittent, with increases in activity observed on February 5–7, 10, 11, 13, 16, 17, and 20–28. On those days, lava fountained and bombs reached heights of 300 to 600 m (800 to 1000 m between February 23 to 25); as a rule, they fell back into the crater. A continuous uneven glow, broken by heat lightnings, was seen over the crater.

On the days mentioned above light- or dark-gray gas-and-ash outbursts rose 400 to 600 m over the crater; at times "cauliflower"-shaped clouds ascended 1.5–2.0 km high.

On February 8, 9, 12, 14, 15, 18, and 19, occasional white-colored gas-and-vapor outburst or quiet steaming were observed over the crater.

The February 28 earthquake changed drastically the activity of the summit crater. The outburst became fewer and weaker, and on March 1, 2, and 3 only very weak fumarolic activity was observed in the crater. On March 28 the eruption ceased.

Phase 3, from March to the end of June, was the period of the Predskazannyĭ parasitic eruption. Fumarolic activity in the summit crater was mild to moderate; there were periods of complete quiescence and periods of activity when a broad snow-white gas-and-vapor column rose to a height of 1.5 to 2.0 km and formed a wide diffused train 15 to 20 km long.

Ash was observed in the gas-and-vapor cloud only 11 times during the entire period.

Glow was recorded twice above the crater on March 27 and April 5; it was weak and uneven; "heat lightning" of relatively short duration occurred at intervals of 10 to 15 min.

After the Predskazannyĭ parasitic eruption ended on June 28 the fumarolic activity at the Klyuchevskoĭ summit crater practically ceased.

The thermal power of the outbursts was calculated by the formula given in [15]:

$$Q = 0.136 \cdot \Delta h^2 U^{1,5},$$

where Δ is the height of the median line in the horizontal stretch of the train, and U is the wind velocity at the altitude reached by the train. The value of Q obtained was 1×10^7 kW. This value is intermediate between the estimated power of the parasitic eruption at Yuzhnyĭ Bocca during the 1975–1976 GTFE and the 1980 eruption of Gorelyĭ [15]. The

crater morphology did not change during the 1983 Predskazannyĭ parasitic eruption.

Klyuchevskoĭ Volcano typically generates either summit or parasitic eruptions. In a parasitic eruption the magma vent is filled with lava or constitutes a magmatic system open for free escape of gases.

In April 1974, when the explosive activity of the summit crater was intense, a vigorous swarm of volcanic earthquakes was recorded on the northern and northeastern flanks of Klyuchevskoĭ [7]. Their hypocenters were confined to a weakened zone between the Piĭp and Yubileĭnyĭ bocche. However, the parasitic eruption which began on August 23, 1974, occurred on the southwestern flank of the volcano, inside a glacier at an elevation of 3600 m (see Figure 1). Apparently this was when the radial fissure was formed on the opposite, eastern flank of the volcano, which erupted in March 1980 without any preceding seismic activity [3], [8].

The March 8 eruption of 1980 was brief and extrusive, with a minimum volume of juvenile material ejected. We can assume that only the opening of the fissure and the resulting decompression caused the magma to ascend to the surface and erupt. It was a portion of the degassed magma left from the summit crater eruption of 1978–1980. After the eruption of March 8, 1980, the magma sank, liberating the vent of the volcano.

In 1983 the intrusion of the magma into the radial fissure in the body of the volcano began. Since this was accompanied by seismic activity it was possible to predict the site and time of the eruption [14]. During the Predskazannyĭ eruption, the melt was degassed through the summit crater, and a relatively "dry" magma ascended to the surface. Genetically, the Predskazannyĭ can be considered a lava bocca of Klyuchevskoĭ.

CONCLUSIONS

The 1983 parasitic eruption of Klyuchevskoĭ was successfully predicted. It was studied from start to finish, under an overall program, by an integrated expedition organized by the Institute of Volcanology. The continuous monitoring provided a comprehensive picture of the dynamics of the Predskazannyĭ eruption.

Predskazannyĭ can be ranked among the most extensive parasitic

eruptions of Klyuchevskoĭ. The bulk of the morphometric evidence places it next to the Bilyukaĭ eruption. The only comparable event was the FNVC eruption of 1974 in the upper reaches of the Bogdanovich Glacier on the southwestern flank of the volcano.

The specific features of the Predskazannyĭ eruption are a single eruptive center and the absence of the chains of craters that are as a rule created during parasitic eruptions along a radial fissure.

The extrusive character of the eruption and the complete lack of ash ejections from the cinder cone are indicative of a low gas content of the magma and a free escape of gases, as a result of which the ascent of the magma to the surface was not accompanied by any phreatomagmatic events. Phreatic explosions producing small amounts of ash were observed only when the lava flow moved within the glacier. Hyaloclastite was not formed in the process. No relationship between the explosive activity of the summit crater and the evolution of the parasitic eruption was established.

As to its elevation, the Predskazannyĭ eruption is one of the highest. Therefore its extrusive character contradicts the earlier conclusion that the index of explosiveness increases with elevation [5].

The final stage of the eruption was characterized by variations in the lava discharge, deformations of the cinder cone, and the transport by the lava of cognate inclusions and xenoliths to the surface.

The above observations, coupled with the seismic and geodetic surveys, provide new ideas that should lead to a revision of some accepted views and to a better understanding of the mechanism of parasitic eruptions at major stratovolcanoes.

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