MRD NOTE BP 33/9

TSUNAMIS IN FIJI

by

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MINISTRY OF ENERGY & MINERAL RESOURCES

MINERAL RESOURCES DEPARTMENT

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ABSTRACT

A preliminary catalogue of tsunamis is compiled for the area around Fiji, including Tonga, Samoa, Vanuatu and the Kermadec Islands. Information for this catalogue has been extracted from published results, local newspapers and unpublished records and reports held at the Mineral Resources Department, Fiji.

Eleven tsunamis in Fiji are listed. The three largest of these with an average maximum amplitude of about two metres, occurred as a result of earthquakes off the coastlines of northern Vanua Levu (1881) and southeastern Viti Levu (1953) and a tsunami with its source in Chile (Savusavu, 1877).

The reef system protects most Fiji coastlines from the tsunami waves from distant and local sources and only one tsunami is known to have caused damage and loss of life.

This occurred on 14 September 1953 and drowned three people in Suva and two in Kadavu. It is considered to have been caused by submarine slumping off the outer edge of the reef system in southeastern Viti Levu which was triggered by the 'Suva' earthquake with magnitude (MS) 6.75 and epicentre in the vicinity of the area of the slumping. Evidence of extensive submarine slumping off the reefs along the southern coast of Viti Levu suggests that the maximum tsunami risk is in the southern Viti Levu - Kadavu area.

Surging in restricted ocean passages may result from tsunamis with a source outside the Fiji region, particularly large ones originating in South America, and tsunami warnings should be broadcast if only to warn local shipping of the potential danger from surging. A simple precaution against tsunami damage to buildings is to construct them at least two metres above high tide level.

INTRODUCTION

Zones of strong earthquakes and volcanic activity near an ocean or sea are also zones of tsunami, or seismic sea wave, occurrences. Fiji lies within the highly active circum-Pacific belt of earthquakes and volcanoes, and zones of shallow earthquake activity (Fig. 1) surround the main Fiji islands so that Fiji could be expected to have relatively high risk from this type of sea wave. However, danger from tsunamis is not publicly recognised, for two main reasons. Firstly, evidence for such events in the past has been difficult to locate, and has certainly not been publicized, and secondly, spectacular tsunamis have been rare during the last few decades. Nevertheless, seismic sea waves do occur, and the cost of tsunami damage will increase with future developments. This development is rapid, so it is becoming increasingly urgent to take precautions now against damage and loss of life from the tsunamis which are sure to occur in the future.

The purpose of this paper is to present a preliminary catalogue of tsunamis. Some events are almost certainly missing from this catalogue but it is proposed to make an assessment of tsunami risk and to stimulate interest in tsunamis to the extent that other researchers will improve the catalogue or use the information for sociological/historical studies.

A tsunami is a wave caused in the sea or a lake subsequent to an earthquake, volcanic eruption, landslide or submarine slide. The term in English is 'tidal wave' (improperly named) or 'seismic sea wave' and in Spanish 'Maremoto', but the term tsunami is now almost universally accepted. 'Tsunami' is derived from the Japanese, 'tsu', denoting harbour and 'nami' a wave.

The United States Department of Commerce, Coast and Geodetic Survey (USCGS) in their publication on tsunamis (1965) give the following information.

'Every island and coastal settlement in the Pacific Ocean area is vulnerable to the onslaught of seismic sea waves. The waves of 1868 and 1877 devastated towns in northern Chile, and caused death and damage across the Pacific. A series of seismic sea waves generated by the eruption and collapse of Krakotoa in 1883 killed more than 36,000 persons in the East Indies. [A similar type of event occurred off the coast of Papua New Guinea in 1888.] Japan lost 27,000 lives to the wave of 1896 and 1,000 more to that of 1933. There have been hundreds more whose effects were less spectacular but which took many lives and did much damage.'

'The phenomenon we call 'tsunami' is a series of travelling ocean waves of extremely long length and period. In the deep ocean their length from crest to crest may be a hundred miles or more, their height from trough to crest only a few feet. They cannot be felt aboard ships in deep water, and they cannot be seen from the air. But the kinetic energy - the energy of movement - represented by a tsunami is impressive. A tsunami "feels the bottom" even in the deepest ocean, and it appears that the progress of this imperceptible series of waves represents the movement of the entire vertical section of ocean through which the tsunami passes. In the deep ocean they may reach speeds of 600 miles per hour.'

'As the tsunami enters the shoaling water of coastlines in its path, the velocity of its waves diminishes and wave height increases. The arrival of a tsunami is often (but not always) heralded by a gradual recession of coastal water, when the trough precedes the initial crest; or by a rise in water level of about one-half the amplitude of the subsequent recession. This is nature's warning that more severe tsunami waves are approaching. It is a warning to be heeded, for tsunami waves can crest to heights of more than 100 feet and strike with devastating force'.

'Tsunamis are believed to originate as vertically displaced columns of ocean water, but the displacing agent has not been positively identified. Seismic or volcanic alterations of the ocean floor, provided they impart some vertical movement to the water column, may cause a tsunami. It has also been postulated that submarine avalanches on the slopes of the Pacific trenches produce tsunamis'.

'The speed of tsunamis varies with water depth, and it is this relationship which permits prediction of tsunami arrival times at all points in the Pacific Ocean area. But no definite correlation has been possible between the configuration of specific regions of the ocean floor and tsunami configuration in those regions. It is not completely clear, for example, why a tsunami's waves may be of negligible size at one point along a coast, and of much larger proportions at other coastal points nearby. Nor is it possible to predict whether the destructive component of a tsunami will lie in its powerful surge across a beach, or in a gradual rising of sea level followed by a rapid draining back to sea'.

'Thus it is impossible to say with any certainty what shape a tsunami will assume at specific locations, or how it will accomplish its destructive work. In treating tsunamis exceptions are the rule.'

Apart from the local topography, factors affecting the size of a tsunami include the source (earthquake, volcanic eruption or avalanche), magnitude and depth, and the amount of vertical movement at the source: for example, many earthquakes are associated with horizontal movement, or transcurrent faulting, which will not directly cause a sea wave. (As we shall see,this type of faulting predominates in Fiji)

Generally tsunamis are not generated by earthquakes with magnitude less than about 6.5 and major tsunamis require an earthquake with magnitude of 7.5 or more for their generation (Iida, 1970).

THE CATALOGUE

As a starting point events in Fiji, Tonga, Samoa, the Kermadecs and the New Hebrides (Fig. 6) which are given in catalogues of tsunamis in the Pacific Ocean (Houston 1980, Iida et al. 1967, Soloviev & Go 1974, 1975) were extracted and listed. To this list were added tsunami data distributed by the International Tsunami Information Centre (ITIC) and data contained in unpublished reports of the Fiji Mineral Resources Department (MRD), and in newspaper articles.

Some tsunamis with maximum wave heights of less than say three metres, are probably missing from the catalogue, and it is possible that larger unrecorded tsunamis could have occurred, particularly before 1900. That major tsunamis with wave heights above about ten metres in the main Fiji islands went unrecorded during the past 100 years is considered unlikely, however it is probable that large unrecorded waves have occurred in remote lightly populated locations.

NOTABLE TSUNAMIS IN FIJI

Tsunamis in the region around Fiji (Fig. 6) were first listed in Table 1 and subsequently the The Fiji Times was searched for reports of possible effects in Fiji of the largest tsunamis given in the table because news of large earthquakes, volcanic eruptions and other catastophic events in the countries in the southwest Pacific was generally circulated to all newspapers and if a related effect was observed in Fiji it was generally described in the Fiji Times.

The Fiji Times was chosen because it has been published regularly since October 1869 and microfilm copies are held by the National Archives in Suva.

For the past decade the list includes several minor tsunamis in Fiji which were only observed on the tide-gauge records and would have been unnoticed without the gauge. An example of such a recording is in Figure 3.

Information pertaining to Fiji tsunamis, extracted from Table 1, is given in Table 2. A discussion of more interesting tsunamis follows.

11 May 1877

An earthquake in Chile caused a tsunami which reached all coastlines in the Pacific with disastrous consequences in Chile, Hawaii and Japan. Waves upto 3.0 metres high were observed in New Zealand (Gilmore & Ridgway, 1982) and in Tonga the tsunami was very obvious and was high enough to refloat a ketch stranded on a reef by a recent hurricane. Effects in the SW Pacific are summarised by Josephson (1878) but he does not mention Fiji.

The Fiji Times reported the following

23 May 1877 (P2, Col5) 'Some remarkable tidal disturbance seems to have taken place lately at Savusavu. Whilst at breakfast on Friday, the 11th May, instant, it then being low water, a sudden upheaval was observed and, three times in succession, the waves, rolling in with great force, encroached far above high water mark. It is supposed that this phenomenon owed its origin to volcanic influence; there having been no corresponding atmospheric change to have accounted for the occurrence.'

13 June 1877 (P3, Col3, extract from Auckland Star, 26 May) 'By arrival of the Sappho [in Auckland] we gain the following items of news:-

'The tidal wave was experienced very strongly at Vavau and Tonga. There were 10 or 11 rises and falls at Vavau on 11th, the greatest rise being about 10 inches, the reef was left quite exposed at times and as it receded it left millions of fish behind it on the rocks.

The effect was very extraordinary. The natives do not recollect anything like it. They put down the Sappho as the cause.'

'At Tonga the wave lifted the stranded ketch 'Pearl' right off the reef and left her in deep water, saving a lot of trouble and expense.'

Note - The 'Pearl' had been stranded by a hurricane on 01 May (13 June P3 Col3)

09 June 1877 (P2, Col6, 7 P3 Col 1-4) 'Early on Friday 11th the shores of New Zealand were washed by a series of gigantic ocean waves .....'

The newspaper followed with lengthy descriptions of the effects in New Zealand but did not recognise that the wave described at Savusavu in the May 23 edition arrived at about the same time and was probably part of the same tsunami.

The predicted travel time to Suva is 17.5 hours so that the first wave would have arrived at 6.30 am, about 'breakfast time', which is consistent with the Savusavu report, and we therefore assume that the unusual waves were caused by the Chilean tsunami. Other islands could have suffered from the tsunami but reports are unlikely due to the poor communications available in 1877.

12 July 1881

The Fiji Times published the following reports.

13 July 1881 (P2 Col7) 'Captain Beatson informs us that yesterday morning we were visited by an unusual rise of waters which came in the shape of a tidal wave. In Levuka Creek it rose at least eighteen inches above the highest mark. His attention was called to it from the noise. After referring to two clocks he found them stopped at 5.25 and 5.33 respectively. Some other person perhaps have noticed the occurrence'.

16 January 1884 'During my residence here I have at various times felt the shocks of seven earthquakes but this is the first occasion on which I have noticed the rumbling sound

described. Some of the previous shocks have been attended by Tidal Disturbances, the rise and fall being as much as six feet in half an hour; on this last occasion it was nearly high water and no perceptible change took place.'

The latter report was from an observer in Macuata, central northern Vanua Levu, who gives a very feasible description of a sea wave which was associated with an earthquake with an epicentre probably in the recognised zone of seismicity to the north of Vanua Levu (Fig. 1) and which occurred before 1884 (Everingham, 1983a).

Although there is no certainty that the wave noted at Levuka in 1881 was associated with one originating to the north of Vanua Levu it does appear to be most likely for several reasons. (a) Captain Beatsons two clocks could have been stopped by weak earthquake waves - there is no other reason for them both to stop at the same time. (b) An earthquake in Fiji's most active zone(that to the north of Vanua Levu, Fig. 1) is over 200 km from Levuka and would only be felt with low intensity there and the tremor could be unnoticed. (c) There is no evidence for a distant source, ie Tonga or the New Hebrides.

It is assumed that the two reports refer to the same tsunami which was caused by an earthquake in January 1881 and which resulted in a sea level rise of about 1.8 metres (6 feet) at an unspecified place on the coast of central northern Vanua Levu.

14 September 1953

The 1953 'Suva' earthquake with magnitude (MS) 6.75 is the most damaging (not the largest) on record in Fiji whilst the tsunami generated by it is the largest on record and the only one known to have caused loss of life. Fortunately the barrier reefs mitigated the effects of the sea waves. For example, although huge waves were observed approaching Suva harbour over the outer reef area the wave height was only about two metres by the time it reached the shoreline (Fig. 4).

The tsunami arrival times at various points suggests that the source region for the tsunami is the outer reef edge between the area of the harbour entrance and Beqa, i.e.in the vicinity of the earthquake epicentre (Fig. 1), and evidence given by changes in the sea floor, broken submarine cables, the very steep nature of the outer reef and the presence of submarine canyons indicates that the tsunami was generated by submarine slumping in this source region (Houtz, 1962).

Houtz (1962) gives an excellent description of the effects of the tsunami part of which is reproduced here.

Effects. The tsunami was not reported beyond a distance of 180 miles from the source, although rises of two feet were observed at these most distant points. The visible effects of the waves must certainly have extended much farther, but were not recorded. It is not known if questionnaires were sent to the eastern Lau group. Waves were observed from the Lomeri mission on the south coast to Tailevu point on the northeast coast of Viti Levu. They were reported south to Kadavu, all along the southern coast of Vanua Levu, and in the western Lau group. The visibly affected area is therefore a circle of 180 miles radius, centering on the source area, with the northwest sector (from due north to southwest) blanked out.

The waves apparently attained their greatest height as they broke against the reef in the entrance to Suva harbor and along the south coast. Estimates of the height of the first and largest wave range from 10 to 50 feet which are rather consistent in view of the fact that the wave was seen at distances of one or two miles. Considering the size of the coral blocks that were dislodged and thrown up on the reef, the wave was appreciably larger than the ordinary storm waves which may occasionally attain 10 or 15 feet. The waves that crossed the harbor and damaged the Suva waterfront were not in excess of six feet before they broke over the sea walls. The tsunami was probably at least as violent along the sparsely settled coast to Beqa, but reports are lacking. However, coral blocks up to 10 feet in diameter were dislodged and the hulk of a wrecked vessel was thrown up on the reef four or five miles southwest of Suva. Sunken logs and miscellaneous debris littered the foreshore after the wave receded. Sand banks were created in the various reef passages while some existing banks were scoured out along the south coast and in Suva harbor.

The table below lists the average heights in feet recorded by eye-witnesses throughout the Colony. These heights are restricted to observations on the foreshore, behind the barrier reefs.

LOCATION	AVERAGE HEIGHT (feet)
Suva, Vitilevu	6
Deuba, Viti Levu	6
Lami, Suva	6
Beqa island	5
Koro island	5
Laucala Bay, Suva	3–4
Cawaci, Ovalau island	3–4
Vunisea, Kadavu island	3
Sawakasa, Viti Levu	3
Levuka, Ovalau island	3
Western Lau group	2

The village of Nakasaleka, Kadavu, is not protected by the barrier reef and is situated at the head of a small bay; here, the wave reached a height of 15 feet. The islets of Nukulau and Makuluva are situated on the barrier reef, facing Nukulau passage, and are unprotected. They were swept by a six foot wave and their recreational facilities were destroyed; the crest of this wave was about 12 feet above sea level. The village of Nukui, east of the mouth of the Rewa river was also badly damaged and is similarly unprotected by the barrier reef.

The Colony, particularly Suva, was saved from serious damage by the barrier reefs that encircle practically all of the islands. The tide was low at the time of the tsunami, and had it been high (three additional feet), the results would have been disastrous.

May 23 1960

This 'Great Chile tsunami' reached shorelines around the entire Pacific, caused devastation in Chile, Hawaii and Japan and nearer Fiji was a nuisance in the Cook Islands and New Zealand. Iida et al. (1967) give a travel time of 13.3 hours to Suva and a period of 60 minutes for the tsunami waves.

Although it appears improbable that in Fiji the tsunami only affected Suva, a description of the waves in Suva harbour is the only one located for this report.

Excerpts from the Fiji Times describe the tsunami effects in Suva harbour.

24 May 1960 (P3 Col4) 'About 9.50 the Suva harbour level fell about 2 feet and the water then flooded quietly back.

'A launch anchored at the Royal Suva Yacht Club was temporarily stranded and a patch of normally covered reef was exposed.'

'The few ships at the wharf showed little effect from the gentle fall and rise of the water'.

25 May 1960 (P3 Col1) ' "The tidal waves generated by the Chile earthquake on Saturday and Sunday 22nd reached Fiji waters about 9 pm on Monday (23rd) night" the Acting Chief Geologist (Mr R.E. Houtz) said at Suva today'.

'The maximum change between high and low levels was three and a half feet.

"The most active period according to the tide gauge was about 10 pm."

..........'

'He said "the backlash of the tidal waves was still apparent in Suva harbour yesterday (24th) when the sea rose and fell by as much as 18 inches".

' ....'

'Walu Bay Surge

'Owners of small craft beyond the bridge at Walu Bay had a busy and hard time in the early hours of yesterday morning trying to save their boats from being damaged each time the sea surged into the bay and retreated.

'A boatowner said that it was the worst surge he has seen in the bay. It was worse than the surge during the 1953 earthquake at Suva.

'Many boats were damaged. Owners stayed in boats from about 2 am till 8.30 am yesterday (24th).

'Boats snapped their stern lines and swung out into the bay. Some swung clear and others came into collision with other boats which had broken loose.'

17 December 1975

Fluctuations in sea level commencing shortly after the minor (MS 5.2) earthquake in 1975 were observed over a period of about an hour and a half at Laucala Bay and for an unknown period at Ono (Everingham, 1983b). In Laucala Bay waters the amplitude, measured from crest to trough, may have been about 0.5 metres (i.e. in the order of half the tidal range) because sand banks appeared and disappeared and the change in level on the barrier reef was sufficient to have a noticeable effect on appearance of the ocean waves breaking on the reef edge, according to reliable observers at the MRD office which is about 2 km from Laucala Bay shoreline and 8 km from the reef bounding the seaward side of the bay. Locations are given in Figure 4.

Unfortunately the only tide gauge data in Suva are smoothed 15-minute mean plots and mean hourly values of the Suva harbour sea level. These data effectively smooth out the tsunami waves and a tsunami in Suva harbour could not be detected.

The occurence of the waves is of particular interest because earthquakes with such a small magnitude do not generally cause tsunamis (Iida, 1970). The tsunami was probably generated by a minor submarine slump caused by the shaking (intensity MM 4-5) in the Suva-Beqa outer reef zone in a similar manner to that of the 1953 tsunami (Everingham, 1983b) which illustrates the ease with which a slump can be initiated. If slumping can be started by relatively low earthquake intensities even a minor shallow tremor in the southeastern Viti Levu seismic zone (Fig. 2) could start a submarine slump should the epicentre be close to a suitable source.

23 June 1977

This is a minor tsunami which was generated by a magnitude 7.8 earthquake about 800 km southeast of Suva. There are no known reports a notable tsunami in the Tonga-Samoa region and tsunami was probably too small to be noticed. It is typical of the relatively numerous tsunamis which result from large regional earthquakes and are recorded by tide gauges. A tracing of the Suva harbour tide gauge record is shown in Figure 3.

Points to note on the Suva marigram are that (a) the first wave is dilatational, i.e. the sea level dropped (b) the first and second incoming waves (sea level rising) are the highest (0.15, 0.1 m), (c) the period of the sea waves, a function of the magnitude of the earthquake source, is 40 minutes (cf. 60 minutes for the 1960 tsunami given by Iida et al. (1967)), (d) sea waves are still occuring at the end of the record in Figure 3, i.e. 10 hours after the first arrival, and (e) between about 0200 and 0230 the combination of the tidal fall and the tsunami caused an abnormally rapid fall in sea level, 40 cm, which would have contributed to surging in constricted ocean passages, river mouths and the like.

DISCUSSION

Tsunamis from distant earthquakes

Major earthquakes in Alaska, Kamchatka, Japan, the Aleutian Islands and the Philippines have generated large tsunamis affecting distant Pacific coastlines, however their effects in Fiji were unnoticeable although minor surges may have occurred and been blamed on the weather. It is unlikely that much worse effects could be expected from future tsunamis generated in those areas.

However tsunamis generated by major South American earthquakes in 1877 and 1960 have penetrated Fiji waters and although effects on record were only minor, possibly populations in remote places in Fiji may have suffered damage or inconvenience. Surging is almost sure to have occurred and it will be important to issue tsunami warnings in future to alert shipping in particular.

Local tsunami sources

Data for Fiji indicate that since the 1850's only two of the larger local earthquakes generated a notable tsunami. Why then are tsunamis not recorded for all the high-magnitude events?

(a) Firstly, earthquakes large enough to cause a major tsunami directly by vertical displacement at the ocean bottom, i.e. with magnitude greater than about MS 7.5, have not occurred in Fiji. The largest earthquake magnitude is MS 7.0 for an event in 1928 (Everingham, 1983a). For an earthquake with magnitude in the range 6.5-7.0 to cause a tsunami (without slumping) it would have to be extremely shallow with a vertical fault displacement at the earth surface.

(b) Most earthquakes in Fiji result from faults with mainly horizontal earth movement, which are poor tsunami generators. For example, focal mechanism solutions for earthquakes in a seismic zone crossing to the north of Viti Levu and Vanua Levu and tectonic theory indicate predominant strike-slip motion

(Sykes et al. 1969, Everingham 1984) which explains the rarity of tsunami-generative earthquakes in this zone. Again, it is interesting to note that both the 1953 Suva and the 1979 Taveuni earthquakes were associated with strike-slip faulting (Hodgson 1956, Everingham 1983c).

(c) Many earthquakes were too deep: only shallow earthquakes are likely to generate tsunamis, yet only 20 percent of the earthquakes occur in the crust at depths less than about 33 km and can be termed 'shallow'. For a focal depth of, for example 80 km, an earthquake would probably require a magnitude of 8.0 or greater to generate a notable tsunami.

(d) Minor tsunamis might have occurred without being observed or recorded, or a recorded event may not have been documented in this survey.

(e) The 1953 and 1975 Suva tsunamis and possibly the 1881 Macuata tsunami were generated by submarine slumps which require a source of rapidly accumulated unconsolidated sediments perched on a steeply sloping base. Marine seismic profiles showing huge slumps and submarine canyons (Holmes, 1982) provide evidence that this condition exists off southern Viti Levu. However large earthquakes in other areas, eg. Koro 1932; Rabi and Taveuni 1919, 1932, 1979; Kadavu 1950, 1963; have not caused tsunamis so that unstable masses of sediments apparently do not exist in many areas of Fiji and the earthquakes' fault displacements are not large enough to generate a sea wave without them.

Tsunamis from volcanism

Fortunately there is no submarine volcanism in the Fiji area and a 'Krakatoa' type of catastrophe appears unlikely to happen here. However, a major eruption or caldera collapse could occur in the Tonga-Kermadec or New Hebrides regions and generate a major tsunami which could penetrate the Fiji islands. Should the tsunami prove to be disastrous near its source a warning to other countries could prove difficult to arrange.

PRECAUTIONS

In the Figure 6 showing regional tsunami travel times it may be seen that the waves from earthquakes in Fiji could generally be expected to arrive at sites in the Fiji islands less than about one hour, and possibly only several minutes, after the earthquake occurrence so that currently an efficient national warning system is not practical. Use of satellite communications could speed up regional communications in the future.

Coastal villagers should be made aware that the best warnings are given by (a) the shaking caused by the earthquakes and (b) the recession of the sea.

Should an earthquake be felt strongly or with medium strength for a long period, eg. about two minutes, coastal residents should prepare for a tsunami.

When the sea recedes from the shore an observer should expect a subsequent sea level rise some two to fifteen minutes later. Safe tsunami lookout points should be selected.

Warnings of large tsunamis with distant sources around the Pacific margins should be broadcast to enable shipping to prepare for surges in sea passages. Historical evidence indicates that South American tsunamis, with a travel time to Suva of about 17 hours (Fig. 5), are most likely to affect Fiji but that they are unlikely to cause major damage or loss of life.

Historical evidence also suggests that tsunamis with earthquake sources in the Tonga-Kermadec or New Hebrides regions with travel times between one hour and two and a half hours (Fig. 6) are unlikely to trouble Fiji. However, there is always the possibility that an unusual event or the evidence of a large wave may be missing and warnings should be relayed whenever major earthquakes occur.

Buildings should be at least two metres above high tide level to avoid inundation by the majority of tsunamis; the changes of any particular village or town being affected by an anomalously large, damaging wave are slight and unpredictable. Special precautions should be taken when siting buildings supplying essential services.

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TABLE 1 TSUNAMIS IN THE TONGA-FIJI-NEW HEBRIDES REGION

YEAR	ORIGIN TIME 180°E Local Time	SOURCE AREA	LOCALITY AFFECTED	SHORE HEIGHT metre	TRAVEL TIME hours	REFERENCE
1853	JUN 24	Tonga	Tonga Niuafo'ou			Fiji Times 1886 Oct 02 (P2 Col3,4,6). Violent volcanic eruption.
1853	DEC	Tonga 21°S 175°W	Tonga Tongatapu			Soloviev & Go (1975) evidence of tilting. Taylor (1978) no tilting, probably a tsunami.
1865	NOV 18 0540	Tonga	Tonga Tau Cook Is	 2? 1.2	 3.7	Soloviev & Go (1975) Violent earthquake
1866	SEP 12	Samoa	Samoa Manua Is			Soloviev & Go (1975) Volcanic eruption.
1868	AUG 14 0445	Chile 18.5°S 71.0°W	Samoa		16.0	Iida et al. (1967). Major Pacific tsunami.
1875?	MAY 10	New Hebrides	New Hebrides Eromanga Is			Iida et al. (1967). Questionable tsunami.
1877	MAY 10 1259	Chile 21.5°S 71.0°W	Samoa Apia Tonga Fiji Savusavu New Zealand	 2-4 2 2	 15 18±	Iida et al. (1967). Major Pacific tsunami. Josephson (1878) Fiji Times 1877 Jun 13 (P3 Col3). Laing (1947) no details. Fiji Times 1877 May 23 (P2 Col5). Fiji Times 1877 Jun 09 (P2 Col6, P3 Col1-4) Josephson (1878)
1878	JAN 10	New Hebrides 19.5°S 169.4°E	New Hebrides Tanna Is			Iida et al. (1967) Volcanic eruption.
1881	JUL 12 0530	Fiji 16°S 179°E MS 6.5-7.0	Fiji Vanua Levu Ovalau	 1.8 0.4		Fiji Times 1884 Jan 16 (P2 Col5). Six feet rise in sea level, Macuata. Fiji Times 1881 Jul 13 (P2 Col7) Eighteen inch rise in Levuka Creek. Year of Vanua Levu tsunami uncertain (Everingham, 1983a).
1881?	NOV 24	Tonga	Tonga? Samoa?			Soloviev & Go (1975) Strong earthquake. No direct evidence of tsunami.
1883?	MAR 24	Samoa	Samoa			Soloviev & Go (1975). Hurricane and earthquake. Tsunami doubtful.
1883?	AUG 27 0507	Krakatoa 16.7°S 105.4°E				Possible atmospheric waves. Fiji Times - nil reported.
1886?	AUG 31	Tonga	Tonga Niuafo'ou			Fiji Times 1886 Sep 29 (P2 Col5), Oct 02 (P2 Col3,4,6). Volcanic eruption. No direct evidence of tsunami.
1905-11		Samoa	Samoa Savii Is			Soloviev & Go (1975). Numerous eruptions and tsunamis.
1907	APR 01 1059	Tonga	Tonga Tongatapu			Soloviev & Go (1975). Major earthquake (Angenheister, 1921), submarine eruption and tsunami. Possibly confused with previous events listed.
1917	MAY 02 0626	Kermadec 28°S 177°W MS 8.0	Samoa ? Apia	 12		Soloviev & Go (1975) Angenheister (1921, 23)

1917	JUN 26 1750	Samoa 16°S 173°W MS 8.3	Samoa Upolu Tutuila	12		Soloviev & Go (1975). Major earthquake Niuatoputapu area, changes in topographic relief possibly occurred. Destructive tsunami at Upolu, Sainili, Pagopago.
			Apia	0.4	0.1	Tida gauge (Angenheister, 1923).
1917	NOV 16 1519	Kermadec 29°S 177.5°W MS 7.5	Tonga			Angenheister (1921).
1918	SEP 08 0516	Kurila Is 45.5°N 151.5°E MS 8.25	Samoa Apia	0.2	9.7	Tide gauge (Angenheister, 1923). Iida et al. (1967).
1919	APR 30 1917	Tonga 19°S 172.5°W MS 8.3	Tonga Haapai Vavau Samoa	2.5 0.2	0.6	Fiji Times 1919 Jun 13 (P3 Col3) Iida et al. (1967) Soloviev & Go (1975) Fiji Times 1919 Jun 13 (P3 Col3) Fiji Times 1919 May 23 (P3 Col3, P4 Col4)
			Upolu, Apia	0.4	0.9	Angenheister (1921, 23)
1920	SEP 21 0239	New Hebrides 20°S 168°E MS 8.0	Samoa Apia		4.5	Angenheister (1923).
1923	FEB 04 0402	Kamchatka 54°N 161°E MS 8.3	Samoa Upolu, Apia		9.7	Iida et al. (1967)
1928	MAY 18 1546	Tonga 21°S 174°W	Tonga Ha'apai Is			Soloviev & Go (1975)
1933	MAR 03 0531	Japan 39.1°N 144.7°E MS 8.3	Samoa Upolu, Apia		30	Iida et al. (1967)
1946	APR 02 0029	Aleutian Is 53.5°N 163.0°W MS 7.4	Samoa Apia	2.4	9.2	Iida et al. (1967)
1948	SEP 09 0309	Tonga 21°S 174°W MS 7.8	Samoa Pagopago	0.1		Iida et al. (1967)
1952	NOV 05 0458	Kamchatka 52.8°N 159.5°E MS 8.25	Samoa Pagopago Apia	1.0	9.7 9.6	Iida et al. (1967) Some damage
1953	SEP 14 1227	Fiji 18.2°S 178.3°E MS 6.75	Fiji Suva Makuluv Beqa Koro Kadavu Nakaseleka	1.8 3.4 1.4 1.4 4.3	0.15 0.2	Houtz (1962). Three drowned by tsunami in Suva, two in Kadavu (Nakaseleka). Damage in Suva Harbour. Waves 3-14m high on outer reef near Suva.
			Samoa Pagopago	0.2		Iida et al. (1967)
			Hawaii Honolulu	0.1	7.3	Iida et al. (1967)
1957	MAR 10 0222	Aleutian Is 51.3°N 175.8°W MS 8.25	Samoa Pagopago Apia	0.3	9.1 9.0	Iida et al. (1967)
1958	NOV 07 1058	Kuril Is 44.5°N 148.9°E MS 8.25	Samoa Pagopago	0.1	9.9	Iida et al. (1967)

1960	MAY 23 0711	Chile 41.0°S 73.5°W MS 8.4	Samoa			Iida et al. (1967) Major Pacific tsunami.
			Tutuila	to 4.9		
			Pagopago	1.0	12.4	
			Upolu	to 4.9		
			Apia	1.5	12.3	
			Fiji			Fiji Times 1960 May 24 (P3 Col4), May 25 (P3 Col1).
			Suva	0.5	13.8	Strong surges in Tamavua River moorings, (Fig. 4).
			Suva	0.5	13.3	Iida et al. (1967). Wave period given – 60 minutes.
1961	JUL 24 0951	New Hebrides 18.5°S 168.3°E MS 7.25	New Hebrides			Iida et al. (1967)
			Vila	0.9		
			Forari	0.9		
1963?	DEC 18 1230	Tonga 24.8°S 176.5°W MS 7.2				Soloviev & Go (1975)
1964	MAR 28 1536	Alaska 61.1°N 147.7°W MS 8.4	Samoa			Iida et al. (1967) Major Pacific tsunami.
			Pagopago	0.2	10.3	
1965	AUG 12 1032	New Hebrides 15.8°S 167.2°E MS 6.4	New Hebrides			Iida et al. (1967)
			Tongoa	2.5		
			Vila	1.0		
1967	JAN 01 0623	New Hebrides 11.8°S 166.5°E	New Hebrides			Iida et al. (1967)
			Vanikolo	2.0		
			Fiji			
			Suva	<0.1		
1967	JAN 01 1015	New Hebrides 11.3 °S 164.8°E	New Hebrides			Iida et al. (1967)
			Vanikolo	0.8		
1968	JUL 25 1923	Kermadec 30.8°S 178.4°W MS 7.2	Fiji			Soloviev & Go (1975)
			Suva	0.1		
1973	JAN 31 0901	Mexico 18.5°N 103.0°W MS 7.5	Samoa			
			Pagopago	0.2		International Tsunami Information Center (ITIC)
1975	DEC 17 0902	Fiji 18.5°S 178.6°E MS 5.2	Fiji			
			Suva	0.25?	0.3	Everingham (1983b)
			Ono		0.5	
1975	DEC 27 0357	Tonga 16.2°S 172.5°W MS 7.8	Samoa			ITIC
			Pagopago	0.75		
			Apia	0.35		
			Fiji			
			Suva	0.08		
1976	JAN 15 0448	Kermadec 29°S 177.4°W MS 8.0	Fiji			ITIC
			Suva	0.22		
1976	AUG 02 2255	New Hebrides 20.6°S 169.3°E MS 6.9				ITIC
1977	APR 02 1915	Tonga 16.8°S 172.0°W MS 7.2	Samoa			ITIC
			Apia	0.07	0.5	
			Pagopago	0.15	0.65	
1977	JUN 23 0008	Tonga 22.9°S 175.7°W MS 7.8	Fiji			
			Suva	0.16	1.4	Tide gauge (Figure 3)
			Samoa			
			Pagopago	0.18	1.6	ITIC
			Tonga			Nothing of note (S.L. Tongilava – pers. comm.)
1977	OCT 10 2354	Kermadec 26.1°S 175.3°W MS 6.9	Fiji			ITIC
			Suva	0.02	2.2	
			Samoa			
			Pagopago	0.02	0.9	
1980	JUL 18 0742	Santa Cruz 12.3°S 166.5°E MS 6.4	Samoa			ITIC
			Apia	0.04		
1981	SEP 01 2129	Samoa 15.0°S 173.1°W MS 7.7	Samoa			
			Apia	0.12		ITIC

TABLE 2 TSUNAMIS RECORDED IN FIJI

YEAR	DATE TIME (LOCAL)	SOURCE AREA MAGNITUDE	LOCALITY AFFECTED	SHORE HEIGHT (m)	TRAVEL TIME (hr)	WAVE PERIOD (min)
1877	MAY 10 1259	Chile 21.5°S 71°W	Savusavu	2	18	
1881?	JUL 12 0530	N of Vanua Levu 16°S 179°E MS 6.5-7.0	N coast of Vanua Levu	1.8		
			Levuka	0.4		
1953	SEP 14 1227	SE Viti Levu 18.2°S 178.3°E MS 6.75	Suva	1.8	0.15	
			Makuluva	3.4		
			Beqa	1.4		
			Koro	1.4		
			Nakaseleka	4.3	0.2	
			Honolulu	0.1	7.3	16
			Pagopago	0.2		
1960	MAY 23 0711	Chile 41.0°S 73.5°W MS 8.4	Suva	0.5	13.3	60
1967	JAN 01 1015	New Hebrides 11.3°S 166°E	Suva	< 0.1		
1968	JUL 25 1923	Kermadec 30.8°S 178.4°W MS 7.2	Suva	0.1		
1975	DEC 17 0902	Kadavu Passage 18.5°S 178.6°E MS 5.2	Suva	0.2?	0.3	
			Ono	0.2?	0.5	
1975	DEC 27 0357	Tonga 16.2°S 172.5°W MS 7.8	Suva	0.08		
1976	JAN 15 0448	Kermadec 29°S 177.4°W MS 8.0	Suva	0.22		
1977	JUN 23 0008	Tonga 16.8°S 172.0°W MS 7.2	Suva	0.16	1.4	40
1977	OCT 10 2354	Kermadec 26.1°S 175.3°W MS 6.9	Suva	0.02	2.2	

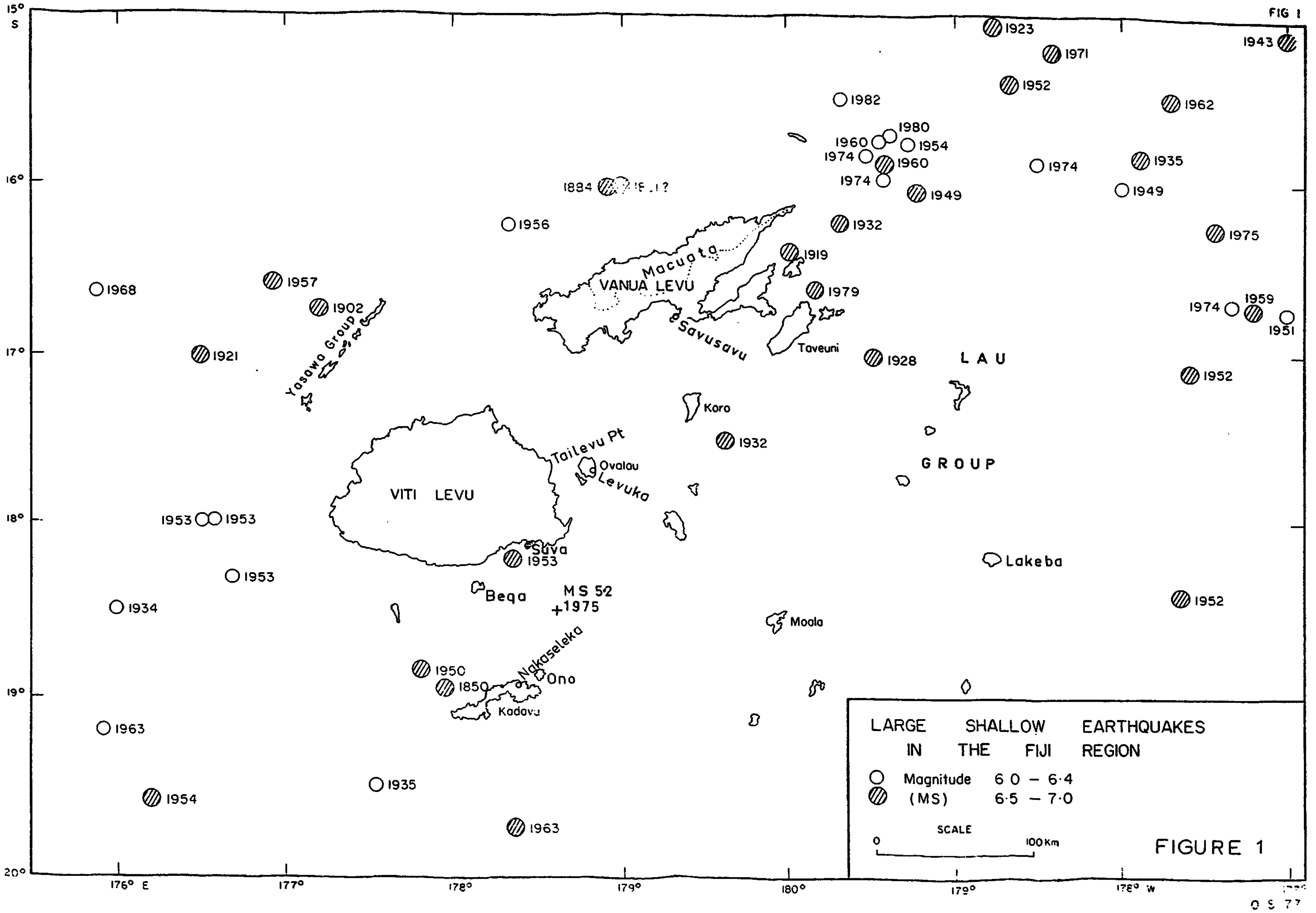
FIG 1
LARGE SHALLOW EARTHQUAKES IN THE FIJI REGION
Magnitude (MS) 6·0 – 6·4
6·5 – 7·0
SCALE
0
100 Km
VANUA LEVU
VITI LEVU
Macuata
Savusavu
Taveuni
Yasawa Group
Koro
Tailevu Pt
Ovalau
Levuka
Suva
Beqa
Nakaseleka
Ono
Kadavu
Moala
Lakeba
LAU
GROUP
MS 5·2
+1975
15° S
16°
17°
18°
19°
20°
176° E
177°
178°
179°
180°
179°
178° W
1923
1971
1943
1952
1982
1962
1980
1960
1954
1974
1960
1935
1974
1974
1949
1949
1884
1956
1932
1975
1919
1957
1979
1968
1902
1974
1959
1951
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1953
1934
1952
1950
1850
1963
1935
1954
1963
FIGURE 1

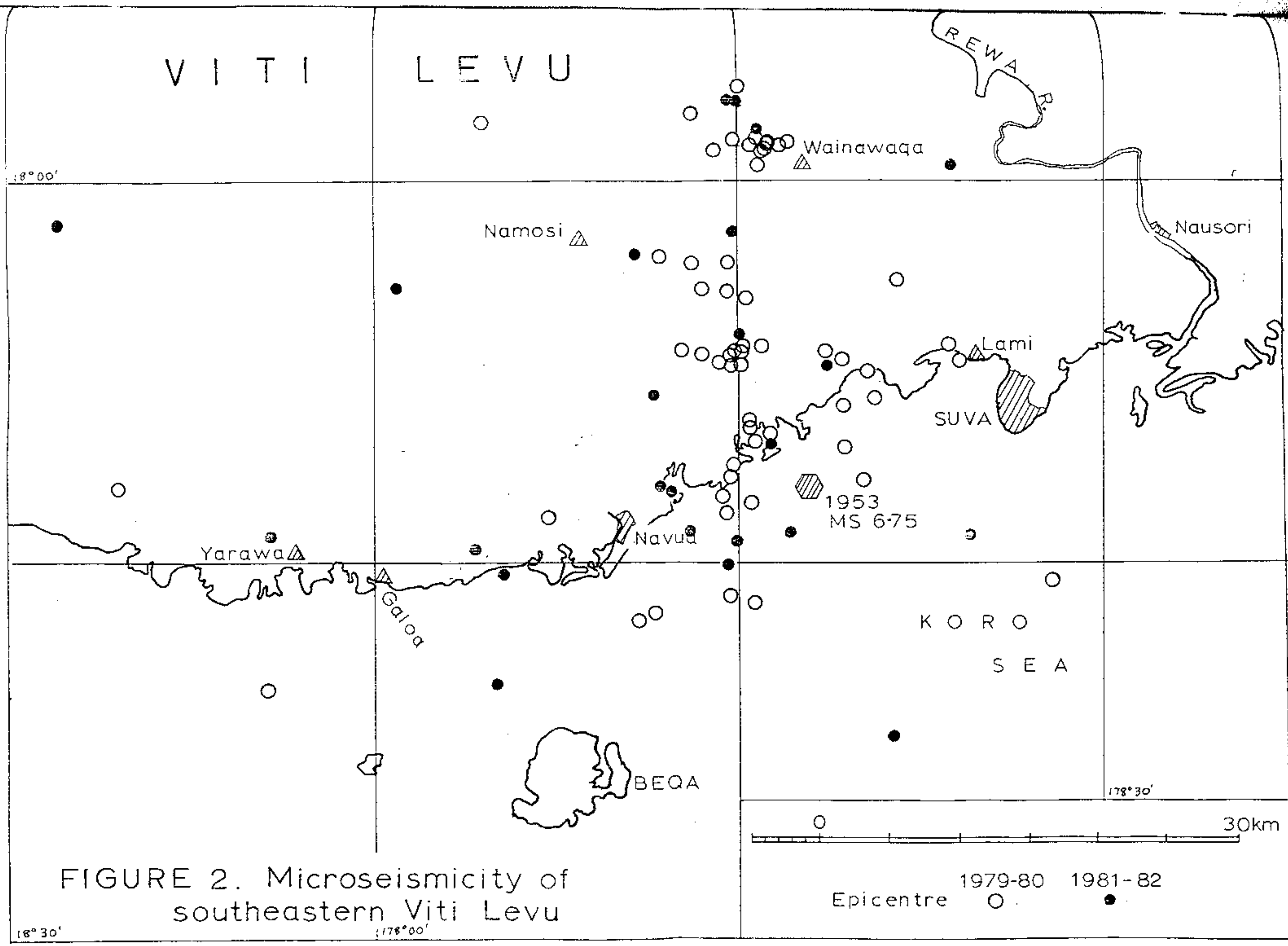


FIGURE 2. Microseismicity of southeastern Viti Levu

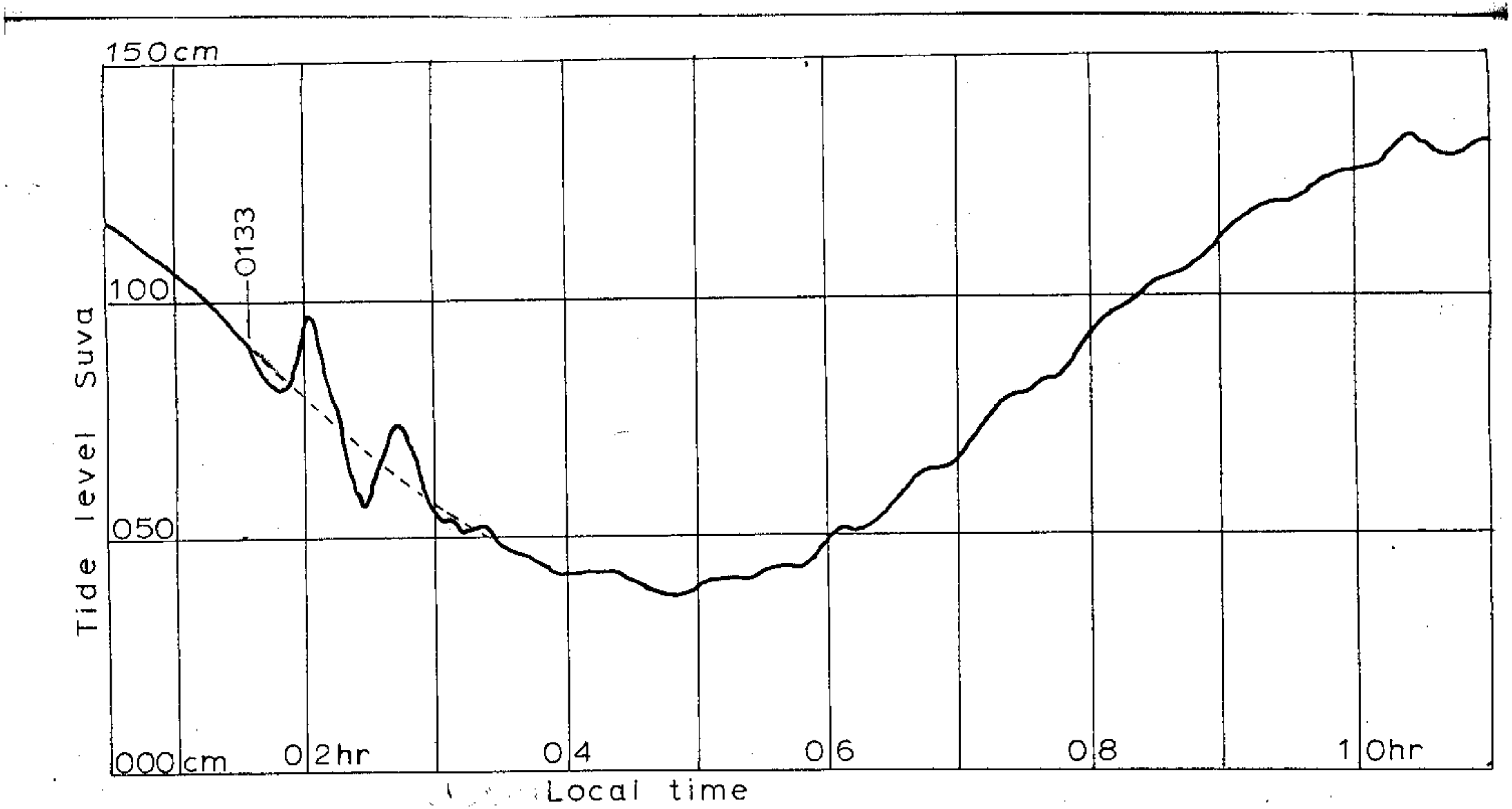


FIGURE 3. TIDE GAUGE RECORD 23 JUNE 1977

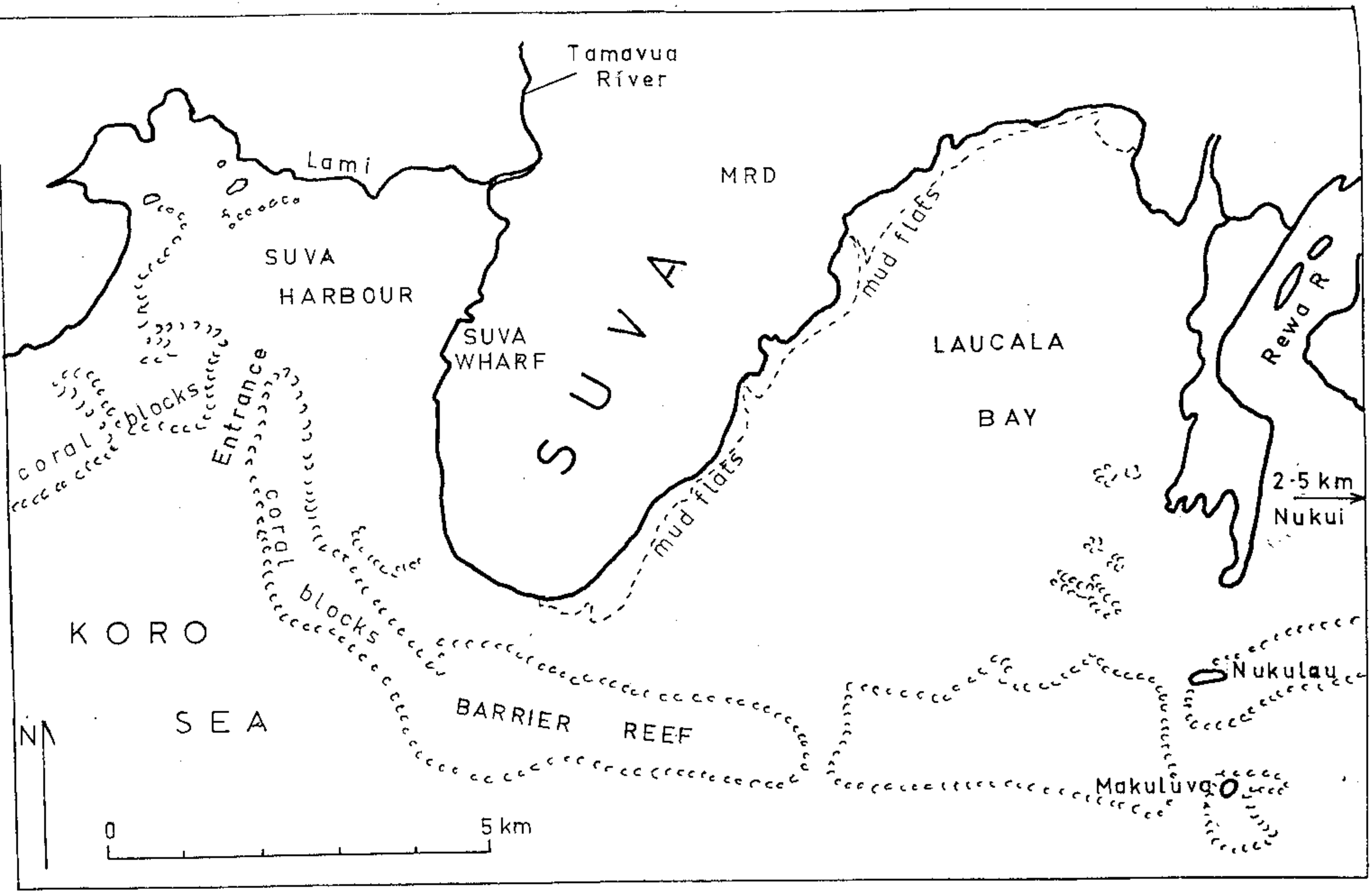
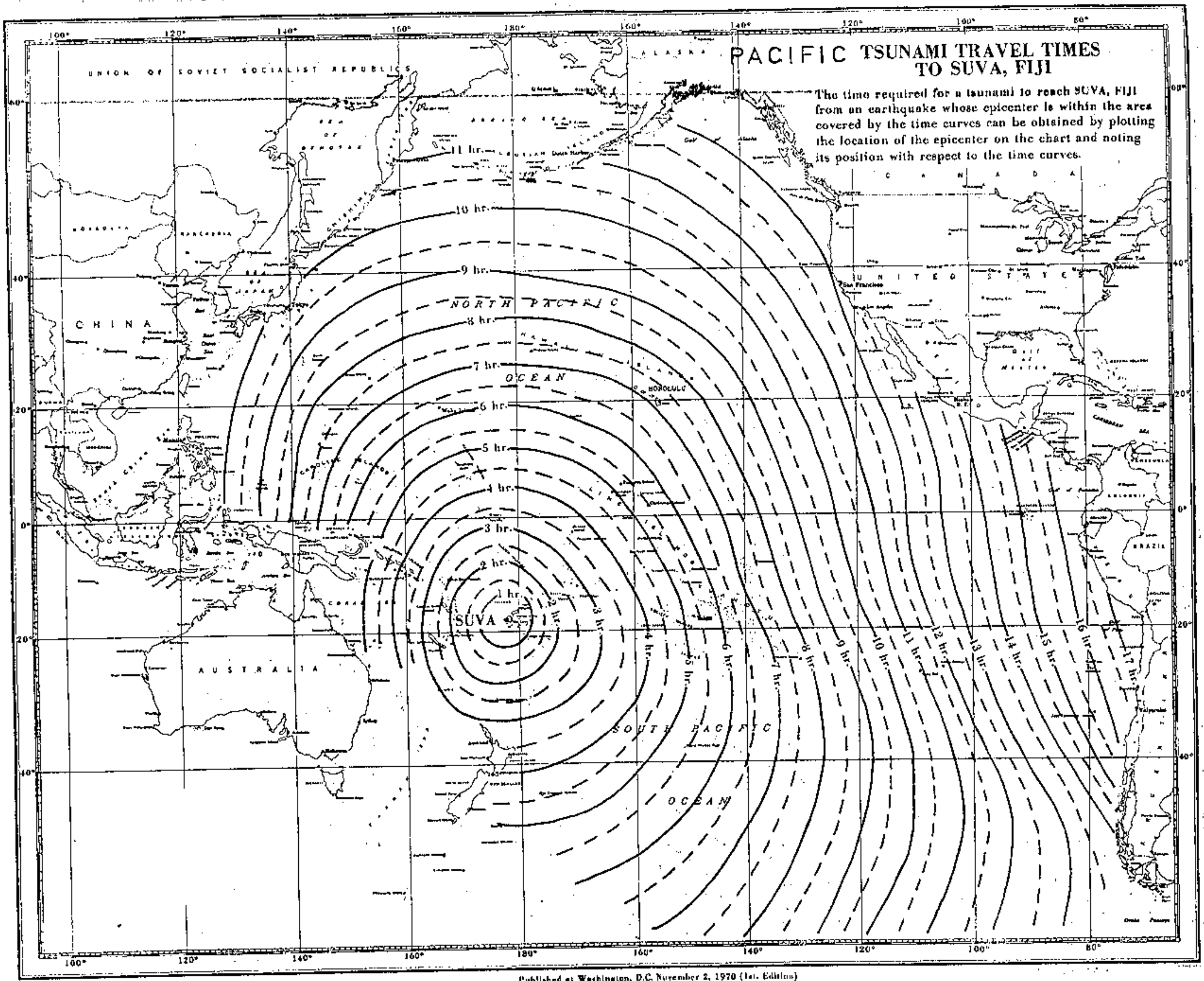


FIGURE 4. Locality map – Suva area



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Rear Admiral Don A. Jones, Acting Director

FIGURE 5.

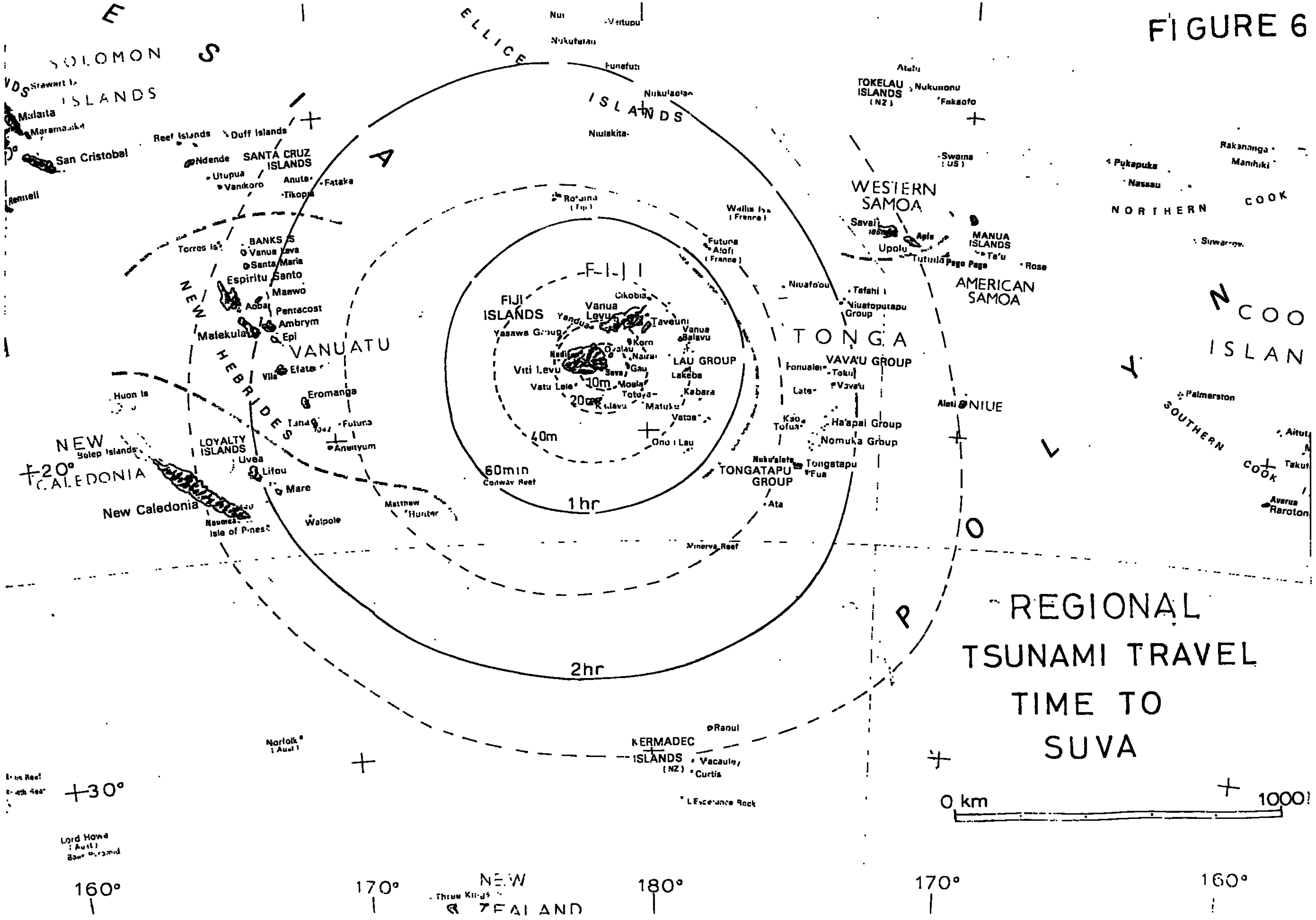

FIGURE 6

REGIONAL TSUNAMI TRAVEL TIME TO SUVA