COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Record No. 1971/32

Oceanographic Investigations in Melanesia, by the Hawaii Institute of Geophysics, 1970 — Equipment and Operations

by

A. R. Brown (Bureau of Mineral Resources)
and J. P. Webb (University of Queensland)

Record 1971/32

OCEANOGRAPHIC INVESTIGATIONS IN MELANESIA, BY THE HAWAII INSTITUTE OF GEOPHYSICS, 1970 - EQUIPMENT AND OPERATIONS

by

A.R. Brown (Bureau of Mineral Resources)
and J.P. Webb (University of Queensland)

CONTENTS

PLATES

SUMMARY

During August and September 1970 the Bureau of Mineral Resources participated in a two-ship seismic refraction operation by the Hawaii Institute of Geophysics in the Solomon Sea, the Bismarck Sea, and the Pacific Ocean north and northeast of New Ireland.

One ship steamed from a given point along predetermined course, launching charges, while the other remained at the point and recorded seismic signals; then the ships reversed roles to record signals from the opposite direction. In recording, one ship used streamed hydrophones and the other used recoverable sonobuoys. The latter improved signal-to-noise ratio by eliminating mechanical connexion to the ship and by operating farther from the ship. Discrimination was further improved by the use of several frequency bands for each sonobuoy.

Other measurements were made, both under way and on station. Under way, four sound sources yielded bathymetric and seismic reflection data, and magnetometer, gravity meter, and temperature measurements were also taken. On station, piston and trigger cores were collected, and heat flow measured using a Japanese Thermal Gradiometer.

1. INTRODUCTION

Between April and December 1970, Oceanographic Research Vessel RV Mahi operated by the Hawaii Institute of Geophysics conducted a cruise (No. 70-04-22) in the southern and western Pacific Ocean. The third leg of this cruise, during August and September 1970, covered an area of Melanesia in the vicinity of New Britain and New Ireland and started from the port of Rabaul.

This leg was principally a two-ship seismic refraction exercise, aimed at improving knowledge of crustal structure in the area. MV Coral Queen was charted in Rabaul to take part in the work (Plate 1A).

The University of Queensland and the Hawaii Institute of Geophysics both participated with the Bureau of Mineral Resources, Geology & Geophysics (BMR) in the New Britain Crustal Investigations of 1967 and 1969 (Wiebenga et al., in prep.). In return BMR and the University of Queensland were invited to participate in this exercise. BMR supplied three personnel of whom two worked on RV Mahi and one on MV Coral Queen. University of Queensland supplied two personnel who worked on MV Coral Queen. Total scientific complement was 16 on RV Mahi and 8 on MV Coral Queen.

Although the work was principally seismic refraction, RV Mahi was capable of carrying out many other oceanographic measurements. MV Coral Queen was equipped by the University of Queensland to conduct continuous seismic and magnetic profiling in addition to her role in the two-ship refraction programme.

This Record covers the Australian participation in this investigation and deals only with the field operation.

2. TWO-SHIP SEISMIC REFRACTION

The seismic refraction technique employed by RV Mahi and MV Coral Queen was basically that described by Shor (Hill, 1963, chapter 2). The plan of operations on each line was to shoot reversed profiles, each ship being equipped for both shooting and recording.

The two ships met at the start of a proposed line. One ship remained at that point ("on station") in order to record the seismic data, while the other ship steamed away on a predetermined course, launching charges at agreed time intervals. When the two ships were at such a distance apart that no further useful data could be recorded, the role of the ships was interchanged. The ship that had been recording started shooting as it steamed towards the second ship, which was then on station at the end of the refraction line.

The shooting procedure was as follows: A charge was made up by the shooter (Plate 1B) under instruction from the shooting controller, who was in radio contact with the recording vessel. A time fuse was cut to an agreed length and the charge was thrown overboard at an agreed time. The charge size, fuse length, and time interval between shots varied according to the distance between the ships and the seismic conditions, and were changed on advice from the recording vessel. Commonly, when the ships were close together, the charge was 1 pound (0.45 kilograms) of Nitramon WWEL, the fuse length was 36 centimetres giving a burning time of about 35 seconds, and the time interval between shots was 3 or 5 minutes. Shooting and recording was continued on most lines until the ships were about 100 kilometres apart. At this distance the charge was conmonly 200 pounds (91 kilograms), the fuse length was 122 centimetres giving a burning time of about 90 seconds, and the time interval between shots was 30 or 45 minutes. For the smaller charges the fuse length was designed so that during the fuse burning time the charge had sunk to the optimum depth, which is equal to one quarter of the wavelength of the bubble pulse, i.e. about 70 metres. For the larger charges it was necessary to allow sinking to greater than optimum depth before detonation, in order that the fuse burning time might be long enough to prevent detonation at ranges likely to damage the ship.

The direct arrival of energy from the shot was recorded on the shooting vessel and, where possible, transmitted to the receiving ship. Two short tone bursts, manually keyed on hearing the direct shot arrival, were also transmitted. These provided an indication of shot instant on the seismic records, but required corrections for keying delay in transmitting the tone and the time of travel of the direct energy from the shot to the shooting vessel.

The recording procedure was as follows: The recording vessel was advised by radio from the shooting vessel when a charge was in the water and the expected burning time of the fuse. A stop watch was started at charge launching instant and the recorder was switched on several seconds before the expected shot detonation time. The shot break and shot tone transmitted by the shooting vessel were recorded, followed by seismic refracted energy (G arrivals), the direct water wave (D), and ocean bottom reflected waves (R).

The direct water wave travel time was used as a measure of the separation of the two vessels.

For refraction recording MV Coral Queen used one or two spar-mounted hydrophones (with preamplifiers), suspended at a depth of 60 metres from a buoyant cable streamed at least 300 metres to windward of the hove-to ship. The arrangement was similar to that described by Shor (Hill, 1963). Signal-to-noise ratios were much improved by slackening the cable at the ship just before expected shot time, in order to eliminate dragging of the hydrophones by the drifting ship.

Hydrophone outputs, after signal conditioning, were recorded on a three-channel monitor recorder and, where possible, on a ten-channel oscillograph. By switching during recording, it was possible to record, on the monitor, shot-break and tone transmissions, low-frequency (ground wave) and high-frequency (water wave) signals from one hydrophone, and one-second chronometer time marks, so that the monitor preserved all essential information for a shot.

The shooting and recording arrangement on MV Coral Queen are illustrated in block diagram form in Plate 6, and a photograph of the equipment appears in Plate 2A.

RV Mahi used AN/SSQ-41A sonobuoys for refraction recording. The arrangement used is shown schematically in Plate 7. The reason for using sonobuoys was to reduce noise picked up by the hydrophones, by eliminating mechanical connexion to the ship and by keeping the hydrophones farther away from the ship. The distance between the sonobuoys and the ship during recording was usually about three kilometres. The military sonobuoys used were modified to have a longer battery life and to be non-sinking, and were recovered after recording each line.

Four sonobuoys were normally launched, as shown in Plate 7, and the signals transmitted by the three which proved to be the least noisy were received by the three available sonobuoy receivers. The output of each receiver was fed to either two or three separate recording channels of a nine-channel high-speed pen recorder, through different bandpass filters. The frequency band selected for maximum enhancement of the seismic refraction signal was about 4-15 Hz. The frequency band used to record the direct water wave was 500-1000 Hz. Any other available channels were used to record the refracted signal also, but with different frequency bands, for example 12-30 Hz. The use of three sonobuoys and several frequency bands for each permitted improved discrimination between signal and noise on the recordings.

The refraction lines shot in the course of the cruise, thirteen in all, are indicated on the track plot (Plate 8). All were reversed except Line R. The longest line shot was Line W, on the Ontong Java Plateau, refraction data being recorded out to a distance of 200 kilometres. Preliminary field time-distance plots demonstrated velocities characteristic of the mantle for some lines only. On others the highest velocity recorded for first-arrival data was that typical of the intermediate crustal layer. The generally large crossover distances for mantle arrivals in this area are a consequence of a thick crust.

3. OTHER MEASUREMENTS

The other measurements made and operations conducted by RV Mahi or MV Coral Queen depended on whether the ship was under way (as during seismic refraction shooting) or on station (as during refraction recording). These will be dealt with separately.

Under-way measurements by RV Mahi

RV Mahi steamed at between 10 and 11 knots, almost without exception, and maintained a 24-hour-per-day operation.

The ship was equipped with four sound sources other than explosives. A 12-kHz Pinger, triggering on a one-second repetition rate, provided a bathymetric profile on an Alpine facsimile recorder using a one-second sweep (Plate 2B). A 3.5-kHz pinger was operated in the same way but provided some penetration into the sub-bottom. The nature of the bottom reflection obtained with this pinger gave some indication of the softness of the bottom and thus was of assistance in the selection of coring sites. The 3.5-kHz pinger was in operation at all times while under way, and sometimes while on station in order to observe the drift of the ship over the ocean bottom. The 12-kHz pinger was not always used, even while under way, as it did not supply any information not obtained from the 3.5-kHz pinger.

The other two sound sources were a sparker, which operated up to 5000 joules, and an air cannon (Plate 3A), which could be fitted with chambers of various capacities up to 120 cubic inches (1.97 litres). These two sources, both trailing behind the ship (Plate 3B), were triggered simultaneously and with a 5-second repetition rate. The sensor for this continuous profiling system was a single-channel seismic streamer trailing behind the ship, made up of one or two sections, each containing 32 hydrophones.

The signal received by the streamer was fed to two Alpine recorders (Plate 2B), both using a sweep of 5 seconds, through two different bandpass filters, which were normally set at 125-250 Hz and 40-90 Hz. These bands recorded, predominantly, energy from the sparker and air cannon respectively. The profile recorded using the lower-frequency band normally displayed the better penetration. In sedimentary areas good seismic reflections were obtained over a record time of up to 1.5 seconds.

Also trailing behind the ship whenever it was under way was a Varian proton precession magnetometer (Plate 4A), the output of which was connected to a chart recorder and also to a digital display.

A surface temperature probe should have been trailed behind the ship but during the whole of this investigation it was inoperative. However, temperature measurements were made every six hours by launching an expendable bathythermograph (XBT). A 'bomb' dropped out of the launcher remained attached to it by a thin copper wire. Water temperature was measured and recorded as a function of depth until the wire broke, which normally occurred at about 500 metres. These data were acquired for the US Navy.

Regular meteorological observations were made, and wind speed and direction were continuously recorded.

At approximately the centre of gravity of the ship a LaCoste & Romberg continuous recording gravity meter was located. The principal quantity recorded on chart was an integration, over a period of 1.5 minutes, of residual spring tension. The meter was suspended freely in a gimbal mounting and corrections for horizontal and vertical accelerations due to rolling of the ship were introduced automatically. Corrections for vertical motion and the Eotvos effect were made in later reduction.

Unreversed sonobuoy wide-angle reflection/refraction profiles were recorded in selected locations indicated in Plate 8. An expendable sonobuoy (AN/SSQ-41A) was thrown overboard and, as the ship steamed away from it, the signal from the sparker and air cannon, triggering on a 10-second repetition rate, was received by the sonobuoy, transmitted to the ship and displayed on an Alpine recorder. In this way seismic reflections recorded when the ship was fairly close to the sonobuoy could be seen to become refractions at greater distances (See Ewing & Houtz, 1969, for examples of this type of record.). On some lines, and at greater distances, charges were fired and the signal received from the sonobuoy was displayed on a highspeed pen recorder.

On-station measurements by RV Mahi

On most stations a piston core and a trigger core were attempted (Plate 4B). The smaller trigger core barrel and much larger piston core barrel were lowered on the same cable to the ocean bottom. The trigger core barrel struck bottom first and penetrated about a metre. This released the piston core barrel, which then penetrated the bottom under the weight of about a tonne of lead. Core recovery varied from nil up to 13 metres. Preliminary analysis of cores on board the ship included the measurement of thermal conductivity, sonic velocity, porosity and water content, sieving and particle analysis, and mineralogical and palaeontological examination.

The ship was also equipped to obtain cores by a method of free falling from the surface using a Boomerang Corer.

Heat flow measurements were made at most stations where cores were taken. A Japanese Thermal Gradiometer was used to measure the temperature gradient in the ocean bottom. This measurement, with that of thermal conductivity measured on the core, together yielded a measurement of heat flow through the Earth's crust. The Thermal Gradiometer, together with a pinger, were lowered by winch, the pinger record indicating the distance of the Gradiometer above the bottom. The Gradiometer was held just above the bottom, where it was assumed that the temperature gradient was zero, and then the probe containing three thermistors was allowed to penetrate. After allowing time for equilibrium to be reached, the probe was withdrawn and again held just above the bottom to establish zero temperature gradient.

Equipment was also available aboard the ship for measuring thermal gradient by a free fall method.

Surface water samples were collected in Nansen casts from various depths down to 150 metres at most stations. These were to be used in the study of micro-organisms and their relationship to the process of sedimentation.

At one station, ocean bottom photographs were taken. Here the seismic recorders indicated that the bottom was hard and inappropriate for coring. The camera and a pinger (Plate 5A) were lowered together by winch. The camera was held a metre or so above the bottom, as indicated by the pinger records, and stereo-photographs were taken at 12-second intervals using a synchronised flashgun.

At one station a rock dredge was used in order to collect hard rock samples from the ocean floor. The dredge consisted of bladed jaws at the opening of a chain basket. It was dragged along the ocean floor on a length of cable about three times the water depth. There was a weak link joining the dredge to the cable, which would break at a pre-set strain if the dredge stuck fast to the bottom.

Plate 8 indicates which of the above operations were conducted at each station. Most stations were located at the ends of seismic refraction lines, as a matter of convenience. However, some were occupied specifically for coring and other operations.

During Leg 7 of the Deep Sea Drilling Project JOIDES (Winterer & Riedel, 1969), sites 63 and 64 were drilled in the area covered by the current investigation (Plate 8).

Under-way measurements by MV Coral Queen

In addition to seismic refraction shooting, MV Coral Queen operated a 4000-joule sparker system and Elsec magnetometer (Plate 5B) as commitments permitted. Performance of the sparker system was unreliable during the early stages of the survey, mainly because of heat problems and difficulties with streamers, but good records, with over one second of sub-bottom section, were obtained in the later phases. The portions of track over which continous profiles were recorded are indicated in Plate 8.

Occasional unreversed sonobuoy wide-angle reflection refraction profiles were recorded but achieved only limited success. The location of these is shown in Plate 8.

On-station measurements by MV Coral Queen

Other than seismic refraction recording, no measurements were made.

4. NAVIGATION

The primary navigation control used by RV Mahi was Satellite Doppler. The navigational computer was manually supplied with ship's speed and heading after any significant change in either parameter, and position fixes were returned approximately every hour.

Ship's heading was determined by gyro-compass, and speed by electromagnetic log. Interpolation between satellite fixes was by dead reckoning using this information.

Additional position fixes were obtained by observations of stars and landmarks. All the above data were used in compilation of the track of RV Mahi (Plate 8).

The ship also possessed an Omega (VLF) Navigation System, but no shore monitor station was operated and little use was made of the data.

MV Coral Queen's only navigation equipment was magnetic compass and tachometer, supplemented where possible by radar observations. All navigation was by dead reckoning and observation of land. Reference was made to the position of RV Mahi whenever the two ships were within radar range. An approximate track has been reconstructed and is shown in Plate 8.

5. OBSERVATIONS

Some delays occurred at the start of the survey, and a certain amount of time was lost while MV Coral Queen returned to port periodically for fuel and water. Not all the scientific objectives were met, but the return was apparently normal for an operation of this type.

An unscheduled scientific observation was provided by the earthquake of 28 August, 0103 GMT, at the southern end of New Ireland (see Plate 8). This was felt strongly on both ships, which were in the area at the time.

Some observations, relating largely to MV Coral Queen, which may be useful in arranging future projects of this nature follow:

(1) In Rabaul at least, not less than one week is needed to outfit MV Coral Queen, or any other similar charter vessel, for a combined geophysical survey. The outfitting should include several hours of shakedown operation in the open sea, in order that functioning of all items of equipment can be checked under working conditions.

(2) Ship-to-ship communications during the survey were generally very good. However, MV Coral Queen's own radio installation was substandard, and communication with shore stations was poor. If the owner cannot provide adequate communications through regular channels, a radio transceiver should be installed for the survey.

(3) Although MV Coral Queen's dead-reckoning navigation was generally good, it did not provide position fixing of the standard necessary for scientific work. In an ocean-going survey the ship should at least carry one man capable of celestial navigation. In a two-ship survey where one vessel has high-order navigation, more could be done towards using radar to determine relative positions of the two ships. This would require upgrading radar system performance, and perhaps using shipborne transponders to improve signal strength and useful range.

(4) A below-decks location on a small ship in the tropics is a difficult environment for the operation of electronic equipment. Heat and humidity as well as electrical interference are likely to be major problems. The provision of air-conditioning and careful attention to the placement and shielding of cables would improve conditions greatly. There is much to be said for the use of a pre-wired, demountable recording cabin, though accommodating this on a vessel like the MV Coral Queen could be difficult.

6. ACKNOWLEDGMENT

The participation of the University of Queensland in this project was made possible by a research grant from the Nuffield Foundation.

7. REFERENCES

EWING, J., and HOUTZ, R., 1969 - Mantle reflections in airgun-sonobuoy profiles, J. Geophys. Res. 74, 6706-6709.

HILL, M.N., (Ed.)., 1963 - The Sea; Volume 3: The earth beneath the sea. Interscience, New York.

WIEBENGA, W.A., et al., - New Britain crustal investigations, 1967 and 1969, Bur. Miner. Resour. Aust. Rec. in prep.

WINTERER, E.L., and RIEDEL, W.R., 1969 - Deep sea drilling project: Leg 7. Geotimes 14(10), 12-13.

A. RV *Mahi* and MV *Coral Queen* in Rabaul

B. Priming a 200-lb (91-kg) charge (MV *Coral Queen*)

A. Seismic refraction and communication equipment (MV *Coral Queen*)

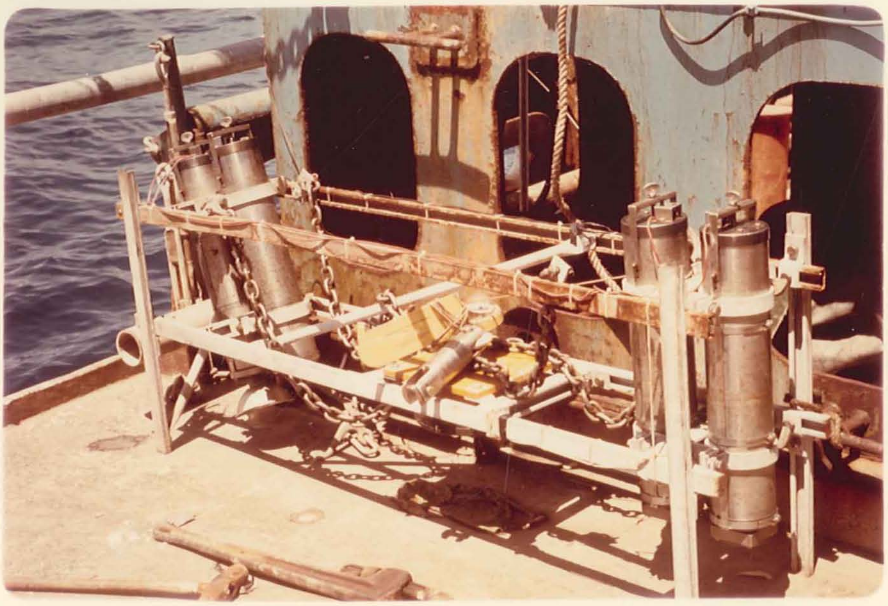
B. Alpine recorders in electronics laboratory (RV *Mahi*)

A. Air cannon (RV *Mahi*)

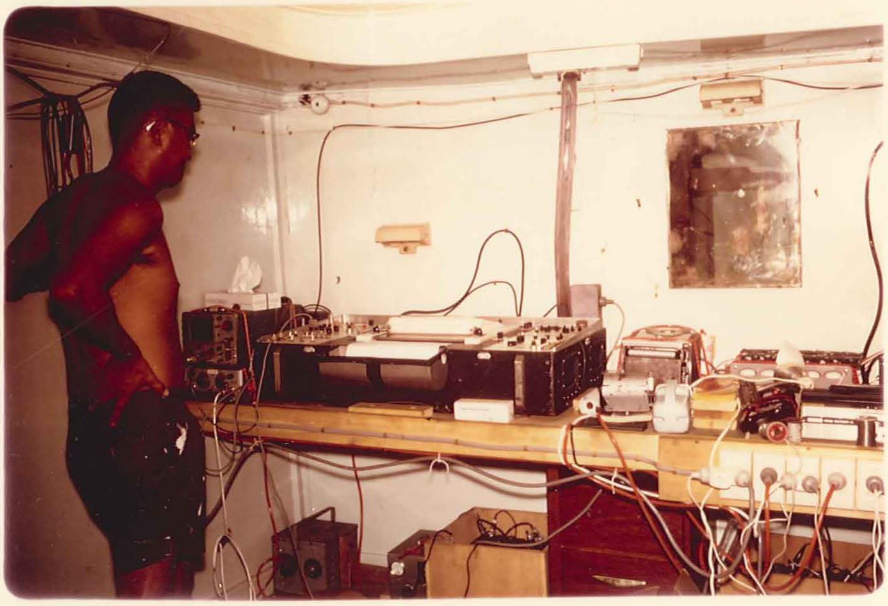
B. RV *Mahi* trailing gear

A. Varian magnetometer detector showing shark damage (RV *Mahi*)

B. Securing bent 37-metre Piston Core barrel (RV *Mahi*)

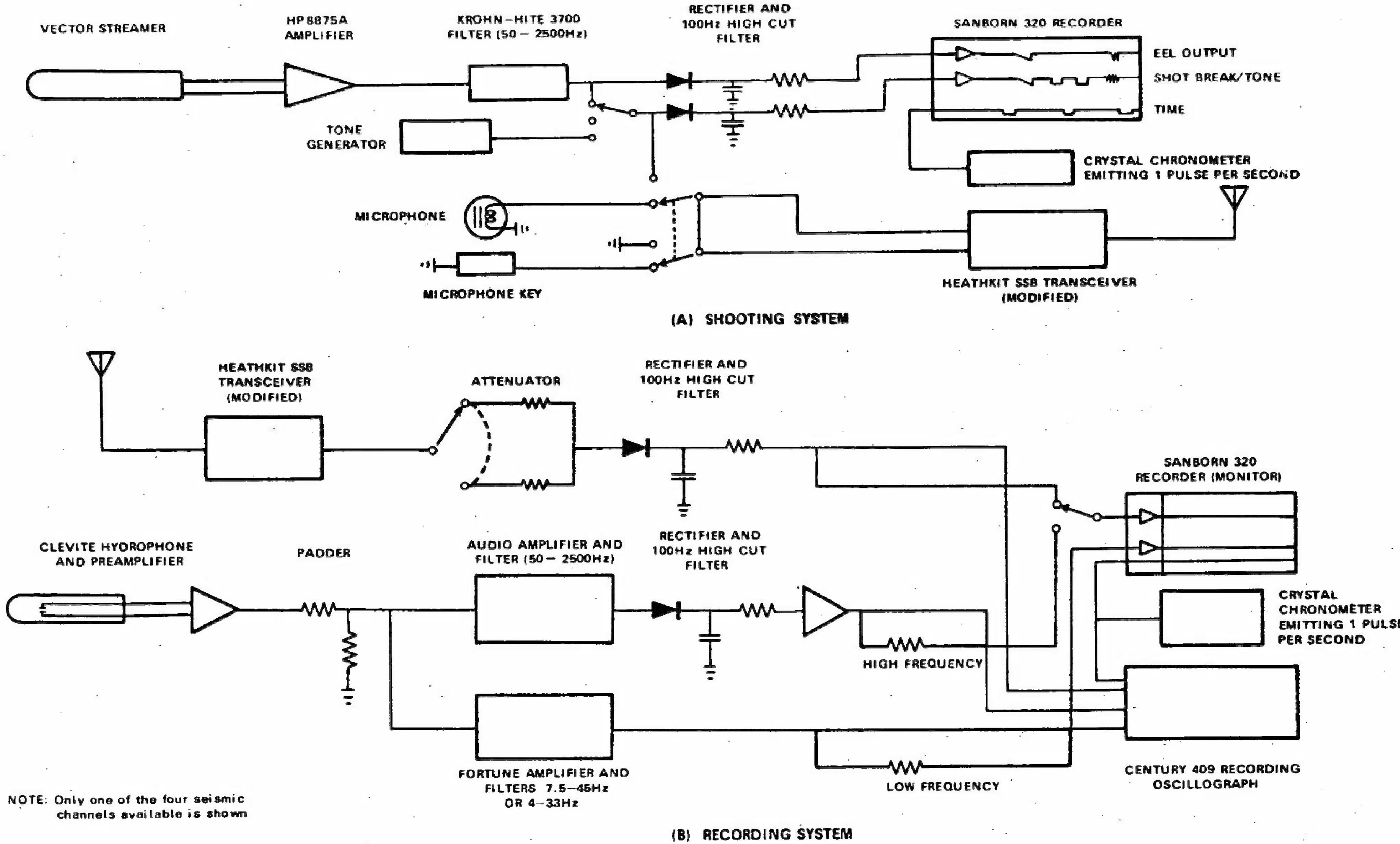


A. Bottom camera (RV *Mahi)*



B. Elsec magnetometer and seismic profiling equipment (MV *Coral Queen*)

TO ACCOMPANY RECORD No. 1971/32

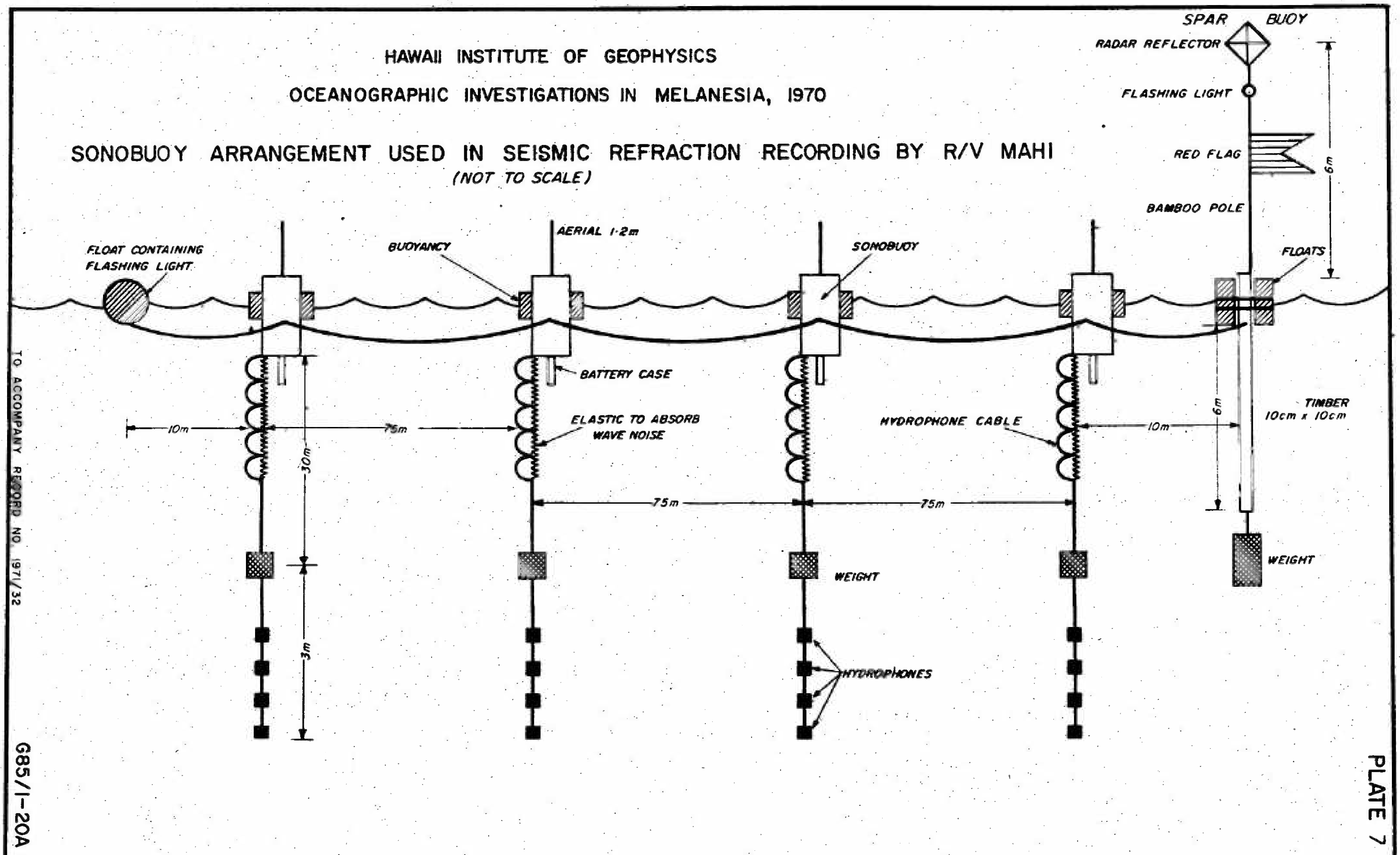


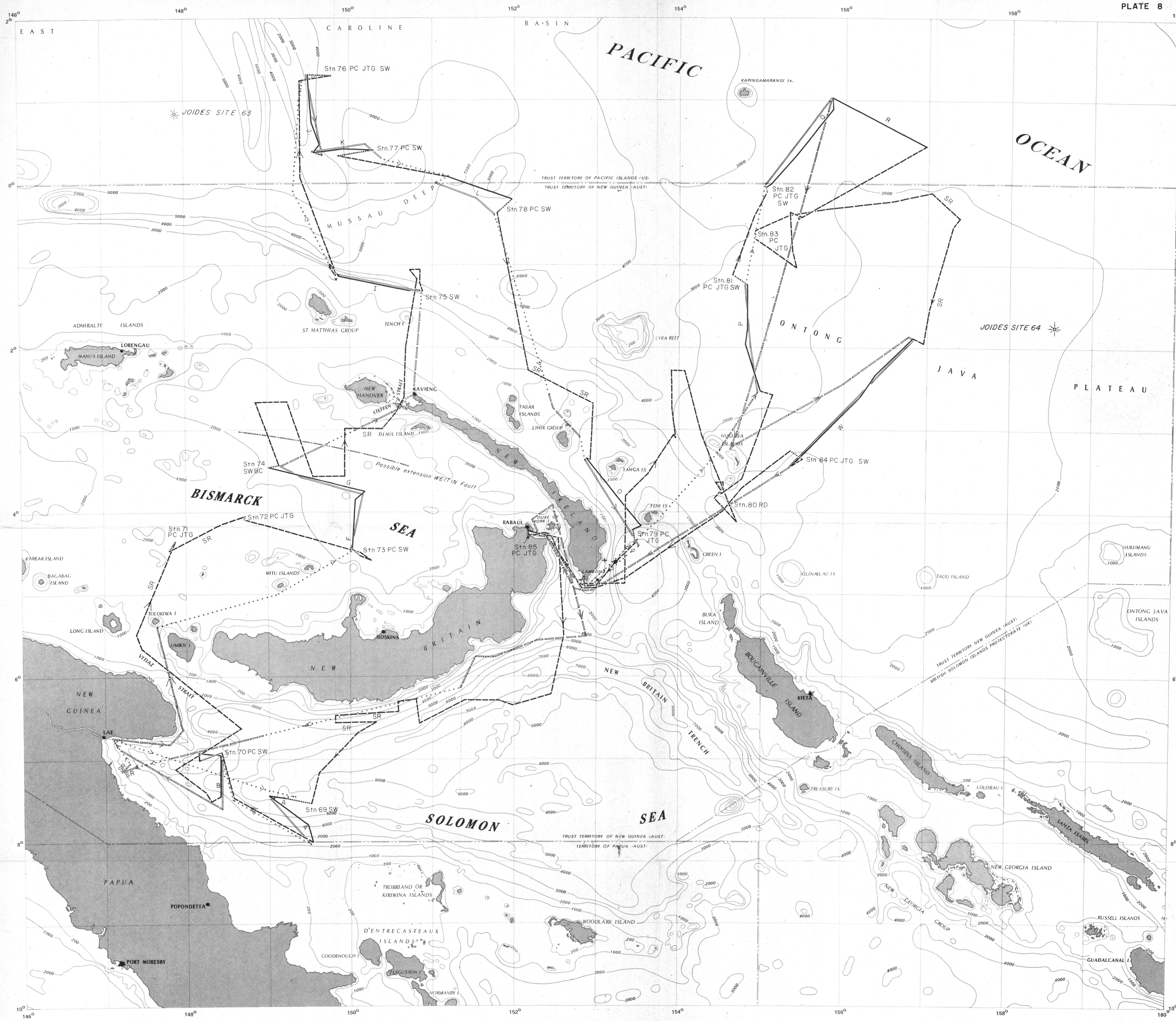
HAWAII INSTITUTE OF GEOPHYSICS OCEANOGRAPHIC INVESTIGATIONS IN MELANESIA, 1970

BLOCK DIAGRAMS OF SEISMIC REFRACTION SYSTEM ON M/V CORAL QUEEN

PLATE 6

G85 3.139 A


HAWAII INSTITUTE OF GEOPHYSICS
OCEANOGRAPHIC INVESTIGATIONS IN MELANESIA, 1970
SONOBUOY ARRANGEMENT USED IN SEISMIC REFRACTION RECORDING BY R/V MAHI
(NOT TO SCALE)
SPAR BUOY
RADAR REFLECTOR
FLASHING LIGHT
RED FLAG
6m
BAMBOO POLE
FLOATS
FLOAT CONTAINING FLASHING LIGHT
BUOYANCY
AERIAL 1·2m
SONOBUOY
BATTERY CASE
10m
75m
30m
ELASTIC TO ABSORB WAVE NOISE
HYDROPHONE CABLE
10m
6m
TIMBER 10cm x 10cm
75m
75m
WEIGHT
WEIGHT
3m
HYDROPHONES
TO ACCOMPANY RECORD NO. 1971/32
G85/1-20A
PLATE 7



MELANESIA

HAWAII INSTITUTE OF GEOPHYSICS
OCEANOGRAPHIC INVESTIGATIONS IN MELANESIA
1970

TRACKS OF R/V MAHI & M/V CORAL QUEEN

SCALE 1:2,500,000

KILOMETRES 50 0 50 100 150 KILOMETRES

Simple conic (modified) projection with standard parallels 5°S and 8°S
Bathymetric contours in metres.

LEGEND

R/V MAHI	M/V CORAL QUEEN	
———	═══	Refraction line
— — —	▭▭▭	Continuous profiling
········	▫▫▫▫	Drifting on station
	∘ ∘ ∘ ∘	No profiling

A Refraction Line A

SR Sonobuoy wide-angle reflection/refraction line

PC Piston Core (and Trigger Core)
SW Surface Water samples
JTG Japanese Thermal Gradiometer
BC Bottom Camera
RD Rock Dredge
● Earthquake felt in this position
\+ Earthquake epicentre

Location	4.6°S, 153.1°E
Origin time	01 02 48.9 UT
	28 August, 1970
Depth	88 km
Magnitude	5.9

Drawn by Geophysical Branch,
Bureau of Mineral Resources,
Geology & Geophysics,
Canberra.

Based on PNG/BO-30

TO ACCOMPANY RECORD No. 1971/32

PNG/B3-4