

## **Northern Group of Kamchatkan Volcanoes: Activity in 1990-1992**

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**This paper continues the description of volcanic activity at the Northern group of Kamchatkan volcanoes since 1935. The period described embraces the years of 1990, 1991, and 1992. The paper describes the evolution of eruptive activity at Klyuchevskoi, Bezmyanni, and Shiveluch volcanoes.**

### **Introduction.**

The Northern group of Kamchatkan volcanoes comprises five active volcanoes (Shiveluch, Klyuchevskoi, Bezmyanni, Uskhovskiy (Dalniy Ploskiy), and Ploskiy Tolbachik) and ten volcanoes classified as extinct. This group is unique in terms of the frequency of eruptions and the diversity of volcanic activity. Concentrated over a limited area, the active volcanoes erupt lavas ranging from liquid basalt to viscous andesite. This motivated the choice of this area for establishing a volcanological station (observatory) in 1935 in Klyuchi City to monitor the volcanic activity.

The aim of this paper is to describe the activity of the Northern group of volcanoes for the period of 1991 to 1992 inclusive. The description is based on the results of the continuous visual observations that were carried out by the staff of the Kamchatkan volcanological station in Klyuchi City. The study of the compositions of the erupted materials was beyond the context of this paper. Generally, the compositions of the products erupted during the period concerned are not essentially different from the products of the past eruptions.

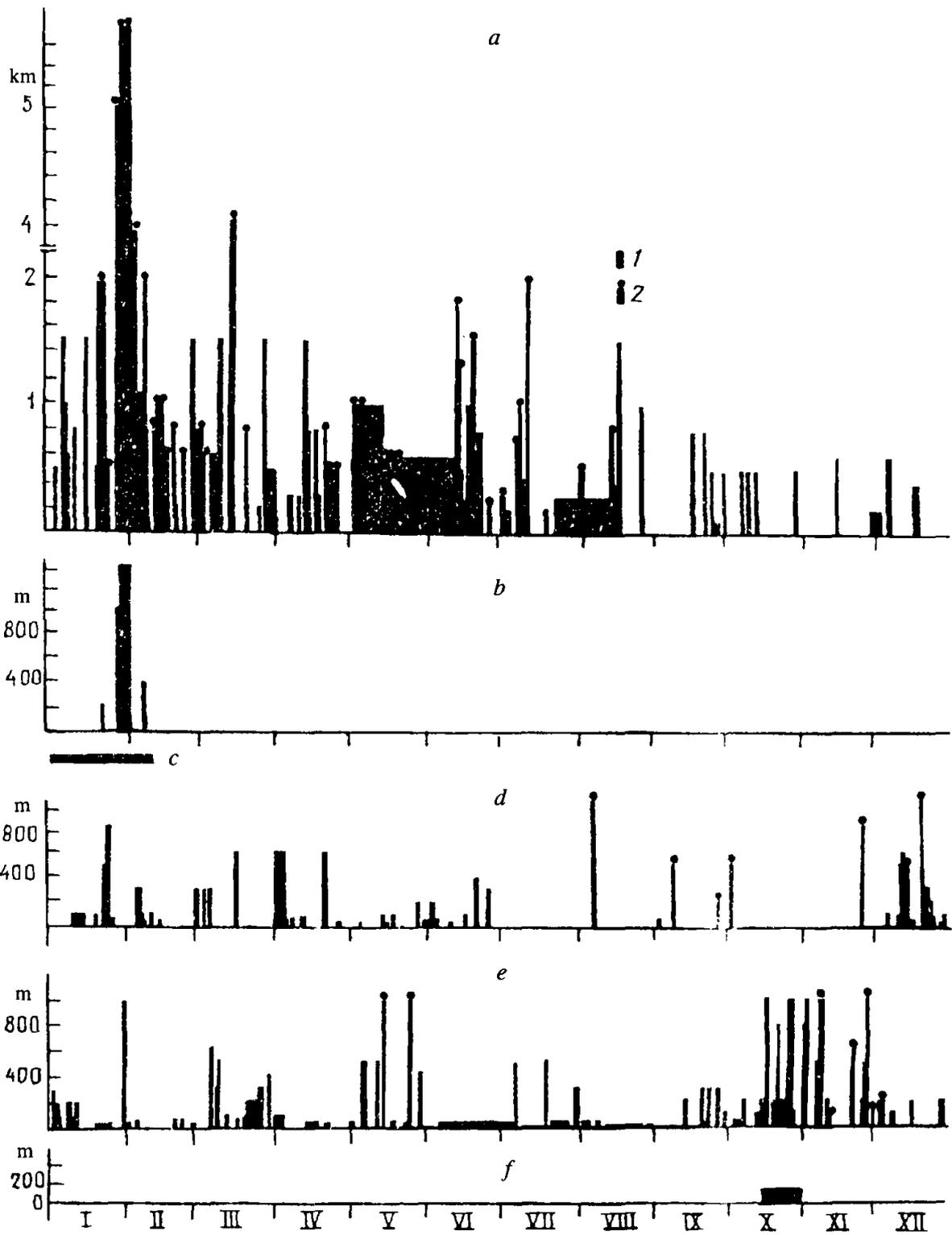
We refer the reader to the list of references for information about the geology of the area and the activity of the volcanoes in the previous years [1-6].

In 1990—1992 volcanic activity continued at Shiveluch, Klyuchevskoi, and Bezmyanni. Mild fumarolic activity was observed at Ushkovskiy and Ploskiy Tolbachik.

### **Klyuchevskoi.**

#### ***General description of the activity in 1990-1992.***

A vigorous explosive eruption occurred at the summit crater in January-February 1990. Following Piip's classification [6], it can be ranked as a paroxysmal event. Red-hot bombs and ash were ejected to the heights of 1.5 and 6 km, respectively. A new crater was formed instead of the old one where cinder cones had grown during the previous, mild, interparoxysmal eruptions.



**Figure 1** Results of visual observations of Klyuchevskoi activity in 1990 (*a, b, c*), 1991 (*d*), and 1992 (*e, f*): *a, d, e* — variations in the heights of steam-gas (1) and gas—ash (2) ejections; *b, f* — variation of bomb heights; *c* — lava issue time

Simultaneously with the termination of this eruption, lava ceased to issue from a bocca that had developed on the eastern slope of the cone. Lava had been flowing 199 days. The period of relative repose that followed the paroxysmal eruption was interrupted by occasional ash explosions of the Vulcanian type. In October 1992 comparatively mild Strombolian eruptions resumed, and the next phase of filling the crater commenced. Because the volcanic activity was concentrated on the floor of a deep crater, the observers from Klyuchi City could see only relatively large explosions. The results of the visual observations of the Klyuchevskoi activity in 1990-1992 are plotted in Fig. 1.

*In late 1989 - early 1990* the volcano was in the state of a flank eruption, which began on July 26, 1989, when a radial fissure developed on the eastern slope at a height of 4300-4400 m, and lava began to issue. In early January the front of the lava flow was at a height of ~ 3200 m. A steam-gas cloud usually rose to a height of up to 200 m above the source of the lava flow, surrounded by a cinder cone, ~50 m high, and red-hot bombs were hurled occasionally to a height of a few tens of meters.

Almost no eruptive activity was observed in the summit crater. Steam-gas clouds, obviously of fumarolic origin, rose to heights of 500-800 m above the cinder cones that filled the entire crater, and small amounts of ash were ejected occasionally.

The first evidence of intensified volcanic activity appeared on January 8, when a steam and gas column rose to a steady height of more than 1 km above the summit crater. During strong wind the gas cloud stretched from the summit to a distance of a few tens of kilometers. During the night of January 16 to 17 the glowing segments on the lava flow were seen to grow longer, which was interpreted as the increase of the lava discharge.

On January 23 a vigorous Strombolian eruption began with the ejection of red-hot bombs to a height of 200 m at a frequency of up to 10 ejections per minute. An eruption cloud, largely steam and gas with a small amount of ash, rose to a height of 2-3 km. On January 24 the amount of ash increased greatly: an ash cover of 30 g/m<sup>2</sup> was recorded in Klyuchi City. On January 29 a climactic eruption began, whose character was defined as subPlinian. At 8 h 40 min local time lava began to fountain in a pulsatory manner to a height of up to 500 m from several vents in the summit crater. The height of the ash- loaded gas column grew rapidly from 1.5 to 3 km. From 9 h 25 min the eruption was slightly less vigorous; thereafter lava fountained again to a height of 1 — 1.5 km above the summit crater, and the eruption column, heavily loaded with ash, rose to a height of 5 km. Numerous red-hot bombs fell on the slopes of the cone and rolled down to an elevation of 3000 m. At 23 h the eruption weakened for a short time. On January 30 lava fountained from three vents to a height of 1.5 km. The heavy eruption cloud was as high as 6 km. This activity continued on January 31 and February 1 (Fig. 2, *a*). As a result of violent explosions, the northern side of the intracrater cinder cone was demolished, and a new crater, a few hundred meters across, was formed. Bombs and ash were ejected continuously to the heights of 1.5 and 6 km, respectively, through its entire floor. The strong westerly wind carried the ash cloud eastward. On February 1 lightning reports were observed in the ash column; at 9 h 20 min two small pyroclastic avalanches descended from the crater along the northwestern trench to an elevation mark of 3500 m.

On February 2 the intensity of the eruption began to weaken. Lava ceased to fountain. An eruption cloud, heavily loaded with ash, was rising slowly above the newly formed crater,



A



B

**Figure 2** Ash-loaded gas cloud above the Klyuchevskoi summit crater: *a* — February 1, 1990, cloud 5 km high: *b* — February 2, 1990, cloud 3 km high. The steam-gas cloud in the right lower corner rises from a gas fissure on the slope. Photos by A. B. Belousov and M. G. Belousova.

~500 m across (Fig. 2, *b*). On February 3 its height reduced to 1 km. The amount of ash diminished. On the night of February 5 to 6 a series of red-hot bomb ejections took place in the summit crater; bombs were hurled to a height of 200-500 m. The gas and ash column was as high as 2 km during this last eruptive phase, which can be interpreted as a paroxysmal eruption.

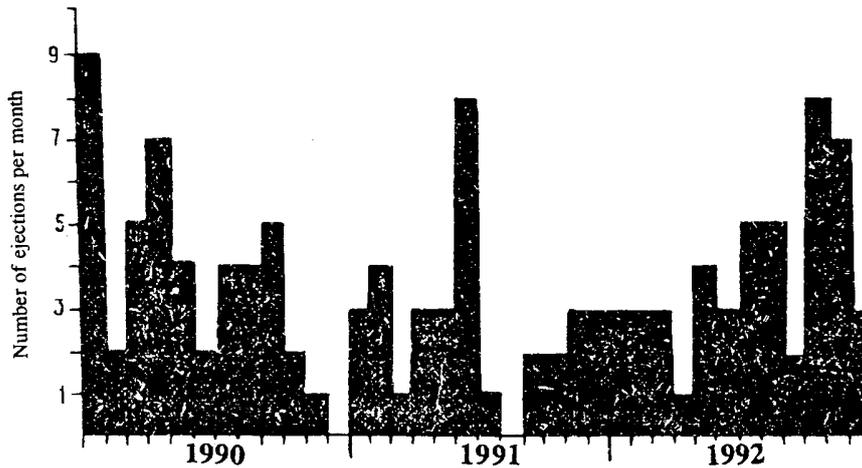
The new well-shaped crater, produced by the paroxysmal eruption, was about 500 m in diameter. The floor of the crater was obscured by fumarolic gases and vapors; its depth was estimated roughly at not more than 300 m. Most of the voluminous ash erupted by the paroxysmal event was deposited largely in the northeastern sector. The fresh ash that fell in the area of cinder cone S (on the ash-fall axis 12 km from the vent) was ~2 cm thick or ~18 kg/m<sup>2</sup>. The ash that fell in Klyuchi City on January 29 and 31 was measured at 32 and 21 g/m<sup>2</sup>, respectively. The total ash volume can be estimated roughly at 0.3 km<sup>3</sup>. Part of the ash was obviously removed to the stratosphere: a typical lateral spread of the eruption cloud, having the form of a disc > 30 km across, was observed on January 29-31 at a height of 5-6 km above crater.

The fissure eruption activity intensified during the paroxysmal eruption at the summit crater. On January 29 the lava discharge increased abruptly. Bombs were ejected, and lava fountained spasmodically to a height of 100-200 m at the issue of the lava flow. On January 30 a new explosive bocca developed above the previous lava vent at a height of 4600 m. Small amounts of ash were ejected from the new bocca to a height of 1 km. The lava flowing from the previous fissure moved at a greater speed and descended rapidly to an elevation mark of 2200 m. As the eruptive activity at the summit crater declined on February, the lava discharge from the fissure decreased greatly. On February 9 the fissure eruption came to an end. On February 7-8 a system of radial (relative to the summit crater) and subhorizontal fissures developed in the area of the bocca from which lava had flowed. The volume of the lava was estimated roughly at 0.03 km<sup>3</sup>.

During the period that followed, by the end of 1990, steam emanated intensively through the entire floor of the summit crater; the clouds rose as high as 100-1000 m. Single and series of ash ejections were observed. Usually they were less than 1 km high; occasional ejections were as high as 3 km. Most of the ash fell near the vent, though on some days (February 14, March 16, April 29, and May 4) ash fell in Klyuchi City (1.5 g/m<sup>2</sup> on March 16 and 250 g/m<sup>2</sup> on May 4).

Some of the ash ejections produced reddish clouds obviously because of the dust from the collapses and debris avalanches on the steep inner walls of the crater. The summit crater activity attenuated gradually from February 6 to the end of the year: that period can be interpreted as a mild, lengthy, explosive eruption of the Vulcanian type, possibly, of a phreatomagmatic origin.

***In 1991*** no eruptions occurred at the volcano. The summit crater activity was identical to that of late 1990. Steam clouds, obviously fumarolic vapors, rose to heights of 200-500 m



**Figure 3.** Distribution of gas-ash ejections on the dome at Shiveluch Volcano by months in 1990-1992.

above the crater, and ash was ejected occasionally to heights of < 1 km. The frequency was a few ejections per month.

*Till late September 1992* the behavior of the volcano was identical to that of 1991. Steam clouds of fumarolic origin rose to heights of 200-500 m above the crater; ash ejections (< 1 km) were very rare and grew slightly more frequent in late September.

A new summit crater eruption was noted at the night of October 12-13. The pulsating glow and red-hot bombs thrown over the crater rim gave evidence of a Strombolian eruption. The usual daytime activity consisted in steam-gas ejections which produced clouds rising to heights of < 1 km. Very little, if any, ash was ejected. The last time when glow was noted in the crater was October 29; that date was taken to be the end of the Strombolian activity in the crater. Subsequently, until early December, steam clouds and occasional ash ejections, less than 1 km high, were noted above the crater. The facts that no volcanic tremor was recorded from the 8th to the 27th of December, and no evidence of eruption was noted suggest that period to have been a pause in volcanic activity. Mild volcanic tremor resumed on December 27. This and the pulsating glow observed above the crater on December 30, 1992, and on January 2, 1993, indicated that a mild Strombolian eruption had continued in the summit crater.

**Bezmyannyi.**

No essential changes occurred in the behavior of this volcano during 1990 -1992. The extrusive—effusive dome that had started to grow in its crater in 1956 continued to grow in an intermittent manner. During the reactivation periods, which lasted from a few weeks to a few months, the obelisks and viscous andesite lava flows continued to be squeezed out slowly. This process was accompanied by avalanches of cold and red- hot materials. Lava flows, not more than a few hundred meters long, and rockslide avalanches moved predominantly in the eastern sector of the dome and its base. Relatively mild explosive

eruptions, accompanied by block-ash pyroclastic flows, 2-6 km long, occurred occasionally (usually 1-3 events per year) during the extrusive-effusive activity. Generally, explosive activity continued one or two days and was superseded again by the extrusive-effusive activity. Ash clouds rose to the heights of 5 -10 km during the explosions. Gases and vapors were emitted actively from the fumaroles during the intermissions between the eruptive phases. Below follows the description of each reactivation period for each year. Unfortunately, the observations ceased to be a regular monitoring after the Apakhonchich seismic station had been shut down in 1989.

The first evidence of reactivation, noted in late January, 1990, were steaming grounds and small rockslides in the southeastern sector of the dome. New obelisks appeared at the top of the dome in mid-February. On March 9, after a number of hot rockslide avalanches, several explosions took place, and an ash cloud rose to a height of 2 km. On March 10 the strongest explosion occurred, which produced an ash cloud ~10 km high and a number of pyroclastic flows. The pyroclastic flows descended along two trenches on the slope of the dome: the old northeastern trench that had been cut by the pyroclastic flows of the 1984 - 1985 eruption and the new southeastern one that started to form during this eruption. The block-ash pyroclastic flows moved in two branches, 5-6 km long. They were identical to the flows of the previous years: they were 2-3, occasionally 5 m thick and had steep fronts of rounded andesite fragments, 1-1.5, sometimes 2 m in size, showing numerous collision imprints. The southern branch contained a large number of variegated fragments of the dome's resurgent material — the products of the new canyon incision and rockslides on the dome slope. The flows did not have clear-cut marginal ridges. Longitudinal ridges of large fragments were formed locally on their surfaces. No pyroclastic surge deposits were observed. The flows were covered by a 2-cm ash layer containing numerous accretionary lapilli 1-3 mm across. The fact that there were very few fumaroles on the flows and they were not surrounded by sublimates indicates that the pyroclastic material contained little gas. After the explosive phase a short (~100 m) lava flow was squeezed out slowly and descended down the eastern slope. On March 22, when the volcano was flied over in a helicopter, the vent of the lava flow looked like a sublatitudinal fissure on the top of the dome, ~30 m wide and — 20 m deep. By that time lava had ceased to flow. Extrusive - effusive activity renewed in April, June-October, and in late November-early December. The most active renewal occurred on August 20, when a series of explosions took place, and a block-ash pyroclastic flow was formed. The ash of the explosions fell in Klyuchi City.

The squeezing of viscous lava flow was observed during infrequent visits to the volcano in February, April, July-August, and November-early December, 1991. Apparently this activity continued with short intermissions throughout the whole year. On November 27-29 several explosions occurred, whose ash was noted by hunters on the snow near the volcano.

On March 12-13, 1992, a mild explosive eruption took place; its ash was carried westward. The amount of ash was 4 g/m<sup>2</sup> in Kozyrevsk town. The ash cloud was 2 km high. This eruption was followed by the short-term squeezing of a viscous lava flow.

**Table 1** Gas–ash ejections on the dome at Shiveluch Volcano in 1990–1992.

<i>Month</i>	<i>Total number of ejections</i>	<i>Days of the month</i>	<i>Dates of ejections observed visually</i>
1990			
January	9	10, 13, 18, 20, 21, 22, 23, 24, 29	29(3)
February	2	7, 15	7(2)
March	5	2, 5, 24, 29, 30	2(3), 5(2), 29(1)
April	7	2, 3, 9, 13, 22, 26, 29	2(0.5), 26(3), 29(1)
May	4	4, 6, 14, 18	-
June	2	3, 4	-
July	4	17, 25, 28, 29	-
August	4	4, 9, 12, 25	4(5)
September	5	1, 15, 17, 20, 21	-
October	2	9, 14	-
November	1	23	-
December	0	-	-
1991			
January	3	14, 22, 26	26(1.5)
February	4	6, 7, 12, 13	7(4)
March	1	3	-
April	3	8, 12, 25	8(3), 25(2.5)
May	3	20, 24, 28	28(2)
June	8	3, 6, 7, 8, 9, 10, 13, 15	3(2), 13(2)
July	1	27	27(3)
August	0	-	-
September	2	24, 29	24(5)
October	2	16, 28	28(1.5)
November	3	18, 27, 29	-
December	3	3, 6, 10	-
1992			
January	3	6, 9, 22	-
February	3	12, 16, 19	-
March	3	10, 29, 31	-
April	1	13	-
May	4	17, 21, 25, 26	-
June	3	5, 22, 24	-
July	5	3, 21, 22, 27, 28	-
August	5	12, 14, 18, 20, 23	-
September	2	21, 28	-
October	8	4, 12, 15, 18, 20, 22, 28, 30	20(1), 22(1)
November	7	2, 15, 16, 17, 18, 20, 26	18(2.5)
December	3	4, 9, 20	4(1.5)

**Note.** Figures in the parentheses denote the heights of visually observed gas-ash ejections, km.

### Shiveluch.

Occasional gas and ash explosions that had been observed since 1984 continued in 1990-1992 (Fig. 3). All explosions occurred on the top of the extrusive andesite dome which had grown in 1980-1981. In contrast to the previous eruptive period, no explosions occurred at

the base of the dome. Mild fumarolic activity was observed on the dome in the periods between the explosions. The explosions were accompanied by spasmodic volcanic tremor lasting from a few minutes to several hours. This permitted the identification of explosions when the volcano was obscured by clouds. All explosions occurred in a sudden manner without any apparent precursors. They took place in a crater of an irregular form, ~200 m across and 50 m deep, elongated along the edge of the flat top of the dome. This crater had been formed by the merging and deepening of a few isolated craters that had been produced during the first years of explosive activity. Each explosion occurred as a powerful and fairly long (up to tens of minutes) ejection of clastic material ranging from fine ash to large blocks. Some material, mainly large blocks, usually fell the crater and moved down the slopes of the dome as avalanches or as small block-ash flows. The largest flows that were produced by the explosion of August 4, 1990, were as long as 2 km. The eruption cloud rose to a height of 1 to 5 km and deposited a narrow belt of ash oriented in the direction of the wind. The ash consisted of angular fragments of crystalline andesite, massive or containing scarce, small rock grains. Some of the grains were severely oxidized. The habit of the grains suggested them to be resurgent ash produced by the crushing of the dome material in 1980-1981. The Shiveluch activity in 1990-1992 is summarized in Table 1.

### **Conclusion.**

The Kamchatkan volcanoes of the Northern group, Shiveluch, Klyuchevskoi, and Bezymyanni, were almost continuously active in 1990-1992. The most impressive event was the Klyuchevskoi eruption in January-February 1990, which can be classified as a paroxysmal event. By the character of its explosive activity, it resembles subPlinian - ultraVulcanian eruptions and is identical to the vigorous explosive eruptions of the volcano in 1945 and 1987.

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