Copy 2

COMMONWEALTH OF AUSTRALIA.

DEPARTMENT OF NATIONAL DEVELOPMENT.

BUREAU OF MINERAL RESOURCES

GEOLOGY AND GEOPHYSICS.

RECORDS.

1956/5.

REPORT ON VISIT TO VULCANOLOGICAL OBSERVATORY, RABAUL

by

John P. Webb

REPORT ON VISIT TO VULCANOLOGICAL OBSERVATORY, RABAUL

by

John P. Webb.

RECORDS 1956/5.

CONTENTS

REPORT ON VISIT TO VULCANOLOGICAL OBSERVATORY, RABAUL

The writer spent the period 26th November-20th December, 1954 at the Vulcanological Observatory, Rabaul. The aim of the visit was to assist in placing the seismological station on a satisfactory routine basis and to advise the Vulcanologist on seismological matters. The report following reviews briefly the work carried out during the twenty-five days spent in Rabaul, comments on some aspects of seismological work there, and makes certain suggestions regarding future improvements to the station.

A - Instruments.

(1) General Vault Arrangement.

The overall layout of the vault is excellent and could not easily be improved. The sub-division of the vault into rooms to house individual instruments is particularly commendable. The Leonard Dehumidifier seems to provide adequate humidity control and ventilation appears quite satisfactory. There is no obvious drainage problem.

(2) Benioff Seismographs.

The 35 mm. film recorder was completely overhauled and cleaned. Particular attention was paid to the drum traversing mechanism, since faulty operation here was suspected, as the cause of the numerous trace offsets which have appeared on the records. The rack and pinion gear and the V-ways and the plates on which the carriage rides were removed and thoroughly cleaned. The V-ways show considerable signs of wear but are apparently still usable, since cleaning was sufficient to eliminate the trace offsets. The recorder wiring was checked and a number of poorly soldered joints were remade.

"Pinging" of the bolts when the recorder motor is running indicates poor alignment of the pulleys on the motor and drum shafts. In view of the danger of breaking bolts, no replacement being available, realignment of the pulleys was not attempted. However, this should be done as soon as extra bolts are available. The strain on the bolts under present circumstances is probably largely responsible for the considerable number of breakages experienced. It is suspected also that small irregularities in drum rotation shown on the records are due to the same cause.

Inspection of the recorder revealed that all three components had been operating with the Seismometer Period Test switches in the "off" position. This has the effect of introducing a 1000 ohms resistor in series with the seismometer and galvanometer, with consequent reduction in sensitivity and disturbance of the damping of the system. Operation under these conditions explains the general absence of background noise and rather poor records of the more distant earthquakes, observed in the past at Rabaul. The switches are misleadingly labelled, since they should normally be operated in the "on" position, so that the 1000 ohm resistors are shorted out. Similar trouble occurred in Brisbane when the Benioffs were first installed.

With the Period Test switches in the correct positions it immediately became apparent that the Sensitivity Dial settings would have to be greatly reduced in order to obtain useable records. The station is apparently in an area of high background noise level (see (7), below), a fact not previously apparent from the appearance of the records. Finding optimum sensitivity dial settings is a matter of trial, and had not been completed before departure from Rabaul. However, this is largely a matter of patience and should present no difficulty. Indications are that no greater sensitivities than 20% of maximum can be used. Nevertheless, even at such low settings, the instruments will be operating more efficiently than before.

Calibration of the Benioffs was carried out using the methods laid down in the U.S. Coast and Geodetic Survey Manual, "Standard Procedure in the Operation of a Short-Period Electromagnetic Galvanometric Type Seismograph". The small calibration test-meter described in this publication was constructed, and proved most useful.

Periods were measured and damping ratios adjusted to the desired values. The following results were obtained:-

	Z	N-S	E-W
Galvanometer period (sec).	.35	.26	.29
Galvanometer damping	Critical	Critical	Critical
Seismometer period (sec).	1.26	1.44	1.45
Seismometer damping	Critical	Critical	Critical

It is hoped that, in future calibrations, the overall damping of each system can be determined as well as the damping of the individual units. The method, based on the tapping test (Sohon, "Seismometry", p.111), is simple, but the calculation of the correct ratio of galvanometer deflections for critical damping presents difficulties in the case where galvanometer and seismometer periods are not equal. When time permits these ratios will be calculated for use in subsequent calibrations.

The final step in the standard calibration procedure is an intercomparison of sensitivity dial calibrations for the three components, in order that they may be all set on the same sensitivity. Although attempts were made to do this on several occasions, it was always found that the noise level was so great as to seriously influence the results, which were quite inconsistent on the higher sensitivity settings. It was decided that calibration could not be carried out over the whole sensitivity range. Instead, when satisfactory settings for routine recording have been established, the intercomparison technique will be used to adjust all three components to exactly the same sensitivity.

It is believed that, when the drum drive pulleys have been realigned and the sensitivities adjusted to a convenient value, the Benioffs will be performing as well as possible within the limits set by the local noise level.

The following spare parts should be kept on hand for replacement purposes (Gilman Scientific Instrument Co. Pasadena, can supply):

6 belts for recorder
5 V-plates for recorder carriage
1 flat plate for recorder carriage
3 ball bearings for recorder carriage
3 sets of hinges for seismometers
1 synchronous motor for recorder.

(3) Willmore Seismographs.

The Willmore seismographs were put in running order and a number of records were obtained in order to gain some idea of the instrument's capabilities. Since the Willmores are not in regular use in Rabaul, only a few brief comments will be made concerning them.

The unit is very compact and is simple to set up and operate. Its portability, and the fact that it can be operated from a battery, make it an excellent field instrument. The most obvious disadvantage is the restricted range of drum speeds available. The highest speed, 53.4 mm/minute, is barely adequate

for serious work on near earthquakes. Recording at this speed one can obtain on a single recorder only six hours record if all three components are used. Thus, routine running of the three components would require four changes of paper per day. One component will record for twenty-four hours on one loading of paper, so that the most satisfactory way of achieving continuous recording with only daily paper change would be to provide a separate recorder for each component.

The supporting spokes in seismometers used in the horizontal position show a tendency to slacken off and bend at the ends, thus displacing the mass from its axial position and allowing it to foul the fixed coil. The circuit built into the recorder for giving each system a test pulse provides a ready means of determining whether a particular seismometer is swinging freely. To re-centre the mass it is usually necessary only to unclamp one end of each of the five spokes, rotate the mass slightly, and reclamp the spokes. It is suggested the seismometers be clamped if they are to be left unused for any length of time. This is particularly important if the galvanometers are out of circuit, because the seismometers are then undamped.

On the only occasion on which the Willmore was used as a field instrument trouble was experienced with the drum drive. Apparently during transportation the recorder case, which is suspended on shock mounts inside a larger wooden case, may move sufficiently to jam the shaft from the motor (in the larger case) to the recorder against the side of the case. This is sufficient to stop the motor turning. The trouble is easily rectified by moving the recorder case slightly on its shock mounts.

Experience indicates that the frequency stability of the vibrator power supply of the Willmore recorder is a good deal better than that of the Rabaul town supply. It is a simple matter to run the recorder from a 6 volt accumulator on trickle charge off the mains. Unless the mains frequency control is good, this would probably be preferable to running directly off the mains if Willmores are to be installed at other centres where a 240 volt AC town supply is available.

It is understood that the Willmore can be supplied with Galvanometers of either 1/25 sec. or 1/4 sec. period. The 1/4 sec. Galvanometer should give a much more useful overall frequency response than would the shorter period unit. The seismograph characteristics would then approximate those of the small model Benioffs at Rabaul. A system using the short period galvanometer would be expected to respond very poorly to the larger period earth motion due to more remote earthquakes. It should respond well to volcanic earthquakes if it is situated in the epicentral region; however, the performance of the longer period system should be quite adequate in these circumstances.

(4) Omori Seismograph.

The Omori Seismograph was dismantled, cleaned, and reassembled in operating order. During reassembly one side of the pivot supporting the linkage arm between pendulum and stylus on the north-south component was broken. A new pivot has been installed and is working satisfactorily.

The free periods and damping ratios of the two components were adjusted to correct values, and the static magnification was determined by means of a tilt test (Sohon p.55). Unfortunately no means of giving a known tilt to the seismometer frame was readily available. The method finally adopted was to tilt the frame by raising one of the lateral levelling, screws, the vertical movement of the seismometer base being measured with a dialgauge. Knowing this, and the dimensions of the base, the angular tilt of the axis of rotation of each seismometer could be calculated. Future calibrations would be greatly facilitated

if some more effective means were provided for measuring such small tilts. Observation, with telescope and scale, of the rotation of a small mirror mounted on one of the lateral levelling screws, as suggested by Sohon (p.53), is recommended.

The following are the present operating constants of the two components:-

N-S Component: Period = 3.6 sec., Static Magnification = 11.9

E-W Component: Period = 3.8 sec., Static Magnification = 10.2

Damping is approximately critical on both components.

No attempt was made to measure stylus friction.

The irregular motion of the Omori drum drive is rather objectionable, but could not be easily removed, since it is a fault inherent in the clockwork drive mechanism. The simplest way of eliminating this defect would be to power the unit with some form of 240 volt synchronous motor. Such action may be desirable at some future time, though it will destroy the seismograph's present independence of mains supply. The stylus of the N-S component at present carries a soldered copper wire writing point. This is not entirely satisfactory and should be replaced at the first opportunity with a platinum wire point similar to that on the E-W stylus. Suitable wire is not available in Rabaul, but will be obtained in Brisbane.

The general siting and accommodation of the Omori leaves little to be desired. The instrument performs well in recording the stronger regional earthquakes; it would be invaluable in the case of a volcano-seismic outburst in the Blanche Bay area. A vertical instrument of comparable sensitivity would probably be even more useful.

(5) Time Control.

Good time control is important in any seismological station, but is doubly so in a station situated, as is Rabaul, in an area of considerable seismicity. It should be possible to time an event on the record with an accuracy with 1/10 sec. An accuracy of this order can be attained only with a clock of small and uniform rate, which is checked frequently against standard radio time signals.

The Synchronome is a good time keeper under normal conditions. However, in Rabaul, where earthquakes are frequently strongly felt, optimum performance is not to be expected. Strong earthquakes can, and do, stop the pendulum, while less severe shocks will have pronounced short term effects on the rate of the clock. In addition, there is the ever-present danger of serious damage to the clock during an earthquake. It is for these reasons that it is believed that the Synchronome clock should be replaced, if possible, with a good chronometer. The Synchronome could perhaps be used at some other installation in an area where strongly felt earthquakes are not common.

The steps now being taken to initiate the recording of radio time signals in Rabaul are commendable, and should lead to greatly improved time control. National Bureau of Standards Station WWVH transmits continuously, so that frequent time checks should be possible. It is suggested that they be made every four hours - continuous recording is neither necessary nor desirable. Experience while in Rabaul suggests that WWVH signal strength is quite high, and it should be possible to make the time signal recording fully automatic. If this is the case, a simple programme clock may be used to switch the radio on at the

desired times. Commercial units are available, or, if desired, specifications can be supplied for the device built in Brisbane.

If the Synchronome clock is retained in Rabaul it will be necessary, before time signal recording begins, to eliminate the strong radio frequency signal generated by arcing at the master clock's seconds contacts. Apart from its effects on nearby radio receivers the sparking is objectionable because of the pitting it produces on the clock contacts. Previous attempts to suppress the sparking have not been successful. Some sparking is inevitable because of the highly inductive nature of the load across the contacts, but it is felt that it may be possible to reduce it to a tolerable level by the use of germanium diodes across the contacts. A suitable diode will be sent in order that this method of spark suppression may be tested.

(6) Power Supplies.

Fluctuations in both frequency and voltage of the Rabaul town supply are extremely troublesome. Steps have already been taken to provide a tuning fork controlled 240 volt 50 c/s supply for the recorder motor. However, only slightly less objectionable are the frequent and sudden drops on line voltage which manifest themselves by a decrease in intensity of the Benioff recording lamps. The resulting weakening of the trace is a serious defect in the record, particularly if it happens to occur while an earthquake is being recorded. The line voltage invariably drops during periods of blackouts when the Observatory auxiliary power supply is in use. This unit is apparently incapable of delivering a voltage greater than 220 volts.

Enquiries are being made at the University's Department of Electrical Engineering regarding the possibility of providing some form of voltage regulation to keep the line voltage to the recorder up to the desired value. It may be possible to incorporate either a constant voltage transformer or some type of electronic voltage stabilization in the tuning fork controlled supply.

Direct current for clock and relay operation is at present obtained from a lead-acid accumulator on trickle charge off the mains. A number of factors, particularly active corrosion at the terminals, necessitate constant attention for this battery. There seems to be a good case for replacement of the present battery with alkaline cells such as the NIFE accumulators used in Brisbane. These represent a considerable investment, but are unsurpassed for ruggedness and reliability. During the five years they have been in use in Brisbane the cells have required, beyond the routine fortnightly topping up with water, no attention other than one replacement of electrolyte. Further information, including current prices of these cells, will be obtained from the Brisbane agents and forwarded to the Vulcanologist.

Provision, in the battery circuit, of an ammeter to indicate the total current drain when all time marking relays operate is desirable. Such a meter, if read daily when the records are changed, provides a quick and simple check for malfunctioning of any of the time marking units. A small 0-2 amps. meter, wired so that it can be switched out of circuit when not in use, is quite adequate.

(7) Background Noise.

A study of past Rabaul records reveals that, although the normal type of short period microseisms as recorded on the Benioffs when in Brisbane are absent, there is present another background "noise". This consists of sustained trains of short period waves of very regular, almost sinusoidal, wave form. In appearance they are remarkably similar to the disturbance, called locally "harmonic tremor", recorded regularly on the seismographs of the Hawaiian Volcano Observatory. It has been suggested that the Hawaiian harmonic tremor, the occurrence of which usually

coincides with periods of eruptive activity, is caused by magma surging in subsurface conduits and chambers.

The true magnitude of this background activity at the Observatory was revealed when the Benioffs were placed in proper operating order during pre-calibration checks. It was immediately apparent that some powerful source of short period earth motion must exist at no great distance from the Observatory.

There are many possible sources for background noise recorded at a seismograph station. A few examples are rail and road traffic, surf on nearby coasts, frost action, and wind generated movements of trees and buildings. A number of possible noise sources exist in the vicinity of the Observatory. There is, however, in Rabaul town one obvious and very efficient generator of ground vibration - the power house. Nearby residents are eloquent in their testimony as to the ability of the power house machinery to set up strong ground motion.

To obtain information on the characteristics of the ground motion generated by the power house, a vertical Willmore was operated about ½ mile west of the power house, in the general direction of the Observatory. Recordings were made soon after dark when the load should be high and the generating equipment operating at peak power. The recorded waveform is complex but shows a strong harmonic of about 2 c/s, approximately the same frequency as the earth motion recorded at the Observatory. Recorded amplitudes suggest that these elastic waves carry sufficient energy to be propagated for considerable distances. At the Omori site at Rapindik ground motion was about 1/10 of that near the power house. There seems to be little doubt that vibration of the power house machinery is capable of causing the observed effects at the seismograph station. In this connection it is of interest to note that it is U.S. Coast and Geodetic Survey policy to place a seismograph station situated on foundation material similar to that at Rabaul no closer than three miles from heavy reciprocating machinery.

It is desirable that further tests be made to establish definitely that the power house machinery is the source of most of the background noise at the Observatory. Correlation between times of peak load at the power house and periods of high noise level at the Observatory would be particularly useful. Willmore records run at points a fixed distance from the Observatory but at different azimuths should indicate the direction of the noise source.

If the role of the power house as the major noise generator is confirmed little can be done except to adjust the seismometer sensitivities to give a tolerable noise level. Earthquakes whose earth motion amplitude at the Observatory is less than that of the noise level, will, of course, not be detectable.

A new power house is being built on a site west of the present one, and somewhat closer to the Observatory. It is to be hoped that effective anti-vibration measures have been taken in the new installation.

(8) General Remarks on Instrumentation.

Though the Rabaul station is well equipped for its primary task of recording earthquakes associated with the Territory's areas of active vulcanism, it is felt that the usefulness of the station from both the global and regional points of view would be greatly increased by the installation of further seismographs. There appear to be at present two major needs. These are:-

(1) The provision of horizontal and vertical seismographs of similar characteristics to the Benioffs, but with much lower

magnification: It is found, for a considerable proportion of the earthquakes recorded by the Benioffs, that the trace amplitudes are so large that the fast movements of the recording light spot do not register well on the film. In consequence P is usually the only phase which can be read for such shocks. It is suggested that consideration be given to the possibility of installing a pair of Wood-Anderson short-period seismographs. Perhaps it could be possible to arrange for the transfer to Rabaul of the two Wood-Andersons, the Kew-type short-period vertical, and the three component recorder at present in Brisbane, on loan from the Bureau of Mineral Resources. It is felt that these instruments could be more usefully employed at a station within an area of considerable seismicity, and, as Dr. Jones indicated at the Canberra conference last October, they will be made available, providing the Bureau concurs, to any station needing them.

(ii) The provision of long period, intermediate magnification, horizontal seismographs. The peak magnification of the Benioffs is for earth particle motion within the period range ½-1 second. For periods greater than 2 seconds the magnification is relatively low, so that the Benioffs do not record very well the S and later phases of more distant earthquakes. The installation of a pair of Sprengnether or similar long period horizontal seismometers would aid greatly in the interpretation of the Benioff seismograms for such earthquakes. The importance of adequate coverage from Rabaul of earthquakes in the intermediate distance range is emphasized by recent work by Taylor and by Reynolds on relationships between volcanic activity and regional tectonic earthquakes.

Early steps should be taken to replace the present tiltmeters at Rabaul with more sensitive instruments, preferably of the recording type. It is suggested that Mr. Jerry P. Eaton, Seismologist, Hawaiian Volcano Observatory, and Dr. Dean S. Carder, U.S. Coast and Geodetic Survey, Washington, D.C., both of whom have had considerable experience with this type of instrument, be contacted for information regarding tiltmeters used by their organizations. In passing it might be mentioned that the Wood-Anderson seismometer is quite sensitive to tilt and, as well as its normal function, performs reasonably well as a type of recording tiltmeter.

D - Record Interpretation and Handling of Data.

A large proportion of the time spent in Rabaul was devoted to discussions of the theoretical background to record interpretation and in the reading of seismograms. The Brisbane seismograms for a group of large southwest Pacific shocks were obtained and compared with Rabaul records for the same earthquakes. All the Rabaul seismograms for November 1954 were read, and the data were prepared for inclusion in the Monthly Seismological Bulletin.

The Jeffreys-Bullen travel time tables (copy of which was left in Rabaul) were used as a basis for the tentative identification of phases and calculation of epicentral distances for near shocks. Since these tables are based on Jeffrey's European crustal structure, they are almost certainly of very limited application to the Solomons - New Britain - New Guinea region; they have, however, been used in the absence of anything better. It is hoped that ultimately there will be available enough data on travel times for the region to permit the preparation of a set of regional travel time curves. Achievement of this is, of course, dependent on the establishment of further stations.

Rabaul, the only seismological station in a large area of high seismicity, is extremely important in the global seismological picture. That seismologists are concerned by the lack of earth-

quake information from the region, is evidenced by the fact that the establishment of further stations in the Territory was the subject of a resolution passed by a meeting of the International Association of Seismology in Rome in October, 1954. It is the need for data which Rabaul can supply, which prompts the writer to suggest that immediate steps be taken to distribute Rabaul earthquake information with the least possible delay and on the widest possible basis.

A first step in the desired direction would be to ensure that the Rabaul seismograms are read daily. The present custom, necessitated by pressure of other work, is to quickly scan the day's records immediately after development, but to defer detailed interpretation until the Monthly Seismological Bulletin is prepared months later. Thus, although the Rabaul readings are eventually distributed, this distribution is too late for the information to be of use in epicentre location.

Ideally the daily record readings for large regional and distant earthquakes should be cabled twice weekly to the U.S. Coast and Geodetic Survey, Washington, for use in the Survey's Preliminary Epicentre Determination Programme. By doing this Rabaul would be cooperating, in the most effective way possible, in international seismology. It is realised that there may be practical difficulties in cabling information to Washington; however, if this is the case, the data could at least be forwarded weekly by Air letter. It will still arrive in time to be of considerable value. A similar weekly Air letter should go to the Bureau Central International de Seismologie (B.C.I.S.) Strasbourg, France. This organisation also determines epicentres, but in addition issues a monthly bulletin which lists, for each earthquake, the principal phases read at all stations supplying data. Publication in the B.C.I.S. Bulletin would ensure wide and relatively rapid dissemination of Rabaul data.

The writer has been most impressed by the system of collecting earthquake intensity data by means of the Monthly Vulcanological Reports. It is felt that this information, for all the larger shocks, should be sent monthly to B.C.I.S. for incorporation in the Monthly Bulletin. Since publication of these bulletins is normally delayed some months, there would be adequate opportunity to collect all a particular months reports before submitting data to B.C.I.S.

The Rabaul holdings of seismological bulletins from other stations should be built up. A list of stations with which bulletins may be exchanged is in preparation, and will be forwarded to Rabaul. In view of the considerable use made in Rabaul of preliminary seismogram readings forwarded by air mail from Brisbane and Pasadena, it is suggested that steps be taken to arrange receipt of similar advices from other stations in the southwest Pacific area. Preliminary readings from Noumea and Apia are likely to be particularly useful.

Some means should be provided for the rapid calculations of epicentral distances using the cosine law of spherical trigonometry. This is done in Brisbane on a small hand calculating machine of Swedish origin, costing about £40/0/0d. If desired, details can be supplied. A large globe is useful but hardly essential if the calculating machine is supplied.

Record storage and preservation is a problem, particularly in hot, humid climates. It is suggested that if possible the completed records be housed in the vault where humidity conditions are relatively good. Specifications of the cabinets used in Brisbane to store the 35 m.m. film records are being supplied.

C - Miscellaneous.

More seismological reference works should be available in the Observatory library. Appended to this report is a list of

suitable books, all of which, so far as is known, are currently available. In addition to these some of the commoner seismological journals should be provided. The "Bulletin of the Seismological Society of America" is particularly useful. "Bibliography of Seismology" published by the Dominion Observatory, Ottawa, and the U.S. Geological Survey publication "Geophysical Abstracts" would be most valuable additions to the library. If desired a list of representative journals will be prepared. It is hoped to supply copies of a few particularly significant papers from Brisbane.

It is hoped that, now the former living space in the Observatory has been vacated, some workshop facilities will soon be provided. A list of suitable tools and equipment is in preparation, and this will be forwarded to the Vulcanologist at the first opportunity.

Although a discussion of staffing problems is beyond the scope of this report it must be pointed out that in the writer's opinion an extension of the seismological work at Rabaul along the lines indicated in Section B can be achieved only by an increase in staff. For the Vulcanologist, seismology is only one aspect of a much larger task, and unavoidable absences from Rabaul make it quite impossible for him to maintain an uninterrupted programme of daily record interpretation.

APPENDIX

Reference Books:

The following books, not at present in the Observatory Library, should, if possible, be provided. As far as it is known all are currently available.

Byerly, P	Seismology	Prentice-Hall	1942
Bullen, K.	Seismology	Methuen	1954
Gutenberg, B. (ed.)	Internal Constitution of the Earth	Dover	1951
Gutenberg, B. and Richter, C.F.	Seismicity of the Earth and Associated Phenomena	Princeton	ed. 1954
Hodgman, C.D. (ed.)	Mathematical Tables from Handbook of Chemistry and Physics		1948
Jeffreys, H.	The Earth	Cambridge	1952
Leet, L.D.	Earth Waves	Wiley	1950
Leet, L.D.	Practical Seismology and Seismic Prospecting	Appleton-Century	1938
Macelwane, J.B.	Introduction to Theoretical Seismology Part I - Geodynamics	St. Louis Uni.	1932
Sohon, F.W.	Introduction to Theoretical Seismology Part II - Seismometry	St. Louis Uni.	1932