COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Report No. 26

ERUPTIVE ACTIVITY AND ASSOCIATED PHENOMENA, LANGILA VOLCANO, NEW BRITAIN

BY

G. A. TAYLOR, G.C., J. G. BEST and M. A. REYNOLDS

Issued under the Authority of Senator the Hon. W. H. Spooner, Minister for National Development.

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LIST OF REPORTS

1. Preliminary Report on the Geophysical Survey of the Collie Coal Basin.—N. G. Chamberlain, 1948.
2. Observations on the Stratigraphy and Palaeontology of Devonian, Western Portion of Kimberley Division, Western Australia.—Curt Teichert, 1949.
3. Preliminary report on Geology and Coal Resources of Oaklands-Coorabin Coalfield, New South Wales.—E. K. Sturmfels, 1950.
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20. Micropalaeontological Investigations in the Bureau of Mineral Resources, 1927-52.—I. Crespin, 1956.
21. Magnetic Results from Heard Island, 1952.—L. N. Ingall, 1955.
22. Occurrence and Distribution of Oil in, and properties of, Glauconitic Sandstone at Lakes Entrance, Victoria.—R. F. Thyer and L. C. Noakes, 1955.

CORRIGENDA

Forward - for 1954/80 read 1955/80.

p. 6, 7 lines from bottom: for 400 read 40.

p. 19 - EARTH TREMORS - insert 'July' after '6th'.

pp.24 & 25 - under sulphur, for 'grains' read 'grams'.

p. 49 - Taylor, 1952 b: reference should be 1952/80.

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FOREWORD

This Report presents the results of investigations carried out from 1952 to 1955 at Mt.Langila volcano by G.A. Taylor, J.G. Best, and M.A. Reynolds, geologists from the Bureau of Mineral Resources, Geology and Geophysics, who have been responsible for the maintenance of the Vulcanological Observatory at Rabaul during these years and for carrying out investigations of volcanic activity elsewhere in the Territory of Papua-New Guinea as required by the Administration of the Territory. Pre-eruption phenomena were studied at two different times by Taylor and Best and the conclusion was reached that an eruptive period was imminent. Recommendations of a precautionary character were made by G.A. Taylor to the Administration of Papua-New Guinea and these were put into effect. Eventually the volcano burst into active eruption on 18th May,1954 and continued to erupt at intervals over the next two years.

This activity was investigated by M.A. Reynolds and is also described in this report, which has been compiled from three papers that were included in the Records Series of the Bureau of Mineral Resources. The titles and authors of these Records are as follows:

Records 1952/92 :	Preliminary Report on an Investigation of Mt.Langila Volcano, June-August 1952, by G.A. Taylor.
Records 1952/80 :	Mount Langila Volcano, by G.A. Taylor.
Records 1954/80 :	Investigations of Langila Crater, May-August 1954, by M.A. Reynolds.

In the field work upon which the first two reports were based Mr.Taylor was assisted by Mr.J.G. Best.

Although, because of its remote position, a detailed record of the course of events leading up to the eruption and of the eruption itself is not obtainable, this report does present a fairly complete picture of the phenomena associated with the 1954-56 eruptive period.

(N. H. Fisher)
<u>Chief Geologist</u>

SUMMARY

Langila Crater is situated seven miles south of Cape Gloucester, which is on the north coast, near the western end, of New Britain. It comprises two adjoining craters, referred to as No.1, southern; and No.2, northern. Activity in No.1 crater is confined to a small fissure in the western half within the crater and some minor vents on the outer north-wes[illegible] There has, as far as can be ascertained, been no change in this ac[illegible]ity [illegible] at least the last fifteen years. The southern half of No.2 crater forms the active crater from which the recent eruption has emanated. Numerous minor vents lie within and on the outer slopes of the crater. The southernmost of these are situated along the northern rim of No.1 crater and appear to have formed along small fracture lines in a direction of 255°. From observations made it was concluded that the explosive phases were centred on the north-western section of the active crater, and that the conduit was inclined towards the north-west, in view of the distribution of the larger ejectamenta to the south and east.

A section on the geography of the Langila Crater area contains details of the physiography and the distribution of native villages. Maps and charts of the area do not show the topographical features in complete detail, and the positions of such villages as are shown are, in most cases, not in accordance with their present locations as shown in the map accompanying this Report.

The first field observations described in this Report were made on visits to the crater between June and August 1952, following reports of increased gas emission at the crater. The No.2 crater of Langila, which had been quite inert in 1938, was found to be producing, at a vigorous rate, gas at a temperature of about 220°C. and with an appreciable content of the oxides of sulphur. Vegetation on the upper slopes was being killed, and the impression was gained that the volcano was trending towards active eruption from No.2 crater.

No.1 crater did not appear to be affected by the increase in No.2 crater.

A further period of investigation in October and November confirmed the impression that eruptive activity might be expected. In addition to the high temperatures, anomalous tilts were recorded, and information obtained from analyses of the condensates from some of the fumaroles also suggested a trend towards eruption. The distribution of native villages relative to the crater was reviewed and it was decided that no immediate action to evacuate them was necessary. Precautionary measures recommended included the provision of a transmitting set to the local observer, Father McSweeney, of Kalingi Mission,

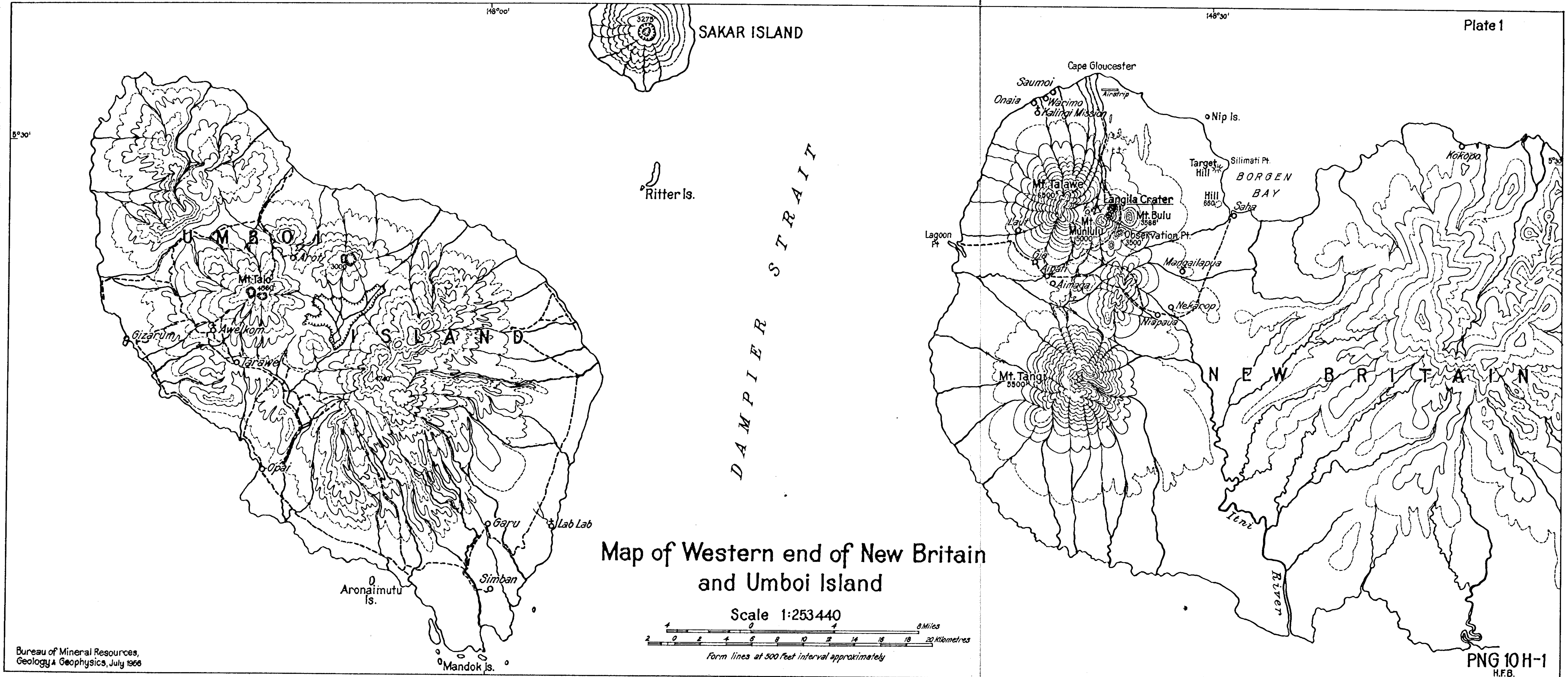


Plate 1
148°00'
148°30'
5°30'
SAKAR ISLAND
3275
Ritter Is.
DAMPIER STRAIT
UMBOI ISLAND
Mt. Talo
4660
Aroi
3000
Awelkom
Gizarum
Tarawe
Opai
Garu
Lab Lab
Simban
Aronaimutu Is.
Mandok Is.
Cape Gloucester
Airstrip
Saumoi
Onaia
Warimo
Kalingi Mission
Nip Is.
Target Hill
Silimati Pt.
BORGEN BAY
Hill 660
Saha
Mt. Talawe
5500
Langila Crater
Mt. Bulu
3586
Mt. Muniulu
5000
Observation Pt.
3500
Lagoon Pt.
Mangailapua
Aimaga
Nekarop
Niapaua
Mt. Tangi
5500
NEW BRITAIN
Kokopo
Itni River
Map of Western end of New Britain and Umboi Island
Scale 1:253440
8 Miles
20 Kilometres
Form lines at 500 feet interval approximately
Bureau of Mineral Resources, Geology & Geophysics, July 1966
PNG 10 H-1
H.F.B.

the maintenance of the Cape Gloucester airstrip and the carrying out of periodical inspections by members of the vulcanological staff.

In the last part of the Report, details of visits in connection with the actual eruption, which began on 18th.May, 1954, are given. Natives of Maingalapua village, which was within the danger area delineated by Taylor in 1952, were dispersed to other villages shortly after the eruption began. It was considered as a result of visits to the area that Europeans and natives were in no danger provided that they avoided the track between Aipati and Cape Gloucester and the area north of Langila Crater. The likelihood of damage to gardens and illness to natives as a result of dust and gas which descended upon villages north-west of the crater was remote and evacuation was not considered necessary.

The increase in activity preceding the eruption was revealed by the area of dead vegetation resulting from the increase in volume of sulphur dioxide gas emitted. The composition of the gases changed between 1952 and 1954, but steam and sulphur dioxide were the two main constituents. There was little or no seismic activity before the eruption. The points at which temperatures were taken in 1952 were inaccessible in 1954 and no comparisons could be made.

The eruptive activity took the form of explosive phases lasting up to four hours, during which large quantities of dust and some bombs were ejected. These occurred at irregular intervals, but white clouds of vapour and gas were given off continuously. The explosive phases witnessed by observers in the area are listed in chronological order, and this is followed by a discussion of the ejectamenta and the type of activity. It was concluded that the volcano was of the closed conduit type and the eruption is regarded as low-grade Vulcanian tending towards pure steam explosion. The pattern and nature of the eruption were almost identical with those predicted by Taylor (1952a). The last reported explosive phase was on March 25th, 1956.

Apart from the initial eruption, which occurred at the time of full moon, subsequent explosive activity, which has been periodic, coincided with the times of new moons. This is discussed in a brief section on luni-solar influences.

INTRODUCTION

Mt.Langila is one of a group of mountains of recent volcanic origin situated near the western end of the island of New Britain (Pl.1). Langila crater, which lies seven miles almost due south of the wartime Cape Gloucester airstrip, is part of a volcanic complex (Pl.2), comprising three craters, Mt.Munlulu, the highest and now probably extinct, and two more recent craters aligned in a north-north-easterly direction from Munlulu (Pl.2). The crater that has been active in the recorded eruptions is the more northerly of these two. The crater rim is about 3800 feet above sea level.

PHYSIOGRAPHY

The dominant topographical feature in the area is Mt.Talawe (Pl.3), an extinct volcano situated 2.5 miles west of Langila. Mt.Langila is in fact on the eastern flank of Mt.Talawe, which is elongated in a northerly direction, forming an effective shield between the active Langila Crater to the east and villages to the south and west. Its slopes reach the coast to the north and west, and a narrow ridge extends in a south-easterly direction from below the southermost of the three prominent peaks at the summit of Mt.Talawe to the south-western slope of Mt.Munlulu. To the north of this ridge, and more or less parallel to it, is another smaller ridge, which is deeply breached at the western end. In the valley between the two ridges at the eastern end, half a mile west of Munlulu, is an old cup-like crater, 700 feet in diameter, now thickly covered with vegetation (Pl.2). About 1500 feet south of this, and 3,000 feet south-west of Munlulu Peak is an old adventive cone, also thickly timbered.

Mt.Munlulu forms the highest point on a ridge aligned in a north-east to north-north-easterly direction. This ridge comprises the Munlulu Crater which is really the remains of three craters situated respectively north-east, west, and south-east of the high point that constitutes Mt.Munlulu and the Langila Craters, No.1 crater which joins Munlulu main crater on the north-east, and No.2 crater north-north-east of No.1. To the north and north-east of Langila, old lava flows, now covered with kunai grass and trees, extend down to the coast. One particularly prominent and well-preserved flow or series of flows covers the north-north-eastern crater-slope of No.2 crater (Pl.2) The structure of Langila Crater and the petrology of these lava flows are described later.

East of the Munlulu-Langila ridge and separated from it by a deep valley are three peaks, also aligned in a north-easterly direction. The northernmost peak is the extinct volcano "Bulu" (Fisher, 1939), or Gulu, which is one mile east of Langila No.1 Crater. The peak to the south-west of Bulu, one mile south-west of Bulu and one mile south-east of Langila No.1 Crater, formed

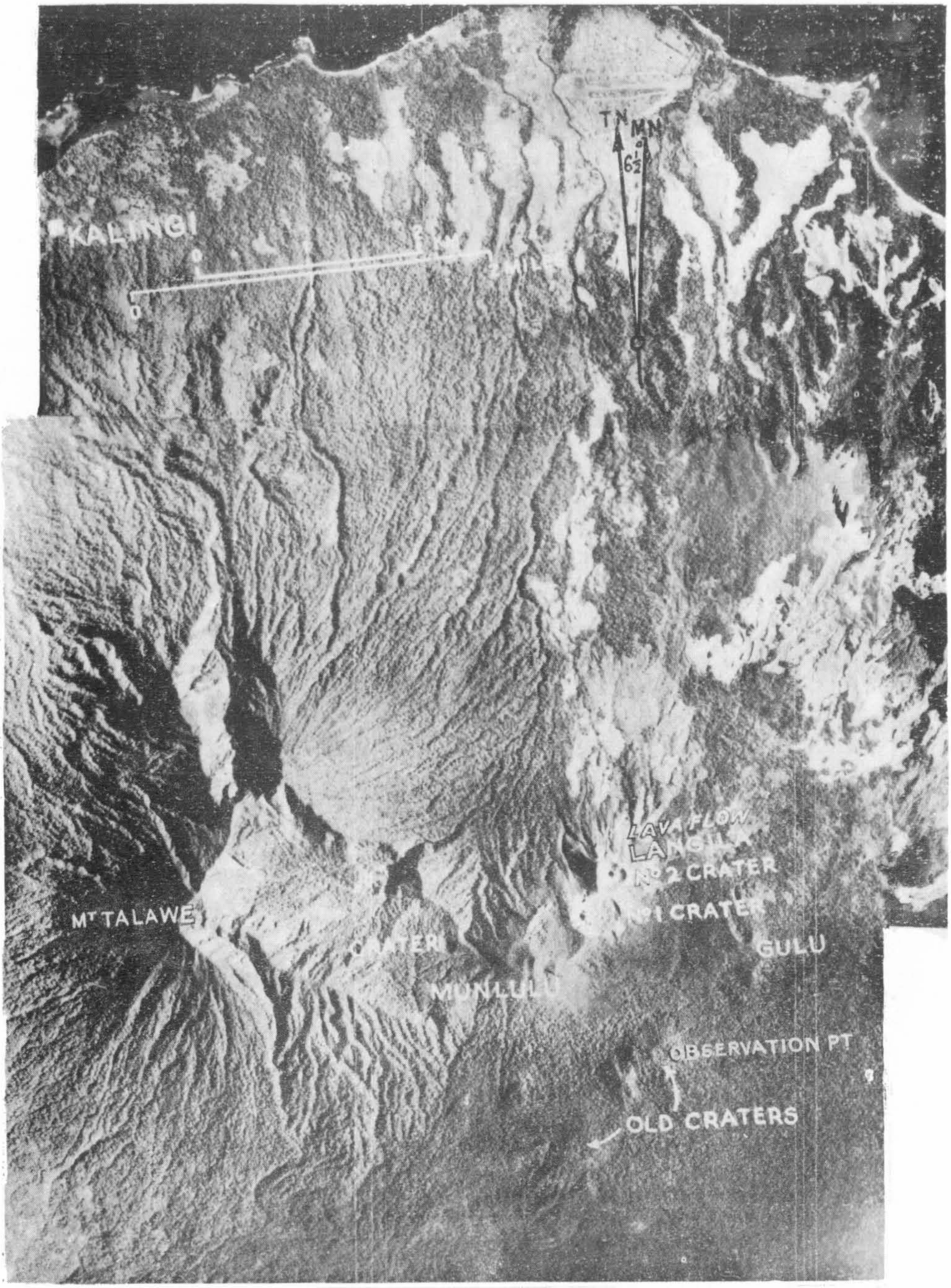


PLATE 2.
Vertical aerial photograph of the Langila-Cape Gloucester area.
Scale 1 inch = 1 mile approximately.
U.S. Dept. of Defense photographs, 25th March, 1947.

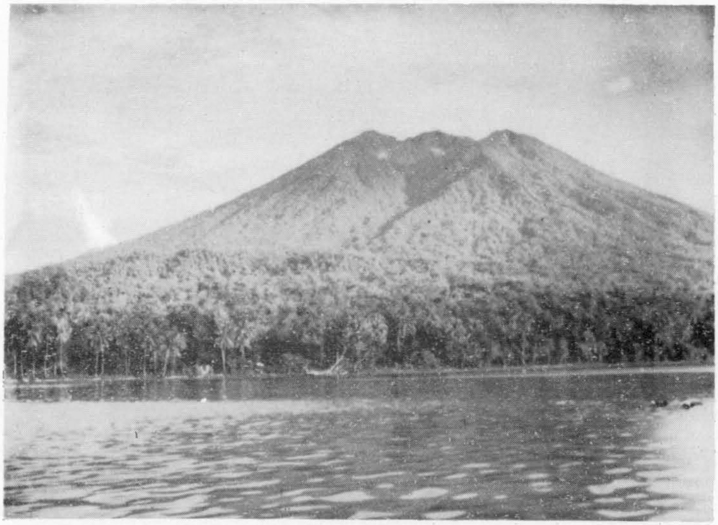


PLATE 3.

Mt. Talawe, looking south-east, taken from south of Warima village by M. A. Reynolds, 26th May, 1954. Steam cloud from Langila can just be seen over lower left slope of Mt. Talawe.

the observation point from which Langila was observed in eruption. Three-quarters of a mile south-west of this peak is another similar one. All three of these peaks still have recognizable craters at their summits, although they have apparently been extinct for some time and are thickly covered with timber. They are within a hundred feet or so of the height of Langila crater.

Previous volcanic activity resulted also in the formation of the peak about 1½ miles east-north-east of Bulu, Hill 660 near the coast in the south-west corner of Borgen Bay, and Target Hill, which is situated near the coast west of Silimati Point. Razorback Ridge, a small feature towards the coast north of Langila, was not inspected, and its true nature is not known.

Immediately south of the track between the villages Aipati and Niapaua (Pl.1) is an old fumarolic area (approximately 120 feet by 60 feet) elongated in a north-north-westerly direction. The distance to Langila was estimated to be between three and four miles and the bearing to be a little east of north. Rocks in the area are bleached and highly altered; there is some sulphur and a faint smell of hydrogen sulphide, but no hot points.

Farther to the east, about a quarter of an hour's walk west-south-west of Niapaua village, are some gas ebullitions from the left side of the river that flows immediately south of the village. Rocks in the vicinity are covered with light brown and green precipitates, and temperatures taken ranged from 47°C to 48°C. According to local natives the area has been known to exist for at least three generations, and activity has remained unaltered for many years.

Other thermal areas were reported by the paramount luluai, Isopaua of Kalingi, to exist inland from the river on the north coast just west of Nip Island, and at the mouth of the river south of Silimati Point (Pl. 1). This last point, however, was active only for a short period about 1950, according to Isopaua, although the position agrees fairly closely with the point where Father McSweeney saw gas bubbles in the sea on 30th May, 1952.

DISTRIBUTION OF NATIVE VILLAGES

Most of the villages are congregated along the north-west coast in the area south-west of Mt.Talawe. A few villages lie inland south and south-east of Langila Crater, but there are none in the area to the east and north. The villages south of Langila Crater are shielded from it by Mt.Munlulu and ridges between Mt.Munlulu and Mt.Talawe, and villages to the south-east are separated from Langila by Mt.Bulu and the topographical features aligned to the south-west.

The danger area in the event of an eruption was established by Taylor (1952a) as within a four-mile radius of the active crater. It was suggested that the only village that was likely to be affected within this area was Mangailapua (Pl.1), situated south-east of Langila Crater. Shortly after the eruption began, Patrol Officer Dwyer went to Mangailapua to ascertain whether the natives had moved to the new site indicated as safe by Taylor. He discovered that attempts by the natives to settle in the new location had been stopped by the luluai of Niapaua village, who owned the land, and that the natives had returned to their old site. Patrol Officer Dwyer dispersed these natives to other villages regarded as safe.

DETAILS OF THE LANGILA CRATERS

Terminology

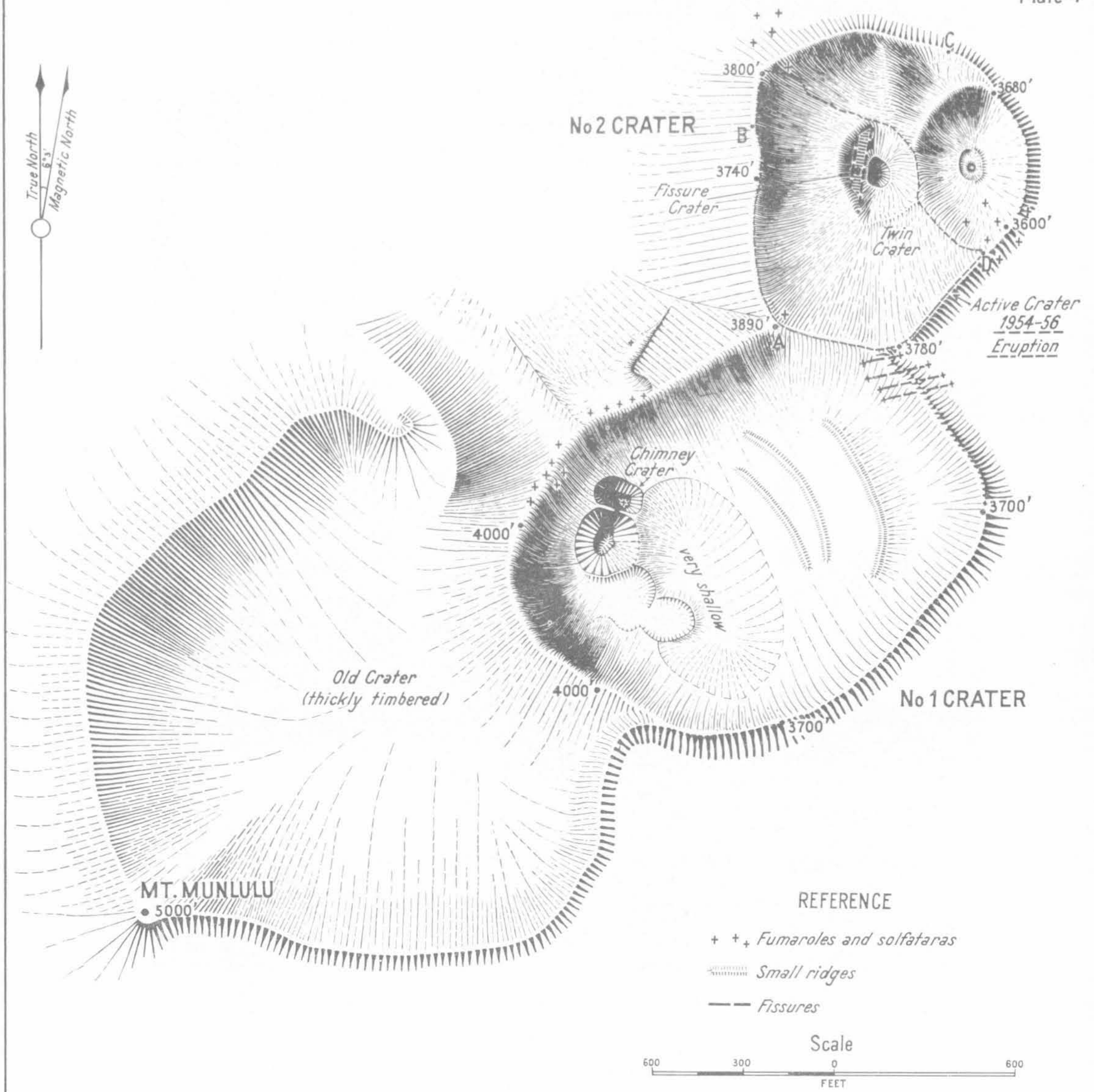
Langila Crater comprises two adjoining craters (Pls.2, 4, 5, and 6) which extend in a direction of approximately 15° from Mt. Munlulu crater. The two craters were referred to as No.1 and No.2 craters by Best (1953). The active centre of No.1 crater was named Chimney Crater by Taylor (1952a). Investigations in 1952 by Taylor and Best were mainly concentrated on the westernmost of the two contiguous craters which form No.2 crater, and this was named Twin Crater. The main centre of activity in Twin Crater was referred to as Fissure Crater.

Structure

No.1 Crater: The shape of this crater is roughly rectangular with rounded corners and it is elongated in a north-easterly direction. Dimensions are 1500 by 1250 feet. The south-western and western end abuts into the old and poorly defined Munlulu crater, and the northern corner forms a common ridge with the southern rim of No.2 crater. The highest portion of the rim is on the south-western side, where the height is estimated at 4,000 feet. Along the north-western side is a steep-sided ridge which at its north-eastern end joins the southern end of the western edge of No.2 crater. The easterly portion is about 300 feet lower and is more easily accessible. There appears to have been numerous active centres within this crater, and remnants of their activity remain in the form of small undulating ridges, the more prominent of which have been shown on the map of Langila Crater (Pl.4). The latest activity that occurred in this crater was confined to the western section of the crater. Recently extinct craterlets and currently active fumarole centres still exist on both sides of the high ridge on the north-western side.

Inside the western rim three contiguous craters are aligned in a north-south direction:

(i) The southern and largest of the three is really a double crater, consisting of two shallow craters aligned in a south-easterly direction and separated by a low ridge. On its western side, this crater is joined to the high south-western wall of the main crater, which is breached at this point. This breach is considered to form part of the crater under



PLAN OF LANGILA CRATER

Compiled from enlarged aerial photographs and topo and compass survey.
Elevations by aneroid.

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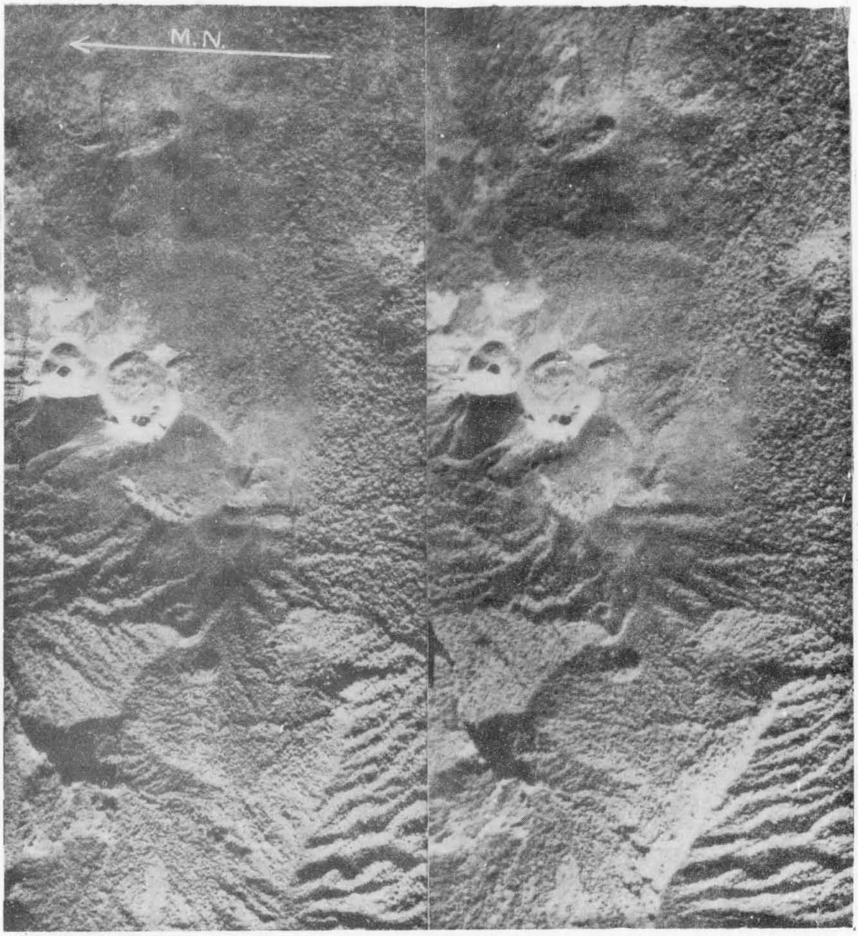


PLATE 5.
Stereoscopic pair of aerial photographs. Langila Craters.
Scale 1 inch = 3,000 feet approximately.

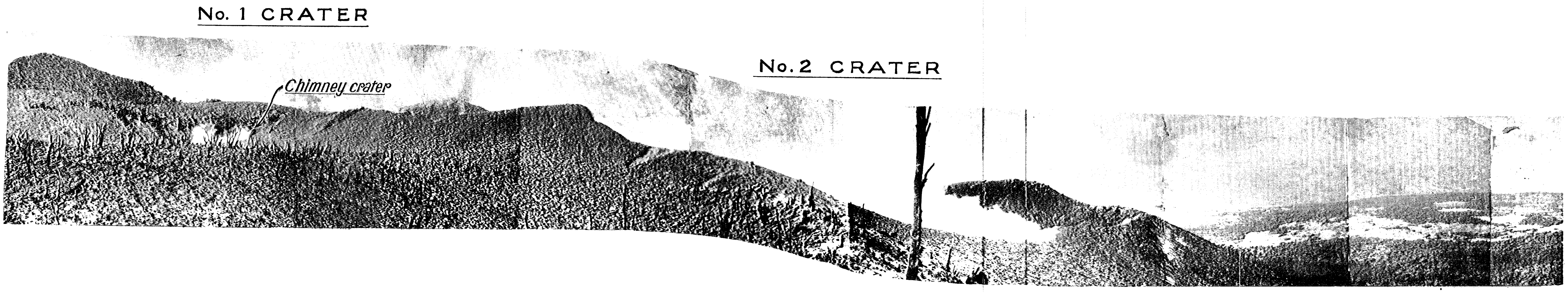


PLATE 6.

Panoramic view of Langila Crater from the north-eastern rim of No. 1 Crater. The photographs have been taken in an arc from the south-west (at left) to the north-east. Photos by Patrol Officer T. Dwyer, 17th June, 1954.

discussion and consequently the crater appears to be elongated in a north-easterly direction. At the bottom of the crater in the north-eastern section is a small outcrop of lava which has been extremely altered by fumarolic activity. This activity no longer persists, nor are there any signs of activity within the crater.

(ii) After the final eruption of the southernmost crater, the focus of explosive activity moved slightly north and formed a new crater whose southern rim, a small saddle-like ridge, now forms an indentation in the northern rim of the southernmost crater. The walls of the crater are steep, particularly on the western side where they form part of the high north-western wall of the main (No.1) crater. They are obscured by landslides, but were probably originally almost vertical. The rim of the crater is about 250 feet in diameter and the depth is about 100 feet. There are no active fumarole areas within this crater.

(iii) Of the three craters, only the northernmost (Chimney Crater, Pl.7) manifests fumarolic activity. This is a small, vertical-sided fissure elongated in an east-west direction and extending from the north-western wall of No.1 crater along the northern rim of the crater discussed above (ii), for about 250 feet. The greatest width, 100 feet, is at the eastern end, and the bottom, which is not visible because of the continuous emission of vapour, is about 250 feet below the rim. This was calculated by estimating the number of seconds taken for rocks dropped in to reach the bottom. The division between the Chimney Crater and the crater to the south, (ii), is a very narrow razorback ridge. The stability of this ridge and the vertical sides of the crater can be attributed to the old lava flows of which they are predominantly composed. The most recent of these flows forms a thin wedge-shaped projection above the eastern half of the southern edge of this crater.

In addition to the gas emission from Chimney crater, solfataric activity occurs outside the No.1 crater rim along the north-western slopes, immediately below the crest of the high ridge which forms the rim in this section (Pl.4). At the south-western end, a few feet below the crest, solfataric activity has considerably altered rocks in an elongate area into white, yellow and pink clayey decomposition products. Gas and vapour are still being emitted from a few very small vents, and some crystalline sulphur is being deposited. North-east of and directly below this area is a platform formed by a small explosion crater. It is situated about 400 feet below the crest of the major crater rim and has a maximum width of 120 feet. Some gas and vapour is still being emitted from the vertical face, consisting of old lava flows, above the eastern margin of the platform. Below and east-north-east of the platform is another small explosion crater; this is the most active of the centres on the north-western slopes of No.1 crater. The two small explosion craters appear to be aligned in the same general direction as the three contiguous craters on the eastern side of the major crater rim.

No.2 Crater (Pl. 7, Figs. 3 and 4): The No.2 crater is rounded in outline at the north-eastern end, but the western, south-eastern, and southern sides are nearly rectilinear. It is smaller than No.1 Crater, about 1050 feet long in a north-north-easterly direction, and 900 feet wide. The elevation of the crater rim ranges approximately from 3,600 to 3,900 feet, and as in the No. 1 Crater, the eastern wall is 200 to 300 feet lower than the western one. On the eastern side is a shallow secondary crater about 500 feet in diameter. Before the 1954 eruption a smaller circular crater, with steep sides and about 300 feet in diameter, occupied the central part of the main No.2 crater.

Although in 1938 no sign of activity showed within this crater, it was here that the fumarole activity developed that was the subject of the investigations in 1952 described in this report, and that subsequently became the eruptive centre. This was called by Taylor the Twin Crater (Pls.4 and 7), because at the time his investigations began it was divided into two sections by a low medial wall. The western active half, which was elongated in a north-south direction, he referred to as Fissure Crater.

Because of the high concentration of gases and the large volume of vapour being emitted, and the direction of the prevailing wind, accurate details of the active vent and of the northern and western sections of Crater No.2 since the 1954 eruption began are not available. From measurements and compass bearings taken in the eastern and north-eastern section it has been possible to establish a rough estimate of the crater's dimensions.

The present active crater which constitutes the south-western half of Crater No.2 (Pl. 4), is elongated in a north-westerly direction and the dimensions are roughly 900 feet by 400 feet. The depth could not be estimated because the sound of stones hitting the bottom could not be heard above the noise of the gas emission. Apart from the upper portion of the eastern wall, which had steep slopes, the crater walls appeared to be sheer-sided. Observations made during the explosive phase on May 29th. suggested that two main centres of activity lie within the crater. The more active of these is situated in the north-western portion, and it was from here that bombs and dust were ejected. The distribution of the larger ejectamenta from explosive phases indicates that the conduit from which the explosive forces originated was not vertical but inclined towards the north-west. During quiescent periods, a large volume of vapour and gases was emitted from this centre. The second centre, situated in the south-eastern half, appeared only to emit a white cloud of vapour with gases, but this was obscured during the initial part of any explosive phase. The activity here is considered as secondary to that of the north-western centre.

Centres of minor activity are situated both within the major crater rim and on the outer slopes. On the north-west slopes there are at least three vents emitting white clouds of vapour and gas (Plate 8). Although close inspection of these vents was impossible, it was noticed from the air that they occurred

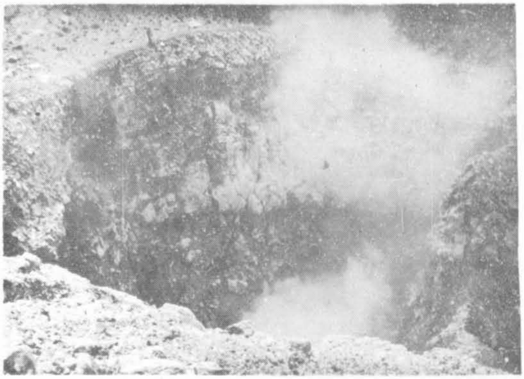


Figure 1.

Chimney Crater, taken from high western rim of No. 1 Crater, looking east. Photo by J. G. Best, August, 1952.

Figure 2.

No. 1 Crater, from south-west rim of No. 2 Crater, looking south. Note vegetation in foreground. Photo by J. G. Best, August, 1952.

Figure 3

No. 2 Crater from south-west rim, showing Twin Crater, looking north-east. Photo by J. G. Best, August, 1952.

Figure 4.

South-western slopes No. 2 Crater, looking north-north-east. Photo by J. G. Best. August, 1952.

PLATE 7.

Figure 1.

Aerial view of No. 2 Crater, looking south-south-west. Photo by M. A. Reynolds, 11th June, 1954.

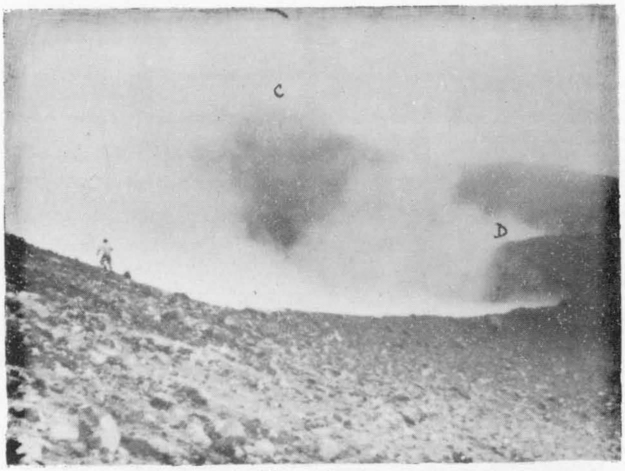


Figure 2.

Eastern rim of No. 2 Crater, looking north-east. Photo by M. A. Reynolds, 18th June, 1954.

Figure 3.

Aerial view of No. 2 Crater, looking south. Photo by M. A. Reynolds, 11th June, 1954.

PLATE 8.

in erosion channels, and that they were emitting a greater volume of vapour than the other centres of minor activity. Active centres along the south-eastern margin of the crater were well defined by the white and yellow precipitates deposited by their vapours. The southernmost of these were situated along the northern rim of No.1 crater. Here the emissions appear to have formed along lines of fracture, and although they are mostly very small their precipitates have formed a series of parallel lines on the surface. The more prominent were regularly spaced at intervals of about 35 feet. The westernmost of these lines extended for 120 feet on a bearing of 255^{o}. It was terminated at its western end by a shallow elongate vent about 12 feet long and 6 feet wide. The main emission of vapour in the area came from this vent. Other main centres of minor activity along the eastern margin were situated below the rim in an erosion channel on the eastern slopes and on the north-eastern rim of the active crater. In the latter locality, precipitates have formed over the ground and cover most of the south-eastern portion of the shallow crater situated in the north-east of No.2 crater. Although the trend was not as obvious here, there was evidence that the main lines of weakness occurred in roughly the same direction as those in the south of the marginal zone.

Two other small vents were noticed from the air. These were situated close to the rim of the inner walls of the active crater, one in the north-west (Pl.8, Fig.1), almost opposite those vents occurring on the outer slopes, and the other in the south-west corner.

THE FIRST INVESTIGATION - G.A. TAYLOR AND J.G. BEST. JUNE - AUGUST, 1952.

DETAILS OF THE INVESTIGATION

The original report of signs of increasing activity at Langila was made by Father McSweeney of the Kalingi Roman Catholic Mission. Father McSweeney was returning from a trip along the north coast on 21st May, 1952, when he noticed condensed steam rising from a new place on the summit of Mount Langila. On a visit to Borgen Bay on 30th.May, he saw gas bubbles in the sea close to the shoreline, adjacent to the small conical hill (Target Hill) which lies on the western side of the Bay (Plate 1). About the same time, he observed that the vegetation on the slopes below the new active centre had begun to die.

Having no radio, he was unable to get the report away until Mr.Stokey called at the mission early in June. Mr.Stokey passed the message on to Rabaul.

J.G. Best attempted to investigate this report but unfortunately suffered an accident en route, and had to return to Rabaul for medical attention.

At the request of the Government Secretary, G.A. Taylor left Popondetta and flew to Lae on 18th.June, 1952, and left by trawler the same day, arriving at Kalingi on 20th.June. He was met by A.D.O. Single, who had come from Kandrian at at the request of the District Commissioner.

An inspection of the volcano confirmed that gas emission had recently increased and revealed a number of phenomena which are usually identified as pre-eruption conditions.

High pressure gas was being emitted from three vents in the central secondary crater within the main northern crater of Langila (No.2 crater). High concentrations of sulphur dioxide were responsible for the killing of the vegetation. Turbulence caused by gale-force winds filled the crater almost continuously with acid gas; as a result the vents were un - approachable for several days. On 26th June the wind dropped sufficiently, in the early morning, to make a descent into the crater practicable. Charring effects on wood exposed in the vents for five-minute periods indicated temperatures of the order 200-300° Centigrade.

The existence of abnormal temperatures having been established, it was important to discover what trend prevailed. This was not possible without additional equipment: gas masks and high temperature recording apparatus were required.

The temperatures did not appear to have reached a critical level; there was little evidence of continuing increase in total gas emission, and tests for earth tremors by means of a mercury pool had been negative. Hence Taylor had few misgivings about leaving the area while equipment was being obtained from Australia.

A.D.O. Single remained in the area to check village locations and carry out a census in order that the information would be available should movement of people be necessary. At his suggestion the local people volunteered to clear the Gloucester airstrip so that it would be ready in the event of an emergency.

Taylor returned to the area on 11th July, and found that A.D.O. Single had returned to Kandrian the previous day and had left a note to say that two reliable reports of earth tremors had been received from the village on the south side of Langila. The tremors had not been felt in the group of coastal villages around the Kalingi Mission.

Carriers could not be obtained until 16th July, when an ascent was made and a base camp set up about 550 feet below the crater. This site was selected to facilitate the daily inspections of the crater and for better observation of subterranean phenomena, should they occur.

Six natives were employed to carry water to the camp, and equipment to and from the crater. This local labour stayed one week, at the end of which they returned to their villages as several of them were sick from the effects of bad weather.

Initial work on temperature observations made it obvious that the recording of temperature data by means of the pyrometer was not practicable without European assistance. Two of the vents were located on the floor of a vertical-sided fissure crater which was thirty feet wide and over a hundred feet long, and had a floor sloping from thirty to eighty feet below the level of the inner wall. Concentration of the corrosive acid gases was very high in this fissure. If temperatures were to be recorded in these important vents it was necessary that the sensitive galvanometer should be left outside the fissure and read by one observer while the other applied the thermocouple to the vents.

In answer to a request for assistance, J.G. Best came from Rabaul, bringing with him native labour, additional equipment, and rations. He arrived at Kalingi on 26th July.

During the following week temperature records were maintained for the accessible vents while a forty-foot ladder was being prefabricated at the base camp for gaining access to the vents on the floor of the fissure crater. The ladder was carried up to the crater on Saturday 2nd August, assembled on the inner crater rim, and lowered into position.

Over the following fortnight temperature data were collected at all the main vents; condensates of the vent gases were collected and chemical tests carried out for the presence of halogens; a crude recording pendulum was constructed; a tape and compass survey of the summit area was carried out; and hot ground areas south of the mountain were examined for indications of recent change.

The observers left the area on 17th August to make a survey of Long Island and Sakar Island volcanoes and to investigate a report that earth tremors had been felt near Ritter Island and smoke had been seen rising from the cone. Native stories indicated an association between past activity of Langila and Ritter.

G.A. Taylor returned to Kalingi on 26th August and checked crater conditions once again before returning to Lae.

PREVIOUS HISTORY

An old native who remembered the last eruption of Langila was found in the coastal village of Onaia near the Kalingi Mission Station. His name was Avel. According to the mission records, he was born in 1875. Judging from his appearance this seemed an underestimate of his age, although his mind was remarkably clear for a man of that age.

From Avel's account Langila erupted when he was a small boy. The eruption was preceded by severe earth tremors which began several days before the initial explosion. The large stones thrown out by the volcano fell close to the crater and the south-east winds brought a light grey dust over the northern slopes. Dust falling on the gardens did not damage them to any extent.

Spasmodic eruptions accompanied by further earth tremors continued for an indefinite period before the activity ended. Four years later Ritter Island erupted, and the accompanying tidal waves drowned most of the coastal people of the western end of New Britain.

Powell (1883), an early traveller in this region, describes an eruption that was in progress in 1878, and this would agree reasonably well with the date indicated by Avel's account. Powell's description suggests that the eruption was much more extensive and severe than Avel's account would indicate.

> p.229: "....we kept on our course for Cape Gloucester. As we approached it we saw a great volume of smoke hanging over the land which obscured the tops of the mountains, and on approaching closer found that it was caused by innumerable volcanoes, small and large, all in violent eruption. It was a most extraordinary sight; there must have been some hundred or more all belching fire and smoke, indeed the land seemed all on fire. We anchored some distance off the shore at the end of a reef, so as to be well away from the natives for the night.
>
> When night came on, the sight was wonderful. Flames seemed to cover the mountainous points of land, and it would have been easy to read a book by the light; the air was full of fine ashes covering and making everything a light grey colour. Tupinier Island was in eruption also, and the noise made by them all was like low continuous thunders."

This description (if reliable) suggests that not only were the numerous parasitic cones on the slopes of Langila active, but fresh lava flows covered extensive areas.

From these accounts it is fairly certain that Langila was in eruption at least in the year 1878. The subsequent period of dormancy of roughly seventy years is conceivably long enough for the accumulation of sufficient energy to support an eruption of major proportions, but most unlikely to produce an outburst of catastrophic violence indicated by extraordinary seismic phenomena.

Information on more recent conditions of Langila crater is available from two sources. When N.H. Fisher (1939) and L.C. Noakes visited the crater in 1938, the No.2 crater showed no signs of fumarole activity but No.1 crater was emitting gas from what Taylor refers to as Chimney Crater, and from the adjacent crater rim, in much the same manner as it was in 1952.

Examination of aerial photographs taken in 1947 shows that a change had taken place since 1938 in the appearance of the Twin Crater in No.2 crater. This was formerly a moderately shallow basin; it appeared to have been reamed out either by the force of escaping gases, or possibly by a small unrecorded phreatic eruption, so that it was now deeper and the sides were steeper than in 1938.

In 1944, Karia, a native of Saumoi village, accompanied some American troops to the crater. At that time, he stated, sulphur dioxide was being emitted from the Twin Crater of No.2 crater, showing that fumarole activity had developed in this crater some time between 1938 and 1944. Trees in the immediate vicinity of the crater were dead, but the vents were less active than in 1952, and the vapour from them was visible from the coast only during wet weather. This suggests that the quantity rather than the quality of the gas emission had changed between 1948 and 1952 - an observation that reduced the significance of the high concentration of acid gases in 1952.

DESTRUCTION OF VEGETATION

A study of the affected vegetation pattern seemed to confirm Karia's story. Trees in and around the active centre appeared to have been dead for several years. They were bare trunks, practically devoid of bark and small limbs. Even with the assistance of sulphur dioxide, it is considered that disintegration from weathering would not produce this effect in less than ten years. Dead trees of a similar age can be seen on the slopes of Tavurvur volcano at Rabaul.

The effects of the most recent increase in gas emission were very obvious. The first plant to be affected was the relatively small bushy tree Cunoniaceae Weinmannia, which is common on the upper slopes of the mountain. The leaves rapidly wither and fall off to give the impression of wintering. The sap gradually dries out and the limbs become brittle as the process of disintegration sets in. A tongue of this recently affected vegetation extended down the northern slopes as far as a mile from the crater.

As the gas concentration increased, closer to the crater, grasses were killed off, and then the more acid-resistant plant types. One of the last to die was the fern Gleichenia dichotoma, and finally the highly resistant broad-leafed sedge, Gahnia. Gahnia was almost the only plant growing over the greater part of the summit area in 1952. This plant resisted spasmodic exposure to the acid gases even on the rim of the Twin Crater. Only on the floor of the crater and the immediate leeward area was it completely destroyed.

Many of the trees on the nearer slopes south of the crater appeared to have been affected by gas. This zone, however, was not nearly so extensive, and many of them had reached such an advanced stage of disintegration that the questions arise:- Had there been earlier unreported fluctuations in the volume of activity at this centre? Are periodic fluctuations a normal pattern of the activity?

Although earlier fluctuations may have occurred, overall observations suggested that nothing comparable with the recent increase has occurred over the last twenty years. The evidence of the vegetation pattern indicated that sulphurous gases had been characteristically emitted for more than ten years and that before then no gases or, at least, no sulphur dioxide, were emitted from this centre.

STRUCTURE AND PETROLOGY

The structure and petrology of the volcano are a valuable index of past activities, and may be helpful in indicating a future pattern of activity, should it occur.

Field observations suggest that Mount Langila is an easterly migration of Mount Talawe crater. An east-west alignment of these two centres with two minor cones extending down to the shores of Borgen Bay could indicate the presence of a deep-seated fracture or a zone of weakness: a zone which favoured the formation of parasitic cones and upon which Langila was eventually established as the main centre of activity. Superimposed on this east-west structure is a secondary alignment of minor cones with a north-easterly to north-north-easterly orientation. The latter structure seems to be confirmed by disposition of Langila summit craters and vents.

The original and largest of Langila craters lay south-west of the present centres. Subsequent activity migrated to the north-east, breaching the wall of the older crater and forming a smaller crater at the lower level. Thus there appears to be a series of three major craters which decline in size and elevation as the activity moves to the north-east. Either the south-west or the western wall of each crater is the dominant physiographic feature. It is perhaps significant that the centre of recent fumarole activity occurs in the north-north-easterly crater.

Extensive lava flows from these centres have, at some earlier date, covered the country to the north of Langila, almost down to the coast. This great apron of flow material rises in gentle slopes of 5° to 10° to the base of the terminal cone, which appears to be composed of flow and fragmental material. The flows are covered with grass and tree vegetation, without a great thickness of soil cover. Flow structures are still apparent in some of the grass-covered areas; rock towers of plastic deformation and gas blow-holes, typical of lavas, can be seen on the track up to the mountain. The condition of the later lava flows is not unlike that of the 1888 flows of Ambrym volcano in the New Hebrides, but they are probably of earlier origin.

Megascopic examination of the lava types suggests that the petrological trend has been towards a more acid lava. Earlier flows are porphyritic in olivine; later material contains augite and appears andesitic in composition. (See Appendix I for petrographic descriptions of various rocks from Langila.)

Such a trend in volcanoes is not uncommon, and it can be associated with a change in its eruptive pattern. The more fluid basic lavas favour open-conduit conditions with continuous activity and the extrusion of lava. Acid lavas are more conducive to explosive conditions and the ejection of fragmental material.

Examination of the ejectamenta in Langila crater suggests that its most recent activity before the 1954-5 eruption had been Vulcanian in character. The temperatures were below the melting point of the ejected lava. The numerous bombs thrown out from the vent were angular blocks showing little evidence of plastic deformation, and true breadcrusting is rare. The last activity might almost be classified as low-grade Vulcanian tending towards pure steam explosion. Long periods of dormancy and major outbursts are typical of this eruptive mode.

In the event of eruption one could fairly confidently expect a repetition of the vulcanian pattern of activity from this centre. This would involve a violent explosive activity with the ejection of solidified lava in the form of bombs, lapilli and dust. Under normal conditions the danger area around the crater should not exceed two miles, though ash and dust would be deposited over a much wider area. Its distribution would be largely determined by the direction and velocity of the winds prevailing at that time.

THE ACTIVE CENTRES

Apart from the rather extensive areas of hot ground, there were three main active centres in the summit area.

The least active was a small steam explosion crater formed just below the rim of the northern wall of the south-south-west (No.1)crater. It was actively solfataric and its walls had been partly converted into mounds of low-temperature products by the slow emission of gases which had no discernible acid content. Temperatures of 98^{o}C were recorded.

On the adjacent inner side of the major crater rim a more active centre was situated. Explosive activity had blown through a thick flow of lava to form a sheer-sided chasm more than 250 feet in depth. Its shape suggested the name, Chimney Crater, and as such it is referred to in this Report. Active vents at the bottom of this crater produced a fluctuating vapour cloud which always hid the lower levels from view. It was obviously a low-pressure emission because the noise of escaping gas was barely audible at the crater rim. Only during high humidity conditions did a visible vapour cloud from this centre drift over the crater rim. Although the presence of sulphur dioxide in the emitted gases was quite appreciable, the concentration was not high. As evidence of this fact, the upper crater wall, which is frequently enveloped in vapour cloud, had been selected by a bird of the cliff-dwelling family as a nesting place. On one occasion the odour of sulphuretted hydrogen was quite strongly detected in the vicinity of this crater.

By far the most active centre of gas emission was in the main north-north-eastern crater (No.2), from which the recent increase in activity was reported. Here the activity originated from a secondary crater roughly 300 feet in diameter and 120 feet deep, referred to herein as Twin Crater. A medial wall divided the base of the crater into two sections, a large funnel-shaped depression on the eastern side, and west of it a smaller elongate cavity, fissure-like in its dimensions, and hence called Fissure Crater. In the southern end of Fissure Crater three powerful vents emitted high-pressure gas with a loud and continuous roar. On the walls above the vents sulphur and other materials had been deposited from the cooling gases, and the rising cloud of white condensates was swept by the prevailing winds over the outer crater rim, leaving in its wake a bleached landscape of skeleton trees, crumbling grasses, and whitened stones.

Systematic observations were concentrated on this most active centre during the period of the investigation. These observations will be considered in detail.

TEMPERATURES

For the sake of convenience the three major vents were labelled A, B, and C. The A vent lay at the southern end of the medial wall beneath an overhanging ledge of rock. Less than fifty feet away the B vent opened out at the base of the western wall of the Fissure Crater, and the oblique C vent lay roughly ten feet to the east of B vent, thus occupying a more or less medial position on the sloping floor of the crater. The temperatures observed in these three vents are set out below:

Date	Temperature (Centigrade)		
1952	A vent	B vent	C vent
	Degrees	Degrees	Degrees
July 29	203	-	184
30	209	-	217
31	207	-	-
Aug. 1	199	-	-
2	192	-	-
3	204	194	218
6	215	226	228
7	215	220	228
8	220	224	226
9	220	220	226
10	212	220	222
11	212	222	222
14	215	222	227
15	222	225	228
16	216	223	231
26	216	225	237

These temperatures are the most reliable recorded during the period of observation. They are at best an estimate of correct temperatures, as the instrument used was a 200^{o} maximum recording thermometer. Some of these figures represent an average of eight readings which may have differed by as much as 30^{o}C.

Results obtained from the electrical pyrometer were excluded on the score of unreliability. Heat dispersal effects from the structure of the vents and turbulent wind conditions so affected this sensitive instrument that the readings were rejected as inconclusive. The thermocouple also deteriorated as a result of corrosion by the vent gases: although it was shielded from direct contact with the gas by glass tubing, the iron element virtually fell to pieces after two weeks of use.

The magnitude of these temperatures immediately suggests abnormal conditions. The presence of superheated steam implies high-pressure gas accumulations or a rising magma column or both. After the temperatures of Tavurvur volcano at Rabaul began to rise in 1940 they reached such a level in two months, and further increase took place during the ensuing six months before the eruption of June 1941.

With Langila, however, the period of observation did not bring to light a major rising trend in the temperature. That in C vent did appear to rise some 20°C without a noticeable rise in A and B vents. This development appeared anomalous because the proximity of the vents suggested that they were fed from a common conduit. It could possibly be explained by taking into account individual vent structures and changes which occurred during the period of observation.

A and B vents sent out vertical blasts of gas from orifices which were four to six feet in diameter. C vent on the other hand had an elongate orifice of dimensions roughly eighteen inches by six inches. From it emerged an oblique jet of hot gas of such force that, unless special care was taken, measuring instruments attached to a twenty-foot pole were thrown out by the powerful blast. Higher temperatures from this obviously higher-pressure centre were not unexpected.

During the latter part of the period of observation, constructive processes changed the shape of the C vent. Materials brought up by the gases were deposited at the mouth, extending the thin-walled process which formed the containing wall of the orifice and consequently deepening the lateral extent of the vent. The attendant constriction of the gas at this point may have had the effect of increasing the pressure sufficiently to affect the temperatures.

The overall impression of the temperature records was one of instability, and further checking of this important index of internal conditions appeared necessary.

THE COMPOSITION OF THE GAS

Apart from the basic emission of steam - the most common of all volcanic emanations - the main constituent of the gas appeared to be sulphur dioxide. This characteristically choking gas is unmistakeable and its lethal effect on vegetation is well known. Concentrations were always high, the vents being rarely approachable without a gas mask. During turbulent conditions in the fissure crater, the filtering medium in the gas mask was quite unable to cope with the existing concentrations. The filters are made to eliminate concentrations up to two percent.

One fluctuating constituent of the gas caused a stinging sensation in the eyes. It was at first thought to be hydrogen chloride, but a silver nitrate test proved negative. Physiological effects may supply a clue to its composition. It was noted while collecting temperature data that if the observer, without a mask, became enveloped with warm gas he experienced the most acute physiological discomfort. Even with eyes tightly closed and breath held an intense burning sensation in the membranes of the nose and eyes was felt. Condensation on any exposed skin also produced severe irritation. It was concluded from these observations that a higher unstable oxide of sulphur was present in the freshly emitted gases; a conclusion which seemed to be confirmed by the fact that copper wire exposed in the vents was often converted to a blue product, which was presumably the sulphate.

The odour of sulphuretted hydrogen was not often detected close to the vents, but was detected quite frequently at a distance from the crater. This could be explained by assuming either the presence of higher sulphides of hydrogen or an inability to detect higher concentrations of dihydrogen sulphide prevailing near the vents owing to paralysis of the olfactory centres, a recognised physiological reaction to exposure to higher concentrations of H_2S. When it was observed that stainless steel articles were blackened in the crater atmosphere it seemed more likely that the higher sulphides were present.

The fact that the observers did not experience any lasting physiological effects from exposure to the gases suggests that concentrations of the very poisonous higher sulphides were low. The extreme irritability and nervous depression experienced after a prolonged period of work in the crater were probably due more to a deficiency in oxygen than to the effects of poisonous gas. The ineffectiveness of the filtering medium in the gas masks may have been a contributory factor.

CHANGES AT THE TWIN CRATER DURING THE FIRST INVESTIGATION

Changes in the actual volume of emission were difficult to gauge owing to the great variation in weather conditions. Humidity, winds and light all affect the appearance of a vapour cloud. It is not practicable to allow for all these variables when the weather is unsettled. It must suffice to say that there was no obvious change in its total volume during the period of observation.

Minor changes occurred at B and C vents. The diameter of B vent increased by more than a foot at the end of July. Dust ejected during the process covered the bright yellow deposit of sulphur on the crater floor. About the same time a small fissure opened beside C vent and began to emit boiling water and grey mud.

A fortnight later the thin-walled process forming the aperture of C vent began to grow as the result of deposition of emission products. The growth of the wall doubled the horizontal depth of this oblique aperture. At the same time the small adjacent fissure began expelling a yellow-brown mud with its gas.

In the second week of August the brilliant yellow sulphur areas on the crater wall above the vents began to darken in colour to a drab yellow; no further change took place during the remaining period of observation. The change was undoubtedly caused by an alteration in the composition of the emitted gases.

SOUND EFFECTS

Surface Noises

Basically the gas escaping from the high-pressure vents produced a flat continuous roar of an intensity that made speech impossible in certain parts of the crater. The pitch of the sound varied with the position of the observer, owing to acoustic effects produced by the crater walls and variation in the individual vent structures.

From the broad A vent, a low-pitched fluted roar was produced - the sound one would expect from gas passing through a long cylindrical pipe. Close to the more constricted B and C vents, the noise was flat and of great intensity. Away from them, however, high-pitched overtones could be heard - localised constriction whistlings which were drowned out near the centres.

Underlying the basic sound effects a definite beat was perceptible. Its frequency was difficult to establish owing to waxing and waning of its intensity. It was more perceptible at a distance from the crater and could sometimes be heard at the camp site.

Close to the vents a secondary phenomenon was observed which may have been related to sounds at depth. The rock near the vents frequently vibrated sufficiently to be felt by an observer. A wooden pole held against adjacent rock always made apparent a definite percussion effect in the character of the gas emission. It suggested that the gas was supplied at depth by very numerous separate small explosions - producing at the surface a pattern of continuous sound and gas emission.

Subterranean Sounds

The first experience of deep-seated sound effects was disturbing, not because of its unexpectedness so much as the hour of its occurrence. At 0230 hours on 22nd July the observer was awakened at the base camp by a noise like a muffled explosion. The sound was more of a low-pitched roar than a rumble. It was accompanied by two powerful vertical bumps and a very short-period ground movement. The phenomenon appeared to last little more than a second. Recurrence at 0730 hours caused some alarm among natives at the camp.

Subsequent occurrences of this phenomenon were observed on 2nd and 15th August. The same low-pitched muffled roar was accompanied by a brief ground quiver. The vertical bumping was not observed again after the first occurrence.

There were probably other unobserved occurrences during the period of observation. The intensity of the phenomenon was such that it would not have been perceptible a mile from the crater and the perpetual noisy winds at the crater elevation were not conducive to good conditions of observation.

These sub-explosive phenomena were the only unquestionable evidence of subterranean developments to support the abnormal temperature and gas conditions in the crater. They were probably caused by readjustments in the pressure system in the conduits beneath the volcano. The release of volumes of gas at the surface vents may destroy the equilibrium in the underlying gas reservoirs, with consequent spasmodic adjustments.

The phenomenon was significant in that it confirmed the existence of high pressures at depth. Before eruption, a marked increase in the frequency and intensity of these adjustments could be expected.

The existing conditions were not regarded as critical, in that their magnitude and frequency did not appear exceptional, when compared with similar observation during phases of the activity of Lamington and Bagana.

EARTH TREMORS

Unless the seismic intensity is extraordinary, the observation of volcanic tremors without instrumental aid is little better than guessing.

Mr. Single reported three tremors felt on 5th and 6th in the villages of Gie, Laut, and Mangailapua. The coincidence of regional tremors, reported from other parts of the Territory about this time, throws some doubt on their volcanic origin. It is often difficult to differentiate the typical slight volcanic tremor from a distant regional tremor.

The luluai Aisapua reported three tremors occurring on the 11th and 12th of the same month. They were allegedly felt at Nekarop, a village five miles south-east of Langila. There was no way of checking the authenticity of this report.

Observations at the crater during the period of the investigation yielded little confirmatory evidence. J.G. Best felt a slight ground movement in the crater on one occasion. Being an isolated observation it is suspect, for there is too much room for human error under such conditions.

A first attempt was made to reduce the likelihood of error by using a mercury pool - with negative results - and later J.G. Best constructed a recording pendulum from scraps of salvage material. This crude instrument was set up to check for ground movement during the ten days absence from the crater, 16th to 26th August. One small tremor appeared to be recorded during that period. When

Taylor returned to Lamington, he constructed a replica of this pendulum. Tests did not supply reliable evidence of its effectiveness in detecting tremors, so that even this evidence at Langila is suspect.

There is no real substitute for a properly constructed seismograph for the observation of the all-important seismic data connected with volcanic activity.

Recent landfalls in the craters may be confirmatory evidence of local earth tremors. All three craters showed evidence of recent falls. Those of the Twin Crater, however, may have been caused by undermining of the walls by the gases associated with the recent increase in activity. It is unlikely that the falls were caused by regional tremors, because Brisbane seismological station reported that no unusual tectonic movement had originated from the Western New Britain area during the previous six months, and the mission people at Kalingi found it difficult to recall the last earth tremor felt in the area.

It seemed quite possible that occasional volcanic earth tremors were occurring, but the evidence for them was by no means conclusive.

It might be argued that the ground vibrations associated with subterranean noises were volcanic earth tremors. In the strictest sense this was probably true. Taylor considered that the short-period movement and brief duration of this phenomenon indicated superficial energy of a relatively low order which was not to be compared with the forces involved in producing a volcanic earth tremor of normal magnitude.

CONCLUSIONS DRAWN FROM THE FIRST INVESTIGATION

At Langila a number of phenomena were present which are usually recognised as premonitory systems of eruption:

(i) Increase in volume of gas emission;
(ii) High concentrations of sulphur dioxide;
(iii) Abnormally high temperatures;
(iv) Subterranean noises.

On the other hand, the absence of definite seismic phenomena, or of an unquestionable rise in the temperature trend, and the fact that no halogens were detected in the emitted gases, indicated that eruption was not immediately imminent. The data were of course incomplete in that there is no substitute for reliable seismic recording.

The importance of the presence in the gases of high concentrations of sulphur dioxide as a critical indicator might be questioned for two reasons. First, it had been reliably established that this gas was characteristic of the emanations nearly ten years previously; and secondly, surveys of volcanoes in other areas have suggested that the emission of sulphur dioxide may be a normal feature of individual volcanoes. It was possible that the absence of halogens might not be significant for a similar reason. However, the fact that there was no sulphur dioxide, nor any activity at all from Twin Crater in 1938, and the close parallel between the condition of this crater in 1952 and that of Matupi crater in Rabaul before the 1941 eruption suggested that such doubts were not valid.

For the remainder of the evidence, the nature of the gas emission and temperature levels were an unquestionable indication that gas had accumulated at high pressure in the reservoirs beneath the volcano. The nature of the adjustments in these reservoirs, indicated by the sub-explosive sound phenomena, suggested that changes were confined to shallow-focus gas accumulation immediately beneath the mountain. The intensity and frequency of the adjustments appeared to be of too low an order to suggest critical conditions. A marked increase in such phenomena could be expected before the inception of an eruption.

It was conceivable that under the above conditions relatively superficial gas accumulation could continue to a critical point, whereupon a steam explosion would not necessarily be preceded or accompanied by appreciable seismic disturbance. The time factor suggested that its effect on the surrounding country would be limited to a relatively small area.

Alternatively the existing conditions could have been the beginnings of a slow increase of activity which would eventually culminate in strong seismic disturbance, as a prelude to a powerful Vulcanian eruption involving the rise of fresh lava from deep-seated sources.

It was hoped that observations to be undertaken in October, 1952, would yield information that would clarify these questions.

RECOMMENDATIONS MADE

No movement of native people was considered necessary as a result of this investigation. North of the volcano, settlement is confined to a group of coastal villages lying about seven miles north-west of the crater. They contain roughly six hundred people. These people are unlikely to be seriously affected by any normal eruption of Langila. South of Langila, settlement is closer but no village is within three miles of the active centre. Should an eruption occur during the north-west season, temporary evacuation of the near villages south-east of the crater may be necessary, as the area may be heavily dusted.

The Kalingi area is under the control of Talasea Government station, which is more than 100 miles away. There was no wireless transmitter at Kalingi and a boat was not always available.

If any sudden development of the volcano were to take place, it might be several days before the official local observer, Father McSweeney, could get news out. It seemed advisable that the Administration should make a transmitting set available to Father McSweeney for a nominal period of six months.

Access to the area is gained by trawler from Lae. Provided that weather conditions are favourable for navigating the Siassi reefs, the journey takes approximately twenty hours. Maintenance of the Gloucester air-strip as an emergency landing ground appeared desirable.

(Shortly after this time an R.A.A.F. aeroplane made an emergency landing at Gloucester strip. The fortuitous clearing of the strip did at least serve one good purpose. Presumably in the event of a volcanic emergency it would provide a rapid means of access to the area.)

THE SECOND INVESTIGATION - G.A. TAYLOR AND J.G. BEST OCTOBER - NOVEMBER, 1952

Further observations of the activity of Mount Langila were carried out during October and November 1952 by G.A. Taylor and J.G. Best.

A camp was established on the upper slopes of the volcano on 18th October and observations were continued until 4th November. The active area was examined for changes in conditions, and instrumental data on temperatures and seismic phenomena were collected. Cement blocks were constructed for the installation of an improvised seismograph and the tiltmeter. The changes observed since the earlier visit are described below.

CHANGES IN VEGETATION

A marked extension of the tongue of affected vegetation on the northern slopes of the mountain was observed. Leafless trees extended half a mile farther from the crater than the August limit. At its maximum the zone reached about one and a half miles from the crater. This increase was attributed more to a persistence of sulphurous gases brought down by the southerly winds than to any increase in gas volume.

The change of season was taking place during October and the north-west winds were becoming more consistent. As a result the trees on the margin of the affected area on the northern slopes were re-shooting and the trees on the southern slopes were being stripped of their foliage.

THE CRATER

A landfall had occurred in the Twin Crater. A mass of material had collapsed from the walls above the main active vents, covering the greater part of the floor of the Fissure Crater with coarse rock debris and large boulders. The access ladder had been destroyed by this fall and the B and C vents appeared to have been covered.

The vents had re-established themselves through this mass of new material with some alteration to their shape and size. The B vent appeared to be slightly smaller and the C vent emerged from a cluster of four separate openings, all nearly as large as the single opening they had replaced.

Although the A vent on the medial crater wall appeared to have suffered little change, close inspection, made possible by the fall of boulders around the lower lip, revealed that the gas came through a fissure extending back under the crater wall. Boulders partially obstructed the fissure but appeared to have little effect on the release of gas.

SOUND EFFECTS

The noise of escaping gas had become less intense and appeared to have dropped since the alteration in the vent structures.

No subterranean sound effects were observed during the period of this inspection.

TEMPERATURES

The following temperatures were recorded:

Date	Temperature (Centigrade)		
1952	A vent	B vent	C vent
	Degrees	Degrees	Degrees
Oct. 20	200	-	-
21	208	-	-
22	205	200	180
23	209	194	212
24	209	194	212
25	208	190	213
26	-	200	210
28	204	179	209
29	180	-	209
30	204	200	211
31	182	170	210
Nov. 2	196	188	201
3	199	165	205

Compared with conditions in August, there appeared to be a fall of 20-30°C in B and C vents and roughly 10°C in A vent.

The generally lower readings of B vent were due to a marginal heated zone which affected the pyrometer readings. If such errors, caused by technical difficulties in the application of the pyrometer, are allowed for, the results give the impression of static conditions during the period of observation.

The temperatures remained abnormally high but no clearly defined trend was apparent.

GAS EMISSION

Little overall change was apparent in the total volume of gas emitted from the crater; the volume had perhaps decreased slightly since the previous inspection, but the change was of such an order that it may have been explainable by an alteration in weather conditions, or by minor constrictions affecting the altered vents.

Similarly, gas composition had not changed very noticeably, except that sulphuretted hydrogen was more obvious; it was more distinct within the crater area and was frequently a nuisance at the camp when night winds carried the gases in that direction.

COMPOSITION OF THE CONDENSATES

Condensates collected from A and C vents in Langila crater during the July-August investigation and from C vent during the October investigation were analysed by Avery and Anderson of Melbourne. The results revealed changes in the composition of the emission products which might be related to the volcano's slowly rising potential for explosive activity.

The C vent samples were collected by placing a glass funnel near the mouth of the vent to allow part of the gas jet to pass down a length of glass tubing to a condensation flask. The A vent sample was laboriously collected by drawing gas slowly from the vent by means of a primitive aspirator. Immediately sufficient bulk of condensate was obtained the liquid was poured into a glass stoppered bottle which was sealed with paraffin wax. The volume collected in each case was 106 millilitres.

The samples were colourless liquids containing different amounts of white or yellowish white flocculent sediment in suspension. The sediment in all samples consisted almost entirely of colloidal sulphur. Definite traces of selenium were found in some of them. Others contained no detectable amounts of selenium.

The proportions of colloidal sulphur were as follows, in grains per litre:

	Vent A	Vent C			
	31.7.52	14.8.52 (1)	14.8.52	29.10.52	31.10.52
Colloidal sulphur	Very small amount	34.00	2.986	4.753	4.386
Selenium	Nil	Present	Present	Not detected	Not detected

The very small amount of sulphur in the vent of A sample and the large amount in vent C 14.8.52(1) sample can be attributed to variation in the methods of collecting. The sulphur precipitates in the tube from the vent to the condensation flask. With the A vent sample, the low pressure aspiration left most of the sulphur in the tube, and with the C vent sample a higher pressure spasm of gas forced a lot of the precipitated sulphur into the condensation flask.

When the precipitates has been removed from the samples they were colourless, strongly acid in reaction and smelled strongly of sulphur dioxide. The analyses showed that none of the samples contained sulphides or free hydrogen sulphide. No carbonates, nor bicarbonates, were present and no free carbon dioxide was detected. Only unimportant traces of hydrofluoric acid were found. Strong traces of boric acid and arsenic compounds were detected in some of the samples. All samples contained free hydrochloric acid, sulphuric acid and polythionic acid in solution. Doubtless, the salts of some of these acids were in solution, but no estimate can be formed as to the manner in which the various radicles were combined.

The total acidity of each sample is expressed in the following table, arbitrarily calculated as sulphuric acid.

Vent	Date	Titratable Acidity calculated as H_2SO_4 (grams per litre)
A	31/7/52	16.513
C	14/8/52(1)	19.012
C	14/8/52	20.629
C	29/10/52	42.483
C	31/10/52	45.374

The relative proportions of the various forms of sulphur present is as follows:

Sulphur

Calculated as S (grains per litre). In sediment-free samples

Vent	Date	Sulphite S	Sulphate S	Polythionate S	Total S
A	31/7/52	0.739	0.114	0.257	1.110
C	14/8/52(1)	0.975	0.474	1.233	2.682
C	14/8/52	1.202	0.440	1.208	2.850
C	29/10/52	3.443	3.710	6.561	13.714
C	31/10/52	3.653	3.770	5.311	12.734

The analytical results confirmed the opinion expressed in the first report on Langila that the emanations contained sulphur dioxide and sulphur trioxide. The presence of polythionates suggested that the hydrogen sulphide in the emanation was largely eliminated by interaction with the above gases to form polythionates and free sulphur.

The variation in acidity of the condensates indicated that the concentrations of the acid gases more than doubled between July and October. At the same time the relative proportions of the constituent acid gases was altering. The proportion of the sulphite component to the other forms of sulphur fell during this period and the proportion of sulphate rose. This variation suggests that the concentration of sulphur trioxide in the emanations was increasing much more rapidly than the sulphur dioxide. The change in gas composition may have accounted for the change in colour of the sublimation products which formed on the rocks above the vent.

The presence of polythionates has been reported (Maclaurin, 1911) in the waters of the crater lake on White Island volcano in New Zealand.

It is unfortunate that no further samples of condensates were collected from vents of Langila before the eruption; for the above results suggest that a progressive change of gas composition may be an important indication of the volcano's increasing potential for activity, and further confirmation of this trend might have supplied more valuable material for prediction.

The collection of condensates from volcano vents, difficult as it may be under some circumstances, seems a far simpler method of obtaining a measure of the concentration of acid gases than collecting definite volumes of the gases at high temperatures. The above results suggest the condensate method as a promising field for vulcanological research.

SEISMIC ACTIVITY

When Taylor and Best arrived at Kalingi, Father McSweeney reported that three tremors had occurred on Saturday, 11th October. The initial shock had been of an intensity sufficient to cause breakages in the Mission Dispensary and the later shocks had been smaller.

The improvised seismograph which had been left set up at Langila had made a record of one major earthquake and two smaller shocks. The direction of movement of the major shock appeared to be south of west.

There is little doubt that the earthquake of the 11th October was responsible for the collapse of the crater walls which had taken place in the Twin Chimney Crater of Langila.

During the period of observation three low intensity earthquakes occurred:

1140	hours	31st October
0445	hours	1st November
0345	hours	6th November

Additional shocks on 1st November were reported by the Niapaua Village people, who live five miles south-south-east of Langila.

After the inspection of Langila, reports of unusual seismic activity on Umboi Island during October and November were investigated. The coincidence of the Langila shocks with the time of strong movement on Umboi suggests that the Langila tremors were originating from a centre on or near Umboi.

At Umboi the seismic disturbance began with a powerful earthquake at 10.17 hours on 11th October. It was estimated by A.D.O. Parish to be of intensity 7 (Modified Mercalli Scale) at Awelkom Mission. The shock was felt throughout the neighbouring islands and as far afield as Popondetta. The range of the earthquake suggested an origin of considerable depth.

Eighteen after shocks occurred within the next four hours and they continued at a high frequency throughout the day and night. By 15th October the frequency had dropped to two or three tremors per day. On the 22nd it increased to four or five per day. On the 28th the intensity of the shocks began to increase. One tremor on the morning of the 31st lasted a quarter of an hour; it overturned bottles and spilled liquid from open containers at Gizarum Mission. Ten tremors occurred on 1st November between 0400 and 0700 hours and four tremors on 6th November.

The position of the epicentre of the disturbance is difficult to determine from the effects of the initial earthquake. The fact that native houses collapsed in villages of Aronaimutu, Mandok and Garu (Pl.1) suggests that the focus lay beneath the southern end of the island. Of two collapsed houses examined at Aronaimutu one fell in a direction bearing 40° magnetic and the other 60° magnetic. As strong magnetic anomalies are said to exist along this coastline it is not possible to give a true bearing. The approximate direction of fall was east of north.

However, observers at Gizarum Plantation asserted that the earthquake appeared to move from east to west, and evidence of severe ground movement in other areas points to a focus more towards the centre of the island. On the road between Tarawe and Opai villages, large boulders were displaced on comparatively level ground and cracks in the road a foot wide were reported. A.D.O. Parish reported a major landslide in the vicinity of the Arot village, north-east of Gizarum.

The Simban River, which drains the southern end of the island, was strongly discoloured after the earthquake, presumably from landslides and extensive collapse of banks. Hence the most widespread and consistent area of damage lies in the south of the island.

TILT

In the study of Asama volcano, Japanese scientists noted that abnormal tilting of the mountain preceded explosive actively by one to one and a half months. Before the eruption there of April 1934 the tilt varied by twenty seconds.

At Langila a tiltmeter was set up on a small concrete block, dimensions 2 x 2 x 1 feet, situated on the north-eastern slope of the volcano, 550 feet below the crater rim. The tiltmeter indicated a most extraordinary crustal movement. Orientated on a bearing 245° through the crater, the tiltmeter indicated a fall of five minutes within the first twenty-four hours. After the 22nd

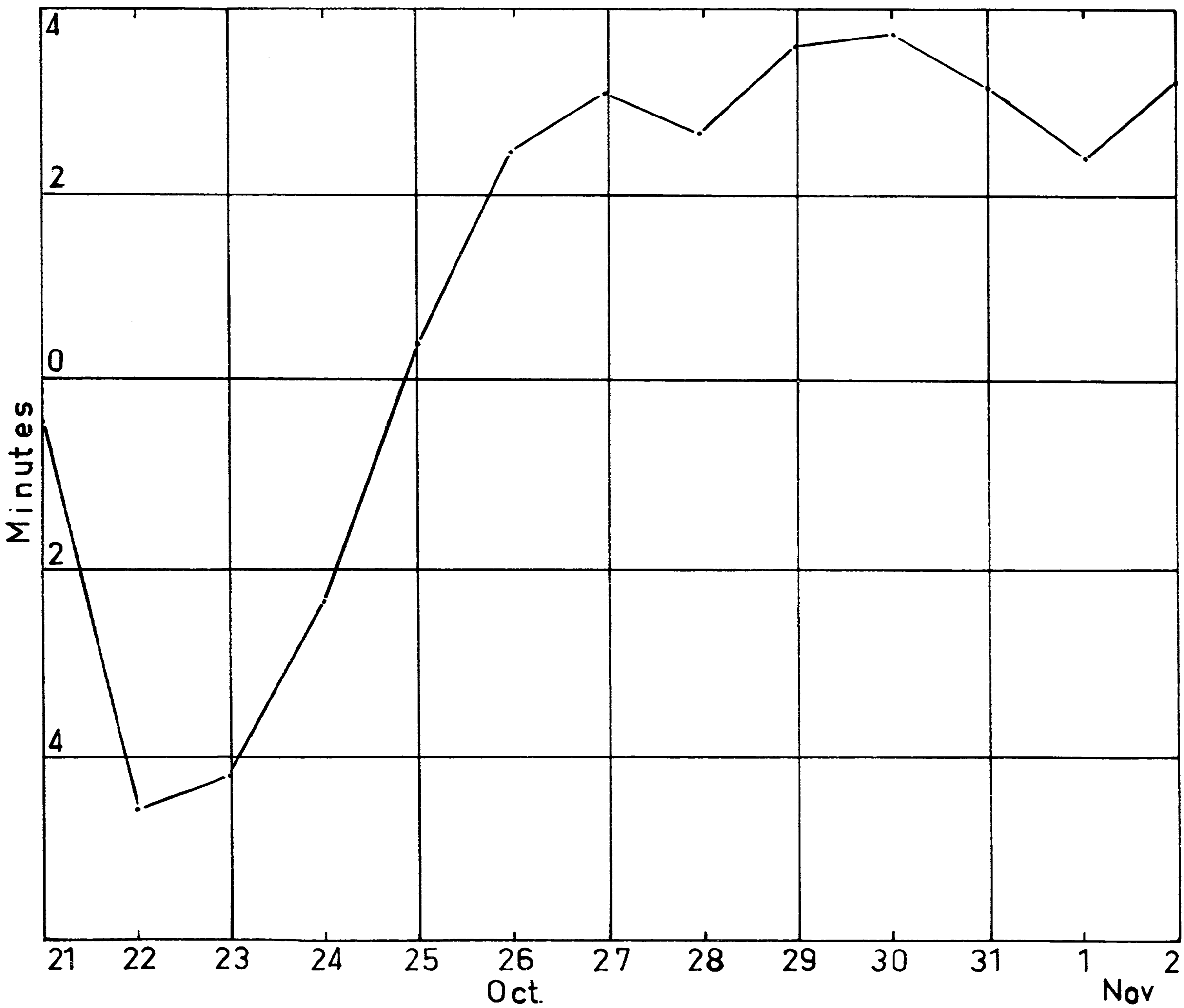
PLATE 9

TILTMETER READINGS

MT. LANGILA

Oct. 21st.- Nov. 2nd. 1952. Readings taken at midday.

Rising graph denotes tilt towards crater.



October, apart from minor fluctuations, the tilt rose steadily day by day through a range of eight minutes. It reached a broad peak on 30th October, declined by nearly one and a half minutes by 1st November and began to rise again slowly (Plate 9).

This unusual movement was at first viewed with some concern, since it was the type of earth movement one would associate with a rising viscous magma. Crater conditions, however, gave little support to this assumption, because conditions appeared virtually static.

In the absence of volcanic confirmation, a relationship with the Umboi seismic crisis seemed probable. Some support to this assumption was given by the earth tremor pattern. As the tilt graph approached its peak the intensity of the earth tremors on Umboi increased. A fall of one and a half minutes occurred during the period of greatest seismic activity, from 30th October to 1st November.

Tilt readings made in locations remote from Langila tended to conform Umboi rather than Langila as the centre of the disturbance. Readings taken near Kalingi Mission, at Gizarum, and Lab Lab, all showed an extraordinary range of variation.

At all stations a fluctuating movement of the instrument repeatedly occurred for protracted periods. It indicated a persistence of long earth waves presumably emanating from the Umboi centre of disturbance. Sensible tremors were rarely associated with this movement.

Of interest is the occurrence of a remarkable period of fluctuation between 1200 and 1400 hours on 5th November. This period of movement may have been due to aftershocks of the North Pacific earthquake which caused widespread tidal waves throughout the ocean. A two to three foot wave partially covered some of the low-lying Siassi Islands late in the afternoon of this day.

The absence of any precedent for such an extraordinary range of tilt as indicated by the readings taken on Mount Langila suggests that the results may be suspect, but consideration of the incidental factors such as temperature variation, shrinkage of the concrete block, or insufficient stability of the block, which may have influenced the readings, does not entirely explain away the apparently anomalous behaviour of the instrument, so the observations are placed on record with qualification.

The measurements of tilt at places in the region relatively remote from the volcano tended to confirm the reality of an extraordinary regional tilt. Here again, however, the foundations of the instrument were subject to possible incidental movement; this time from temperature changes. Readings at Warimo village on the coast, eight miles from Langila, produced a movement which ranged through two and a half minutes during a period of twenty hours; readings on the west coast of Umboi Island, forty-eight miles from Langila, ranged through one and a half minutes in nine hours; at Lab Lab on the east coast of Umboi, thirty miles from Langila, the tilt range mounted to one and a half minutes in four hours. The instrument was aligned at each of these stations through the epicentre of the earthquake disturbances, which was presumed to lie on the southern end of Umboi Island. This assumption was based on the intensity of the damage in that region from the earthquake of 11th October. (Position, according to U.S.C.G.S., 6^{o}S, 149^{o}E.) Unfortunately readings at the above sites were of insufficient duration to assess the daily fluctuation due to temperature changes. The temperature factor at Gizarum would have been negligible because the readings were taken during a period of continuous light rain when the temperatures would have been nearly static. At Warimo and Lab Lab temperature variations may have contributed to the range of tilt variation.

The view that tilt readings were essentially due to crustal tilt rather than incidental factors is influenced to a certain extent by the fact that, at each of the stations, a fluctuating movement of the tiltmeter bubble occurred spasmodically, indicating the presence of long-period ground-waves which were undoubtedly due to crustal adjustments which followed the strong earthquakes of 11th October.

Subsequent developments in the western volcanic arc strongly suggest that the abnormal activity of Langila and the Umboi earthquakes were early manifestations of unusual regional stress conditions which were quite widespread.

CONCLUSIONS DRAWN FROM THE SECOND INVESTIGATION

1. Abnormal temperatures at Langila volcano persisted but no clearly defined trend was apparent. A fall of some 20-30^{o} had taken place since August.

2. The total volume of gas emission might have declined slightly but the content of sulphuretted hydrogen had apparently increased. The proportion of acid gases, particularly of the higher oxides, had increased markedly.

3. Subterranean adjustments indicated by the deep-seated sound effects of early observations were no longer evident.

4. A regional seismic disturbance centred on or near Umboi was producing crustal distortional effects which were very marked in the Langila area.

An assessment of the significance of these factors did not lead to very reassuring conclusions.

It is not unusual for a volcano to show signs of increasing activity for a period and then subside again into dormancy for many years. A typical example is the behaviour of Mount Catarman in the Philippines. In 1897 this mountain began emitting sulphurous vapours which caused the destruction of the agricultural areas on the leeward slopes. The abnormal gas emission lasted six years and was frequently accompanied by subterranean sounds. By 1902 the activity had died away. It was not until 1948 that a major eruption of this volcano took place.

To conclude at this stage that Langila would exhibit a similar pattern would be premature, particularly in view of the unusual seismic disturbance in the region. A broad relationship between tectonic disturbances and volcanic eruption sometimes holds. As instances of such a relationship the following may be quoted: Katmai eruption 1912, Rabaul eruption 1941, Ambrym eruption 1950. Each of these outbursts was associated with regional seismic disturbance.

Hence it appeared advisable to keep this area under special observation for the time being, and the following recommendations were made:

1. That a wireless transmitter (as had been formerly suggested) should be supplied to the Local Observer, Father McSweeney of Kalingi Mission, to enable him to report immediately any sudden change in conditions of Langila, and that when this set was installed, receiving stations should be instructed to give special priority to vulcanological reports.

2. The Gloucester airstrip should be maintained as an emergency strip. It had already been cleared and used but would require further attention if it were to remain open. Stumps on the eastern end of the strip should be removed.

3. An inspection of the volcano should be carried out early in March 1953 *, and this survey should include (a) a checking of Ritter Island for gas ebullition and signs of activity and (b) an inspection of the hot points on Umboi Island with particular attention to the crater group near Awelkom Mission.

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* Owing to abnormal activity elsewhere in the region, this survey could not be made, but an inspection of the thermal areas in Umboi Island was made by J.G.Best (1953) in late January and early February 1953.

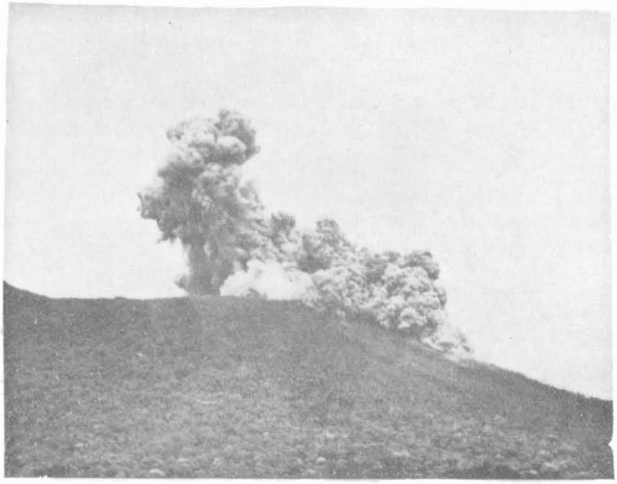


Figure 1. (1255½ hrs.)

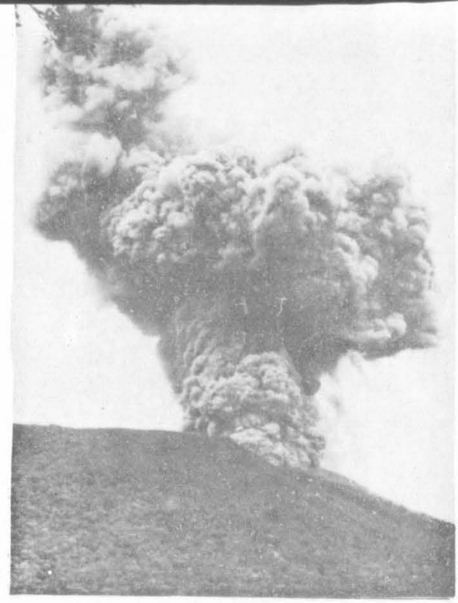


Figure 3. (1257 hrs.)

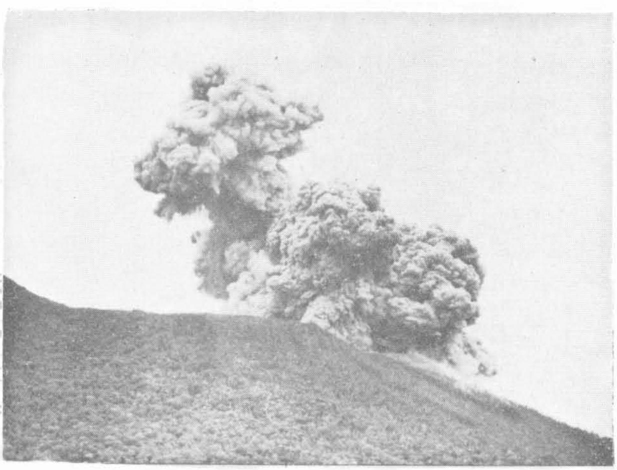


Figure 2. (1256 hrs.)

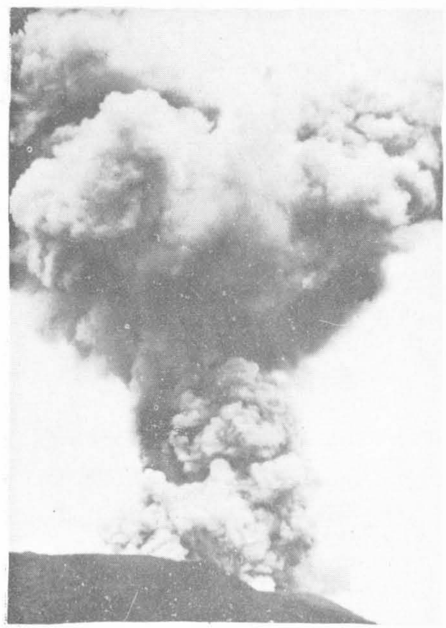


Figure 4. (1259 hrs.)

PLATE 10.
Comparative views of eruptive activity, 29th May, 1954.

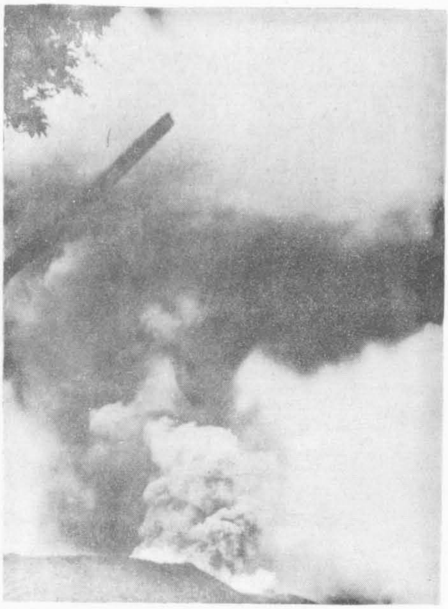


Figure 5. (1304 hrs.)

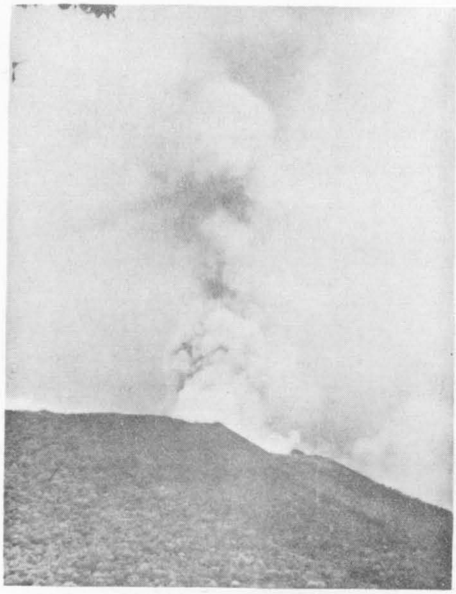


Figure 6. (1330 hrs.)

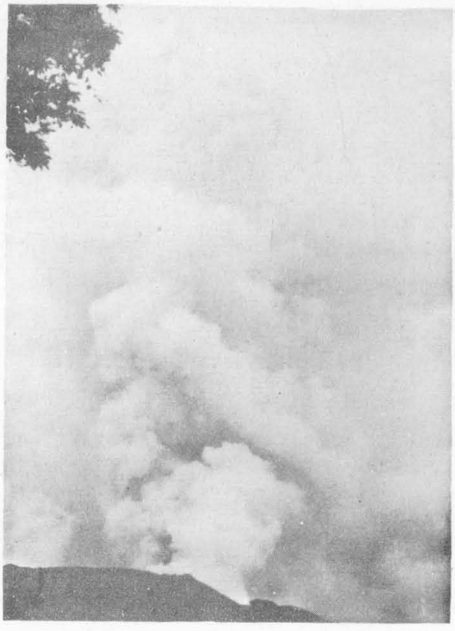


Figure 7. (1337 hrs.)

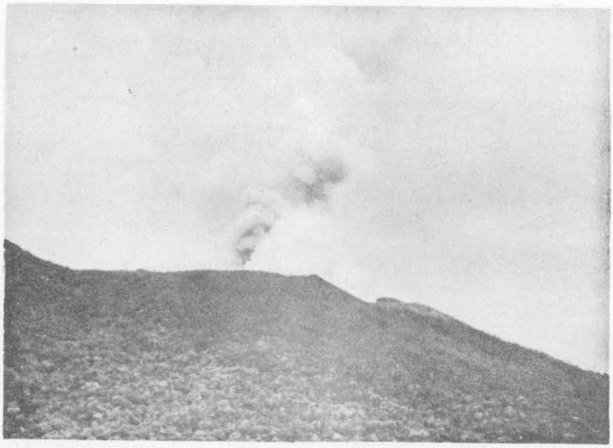


Figure 8. (1405 hrs.)

PLATE 10.
Comparative views of eruptive activity, 29th May, 1954.

THE ERUPTIVE PERIOD MAY 1954 - MARCH 1956

Langila crater burst into active eruption on 18th May,1954, and M.A. Reynolds, who was at that time in charge of the Rabaul Observatory, was assigned to make an investigation of the area involved.

The main objective was to ascertain the possible danger to the European and native population in the vicinity, but some details of the explosive phases of the activity were obtained and a brief survey of the crater was conducted when the explosive phases had temporarily ceased.

DETAILS OF THE INVESTIGATION

The first news of an eruption at Langila Crater was received in Rabaul on 20th May, 1954, but owing to a delay in the departure time of the Qantas aircraft, Reynolds was unable to travel to Lae until the 24th May. An aerial in - spection of the crater was made on this trip and further observations were possible from the Avro Anson aircraft en route to Cape Gloucester airstrip on the following day. Explosive phases of the activity were witnessed from the airstrip shortly after arrival, from a native canoe about one mile out to sea, from Warimo, one of the Kalingi group of villages, on the 26th, and from the Government ship "Alia" on the morning of the 27th.

On the afternoon of 27th May, Reynolds, accompanied by Patrol Officer T. Dwyer, police boys and carriers, walked from Lagoon Point to Aipati (Pl. 1). Departure for Langila was delayed until the morning of 29th May because of rain, and it was not until mid-day that a camp was established in a position from which observations of the crater could again be made. This was an excellent vantage point, situated on the peak about 6,000 feet south-south-east of the active crater. When observations began gases were being emitted and formed white cumulose clouds which ascended to 1,000 feet above the crater. At 1255 hours bombs and dust were ejected from the crater with explosive violence (Plate 10). By 1300 hours the dark grey cumulus clouds formed by dust and vapour had risen to a height of roughly 4,000 feet above the crater. The emission of dust and vapour continued thereafter until at least 1450 hours, when cloud from the south-east moved between the crater and the observation point and obscured the view. This activity confirmed an earlier impression, formed from information supplied by observers in the locality and from personal observations, that in view of the physiography and the prevailing south-east wind, there was no danger to either Europeans or natives provided that pig-hunts in areas north of Langila were prohibited, and provided that the track between Aipati and Cape Gloucester were avoided. With these two conditions, permission was given for the start of the "sing-sing" at Kalingi, where about 1,000 natives had gathered.

A report that Manam Island had erupted had been heard on the radio on the evening of the 28th May, and Reynolds was required to leave Langila to investigate this report. He returned to Kalingi on 11th June.

Observations had been continued during his absence by Patrol Officer Dwyer, who reported that there had been no explosive activity since 5th June as far as could be ascertained under prevailing adverse weather conditions.

The Kalingi "sing-sing" with the accompanying complicated process of pig exchanges had begun just before 11th June, and it was not possible to obtain carriers until 16th June. The party then travelled by canoe to Sahe, and Niapaua was reached that evening. On the following day, after a preliminary investigation of the crater had been completed, a camp was established about one mile south of Langila near the track which runs from Aipati to Cape Gloucester. The crater was inspected and a brief survey conducted during the next two days. Rain, accompanied by a cold wind from the south-east, caused discomfort, particularly to the police boys and carriers who ventured into the crater. In addition low-lying cloud enveloped the crater most of the time and restricted movement in and around the crater.

Under the circumstances Reynolds decided to return to Sahe on 20th June, and proceed next day by native canoe to Warimo. In view of the nature of the activity and because of Rabaul commitments, a longer stay in the area was unwarrant ed and Reynolds departed for Talasea on the mission boat on 22nd June, and returnec to Rabaul by air on 24th June. At the time of departure, a small white cloud was being emitted from Langila Crater.

This form of activity continued thereafter and, apart from an explosiv phase recorded by Patrol Officer Dwyer on 2nd July, no other explosive phase was witnessed until 14th July. From then until 5th August there were numerous dust emissions and the inhabitants of the area on the western coast between Cape Glouces ter and Lagoon Point were subjected to considerable discomfort by the dust and gas. (Plate 11, Fig 1)

Large quantities of dust settled on the mission buildings, the neighbouring villages and gardens, and many natives were afflicted with sore eyes and throats. The gas accompanying the dust clouds would probably have aggravated such afflictions. As a result, local natives were apprehensive about this activity - the more so when dust clouds obscured the sun and it became quite dark. These details were received in Rabaul from Patrol Officer Dwyer and the master of the "Theresa May", and it was decided that Reynolds should return to the area as soon as possible to determine whether evacuation was necessary. Although evacuation would have been a simple matter, it was considered undesirable, because distribution of natives from the coastal villages to other villages to the south would hav resulted in a drain on the food reserves of these places and this would have eventu ally created a food shortage.

Accompanied by the Assistant District Officer, Talasea, and Dr.J.MacKa District Medical Officer, Reynolds arrived at Kalingi on 6th August. Although ther had been recent heavy rains, a mantle of dust still lay over most of the vegetatio the area. Local inhabitants were questioned and a medical check was conducted on

Figure 1.

Eruption seen from vicinity of Patrol Rest House, west of Kalingi Mission, 29th July, 1954. Photo by T. Dwyer.

Figure 2.

Remains of vegetation, upper part of north-eastern slopes of No. 1 Crater. Photo by T. Dwyer, 17th June, 1954.

Figure 3.

Bread-crust bomb from May-June, 1954, eruption. Photo by M. A. Reynolds, 19th June, 1954.

PLATE 11.

the next day. The following facts were established:

1. The natives were in good health and had suffered no ill-effects from the dust and gas;
2. As a result of the rain, gardens were in good condition and it seemed unlikely that food crops would be affected;
3. Many natives from the Kalingi villages, which because of their position were most likely to suffer from the present activity, had departed on their annual trading visit to the Kombi villages, about fifty miles east, on the north coast of New Britain.

It was therefore considered that there was no immediate need for evacuation but that Reynolds should stay in the area for a few days to observe the effects of further activity. There were no explosive phases during the following days, and because of this and the fact that the "Theresa May" was available for transport back to Talasea, he left the area on 23rd August. Explosive activity which commenced on 26th August was first reported by the master of the "Airco" and a later report including some details of activity up to 30th August was received from Captain Harris of the U.S.Survey Ship.

Additional activity in early September was reported by the master of the "Matoko", and this continued until 12th September. Further eruptions were reported on 1st October, 30th October and 6th November 1954, 15th to 17th February 1955, and on 1st, 6th,and 16th June 1955. Light activity also occurred in March 1956.

PRE-ERUPTION CHANGES

Volume of Gas Emission and Effect on Vegetation

Although No.1 crater had been emitting gas and vapour for at least 16 years and continued in this solfataric condition throughout the present activity, other changes in the activity of Langila Crater date back to at least 1944. These have occurred entirely in No.2 crater. Fisher (1939) refers to this crater as inactive, but the native, Karia, reported that the vents which formed the Twin Crater within No.2 crater were slightly active in 1944. At that stage, some vapour could be seen from the coast during wet weather, and trees in the immediate vicinity of the crater were killed by the gas. By the end of 1952 the volume of gases and vapour being emitted from the Twin Crater had increased, and there was an area of dead and dying vegetation on the north-western flank. The south-eastern portions of Langila Crater were apparently not affected to the same extent as the north-western flank, and one must assume that either there had been fluctuations in the increase in activity with greatest emissions of gases during the seasons when winds were predominantly from the south-east (April-September), or that most of the area of dead and dying vegetation on the north-west slopes had resulted from the increase in activity reported by Father McSweeney in May, 1952. In view of the fact that this area of afflicted vegetation was noticeably extended to the north-west between June and November, 1952, the second hypothesis is favoured.

Further evidence in support of this assumption, and of a continuous increase in activity between that time and the eruption, was the distribution of vegetation as noted during Reynolds' investigations. Apart from a narrow strip of vegetation which reached almost to the rim of the crater on its north-eastern slopes, there was no live vegetation in the area immediately surrounding No.2 crater (Pl.8, Fig. 3, and Pl.11, Fig.2). The northern half of No.1 crater was devoid of live vegetation and the only remnants of the thick vegetation which previously existed were the trunks of small trees distributed along the southern and eastern margins of this area. This condition might be considered to be a result of the distribution of ejectamenta during explosive phases of the present activity. However, along the high western rim of No.1 crater,where there was little depositio the sedge, <u>Gahnia</u>, which previously extended to the south-west rim of No.2 crater (Pl.7, Fig. 2),was absent as far south as above the Chimney Crater (about 250 yards) Also, the remnants of a dead moss-like plant still adhered to boulders deposited on the ridge during a previous eruption. On the eastern slopes of No.2 crater, the upper area was completely denuded of vegetation, and this area was encompassed by a band of dead and dying vegetation. The lower portions of this band are a little above half the distance from the base to the rim of the cone. The western and north ern slopes were devoid of vegetation down to the base of the cone.

<u>Composition of Gases</u>

Apart from the large volume of steam emitted, at least two distinct gases were emanating from No.2 crater. The most prominent was sulphur dioxide, whic could be smelt to the lee side of the crater at a distance of at least seven miles. The concentration of this gas in the vicinity of the crater was such that it was impossible to walk around the rim even in a respirator. Another gas, detected during the examination of the crater in June, had a sweet odour and was similar to the smel produced during the coking of coal. This gas did not produce the same physiological reactions as the gas noticed by Taylor and Best in 1952 and considered by them to be a higher unstable oxide of sulphur. Although Reynolds was not subjected to exposure to this gas for long periods, he considered that at least some of the effects would have been felt if it were the same gas as encountered by Taylor and Best. On this supposition he concluded that there had been an alteration in the composition of gas since 1952.

These two gases, together with steam, were being given off from most of the minor centres of activity examined by Reynolds, including those on the western slopes of No.1 crater. No change was noticed in the gas composition of the Chimney Crater where, apart from steam, sulphuretted hydrogen was still predominant.

Sulphuretted hydrogen was smelt at Kalingi Mission during the July-Augu activity, when inhabitants of that area were subjected to considerable discomfort by the dust and sulphur dioxide. The wind from the south-east is generally strongest during these two months, and it is possible that the sulphuretted hydrogen emanated from Chimney Crater and not, as first suspected, from No.2 crater.

Seismic Activity

Tremors were recorded by Father McSweeney on 10th and 19th May, 1954. The first was of strength 2-3 (Mercalli) and was felt in villages south, west, and east of Langila Crater. This was classed as tectonic and occurred at 1600 hours (local time), according to the report received. The master of the "Irene", which was anchored near Warimo village, gave the time for this tremor as 1630 hours. At this time a tremor was recorded on both the seismographs at Rabaul, and was also recorded on Brisbane University seismographs. On the evidence available, this tremor is considered to be of tectonic origin, and to have had an epicentre in the vicinity of Umboi Island. The second tremor recorded, May 19th, was classed by Father McSweeney as strength 2, "volcanic (possibly)" and was felt at Kokopo and Bariai (two villages on the north coast, east of Borgen Bay). It is not known whether there was an explosive phase of the eruption at this time, as there was no observer of the volcano in the area, but in view of the distance from Langila of these villages, this tremor was probably tectonic.

According to natives at Aimaga, a small tremor was felt at the same time as the first of the explosive phases at noon on 18th May.

Conclusions on the increase in seismic activity cannot be drawn from the above observations, as they were made at distances of at least three miles from the crater. However, it is considered that severe earthquakes in the vicinity of the crater would have resulted in the dislodgement of the large boulders which stand exposed on the western rim of No.1 crater, and in some landslides in that locality. Landslides were noted in the inactive crater south of and adjoining Chimney Crater, but these were more likely to have occurred at the time of the formation of this latter crater.

Other tremors reported from Kalingi during the 1954 activity are, briefly:

June 7, 2020 hours (local time): Strength 2 (Mercalli), tectonic, recorded on seismographs at Rabaul, reported by Father McSweeney.

July 19, 1500 hours: Strength 3 (Mercalli), volcanic, reported by Father McSweeney.

July 20, 2355 hours: Volcanic, reported by police boy, Corporal Benga.

July 21, 0600 hours: Volcanic, reported as above by Corporal Benga.

Crude seismographs were constructed at Aipati during the May-June investigations, and at Kalingi Mission during August. The first was operative from the afternoon of 27th to the morning of 29th May, and the latter from 7th until 16th August, but no movements were recorded. Although neither of these constructions could be regarded as highly sensitive, it is considered that tremors would have been registered had they occurred. During the same period in August, the tiltmeter was set up on a concrete block at Kalingi Mission, and readings taken. Although protected to some extent by a wooden cabinet, solar heat caused variations during each day. A graph showing daily variations of the tiltmeter, which was orientated east-west, is included in this report (Pl.12) Readings were taken during Reynolds' absence at Borgen Bay by Fathers McSweeney and Rose. Actual readings are shown by dots, and the continuous lines indicate the trend of the variations. The upward trend represents tilt up to the east or down to the west. The early downward movement on 15th August probably resulted from the heavy rain which commenced at Kalingi at midday and continued throughout the afternoon. This possibly also occurred on 11th August. Apart from this, however, the generalized graph does show a net downward tilt to the east over the period of observations.

<u>Temperatures</u>

Only the centres of minor activity on the south-east rim could be measured by Reynolds. Here the temperatures ranged between 95° and $97^{\circ}C$. No temperature measurements were possible within the No.2 crater.

<u>THE ERUPTION</u>

Before the first explosive phase on 18th May, there had been signs of an increased emission of the "yellow-white" cloud from Langila Crater, and these were first noticed on 1st May by Mr.K.Ryall, master of the "Irene". At the beginning of May, the cloud was ascending to about fifty feet above the crater, and thereafter the volume increased gradually until 15th May, when the height was estimated to be one hundred and twenty feet above the crater. The volume did not increase between 15th and 18th May, but between the explosive phases which occurred periodically thereafter, it was noticed that the white cloud ascended generally to a height of about three hundred feet. The actual eruption is therefore considered to have begun on 18th May, and consisted of the continuous emission of the white vapour cloud, with the explosive phases occurring at irregular intervals for periods of up to four hours. The details are given chronologically:

<u>May 18, 1150 hours</u>

The initial explosion was accompanied by a black, dust-laden cloud emission and a loud roar which lasted for between ten and fifteen seconds. The first cloud rose as a vertical column, which was replaced by convolute dark grey clouds of vapour and dust. The crater is not visible at Aimaga village, but natives from this village stated that "flame" appeared in the cloud shortly after the explosion. White, geyser-like emissions were noticed from the vents on the north-west slopes of the crater. The dark grey cloud emission was witnessed for about four hours before low atmospheric cloud obscured the view.

May 19.

There were no witnesses in the area.

May 20, about 1800 hours

Dense black clouds of dust were noticed by Patrol Officer Dwyer who was at Mangailapua village. This activity was not visible after 1900 hours.

May 21, 1100 hours

This activity was witnessed by Patrol Officer Dwyer from a position about one and a quarter miles south-south-east of the crater. The initial explosion was accompanied by a loud roar, which lasted about five seconds, and rocks could be heard falling in the bush. Dust emission continued for one and a half hours.

May 22, 1000 hours

Atmospheric cloud obscured the crater at this time, but dust could be seen falling on the north-western slopes of Mt. Talawe. This activity appeared to continue until approximately 1430 hours.

May 22, 1650 hours

At the time of this explosion there was no wind, and the grey convolute cloud of vapour and dust rose to an estimated height of 15,000 feet above sea level. Dust eventually settled over the area north-west of the crater including the villages along the coast near Kalingi, but no damage was done. Pisolites about the size of match heads fell on the deck of the "Irene", which was at sea between Kalingi and Lagoon Point at the time. Owing to the slow dispersion of the dust and resultant low visibility, the duration of the emission could not be determined.

May 23, 1120 hours

An almost vertical column of black dust rose to a height of 7,000 to 8,000 feet above sea level, and a loud roar of two seconds' duration was heard at Aipati Village. After this, a column of white vapour was noticed, but no further dust emissions. The crew of a small ship passing north of the crater were able to see bombs falling shortly after the initial explosion.

May 24, 0130 hours

A high mushroom-shaped cloud was noticed above the crater from a ship anchored near Kalingi. The height of the top of the cloud was estimated to be 8,000 feet above sea level.

May 25, 1730 hours

An explosive release of vapour and gas occurred and the resulting white cloud formed a column which ascended to about 8,000 feet. This was followed by the normal emission of gas and vapour (white cloud to about 300 feet above crater), until 1820 hours.

May 25, 1820 hours

There was an emission of dust similar to that recorded on May 23rd. The height to which this column ascended was estimated to be 10,000 feet above sea level. Lightning was noticed shortly after the initial explosion, about 2,000 feet above the crater, and two or three red-hot bombs were ejected to just above the rim and appeared to fall south of the crater.

May 25, 2010 hours

Another black dust emission, as above, and accompanied by a red glow just above the crater, formed a cloud which was faintly discernible.

May 25, 2130 hours

It is considered that another emission occurred at about this time, when another column, barely perceptible against the darkness, was noticed. That evening there was a severe electric storm over Kalingi.

May 26, 0720 hours

The activity on this occasion followed the more general pattern of vapour, dust emissions, and formation of grey voluminous clouds. More prominent dark grey dust emissions occurred at 0720, 0908, 0925, and 0940 hours. On these occasions it was noticed that the cloud tended to spread out over the crater before ascending. The rate of ascent was estimated to be about 1,000 feet per minute. Vapour from the small vents on the north-west slopes of the crater formed a white cloud which ascended to about 500 feet above the crater during this activity The crater was not visible because of atmospheric cloud from 0945 until 1630 hours, when activity was confined to the more common emission of gas and vapour.

May 27.

Large convolute clouds of dust and vapour, as above, were ascending from the crater when observations began at 0830 hours. Although atmospheric cloud periodically obscured the crater, it was possible to watch most of the activity. The dust emissions ceased about 0945.

May 28, 0810 hours

A single column of dust rose quickly to a height of 8,000 feet above sea level. The cloud, which was chocolate-coloured, appeared to move en masse to the north-west over the airstrip, according to Assistant District Officer Foley, who witnessed the activity from the sea north of the crater.

May 29, 1255 hours (Plate 10)

This activity was witnessed from the position chosen by Patrol Officer Dwyer on May 21st, and was preceded by an increased emission of gas and vapour. The white cloud formed ascended at times to about 1,000 feet above the crater. The initial sharp explosion and the dispersion of ejectamenta caused some consternation at the observation point, because the dark grey cloud first appeared to move over the crater rim in an easterly direction. Ejected rocks appeared out of the cloud at about 400 feet above the crater, and fell to the south and south-east at no great distance from the crater. The cloud then increased in volume and rose to about

4,000 feet above the crater in about four minutes. On this occasion the cloud was mushroom-shaped and convolute until it reached the height of 4,000 feet, when the prevailing wind caused it to spread towards the north-west. By 1300 hours, the lower portions of the cloud were lighter in colour owing to an increased emission of vapour, and dust could be seen dropping from the lower portions of the blanket of cloud extending towards the sea. The slowly falling dust formed a dark background, and the white vapour clouds emitted over the next quarter of an hour stood out in sharp contrast. Another distinct explosive dust emission began at 1320 hours, but this was neither as pronounced nor as voluminous as the initial explosion. On this occasion the convolute clouds ascended immediately instead of spreading out, and it was therefore possible to observe that dust emission was confined to the north-west section of the crater, while a white vapour cloud continued to form above the eastern centre of activity. Rocks were heard falling at 1325 hours, but it was impossible to detect whether they had been ejected to the outer slopes or whether there had been a collapse of part of the wall within the crater. The next notable increase in dust emission occurred just after 1400 hours; this continued for twenty minutes. At 1413 hours, another rumbling suggestive of collapse within the crater was heard. Large volumes of dust and vapour were continually emerging from the crater until 1450 hours, when further activity was obscured by low atmospheric cloud which moved down the gully between the Munlulu-Langila ridge and the observation point. During these observations small white clouds had been forming just north of the eastern se tion of the crater. These are believed to have been from the minor centres of activity on the rim. The atmospheric cloud dispersed at 1715 hours, by which time the explosive phase had finished, and small white clouds of vapour and gas were being formed.

<u>May 30, 31</u>

Bad weather conditions made it difficult to give details of the activity on these two days. There appeared to be a darker cloud formation over the crater about 1730 hours on 31st May, but no dust was seen to fall to the north-west.

<u>June</u>

Indications of explosive activity were noticed on 4th and 5th June, but low cloud obscured most of the detail. Except on these two days, there were no other obvious signs of additional explosive phases.

<u>July 2, about 1400 hours</u>

A single explosion with dust cloud rising to 8,000 feet above sea level was seen.

<u>July 14</u>

A convolute grey cloud was seen ascending to 6,000 feet by Patrol Officer Dwyer from the village of Asaimapua, near the south coast of New Britain. The time was not noted on this occasion.

<u>July 15, 1540 hours</u>

The dust cloud ascended on this occasion to about 12,000 feet above sea level

July 16 ★

Explosive phases at 1115, 1515 and 1630 hours.

July 17

Explosive phases at 1130 and 1300 hours.

July 19

Explosive phases at 0800, 1115, 1810 hours. The 1115 eruption was greater than usual and was accompanied by a strong smell of sulphur dioxide, according to observers at Kalingi.

July 20

Explosive phases at 0655, 0945, 1500, 1715 hours.

July 21

Explosive phases at 0500, 0815, 1150, 1530, 1830 hours.

July 22

Explosive phases at 0605, 1115, 1700, 1930 hours.

July 23

Explosive phases at 0630, 1005, 1120, 1130 hours. Dust clouds rose to 12,000 feet from the two latter phases. Loud roars were heard from the Kalingi Mission, and flashes of light were observed; there was again a strong smell of sulphur dioxide. (These were regarded as the strongest explosions experienced until the time these details were received, i.e. 16th August.) Explosive phases also occurred at 1530, 1810 and 1945 hours.

July 24

Explosions at 0900, 1250, 1600, 1735, 1900 hours.

July 25

Explosions at 0630, 1000, 1730 hours.

July 26

Explosions at 1725 hours.

July 27

Explosions at 1330 hours

July 28

Explosions at 1000, 1230, 2000 hours.

July 29

Explosions at 0900 (Pl.11, Fig. 1) 1930 hours.

July 30

Explosions at 0400, 1500, 1708 hours.

★ Details of unusual or very strong activity only were obtained from the 16th onwards, since smaller explosive phases followed the general pattern described above.

July 31

Explosions at 0810, 1240, 2130 hours. The 1240 explosive phase was accompanied by a roar lasting five seconds; the dust cloud rose to over 8,000 feet, there were two other explosions within the next three minutes. The 2130 phase was similar, and was accompanied by a flash of light.

August 1

Visibility was bad due to rain and mist, but a distinct black cloud was observed at 0800, and rose to about 8,000 feet above sea level.

August 2

Explosive phases at 0300, 1000 and 1830 hours.

August 3

Eruptions at 0745, 1235, 1540 to 1550 hours. A heavy pall of dust descended over the west coast as far south as Tauali, and breathing was difficult.

August 4

0945	-	1030 hours	:	15 explosions
1230	-	1315 hours	:	15 explosions
1400	-	1415 hours	:	7 explosions
1830	-	1900 hours	:	5 explosions

These observations were made from the north coast, and from the western part of Borgen Bay. Explosions continued during the night but had ceased by the following morning.

August 5

Explosions at 0800, 0815 and 1145 hours.

August 6

Explosion at 0945 hours.

August 6 - 24

Emission of white cloud of vapour and gas.

August 24

Renewed activity.

August 26

A black cloud of dust rose to 500 feet above the crater at 1730 hours. This report was received from the master of "Airco".

August 27 - 30

Details of activity in this period were given by Captain Harris of the American survey ship which arrived at Borgen Bay on 28th August. American troops stationed at Borgen Bay reported to Captain Harris that the volcano had been active periodically since 26th August. A strong explosion occurred at 1500 hours on 27th August. Dark clouds of dust were emitted between 1100 and 1200 hours on 28th August, and after rising to about 5,000 feet above the crater, spread out to the north-west. At about 1600 hours on the same day, there was another slight eruption. Accurate details were not recorded but a blast heard about 1130 hours on 29th August was considered to have emanated from the volcano. (Captain Harris at that time was in jungle country and was unable to see the volcano.) A very heavy emission of dust occurred at 0900 hours on 30th August, another at 1215 hours, and still another explosive phase at 1500 hours.

<u>September 1 - 12</u>

Explosive phases occurred three or four times each day over this period. The master of the "Matoko" reported witnessing two explosive phases, the first of which commenced at 1730 hours on 8th September. Dust fell in the vicinity of the villages on the north-west coast. The "Matoko" departed from the Kalingi anchorage on the morning of 9th September, when there was a small white cloud emission. The last phase of this period of activity commenced at 0845 hours on 12th September.

<u>October 1</u>

A cloud of dust rose to 1200 feet above sea level after an explosion at 1445 hours, and spread over the coastal area north-west of the crater.

<u>October 2 - 29</u>

Slight activity.

<u>October 30</u>

Renewed explosive activity at 0610 and 1300 hours.

<u>October 31</u>

Three distinct explosions.

<u>November</u>

Explosive phases occurred during the period 1st - 13th November, the strongest at 0745 hours on 6th November. This was noticed from Arawe, 60 miles distant on the south coast of New Britain.

<u>February 1955</u>

The volcano was active during February and the strongest explosive phases occurred between 15th and 17th.

<u>June 1955</u>

The last activity reported in 1955 consisted of eruptions on 1st, 6th and 16th June. At Kalingi an increase of "hydrochloric acid" gas was noticed in the exhalations from the volcano during these eruptions.

<u>March 1956</u>

Renewed activity occurred, with a light cover of dust over the area, on 25th March. Activity for the remainder of the month was only slight. Reports for the period November 1954, to March 1956, are incomplete and other eruptions besides those listed above may have occurred.

Throughout the foregoing list of eruptions, explosive phases noted occurred mainly during daylight hours. It can be assumed that there were many explosions during nights over the same periods, but observations could not then be made . In addition, on some days no reliable observers were in the vicinity of Langila, and the record above, even before November 1954, cannot be regarded as complete.

The products of the explosive phases were distributed according to size. Large volumes of vapour and dust spread to the north-west during most of these phases to distances of seven miles and sometimes more. Dust descended upon Kalingi Mission and neighbouring villages in July and August, but no damage was caused. Natives of Aipati village think that some dust fell south of the crater, and a creek originating from the southern side of Munlulu or the ridge to the west, and flowing west of Aipati, was contaminated from 20th to 24th May. This was the only report of deposition south of Mt.Munlulu, and neither villages nor gardens were affected. Ejectamenta of bomb size were thrown out in the area south and south-east to within one and a half miles from the active crater. These rocks consisted mainly of angular blocks showing no evidence of plastic deformation, and were derived mostly from old flows of lava through which the main vent had been formed. The volcano is of the strato type, and some blocks were probably from the ash beds which are interbedded with the lava flows. Some of the ejected rocks still retain a coating of the sublimation products deposited when the rocks formed part of the walls of the crater.

The largest deposit of ejecta was collected just south of the main crater in a shallow depression at the northern end of No.1 crater. Here they were intermixed with blocks from a previous eruption, some of which could be distinguished by the adherent dead grass and vegetation. Some cognate ejecta were deposited either as bread-crust bombs (Pl.11, Fig. 3) or as small masses of coarsely vesicular scoria. Of the accessory ejecta, the most common rock type is basalt, but blocks of agglomerate and volcanic breccia are also present. Rocks ejected to the south-east beyond the rim of crater No.1 broke branches of larger trees and felled some smaller types. A few bombs, about six inches in diameter, were deeply embedded in the trunks of trees which they had felled. Where they had reached the ground without encountering any large obstacle, the bombs had formed shallow craters up to six feet in diameter.

Deposition on the western and northern slopes could be examined only from the air, and apart from dust which may have formed a thin layer over the surface, there was little evidence of an accumulation of ejectamenta. Examination of photographs taken in 1952 revealed that there had been no alteration in either height or configuration of the western and northern rims of crater No.2 (Pls.4, 7, and 8.) No rocks which could have been recently ejected were noticed in the shallow crater in the north-east of No.2 crater, and the coating of sublimation products on the surface of the south-eastern portion did not appear to have been affected by any recent deposition. It was concluded on this evidence that most of the rocks on the northern slopes had been deposited during a previous eruption.

THE NATURE OF THE ACTIVITY

The previous eruption of Langila had produced ejecta consisting predominantly of dust and angular blocks. The absence of pumice and the presence of angular breadcrust bombs in the ejecta suggested that it had originated from a viscous low-temperature magma relatively poor in volatiles. The configuration of Chimney and Twin craters indicated steam explosions as a final phase of this earlier activity. It was expected by Taylor, in 1952, that future activity would be of a similar type, in the absence of extraordinary signs of deep-seated movement.

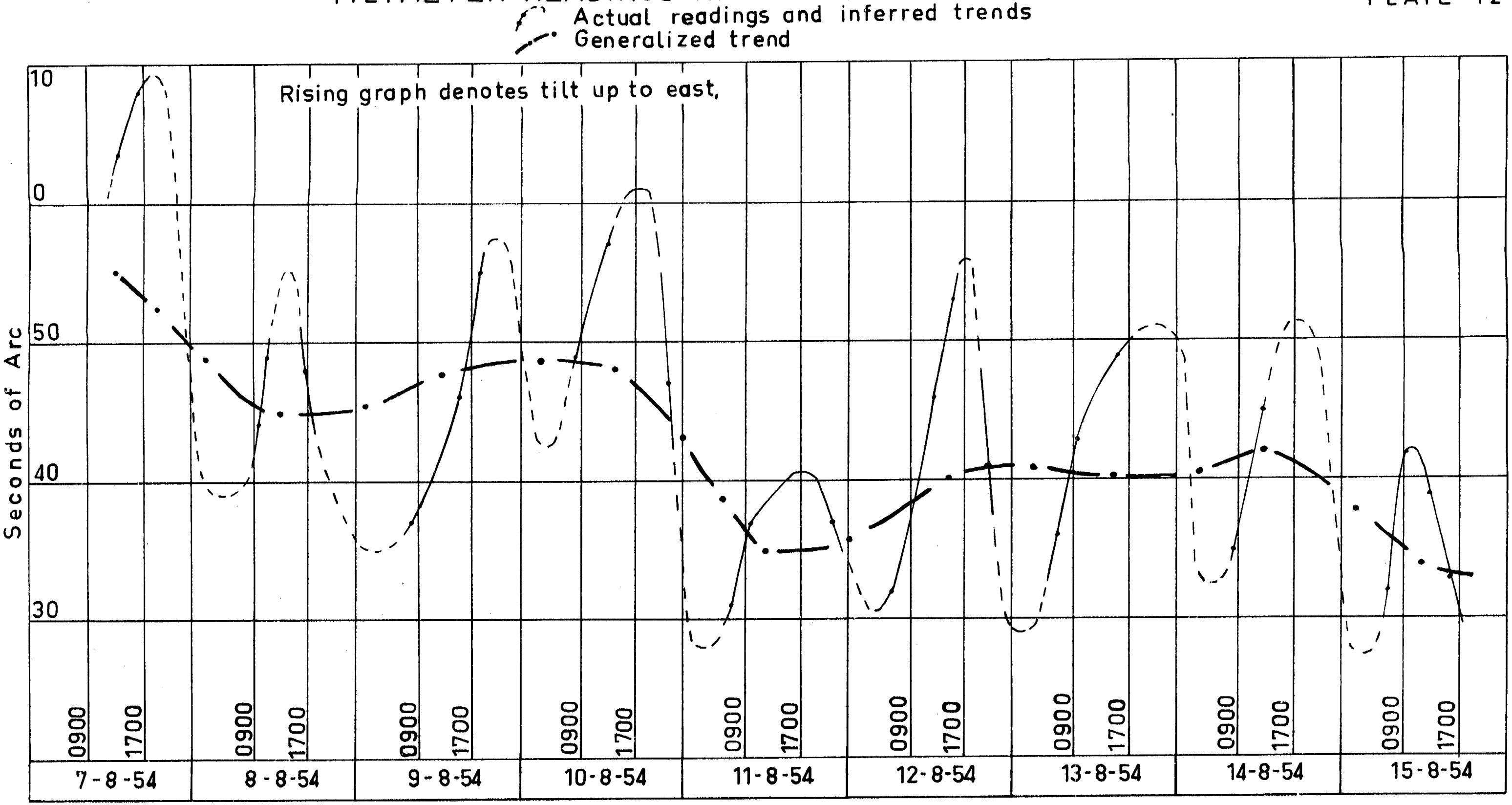
This prediction has been realised in the characteristics of the recent eruption. An absence of precursory volcanic earthquakes in the area suggests an absence of great pressure accumulation and probably a rather superficial location for the magmatic source of the eruption. The typically Vulcanian ejecta and the pattern of intermittent activity appear indicative of a magma low in temperature and high in viscosity.

The broad pattern of activity is composed of periods of intermittent explosive activity, up to three weeks in duration, separated by lengthening periods of calm. The behaviour seems to be consistent with the view that the activity is derived from a magmatic body which, having reached a state of inequilibrium through local oversaturation with volatiles, removes its constraining plug by a strong explosion and releases its gaseous energies in a series of spasmodic explosive episodes. As far as one can gather from the data available , the most powerfully explosive of these episodes occurred in two periods separated by a little more than two weeks of calm, in August 1954. The later activity has been less intense and more infrequent. The total energy seems to be declining.

Reynolds noted three kinds of explosive phenomena: a voluminous emission of grey clouds of vapour and dust which lasted up to four hours; less common short explosions of steam; and columnar black clouds with which incandescent bombs were often projected. The nature of such variations in explosive activity is governed by the rate of gas evolution from the magmas. Veerhogan's paper (1951) on the mechanics of ash formation has indicated the complexity of the vesiculation process. Among the factors which determine the rate and mode of gas evolution he has drawn attention to : initial water content of the magma, degree of oversaturation, rate at which saturation develops, cause of oversaturation, viscosity, surface tension, temperature, depth, nature and amount of suspended crystals. It is expected that inhomogeneities involving such factors will exist in a conduit magma, especially a viscous magma in which gas fluxing is at a minimum. The variation in types of explosion at Langila suggests a conduit magma in which separate gas phases operated.

One phase functioned at depth where gas at high pressure periodically accumulated in the magma, which blasted its way through overlying more inert magma, to project bombs, blocks and fine black ash. The explosions sometimes initiated a slower vesiculation process which produced voluminous grey clouds of ash and vapour

TILTMETER READINGS KALINGI STATION AUGUST 1954 PLATE 12



These ash emissions lasted up to four hours. Sometimes they occurred without violent initial explosion; they may, therefore, have been independent of the disrupting effects of deeper explosions, and may have been related to a vesiculation process in the upper part of the lava column. Emissions of this type appear to have been most numerous following the night of 25th May, 1954, when an incandescent glow was seen in the crater.

Appa ently changes in the equilibrium of some parts of the magma were favourable for the separation of the volatiles into localised pockets from which they found release as steam explosions. These were one of the types of explosion noted by Reynolds during the early course of the eruption.

During some periods, the explosive activity tended to occur three or four times a day at intervals which suggested a more or less rhythmical pattern of release. This was particularly characteristic of activity in early September, 1954, when the eruption was well established, and presumably, when many of the early inhomogeneities had been removed from the conduit magma. Rhythmic explosions appear to be characteristic of the more viscous magmas. They were notable features of certain stages of the activity of Pelee, Lamington, and Long Island, often attaining a geyser-like regularity. The mechanism of this activity may be related to a vesiculation rate which is inhibited by the viscosity of the magma in such a way that a more or less consistent lag develops between the introduction of reduced pressure by explosive release and the "flash point" of further explosive vesiculation.

REGIONAL VOLCANIC ACTIVITY

If the activity of Langila volcano is fitted into the regional pattern of events between November 1951, and December 1955, it is difficult to escape the conclusion that special conditions of regional stress along the island arc, west of New Britain, are a basic causative mechanism in the volcanic activity.

Firstly submarine activity was reported east of Karkar Island in November 1951. In May 1952 gas emission increased from Langila at the eastern end of the arc. In April 1953 gas emission increased from Manam volcano at the western end of the arc. In May 1953, Long Island, in the centre of the arc, began erupting and seven weeks later submarine activity began in St.Andrews Strait (Tuluman Volcano) in the Admiralty Islands. Spasmodic activity has continued from these two centres. In May 1954 explosive activity began at Langila volcano, two years after the initial signs of increasing activity. In June 1954 further increases of gas emission were reported from Manam volcano and in August the neighbouring Bam Island produced mild explosive activity which recurred at intervals until early 1956.

SEISMIC ACTIVITY

An interesting group of precursory tectonic earthquakes occurred near Langila during the three years before the year of the eruption. Here were the early signs of abnormal stress which seems to play such an important part in developing conditions favourable to eruption. The geological pattern on Western New Britain suggests the possibility of a fault trending east-north-east across the end of the island.

If this is so, most of the precursory earthquakes occupy a position opposite Langila on the other side of the fault. Such a disposition of early earthquakes has been found significant at other volcanic centres.

It should be placed on record that the aftershocks of the earthquake of 11th October, 1952, continued to be felt on Umboi until the 14th December, 1952. Most of the shocks were slight and very few of them were strong enough to be felt while standing.

The following list of tremors was reported by Mr. G.A. Noller of the Australian Lutheran Mission on Umboi Island:

Date	Time	Intensity (Modified Mercalli)	Duration
1954			
Aug. 6	4.45 a.m.	2	6 seconds
" 6	9.45 a.m.	3	11 "
Sept. 12	3.15 a.m.	3	40 "
" 29	4.10 a.m.	3	45 "
" 30	6.00 a.m.	1	5 "
Oct. 2	8.57 p.m.	1	3 "

LUNI-SOLAR INFLUENCES

During the preparation of this section of the report it has become obvious that additional information on astronomy will be required before facts available can be analysed completely. Only the observed facts concerning the effects of luni-solar influences on the pattern of the eruption at Langila Crater, therefore, are considered here.

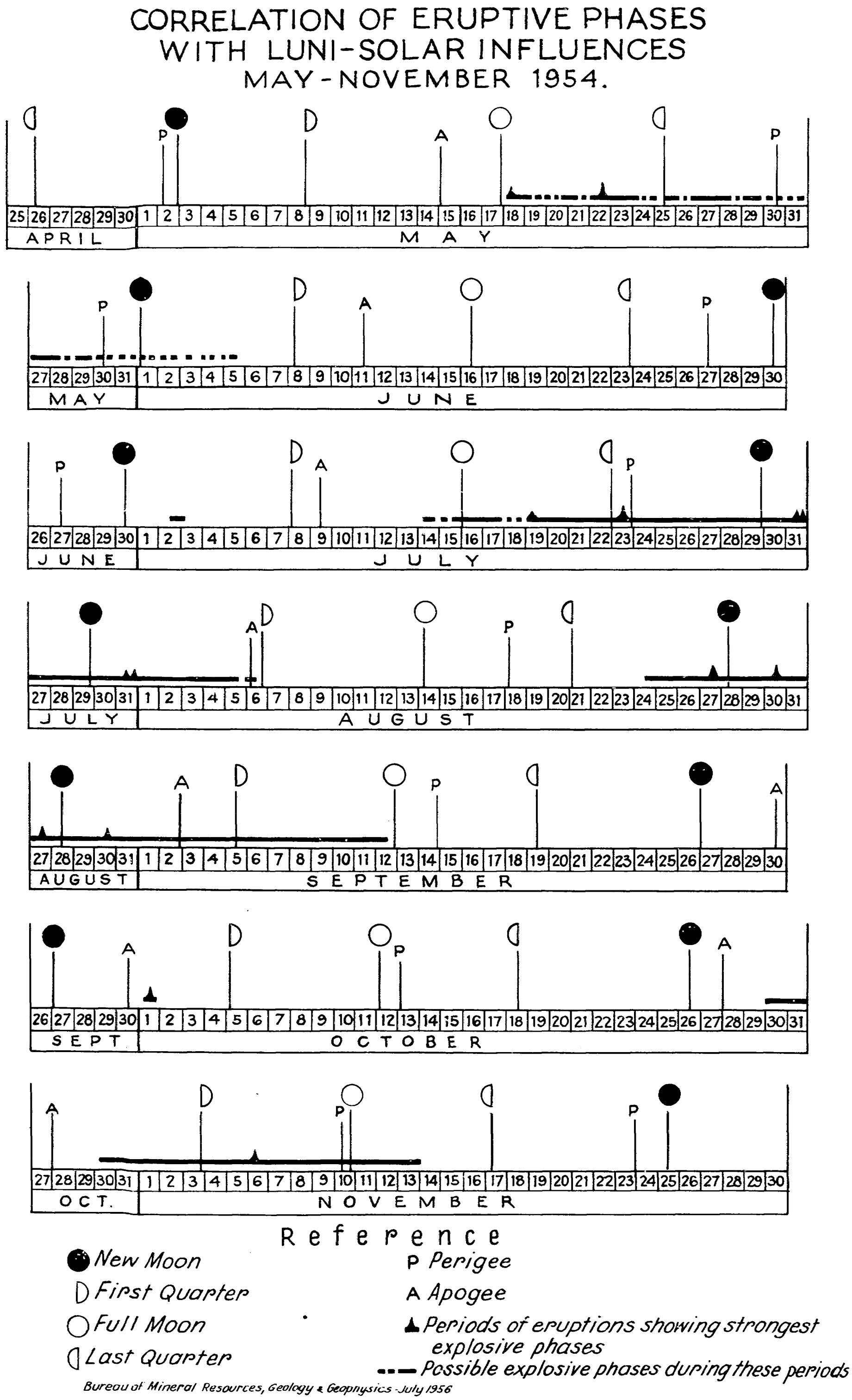
Plate 13 shows periods of activity, phases of the moon, perigees and apogees. The times of phases, perigee and apogee of the moon were taken from the Nautical Almanac for 1954. The following observations are prompted by the results presented in that figure:

(1) The increase in gas and vapour emission noticed by Mr.K.Ryall, master of the "Irene", from 1st until 15th May followed a strong maximum when both the sun and moon were in conjunction and when the moon was at perigee. The eruption started on 18th May and, although adverse weather conditions made observation of the crater difficult at the end of May and in early June, this period of eruption probably ended on 5th June.

(2) The next eruption occurred on 2nd July, five days after perigee and two days after New Moon.

(3) On 14th July, at the time of Full Moon, another period, during which more than ninety explosive phases were witnessed, began, and continued until 6th August. The strongest explosions experienced since eruptions began in May were reported as occurring at 1120 and

PLATE 13


CORRELATION OF ERUPTIVE PHASES WITH LUNI-SOLAR INFLUENCES MAY-NOVEMBER 1954.
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
SEPT
OCTOBER
OCT.
NOVEMBER
P
A
Reference
New Moon
First Quarter
Full Moon
Last Quarter
P Perigee
A Apogee
Periods of eruptions showing strongest explosive phases
Possible explosive phases during these periods
Bureau of Mineral Resources, Geology & Geophysics - July 1956

1130 hours on 23rd July, almost coincident with the time of perigee. On the other hand, 42 explosions were counted on 4th August within two days of apogee.

(4) The next period began on 24th August between Last Quarter and New Moon, and continued until 12th September, the date of the Full Moon. The strongest explosions occurred close to the date of the New Moon.

(5) The single explosion recorded on October 1st was between New Moon and First Quarter, but within twenty four hours of the time of apogee.

(6) Another period of eruption began on 30th October, and continued until 13th November. Although this period commenced between New Moon and First Quarter, activity was apparently still quite strong at the time of Full Moon. It is interesting to note, however, that the Full Moon and perigee were almost coincident on 10th November.

These observations by no means prove conclusively that one can expect eruptions at times of luni-solar maxima, but they do not take into consideration other factors such as the relative forces acting on the earth at times of syzygies, apogees, and perigees; and perihelion times are not even considered.

The well-known vulcanologist, F.A. Perret, discussed luni-solar influence (Perret, 1950) in all his major vulcanological reports. Although his work was mainly connected with the open-conduit type of volcano (as compared with Langila Crater which is regarded as closed-conduit), he found that it was generally possible to expect the greatest activity of an erupting volcano when luni-solar influence was at a maximum. The extent to which he believed in this theory can be gauged from the following statement: "I have always profited in a practical way by a knowledge of the dated luni-solar maxima and minima in planning my excursions under active volcanic conditions. This is revealed in many of my works, and this knowledge has been employed in the plotting of diagnosis and prediction curves".

Although it may not be possible to apply Perret's methods extensively to an eruption such as that at Langila, there is no doubt the basic idea of a relationship between luni-solar forces and volcanic activity is sound. Recent quantitative work has established a definite relation between earthtides and the flow of oil wells (Tomaschek, 1952) and between tidal forces and the pressure of artesian wells (George and Romberg, 1951). It is not therefore unexpected that the same forces acting on the plastic, fluid, and volatile elements of a volcanic magma should produce some response.

In the present example, the suggestive nature of coincidences of explosive periods with luni-solar positions of opposition and conjunction and also with the perigee position of the lunar orbit has already been pointed out. In effect the magnitude of the earth-tide forces may influence the eruptive behaviour of the volcano.

But it is also apparent that the direction of the tractive forces of the sun and moon are even more important in initiating explosive activity, for each of the four explosive phases of the volcano's activity began during periods close to maximum lunar declination: that is, during periods when north-south tangential forces of the moon were at the maximum. In view of the apparent structure of the area this is a very reasonable relationship. It has already been pointed out that Langila appears to be an easterly migration of the ancient Talawe volcano, and two other cones to the east of Langila suggest the reality of a controlling deep-seated fracture aligned east-west. Given this structural condition, the tangential component of the tractive forces of the moon and sun reaches a maximum in positions of extreme declination and produces a state of tension along the fracture. The resultant relief of stress presumably aids processes of vesiculation and liquefaction in the magma of the volcano, with the result that an eruption will ensue if forces within the volcanic system are close to critical equilibrium conditions.

In this relationship it is evident that the mobile moon with its rapidly varying declination is the more important agent in influencing the volcanic system. The change of solar declination is relatively slow and being a more constant influence has less obvious effects. However, it is probably not entirely coincidental that the early explosive phases of Langila occurred when the sun and moon were producing opposing tensional forces close to the period of the sun's maximum northerly declination. It is obvious that in opposing declination positions north and south of the equator the planets produce maximum tensional forces on east-west structures close to equatorial latitudes, and these tensional conditions reach their periodic maxima when the sun is farthest from the equator.

It seems to be significant that many of the recorded eruptions in this arc have begun in March or June, for it supports the above view that luni-solar influences play a dual role. In March, the sun is close to its zenith position for these equatorial latitudes and the vertical component of the solar tractive force reaches a maximum, and compression is greatest. In June, with the sun close to its maximum declination for these latitudes, the tangential component of the solar tractive force reaches a maximum, and tension is greatest.

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APPENDIX

PETROLOGY OF VOLCANICS FROM MT.LANGILA

by

J.Kerry Lovering

The olivine-hypersthene basalts from Langila volcano can be divided petrologically into three main types; this division corresponds generally with the ages of the material from which the specimens were obtained. The first type (slides 1125 & 1127), the oldest in the collection, comprises specimens collected from the northern outside slope of Crater No.1., and from a flow within this crater, through which the chimney Crater was blown. Type 2 includes specimens from a lava flow about four miles north of the crater (slide 1126) and from bombs, probably of older material, ejected during the eruption in May 1954 (slides 1908 and 1910).

Type 3 is represented by a number of specimens; - the vesicular interior of a bread-crust bomb found in No.1 crater, probably representing material thrown out by the 1878 eruption (slide 1123); a specimen from a massive flow which appears to overlie a flow of type 2, about three and three-quarter miles north of the crater (slide 1124); and angular fragments of fresh lava from the 1954 eruption (slides 1911, 1912, 1913).

DESCRIPTION

The Langila volcanics are vitrophyric in texture, and are commonly vesicular; all have approximately the same percentages of phenocrysts of plagioclase (20%-30%), orthopyroxene (6 - 7%), clinopyroxene (2 - 5%), magnetite (3 - 5%) and olivine (1% or less).

Most plagioclase phenocrysts are zoned. Many grains contain elongated fluid inclusions which may indicate a xenocrystic origin (Kuno, 1950, p.968). Many other grains contain rectangular or irregularly-shaped blebs of brownish glass which give a microplakitic texture to the grains. Pleochroic orthopyroxenes and clinopyroxenes are characteristic of each type, and will be described later.

Accessory olivine is found in most of the rocks; it trends with time from forsterite ($+2V = 86^{\circ}$) to chrysolite ($-2V = 87^{\circ}$). Forsterite grains of Type 1 are commonly surrounded by hypersthene crystals and grains of magnetite. Many chrysolite grains in Type 3 have clinopyroxene rims.

Accessory apatite is seen in some of the angular fragments of lava from the 1954 eruption.

Cognate xenoliths are found in almost every thin section of these volcanics and appear to be of petrogenetic significance. In the older rocks of Types 1 and 2, the cognate xenoliths are composed of graphic intergrowths of hypersthene and magnetite which are probably derived from olivine; these intergrowths are commonly surrounded by a shell of crystalloblastic orthopyroxene grains. Clinopyroxene grains are also occasionally present. In rocks of Type 3, the cognate xenoliths consist of aggregates of orthopyroxene, magnetite, clinopyroxene, and plagioclase.

The significant differences between the three types lie in the nature of the orthopyroxenes and of the groundmass.

TYPE 1.

Porphyritic phenocrysts up to 1 mm. in size are distributed in a groundmass which flows around them in a sub-trachytic fashion. The groundmass is darker and finer than that of the other types, and consists of microlites of plagioclase and pyroxene, dusty iron ore, and interstitial fawn-coloured glass.

The plagioclase phenocrysts of Type 1 are labradorite (An 65) with a few rare bytownite (An 84) cores.

The orthopyroxene is hypersthene, continuously zoned, and ranging from 65 to 60 per cent $MgSiO_3$; the optic angles range from 60° to 56° and birefringences range from 0.011 to 0.012. The hypersthene is evidently not in equilibrium with the magma, because most grains have resorbed margins; many grains are rimmed with clinopyroxene which has a positive optic angle of 60° to 62°. This clinopyroxene is ferroaugite (Hess, 1949).

Phenocysts of augite with optic angles of 56° have reaction rims of ferroaugite.

The olivine of Type 1 is forsterite.

TYPE 2.

Phenocrysts up to 2 mm in size are set in a dark brown volcanic glass which has a refractive index less than that of balsam, and which contains some microlites of labradorite and pyroxene and granules of iron ore.

Most of the plagioclase phenocysts have a bytownite core (An 88) surrounded by a zone of bytownite (An 84) which commonly contains glass inclusions and elongated fluid bubbles. The outermost rim is labrodorite (An 65).

The orthopyroxenes are hypersthenes with negative optic angles of 52°. These hypersthenes, with about 50 per cent $MgSiO_3$, are intermediate in composition between orthopyroxenes of Types 1 and 3. A few grains are zoned; the outer rim of orthopyroxenes approaches the composition of the ferrohypersthenes in Type 3.

Many hypersthene grains have a rim of ferroaugite with optic angles ranging from 60° to 62°. Augite phenocrysts in these rocks have positive optic angles ranging from 54° to 56°; ferroaugite reaction rims are seen around the augite.

TYPE 3.

The phenocrysts in Type 3 are set in a groundmass of almost colourless glass containing abundant microlites of plagioclase and pyroxene and granules of iron ore.

The plagioclase phenocrysts of slides 1123 and 1124 are mainly bytownite (An 75) with thin rims of labradorite, and labradorite (An 65 - 70) with small bytownite cores is present in the 1954 lava.

The orthopyroxenes range in composition from 40 to 30 percent $MgSiO_3$; negative optic angles range from 62^o to 68^o and birefringences range from 0.015 to 0.017. Kuno (1954) classes these as ferrohypersthene.

Rims of ferroaugite with a positive optic angle of 62^o are found around many ferrohypersthene grains. Phenocrysts of clinopyroxene are augite with a positive optic angle of 54^o and X refractive index of 1.690; these are continuously zoned and the outermost reaction rim is ferroaugite.

DISCUSSION

The crystallization of the Langila volcanics appears to have followed a normal petrogenetic trend, particularly in the progressive enrichment of the pyroxenes in iron. This trend can be observed in the phase relations within individual rocks as well as in chronologically successive lava-types.

Three concurrently operating trends (previously noted by Poldervaart and Hess, 1951, p 480) are apparent in the crystallization of these rocks:

1) Magnesian olivine reacts with the magma to form magnesium-rich orthopyroxenes which trend towards iron-rich orthopyroxenes.
2) Magnesian augite trends towards ferroaugite.
3) Bytownite felspar trends to labradorite.

Magnesium-rich olivine probably formed first; phenocrysts of forsterite are found in Type 1 and cognate xenoliths of orthopyroxene and magnetite are probably the result of reaction between olivine and the saturated magma. Phenocrysts of chrysolite in Type 3 demonstrate a trend towards enrichment in iron.

Magnesian clinopyroxenes (augite) probably started to crystallize soon after the formation of olivine. Zoning of augites by reaction between augite and the magma resulted in an outermost rim of ferroaugite. This minor trend from magnesium-rich to iron-rich clinopyroxenes is found in all specimens.

In the oldest lavas studied (Type 1), orthopyroxenes with a $MgSiO_3$ content of 65 to 60 percent probably started to crystallize at about the same time as augite; but they were evidently rot in equilibrium with the magma, because many have resorbed margins. Many grains also have a rim of ferroaugite.

There seem to be two possible explanations for the ferroaugite rim, which is not a reaction rim.

1) The orthopyroxenes are xenocrysts in the basaltic magma; they were incorporated in the magma while ferroaugite was forming.

2) The orthopyroxenes formed in the magma and were being resorbed as they were not in equilibrium with it, when the rate of cooling became rapid, and ferro-augite, which forms under these conditions (Kuno, 1955), crystallized around ortho and clinopyroxenes,

The orthopyroxenes of Type 2, having about 50 percent $MgSiO_3$, and the ferrohypersthenes of Type 3, with 40 - 30 percent $MgSiO_3$, are also rimmed with ferroaugite and the same explanations could be applied. The ferrohypersthenes, however, must have started to crystallize at a much lower temperature than the hypersthenes of Type 1. Kuno, who in 1950 described ferriferous orthopyroxenes in Japanese volcanics, suggested (1950, p.995) that volatile substances may be associated with cognate xenoliths and may lower the crystallization temperatures of components of the magma. Cognate xenoliths are, certainly, abundant in Type 3.

Kuno (1955) considers that the increase in the percentage of salic elements in the magma, resulting from magmatic differentiation, increases the rate of cooling and lowers the crystallization temperature of the magma, and thus permits the crystallization of ferriferous orthopyroxene.

The overall trend of the orthopyroxenes is toward enrichment in iron as the magma trends toward a more acidic type.

The crystallization of the felspars parallels that of the ferro-magnesian minerals; individual grains have bytownite cores rimmed with labradorite. No definite compositional trend in the lava-types could be established because phenocrysts in lavas of Type 2 are, if anything, more calcic than those in lavas of Types 1 and 3.

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