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PRELIMINARY REPORT - VOLCANIC ACTIVITY AT CONE NO.7  
TULUMAN ISLANDS, MANUS DISTRICT  
NOVEMBER - DECEMBER, 1956

by

M.A. Reynolds



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## I. INTRODUCTION

In response to signals received from the District Commissioner, Manus District, the writer left Rabaul on 28th November 1956 to examine volcanic activity from a new centre in the Tuluman Islands group. The area was inspected from the aircraft en route Momote; observations were continued from 29th November until 5th December from Administration vessels "Eros" and "Harbob", and from Baluan Island. A chain and compass survey of the remnants of islands formed by Cones Nos. 2 and 4 and Cone No. 3 was completed during this period. The writer returned to Rabaul on 6th December.

The assistance of the following officers and personnel is gratefully acknowledged:

District Commissioner J. Preston White, A.D.C.,  
W.G. Murdoch, Mr. J. Kemsley (Master of "Eros"),  
Capt. B. Tingwell and crew of QEA aircraft in  
which writer travelled to Momote, F/Lieut. B.  
Hawthorn and crew of R.A.A.F. Crashboat.

The help given by Police Constables William and Sasangi was also appreciated.

A complete report will be presented when photographs are available and maps have been completed.

## II. PREVIOUS INVESTIGATIONS

Vulcanological observations have been made previously in the Tuluman Islands area by J.G. Best (1953-54) and the writer (1954-55). Records prepared from these investigations have been incorporated in Report No. 33 of the Bureau of Mineral Resources, Geology and Geophysics, Canberra. This report is now in press. Information from Report No. 33 which is relevant to the discussion on the November-December 1956 activity is reviewed briefly hereunder.

1. To overcome the difficulty of nomenclature, it was proposed that all islands formed during volcanic activity in the area in the St. Andrew Strait just south of Lou Island be called the Tuluman Islands. It was also suggested that the cones be numbered in chronological order of formation, as follows -

Cone No. 1 (Submarine): Active in June 1953, October 1954 and May 1955; the lava dome built up above sea-level on 6th June, 1955, and subsided below sea-level when activity ceased on 26th June, 1955.

Cone No. 2: Active in November 1953, July 1954 when cone built up above sea-level, and February 1955 at the same time as Cone No. 4. Cone No. 2, the north-eastern portion of the composite island formed together with Cones No. 4 and 5, was estimated to be about 800 yards south-west of Cone No. 1

Cone No. 3: Active in April 1954(?), and July 1954 when island formed about  $\frac{3}{4}$  mile west of Cone No. 1.

Cone No. 4: Formed large island which overlapped the western end of Cone No. 2 in February 1955.

Cone No. 5: Active in February, March 1955; joined to island formed by Cones Nos. 2 and 4 by sand bars built up from volcanic material; crater about 800 yards south-west of the crater of Cone No. 2.

Cone No. 6 (Submarine): Active from March until May 1955; estimated to be about 600 yards south of Cone No. 5.

2. A study of the volcanic activity led to the following conclusions:

- (a) Magmatic gases were the source of the thermodynamic energy.
- (b) The first phase of activity was submarine lava extrusion; surface manifestations resulted from gas-charged masses of lava flaking from the cone and floating to the surface, where removal of hydrostatic pressure enabled gases to escape, often with explosive force.
- (c) The intermittent nature of the activity was caused by the process of accumulation and release of gas in the magma column.
- (d) The second phase commenced when lava extrusion built the cone above sea-level; gas accumulation in the magma column proceeded until the pressure was sufficient to remove the lava plug at the top of the column. With no restricting hydrostatic pressure the release of gas was violently explosive, disintegrating the plug and causing comminution of molten lava to dust; this phase resulted in the formation of islands composed of volcanic dust and larger ejectamenta.

3. Between May and August 1955 there were mud eruptions from Cones Nos. 2 and 4; it was considered that these indicated that a decadent stage had been reached.

4. There was evidence to suggest that volcanic activity in this area was responsive to luni-solar influences.

5. The centres of activity are arranged along a line which has convexity to the north-west, corresponding with the arcuate form of Lou Island, the remnant of the rim of a large volcano.

Minor eruptions since August 1955 have been reported in signals and monthly vulcanological returns from Baluan Island; these were not investigated, and the details given hereunder have been taken from the above-mentioned reports.

1955: September 20. Small vapour clouds were noticed rising intermittently from the vicinity of Cone No. 1.

September 26-- Submarine activity from approximately  
28. 500 yards east of Cone No. 2.

- 1955: October 3-7. Renewed activity; surface manifestations spread over area centred about 300 yards east of Cone No. 2.
- October 15, 16, 23, 27, 28 (record not complete). Mud eruptions and strong vapour emission from vent near western rim of Cone No. 4.
- October 31. It was noticed that the sea had gained access to the crater of Cone No. 4 through a breach in the western rim.
- November 7-25. Natives reported activity from Cone No. 4.
- 1956: March 29, 30. Slight increase in vapour; natives reported that while in vicinity of volcano, shocks were felt similar to submarine explosions of dynamite.

### III. ACTIVITY, NOVEMBER - DECEMBER 11th, 1956

The main centre of activity during this period was 300 yards north of the eastern end of the island formed by Cones Nos. 2 and 4. This is possibly a new centre of activity and will tentatively be referred to as Cone No. 7. The occasional mud eruptions from the submarine source just west of the western margin of the remnant of Cone No. 4 were not from the main vent, but from the depression which formed just south of it in July 1955; these will be referred to Cone No. 4.

The first report of activity received on 27th November stated that Tulumán Volcano was again active, and that vapour clouds were rising to 2,000 feet above sea level at intervals of about 5 minutes. The second pilot of the aircraft in which the writer travelled to Momote, Mr. Kingsley Roberts, had noted in his diary that he had seen a slight steam emission from the vicinity of Cone No. 7 on the 8th November; the volume of vapour was about the same as that from the neighbouring island of Cones Nos. 2 and 4. This information confirms the report given in the November monthly vulcanological return from Baluan Island that on 7th November "Tulumán erupted, no times given, site of eruption not known." Mr. Roberts flew over the area again on 15th November, and noticed that the vapour cloud has increased in volume and had risen to a height of from 200 to 300 feet above sea level. At the time of the aerial inspection on November 28th there was a steady emission of steam and gas from the cone which had built up to about 10 feet above sea-level. A cumulous cloud had formed above the vapour, and extended upwards to a height of about 7,000 feet. The colour of the vapour column up to about 1,000 feet varied from orange to brick red; this colour was contributed by the emission from the main central vent. A subsidiary amount of white vapour was added to the column by the steam being formed at several places around the outer rim of the cone.

Details of the activity from 29th November until 5th December are given hereunder in chronological order:

November 29.

At 0500 hours, while travelling from Lorengau to Momote the District Commissioner noticed that the column of vapour rose to an estimated height of 20,000 feet. By 0700 hours, however, a wind had developed from the south-east, and the vapour cloud was cumulous and did not ascend higher than about 5,000 feet. The first explosive activity was witnessed at 0730 hours from north of Lou Island; a separate column of vapour rose vertically from what appeared to be a source just west of the main vapour column and penetrated the overlying cumulous bank. At 0750 hours there was another explosion followed by frequent spasmodic explosions during the rest of the morning. Jet-like extrusions of steam and dust accompanied by loud roars, similar to those noticed during previous eruptions also occurred at spasmodic intervals. They lasted for periods of up to 10 minutes duration, and were often directed at angles of as much as 45° to the vertical, thus giving a fountain-like appearance to the extrusion. There was a mud eruption from the submarine vent of Cone No. 4 at 1033 hours; the ejected material, which appeared to be dark grey to black mud, was forced to a height of about 100 feet above sea-level. Another explosion from Cone No. 4 occurred at 2100 hours. The frequency of explosions from Cone No. 7 diminished during the afternoon and night. An unusual feature of the activity witnessed at night was that, apart from the red glow of the dome, there was an incandescent glow at the surface of the sea. The glow was continuous and remained in the same area near the western margin of the cone.

November 30.

The main activity of Cone No. 7 was the continuous emission of orange and white coloured vapour. Submarine activity commenced at a position midway between Cones Nos. 7 and 2 during the morning, and blocks of lava appeared at the surface at half-hourly intervals. Most of the explosions witnessed during the day were from this source. There was one explosion at 1230 hours from Cone No. 4. The thermal area south of Baun village on Lou Island was inspected during the afternoon; temperatures and conditions were the same as reported in June and August 1955. The maximum temperature recorded was 101°C. at the western end of the swamp lake.

December 1.

There was continuous emission of vapour from Cone No. 7; the only explosions witnessed were one from Cone No. 7 at 0955 hours, and from Cone No. 4 at 0915 and 1210 hours. There was no further submarine activity.

December 2.

No explosive activity was witnessed; there was an apparent increase in volume of vapour during the afternoon, but this may have been due to greater condensation owing to the squall which developed at that time from the south-west.

December 3.

Explosive activity at Cone No. 7 commenced at about 1100 hours and continued intermittently throughout the day and night. The most active period was between 1530 and 1730 hours, when there were at least 8 explosions at Cone No. 7 and one at 1605 hours from Cone No. 4. Before and after this period, explosions occurred at intervals of about one hour.

December 4.

There was continuous vapour emission from Cone No. 7 and occasional explosions; Cone No. 4 erupted mud at 1125 and 1205 hours.

December 5.

Apart from vapour emission there was no other activity during the morning. After a strong explosion at 1350 hours and other explosions of less intensity during the next hour, it was noticed that a change had occurred in the pattern of activity. The first indication was that the island had built up to an almost perfect inverted cone, the apex of which was about 40 to 50 feet above sea-level.

The basal portion of the cone to an height of about 20 feet was light grey in colour and composed of lava flows and some large blocks ejected during explosions. The two most recent lava flows were on the north-east and north-west sides (noted during a close inspection at 1530 hours). The fact that the flow on the north-west side was overhanging a vertical drop to the sea indicated that the lava cooled very quickly or had already commenced to cool before extrusion. It was also noticed during the close inspection that a large bomb rolling down the side of the cone had impressed a shallow gutter in the surface of molten lava; this bomb was at that time perched about 5 feet above sea-level at the bottom end of the gutter.

The upper part of the cone was brown to red in colour and appeared to be scoriaceous. Steam and gas were being emitted, often with great force, from vents and fissures in the central part; a large volume of finely comminuted orange-brown material was also emitted from this source.

The next explosion at 1550 hours was more violent than preceding explosions; the upper part of the cone (an estimated volume of 2,000 cubic yards), and probably a large volume of underlying material was disintegrated and ejected. The District Commissioner, who had his back turned to the cone at the time of the explosion experienced sharp pain in his ears.

Immediately after the explosion, only the light grey basal portion of the cone remained above sea-level. During the next five minutes red-hot lava in a solid state was forced upwards and reformed the cone as it existed prior to the explosion. The upward movement was accompanied by jet-like emissions of steam, gas and orange-brown dust. The scoriaceous appearance and brown

to ochre red surface colour of the surface formed gradually after upward movement had ceased.

The pattern of activity described above continued until midnight, when observations were discontinued. There were explosions at 1614, 1710-15 (4), 1800, 1810 (small), 1850 (small), 1905, 2018, 2125, 2220 (small), 2233, 2300 hours. The lava plug forced up after the 1614 explosion contained large angular accessory blocks which were stained dark green. As the lava cooled the outer edges of the stain appeared to fade to a pale yellow colour. A large crack appeared on the western side of the dome after the 1710-1715 explosions; it extended from the top of the dome (plug) almost down to sea-level and gradually expanded over a period of about 20 minutes. At the same time it was noticed that the lava flows seen at 1530 hours had fractured and slipped down to sea-level and that either the eastern side had been breached and filled by the plug portion of the dome, or material from the plug had over-flowed the rim of the stable lower portion of the dome. Because of the apparent solid condition of the plug when it appeared, the fracture and slippage of the lava flows, and the fact that steam being formed at sea-level on the eastern side did not vary in volume, the first of the two alternative suggestions is more likely correct. The jet-like emission of vapour was seen very well at night, particularly after the 2125 explosion; on this occasion red-hot particles were ejected to over 100 feet above the vent and the accompanying roar was so loud that conversation was practically impossible within  $\frac{1}{2}$  mile of the dome. Generally the jets forced through vents on the top of the dome, causing lava in the vicinity to glow more brightly (the glow changed from red to orange in colour); flame from the vents reached on the average 20 feet above the vent.

During observations from the leeward side of the volcano, it was possible to obtain some indications of the gaseous emanations. The only obvious smell in the vapour was sweet and somewhat nauseating; it was similar to the smell of burning tar noticed by Best during his investigations of lava flows on Cone No. 3 in 1954. A slight smell of sulphur could be detected accompanying this gas.

Since the commencement of this report, the following information has been received from the Assistant District Officer at Baluan Island.

December 6. Audible explosions at 0655, 0834, 0844, 0951, 0959, 1055, 1222, 1933, 2012, 2025, 2028 hours. (N.B. strong wind after midday and no explosions heard.)

December 7. Explosions heard at 0003, 1115, 1226, 1737, 1739, 1932 hours; probably some explosions not heard due to wind.

- December 8. One explosion heard at 0828 hours.
- December 9. The wind was not as strong, and explosions were heard at 0555, 0852 and 1631 hours; there was an increase in volume of the red material being emitted.
- December 10. Mild explosions at 0900, 1836, 2050 and 2143 hours.
- December 11. Mild explosion at 1149 hours. (Report finished before 1500 hours for mailing.)

#### IV. SEISMIC ACTIVITY

As on previous occasions of volcanic activity in this area, no earthquakes have been felt preceding or during eruptions. A shock recorder was operated undamped from 29th November until 3rd December at the southern end of Lou Island; the recorder was placed at a height of about 20 feet above sea level on a flat bed of rocks set into a coarse-grained pumice deposit. On 3rd December, the shock recorder was placed on the island of Cone No. 4 at a position about 400 yards west of Cone No. 7 and 350 yards north of the active vent of Cone No. 4; it was set to record the east-west components of any movements.

The only movements shown were those recorded at the times of explosions between 1135 and 1625 hours on 3rd December when the shock recorder was stationed on the island of Cone No. 4. Movements resulting from activity of Cone No. 7 were of short duration and the maximum displacement was 2mm. There were a series of movements for  $2\frac{1}{2}$  minutes owing to the explosion at the active vent of Cone No. 4 at 1605 hours, and the maximum amplitude was 8 mm.

The conclusions reached from this information were -

- (1) Both longitudinal and transverse waves were generated by the explosions; in the case of explosions from Cone No. 7, transverse waves were not transmitted to Cone No. 4.
- (2) Explosions occurred at the surface and were the cause of wave propagation.
- (3) The islands of Cone No. 7 and Cones Nos. 2 and 4 were separated by deep water.

#### V. LUNI-SOLAR INFLUENCE

In a previous report on activity at Tulumán Volcano, the writer concluded that luni-solar influences had applied during periods of volcanic activity. "The strongest effects were noticed

- (a) when the sun and moon were in equatorial positions near the zenith of the activity; and
- (b) on the three occasions when the sun and moon were occupying zenith positions close to the Tropics of Cancer and Capricorn respectively and were in opposition."

On 7th November 1956, there was a mild eruptive period when the moon was at its southernmost declination and the sun was approaching the Tropic of Capricorn. The main period of activity commenced on 27th November when both the moon and sun were approaching the Tropic of Capricorn; the strongest activity occurred at a time when the sun was at the Tropic of Capricorn and the moon had reached its southernmost declination and was in conjunction with the sun. Although the tensional pull of the sun and moon in these positions would not be as great as in positions given in (b) above, it would still be great and the period can be considered as one when strong luni-solar influence applied. (The sun and moon were similarly placed at their southernmost declinations at the end of December 1953, when there was increased activity from Cone No. 2 where submarine lava extrusion had commenced on November 14th.)

## VI. OTHER ISLANDS

Since the writer's last visit to this area in March 1955, there had been much erosion. A map showing the islands in detail will be prepared for a later report, and for the purposes of this report a description of the islands is given hereunder.

1. Cone No. 3. Only small remnants of the island mapped in March 1955 remained in December 1956. The rim of the crater was completely eroded away, and apart from a thin layer of pumice dust one foot thick, the island was composed entirely of lava. This lava marked the eastern side of the crater, and hence the island was horse-shoe shaped; determination of the strikes of small folds exhibited by lava exposed just above sea-level around the margin of the island indicated that the point of lava extrusion was near the inner, eastern crater rim. The island had a width of 20 yards and was about 100 yards long in a north-south direction; the maximum height above sea level was about 10 feet.

The sedimentary deposit of pumice and sand which extended for about 800 yards north of the northern crater rim in March 1955 had been eroded away, except for a small elongated portion at the northern end. This had been left as an island joined by a shallow submarine bar to the north to another small island formed subsequent to March 1955 by deposition on the reef at the southern end of Lou Island.

The only activity noticed in the vicinity of these islands was an area of submarine gas ebullition about 100 yards west of the crater; owing to the effervescence, the sea above the active area appeared green in contrast to the dark blue of the surrounding sea. The temperature of the water above the area was 32°C.

2. Cones Nos. 2 and 4. The western half of this island as mapped in March 1955 and the island of Cone No. 5 which joined it to the south had been washed away; the eastern half of the island, formed mainly by Cone No. 2, was almost the same as in March 1955. The crater of Cone No. 2 had not altered and was still thermally active at the eastern end. A steep-sided crater into which water had entered by infiltration had formed south-west of Cone No. 2 crater; this was circular in outline and about 70 yards in diameter. No explosive activity has been seen from this crater, which probably formed after subsidence in this area in May-June 1955. There was also subsidence at that time on the north side of Cone No. 2 and south of the main vent of Cone No. 4. The northern zone which was submarine was still thermally active. The western portions of the crater of Cone No. 4 and of the depressed zone to the south had been removed by erosion and only the steep-sided eastern rim of the subsided zone remained; there was

a small lava peninsula along the northern side of this rim. The focus of activity of Cone No. 4 shifted to the south after the February 1955 eruption, and subsequent activity in the form of mud eruptions have emanated from the zone of subsidence. The sea gained access to the new crater during October 1955, and erosion of the western half of the island proceeded rapidly thereafter. Mud eruptions in November and December 1956 were from this new crater which was then submarine, and submarine gas ebullition was noticed in areas to the west and south-west.

On December 1st, temperatures of 102°C. were measured in a very active thermal point at the base of the eastern rim of the subsided zone. When visited again two days later, there were fissures through this point and activity appeared more vigorous with boiling water being ejected to a height of about one foot above the base of the fissures; the maximum temperature, however, was still 102°C. Small landslides around the rim had accompanied the fissuring, and ground in the vicinity of the lava peninsula had become much hotter according to native police assistants who walked over the area in bare feet during both visits.

Thermal activity in other parts of the island was concentrated along the numerous fissures which had developed. The main fissures and faults shown by Assistant District Officer E.G. Hicks in the sketch which he prepared in August, 1955, still existed. There were also numerous small cracks parallel to the major fractures which extended for distances of up to 200 yards across the island in directions of from north to north-east towards south to south-west. Other fractures were developed around the remnant of the crater rim of Cone No. 4. Small amounts of sulphur had been deposited on the surface at the centre of the island near the eastern rim of Cone No. 4 crater.

## VII. CONCLUSIONS

1. The spasmodic mud eruptions at Cone No. 4 were similar to those which have occurred from the same vent since May 1955, and appeared to occur independently of eruptions from Cone No. 7. The record of activity obtained on the shock recorder on 3rd December indicated that Cone No. 7 was not connected with Cones Nos. 2 and 4 near the surface. Cone No. 7 is considered to be, therefore, a separate centre of activity.
2. The appearance of Cone No. 7 above sea level was not immediately preceded by submarine activity as in the formation of other islands. The activity, therefore, commenced close to the surface, and submarine activity previously attributed to Cone No. 1 will have to be reconsidered as possibly having originated from Cone No. 7.
3. It is considered that lava in the conduit was not often fluid because ejectamenta were of large dimensions and there was very little dust.
4. The volume and pressure of gas accumulated for the eruption of Cone No. 7 in November and December 1956 was not as great as for activity at other centres in 1954-55. This statement is based on above conclusion (3) and on the following facts:
  - (1) during periods of explosive activity, the intervals between explosions were longer than during previous eruptions;
  - (2) there were lava flows after the cone had built up above sea-level, and these were obviously very viscous on extrusion.

5. The extrusion of lava from a fissure on the lower slopes of Cone No. 7 and the consequent submarine activity on 30th November relieved the pressure in the main conduit; this fissure was probably sealed because of the conditions stated in (4) above.

6. The unusual activity on 5th December could also be attributed to the small volume of gas accumulated; the point of accumulation of gas was obviously at no great depth in the conduit because the lava plug filled the main vent very quickly after explosions. Once the resisting pressure of the plug had been removed by explosion, temperature dropped due to fall in gaseous pressure and the lava solidified. There was, however, sufficient pressure to force lava in the red-hot solid condition up into the main vent to form another plug. Gas accumulated in the upper plug portion during this process escaped by forcing jets through weak sections of the surface; the additional escape of gas by this means resulted in further cooling of the lava and temporary stabilisation of the plug.

7. The nature of the activity indicates that luni-solar influence was largely responsible for triggering the eruption at Cone No. 7. The independent mud eruptions from Cone No. 4 are also considered as manifestations of luni-solar influence; response to periods of strong luni-solar influence has been observed from this centre previously.

8. From the above discussion it is concluded that activity at Cone No. 7 has not been as intense as during eruptions in 1954 and 1955 owing to the fact that there has been less gas accumulation than previously. There are two possible explanations for the decline in intensity of the activity:

- (1) the eruption was triggered prematurely by luni-solar influence;
- and (2) owing to the release of large amounts of gas during eruptions since 1953, the energy derived from this source is now almost expired and activity in the area is declining.

Distribution:

Assistant Administrator  
Chief Geologist  
District Commissioner, Lorengau  
Commanding Officer, R.A.A.F. Station, Momote  
Assistant District Officer, Baluan Patrol Post.

TSUNAMIS

It is considered that the main danger to the inhabitants of islands in the vicinity of Tuluman volcano and also in other places in coastal regions of islands in the Manus District would be catastrophic eruption similar to that of Krakatoa in 1883 and the generation of tsunamis. (Tsunamis are often referred to as "tidal waves"; as these waves have no connection with tides, the Japanese word "tsunami" has been adopted to refer to them.)

Information available concerning the possibility of such an eruption and tsunamis is given briefly hereunder:

1. In response to a letter from the Assistant Administrator (AD 93/4/7 of 14th December, 1955), G.A. Taylor prepared some comments on the "Evacuation of Baluan - Lou Island Areas." After a comparison between the 1883 eruption of Krakatoa and the 1953-55 eruptions of Tuluman, Taylor concluded "The above observations suggest that the catastrophic explosions of Krakatoa were preceded by tectonic earthquakes on a grand scale and numerous local volcanic tremors, some of unusual magnitude, were associated with the early phases of the activity. The culminating explosions were preceded by four months of explosive activity of unusual violence and growing intensity with extensions of the sources of activity to a multitude of vents.

"No marked seismic activity has been associated with the activity of the Tuluman centres. The activity appears to have been correspondingly mild and predominantly effusive rather than explosive. Seismic phenomena of an unusual character and a change in the type and pattern of the activity would presumably precede explosions of a magnitude which could be considered a menace to habitation on surrounding islands."

The eruption in November December 1956 was not as intense as during previous eruptions and it was considered that activity in the area was declining.

2. Tsunamis may be caused not only by catastrophic submarine eruptions, but also by submarine land slips started by earthquakes, submarine faulting and atmospheric conditions. Gutenberg in a paper "Tsunamis and Earthquakes" (Bull. Seis. Soc. Am., 29(4), Oct. 1939) gives the following details of tsunamis:

"Strong earthquakes occurring near an oceanic coast are sometimes followed by alternating advances and recessions of the sea, which may even rush inland several kilometers over beaches, carry ships ashore, crush houses, then recede far beyond the normal shore, and in repeated oscillations cause great damage and loss of life. In the open ocean, these waves are of so great length that they are not dangerous. In general, their period is between a quarter and a half-hour; their velocity in an ocean of the constant depth  $h$  is approximately  $\sqrt{gh}$ . This gives about 220 m/sec. in water 5 km. deep, and about 70 m/sec. in water 500 m. deep; the corresponding lengths of waves with a period of 30 min. are about 400 km. and 130 km. respectively."

From the above information it has been calculated that for a depth of 100 fathoms, the waves travel at about 100 miles per hour, and for 10 fathoms, at 30 miles per hour.

3. Taylor also made the following note on tsunamis:

"The tsunamis or "catastrophic" waves which can originate from submarine eruptions are often preceded by a recession of the sea. First the sea withdraws exposing extensive areas of the sea floor on gently sloping coasts. Sometimes the water returns gradually but mostly a high wave comes rolling in. The time interval may be several minutes to one or two hours. Possibly when the coast lies close to the origin of the wave the time interval is short. I have the impression from the story of a native who witnessed the tsunamis from the Ritter eruption of 1888 that the sea withdrew several minutes before the wave arrived on the coast at Kalingi about 16 miles from the volcano. Enough time elapsed for the natives who were in canoes outside the exposed reef to explore the possibilities of regaining the offshore lagoon before they were swept over the reef and inland by the arriving wave. Knowledge of this withdrawal characteristic of tsunamis may enable people in favourable areas to gain higher ground before the arrival of the wave crest."