Volc. Seis., 1990, Vol.10(6) pp.839–863
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Printed in the United Kingdom

THE 1985 ERUPTION OF BEZYMYANNYI

M. A. ALIDIBIROV, G. E. BOGOYAVLENSKAYA, I. T. KIRSANOV, P. P. FIRSTOV, O. A. GIRINA, A. B. BELOUSOV, E. Yu. ZHDANOVA, and A. I. MALYSHEV

Institute of Volcanology, Far East Division, USSR Academy of Sciences, Petropavlovsk-Kamchatskii

(Received December 22, 1987)

The 1985 eruption of Bezymyannyi has been the largest event since the 1956 catastrophic eruption. A directed blast destroyed part of the volcanic dome and deposited specific pyroclastic material. A series of pyroclastic flows moved downslope. The products of eruption have been examined in detail and classified into several genetic types. Although the eruption of 1985 was much weaker than that of 1956, it resembled the latter in activity.

INTRODUCTION

Bezymyannyi is one of the most active volcanoes in Kamchatka. The present-day cycle of its eruptive activity commenced with the catastrophic eruption of 1955–56 after which a volcanic dome, called Novyi, began to grow in its crater [3, 4].

The 30-year period of the Bezymyannyi activity can be divided into three decades.

1. The first decade (1955-1965) was characterized by a nearly continuous squeezing and elevation of rigid older lava blocks by the pressure of the new lava rising from below. This process was accompanied by occasional strong explosive eruptions. The explosions of 1962 and 1965 produced some 0.015 km^3 of pyroclastic material.

2. The activity during the second decade (1965-1976) consisted in the intrusion of small portions of plastic lava along fissures and zones of weakness in the volcanic dome in the form of dikes and in the elevation of some older lava portions. No strong explosions occurred and the volume of pyroclastic material was not more than 0.005 km^3 [5].

3. The last decade (1977-1987) was marked by intensification of volcanic activity. Eruptions occurred almost every year and were distinguished by short, often strong, explosive episodes. Avalanches of the previously elevated lava blocks became more frequent and viscous lava was extruded to form lava flows, some of which continued to flow for as long as a year.

Nearly every eruption began with explosions and the squeezing of andesite blocks from the upper, active part of the volcanic dome. During the active stage, explosions were more violent and produced pyroclastic flows 6 to 8 km long and 0.006 to 0.02 km^3 in volume. Each paroxysmal stage lasted from a few hours to two or three days. The pyroclastic flows "plowed" channels on the slopes and by 1980 a deep trench (max. depth 50 m) was formed at the base of the volcano. Commonly, the eruptions terminated with lava outpouring and the formation of lava flows ranging between 300 and 500 m in length. In 1981 and at the beginning of 1982, lava was erupted intermittently during a period of more than a year and covered the eastern and northeastern slopes of the volcanic dome.

Eruptive activity was most intensive in 1984 and 1985. In the fall of 1984 violent explosions destroyed the upper part of the volcanic dome and produced a pyroclastic flow 8 km long [7]. The volume of the erupted pyroclastic material was estimated at about 0.02 km^3. The eruption ended with the outpouring of a lava flow.

Thus, the eruptive period of the present activity of Bezymyannyi offered outstanding possibilities to the volcanologists for the study of a devastating directed blast in 1956 and enabled them to observe for 30 years the growth of an extrusive dome in the crater and the periodic eruptions of different types and intensity. Of particular interest was the 1985 eruption which provided a wealth of new data.

The eruption was surveyed by a group of researchers from the Institute of Volcanology within the framework of the program "Bezymyannyi-85" under the supervision of S.A. Fedotov. Below follows the description of the eruption based on field observations, the examination of the fresh ejecta immediately after it was deposited, and on the correlation of the visual observations with the acoustic and seismic signals recorded at the seismograph station "Apakhonchich" [8].

VOLCANIC ACTIVITY DURING THE 1985 ERUPTION

The 1985 eruption of Bezymyannyi was not an ordinary event in many respects. It was distinguished by a partial collapse and destruction of the volcanic dome, a directed blast, a series of long pyroclastic flows, deposition of pyroclastic waves, an unusual composition of volcanic gases [6], and other specific features.

The eruptive activity can be subdivided into three conventional stages.

Preculmination stage. The 1985 eruption was preceded by lower seismicity as compared to the eruption in the fall of 1984. The first indications of the eruption were noticed on June 12, when portions of older lava began to be squeezed out from the summit of the volcanic dome and collapsed. A sketch showing the development of the summit collapse is given in Figure 1.

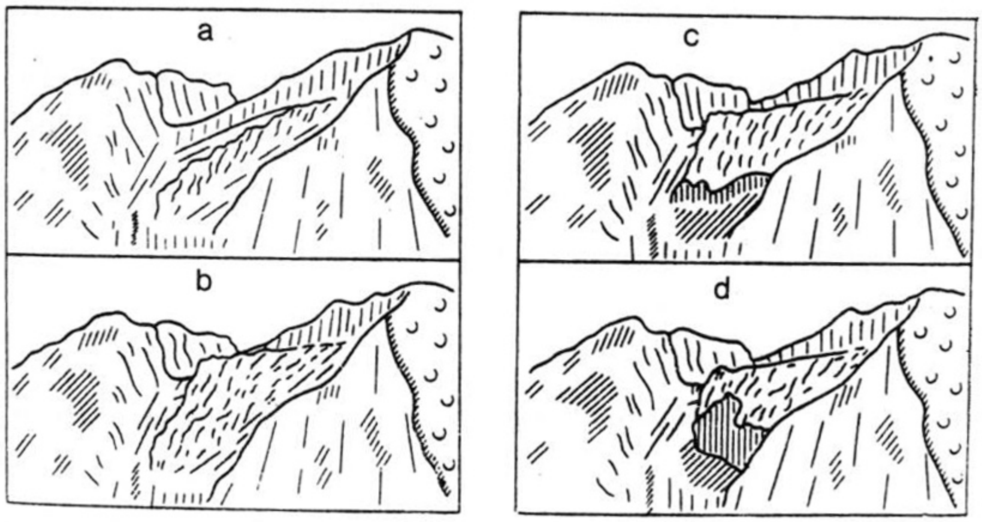


Fig. 1. Sketches showing lava extrusion in Novyi dome: a - June 15; b - June 22; c - June 24; d - June 25. Drawing by A.I. Malyshev.

The process of squeezing was nonuniform: the strongest activity was observed on June 18 and 24-25. By the end of June, the squeezed-out block rose 100 m above its base (Figure 2). On June 29 the first small pyroclastic flows, about 5 km long, were produced.

Culmination stage bagan on June 30 and ended on July 1. The activity was observed from a camp specially installed near Zimin Volcano, 8.5 km from the Novyi volcanic dome, by M.A. Alidibirov, A.I. Malyshev, and P.P. Firstov and from the seismograph station "Apakhonchich" by E.Yu. Zhdanova. Regrettably, the conditions were unfavorable for visual observation, because most of the time the summit was obscured by clouds and the eruption occurred at night.

The initial activity began at 5:15 p.m. on June 30 with a noise and at 6:30 p.m. a terrific roar was heard. At 8:00 p.m. radio communication was jammed, probably by electric discharges. At 8:20

p.m. pyroclastic flows appeared and flowed for half an hour. Red-hot pyroclastic material filled the channels of two creeks to a distance of 10 km (Figure 3). The interaction of the hot ejecta with water caused intense phreatic activity. Electric discharges grew in number during the eruption of pyroclastic flows. Discharges of 200-400 m were observed in the frontal portion of the ash cloud from the camp at a distance of 8.5 km. The thunderstorm activity remained high until 11:00 p.m. and the number of visible discharges and noise effects decreased notably by 1:00 a.m. on July 1.

The pyroclastic flows reaching a maximum length of 8 km were observed at 10:40, 11:05 and 11:50 p.m. on June 30 and at 0:25 a.m. on July 1. At 1:15 a.m. on July 1 a noise and rock avalanche thunder resumed and at 1:35 a.m. a pyroclastic flow was erupted which was followed at 2:08 a.m. by another flow. At 2:20 a.m. a noise resembling the noise of a jet engine was heard. It was intermittently accompanied by a thunder roar. The noise was low-frequency and variable in intensity. At 2:50 a.m. the noise had a maximum intensity during 30-40 s periods, at 3:00 a.m. the period of noise intensity variation was 35-40 s, and at 3:17 a.m. a strong uniform noise was heard for about 140 s. The time interval between 2:00 and 3:00 a.m. was probably the time when a NE directed blast occurred after a rockslide avalanche unroofed the hydrothermal system of the Novyi dome and triggered the blast. The blast demolished two observation cabins located at a distance of 3.5 km from the volcanic dome (Figure 4).

At 3:20 a.m. a wide-front, glowing pyroclastic flow rolled downslope and travelled a distance of 12.3 km from the crater. The temperature of the pyroclastic material must have been 600-700°C. At that time lightnings were almost incessant. Later, the thunderstorm activity subdued and ceased by 6:00 a.m. In the morning, the area covered by pyroclastic deposits was steaming intensely and phreatic explosions were almost incessant.

Fig. 2. Novyi dome of June 2, 1985: a - general view of the active zone.

Fig. 2. b - hanging block in the summit of the dome. Photo by A.B. Belousov.

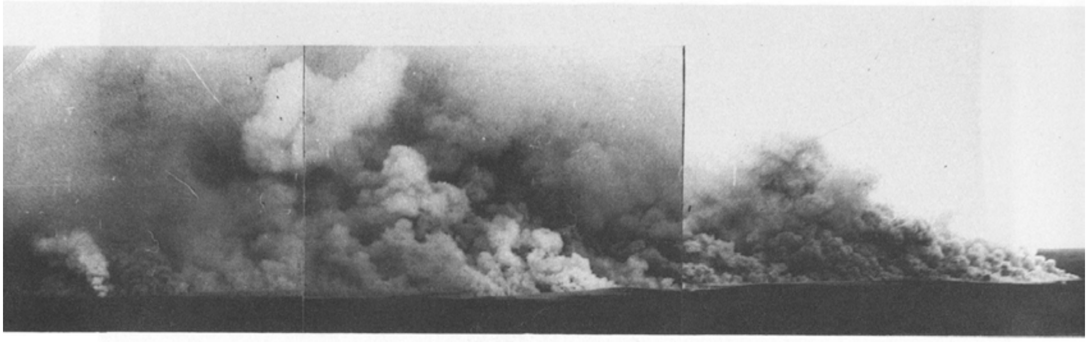


Fig. 3. The frontal part of a moving pyroclastic flow (June 30, 1985, 8:20 p.m.). Photo by P.P. Firstov.

To conclude, the culmination stage of the eruptive activity began on June 30 (20 hours after the outbreak) with a series of pyroclastic flows which were probably responsible for the first rockslides from the eastern slope of the volcanic dome. The debris of the old lava mixed with the juvenile pyroclastics to form a block-ash flow.

Fig. 4. Remnants of observation cabins destroyed by a directed blast. Photo by P.P. Firstov.

After a short period of inactivity, at 1:15 a.m. on July 1, a noise and avalanche thunder intensified and the next series of pyroclastic ejections took place to form block-ash and juvenile pyroclastic flows.

Postculmination stage was marked by an abrupt decrease in activity. During the morning of July 2 a 4-km pyroclastic flow was erupted and lava began to outpour. The glow of the lava flow was seen during the night on July 2.

In early July, the process of lava extrusion was localized in the upper part of the trench which had been deepened and broadened during the culmination stage. Red-hot lava cascades developed at the lava front and at the eastern blocks of the dome. By July 14, a bulge appeared in the basin which was formed as a result of the collapse and directed blast. This elevation divided the lava flow into the upper and lower portions.

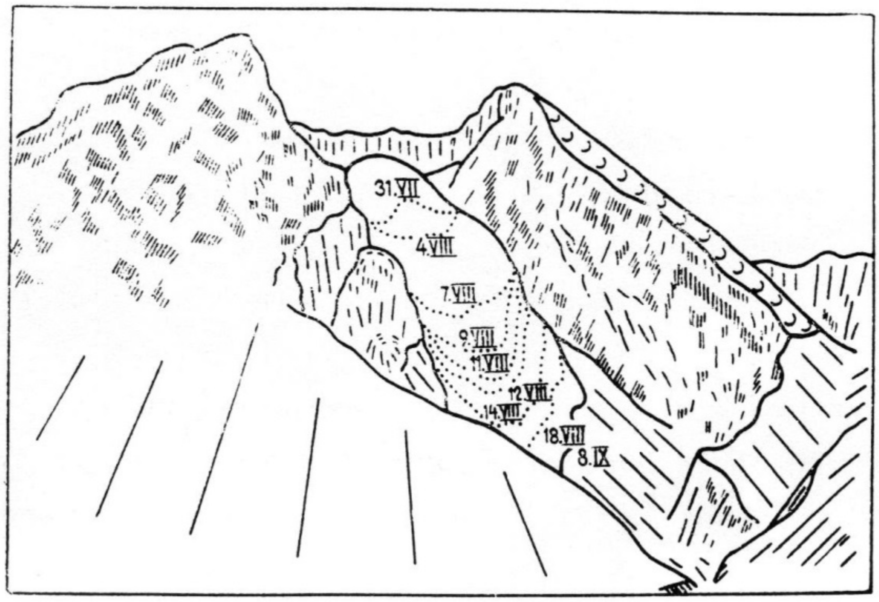


Fig. 5. Sketch showing movement of lava front from June 31 to September 8, 1985. Drawing by A.I. Malyshev.

On July 30 a new volcanic dome began to grow in the place of the bulge. Its growth was accompanied by lava avalanches, red glare at night, and increased seismic activity. During the period that followed lava was slowly outpouring to form a lava flow. Figure 5 shows the successive positions the lava front occupied as the flow moved during a period of July 31 to September 8. In mid-September the lava flow came to a halt. By that time lava filled the floor of the basin.

Then followed a month of inactivity after which the volcano became active again on October 15. A series of rockslide avalanches unroofed the vent and a new lava flow was erupted. It filled the basin almost wholly and ceased to flow on December 14. On December 20 the flow was covered with snow.

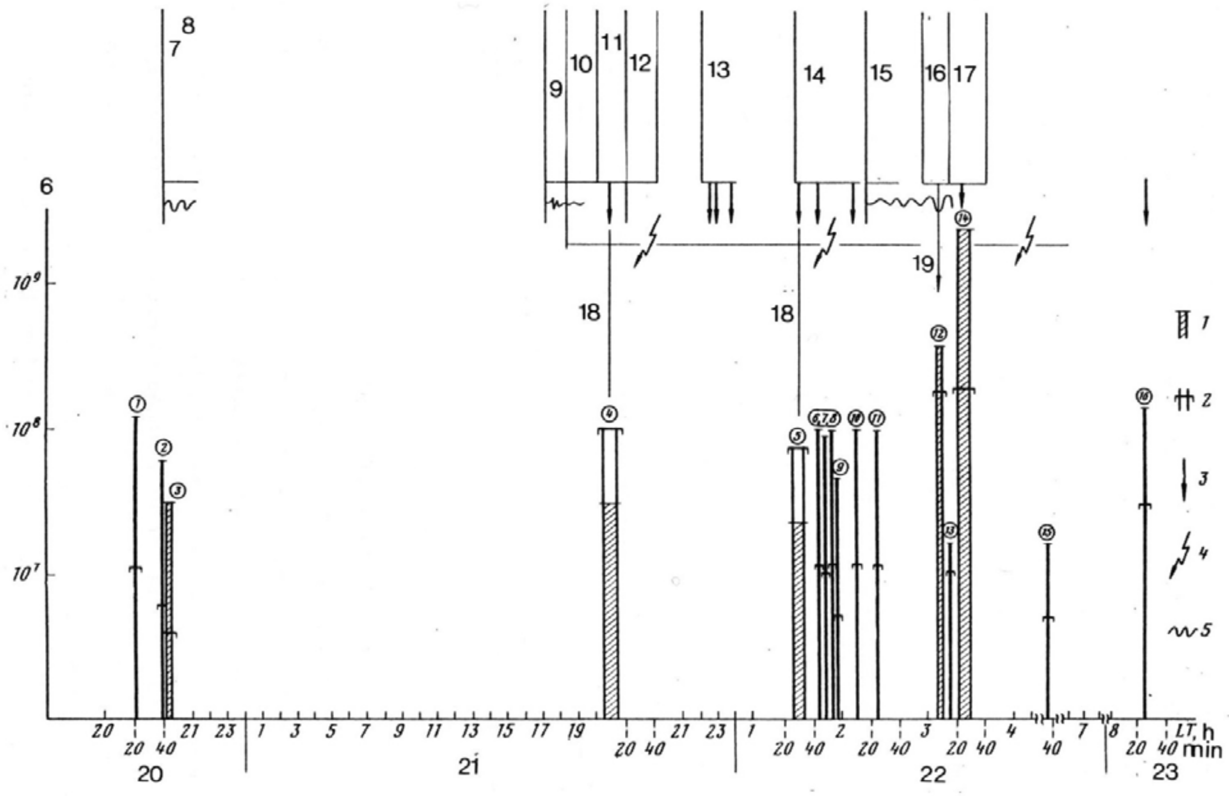
ACOUSTIC AND SEISMIC EVENTS RECORDED FROM JUNE 29 TO JULY 1

The seismic and acoustic events which accompanied the culmination stage of the Bezymyannyi activity were recorded at the seismograph station "Apakhonchich" located at a distance of 16 km from the volcano [8].

Infrasonic events (0.4-2 Hz) having a maximum duration of several minutes were distinguished among the acoustic signals. They coincided in time with a continuous seismic signal (volcanic tremor). Besides, short-duration acoustic pulses were recorded each time explosion earthquakes took place.

The acoustic and seismic records were correlated with the visual observations to reconstruct the eruption dynamics. The results of correlation are summarized in Figure 6 where the acoustic and seismic signals are identified with the eruptions of pyroclastic flows. Arrows indicate the pyroclastic flows that were observed visually. Based on the analysis of the acoustic records, 16 pyroclastic flows were identified. The most powerful sources of acoustic energy were flow 12 ($W = 3.6\times10^8$ W) and flow 14 ($W = 2.3\times10^9$ W). The seismic energy produced by flow 14 was 1.8×10^8 W.

The acoustic signal generated by flow 12 has a form which differs markedly from the other signals. It has the maximum amplitude 40 s after the arrival of a group of seismic waves, the pattern similar to



6
10^9
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13
14
15
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Fig. 6. Energy of acoustic and seismic sources: 1 - acoustic source; 2 - seismic source; 3 - visual observation of pyroclastic flows (PF); 4 - thunderstorm; 5 - noise. Prepared by P.P. Firstov. 6 - W,W; 7 - continuous noise; 8 - PF discovered in the morning; 9 - noise and roar; 10 - thunder; 11 - generation of 10-km PF; 12 - strong discharges; 13 - small PF's; 14 - PF generation; 15 - continuous noise; 16 - strong jet-engine sound; 17 - juvenile PF of cherry-red color, T = 700-800°C; 18 - block-ash flow; 19 - directed blast; 20 - June 29; 21 - June 30; 22 - July 1; 23 - July 2.

that of an explosion earthquake. This indicates that this signal was caused by explosion. It seems reasonable to assume that it was produced by the directed blast. It should be noted that for most of the events the acoustic sources were more powerful than the seismic sources, except for the signals of flows 4 and 5. The power of an acoustic source depends on the amount of heat given off by the flow which is controlled by the temperature, area, gas content, and type of the pyroclastic material. The simplest explanation of a lower amount of heat emitted by flows 4 and 5 is that they consisted of a block-ash material.

TYPES OF DEPOSITS PRODUCED BY 1985 ERUPTION

The types of the pyroclastic deposits were identified using the genetic classification offered by Fisher and Schmincke [9] and the terminology suggested by Wright et al [10] and by Bogoyavlenskaya and Braitseva [2].

The detailed examination of the products of the 1985 eruption of Bezymyannyi resulted in the identification of the following types of pyroclastic deposits: (1) block-ash flows; (2) juvenile vesicular-andesite pyroclastic flows; (3) directed-blast deposits; (4) pyroclastic waves; and (5) ash deposited by ash clouds of pyroclastic flows.

Deposits of block-ash flows are typical of the Bezymyannyi eruptions that were associated with the growth of the Novyi volcanic dome. Intrusion of rigid extrusive blocks usually involves the partial destruction of a volcanic dome by explosions and the formation of small pyroclastic flows.

During the culmination stage of the 1985 eruption a large block of the eastern flank of the Novyi dome was destroyed as a result of successive collapses and rockslides. The debris thus produced mixed with the juvenile pyroclastics and were deposited as a block-ash flow in a narrow sector of the eastern base of the volcano at a distance of 7 or 8 km from the volcanic dome (Figure 7, a). The flow had a maximum thickness of 8 m at the southern margin and a minimum of 0.5 m at the northern margin. It amounted to 4 km^2 in area and about 0.02 km^3 in volume.

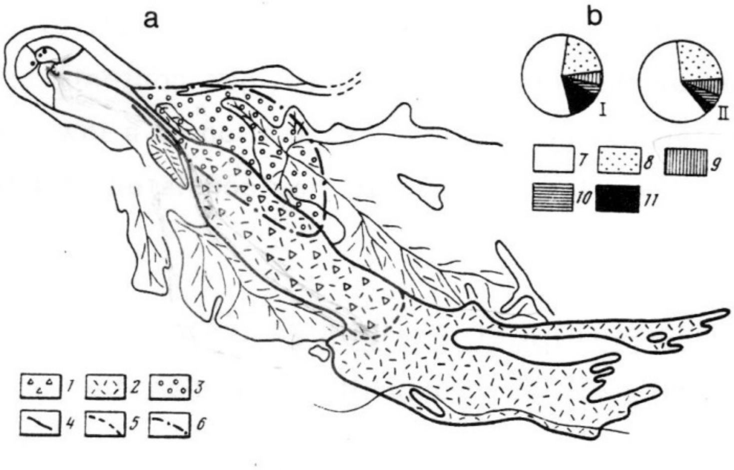

Fig. 7. Sketch map of pyroclastic deposits erupted in 1985: (a) 1 - block-ash flow; 2 - juvenile andesitic pyroclastic flow; 3 - directed-blast deposits; 4, 5, 6 - boundaries of juvenile, block-ash and directed-blast deposits, respectively. (b) Amount of rock fragments in block-ash (I) and juvenile (II) flows. Size of fragments, m: 7 - 0.05 to 0.29; 8 - 0.3 to 0.5; 9 - 0.51 to 0.7; 10 - 0.71 to 1; 11 - 1 to 3. Prepared by O.A. Girina.

A characteristic feature of the block-ash deposits is the abundance of coarse material. Along with a chaotic distribution of fragments, a feature common to pyroclastic flows, coarse fragments tended to be concentrated in the middle part of the flow. Most of the fragments were of the dense older lava of the dome and some of vesicular juvenile material. There were also some blocks of a poorly lithified material deposited by pyroclastic flows during some of the earlier eruptions; they had been probably excavated during the trench formation.

To sum up, the flow material consists of large blocks ranging between 5 and 0.5 m in size (8-10% of the flow volume), 0.49-0.05 m fragments (35-45%), and gravelly volcanic ash (45-55%). The predominant size of fragments is 0.3 to 0.5 m (20%), the size over 1 m ranking second (10-12%).

*The juvenile andesitic pyroclastic flows** descended down the eastern slope of the volcano, travelled for a distance of 12.3 km, and merged to form one flow with two tongues (Figure 7, a). The northern tongue has a length of 12.3 km and the southern 11.6 km. These flows rolled over the deposits of the block-ash flows and covered them as a 1.5-2 m layer. They have a maximum thickness of 5-5.5 m in the depressed areas 7 or 8 km from the volcanic dome. The maximum width of the final flow is 1.7 km. The deposits become thinner toward the margins and are fringed with the sandy deposits of the pyroclastic waves at the front. The deposits of the juvenile ejecta cover an area of 10.5 km^2, average 2.5 m in thickness, and amount to about 0.026 km^3 in volume.

This type of pyroclastic flow is typically distinguished by a high content of gravel and volcanic ash (60-70%) which fill the space

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*The term "juvenile" is used here to discriminate between the previous and this type of pyroclastic flows and to emphasize that the material was derived from magma.

between 5-0.5 m blocks (5-7%) and fragments ranging between 0.49 and 0.05 m in size (25-30%). The fragments are subrounded and consist of juvenile vesicular andesite (60%) and of the dense older lava of the dome (40%). The predominant size is 0.3-0.5 m (Figure 7, b).

At the time the deposits were examined many of the large blocks had a surface temperature of 20 to 70°C and the temperature inside them was 200-300°C and more. A foam material was seen to fill large cracks in some blocks.

Distinctive features of these deposits are a high gas content and low density (20 measurements gave a density of 1.49-1.88 g/cm^3). According to V.Yu. Kir'yanov, the mineral composition of the 0.1-0.063 mm ash is 34% volcanic glass, 46% plagioclase, 8% dark-colored minerals, 8% pyroxene, and 4% rock fragments. The median diameters of the ash particles are within 0.23-0.3 mm (Figure 8, d).

So, the reasons why we identified these deposits as a special type of the pyroclastic flows were the abundance of juvenile andesite blocks with a temperature of more than 300°C, a high gas content which manifested itself in a high mobility of the hot ejecta which was deposited at a distance of 12.3 km (2 or 3 weeks after the eruption its temperature was over 300°C and a thickness 2 or 3 m), and a specific juvenile composition of the volcanic gases [6].]

The directed-blast deposits extend as far as 5-6 km from the volcanic dome (Figure 7, a). They vary in thickness from 1.5-2 m at the base of the volcano to fractions of a centimeter in the marginal parts. They cover an area of about 7 km^2 and measure about 0.001 km^3 in volume. They occur as SE-oriented flat-topped hills less than 2 m in height at the base of the volcano and as a thinning mantle away from it.

In the vicinity of the volcano the directed-blast deposits consist of coarse unstratified gravel and sand material containing large fragments (up to 15 cm) of andesite. At a distance of 3-4 km outward they become stratified (concordant or occasionally, inclined bedding) and more fine-grained. They consist of medium- to fine-grained sand with a median diameter of 0.16-0.35 mm (Figure 8, d).

TABLE I

Chemical Composition of Pyroclastics, %, 1985 Bezymyanni Eruption

Oxides	Andesite fragments (n = 20)	Matrix (n = 5)	Directed-blast sand (n = 7)	Ash (n = 5)
SiO_2	58,70—54,20 (56,54)	57,14—54,82 (56,09)	57,24—55,20 (56,24)	61,60—60,52 (60,86)
TiO_2	0,92—0,69 (0,81)	0,83—0,75 (0,79)	0,88—0,66 (0,68)	0,78—0,65 (0,71)
Al_2O_3	18,53—17,06 (18,10)	18,62—18,45 (18,48)	18,04—17,65 (17,95)	18,00—17,13 (17,76)
FeO	4,51—1,99 (3,02)	4,62—3,34 (3,94)	5,45—3,31 (4,05)	3,56—2,82 (3,28)
Fe_2O_3	5,97—2,87 (4,51)	4,28—3,10 (3,40)	4,25—3,25 (3,70)	2,84—2,28 (2,59)
MnO	0,12—0,08 (0,10)	0,12—0,06 (0,10)	0,14—0,08 (0,11)	0,11—0,09 (0,10)
MgO	5,97—3,04 (3,98)	4,92—3,40 (4,08)	4,62—3,84 (4,20)	3,80—3,00 (3,56)
CaO	8,46—6,97 (7,67)	8,00—7,74 (7,83)	7,93—7,36 (7,52)	6,37—5,39 (5,70)
Na_2O	3,50—2,89 (3,22)	3,31—3,07 (3,22)	3,38—2,75 (3,11)	3,68—3,17 (3,33)
K_2O	1,38—1,00 (1,24)	1,27—1,00 (1,18)	1,36—1,05 (1,23)	1,66—1,47 (1,55)
H_2O^+	0,58—0,13 (0,25)	0,30—0,24 (0,26)	0,23—0,17 (0,20)	0,15—0,15 (0,15)
H_2O^-	0,50—0,05 (0,21)	0,30—0,03 (0,22)	0,31—0,06 (0,18)	0,36—0,15 (0,30)
P_2O_5	0,52—0,02 (0,28)	0,20—0,00 (0,12)	0,31—0,00 (0,22)	0,59

Note. (n = 20) is the number of analyses; average values are given in parentheses. Analysts, N.R. Gusakov and G.F. Knyazeva, Laboratory of Institute of Volcanology.

TABLE II

Mineral Composition of Andesites, Bezymyannyi, 1985

Andesites	Phenocrysts, %							Ground-mass, %
	Pl-I	Pl-II	Pl-III	Opx	Cpx	Mt	Amf	
Juvenile	21.00	13.30	16.10	10.50	4.90	3.50	0.70	30
	20.46	11.16	11.60	8.06	4.96	3.72	2.4	38
Resurgent	18.85	16.90	9.60	5.85	6.50	5.20	2.60	35
	17.55	14.30	13.65	5.20	5.85	4.55	3.25	32

Note. Juvenile andesite is fresh material erupted in 1985; resurgent andesite is the material of the Novyi dome.

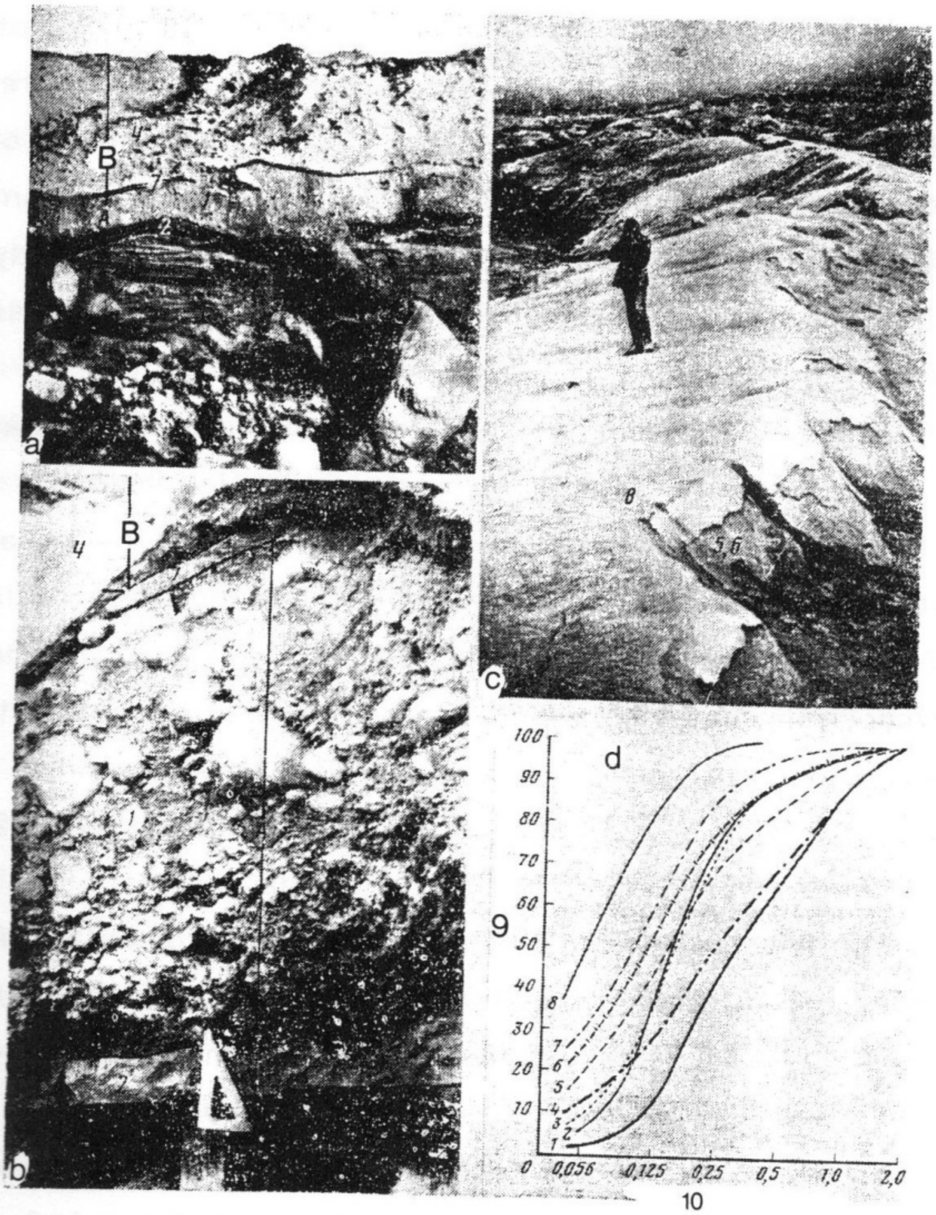

Fig. 8. Pyroclastic deposits produced at Bezymyannyi during the 1985 eruption; a, b - geologic sections at Tundrovyi Creek, 8 km from Novyi dome. Photo by A.I. Malyshev; c - dune-shaped landforms produced by pyroclastic waves, 5.5 km from Novyi dome. Photo by O.A. Girina; d - cumulative curves representing pyroclastic grain-size distribution: 1 - matrix of pyroclastic flow A; 2 - matrix of pyroclastic wave A; 3 - matrix of directed-blast deposits [1]; 4 - matrix of pyroclastic flow B; 5, 6 - matrix of pyroclastic wave deposits; 7 - matrix of pyroclastic wave B; 8 - ash-cloud deposit; 9 - content, %; 10 - grain size, mm. Calculation by O.A. Girina. Figures on photos a and b correspond to figures on cumulative curve.

A closer examination of the deposits [1] revealed a kind of a transition zone at a distance of ~3 km from the volcano, where the directed-blast deposits have a two-layer structure: the lower bed consists of poorly sorted coarse sand containing a large amount of andesite fragments up to 2 cm in size and the upper, of slightly stratified, well-sorted, medium-grained and at the top fine-grained sand with scarce andesite fragments.

Pyroclastic wave deposits associated with the growth of an extrusive dome inside the crater have been identified in the Bezymyannyi area for the first time. Deposits of this type were discovered at the bases, on the surface, and around the pyroclastic flows, as well as beyond their fronts. When we examined the hot, soft juvenile pyroclastic material, which was rapidly washed out by the creeks, we managed to identify two or, in places, three units successively overlying one another in one flow. This was done 2 weeks after the eruption. We found that each unit was underlain by a pyroclastic wave deposit (Figure 8, a and b) which consisted of well-sorted, uniform, fine- or medium-grained sand with a median diameter of 0.1 m or 0.15 m, respectively. Commonly, medium-grained sand was found under the coarse ash and very fine sand under the fine-grained ash (Figure 8). The average mineral composition of the pyroclastic wave deposits (Figure 8, units 2 and 7, 0.1-0.063 mm grain size) is as follows: 16% volcanic glass, 51% plagioclase, 10% dark-colored minerals, 10% pyroxene, and 13% rock fragments (after V.Yu. Kir'yanov).

Outside of the ash flows, deposits of this type occur as isolated lenses, dunes, or spatters on the neighboring hills, or form a kind of dune topography (Figure 8, c). The deposits often exhibit a clear-cut horizontal or inclined bedding and occasionally have a massive appearance. Commonly, they drape the underlying rocks. They consist for the most part of fine- to medium-grained sand ranging between 0.09 and 0.17 mm in median diameter. Lenses of coarser material with fragments up to several centimeters have been encountered. The density of the material is 1.43 to 1.59 g/cm^3 (19 measurements); the thickness of the deposits averages 0.4-0.5 m; the approximate volume is 0.005 km^3. The reasons for identifying this material as pyroclastic waves were the genetic relations of the deposits with the pyroclastic flows, good sorting, draping, and cross bedding.

Products of air-fall deposition from ash clouds accompanying pyroclastic flows covered an extensive area around the volcano and were also recorded at the tops of some units in the pyroclastic deposits.

As pyroclastic material moves downslope, it undergoes a kind of sorting: coarse, heavy material tends to be deposited on the ground surface (pyroclastic flows) and fine, light ash rises above it to form an ash cloud. Air-fall deposition begins some time after pyroclastic flows cease to move. The thickness of ash-cloud deposits depends on the wind direction and differences in the specific gravity of ash particles. In the Bezymyannyi area the thickness of the ash-cloud deposits was 5-6 cm near the dome and 1-1.5 cm on the slopes of the Ziminy cones facing Bezymyannyi in the area of the Plotina extrusive domes. The material consists of silt-size particles with a median diameter of 0.06-0.07 mm near the volcano (Figure 8, c and d). Accretionary lapilli up to 5 mm in diameter were encountered at the base of the deposits.

COMPOSITION OF THE 1985 ERUPTION PRODUCTS

The pyroclastic flows contain blocks and smaller fragments of black, dark- and light-green, dark- and light-gray, hornblende-pyroxene andesites ranging in texture from very dense, glassy to vesicular types.

The andesite blocks and the material filling the space between the fragments in the pyroclastic flows, direct-blast deposits, and pyroclastic waves are similar in SiO_2 content. They vary betwen 54.2

and 58.7% SiO_2 and average 56.1-56.5% SiO_2. The ash-cloud deposits are notably higher in SiO_2: 60.4 to 61.6% and 60.9%, respectively (Table I).

All products of this eruption are normal calc-alkalic rocks typical of all historically dated eruptions of Bezymyannyi.

The andesites are seriate-porphyric rocks. The phenocrysts are plagioclases (Pl), orthopyroxenes (OPx), clinopyroxenes (CPx), magnetites (Mt), rare crystals of hornblende (Amf), and single grains of olivine (Ol). The mineral composition of the andesites is presented in Table II.

Plagioclase. Three plagioclase generations have been identified. The plagioclases of the 1st generation (Pl-I) are 1.5 to 3 mm in size and consist of a uniform core (An 65-70) and several zones. The innermost zone (An 56-60) contains glass and gas bubbles. The next zone exhibits a rhythmic zonal pattern with An varying from 40 to 72. The outer zone is more silicic: An 25-32. The intermediate zone has unveven, resorbed boundaries. The Pl-II phenocrysts are 0.5 to 0.6 mm in size and have cores comparable in composition with the Pl-I second zone and outer zones, with the rims of the pl-I grains. The Pl-III phenocrysts, or rather subphenocrysts, 0.1 or 0.2 mm in size, are compositionally similar to the rims of the Pl-I and Pl-II grains (An 22-47).

Pyroxene. The orthopyroxenes and clinopyroxenes are of two generations. OPxI occurs as elongated prismatic crystals 0.7 to 1.5 mm in size. According to its optical properties, the mineral has been identified as hypersthene (En 52-76). Some grains have a zoned structure with the cores higher in Mg. The grains are overgrown with monoclinic pyroxene and magnetite. OPxII forms small isometric prismatic crystals and tablets 0.1 to 0.3 mm in size (En 68-75). CPxI occurs as clear-cut prismatic crystals and rounded grains, 0.7 to 1.2 mm in size. Some grains have thin margins of magnetite. CPxII occurs as isometric crystals 0.1 to 0.3 mm in diameter, overgrows the hypersthene grains, and replaces hornblende. The CPxI and CPxII crystals have a zonal structure. According to its optical properties, the mineral has been identified as augite.

Magnetite has been found in xenomorphic crystals, 0.3-0.5 mm in size, associated with pyroxenes and also in idiomorphic crystals, where it replaces orthopyroxene, hornblende, and other minerals.

Hornblende. Normal hornblende has been encountered almost in all rock types as 0.8-2.5 mm brown crystals, opacitized to some or other extent. It is often totally or partially replaced by plagioclase, pyroxene and magnetite aggregates. In some cases minute crystals of darker, basaltic hornblende have been observed.

Olivine appears as widely scattered rounded grains, 0.4 or 0.5 mm in size, with orthopyroxene developed along the uneven borders of the grains.

The groundmass is hyalopilitic, occasionally intersertal. Numerous microlites of plagioclase, pyroxene, and magnetite are set in transparent glass. The proportion of the glasses of different color and microlites in the groundmass is given in Table III.

TABLE III

Proportion of Glass and Minerals in Groundmass, %

Groundmass	Glass	Plagioclase	Pyroxene	Magnetite
With brown glass	70	15	10	5
With colorless glass	85	7	5	3

The presence of several generations of rock-forming minerals facilitated the reconstruction of the succession of their crystallization. The cores of plagioclases I, olivines, orthopyroxenes I, hornblendes, and probably magnetites crystallized under the stable conditions of the magmatic source, where the melt and volatiles were at equilibrium until the eruption began. The rhythmically zoned plagioclases and the late pyroxenes and magnetites were formed and the hornblendes were decomposed, when equilibrium was violated as magma was rising toward the surface along the conduit. The rims of the phenocrysts and the microlites were formed during the final stage of crystallization on or near the surface.

CONCLUSION

1. The 1985 eruption of Bezymyannyi lasted from June 12 to December 14. It varied in activity from the extrusion of viscous lava to explosive eruptions and lava outpouring.

2. A distinctive feature of the eruption was a directed blast which destroyed a large portion of the Novyi dome.

3. The products of the eruption were examined in detail to reconstruct the sequence of eruptive events and identify the genetic types of the pyroclastic deopsits. The 1985 eruption of Bezymyannyi differed from the previous eruptions by the formation of extensive juvenile pyroclastic flows (12.5 km). Well-defined pyroclastic waves and ash-cloud deposits were produced.

4. Several generations of the rock-forming minerals record the sequence of mineral crystallization in the magmatic source, on the way of magma to the surface, and under the surface conditions. According to the chemical composition, the products of eruption were identified as calc-alkalic rocks typical of the historic Bezymyannyi eruptions.

5. The 1985 eruption of Bezymyannyi was one of the most impressive and powerful eruptions of the volcano since 1956. Although the eruptions of 1956 and 1985 cannot be compared as to the volume of the erupted material (3 km^3 and 0.05 km^3, respectively), there is a definite similarity between them in eruptive activity.

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