The 1965 Eruption of Taal Volcano

Catastrophic explosions are caused by lake water entering a volcanic conduit.

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From 28 to 30 September 1965 there occurred a moderately violent phreatomagmatic explosive eruption of Taal Volcano in southwest Luzon, Philippines, about 60 kilometers south of the city of Manila (Fig. 1). The eruption covered an area of approximately 60 square kilometers with a blanket of ash more than 25 centimeters thick. Present records of casualties show that 51 bodies have been recovered and 138 persons are missing. The center of the eruption was on the southwest side of Volcano Island, an irregularly shaped island about 5 kilometers in diameter, in Lake Taal. Lake Taal is approximately 20 kilometers in diameter. Some authors consider it a caldera lake that occupies a depression formed by collapse of a former volcanic edifice of unknown height (*1*).

Since the year 1572 there have been 26 explosive eruptions of Taal Volcano. All have occurred on, or very close to, Volcano Island. Before 1749 most of the eruptions took place on the northwest or southwest part of the island. The 12 eruptions that occurred from 1749 to 1911 were centered in the large crater in the middle of the island. The 1965 eruption is the first since 1749 to be located on the flanks of the island.

The last previous eruption, that of 1911, was far more violent. It not only obliterated most life on the island but caused extensive damage to life and property on the shores of Lake Taal, except south and southeast of Volcano Island (*2*). Approximately 1335 persons lost their lives.

This article is based on field investigations made by us during and after the eruption, until 13 October. Because of the limited time, and because of the logistics problems resulting from the eruption, the data gathered are incomplete, and this report must be considered preliminary.

Chronological Summary

Before the eruption there was no noticeable change in seismic or tilt activity. However, water temperature in the central crater lake on Volcano Island showed a marked increase during early July 1965 from its 1964 average of 30° to 33° to 45°C on 21 July. By 25 September, when the last measurement prior to the eruption was made, the temperature had fallen to 43°C. On 5 October, after the eruption, the temperature was still 43°C.

Shortly after 0200 hours on 28 September 1965, residents of Volcano Island in Lake Taal were awakened by a rumbling, roaring, and hissing noise. People on the west-central coast of the island saw incandescent material shooting high in the air from the general vicinity of the newly formed cinder cone. This initial fountaining of basaltic spatter, cinders, and pumice was described as appearing like an enormous Roman candle. The color was distinctly red, not red-orange or orange. Some describe the fountaining as vertical, others describe it as directed toward the lake (toward the west) at perhaps 45 degrees from the vertical.

The observer with the Philippine Volcanological Commission, who was stationed at the seismograph station on the west-central coast of Volcano Island, was awakened a few minutes past 0200 hours. He felt earthquakes, heard rumbling noises, and immediately went to the seismograph, which had been recording earthquakes for several minutes. He noted that the double amplitude of the earthquakes was about 5 centimeters on the drums of the three-component Akashi seismometer system, which has a magnification of about 250. This smoked-paper record will probably not be seen again because the station was subsequently covered with 3 meters of ash. Other seismometers on the north shore of Lake Taal and in Manila show continuous strong seismic activity from 0220 to 0920 on 28 September.

The observer left the station about 0213, with 20 other persons from the nearby area, aboard the Commission's 14-foot (4.2-meter) boat, which has a normal capacity of six people. At the time they left, the explosive jetting of incandescent material continued, but as yet only very small, sand-size particles were falling.

The observer returned by boat to the station at about 0325 but did not land. Explosions were continuing and ash was falling, but there were no noticeable air currents from the center of the activity, which was slightly more than 1 kilometer to the southeast. The observer was protected by a wet blanket, but he noticed that the falling ash was warm, not hot.

Between 0240 and 0330, a person on the northwest tip of Volcano Island observed a continuous display of lightning in the eruption cloud. The lightning and its accompanying thunder caused confusion in the reports regarding the presence of incandescent volcanic material and the time of the explosions.

The major explosive phase, apparently caused by lake water gaining access to the volcanic conduit, lasted from 0325 to about 0920 on 28 September. During this time enormous eruption clouds developed which were clearly visible from Manila, 60 kilometers to the north. These clouds reportedly rose to heights of 15 to 20 kilometers and were continually laced with lightning. At the base of the main cloud column a flat turbulent cloud spread out, radially transporting ejected material with hurricane velocity (Fig.

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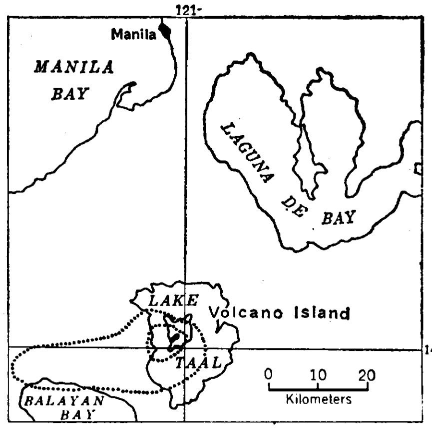


Fig. 1. Index map showing location of Lake Taal and Volcano Island, site of the recent eruption of Taal Volcano. Outer and inner dotted lines enclose, respectively, areas of ash thickness greater than 1 centimeter and greater than 50 centimeters.

2). Residents in the zone of ash fall on the west coast of Lake Taal reported that warm, wet ash fell very heavily slightly before daybreak, at about 0500. At about the same time, high waves swept that coast.

Aerial observation at 0830 showed many explosions occurring along the southwest-trending line of the present explosion crater, but the most intense activity was near the northeast end of the crater. The explosions migrated irregularly back and forth along this line. The present explosion crater formed during this major explosive phase; this crater (Fig. 3), which is occupied by a new inlet of Lake Taal, was first noticed from the air at about 1100.

From 0920 on 28 September to 0600 on 30 September the explosion crater area was continually racked by explosions of somewhat reduced intensity. Explosion clouds were not nearly as high as those reported earlier and did not have their characteristic tiered shape.

From 0600 to 1550 on 30 September smaller explosions occurred during the waning period of activity. The new cinder cone within the explosion crater was apparently built during this phase. Small explosions every 5 to 10 minutes hurled up steam and black ejecta, much of which fell back into the vent area. After the last explosion, at 1550 on 30 September, steam puffs were observed above the new cinder cone, and these continued for several hours. About one-fourth of the surface of the new lake within this cinder cone was covered by a drifting, orange scum containing sulfur, arsenic, and iron, as determined by preliminary chemical analyses.

The temperature near the surface of the new lake within the cinder cone was 77°C on the morning of 3 October, and a thin steam cloud hovered over the lake. On 5 October the temperature was 76°C, and on 8 October it was 72°C. On 3 October the water temperature at the surface in the new inlet filling the explosion crater was 32° to 33°C, except within about 0.2 kilometer of the new cinder cone, where the temperature increased gradually to about 36°C.

During the evening of 9 October, the continual landsliding at the head of the new inlet caused disturbances that eroded the northeast side of the new cinder cone and breached it, forming a horseshoe-shaped rim. It is possible that a single large landslide from the cliff swept across the lake floor and struck the side of the cone. This is suggested by the fact that talus debris (similar to that occurring on the wall of the explosion crater, and foreign to the cinder cone) was noticed on the crest of the cinder cone adjacent to the new breach after the night of 9 October.

On 12 October, when a boat was taken inside the horseshoe-shaped cinder cone, the maximum water temperature was 46°C, the average water depth was 3 meters, and the maximum water depth was 11 meters. The temperature at the water surface of Lake Taal was 29°C on 12 October. Several areas of bubbling water were present within the new cinder cone and south and west of it, but the temperature was not higher in these areas than elsewhere, and the gas had no color or odor.

Explosion Crater

The explosion crater formed during the period 0325 to 0920 on 28 September is about 1.5 kilometers long and 0.3 kilometer wide (Fig 4). The crater is open to the lake on the southwest and is occupied by an arm of Lake Taal. Cliffs at the northeast end of the crater are about 150 meters high, and concentric fault scarps

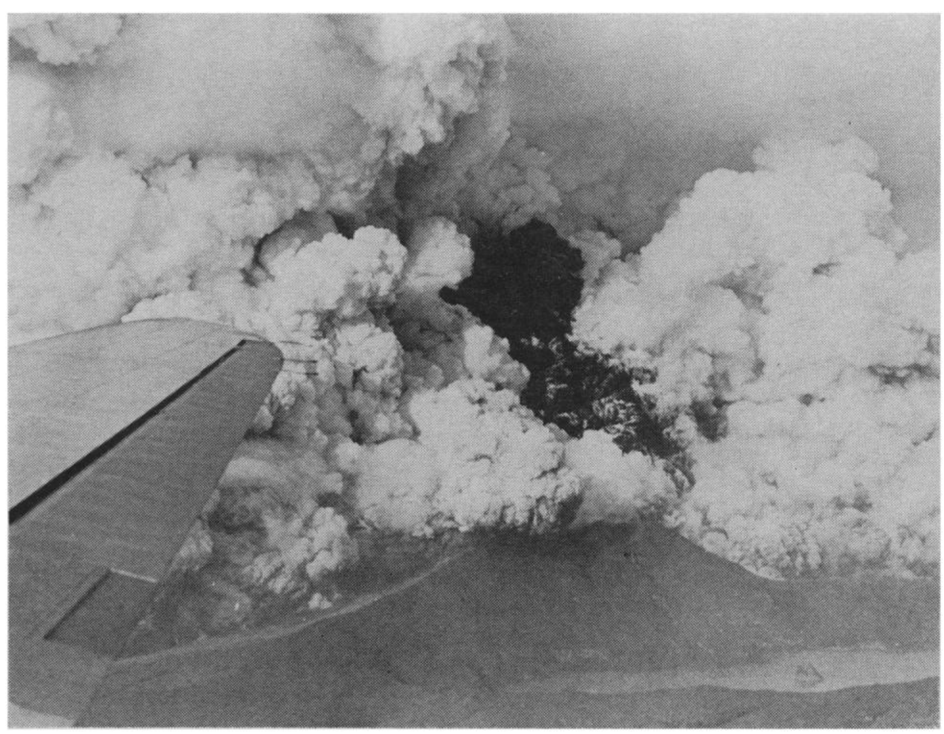
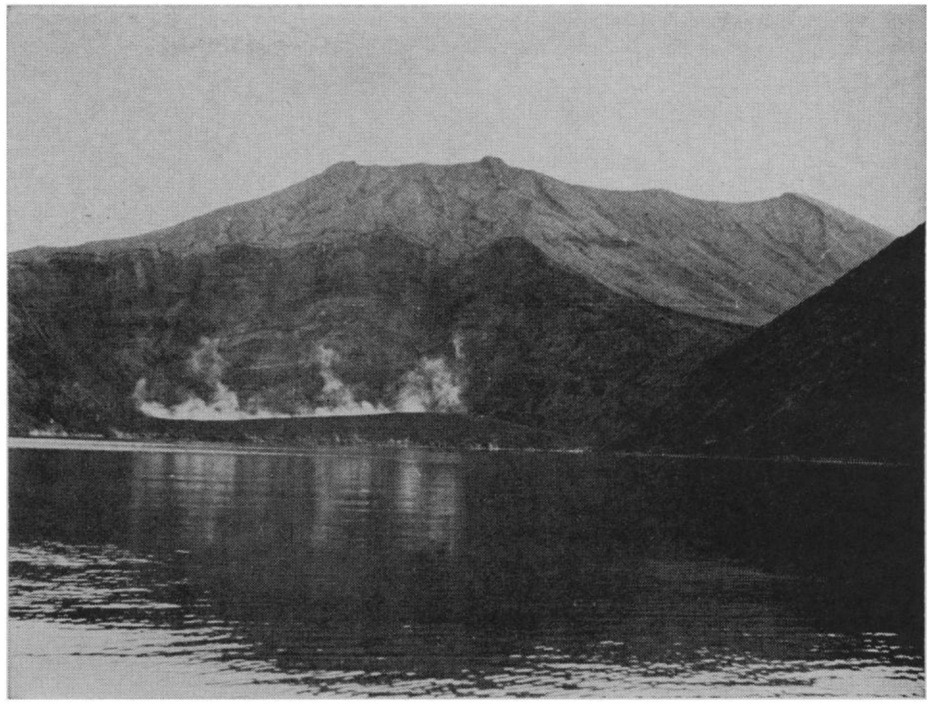


Fig. 2. Aerial view from northeast of Taal Volcano in eruption during the morning of 28 September. The central dark part of the cloud, laden with vertically ejected pyroclastic material, is directly over the volcanic vent. Horizontally moving gray eruptive cloud is visible on the ground surface on both sides and is feeding more billowy-textured white clouds above; gray cloud is also spilling over the edge of the crater rim. Vertical distance from the surface of the central crater lake (foreground) to the high point of the crater rim is about 300 meters. [U.S. Navy photograph]

Fig. 3 (top right). Cinder cone within the newly formed explosion crater as it appeared on 7 October 1965. Note steam rising from the lake within the cinder cone and from the outer edges of the cone. The cone is 250 meters in diameter at lake level, and the wall of the explosion crater behind it is about 150 meters high. The highest ridge is that seen in Fig. 2, viewed from the opposite side.



bounding landslide blocks are forming around the crater, particularly on its northwest side.

A preliminary estimate of the volume of the explosion crater above lake level is about 25 million cubic meters. Preliminary soundings show that the deepest part of the bay is about 50 meters deep. Hence the total volume of material removed from the explosion crater is probably about 40 million cubic meters.

The small breached cinder cone at the northeast end of the explosion crater is about 250 meters in diameter (Fig. 3). The highest point on the rim of the cone is 18.5 meters above the level of Lake Taal.

Ejecta

Approximately 90 million cubic meters of ejecta were thrown out of the explosion crater and spread over Volcano Island, the bottom of Lake Taal, and the area to the west (Fig 4). Deposits thrown out by the volcanic explosions are of two major types: (i) juvenile magmatic material from depth, and (ii) shattered and pulverized old lava, ash, and lake sediments that filled the space now occupied by the explosion crater. Both types of ejecta were distributed in three ways: (i) by direct projection from explosion vent, (ii) by transport in horizontally directed dense, turbulent clouds laden with mud, steam, and coarse ejecta, and (iii) by fallout of fine material blasted to high elevations, blown by the winds, and carried to earth commonly by mud rains.

Apparently in the early stages of the eruption, magmatic material reached

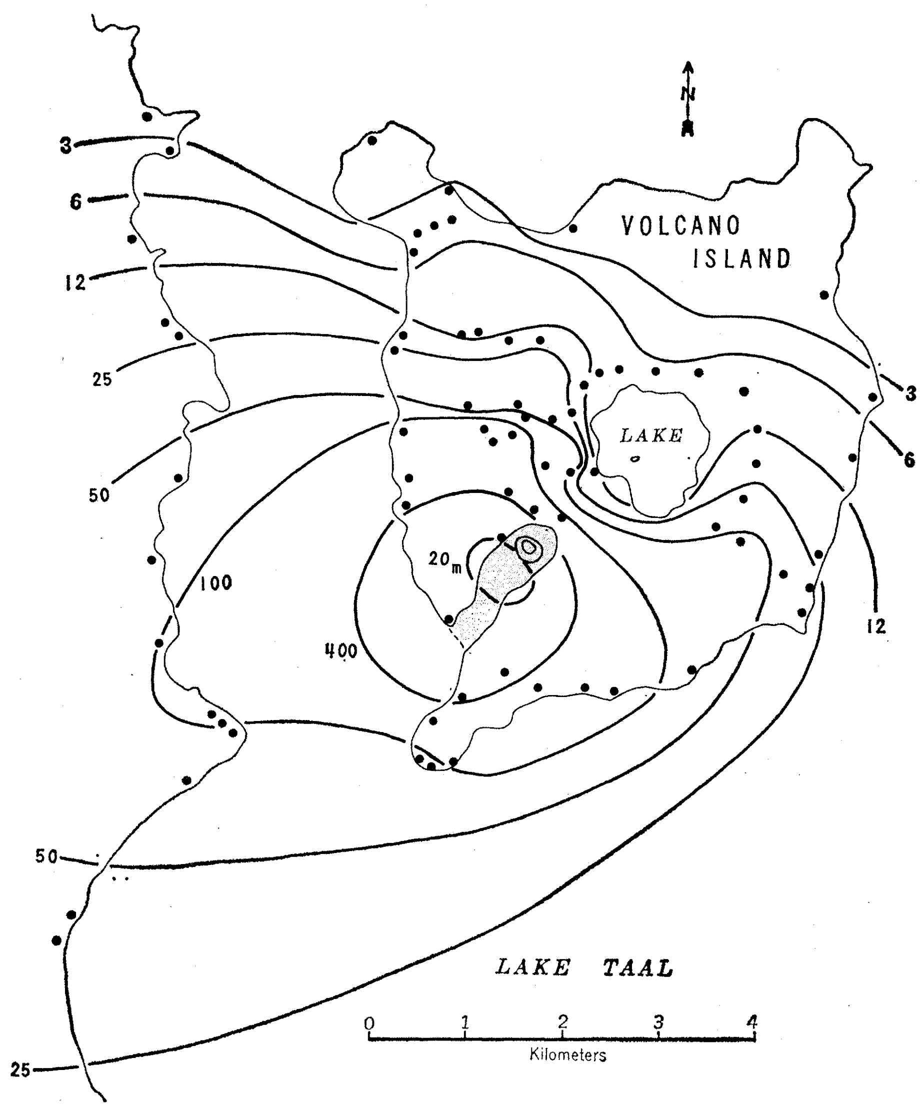


Fig. 4 (bottom right). Map showing thickness (in centimeters or, for the central area, in meters) of ejecta from Taal Volcano. Dots indicate points of measurement. The shaded area is the new explosion crater occupied by the lake inlet and the new cinder cone.

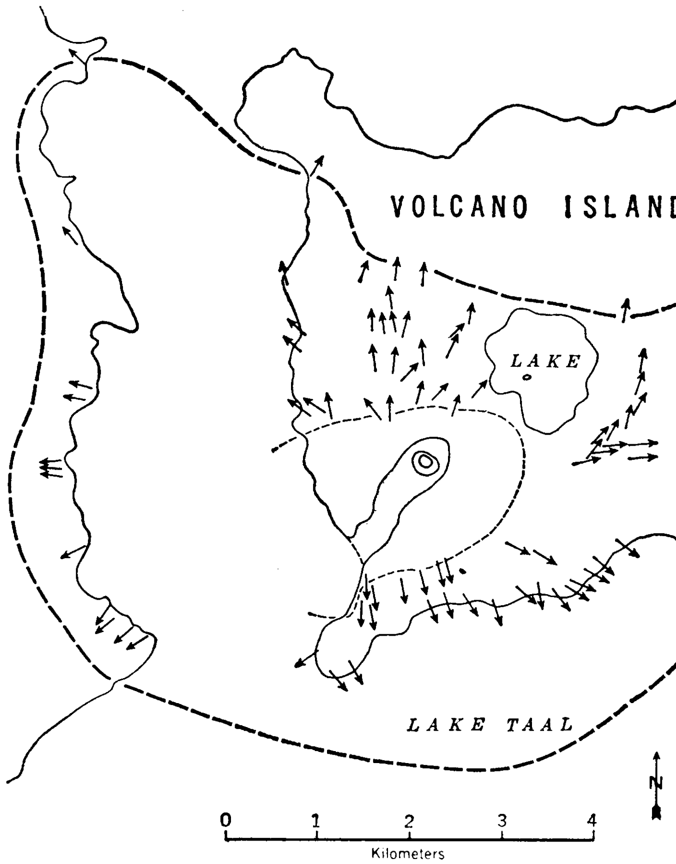


Fig. 5. Map showing the area affected by horizontally moving mud-laden eruptive clouds. (Arrows) Direction of horizontal blasts; (thick dashed line) outer limit of effect of directed blasts; (thin dashed line) outer limit of complete destruction of tree stumps; (shaded area) new explosion crater occupied by the lake inlet and the new cinder cone.

the surface and was ejected high in the air. The bottom 1 centimeter of the ash section at the old seismograph station (on the coast 1½ kilometers north of the new inlet) contains basaltic spatter up to 8 centimeters in diameter. Mixed through this ash section are layers of fresh pumice lapilli, apparently rounded by abrasion in the turbulent cloud.

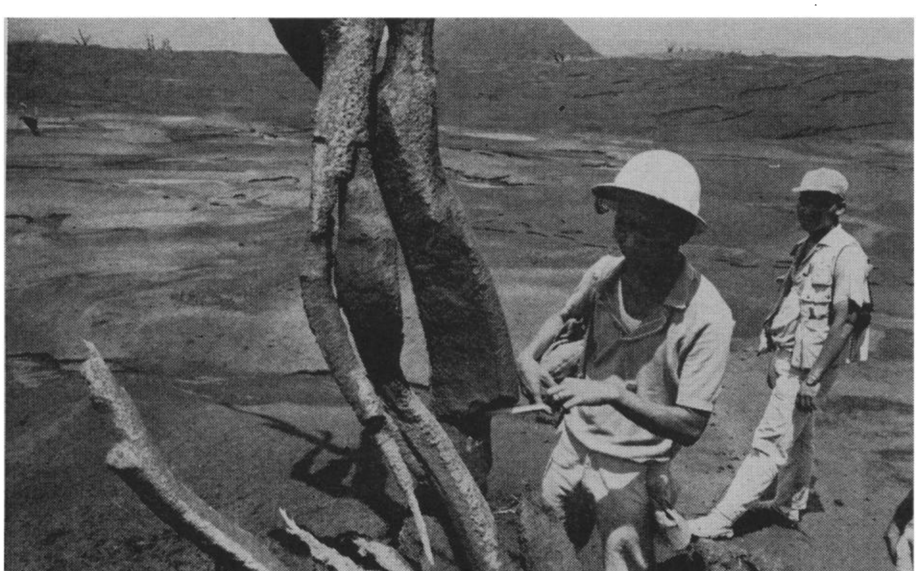


Fig. 6. Trees sandblasted and coated with mud only on the side toward the explosion crater, 1 kilometer away (toward the right). Maximum thickness of the mud coating, 13 centimeters.

Magmatic material was common also during the waning stages of activity. The new cone is made almost entirely of fresh, vesicular basaltic glass in the form of lapilli, ash, and volcanic bombs. The glassy, ellipsoidal bombs commonly have poorly developed bread-crust surface texture and some are more than 40 centimeters long. Some of the more vesicular blocks floated. The basalt is porphyritic, containing phenocrysts of plagioclase, augite, and olivine.

The shattered and pulverized old material thrown out of the explosion crater is intimately mixed with juvenile material, and the relative proportions of each are difficult to determine. Comparison of the volumes of the crater and of the ejecta suggests that the proportion of juvenile material is small, when the attendant decrease in specific gravity is considered.

Ash, lapilli, and blocks transported by horizontally moving eruption clouds compose the dominant part of the ejecta within the blast area shown in Fig. 5. Within 1 kilometer of the explosion crater, blocks up to 50 centimeters in diameter are common, and one block about 3 meters in diameter was noted 150 meters north of the explosion crater. At a distance of 2.5 kilometers from the crater the maximum diameter of the ejecta particles is about 1 centimeter.

Those blocks that landed on the surface produced typical impact craters, and buried craters or bomb sags are exposed in stream gullies. Much of this material is a chaotic mixture of fragments of all sizes, from silt-sized ash to blocks as much as 50 centimeters in diameter. The material commonly is crudely stratified, with dune-type bedding.

Within the area of blast effects, air-fall material is dominant in the top and bottom of the section, and the explosively transported material occupies the middle. Outside the area of blast effects, air-fall material is the dominant ejecta. Much of the air-fall material is composed of accretionary lapilli in well-defined layers, generally with smaller and broken lapilli on the bottom of the bed and larger lapilli, as much as 10 millimeters in diameter, near the top. In some places the accretionary lapilli are as much as 20 millimeters in diameter. These lapilli were formed by accretion of fine ash to a wet nucleus as a result of the abundant moisture in the eruptive clouds. In one section 80 centimeters thick, on the west shore of Lake Taal, four distinct layers of accretionary lapilli are present. Between the lapilli layers are beds of fine ash, some of which contain layers of pumice or accidental fragments up to 3 or 4 millimeters in diameter.

Because of prevailing east and east-northeast winds, the zone of ash fall from the high eruption clouds extends for a great distance to the west. Ash more than 1 centimeter thick extends 33 kilometers to the west and only 6 kilometers to the east of the explosion crater (Fig. 1), and a deposit of fine volcanic ash was reported on Lubang Island 80 kilometers to the west.

Blast Effects

Effects of a series of tremendous blasts and their resultant horizontally moving eruptive clouds are evident within an area (Fig. 5) extending 2 to 6 kilometers from the explosion crater. In a ½- to 1-kilometer zone ringing the crater, all trees and stumps have been removed above the present level of new ejecta, which averages several meters in thickness. In the next zone, about ¼ kilometer wide, the trees remain but are strongly sandblasted and have little or no coating of mud. The sandblasting has abraded them to as little as half their former thickness, but the abrasion has been only on the crater side of the trees; although as much as 15 centimeters of wood has been removed from the crater side, the other side is usually still bark-covered. In the next zone all the trees show the effects of sandblasting and many have thick coatings of mud (Fig. 6). The mud forms aerodynamic, parabolic coatings as much as 40 centimeters thick which point toward the crater. Generally when the mud coatings (now dry ash) are carefully sectioned they are seen to consist of several layers, each grading from coarse sand-size material closest to the tree to fine silt-size ash at the outer boundary. On several trees three well-defined blasts can be identified, but some trees have five or more distinct layers of ash. Many of the mud coatings show slight changes in azimuth of the blast from one layer to the next.

Outward from the crater toward the outer limit of the area of blast effects, the blast direction is recorded not only by the mud coatings but, successively, by stripping of the bark of trees, the breakage direction of stands of bamboo, tilting and deroofing of houses, stripping of palm tree fronds on the blast side (Fig. 7), and faint scarring of the bark of small bushes.

Cattle that were grazing inside the old crater survived the eruption. However, one large calf found there had been blinded and had had the hair sandblasted off the back of its ears

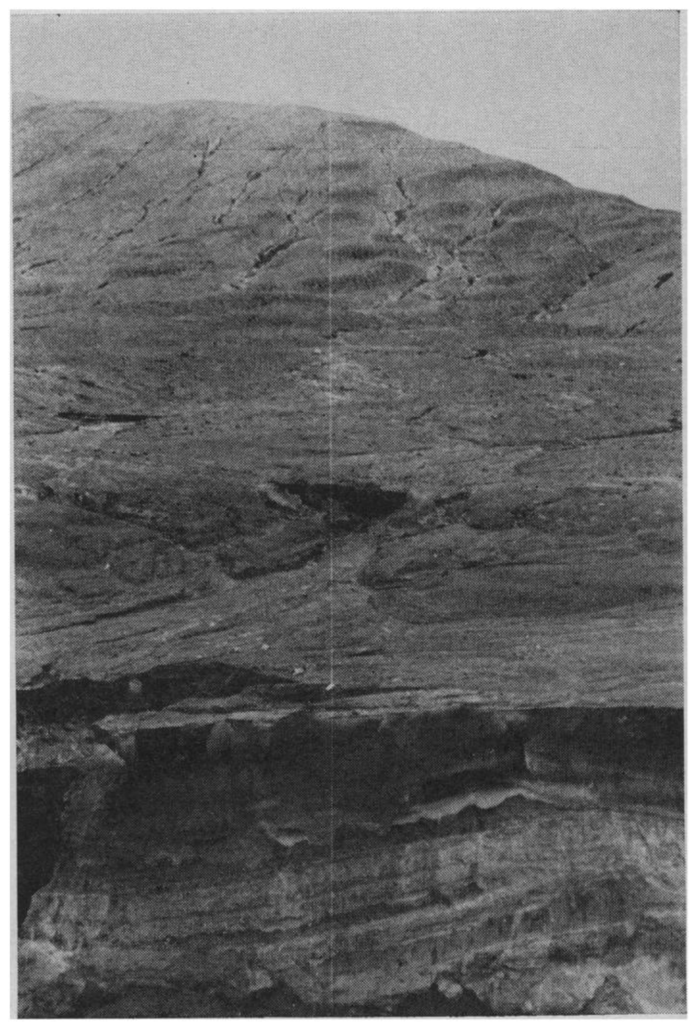


Fig. 7 (left). Palm tree defoliated on the side toward the explosion crater, 2½ kilometers away (toward the left), by horizontally moving mud-laden eruptive cloud. Fig. 8 (right). Ash section (2.5 meters thick) exposed in the wall of a stream channel 1 kilometer south of the explosion crater. Note dune bedding in the ash and displacement of the dune crest to the left toward top of section; the eruptive cloud came from the right. Dunes are visible on the hill in the background.

and off its rump. After being blinded, the calf apparently faced away from the direction of the blasts.

In the entire area affected by the blast, there is no evidence of charring or burning. In the zone of mud plastering, it appears, the temperature of the debris-laden cloud was below 100°C, because the mud must have been mixed with water, not steam, to have been so sticky. The narrow inner zone of sandblasted trees not covered by mud may have been blasted by steam clouds slightly above 100°C.

In the inner half of the area of blast effects, giant ripple marks or sand dunes are common (Fig. 8). They are oriented roughly at right angles to the direction of blast and have a wavelength of 3 to 15 meters and a height of about 1 meter. They can be clearly seen in section where gullies cut the ash, and they are present at depth in many horizons. They are steeper on the blast side and show evidence of scouring on that side. Migration of the crest away from the blast as the deposit was built up by deposition from each successive horizontal eruptive cloud.

Although trees in deep gullies and on the lee side of hills are less damaged by the blast effects than trees in more exposed sites, it is evident that the eruptive clouds followed the contours of the ground, passing up, over, and down the ridges. Scouring is evident even within the old central crater, which is surrounded by a cliff more than 100 meters high. The thickness of the ash-laden part of the horizontally moving eruptive cloud is not known, but mud is plastered on the blast side of the highest trees, 5 meters tall.

Other Effects

Outside the zone of blast action, extensive damage was done to houses and vegetation by the heavy fall of ash. Where the ash blanket is thicker than about 10 centimeters the fronds of palm trees are broken down, and banana trees are damaged where the ash thickness is more than 5 centimeters.

The explosions within the crater area produced shock waves that generated water waves, which probably reached maximum height between Volcano Island and the west shore of Lake Taal. These waves capsized some of the boats filled with the fleeing residents of the island and accounted for many of the fatalities. The maximum height of the waves is not known, because evidence of wave height during the early, most violent phase of the eruption is now covered by layers of ash. However, on the west shore of Lake Taal, directly west of the mouth of the explosion crater, there is clear evidence that waves reached 4.7 meters above lake level and swept inshore as much as 80 meters. The debris left by these waves is on top of the air-fall ash, hence the waves must have occurred very late in the eruption. Undoubtedly much larger waves swept that coast earlier.

A streamflow gage 1.5 kilometers downstream from the outlet of Lake Taal shows an increase of flow from an average of 20,500 liters per second for several days before the eruption to a maximum of 28,400 liters per second on 28 September, followed by decreases to 23,800 liters per second on 29 September, and 22,800 liters per second on 30 September. Such an increase is probably due to excessive wave action and to seiches produced by the explosion shock waves, as well as to displacement of water by the ash fall and to the inordinately heavy rain that accompanied the eruption.

Immediately after the eruption, extensive slumping occurred at the site of stream deltas on the south shore of Volcano Island and the west shore of Lake Taal. The slumping, which produced notches up to several hundred meters wide in the previous shoreline, generally occurred where the ash thickness was greater than 1 meter. Such downslope slumping was presumably the result of rapid overloading of the deltaic deposits below lake level by swollen, ash-laden streams.

Summary

A moderately violent phreatomagmatic explosive eruption of Taal Volcano, in the Philippines, occurred from 28 to 30 September 1965. The main phreatic explosions, which were preceded by ejection of basaltic spatter, opened a new crater 1.5 kilometers long and 0.3 kilometer wide on the southwest side of Volcano Island in Lake Taal. The eruption covered an area of about 60 square kilometers with a blanket of ash more than 25 centimeters thick and killed approximately 190 persons.

The clouds that formed during the explosive eruption rose to heights of 15 to 20 kilometers and deposited fine ash as far as 80 kilometers west of the vent. At the base of the main explosion column, flat, turbulent clouds spread radially, with hurricane velocity, transporting ash, mud, lapilli, and blocks. The horizontally moving, debris-laden clouds sandblasted trees, coated the blast side of trees and houses with mud, and deposited coarse ejecta with dune-type bedding in a zone roughly 4 kilometers in all directions from the explosion crater.

References and Notes

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