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RESEARCH IN SEISMOLOGY, VULCANOLOGY AND TSUNAMI OCCURRENCE IN AUSTRALIA AND PAPUA NEW GUINEA

Compiled by

G.A.M. Taylor and P.M. McGregor

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Introduction

Investigations in these fields are made by several governmental and non-governmental agencies. Table 1 lists the permanent recording observations and stations (grouped under the operating agencies); their locations are shown on Plate 1.

Governmental Agencies

Bureau of Mineral Resources, Geology and Geophysics (BMR)

The BMR is the Commonwealth Government's authority on seismology and volcanology. Seismological studies are made by the Geophysical Observations Sub-Section which has a central co-ordinating group in Canberra. The three main observatories are at Mundaring (W.A.), Port Moresby (PNG), and Toolangi (Vic.); minor observatories are at Macquarie Island and Mawson (Antarctica). Each of the main observatories controls a number of outstations. The observatories are permanently manned by professional geophysicists and technical officers; the numbers range from one (Antarctica) to six (Port Moresby).

The observatories' basic programme comprises continuous seismological recording and analysis for international, regional, and local purposes. A main aim is the determination of seismicity and earthquake risk. Allied studies are made on travel-times of seismic waves and crustal structure, utilizing earthquakes and explosions. (Work with explosions is carried out in conjunction with BMR's Regional Structural Surveys Group and the Seismic, Gravity and Marine Group). Computer programmes are used at Port Moresby and Canberra for the rapid location of major regional or felt earthquakes. Macroseismic studies are also made of these events.

Data from all stations are sent once or twice a week to the US ERL for the preliminary determination of hypocentres, and are mailed in report form later to interested organizations. Final data are collated in Canberra and sent on magnetic tape to ISC, Edinburgh. Results of special investigations are reported in BMR publications or in scientific journals.

Port Moresby Observatory is connected to the Pacific Tsunami waring service and the US ERL plans to install a visual recorder there.

BMR also operates a strong motion data centre in Canberra. Accelerograms recorded by several organizations in Australia and Papua New Guinea are processed, digitized and analysed there. The results are supplied to contributors and on request to others interested. The object is to obtain data on the motion of the ground and of structures near earthquakes in a form suitable for engineering applications.

BMR's volcanological programme is described in the next section.

Papua New Guinea Geological Survey and BMR

Volcano surveillance and related research

Surveillance of active volcanoes in Papua New Guinea is carried out by a Volcanological Section of the Geological Survey, a division of the P.N.G. Department of Lands Surveys and Mines. Professional staff of the Geological Survey is made up of officers detached from the Australian Bureau of Mineral Resources: their operations are financed by the P.N.G. Administration.

The Volcanological Section comprises five earth scientists, four technical officers and about 20 auxiliary staff. It is based on the Central Volcanological Observatory at Rabaul, from which it supervises the operation of five permanent regional instrument stations established in other volcanic areas of the country (Table 1).

Four additional stations are under construction and temporary stations are established from time to time in volcanic areas under special investigation.

All reports of phenomena associated with changes in volcanic activity are referred to the Rabaul Observatory for assessment and investigation. Advice is provided to the Administration on the precautions necessary to safeguard life and property (Appendix I).

The main factors studied at present as an aid to warning of volcanic eruption are seismic activity, both local and regional, tilt and changes of height, vent temperatures, gas compositions, and other changes in thermal activity. Eruptions are subjected to intensive instrument and observational studies.

In addition, other studies, by or in co-operation with the Bureau of Mineral Resources, are carried out to shed light on crustal or mantle characteristics in the region.

The BMR is currently carrying out a series of crustal study projects in Papua New Guinea with the co-operation of Australian Universities and the University of Hawaii. Seismic refraction and reflection techniques are used and combined with gravity, magnetic and geological studies to produce crustal models as an aid to better interpretation of seismic activity and as a means of appreciating the broad tectonics of the region. Detailed refraction studies are made in some volcanic areas under special surveillance.

Plans are under way to measure crustal movement in two areas of Papua New Guinea by means of laser geodimeter equipment. This project is being carried out in co-operation with the Division of National Mapping in Canberra.

A broad study of the petrology of Quaternary volcanoes in Papua New Guinea is in progress. An attempt is being made to relate lava characteristics to the structural and seismic environment as a means of gaining a better understanding of island arcs, volcanic mechanisms, and the source of magmas. This work is being undertaken by Canberra-based BMR staff in co-operation with the resident staff in Papua New Guinea.

Since tsunami occurrence and changes in strandline level have been precursors to volcanic eruption at Rabaul the Volcanological Observatory has a special interest in movements of the sea and operates a tide gauge and monitors local level changes by strandline markers. Trans-Pacific and local tsunamis occasionally affect the area in a mild way. The Observatory is unable to participate at present in the Pacific warning system because of the lack of 24-hour communication.

Advisory Committee of Seismology and Earthquake Engineering

This body comprises four engineers, one geophysicist, one engineering geologist, one geologist, one civil defence and emergency services expert and meets regularly at Port Moresby. Its chief functions are (a) to advise government departments and non-government bodies on seismic problems referred to it; (b) to make recommendations to appropriate government departments and other official bodies on matters connected with earthquakes in Papua New Guinea. This committee is represented on the Australian National Advisory Committee on Earthquake Engineering.

Non-Governmental

Riverview College Observatory (N.S.W.)

The Observatory is in the grounds of the Jesuit College (near Sydney) and seismology is included in its programme. Its operations are assisted by an annual grant from BMR.

Activities at present are confined to station seismology. It is operated by College staff.

University of Tasmania and the Hydro-Electric Commission

The University Geology Department, in conjunction with the State Hydro-Electric Commission, operates a network of seismograph stations for the study of regional seismicity. Two more stations (Strathgordon and Scott's Peak) in southwestern Tasmania are planned to be operational in 1972. Related studies (seismic wave velocities and crustal structure) are made. The programme is directed by the Reader in Geophysics; staff comprises a lecturer; computing and technical assistants, and graduate students. Data from all stations are reported to US ERL and ISC, and distributed in bulletin form.

The Hydro-Electric Commission's geological section includes a seismologist whose main function is the application of seismology to engineering geology. Data are obtained from the main seismograph network, and from temporary, closely-spaced networks of seismographs and accelerographs installed near major construction projects to study micro-earthquakes.

<u>University of Adelaide (S.A.)</u>

The University Physics Department has a seismological programme involving the operation of a World Standard station (ADE) and a network of regional stations for seismicity studies (Table 1). Only data from ADE are distributed regularly.

Two accelerographs are operated in the Adelaide area.

Personnel include academic staff, technical assistants, and graduate students. Crustal structural and allied topics are investigated. The agency has participated with BMR and other universities in several major field programmes using explosions as sources. These co-operative programmes will continue.

<u>University of Brisbane (Queensland)</u>

The Physics Department operates seismographs at Brisbane and Charters Towers. Data from both stations are reported regularly to US ERL and ISC. Personnel are academic staff, technical assistants and graduate students.

Joint ventures with BMR and other agencies have been and will continue to be undertaken.

Australian National University (Canberra)

The Department of Geophysics and Geochemistry is involved in basic research in seismology as well as routine reporting of seismic data. Personnel include two academic staff, a research scientist, two laboratory assistants, research students, and technical staff. The university operates a three component long and short period station at Canberra (CAN), eleven other short period vertical stations in south-east Australia and a twenty element short period vertical array (WRA) at Tennant Creek, N.T. (Table 1). Three long period vertical instruments are currently being installed in the Tennant Creek area. Teleseismic readings from CAN and WRA are reported regularly to the USCGS. The southeast Australian stations are used for routine location of approximately 100 epicentres a year in a study of local seismicity. These stations are in the process of being converted into a telemetered large aperture array centred at Canberra.

Special computer facilities are available for the analysis of WRA array data. The array has been used in studies of the velocity structure of the upper and lower mantle and in detailed analyses of the signals from large nuclear explosion.

A low power, portable, tape recording seismic station, capable of unattended operation for one month, has been developed at the University. Ten of these instruments have been used in explosion studies of the crust and upper mantle. They are also being used to monitor localized seismic activity associated with the filling of large dams in N.S.W. and W.A.

National Advisory Committee on Earthquake Engineering

This body was formed in 1970 and comprises representatives of most of the above agencies, and governmental and private engineering groups. Its main objective is to collate, and advise on, engineering aspects of seismology. It has sub-committees concerned with particular facets, and it is planned that meetings will be held several times annually.

Table 1

AUSTRALIAN SEISMOGRAPH STATIONS

1. Government

(a) Bureau of Mineral Resources

Western Australia

Mundaring	MUN	World Standard SP World Standard LP Supplementary SP
Kalgoorlie	KLG	SP-ZNE
Meekatharra	MEK	SP-Z
Karratha	KAA	SP-Z
Kununurra	KNA	SP-Z

Papua New Guinea

Port Moresby	PMG	World Standard SP World Standard LP Supplementary SP Supplementary LP
Goroka	GKA	SP-Z
Kavieng	KAV	SP-Z
Konedobu	KDB	SP-Z
Lae	LAT	SP-ZNE
Momote	MOM	SP-Z
Talasea	TLS	SP-Z
Wabag	WAB	SP-ZNE

Victoria

Toolangi	TOO	SP-ZNE *LP-ZNE

* In co-operation with Lamont-Doherty Geological Observatory.

Macquarie Island	MCQ	SP-Z
Mawson	MAW	SP-Z LP-NE
Norfolk Island	NIA	SP-Z

Northern Territory

Alice Springs	ASP	SP-ZNE
Darwin	DAR	SP-Z

(b) Papua New Guinea Geological Survey

Rabaul	RAB	World Standard SP World Standard LP Supplementary SP ZNE LP NE
*Taviliu	VUL	SP-Z
*Tavurvur	TAV	SP-Z
*Rabalanakaia	RAL	SP-Z
*Sulphur Creek	SUL	SP-Z
*Wanliss Street	WAN	SP-Z
Agenahambo	AGE	SP-Z
Esa'ala	ESA	SP-ZNE LP-ZNE
Kobuan	KOB	SP-Z
Tanaka	TAN	SP-Z
Tabele	TBL	SP-Z

* Stations in the Rabaul Harbour Network.

2. Non-Government

Tasmania (University of Tasmania)

Burnie	BNE	SP-Z
Hobart	TAU	World Standard SP World Standard LP
Lemonthyme	LMT	SP-Z
Moorlands	MOO	SP-Z
Sheffield	SFF	SP-Z
Savannah	SAV	SP-Z
Tarraleah	TRR	SP-Z

Queensland (University of Queensland)

Brisbane	BRS	SP-ZNE LP-ZNE
Charters Towers	CTA	World Standard SP World Standard LP

South Australia (University of Adelaide)

Adelaide	ADE	World Standard SP World Standard LP
Cleve	CLV	SP-Z
Hallett	HTT	SP-ZN
Island Lagoon	ILN	SP-Z

Partacoona	PNA	SP-Z
Sevenhill	SNL	SP-Z
Umberatana	UMB	SP-Z

<u>New South Wales and Australian Capital Territory</u>

(Riverview College Observatory)

Riverview	RIV	World Standard SP World Standard LP

(Australian National University)

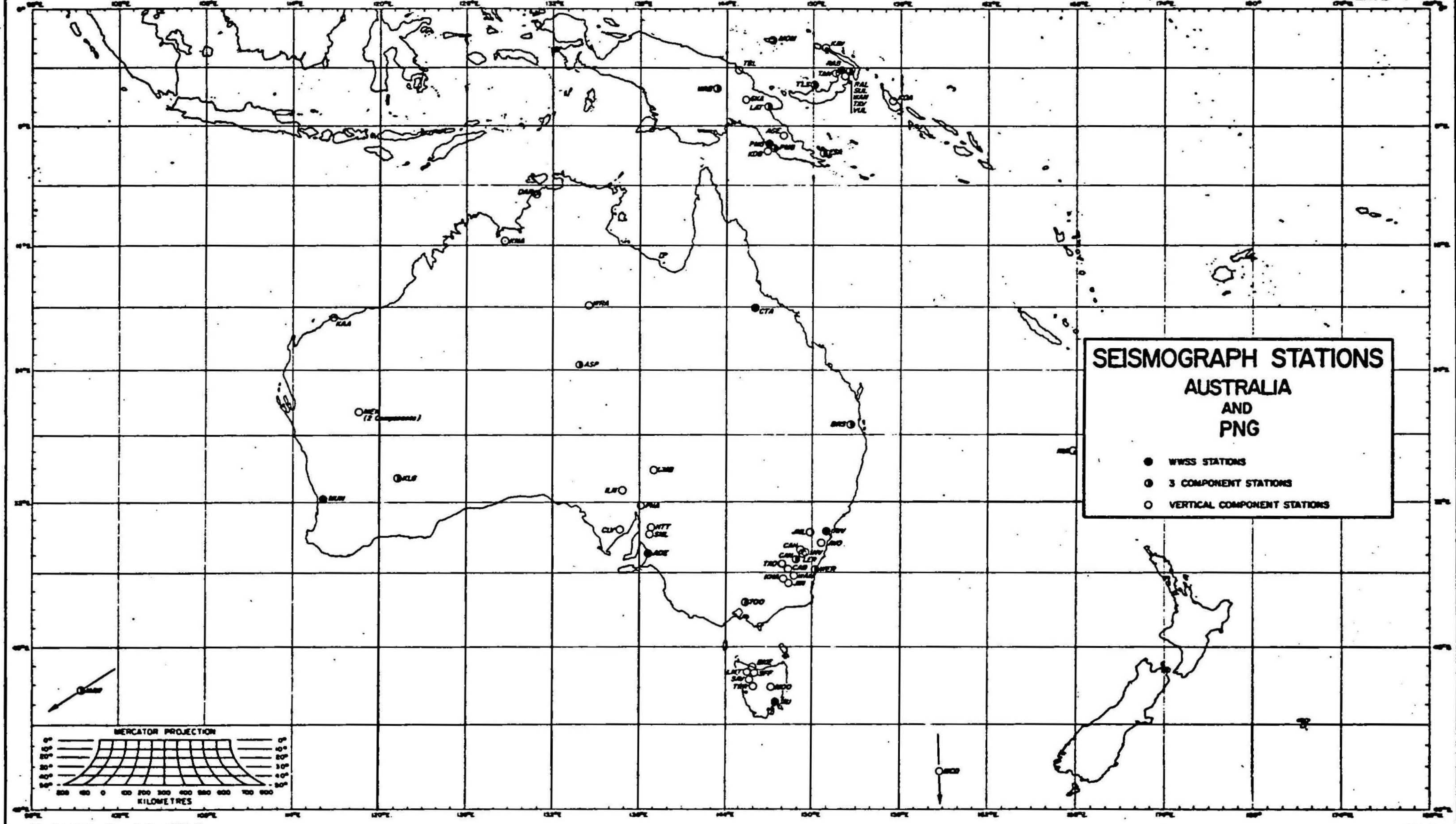
Avon	AVO	SP-Z
Cabramurra	CAB	SP-Z
Canberra	CAN	SP-ZNE IP-ZNE LP-ZNE
Castle Hill	CAH	SP-Z
Inveralochy	INV	SP-Z
Jenolan	JNL	SP-Z
Jindabyne	JIN	SP-Z
Khancoban	KHA	SP-Z
Lerida	LER	SP-Z
Talbingo	TAO	SP-Z
Wambrook	WAM	SP-Z
Werombi	WER	SP-ZNE

<u>Northern Territory</u> (Australian National University)

Warramunga array	WRA	

In co-operation with UK Atomic Energy Authority (Blacknest, U.K.).

PLATE 1



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APPENDIX I.

The Surveillance of Volcanoes in the Territory of Papua and New Guinea

By G. A. M. Taylor, G.C.*

The islands of Melanesia are located in a tectonically unstable zone which extends in an almost continuous belt around the margins of the Pacific Ocean. The stresses set up in this zone, possibly by movements in the mantle, find spectacular expression in earthquakes and volcanic eruptions, and less dramatic expression in slow distortions which raise island chains and mountain ranges and which depress the sea floor to form ocean trenches.

The known history of vulcanism in the south-west Pacific region is short and incomplete. We do know that eruptions of catastrophic proportions occurred during the last half of the 19th century, originating from volcanoes ranging from Krakatoa in the East Indies to Tarawera in New Zealand. Several less publicized eruptions of comparable magnitude originated from volcanoes in the intervening Melanesian islands.

Daily descents were made by vulcanologists to investigate abnormal temperatures and gas compositions in the crater of Langila volcano on the eastern flank of Mount Talawe, 3,000 feet above sea level on the west coast of New Britain.

DURING THE present century several eruptions of exceptional magnitude have occurred in Melanesia. These have drawn attention to the need for systematic study of such phenomena. It is difficult, however, for governments in underdeveloped countries to allocate funds for scientific research aimed at mitigating the effects of latent catastrophes.

Memories of volcanic disasters are short, and the view that the study of active vulcanism is little better than an academic exercise is still held by a surprising number of otherwise well-informed people. 'You cannot stop eruptions' is a familiar comment, with the implied question—so why waste peoples' time and money by establishing institutions to study them?

The following notes attempt to outline some aspects of the vulcanologists' work in the Territory of Papua and New Guinea, where the Administration actively supports this branch of scientific research.

Of the 40 known volcanic centres in the Papua and New Guinea region which are believed to have a potential for eruption, 19 have erupted within historic time and 12 of these during the last 30 years. Most of the volcanoes are characteristically dormant. At present, only two—Manam and Bagana—manifest eruptive cycles which are long-continued events extending over several years. The majority of dormant volcanoes produce some mild form of thermal and solfataric activity which may show little change over the years; even this mild form of activity may be absent.

Warning Phenomena

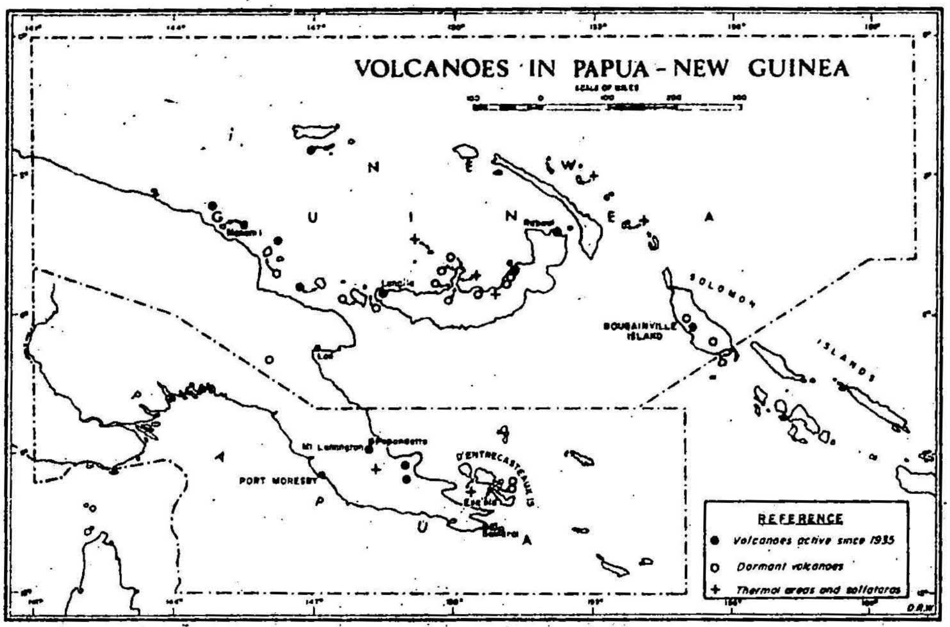
Reactivation of a dormant volcano leading to paroxysmal eruption may be preceded by warning phenomena of various kinds which may anticipate the outburst by years, months, or days. These phenomena may vary widely in intensity and type from eruption to eruption and from volcano to volcano. The rising magmatic pressures in the conduits beneath the volcano may produce local earthquake swarms which are strong enough to be felt in the neighbourhood of the volcano. Seismic instruments provide the most reliable method of detecting disturbances of this type.

Tumescence or distortion of the terrain near a volcano by magma upwelling beneath is most conveniently detected with instruments designed to measure small changes in tilt. Very localized changes in the temperature of fumaroles in a crater, with associated changes in gas composition, give warning of some eruptions. The thermal areas may increase in size and there may be a visible increase in the volume of gas exhalation. Increases in thermal activity often first become evident by such secondary effects as the dying off of vegetation, or landslides in crater areas, or the presence of dead fish on the shores near coastal volcanoes.

An appreciation of the significance of such changes is ideally made by qualified scientific staff on a background of regular observations which include continuous monitoring of movements at depth by appropriate instruments. An adequately equipped and staffed volcano observatory is the best safeguard against eruption without warning.

This ideal is seldom realized in practice since the economics of establishing a volcano observatory on every volcano with a potential for eruption is prohibitive. The volcano surveillance system in the Territory is organized around a central observatory situated in the key point of Rabaul. This point is roughly

* Bureau of Mineral Resources, Canberra, A.C.T., Australia.



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halfway between the two major volcanic lines, and as Rabaul is also the main shipping outlet for the Bismarck Archipelago, the need for monitoring the activity of volcanoes in the harbour area is greater than anywhere else in the region.

The Rabaul Volcano Observatory is staffed by two earth scientists, two technical officers, and auxiliary personnel.(1) It is equipped with seismographs, tiltmeters, and thermometric gear. Seismic disturbances of local and regional origin are recorded continuously and the information on regional earthquakes (teleseisms) is sent to international data centres for analysis. Local crustal distortion of volcanic origin is detected by tiltmeters, tide gauges, and strand-line level markers. Movements are checked by precise levelling surveys. Thermal areas inside and outside craters are checked weekly and temperatures measured.

The observatory staff is kept advised of conditions at other volcanic centres in the Territory by local observers. A formal monthly report book has been designed and distributed to about 100 observers throughout the Territory for reporting earthquake occurrences and changes in volcanic activity. The book contains basic information on warning phenomena and on the 'Modified Mercalli' scale of earthquake intensity. These monthly reports are supplemented by radio messages from the local observers and by reports from airline pilots who often see changes in the craters not observed by local residents.

All reports received at the observatory are assessed by the vulcanologist and, if warranted, a field investigation is carried out, sometimes with portable seismic and tilt equipment. Should the investigation confirm the existence of abnormal activity, an observation post may be established on the volcano. This is equipped with basic seismic and tilt instruments and a radio transceiver. A local assistant may operate a station of this kind and he would keep the vulcanologist informed of the condition of the volcano by daily radio messages. This technique is particularly applicable to a volcano which is building up slowly to paroxysmal eruption. Immediately a change in trend of the volcano's activity is apparent, the vulcanologist from Rabaul carries out a detailed investigation and reports to the Administration.

Expansion of Instrument Facilities

The study of seismic events of volcanic origin in recent years has emphasized the importance in predicting eruptions of an ability to trace the movement of earthquake swarms from focus to focus. Such a facility is of first importance in a situation such as we have at Rabaul where a number of potentially active craters are relatively close to an area of close settlement. It calls, naturally, for more complex instrumentation—instrumentation of the array type in which several seismometers pick up the signal from any disturbance in the volcanic area.

The Administration of the Territory is installing equipment of this type at Rabaul.(2) It will be based on the research of Professor G. Newstead, formerly of University of Tasmania, now of the Australian National University, Canberra, whose work on the telemetering of seismic signals has won him an international reputation.

Ground vibrations from earthquakes will be converted to electronic signals by seismometers located near each of the volcanoes, in Rabaul harbour. These signals will be modulated before being transmitted by underground cable to demodulators and recording equipment at the central observatory. High-frequency radio will be used for carrying the signal to the observatory from only one of the five seismometer stations since the reliability of this carrier system under all conditions is in some doubt.

Before a network of this type can work effectively it is necessary to know something of local crustal structure and the travel time velocities of earthquake waves. This information will be obtained from a seismic refraction survey which will be carried out by the Australian Commonwealth Bureau of Mineral Resources.(3)

The Regional Network

A considerable body of evidence suggests that stress conditions in the crust and mantle as manifested in the occurrence of tectonic earthquakes have some bearing on the time and nature of volcanic eruptions. To throw more light on this hypothesis, approval in principle was obtained several years ago to establish two additional observatories in other parts of the Territory. By supplying further information on the arrival times of phases in tectonic disturbances they will greatly increase the central observatory's capacity for pinpointing their origins.

The sites selected for these stations are: Manam Island, lat. 4°07'S, long. 145°05'E. and at Esa-ala, lat. 9°44'S. long. 150°49'E. This basic network gives a triangle with almost equal sides of about 400 miles. Besides giving good triangulation data on tectonic earthquakes in the region, these stations, sited near important volcanic centres, also act as continuous monitors on local volcanic activity. Both stations are equipped initially with Benioff seismographs and with water-tube tiltmeters. Continuous operation began in 1965.

Data on tectonic earthquakes are also contributed by two other recording centres. One is the vulcanological station established by the Administration on the slopes of Mount Lamington near Popondetta. The other is the geophysical observatory at Port Moresby, which is maintained independently by the Australian Commonwealth Government for studying ionospheric, magnetic, gravity, and seismic phenomena of the region.

Field Investigations

The mechanics of the surveillance system are best illustrated by describing

(1) For current staff establishment, see page 2. (2) Installation of the inner network of telemetred stations has been completed and has been operating satisfactorily for many years. (3) BMR completed crustal study surveys in the New Britain area in 1967 and 1969 and another survey is planned for 1972.

briefly examples of the investigations of reports of increased volcanic activity.

In May, 1952, a missionary living on the western end of New Britain reported a change in the volume of gas being exhaled from Langila, a volcano which had last erupted about 1870. Access to the area was gained by boat, since the wartime airstrip at Cape Gloucester was unserviceable.

The activity originated from one of a group of craters situated 3,000 feet above sea level on the eastern flank of an extinct cone named Mount Talawe. From the Kilenge villages on the coast, six miles north-west of Langila, a cloud of white vapour could be seen pouring over the rim of the crater as it was swept down the leeward slopes by the strong prevailing south-easterly winds.

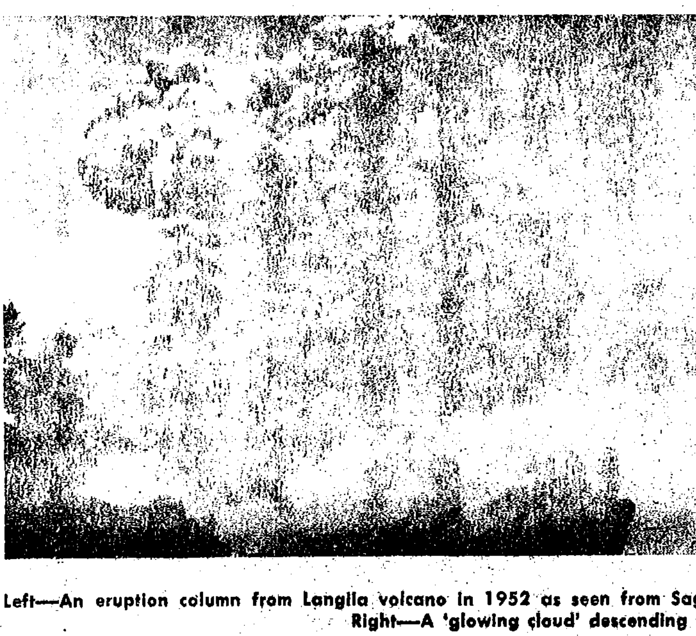
The mountain was climbed *via* a native hunting track. After five hours' walk from the coast the investigating party reached a point about a mile from the crater. Here, the rain forest had been stripped of its leaves by sulphur gases in the exhalation cloud. Inspection of the crater area confirmed the existence of abnormal conditions. Noisy pressurized vents had broken through the floor of a small funnel-shaped crater which had been inactive on inspection 13 years previously. Temperatures of the vents greatly exceeded 100°C.—the normal level for passive conditions, and the presence of choking sulphur gases was a further indication of increasing eruptive potential.

In order to check the trend in crater conditions they had to be observed systematically. A camp was established on the flank of the volcano and equipment was obtained to facilitate collection of data on temperatures, gas compositon, tilt, and seismic movements. Daily, descents were made into the crater, with the aid of gas masks, to check temperatures and gas compositions. Three months of checking revealed—

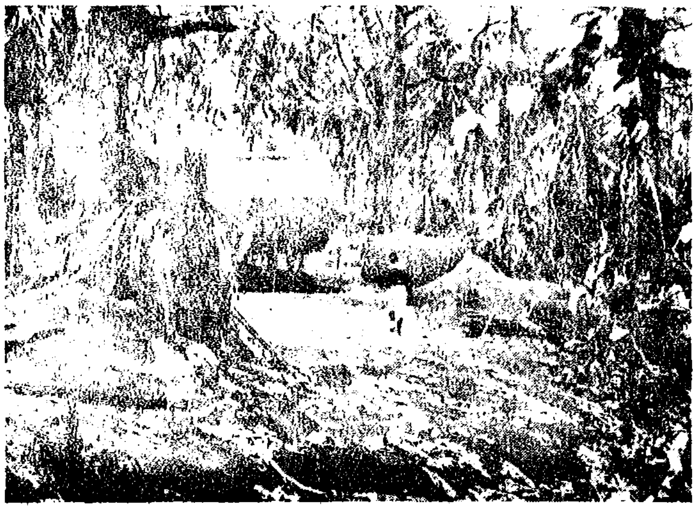
1. Abnormal temperatures which showed no clear trend;
2. A rising trend in acid components in the exhalations;
3. The occurrence of subterranean explosions in the conduits beneath the volcano; and
4. An absence of evidence for volcanic earthquakes.

These observations were assessed as being indicative of a slow build-up to eruption, and precautionary recommendations included the need for further checking on the condition of the volcano. No movement of people was considered necessary.

A 'glowing cloud' sweeps down towards the sea during the eruption of Manam volcano on 17th March, 1960. Behind its path was left an area of flattened, scorched, and burning forest.



Left—An eruption column from Langila volcano in 1952 as seen from Sag Sag, 6 miles south-west of the crater. Photo by courtesy of Mr Law. Right—A 'glowing cloud' descending the flanks of Manam volcano, 1957.



Left—Effects of the 1957 eruptions of Manam. A lava flow moving down from the south-east valley consumed the remnants of a forest destroyed by earlier 'glowing clouds.' Right—A native village after the rain of ash and lapilli.

The actual eruption occurred two years after the increased activity had been first noted by the local people. It took the form of intermittent vulcanian explosions of relatively moderate intensity. The type of activity had been predicted from observations made during the field investigations. The local population was not seriously affected by the eruption.

Manam Volcano

A new cycle of eruptive activity began from Manam volcano in December, 1956, after a dormacy period of approximately ten years. The early activity took the form of rhythmical ejections of fragmental material and small lava flows. An observation post was established on the island in June, 1957, and equipped with seismic and tilt instruments and a radio transciever. A trained local observer was instructed in preparing daily signals which would keep the staff of the central observatory at Rabaul advised of the scale of crater activity and of seismic and tilt phenomena.

During the ensuing six months the continuous observations of the observer were supplemented by studies carried out by scientific officers from the central observatory who visited the island from time to time. These studies brought to light a number of important developments, chief among which was the clear evidence that this basaltic volcano had the capacity to produce activity of the Peléan type.

The predominant activity of the volcano was a relatively harmless rhythmical ejection of incandescent fragmental material commonly known as Strombolian in type. Occasionally, however, the explosions took the form of a massive disgorgement of hot fragmental material which swept down the flanks of the mountain at high speed, burning and destroying everything in its path.

This was the 'glowing cloud,' the most dangerous of all volcanic phenomena. This observation immediately raised doubts of the safety of certain settlements on the island, despite the protestations of local natives and missionaries that they had been immune during earlier eruptions. Other developments which did nothing to reassure the vulcanologist were a rising trend in the frequency and intensity of the intermittent explosive phases and the indication of consistent tumescence of the mountain by the tilt readings.

In November, 1957, it was suggested to the Administration that the volcano was building up to a climactic eruption which would possibly take place in December/January or June/July of the following year.

The Administration evacuated the whole population from the island in mid-December. A series of climactic eruptions in January, February, and March produced explosive and effusive activity of remarkable proportions. A rain of blocks, lapilli, and ash stripped the forest on the western side of the island and covered native gardens with coarse deposits, in many places exceeding 12 inches in depth. Ponderous glowing clouds swept down the four main valleys which dissected the cone, and destroyed areas of forest, some gardens, and part of an empty village on the south-west coast. Deposits left by some of these hot pyroclastic flows exceeded 50 feet in depth.

A second observation post had been established on the island at the time of the evacuation. The vulcanologists maintained continuous observations, both during the phase of climactic eruptions and for four months afterwards. At the end of July, 1958, re-occupation of the island was recommended and one of the observation posts was withdrawn.

At the end of 1959 Manam again showed signs of serious instability. The vulcanologists re-established a second observation post on the island and recommended precautionary measures to safeguard the population.

Danger areas were nominated and arrangements made to maintain a continuous watch on the mountain with the assistance of local police and village leaders. In the event of an eruption, relevant village groups had instructions to move to safe areas.

A study of the volcano's previous pattern of activity suggested that the eruption would probably occur in March, a peak period for earthtides. The event began on the morning of 17th March with voluminous explosive ejections of fragmental material which swept down the north-eastern valley to a point very close to a coastal village and only a few hundreds yards from the sea. It left in its path an area of flattened, scorched, and burning forest.

Although the village people *en masse* had followed instructions and moved to a safer area, before this initial explosive phase of the eruption was actually over, the over-curious village leaders were inspecting the new deposit in the highly dangerous avalanche valley. Whether such action was from bravado, ignorance, or overwhelming casualness is a moot point. It constitutes one of the difficulties inherent in safeguarding people in volcanic areas.

The explosive outburst from Manam was followed almost immediately by heavy outpourings of lava which continued for more than two months. Most of this material was retained in the amphitheatre-headed north-eastern valley. Garden land and settlements were unaffected.

A new phase of explosive activity, which began in June, 1960, continued intermittently throughout the year. This was assessed as 'normal' and did not require the precautions and intensive observations of the March eruption.

Intermittent activity still continues from Manam and a continuous watch on the volcano is maintained. The establishment of a permanent observatory on the island will assist greatly in a more effective study of the volcano's behaviour pattern.

A paroxysmal eruption from Mount Lamington throws a column of gas and fragmental materi… 40,000 feet above the crater, 21st January, 1951. Photo by courtesy of Capt. A. Jacobson.

Mount Lamington Disaster

The volcano with the greatest potential for catastrophe is the long-dormant specimen which produces a paroxysmal outburst early in its eruptive cycle. If the eruption is of the Peléan type its potential for disaster is enormously increased. If the mountain is unrecognized as a volcano and is located in a tropical environment, where its summit is obscured for most of the time by cloud, the chances of most of the early warning signs going unnoticed are multiplied even further.

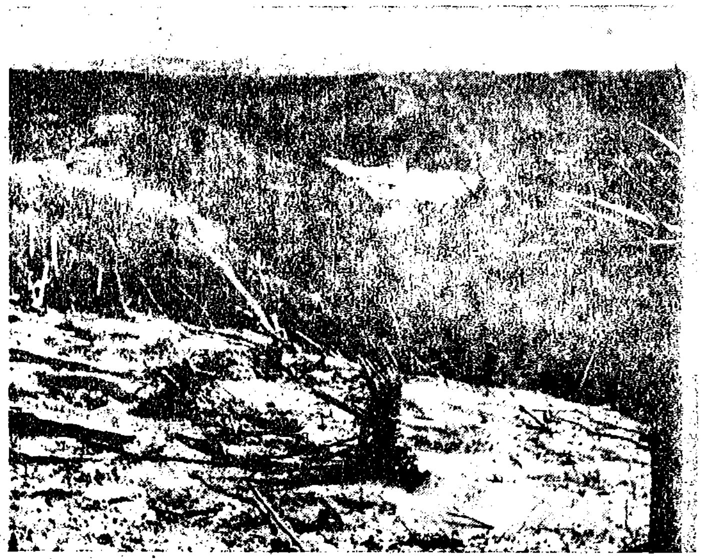
These were the conditions for the Mount Lamington eruption of 1951. In that year, not more than six days after the emission of gas was first observed, this unrecognized volcano produced the most powerful Peléan eruption that has ever been observed. About 90 square miles of country were devastated, and nearly 3,000 lives were lost.

As there is a salutary lesson in the facts of this disaster it is worthwhile outlining some of the salient points of the eruption and its preliminary phenomena.

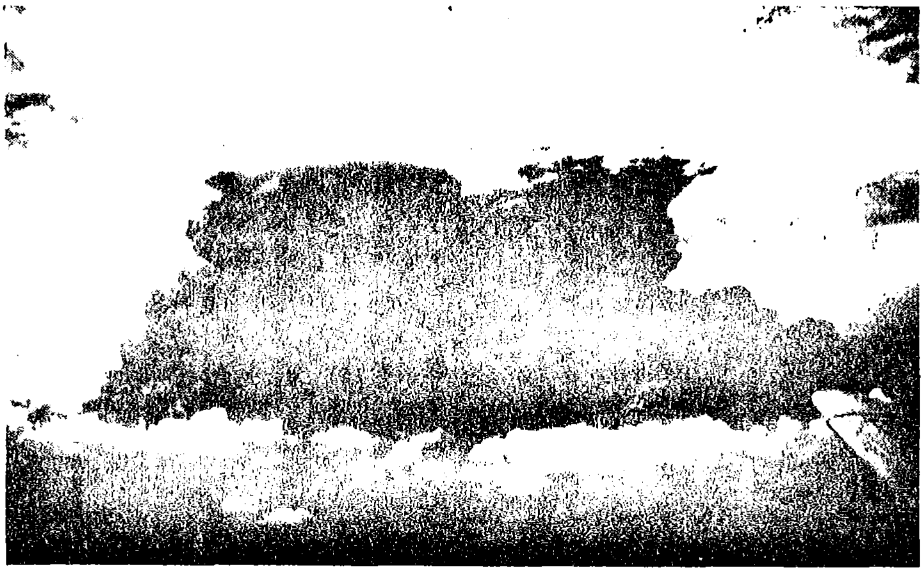
Mount Lamington lies about 30 miles from the northern coast of Papua, at the western end of the dissected Hydrographer Range, a volcanic pile which has been extinct since early pleistocene times. Lamington's summit consists of a rugged group of peaks which have elevations close to 6,000 feet. Before the eruption the upper slopes were heavily forested, and the lower slopes contained native gardens, villages, and a government station six miles from the summit.

Towards the end of 1950 a forestry officer from the government station made an ascent of Mount Lamington to investigate the dying off of trees in the summit area. He found the cause to be hot ground, and noted that small landslides were occurring in the affected area. Several people living in the di[s]trict subsequently noticed landslides ne[ar] the summit area. Landslides are a com[-]mon phenomenon in the mountains [o]f New Guinea, and thermal areas a[re] numerous. Apparently no great impor[t]ance was attached to either observatio[n] and they were not reported to the vu[l]canologist at Rabaul.

During the week before the erupti[on] weather conditions were unsettled an[d] the summit was obscured for much [of] the time. On Monday, 16th Januar[y] 1951, in the late afternoon the clou[ds] momentarily lifted from the mountain [to] reveal a thin column of vapour ascen[d]ing from a point among the peaks. It ha[d]



Left—The Lamington slopes above the government station site were swept bare of all vegetation. Right—the splintered remnants of the rain forest … Lamington's devastated area.



The base of the column expands rapidly as the avalanche of hot fragmental material sweeps down the slopes of Mount Lamington. Photo by courtesy of Capt. A. Jacobson.

the appearance of smoke from a native camp fire.

By the next day, gas emission had increased and late in the afternoon small earthquakes were felt at the government station. An appreciable increase in both phenomena was observed on Wednesday and, on Thursday, a marked increase with pulsating ash emission. By Friday, everyone in the area knew that an eruption was in progress, but it was not until late in the day that some people realized that the centre was nearby. One observer reported on Friday morning that the centre was 80 instead of only 10 miles away.

Such an observation may seem incomprehensible to anyone who has not lived in a rain-forest environment, where visibility is often confined to a few hundred yards and communications are poor.

It was also on the Friday that developments at Lamington became common knowledge outside the area. The Territory radio station included an item in its news service.

By Saturday, active areas within the crater had extended greatly and an almost continuous billowing column of ash rose 25,000 feet above the mountain. Unfortunately, this material was carried by the prevailing winds to lightly settled areas in the rough country south of the crater. With southerly winds the ash would have fallen on the relatively closely settled northern slopes, and many of the indigenous peoples might have moved away from the crater.

On Sunday, 21st January, at 10.40 a.m., the irregular rumbling of the volcano gave way to a sustained roar and a great explosion hurled a column of gas and fragmental material 40,000 feet above the volcano where it formed a huge expanding umbrella. Then, the occupants of a passing aircraft were alarmed to see the base of the column expand with astonishing rapidity, as if the whole mountain were disintegrating.

This was the expansion cloud from the avalanche of hot fragmental material which was sweeping down the slopes of the volcano with hurricane force velocities. Within a few minutes, more than 60 square miles of country around the mountain had been completely devastated, and the hot cloud enveloped another 30 square miles before its energy was spent.

Other powerful eruptions followed on the heels of this event. It was June before the explosive phase changed completely to a quiet, effusive activity which then continued for several years. This post-climax period was an anxious time for all concerned. There were few precedents to go by. The type of eruption had first been recognized less than fifty years before. The prototypes, Pelée and St. Vincent in the West Indies, had exhibited little consistency. One of the post-climax eruptions at Pelée had claimed a thousand more lives, and powerful eruptions from St. Vincent were still continuing ten months after the disastrous initial outburst.

The Administration had acted promptly at Lamington by moving all indigenous people living within a 10-mile radius of the crater to evacuation camps. No casualties were caused by the post-climax eruptions.

It is not always realized that the secondary effects of an eruption may present serious problems. The increased run-off caused by the destruction of vegetation can cause serious river flooding and rapid silting up of stream beds. The floodings at Mount Lamington caused some loss of equipment and necessitated removal of one of the evacuation camps. Mudflows which frequently descended the mountain as hot, roaring torrents closed roads and hindered communications generally. River crossings, which had to be kept open, necessitated a permanent labour force to remove the debris left by the daily flash floods.

Mount Lamington has now returned to the dormant state. All that remains of the former activity are a few vents emitting a little vapour. A new forest has sprung up on the slopes and most of the signs of disastrous eruption have been obliterated. Possibly within a decade or two nothing will remain to identify this volcano as having been recently active.

A vulcanological station has been established on the north-western slopes of the mountain to ensure that any change in the condition of the volcano will be quickly detected.

The Lamington catastrophe drew attention to the extraordinary destructive power of volcanic eruption and to the need for close study of such phenomena. Without this stimulus the 1958 eruption of Manam, in terms of human lives, may have been a different story.

Vulcanology has been described as the 'Cinderella' science which only marches forward on the ashes of catastrophe.

A very real effort is being made in most countries concerned with active vulcanism to change this picture. More support is being given to the formation of specialist groups for the full-time study of volcanoes and the abiding problems of eruption prediction.

Although vulcanology is generally regarded as a narrow specialist field, it is, in fact, a broad unifying discipline calling on and contributing to results of research in many branches of earth science.

Workers in the fields of geology, physics, chemistry, seismology, and electronics all assist in unravelling the complex story of volcanic mechanism. In fact, it is becoming increasingly difficult for the practising vulcanologist to keep up with the many developments in his field of science. In this respect the meetings of the International Association of Vulcanology are invaluable in providing a forum where men working in various disciplines can make known the results of their work and, with mutual benefit, discuss problems and progress.