

Directed volcanic blasts.

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During explosive eruptions of certain volcanoes the pyroclastic material is not ejected vertically upwards, but obliquely, sometimes horizontally or nearly horizontally. Eruptions of such a kind can be called directed volcanic blasts. For the first time a similar term « Pelean cloud of directed explosion » (nuée péleenne d'explosion dirigée) has been introduced by Lacroix (1930, p. 459) for the strongest explosions of Mont Pélée volcano on May 8th, May 20th and August 30th of 1902. Each of these explosions has been directed horizontally or obliquely downwards and affected definite sectors at the foot of the volcano causing damages on an area of 60-70 sq. km. independently of its relief. Lacroix made a distinct difference between these explosions and the « glowing clouds of avalanches » (nuées ardentes d'avalanches), which originated during the collapse of certain parts of the growing dome and which followed river valleys under the force of gravity. Similar avalanches can arise in an explosive way during comparatively weak explosions (usually vertical or nearly vertical) on the periphery of domes.

Very often the literature on volcanology uses the term « glowing clouds » (nuées ardentes) for three different phenomena: 1) directed blasts embracing more or less extensive areas and affecting the territory independent of its relief, 2) explosive incandescent avalanches, the route of which is fully determined by relief conditions and the force of gravity, and 3) avalanches caused by collapses. Admittedly, both types of incandescent avalanches (explosive and collapse) are quite close to each other both in the character of movement and in the specific features of deposition, etc. And yet directed blasts sharply differ in the conditions of their expansion, character of deposition and other features from incandescent avalanches of any type.

A traditional unification of these essentially completely different phenomena causes various misunderstandings. The author deals with this subject at greater detail in another paper (GORSHKOV, 1962, I & II).

Under the term « directed blasts » the author understands only laterally directed explosions the air wave of which affects a certain

area and the pyroclastic material of which is spread with a force over this area independent of its relief.

For the first time directed blasts have been studied in 1902 on Mont Pélée volcano (LACROIX, 1904; JAGGAR, 1949, and many others).

The explosion of May 8th, which affected an area of about 60 sq. km in the south-western sector at the foot of the volcano, destroyed Saint Pierre, a town at a distance of 7-8 km from the crater and separated from the volcano by two river valleys. The entire population of the town perished. Ships that have been anchored in Saint Pierre Bay have been badly damaged, some of them had sunk and a considerable part of the crews had lost their lives. The few eye-witnesses who remained alive said that at first a dark cloud of ashes burst out of the crater and in 1-2 minutes reached the town. A hurricane-like gust of scorching wind was felt for a moment (air wave), after which hot ashes, sand and mud began to fall causing all the victims. The clothing on the corpses did not charred, but where open the skin had traces of burns like those of hot steam. The death was caused not so much by burns but by asphyxia as the lungs became ruined by inhaling incandescent particles of volcanic ashes. The thickness of sand in the town was only several centimeters and large-size material was completely absent. The pyroclastic material of this explosion was spread more or less evenly, independent of the relief. Such explosions have been repeated on May 20th and August 30th of 1902.

After the Mont Pélée eruption directed blasts have been recorded and studied on other volcanoes as well.

The author has studied a strong directed blast on March 30th 1956 on Bezymianny volcano (Kamchatka). The explosion has ruined a considerable part of the volcanic edifice; at a distance up to 25-30 km to the south-east of the crater the trees have been broken and partly burnt; incandescent sand and ashes fell over an area of about 500 sq. km, the snow melted there and a tremendous mud flow was formed. Following the directed blast an incandescent agglomerate flow 18 km long and up to 60 m thick burst out of the new crater and rushed down the valleys of adjacent rivers (GORSHKOV, 1957 and 1959).

Comparatively weak directed blasts took place on May 19th and 22nd, 1915 on Lassen Peak volcano (California). As a result of these blasts trees were broken and felled at a distance up to 5-6 km from the crater in a narrow sector north-east of the volcano over an area of 10-12 sq. km. In some places the bark has been torn off and

particles of sand penetrated to a depth of 2 cm into the wood. There has been very little ashes and yet it melted the snow so that mud flows were formed (DAY and ALLEN, 1925).

Similar in their force were, apparently, directed blasts on December 4th and 6th 1951 on Hibok-Hibok volcano (Camiguin island, the Philippines). Here on an area of about 10 sq. km and a distance up to 6 km north-east from the crater coconut trees were broken and fallen. Different from Lassen Peak here directed blasts were accompanied by incandescent avalanches (ALCARAZ, ABAD and QUEMA, 1952; MACDONALD and ALCARAZ, 1956).

Much stronger was the directed blast on January 21, 1951 on Lamington volcano in New Guinea. Here the area affected by the blast exceeded 200 sq. km; at a distance up to 13 km north of the crater the entire vegetation has been destroyed and houses have been ruined. The bark has been torn off the trees and at a distance up to 3 km from the crater even the soil has been peeled off. Numerous human victims, just as in Saint Pierre, have been caused mainly by asphyxia as the result of burns in the lungs.

An analysis of literature data on the eruption of Katmai volcano in Alaska in 1912 led the author to a conclusion that the explosion on Katmai on June 6, 1912 was like that on Bezymianny volcano. The explosion was directed to the north-west and to the south; at a distance up to 30 km from the crater the vegetation has been broken and partly fallen. The sand flow of the Valley of Ten Thousand Smokes is associated by the author with the summit crater of Katmai (GORSHKOV, 1962 I & II).

A very interesting eruption took place on July 15, 1888 on Bandai-san volcano in Japan (SEKIYA and KIKUCHI, 1889; KNOTT and SMITH, 1890). Usually this eruption is quoted as an example of a phreatic explosions. Now, however, comparing this eruption with others it is absolutely justifiable to include it into the category of « directed blasts ». The eruption lasted for less than an hour; there have been 15-20 strong explosions, the last of which was the strongest and was directed horizontally northwards. As a result, a vast hoof-like crater has been formed on the northern flank with a maximum width of 2463 m and a depth up to 2274 m. The altitude of this side of the mountain decreased by 165 m. Over 1 km³ of loose pyroclastic material has been ejected with a tremendous force in a northward direction; fragments were falling at a distance up to 9 km from the crater. The intermontane depression with an area of about 70 sq.

km at the northern foot of the volcano has been buried under a thick layer of « earth and stones » and a flat sandy desert had been formed in the place of a hummocky surface. An agglomerate flow over 4 km long and up to 40 m thick descended into the upper reaches of the river Nagase. The directed blast affected also the eastern part of the volcano. Here, at a distance up to 5 km from the crater the trees have been fallen and an agglomerate flow up to 5 km long and over 60 m thick streamed along the Biwa-sawa gorge. As a result of the eruption five villages have been completely buried under the pyroclastic material and seven villages have been partly destroyed. The devastation have been caused by an air wave, which has been described as a gust of a « hurricane » or a « terrible wind blast ».

Pyroclastic or agglomerate flows observed later on other volcanoes, were, apparently, recorded there on Bandai-san for the first time, but they have been not fully understood. They have been described there as streams of « earth and stones » caused by ordinary collapses and landslides.

A directed blast took also place on another Japanese volcano — Asama — on August 5, 1783 (ARAMAKI, 1956). The blast affected a rather narrow sector north of the volcano and right after the explosion a big agglomerate flow descended along the flank, dammed up the river and caused the formation of an enormous mud flow.

It is very possible that the gigantic eruption of Merapi volcano in Indonesia, which in 1006 destroyed Maratham state (BEMMELEN, 1956) was also of the directed blast type.

Directed volcanic blasts belong to the category of the most devastating eruptions. The area affected by the blasts comes sometimes to hundreds of square kilometers; throughout this territory there is either a complete or partial destruction of buildings, an annihilation of forests and, as a rule, a perish of everything alive. The Mont Pélée eruption of 1902 cost about 30.000 human lives. The eruptions of Asama, Bandai-san, Lamington and Hibok-Hibok volcanoes also caused considerable destructions and losses of hundreds and thousands of lives. During stronger eruptions of this kind the volcanic edifice is partly destroyed and big agglomerate and mud flows are originated, which often trespass on the area directly affected by the directed blast and cause additional damages.

As a rule, directed blasts take place after a lengthy repose period of the volcanoes, which might last for hundreds or thousands of

years. Often these volcanoes are considered to be extinct (Lamington, Bezymianny). The pyroclastic material of directed blasts proper consists of resurgent ashes, which indicate an explosion of a completely solidified material. The temperature of the ashes comes to 400 - 500° C. Quite often fires are breaking out. Often the temperature is lower and victims are due not so much to surficial burns as to asphyxia as a result of scald in the lungs. When the destruction of the volcanic edifice is great (Bandai-san, Bezymianny), the blast ejects also larger blocks sometimes several tens of cubic meters by volume, but the temperature of this part of material is always low.

The energy of the comparatively moderate blast on August 30, 1902 on Mont Pélée volcano is determined as 10^{21} ergs (GORSHKOV, 1960). The blast at Lassen Peak has been ever weaker. However, even these values are equivalent to the explosion of atomic and hydrogen bombs.

For one of the most detailedly studied examples of directed blasts — Bezymianny Volcano — a lengthy seismic preparation has been recorded by instruments. Earthquakes began three weeks before the awakening of the volcano and 5 months before the paroxysmal blast. In many other cases preliminary earthquakes have been recorded directly by the inhabitants of neighbouring villages.

It can be assumed that in all cases directed blasts are preceded by weak or moderate earthquakes. From this point of view the appearance of a stabile seismic activity with hypocentres under andesitic volcanoes, which are considered to be extinct or dormant for the long time, is a very dangerous sign.

The azimuth of a directed blast can be determined by the topography of the circum-crateral part (Mont Pélée, partly Lamington), by the place of fumarolic fields (Bandai-san) or by the place of a preliminary deformation of the volcanic edifice (Bezymianny).

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