The Earthquake Swarm in the New Hebrides Archipelago, August 1965

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Abstract

A study of macroseismic data, of epicentre determinations, and of energy relations shows that during the August 1965 earthquake swarm in the New Hebrides, three strong earthquakes originating beneath the crust were followed by numerous aftershocks, which appear to be related to tectonic readjustments within the crust and to tectonic effects observed at the surface.

Introduction

In August 1965 an earthquake swarm occurred in the northern part of the New Hebrides Archipelago. The three largest shocks, which were on August 11 and 12, had magnitudes of 7 or more, and caused damage on the islands of Espiritu Santo and Mallicolo. They were followed by numerous aftershocks, which continued until September.

Fig. 1.—Uplifted coastline on the north-west coast of Mallicolo. The white markings are caused by dead coral raised above high-tide level.

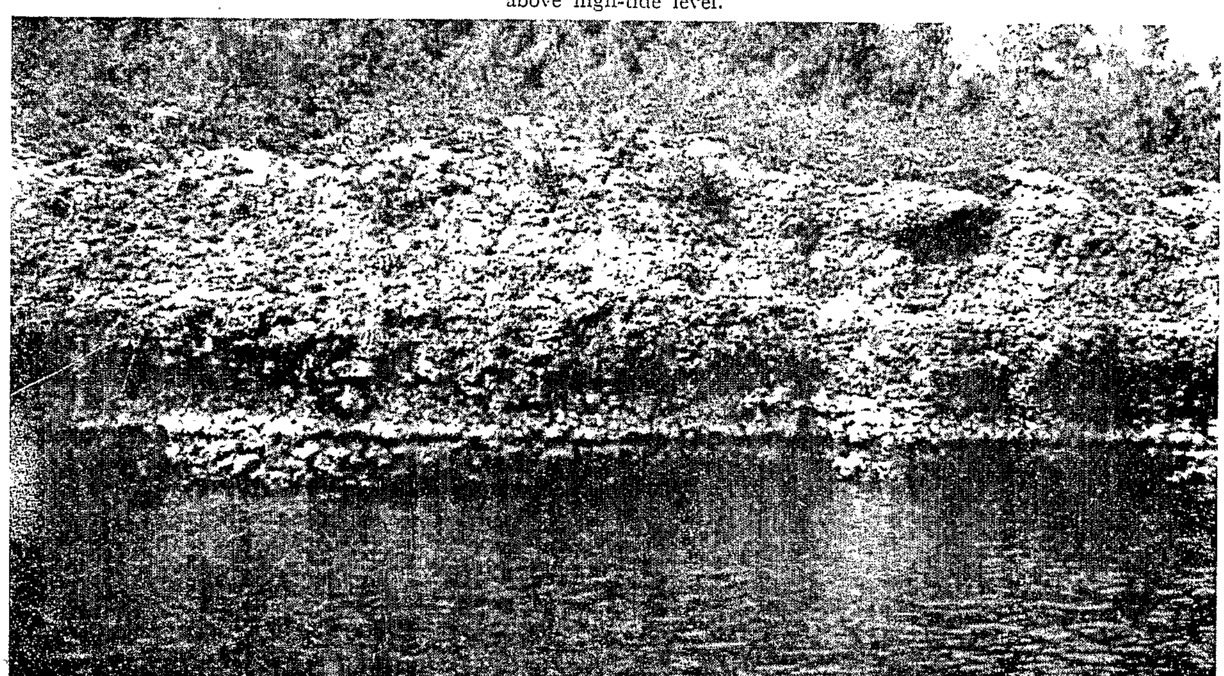


Fig. 2.—Closer view of the uplifted coastline. The amount of uplift was approximately 80cm.

Recent Crustal Movements, Royal Society of New Zealand, Bulletin 9, pp. 141–148, 9 figs, 1971

MACROSEISMIC OBSERVATIONS

The earthquakes of 1965 August 11d 03h 40m 56s, 11d 22h 31m 54s, and 12d 08h 01m 43s U.T. were responsible for the most serious damage.

1. Collapse of the wharf at Port-Sandwich and of the Quai Gubbay at Luganville.
2. Serious damage to buildings in many places, for example, at Luganville, Norsup, Sarmette, Lakatoro, and Lamap.
3. Breakage of water supplies and telephone lines.

On August 13 an aftershock gave rise to a tsunami 2m in height, which resulted in the loss of several small ships on the west of Espiritu Santo, and the destruction of coastal installations.

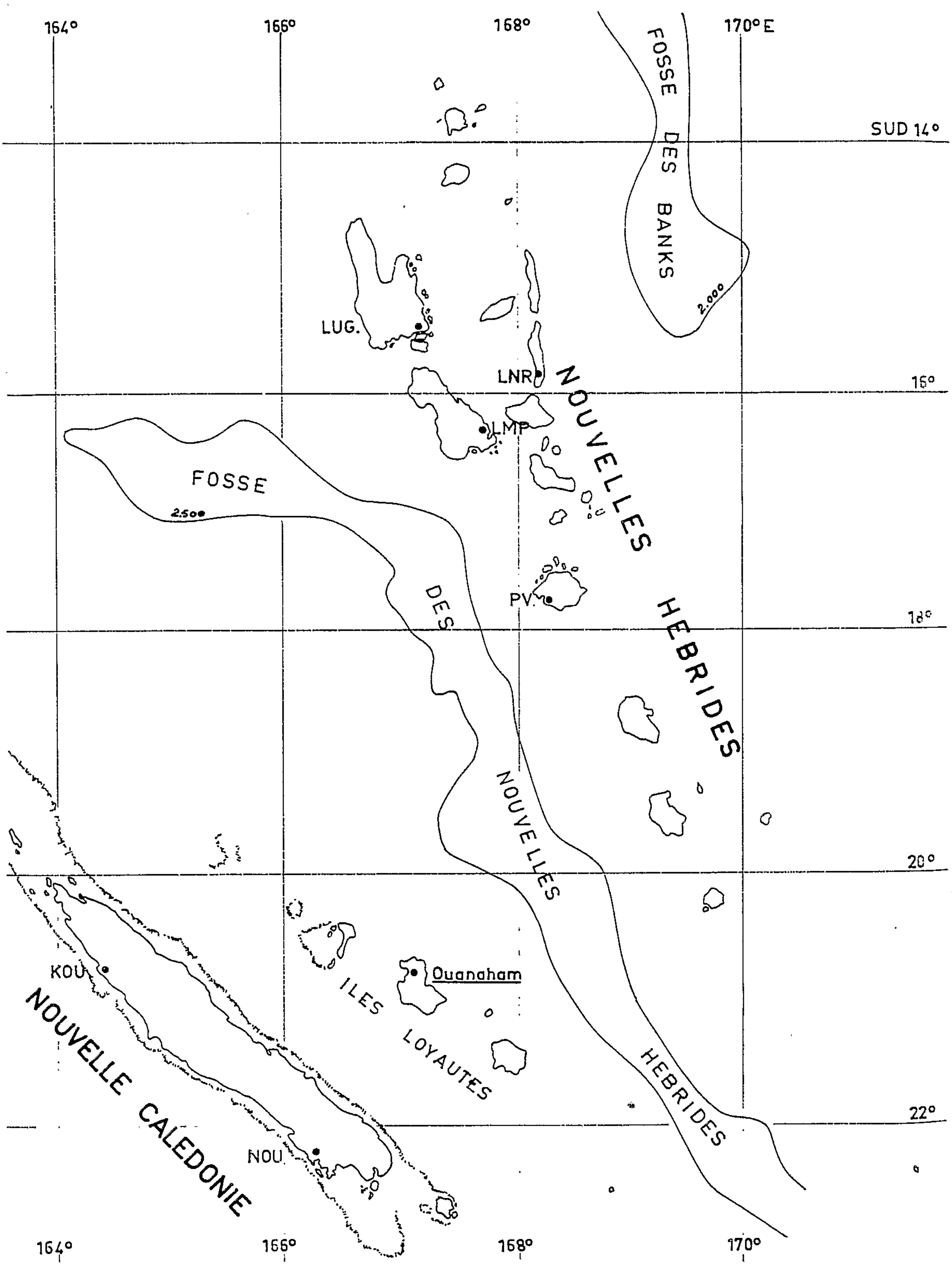


FIG. 3.—Locality map, showing positions of the sseismograph stations of the ORSTOM network.

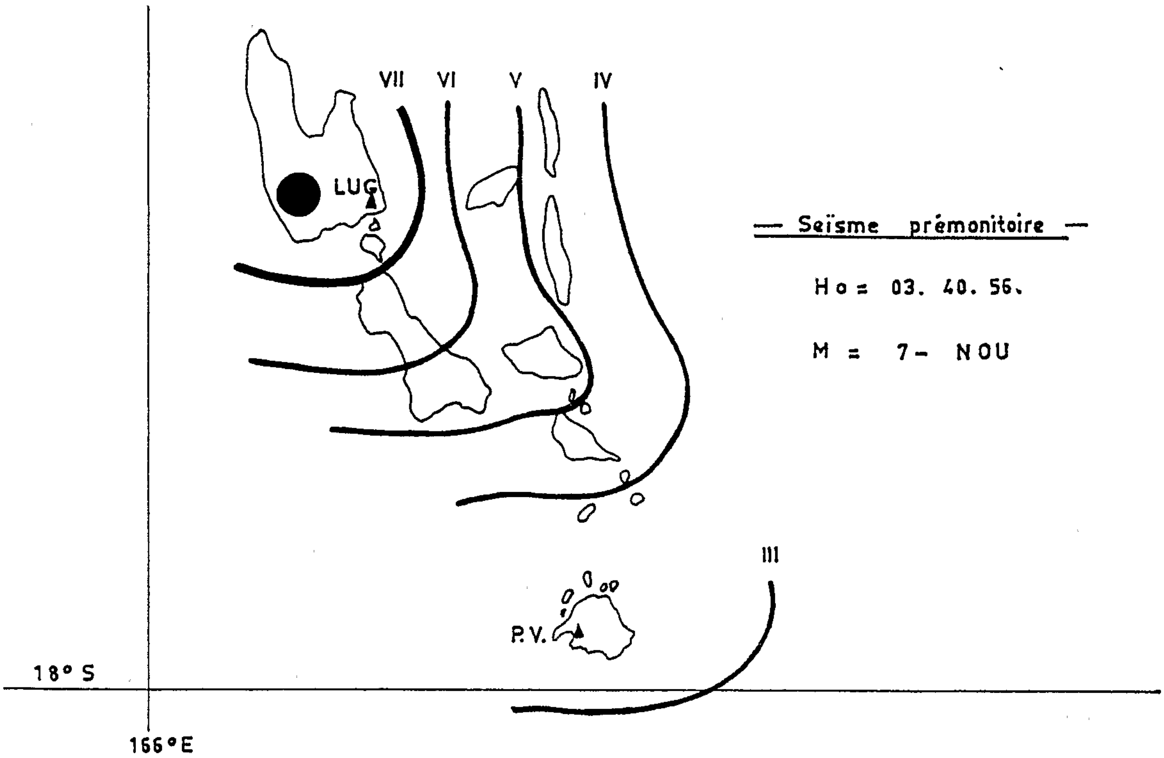


FIG. 4.—Isoseismals of the earthquake of 1965 August 11d 03h 40m U.T.

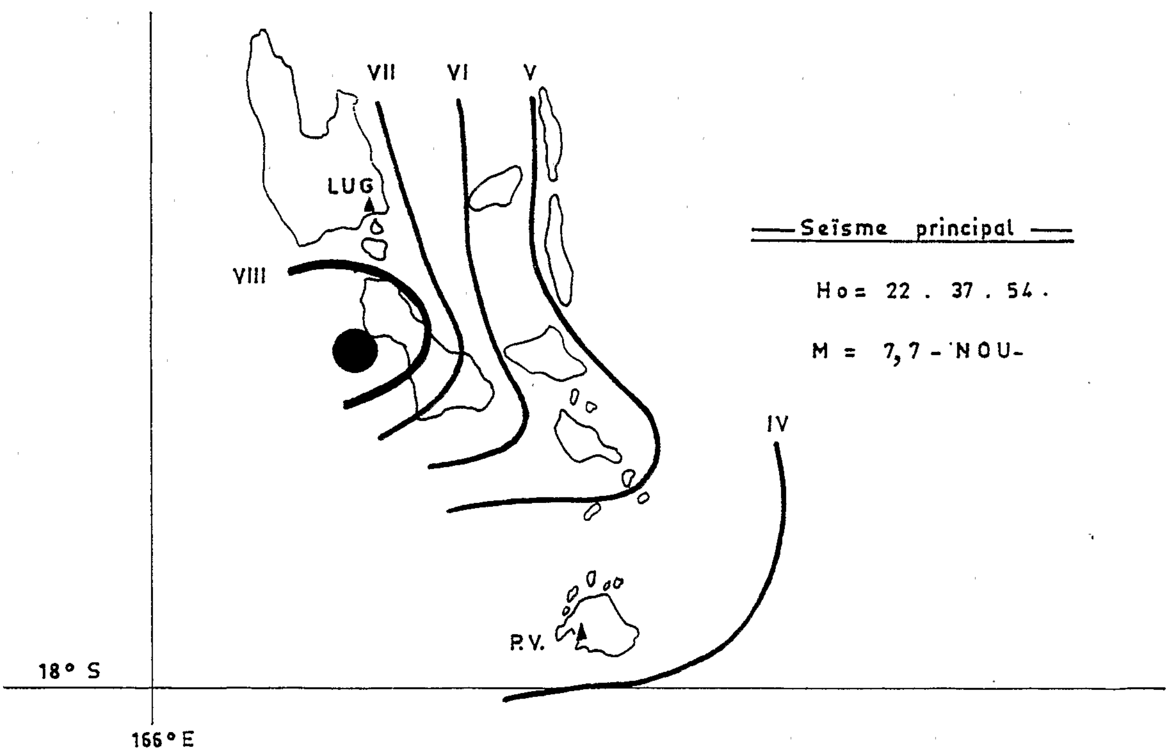


FIG. 5.—Isoseismals of the earthquake of 1965 August 11d 08h 01m U.T.

On August 11 and 12, an uplift of 0.5–0.8m in the northern part of the island of Mallicolo appeared along 100km of the coastline, and in the sea bed in the Norsup region (Figs. 1 and 2). In addition, slumping of the ground, landslides, and fissuring were found on all the islands inspected. Figs. 4 and 5 are isoseismal maps for the two largest shocks, on August 11. Some of the aftershocks resulted in less serious damage. There were 62 on August 11, 12, and 13.

EPICENTRE DETERMINATIONS

Epicentre determinations were made by the following methods, using the five stations of the ORSTOM network, at Noumea, Koumac, Port-Vila, Ouanaham, and Luganville (Fig. 3).

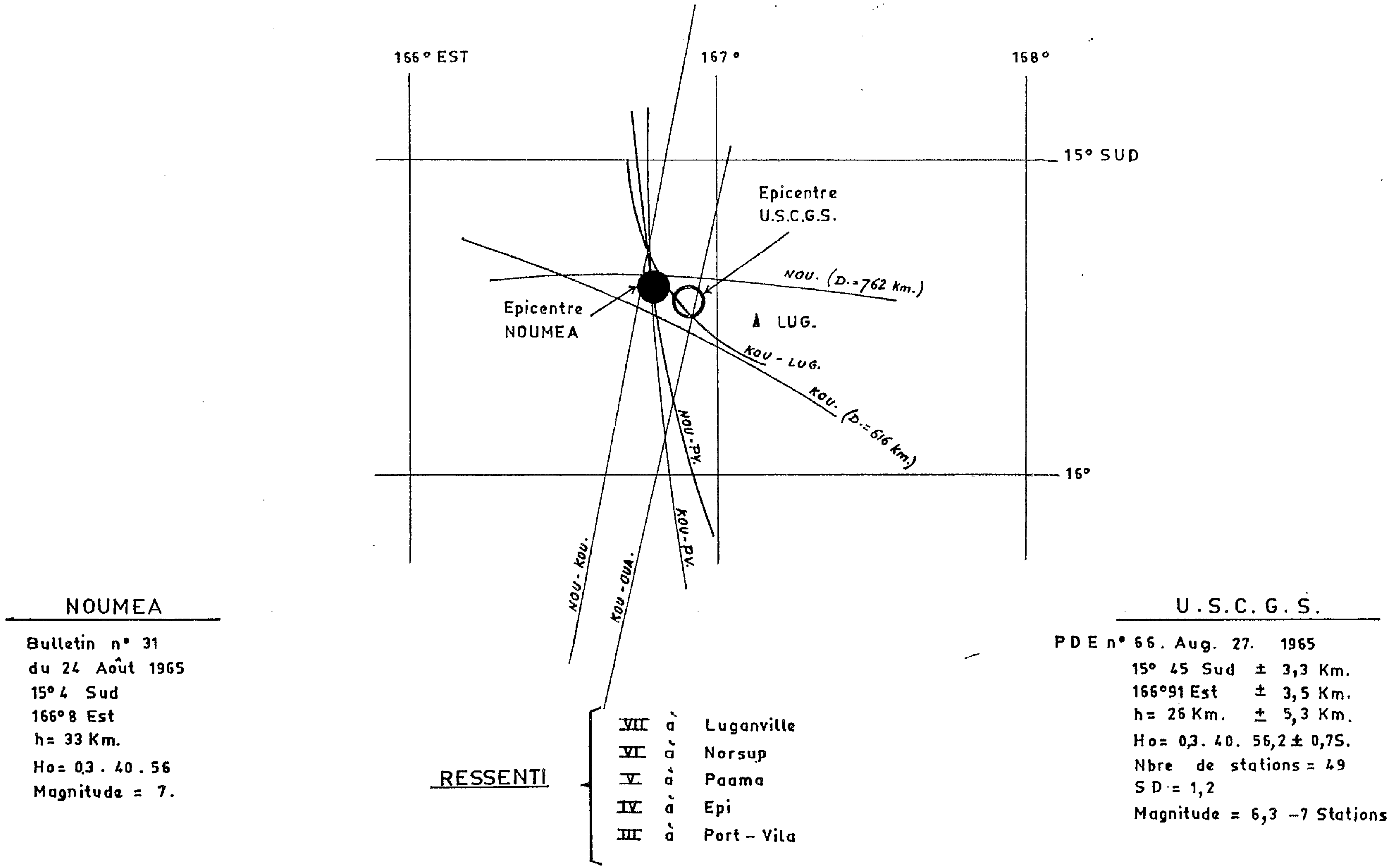


FIG. 6.—Epicentre determination for the earthquake of 1965 August 11d 03h 05m U.T.

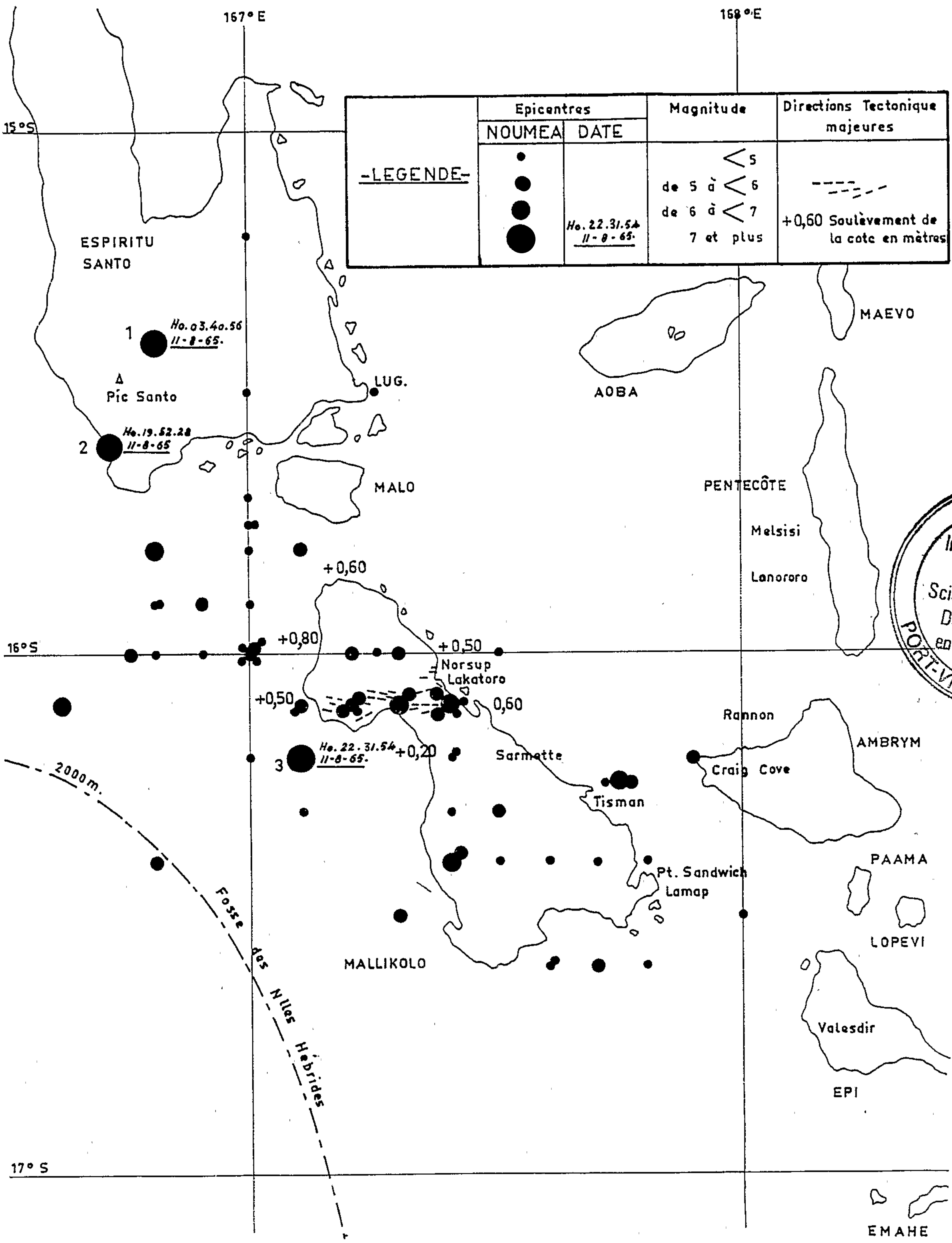


FIG. 7.—Epicentres of earthquakes occurring during the 1965 New Hebrides swarm.

From P-arrival Times.—Graphs were constructed showing the foci of epicentres giving a constant difference in arrival time at a pair of stations. These were determined point by point, as the apparent velocities of propagation (obtained from the 1940 Jeffreys–Bullen Tables) are dependent upon the epicentral distance.

A circle of radius *n*km centred at one of the stations will correspond to a travel time t_1. The positions of the epicentres corresponding to differences of arrival time of 1, 2, 3, . . . m seconds will lie at the intersection of the first circle with a family of circles centred at the second station, and having radii corresponding to the travel times $t_1 + 1$, $t_1 + 2$, $t_1 + 3$ . . . $t_1 + m$ seconds, as given by the tables.

In this way, the seismic region of the New Hebrides was covered by a set of 10 graphs (corresponding to five stations, or 10 station-pairs), and worked out for different focal depths.

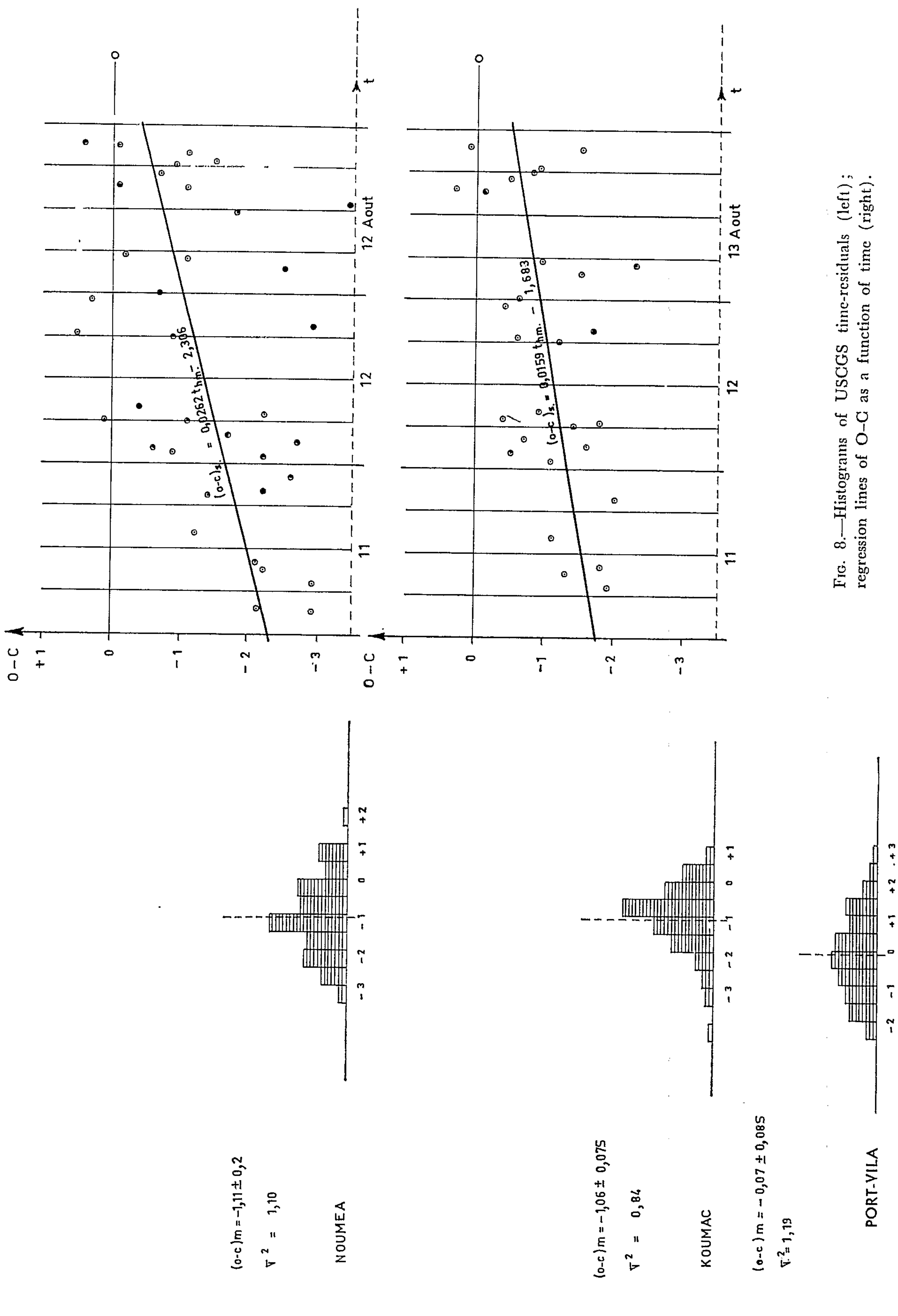
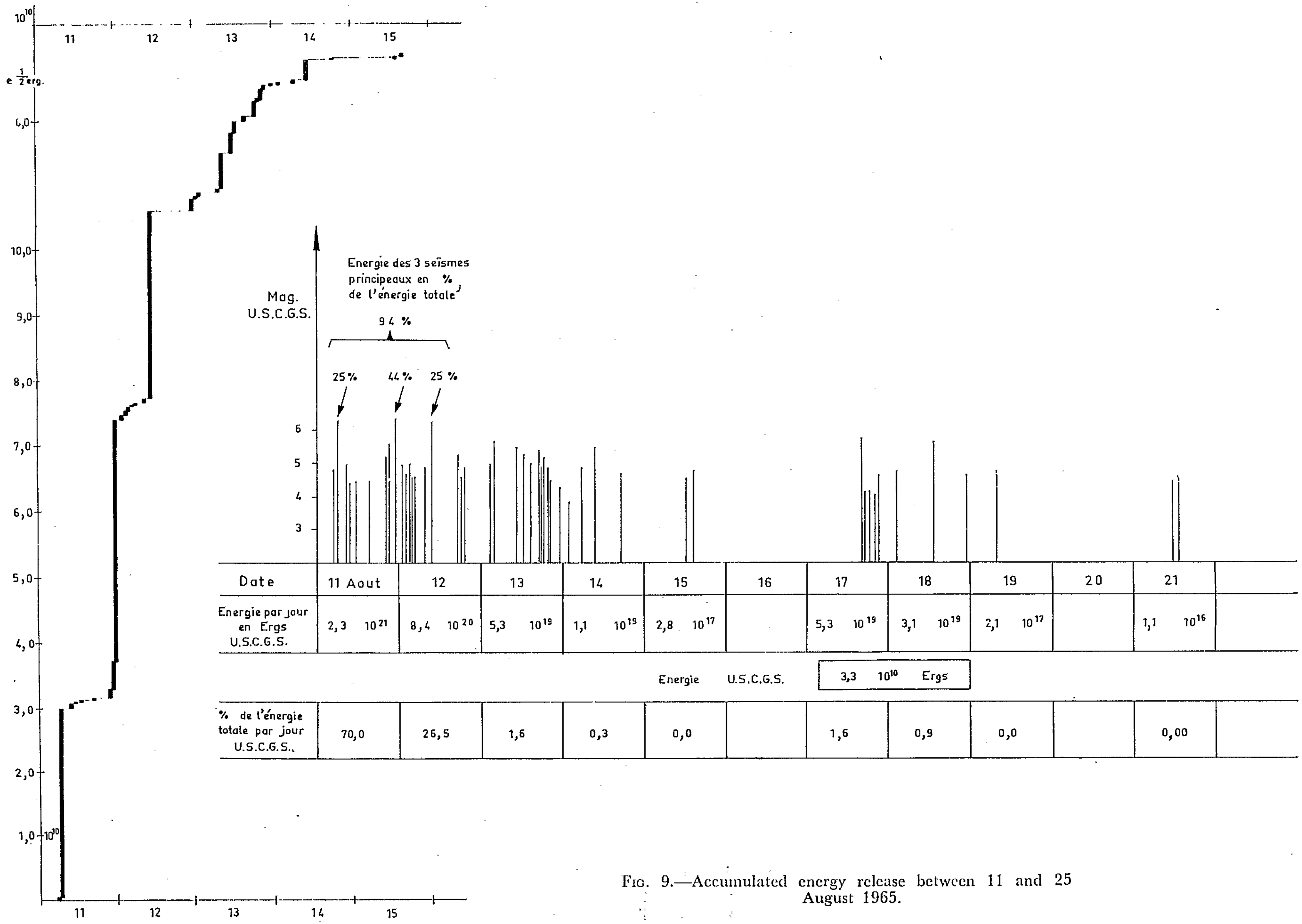


FIG. 8.—Histograms of USCGS time-residuals (left); regression lines of O–C as a function of time (right).



Date	11 Aout	12	13	14	15	16	17	18	19	20	21	
Energie par jour en Ergs U.S.C.G.S.	2,3 10^{21}	8,4 10^{20}	5,3 10^{19}	1,1 10^{19}	2,8 10^{17}		5,3 10^{19}	3,1 10^{19}	2,1 10^{17}		1,1 10^{16}	
Energie U.S.C.G.S.	3,3 10^{10} Ergs											
% de l'énergie totale par jour U.S.C.G.S.	70,0	26,5	1,6	0,3	0,0		1,6	0,9	0,0		0,00	

FIG. 9.—Accumulated energy release between 11 and 25 August 1965.

... n Epicentral Distances.—When S-waves were recorded, the S–P intervals could be used to obtain epicentral distances from the Jeffreys–Bullen Tables. Fig. 6 shows an example of an epicentre determination, for the shock of August 11d 03h 05m 56s. During the swarm, 211 such determinations were made.

In its bulletins, the USCGS prints epicentres based on the records of its world-network stations for most of the shocks. The USCGS positions seem to be systematically displaced a little to the east with respect to ours, which are in good agreement with the macroseismic observations of the main shocks (Figs. 4 and 5). The principal epicentres determined at Noumea are shown in Fig. 7.

HISTOGRAMS OF USCGS TIME-RESIDUALS

In the USCGS Earthquake Data Reports, O–C residuals (observed–calculated arrival times) are given for the stations used in their epicentre determinations, and these include Noumea. Histograms of these residuals have been drawn for the stations at Noumea, Koumac, and Port-Vila, which recorded the greatest number of shocks. Luganville was put out of action by the first shock, and Ouanaham recorded only a small number of aftershocks, because of its low magnification. The variances are close to 1, which corresponds to a probable error of the average values that is less than ± 0.2 seconds.

It is concluded that the two New Caledonian stations have identical average values of $O-C = -1 \pm 0.2$ seconds, and that the corresponding value for Port-Vila is -0.1 ± 0.1 seconds. Further, O–C at Noumea and Koumac increased from -2.5 to about 0.5 seconds during the first three days of the swarm (see Fig. 8). The regression lines obtained are:

$$\text{Noumea } (O-C) = 0.0262\ t_h - 2.306$$
$$\text{Koumac } (O-C) = 0.0159\ t_h - 1.683$$

This result will be used in the interpretation.

ENERGY RELATIONS

Values of unified magnitude M are quoted in the USCGS bulletins. The liberated energy in ergs can be obtained from these by the relation

$$\log E = 5.8 + 2.4\ M \quad \text{(Richter, 1958)}.$$

Fig. 9 shows the magnitudes M as a function of time, a table of liberated energies, and a graph of the accumulated energy release. Of the total energy, 95 percent was liberated in the three main shocks, 45 percent of it in the shock of August 11d 22h 31m 54s.

INTERPRETATION

Although the epicentres are accurately known, the focal depths are uncertain by $\pm$ 20km at least. This is apparent from several of the observed facts:

1. The increase in the value of O–C at Noumea and Koumac could be the result of a decrease in focal depth. C remains constant, since Jeffreys–Bullen Tables for a uniform depth of 33km were employed throughout, and O increases.
2. The aftershocks recorded after the main events show the multiple P and S pulses characteristic of crustal earthquakes, and both surface-waves and T-waves are prominent.
3. There was no tsunami associated with two of the main shocks, although their epicentres were at sea; but the small aftershock of August 13 produced a tsunami 2 metres high.

These observations can all be explained if the three main earthquakes, originating beneath the crust, are considered to have given rise to crustal readjustments, in which only 5 percent of the total energy was liberated. These aftershocks were, moreover, for the most part located in the east–west fracture zone (Fig. 7) reported by geologists and readily visible in aerial photographs, which corresponds to the southern limit of the north Mallicolo zone of uplift.

REFERENCES

JEFFREYS, H.; BULLEN, K. E., 1968. *Seismological Tables.* Gray-Milne Trust, London. 50 pp.

RICHTER, C. F., 1958. *Elementary Seismology.* Freeman and Co., San Francisco. pp. 364–367.