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BEZYMYANNYI ERUPTION OF AUGUST 2, 1989

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During the Bezymyannyi eruption of August 2, 1989, lava began to flow in the course (in the middle) of a vigorous blast in the crater of the volcano. A pyroclastic flow was formed simultaneously with the lava flow. A block-and-ash flow deposit was produced by the mixing of juvenile material and the lithic debris produced by the destruction of the frontal parts of the 1987-1988 and 1989 lava flows.

After a powerful explosive eruption of 1985, Bezymyannyi was in the state of a moderate eruptive activity: a slow viscous andesite extrusion was interrupted from time to time by tephra ejections and small pyroclastic flows [2], [9]. After the June 1986 eruption, a viscous lava flow was slowly extruded and numerous incandescent avalanches, associated with it, occurred on the Novyi dome throughout 1987. Avalanches were most frequent in the SSE sector of the dome. In early 1988, a new lava flow descended in this sector [7]; in August 1988, it was covered by snow.

In July 1989, a weak fumarolic activity was observed, and small debris falls occurred, largely at the contact between the last lava flow and the stable southwestern sector of the dome.

A culmination eruption occurred on August 2, 1989. It was observed by Yu. V. Demyanchuk and N. A. Zharinov, the workers of the Levinson-Lessing Kamchatkan Volcanological Station, Russian Academy of Sciences, from the volcanologists' camp, 7 km from the crater. Demyanchuk described the eruption as follows. "5:00 a.m. - scarce ash ejections, glare in the crater; close to 6:00 a.m. - ash ejections grew more frequent." Occasional incandescent avalanches slided down from a red-hot block in the southern sector of the dome, at the contact between the last lava flow and the old, stable part of the dome, slightly below the crater. "6:00 a.m. - more intensive ash ejections; 6:30 a.m. - ash-loaded column 0.8 km high; almost continuous ash ejections; 6:35 a.m. - 1.5 km column; 7:00 - 8:35 a.m. - blast (Figure 1), roar in the crater growing louder, incandescent avalanches sliding down

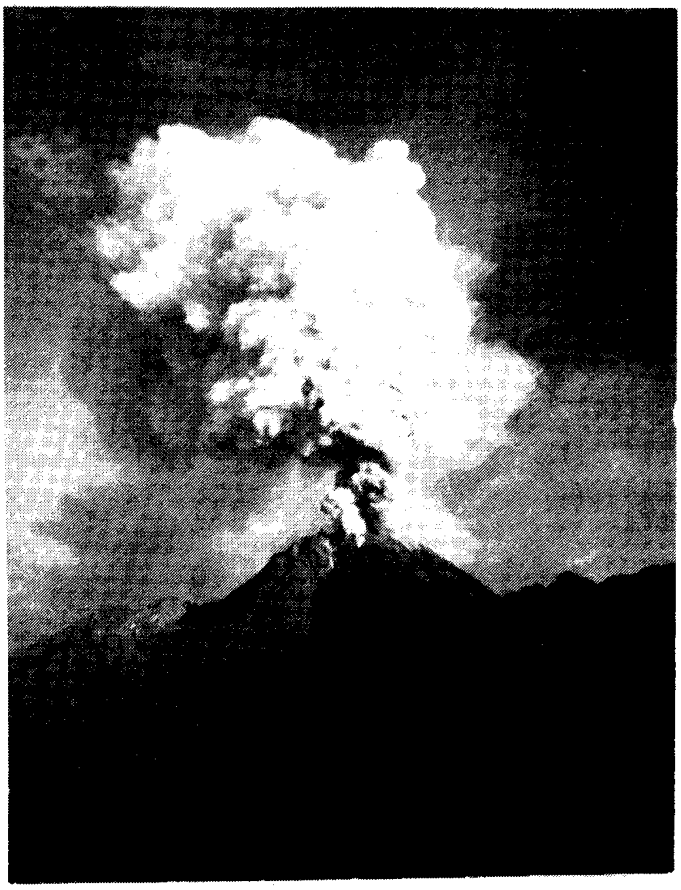


Figure 1 Blast at Bezymyannyi Volcano. August 2, 1989, 8:10 a.m. Photo by Yu. V. Demyanchuk.

the northern trench on the dome; 8:40 a.m. - dark patch of newly squeezed lava; 9:40 - 10:00 a.m. - blast, ash ejections weakened; 10:15 a.m. - ash ejections ceased, the top of the dome closed by the clouds, fresh lava patch seen between them; 11:30 a.m. - short red-hot avalanches in the northern trench, oval fresh lava patch growing before the eyes, slight westerly wind; 12:50 - 16:00 p.m. - weak ash ejections, occasional explosions; 16:00 p.m. - explosion and a pyroclastic flow 3 km long; 16:12 p.m. - second pyroclastic flow traveled 4 km; 16:20 p.m. - third, largest pyroclastic flow traveled 5.5 km. Thereafter, small pyroclastic flows were erupted fairly frequently, but were not longer than 2-3 km. By 19:00 p.m. - activity declined."

According to Demyanchuk, at 5:45 a.m. of August 3, there was a strong ash fall. At 7:10 a.m., after the clouds were dispersed, a steaming fissure was seen in the southern part of the dome, at the contact between the recent lava flows and the old portion of the dome. From 4:30 to 11:00 a.m., ash-loaded gas ejections and small red-hot avalanches were observed. At the SSE contact between the last lava flow and the stable portion of the dome, the pyroclastic flows produced a hollow and a new trench (Figure 2). The further activity consisted in the squeezing out of a three-tongued viscous lava flow and the formation of numerous red-hot avalanches at the front of the moving lava.

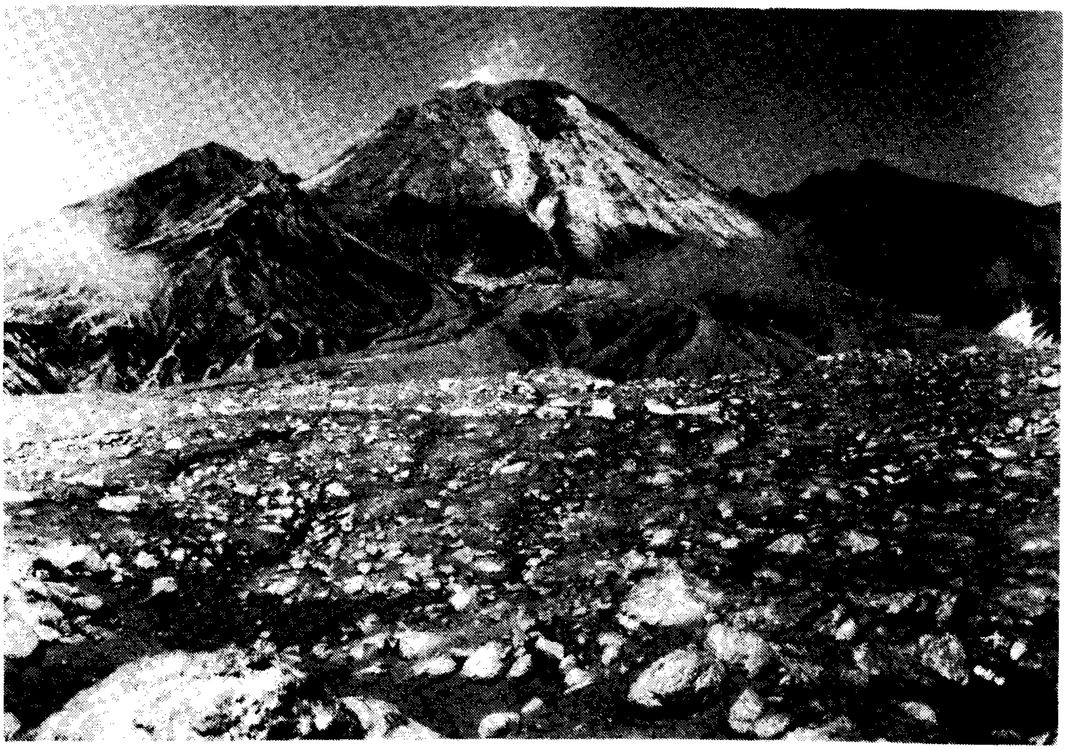


Figure 2 Novyi dome on Bezymyannyi, August 2, 1989. Photo by O. A. Girina.

On August 8, 1989, we examined the pyroclastic material, deposited as a result of the August 2 eruption in a narrow canyon along the southern side of the Valley of Flows, at a distance of 5.5 km from the vent. The area of the deposit was 0.45 m^2, the thickness, not more than 3-4 m, and the width of the front, 150 m.

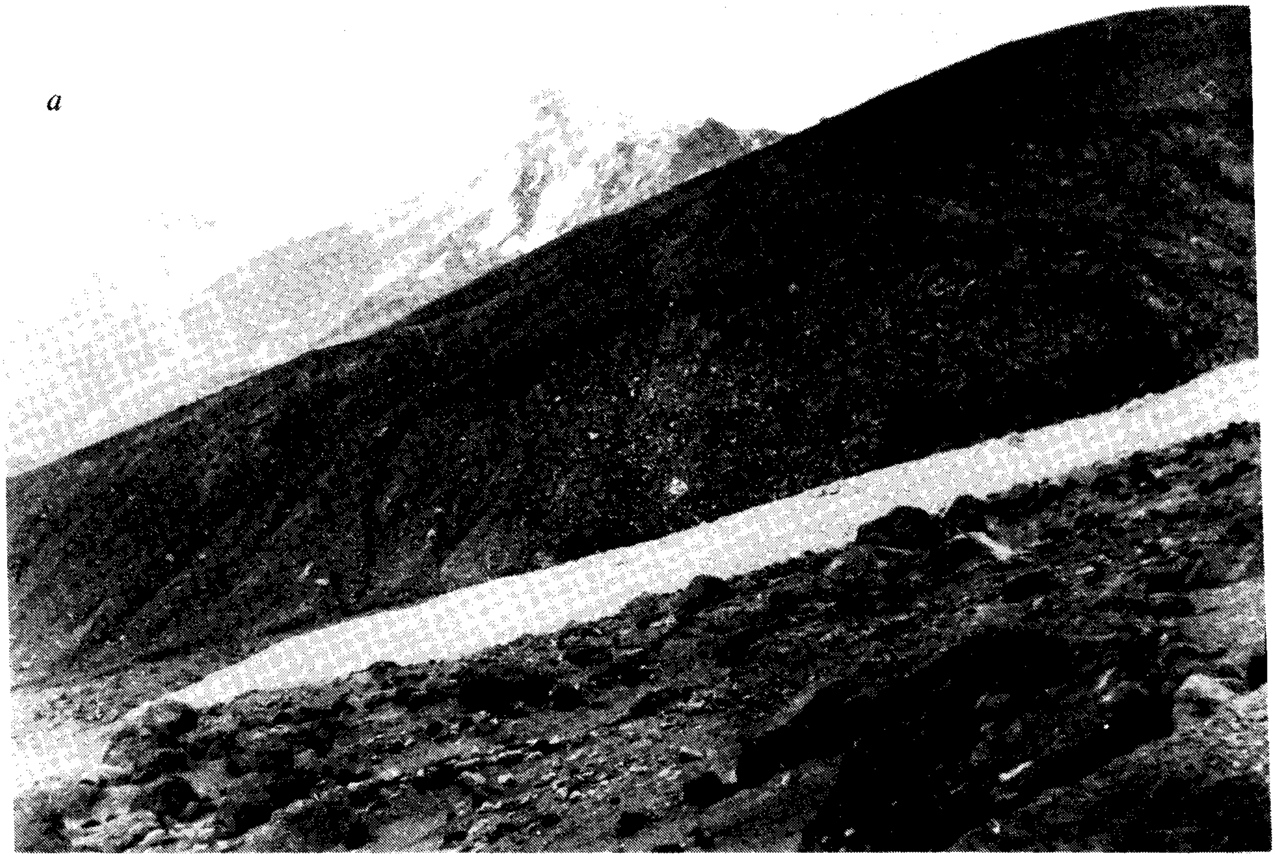
The ash of the clouds above the pyroclastic flows was deposited largely in the NNE part of the Valley of Flows; it had a thickness of 1-2 cm.

Taking the average thickness of the pyroclastic deposits to be ~ 2 m, the volume can be roughly estimated at 1×10^{-3} km^3.

Three portions could be easily distinguished in the pyroclastic flow, the front of each overlapping the previous portion. The heights of the frontal ridges were 2.6 m in the first portion (Figure 3, *b*), 1.5 m in the second, and 0.5 m in the third. Where the flow traveled acrose a creek, a small marginal ridge was formed.

The pyroclastic deposits were composed of abundant fragments of andesite lavas, ranging from very light (whitish) to black, varying in density and porosity, and immersed in a sand-ash filling material. In the place of issue, the flow was dominated by large hot blocks, 3 to 5 m across. The first pyroclastic portion contained a large number of blocks of 1-2 m size, much larger than in the subsequent portions, and about 40-50 percent of the filling material. In the middle of the deposit, there was a large number of fragments, 30-40 cm across, many of them being light-colored and dense; the filling material amounted to 50-60 percent.

a



b

Figure 3 Pyroclastic flow during Bezymyannyi eruption of August 2, 1989: *a* - front of the flow, *b* - view of one of its elements. Photo by O. A. Girina.

By the proportion of the large fragments and the filling material, the presence of marginal and frontal ridges, and other features, the 1989 pyroclastic flow can be classified, according to [10], as a block-and-ash flow. In contrast to the Besymyannyi eruptions of 1984-1986, this pyroclastic flow did not contain recognizable pyroclastic surge deposits.

The SiO_2 content of the andesite lava fragments averages 58.07 wt.% (four analyses) and that of the filling material 57.25 wt.% (three analyses). The ash of the clouds above the flows and the tephra are more silicic because of the eolian differentiation of the tephra and the layering differentiation of the pyroclastic material, as it moved down the slope (Table 1) [3], [4], [5], [6], [8], [10]. Generally, the 1989 eruptions are andesites, obviously typical for dating the Besymyannyi eruptions [2].

By the grain size, the filling material of the largest portion of the flow is a medium-grained sand, that of the other portions, a fine-grained sand, and the ash of the cloud above the flow, dust-size sand (Table 2). These grain sizes are typical of the latest Bezymyannyi eruptions [4].

The density of the naturally deposited flow does not vary much: 0.5 to 1.59 g/cm^3 (seven measurements).

The temperature measurements, carried out 6 days after the eruption, indicated a fairly rapid cooling, which was facilitated by the deposition of the flow in a creek channel. The highest temperature was 105°C at a depth of 25.5 cm of the first portion, 140°C at 25 cm of the second portion, and 80°C at 32 cm of the third. Near the large blocks, temperature was not higher than 200°C at a depth of 6-7 cm. Eight or nine days after the eruptions, the pyroclastic flow was almost completely washed away by a heavy storm rain.

DISCUSSION OF RESULTS

The chemical composition of the filling material of a pyroclastic flow is known to represent best of all the bulk chemistry of the erupted products [4]. The bulk chemical composition of pyroclastic deposits provides information of the proportion of the resurgent and the juvenile material. The grain size and other properties of the filling materials enable one to distinguish between various types of flows. For example, juvenile pyroclastic flows of vesicular andesite contain a larger amount of fine-grained material ($<$ 0.056 mm) than do block-and-ash flows [2].

The chemical compositions of the filling material of the pyroclastic flows and of the fresh andesite lavas of the 1989 eruption of Besymyannyi are nearly identical, except that the filling material is higher in Fe_2O_3 (see Table 1). The filling material of the flow as a whole seems to contain slightly more resurgent than fresh juvenile material. A comparison of the 1989 pyroclastics with the pyroclastic material deposited by the eruptions of June 30 to July 1 and of July 30,

Table 1 Chemical composition of materials erupted at Bezymyannyi on August 2, 1989.

Oxide	*Andesite lava*			
	G30	*G33*	*G32*	*G37*
SiO_2	58.34	58.12	56.80	59.04
TiO_2	0.30	0.80	0.73	0.30
Al_2O_3	16.76	18.82	19.00	17.56
Fe_2O_3	2.76	2.39	2.62	2.79
FeO	4.84	4.26	4.52	4.75
MnO	0.15	0.11	0.11	0.18
MgO	4.12	3.18	3.68	3.82
CaO	6.92	7.12	7.28	6.70
Na_2O	3.50	3.13	3.07	3.52
K_2O	1.30	1.26	1.20	1.30
H_2O^-	0.28	n.f.	0.06	n.f.
H_2O^+	0.41			0.28
LOI		0.72	0.27	
P_2O_5	0.18	0.16	0.16	0.17
Total	99.86	100.07	99.50	100.41

Note. G30 to G29 - sample numbers: G30, G33, and G32 - gray, well crystallized, dense andesite from hot blocks 1 km from the vent; G37 - fresh gray andesite 100 m from the lava flow front; G12, G15, and G17 - filling material in 1st, 2nd and 3d portions of the pyroclastic flow, respectively; G20 - 5 km from the vent; G23 - 3.5 km from the vent; G29 - from the saddle between Bezymyannyi and Kamen (courtesy of O. C. Chubarova). Analyses were performed at the Institute of Volcanology. Analysts N. A. Soloviev and A. M. Okrugina.

1985 [1], [2] revealed their obvious identity. The chemical composition of the pyroclastic flow, 1.5 km long, deposited in the canyon of the Novyi dome on July 30, 1985, is the following, wt.%: 54.82 SiO_2, 0.82 TiO_2, 18.48 Al_2O_3, 4.62 Fe_2O_3, 3.29 FeO, 0.09 MnO, 4.01 MgO, 8.0 CaO, 3.09 Na_2O_3, 1.14 K_2O, 0.17 H_2O^+, H_2O^- not determined, 0.25 H_2O_5, total 99.65 (analyst N. R. Gusakova, Institute of Volcanology). This flow was formed as a result of a partial collapse of the dome near the southern side of its erosion trench [1]. Here, too, the pyroclastic material is slightly oxidized, and the resurgent material is likely to prevail over the juvenile. The deposits of the block-and-ash pyroclastic flow, produced during the eruption of June 30 to July 1, 1985, also contain more resurgent than juvenile material, because this flow was formed as a result of a series of collapses of old blocks from the eastern sector of the Novyi dome [2]. The compared flow of 1989 and two flows of 1985 are virtually identical or very close in grain size (see Tables

Pyroclastic flow fill			Ash from cloud above flow		Tephra
G12	*G15*	*G17*	*G20*	*G23*	*G29*
55.74	58.58	57.43	61.14	61.32	62.20
0.31	0.29	0.28	0.23	0.23	0.78
19.23	17.57	17.54	17.56	18.06	17.60
5.58	6.33	6.32	4.90	2.69	3.11
2.30	1.47	2.02	0.43	2.02	1.81
0.11	0.15	0.16	0.15	0.10	0.09
3.82	3.46	3.61	2.08	2.61	2.32
7.26	6.74	7.63	6.46	6.36	6.44
3.52	3.52	3.60	3.82	3.74	3.50
1.29	1.30	1.30	1.66	1.87	1.68
0.06	n.f.	n.f.	0.16	0.03	0.07
0.24	0.47	0.30	1.00		
				0.39	0.51
0.18	0.18	0.18	0.17	0.13	0.17
99.64	100.06	100.37	99.76	99.57	100.28

2 and 3).

The above evidence justifies the conclusion that apart from the eruption of juvenile products, a considerable contribution to the formation of the 1989 pyroclastic flows was made by the desintegration of the frontal parts of the 1987-1988 lava flows and of the lava flow erupted in 1989. Cooling cracks in the 1987-1988 lava flow favored the instability of the lava blocks. Extensive fumarolic activity in the repose periods and explosive activity during the eruption, which lasted almost three hours, as well as the extrusion of new lava, resulted in the desintegration of the lava flow fronts. The material of the block-and-ash pyroclastic flow was formed as a result of the mixing of the juvenile material and the debris of the 1987-1988 and 1989 lava flow fronts.

Table 2 Grain size of pyroclastic material deposited during Bezymyannyi eruption of

	Sample number	Particle size		
		<0.056	0.056-0.071	0.071-0.125
1	G12	7	3	10
2	G15	11	4	13
3	G17	13	4	13
4	1985(13)	3	2	12
5	G2BK	8	3	11
6	G14	50	8	16
7	G23	68	7	13

Note. 1, 2, 3 - filling material of the 1989 pyroclastic flow: 1 - 1st portion, 2 - 2nd portion, 3 - 3d portion; 4 - filling material from the block-and-ash pyroclastic flow produced during the eruption of June 30 - July 1, 1985, average of 13 analyses; 5 - filling material from the July 30, 1985, pyroclastic flow; 6 and 7 - ash from the cloud above the 1989 pyroclastic flow at a distance of: 6 - 5 km, 7 - 3.5 km from the vent.

Table 3 Grain size characteristics of the pyroclastics deposited on Bezymyannyi during

	Sample number	Median diameter	Average size
1	G12	0.27	0.40
2	G15	0.23	0.33
3	G17	0.22	0.33
4	1989(3) av.	0.24	0.35
5	1985(13) av.	0.27	0.39
6	G14	0.056	0.09
7	G23	0.033	0.05

Note. 1, 2, 3 - filling material in three portions of the 1989 pyroclastic flow; 4 - average for 1989; 5 - average for the 1985 block-and-ash flow; 6, 7 - ash from cloud above the 1989 pyroclastic flow.

DISTINCTIVE FEATURES OF THE 1989 ERUPTION

1. Lava began to flow in the course (in the middle) of a powerful blast.
2. Pyroclastic flows originated simultaneously with the lava flow.
3. Pyroclastic flows were formed slightly below the summit in the SSE sector at the contact between the 1987-1988 lava flow and the stable portion of the dome.

August 2, 1989 and 1985.

fraction, mm			
0.125-0.25	0.25-0.5	0.5-1.0	1.0-2.0
27	24	18	11
25	22	17	8
24	21	17	8
30	24	19	10
26	23	19	10
15	6	3	2
8	3	1	-

the eruptions of August 2, 1989 and 1985.

Sorting coefficient	*Standard*	*Skew*	*Excess*
0.36	0.38	0.60	1.13
0.31	0.34	0.58	1.23
0.32	0.34	0.60	1.21
0.33	0.35	0.59	1.19
0.32	0.34	0.60	1.20
0.08	0.11	0.75	1.99
0.01	0.05	0.68	1.75

A new trench was produced on the dome by them.

4. The material of the block-and-ash pyroclastic flow was formed as a result of the mixing of the juvenile material and the products of desintegration of the 1987-1988 lava flow fronts.

5. Pyroclastic surge deposits, common for the previous eruptions, were not found.

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