ACADEMY OF SCIENCES OF THE USSR

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RESULTS OF RESEARCHES ON THE INTERNATIONAL GEOPHYSICAL PROJECTS

CATALOG OF TSUNAMIS IN THE PACIFIC 1969—1982

S. L. SOLOVIEV, CH.N GO, AND KH.S KIM

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**Translated from Russian by
Amerind Publishing Co. Pvt. Ltd., New Delhi (1988)**

МЕЖДУВЕДОМСТВЕННЫЙ ГЕОФИЗИЧЕСКИЙ КОМИТЕТ
РОССИЙСКОЙ АКАДЕМИИ НАУК

РЕЗУЛЬТАТЫ ИССЛЕДОВАНИЙ
ПО МЕЖДУНАРОДНЫМ ГЕОФИЗИЧЕСКИМ ПРОЕКТАМ

КАТАЛОГ ЦУНАМИ В ТИХОМ ОКЕАНЕ
I969 - I982

С.Л.СОЛОВЬЕВ, Ч.Н.ГО, Х.С.КИМ

МОСКВА I992

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PREFACE TO THE ENGLISH EDITION

The compilation of this catalog began in 1974-1976 and was completed in 1983-1984. Since its publication in Russian in 1986, new data on tsunamis and tsunamigenic earthquakes in the Pacific Ocean for the time period covered have become available. It is, of course, preferable to incorporate these new materials into the English edition of this catalog. Unfortunately, this goal is impractical due to the authors now being professionally separated and engaged in separate career pursuits.

Moreover, the majority of data used for the compilation of the catalog was originally written in English. It would be normal procedure to recompile the English sections of the catalog by direct access of these original sources rather than trusting a double translation (from English into Russian and then back from Russian into English), a process which risks altering the meaning of the text. Once again, the above mentioned reasons did not allow the authors to undertake such a recompilation.

Finally, the authors input into this English edition of the catalog was limited to a thorough review and editing of the available English translation. Their main efforts were aimed at preventing the distortion of the scientific meaning of the text. Restoration, in all cases, of the original spelling of the information was of secondary concern. The authors hope that the main task has been achieved.

On the other hand, there were many difficulties in restoring original geographic names mentioned in the catalog. It is impossible to affirm that this job has been done without occasional errors in generally unknown geographic names. A few misprints were found in the Russian original and these were corrected for the English version.

The authors express their enthusiasm for the publication of this English edition. Any catalog is a necessary tool that is potentially useful for many theoretical and practical purposes. The original Russian edition of this catalog could be used by probably no more than one hundred people. Hopefully, this English edition will be useful for a much larger number of people.

Before publishing this catalog in English, there were some doubts on the advisability of including Appendix 3 which contains data on tsunamis in the New Guinea/Solomon Islands area and which are additional to the data in the main catalog by Soloviev and Go (1974). The bulk of the data in Appendix 3 was taken from the catalog by Everingham (1977) and other publications by this scientist. The reproduction of these data after their double translation seemed unnecessary. The final decision to keep Appendix 3 was determined by the following considerations: 1) the original catalog by Everingham was issued in the form of a report and probably was of a limited number of copies and hence was not widely available; 2) a few additional entries taken from other sources were also included in this appendix. Nevertheless, anyone having questions regarding tsunamis in the above mentioned area is advised to refer to the works by Dr. Everingham.

This translation has been produced only due to the long-term efforts of the World Data Center A which has well known interests in the tsunami problem. At the last stage of the publishing process, the assistance of the Soviet Geophysical Committee has also been very important. The authors express their sincere thanks to all persons whose kind contributions have made possible the publication of this translation.

Prof. S.L. Soloviev
Moscow, 1991

WDC-A Contributors to the English Edition:

The following members of the World Data Center-A contributed to the work of translating and preparing the manuscript for publication:

Herbert Meyers, as Director of WDC-A for Solid Earth Geophysics actively encouraged the original translation and the subsequent efforts to see it published and made available to English reading scientists worldwide. He has generously given of his and his staff's time to realize this endeavor.

James F. Lander, formerly Director of WDC-A for Solid Earth Geophysics remains associated with it through the University of Colorado. He encouraged the original translation of the catalog into English so that it would be available to him and Patricia Lockridge as a resource for their *United States Tsunamis* study. Once this purpose was achieved he worked to have this English translation published. This required entering the text into a word processing/desktop publishing system for incorporation of the author's comments, further editing, and preparation of camera-ready copy. Mr. Lander coordinated this overall WDC-A effort and reviewed the entire text to assure that the author's meaning was not altered in transcription.

Craig A. Clark edited the entire text. He designed the layout and physical appearance of the publication, arranging tables, charts, illustrations, bibliography, and appendices as they appear here. Using a desktop publishing system, he produced the camera-ready copy.

Sandy Furney transcribed most of the original English translation including the tables and appendices and made the author's corrections. Patricia Lockridge and Jean L'Heureux prepared figures with English names annotated. Joy Ikelman reviewed the final draft for textual accuracy and provided technical advice for the layout and the preparation of camera copy.

ABSTRACT

All available information on 85 tsunamis observed in the Pacific Ocean during the period 1969-1982 has been collected and systematically arranged in this book. Maps of sources and copies of tide gauge records of tsunamis are presented and the wave intensities determined. A list has been prepared showing the main parameters of the earthquakes and the intensities of the tsunamis. This list and the other auxiliary data are included in the appendix to the catalog.

This work was conducted under the International Cooperation on Problem of Tsunami and was coordinated by the International Tsunami Information Center and the Working Group on Tsunami Warning Services in the Pacific, created by the Intergovernmental Oceanographic Commission and UNESCO.

Editor-in-Chief
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CONTENTS

INTRODUCTION

The development and perfection of protective measures against tsunamis (destructive waves produced by underwater earthquakes that play havoc on the Pacific Coast) is not possible without the collection and systemization of factual data on tsunamis.

A detailed catalog of tsunamis in the Pacific Ocean, exclusive of the USSR, was published many years ago, covering a period from antiquity to 1968 inclusively [Soloviev and Go, 1974, 1975, 1977, and 1978]. The main data on tsunamis on the Pacific Coast of the USSR are contained in the work of Soloviev (1978a).

In the present catalog we have included data on tsunamis in the Pacific Ocean from 1969-1982. Moreover, we have also included the Indian Ocean coast of Indonesia in order to completely describe the Indonesian seismogenic and tsunamigenic zones.

The material is presented in chronological order which distinguishes this catalog from the earlier ones. For each event, we first give the date (according to local time), followed by a characterization of the earthquake or volcanic eruption, and a description of the tsunami and its parameters as recorded by the instruments. Given last are the earthquake data and the intensity of the tsunami evaluated on the Imamura-Iida-Soloviev scale [Soloviev, 1972; Soloviev, 1978a].

For local time we use the notation hr, min, sec and for universal (Greenwich) time h,m,s. The surface effect of earthquakes measured on 12-point scales [MSK-64, GOST 6294-52, Mercalli-Cancani-Sieberg, modified Mercalli (MM)] is given in Arabic numerals. The effect as measured on the Rossi-Forel scale and by the Japan Meteorological Agency (JMA) is given in Roman numerals.

The height of a tsunami is understood to be the difference between the highest and lowest water levels for the oscillation; the amplitude is arbitrarily understood to be half of that height. Other definitions can be found in the forwards to the catalogs [Soloviev and Go, 1974, 1975].

In the appendix section of this book is a listing of the main parameters of earthquakes and tsunamis, an index of locations where tsunamis were observed, and maps indicating these locations and other geographic points mentioned in the text. A separate appendix contains a supplement to the previous catalog [Soloviev and Go, 1974] of tsunami data for the islands of New Guinea, New Britain, New Ireland, and the Solomon Islands up to 1969.

In all, the catalog contains data on 85 tsunamis, of which 78 are of seismic origin. Figure 1 (see enclosure) shows the locations and the intensities of the tsunamis. The number of seismogenic tsunamis for each half step of intensity are distributed as follows:

Intensity	3	2½	2	1½	1	½	0
Number of cases	3	2	4	1	6	7	22

Intensity	-½	-1	-1½	-2	-2½	-3	-4
Number of cases	2	6	6	6	3	9	1

Weak tsunamis with intensities of I ≤ 0 are not all listed in this catalog. This is because of the imperfect system of tsunami observation and the voluntary publication of these data.

Listed by the seismogenic and tsunamigenic zones identified in the earlier catalogs, tsunamis which occurred during 1969-1982 are distributed as follows:

Region	Number of tsunamis
Alaska and Aleutian Islands	2
Kamchatka and Kuril Islands	14
Bering, Okhotsk and Japan Seas	6
Japan	11
Bonin and Mariana Islands	2
Ryukyu Islands and Taiwan	2
Philippines	8
Indonesia	4
New Guinea, New Britain, New Ireland	7
Bismarck Archipelago	1
Solomon Islands	7
New Hebrides Islands	0
Tonga and Kermadock Island	7
New Zealand	0
Antarctica	1
Chile-Peru	5
Central America	2
USA and Canada	0
Hawaii	1

The Aleutian, Alaskan, Ryukyu-Taiwan, and New Hebrides zones can be considered to have an anomalously low number of tsunamis. In the latter two zones, as well as the Indonesia zone, it is quite possible that even I ≥ 0 tsunamis are not represented here due to the imperfect system of obtaining, collecting, and publishing information on waves.

The Kuril Islands, Hokkaido, Philippines, New Ireland, and the Solomon Islands zones are among those with higher numbers of tsunamis for this period.

The following tsunamis during the 1969-1982 period resulted in human deaths and considerable material loss: Hawaii (Kalapana), November 29, 1975; Philippines, August 17, 1976; Indonesia, August 19, 1977; Colombia, December 12, 1979. At the same time, it must be noted that tsunamis with limiting intensity I = 4 for the period under review in the Pacific Ocean, fortunately did not occur. However, such catastrophes are inevitable in the future, in view of which the need to investigate these waves does not decrease at all.

A tentative list of tsunamis in the Pacific Ocean after 1968 was compiled by S.L. Soloviev during his tenure with the Sakhalin Complex Scientific Research Institute of the Academy of Sciences of the USSR [Soloviev, 1982]. Major work on the compilation of the catalog was later completed at the same institute (now the Institute of Marine Geology and Geophysics of the Academy of Sciences of the USSR) by Chan Nam Go, and Khen Sen Kim with participation from and under the guidance of S.L. Soloviev (now at the P.P. Shirshov Institute of Oceanology, Academy of Sciences of the USSR, Moscow). In finalizing the manuscript, considerable help was rendered by E.A. Tikhonova. All illustrations included in this catalog were prepared by Ri Rey Ko. The authors express their deep gratitude for this cooperation. The authors also express their gratitude to Drs. A.I. Ivashchenko and A.A. Poplavskii, heads of departments who offered great help and cooperation in the execution of this work, and to Profs. S.S. Voit and A.A. Nikonov who read the manuscript carefully and made valuable comments and counsel.

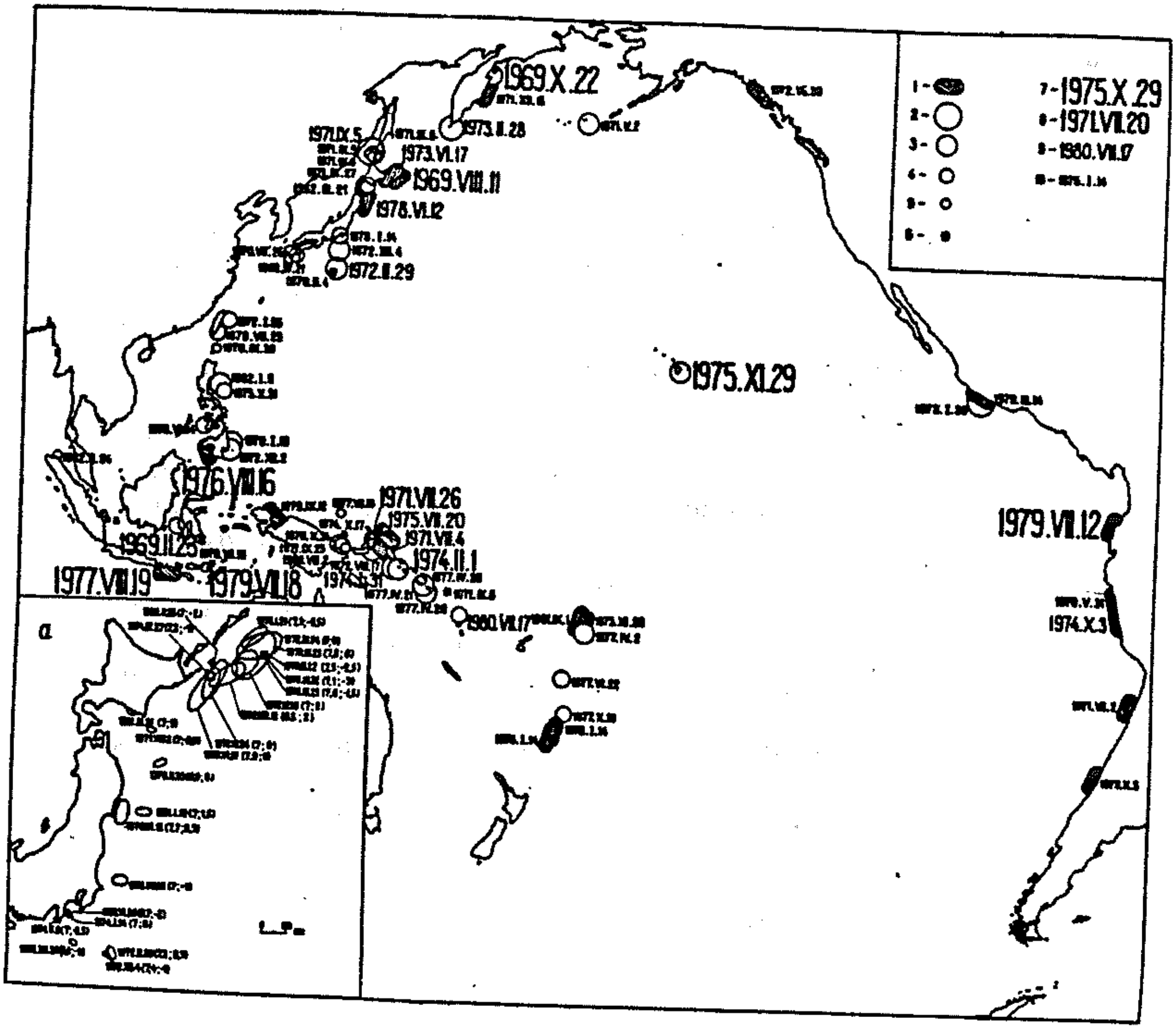


Figure 1: Schematic map of tsunami sources in the Pacific Ocean during 1969-1982

Key to tsunami sources of seismic origin: 1. M≥ 8; 2. 8>M ≥ 7.5; 3. 7.5 >M≥7; 4. 7 > M ≥6.5; 5. M <6.5; 6. Tsunami sources of volcanic origin; Intensity of tsunami: 7. I = 2½-3; 8. I = 1½-2; 9. I = ½-1; 10. I ≤ 0;

Figure 1a (inset): Map of tsunami sources in the southern part of the Kuril Islands and the northeastern part of Japan. Figures in parentheses denote the magnitude (M) of the earthquake and the intensity (I) of the tsunami respectively.

February 23, 1969, 8 hr 56 min. An earthquake occurred on Sulawesi (Celebes), Indonesia. A strong shock was felt in Madjene. Foundations of 80% of the brick buildings were damaged severely and some of them were destroyed completely. Gaping cracks 50 m long caused damage to one brick building. Three brick buildings were damaged severely. Destruction in the center of the bazaar led to one unfortunate event. The quay in the harbor showed cracks at several places. On the outer side of the harbor the bottom may have subsided. The thickly populated areas of Jtampalagian and Wonomoeljo suffered; these areas are situated on alluvial ground and lie 30 and 50 km respectively east of Madjene. In most cases wooden houses were not affected by the earthquake and greater destruction was caused by damage to nonreinforced walls. Mausoleums were damaged because these old brick structures were built without reinforcement. Several bridges in the valley were destroyed.

The earthquake produced a tsunami and waves descended upon the coastal villages north of Madjene. Their height was 4 m in Paletoang and 1.5 m in Parosanga and Palipi. There were mainly wooden structures in these villages; houses along the bay were washed by tsunami waves. The banana plantations in the coastal area were damaged. Large blocks of Neogene calcareous clays and tuffs were thrown on the road at several places between the villages of Somba and Parasanga. The coral reef edges projecting above water were destroyed to some extent and thrown on the coast. According to an eyewitness account a roar was heard from the seaside. [NL, Vol. 2, Nos. 2, 3, 1969; SN, Vol. 59, No. 4, 1969; SI, Nos. 425, 455, 504, and 505; Von Hake and Cloud, 1971; Soloviev, 1982].

[February 23; 00 h 36 m 56.6 s; 3.1° S. Lat., 118.9° E. Long.; 13 km; M = 7.4; I = 2].

April 21, 1969, 16 hr 19 min. An earthquake occurred in the Huga-Nada region of Japan and was accompanied by a tsunami. Tsunami records obtained from tide gauge stations are shown in Figure 2 and the parameters obtained from these records are given in Table 1.

Tsunami onsets are indecipherable in the records of the Tosashimizu and Hososhima stations while tsunami-like oscillations are observable in the records of the Muroto and Kamae stations. The tsunami onset is clearly identifiable, beginning with the drop in tide level as recorded by the Muroto station, 42 minutes after the earthquake. Figure 3 shows the contour of the tsunami source, obtained from the travel time of the wave front. ["Earthquakes and tsunamis...", 1970; Hatori, 1971a; Tokunaga and Katsumata, 1971; Soloviev, 1982; Watanabe, 1983].

[April 21; 07 h 19 m 27.5 s; 39.2° N. Lat., 131.9° E. Long., 41 km; M = 7.0; I = -3].

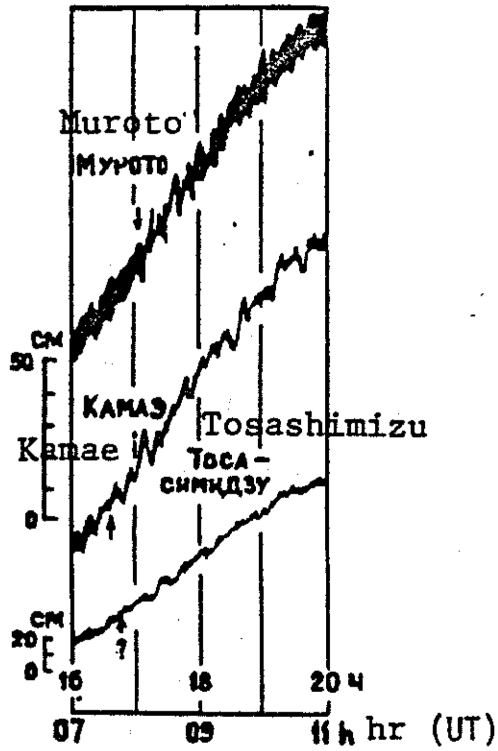


Figure 2: Records of tsunami of April 21, 1969.
The proposed onsets of tsunamis are shown by arrows.

Table 1: Tide gauge data on tsunami of April 21, 1969

Place	Travel time (min)	Initial wave Amplitude (cm)	Period (min)	Height of the maximum wave (cm)
Odomari	-	-	12	-
Aburatsu	-	-	10	-
Hosojima	-	-	-	?
Kamae	18	5	15	15
Yawatahama	-	-	-	10
Tosashimizu	27(?)	5	-	10
Muroto	42	6	12	20

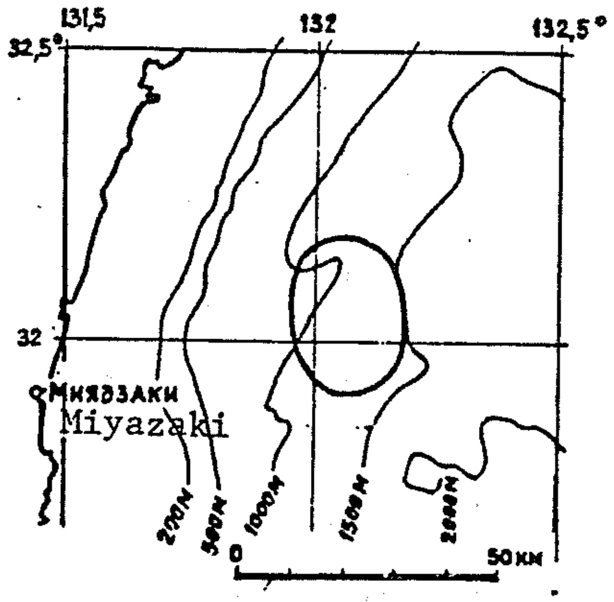


Figure 3: Tsunami source of April 21, 1969.
(Hatori, 1971a).

August 2, 1969. New Guinea. Several shocks were felt in Lae in the later part of the day. Small tidal waves were produced by crust shifting along the Lae coast. [Everingham, 1973, 1976, 1977; Soloviev, 1982].

[6.6° S. Lat., 146.9° E. Long., 17 km; M = 5.4; I = -1].

August 12, 1969, 8 hr 27 min. An earthquake occurred 90 km southeast of Shikotan Island with a magnitude of M = 8.2. The maximum intensity of the earthquake, observed on Shikotan Island, was 7½ points.

The earthquake began with initially weak shocks which quickly increased to maximum intensity. Noticeable shocks continued for two to three minutes. The earthquake was preceded by a powerful low rumble which was clearly heard on the islands of the Malyi Kuril Ridge, Kunashir, and Iturup, 200 km from the epicenter.

The earthquake was felt as far as 1,000 km to the south in Tokyo (Honshu), 525 km to the northwest in Listvinichnoe (Sakhalin), and 650 km to the northeast in the Matua Island. Figure 4 shows the scheme of the surface effect of this earthquake.

The earthquake caused a tsunami which was visually observed on Kuril (Table 2) and was recorded by tide gauge instruments on the Kuril, Sakhalin, Hokkaido, Honshu, Wake Atoll, and the Hawaiian Islands [Table 3 and Figure 5].

The maximum tsunami height (5 m) was recorded by the echo sounder from a medium-size fishing trawler No. 84-33 (Captain N.A. Kukushkin) in Tserkovnaya Bay on the ocean side of Shikotan Island. In the neighboring Dimitrova Bay, the vertical record of waves apparently reached 3-4 m (estimate based on marine algae, driftwood, and fragments of boxes and barrels which were thrown onto land). In other places the height of the tsunami rarely exceeded 1-1.5 m. According to the reported visual observations on islands of the Malyi Kuril Ridge, the tsunami began with a gradual lowering of the ocean level which was followed by an intense rise. Bores were not observed. The number of waves observed at different points varied from three to six. The maximum number was recorded at Burevestnik (Iturup Island). The wave periods varied from six to thirty minutes. The first wave was the largest everywhere.

The tide gauge records show the first wave as a rise in water level except at Yuzhno-Kuril'sk where a fall was recorded first. The maximum heights of waves recorded by tide gauges were noticed in Yuzhno-Kuril'sk (Kunashir Island) and Burevestnik (Iturup Island) (Figure 5).

The tsunami appeared at the low tide and did not damage the island's coastlines. Thanks to the early warnings, measures were taken to ensure the safety of the population of coastal regions and of the fleet. [NL, 1969, Vol. 11, No. 4; SI Nos. 716-719; 721, 725; Hatori, 1970, 1971b, 1974a, 1974b, 1976b, 1979, 1982b; SN, 1970, Vol. 60, No. 1; Von Hake and Cloud, 1971; Leonov et al., 1972, 1973; Amano, 1974; Soloviev, 1978a, 1982; Watanabe, 1983].

[August 11; 21 h 26 m 36 s; 43.6° N. Lat., 147.9° E. Long.; 30 km; M = 8.2; I = 2].

Table 2: Data on visual observation of the tsunami of August 12, 1969.

Place	Maximal rise of water (m)	Period (min)	Remarks
Iturup Island			
Sentyabr'skii	1.5	20	
Burevestnik	1-2	25	Began with an ebb. The ocean level fell by 2.5-3 m
Villages on the western coast	(up to 1)	-	-
Kunashir Island			
Tyatino	-	-	Water receded by 150 m
Otradnoe	1.2	-	Water penetrated 250 m inland

Shikotan Island			
Malokuril'skoe	1	20	Water receded by 150 m
Krabozavodsk	1	30	
Tserkovnaya Bay	5	-	Height of tsunami determined by ship's echo sounder
Dimitrova Bay	4	-	-
Polonskogo Island	1.5	30	Water receded by 200 m
Yurii Island	1	10-20	-
Zelenyi Island	2	-	Water receded by 200 m
Tanfil'eva Island	1	20	-

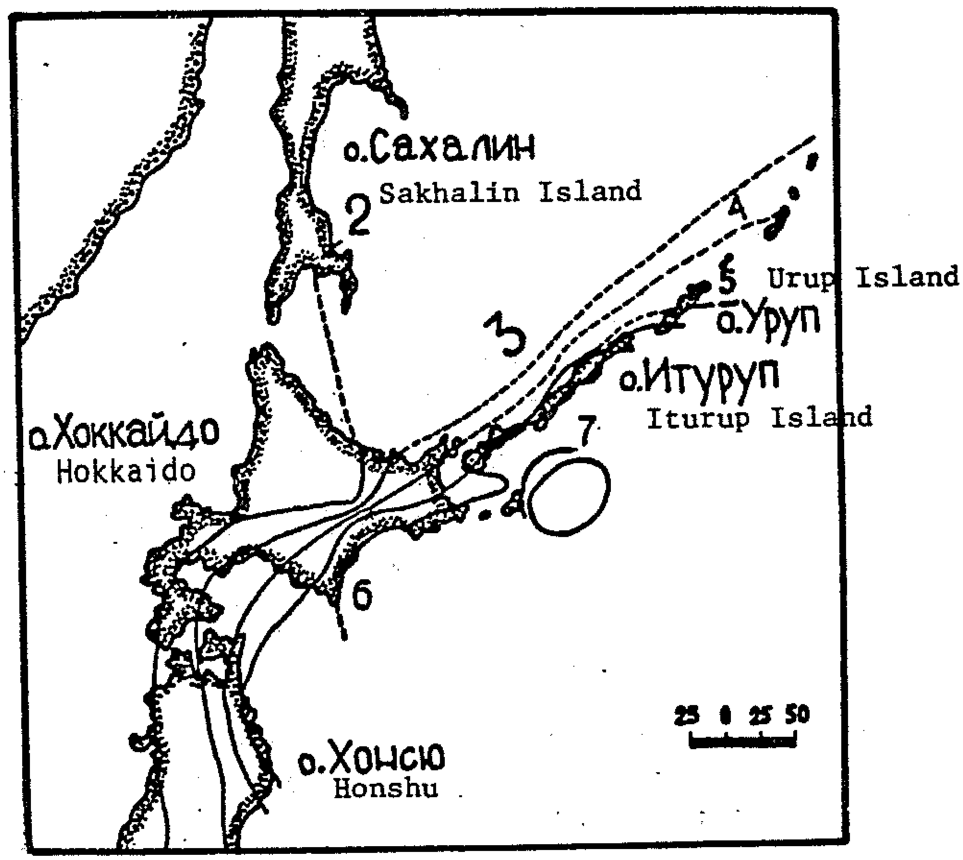


Figure 4: Surface effect of the earthquake (measured on a 12-point scale) and tsunami source of August 12, 1969. ["Strong earthquakes...", 1972].

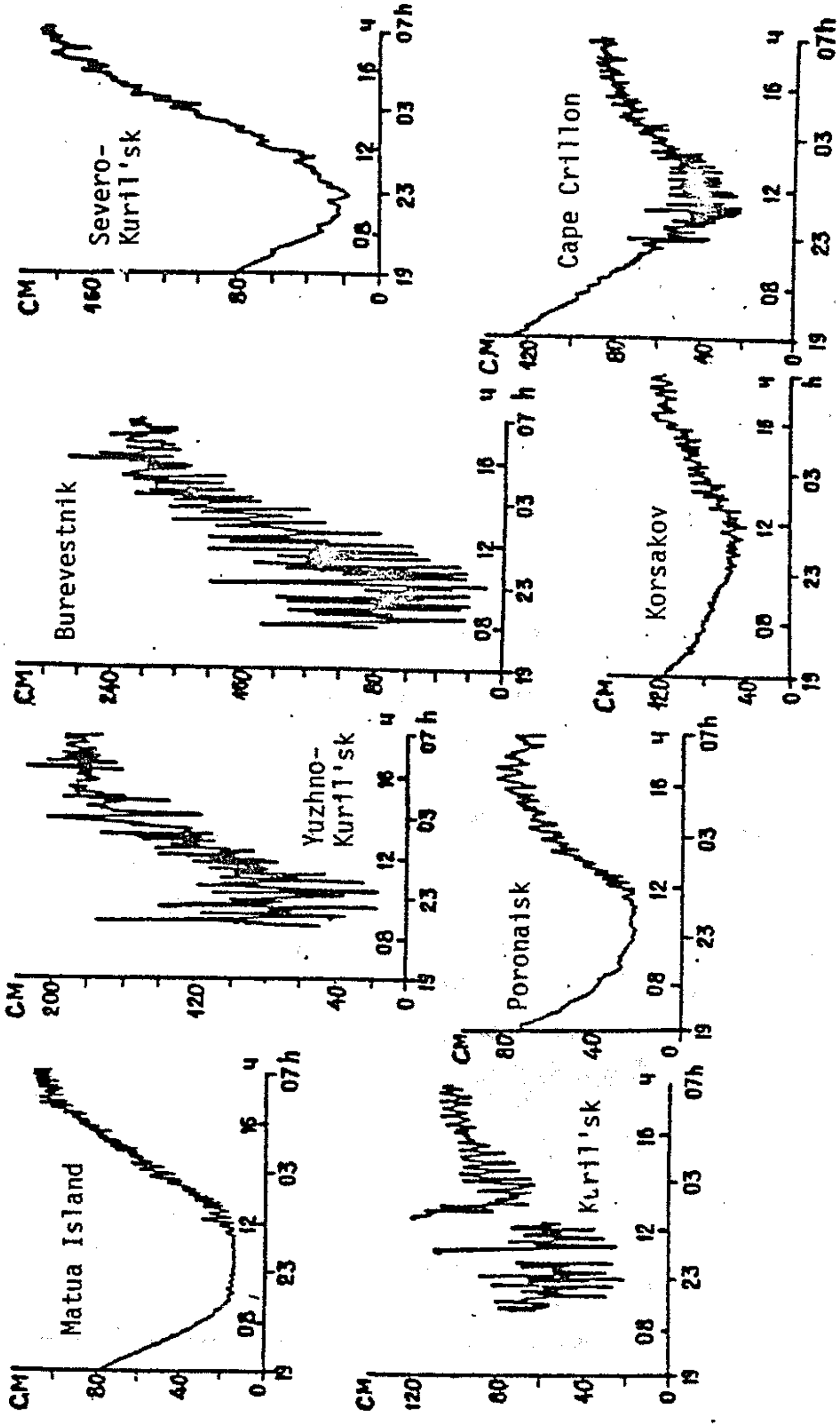
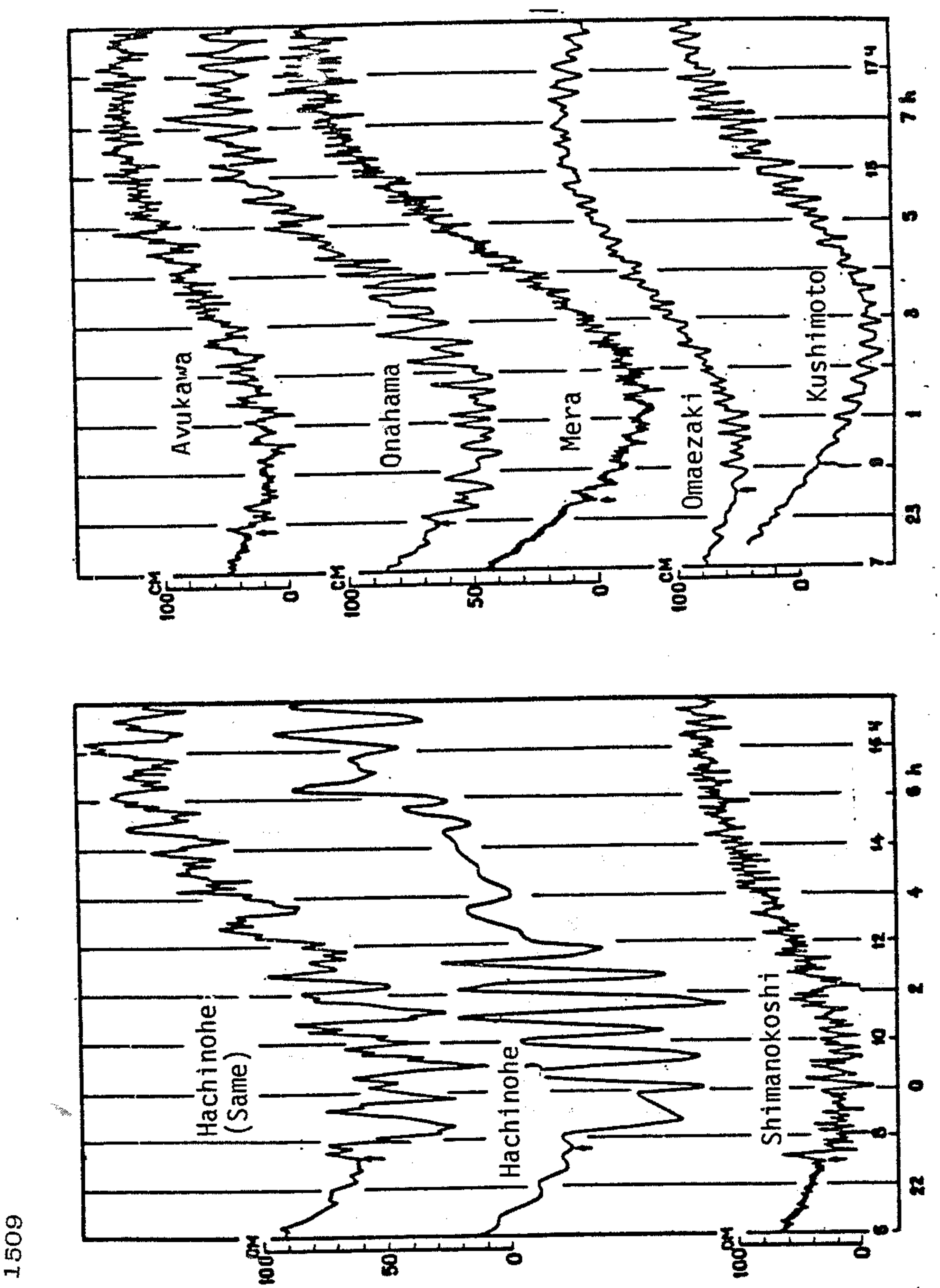


Figure 5 (pages 10-13): Records of the tsunami of August 12, 1969 by tide gauges on the coast of the USSR and Japan.
[Shikotan Earthquake..., 1973]



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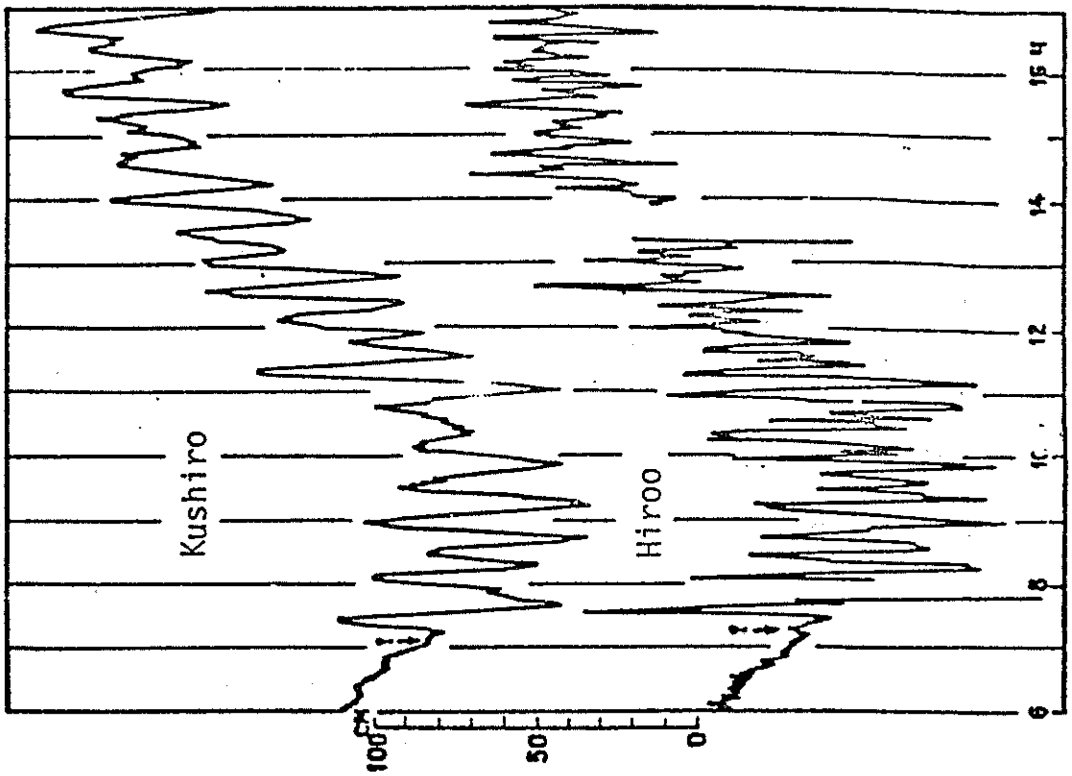

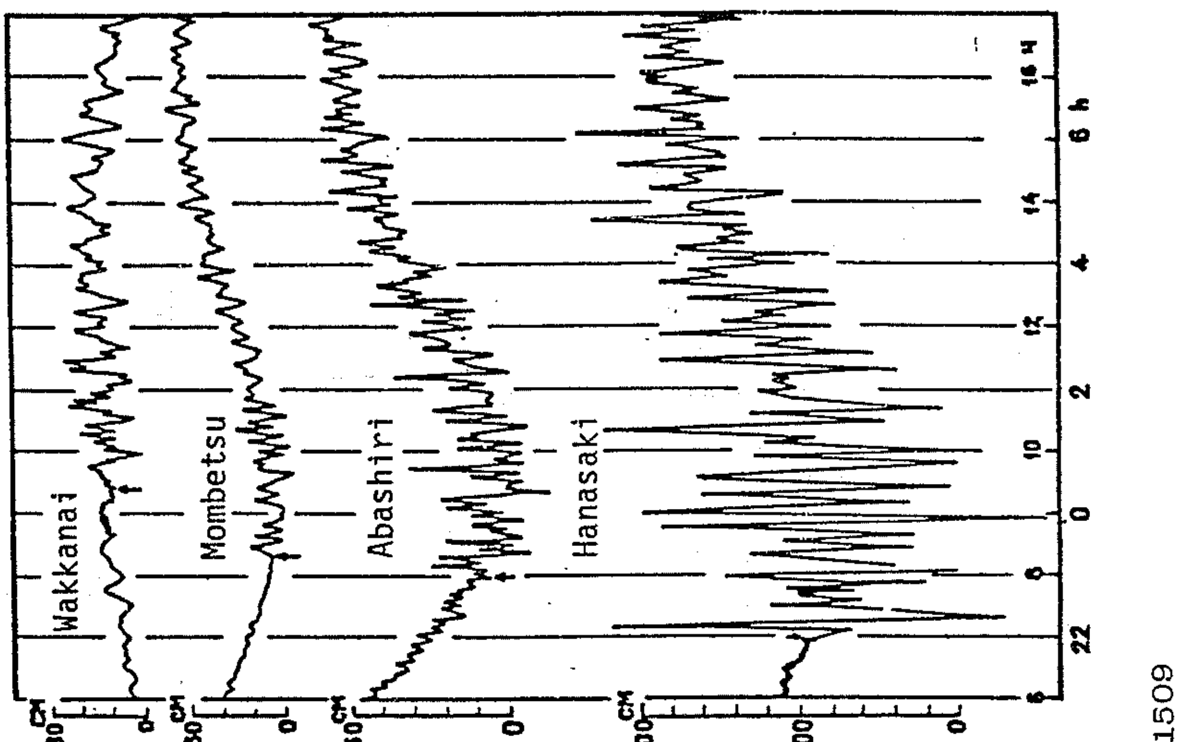

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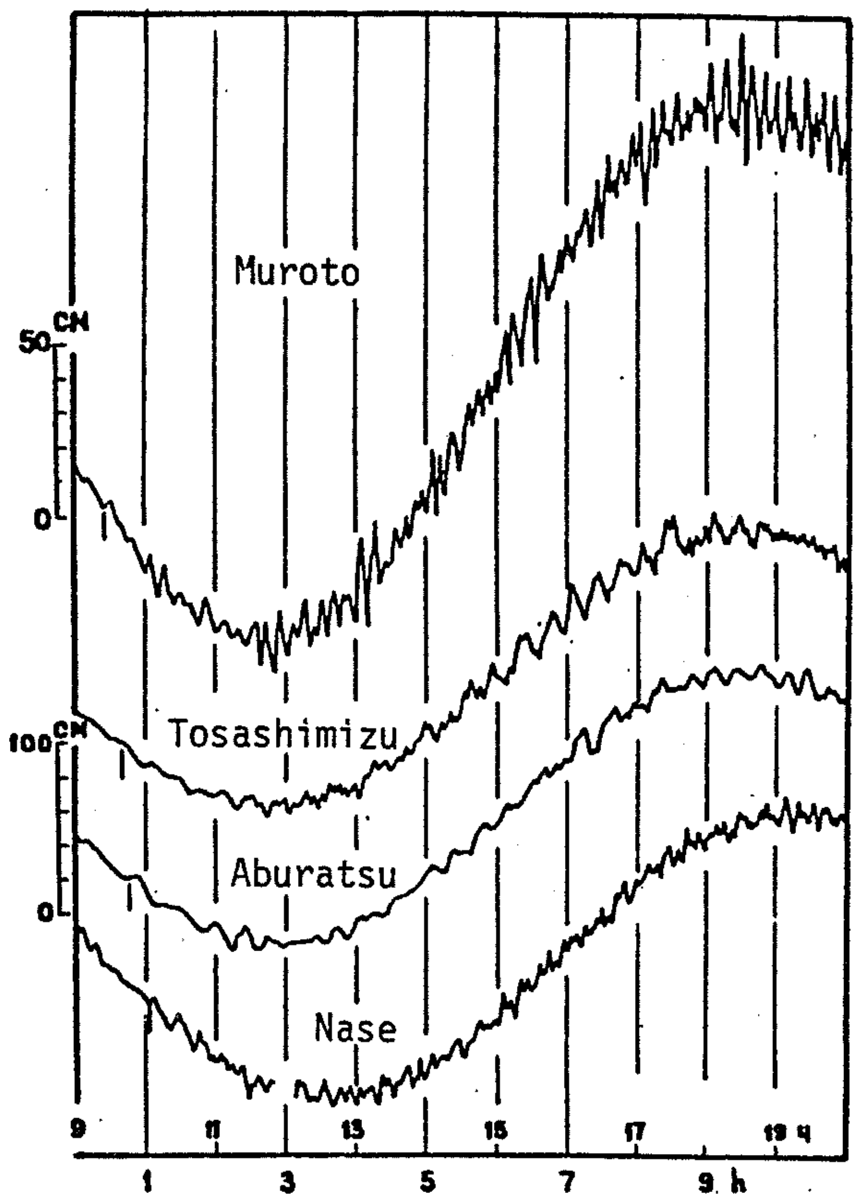

Figure 5 (continued)

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Table 3: Tide gauge data on the tsunami of August 12, 1969

Place	First wave: Travel time (hr min)	First wave: Amplitude (cm)	First wave: Period (min)	Amplitude of the maximum wave (cm)
Severo Kuril'sk	01 50	+ 8	35	20
Matua	01 45	+ 3	10-15	13
Kuril'sk	01 15	+20	10	60
Burevestnik	00 30	+72	25	103
Yuzhno-Kuril'sk	00 55	-23	25	105
Poronaisk	04 00 ?	+ 5	15	12
Korsakov	02 20	+ 6	15	26
Cape Crillon	02 15	+11	5	27
Wakkanai	02 56	+ 6	30	13
Mombetsu	01 52	+16	12	17
Abashiri	01 30	+16	24	26
Hanasaki	00 32	-22	12	150
Kushiro	00 38 ?	- 3	40	47
Hiroo	00 50 ?	- 4	30	78
Urakawa	01 00	+15	20	62
Tomakomai	01 25	+10	65	20
Muroran	01 30	+ 6	62	12
Hakodate	01 42	+ 8	30	23
Hachinohe	01 16	+15	52	66
Shimanokoshi	01 00	+35	10	38
Miyako	01 04	+27	26	29
Kamaishi	01 07	+16	30	1[illegible]
Ofunato	01 11	+34	36	34
Kesennuma	01 17	+33	42	44
Enoshima	01 10	+13	60	-
Onagawa	01 26	+31	32	31
Ayukawa	01 24	+18	28	40
Matsukawaura	?	-	-	14
Onahama	01 37	+10	22	26
Hitachi	01 39	+16	42	25
Choshi	01 34	+22	32	22
Mera	01 55	+ 8	18	27

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Kozu Jima	01 52 ?	+ 2	-	6
Miyaki Island	?	-	-	10
Minamiizu	01 56	+ 4	20	10
Omaezaki	02 06	+ 6	22	13
Owase	02 44	+ 6	14	17
Uragami	02 40	+ 6	23	15
Kushimoto	02 34	+ 5	28	30
Muroto	02 58	+ 5	36	21
Katsurahama	?	-	-	8
Tosashimizu	03 12 ?	+ 4	36	16
Kamae	03 48	+ 7	20	12
Aburatsu	03 19	+ 7	34	12
Nishinoomote	-	-	-	2
Nase	03 34	+ 6	22	10
Midway	-	-	-	25
Kauai	-	-	-	-
Nawiliwili	-	-	-	20
Maui	-	-	-	-
Kahului	-	-	-	22
Wake Island	-	-	-	12

November 23, 1969. In the Ozernoy Gulf region of the western Bering Sea off of the northeastern coast of Kamchatka, an earthquake occurred at a magnitude M = 7.7, producing shocks of 8 point intensity at nearby places on the coast (Figure 6). It produced tsunami waves up to 10-15 m high. The source region, determined by the size of the compact cluster of aftershocks in the first days after the main shock, was 100 km x 40 km. This was the strongest earthquake in Kamchatka since May 4 (May 5, GMT), 1959 when an earthquake occurred at a magnitude M = 7 3/4 - 8 in the Shipunskii Peninsula area. Due to the sparsely populated coast, data on the tsunamis generated by this earthquake are available from only a few points (Figure 6).

At the mouth of the Ol'khovaya River, 15-20 minutes after the earthquake, the approach of two 10 m high waves was noticed. The directions of the wave fronts varied somewhat; most likely it was a single wave with a curved front. At the Hydrometeorological Service building at the river mouth, the wave rose to about 12-15 m. Twenty minutes later, another wave, 3-5 m high, was noticed. The first wave ripped the cedar bushes and the wall of the wooden bath was broken. The wave passed 500 m up the river throwing a boat with barrels of fuel over the breaker belt at the mouth of the river. Broken river ice about 20 cm thick was scattered on the river terrace for a distance of 300 m.

On the coastal area between Cape Ozernoy and the mouth of the Ol'khovaya River, after the tsunami, seaweeds were scattered about 50-70 m from the breaker belt and to a height of 8 m At Cape Ozernoy, the height of the debris line was lower at about 5 m. The fuel barrels were swept away. At the mouth of the Ozernaya River, about twenty minutes after the earthquake, the bank was submerged to a depth of 5-7 m. Along the coastal area of the Ozernoy Gulf, from Cape Ozernoy southward to where the coastline turns east, remnants of seaweed could be seen from the air.

Between the village of Khailyulya and Ivashka in the Karaginskiy Bay, the coast was submerged to a depth of 5-7 m and a width of 20 m. The wave was not observed.

In the village of Nikol'skoe on Bering Island, three waves attained heights of 1.5-2.5 m. A resident, N.A. Emel'yanov, who was passing along the breaker belt, was carried by the first wave into the ocean, 100-150 m away from the coast. The second wave passed over the dry belt, inundating it again and carrying the resident back (reported by N.A. Shchetnikov). The waves submerged up to 25 m of the coastal belt.

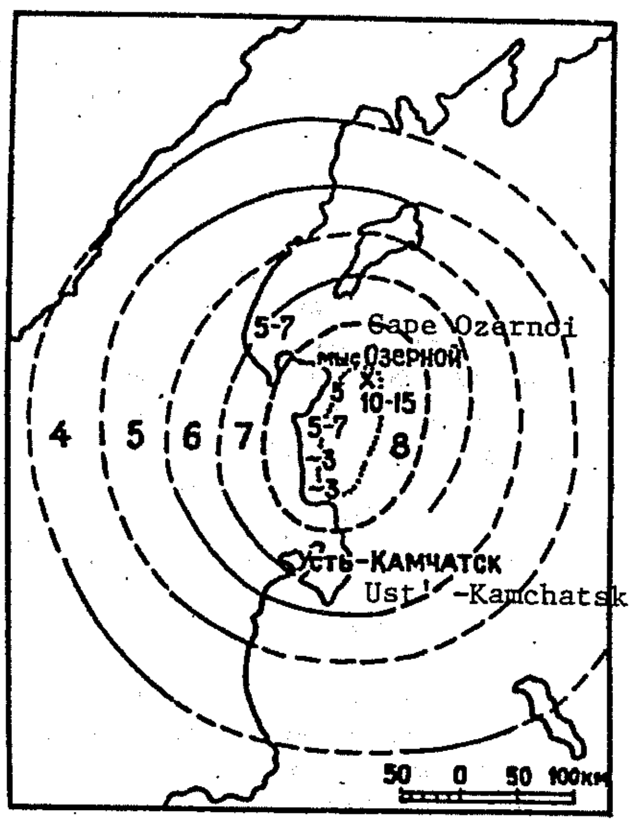

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Figure 6: Surface effect of the earthquake and the source of the tsunami of November 22, 1969.
(Numerals indicate the height of tsunami waves in m.)
[Fedotov et al., 1973]

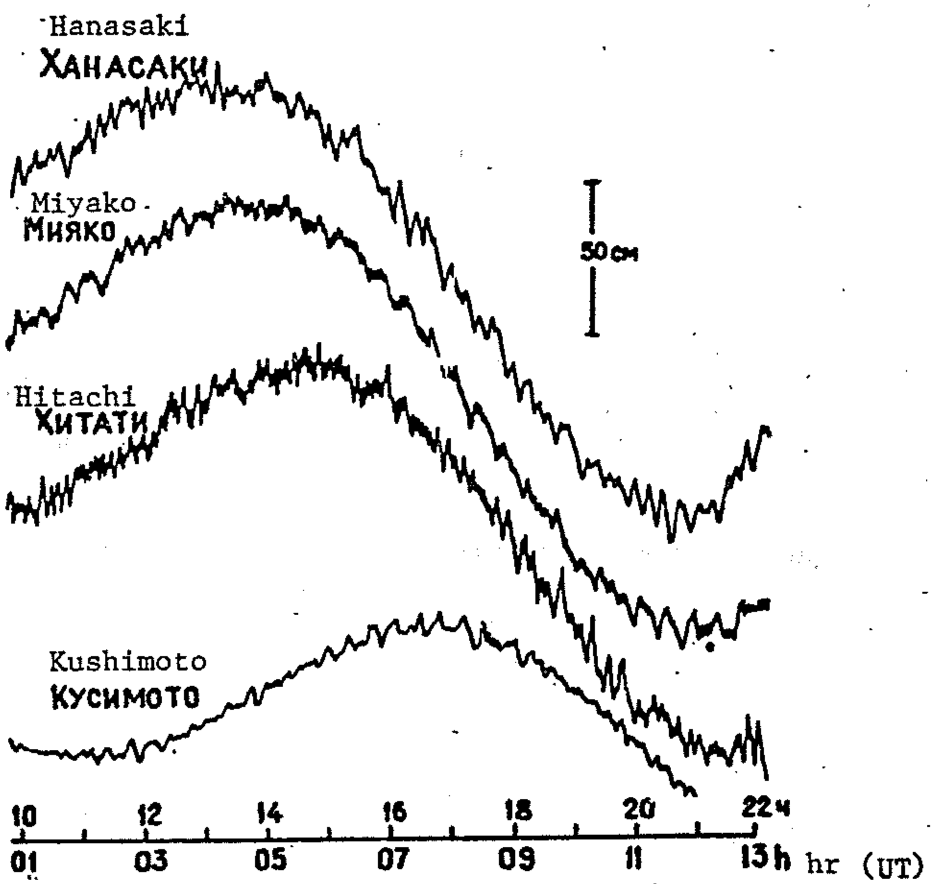

Figure 7: Records of tsunami of November 22, 1969 by tide gauges situated in Japan [Hatori, 1982b].

In Lavrova Inlet, the funnel-shaped fjord of the bay on Govena Peninsula (northeastern corner of the map, Figure 6) the waves washed away three lighters and a fish pump (reported by Kamchatka Fishing Trust).

This tsunami of November 22, 1969 was recorded by instruments on the Aleutian and Hawaiian Islands. Very weak waves were noticed on the Japanese coast (Figure 7). The tide gauge data is reproduced below:

Place	Height (cm)
Ust'-Kamchatsk	20
Attu	55
Shemya	65
Adak	15
Unalashka	10
Midway	5
Honolulu	5
Kahului	20
Hilo	5

[SI, No. 829; NL, 1970, Vol. 3, No. 1, 2; SN, 1970, Vol. 60, No. 3; Von Hake and Cloud, 1971; Fedotov et al., 1973; Soloviev, 1978a, 1982; Hatori, 1982b].

[November 22, 23 h 09 m 37 s; 57.8° N. Lat., 163.7° E. Long.; 30 km; M = 7.7; I = 3].

<u>January 10, 1970; 15 hr 07 min.</u> A strong earthquake occurred in the Philippine Islands. In Davao it became dark everywhere. In Buluan windows rattled and buildings swayed. The National Weather Bureau reported that the earthquake was felt at an intensity of VI points (on the Rossi-Forel scale) in Davao; V points in Kagayan, Oro, and Hinatuan; IV in Surigao; III in Taloban; II in Cebu and Virak.

A considerable tsunami was observed. The tide gauge in Malakal (Palau Island of the Caroline Islands) recorded the wave with an amplitude of 6 cm. [NL, Vol. 3, No. 2, 1970; SN, Vol. 60, No. 4, 1970; Coffman and Von Hake, 1972; Soloviev, 1982].

[January 10; 12 h 07 m 07 s; 6.8° N. Lat., 126.7° E. Long.; 46 km; M = 7.3; I = 0].

<u>February 4, 1970.</u> The submarine volcano Bayonezc which is south of Japan erupted. The underwater eruption of the central crater, produced a lava dome and reached a height of 100 m (water column 200-300 m wide). The explosion was accompanied by smoke that was colored by sulphur and was followed by a column of water which rose to a height of 200-500 m and 100 m wide. The yellow water covered an area 1,000 m x 2,000 m in the southwest. The area covered by floating pumice was 50-100 m x 1,000 m with pumice pieces up to 40 cm across. [SI, Nos. 859, 927, 938; Gushchenko, 1979].

[31.55° N. Lat., 139.55° E. Long.].

<u>April 7, 1970, 13 hr 34 min.</u> A strong earthquake covered an extensive region which included the whole of Luzon, Philippines and the northern part of the Visayan Sea. The earthquake was felt at an intensity of VII points (on the Rossi-Forel scale) in the region of Greater Manila: in Tugegarao, Baler, Dagupan, Baguio, Cabanatuan, Infanta, and Gulod. Fourteen people died and over 200 were injured. There was great destruction in the Manila region. [NL, Vol. 3, N2, 1970, Scinner and Watanabe, 1970; SN, Vol. 60, No. 5, 1970; Coffman and Von Hake, 1972; Soloviev, 1982].

[April 7; 05 h 34 m 05.6 s; 15.8° N. Lat., 121.7° E. Long.; 37 km; M = 7.3; I = 1].

May 31, 1970, 15 hr 23 min. A catastrophic earthquake occurred in Peru. Its epicenter was about 36 km from the Peruvian coast facing Chimbote. The depth of focus was 43 km. This earthquake is considered the worst calamity in the Western Hemisphere since 1932. About 20,000 people lost their lives, 50,000 were missing, 50,000 were injured, and about 500,000 were left without food. The monetary losses caused by this earthquake were estimated at $230 million.

The area affected by the earthquake was extensive and covered the region along the coast for a few hundred km, from Pisco in the South to Chiclayo in the North (Figure 8). In Chiclayo, about forty people were injured and the church was destroyed. The maximum intensity of VIII points on the Rossi-Forel scale was observed in the coastal area from Casma to Chimbote and in the valley of the Santa Rio River from Aija to Caraz; Chimbote, with a population of 80,000 was destroyed up to 50-70%. Huaras, with a population of 50,000-65,000 was destroyed up to 70%. The mud-clay construction of the houses was the reason for such severe destruction in the populated areas. The valley of the Santa Rio river experienced ice avalanches, rock slides, and sludge which flowed 16 km down the valley. In Yungay, situated in the valley, nearly 19,000 people died; only 2,500 survived. The city was buried under a layer of sludge more than 4 m thick. Village Ranrajirka, with a population of 1,800 was totally destroyed and almost all residents were lost without a trace. The speed of the mud flow reached 200-400 km/hr. [SN, Vol. 60, No. 6, 1970].

Weak tsunamis, produced by the earthquake, were observed along the Peruvian coast. In Chimbote, a 76 cm high wave was recorded; in La Punta (Callao region), the height was 61 cm.

Tsunami waves were observed on the Japanese coast. Tide gauge data are given in Table 4. [SI, No. 963; Coffman and Von Hake, 1972; Hatori, 1981a; Soloviev, 1982; Watanabe, 1983].

[May 31; 20 h 23 m 27.3 s; 9.0° S. Lat., 78.8° E. Long.; 43 km; M = 7.8; I = 0].

Table 4: Tide gauge data for the tsunami of May 31, 1970 in Japan

Place	Travel time (hr min)	Initial wave: Amplitude (cm)	Initial wave: Period (min)	Height of the maximum wave (cm)
Hanasaki	20 22	6	16	9
Hiroo	20 46 ?	5	10	12
Hachinohe	20 47	2	40	10
Enoshima	20 38	3	40	8
Ayukawa	20 40	5	18	14

Onahama	20 40	3	20	7
Mera	?	-	-	7
Omaezaki	20 52	4	18	9
Kushimoto	?	-	-	8
Muroto	?	-	-	9
Tosashimizu	?	-	-	13
Aburatsu	?	-	-	10

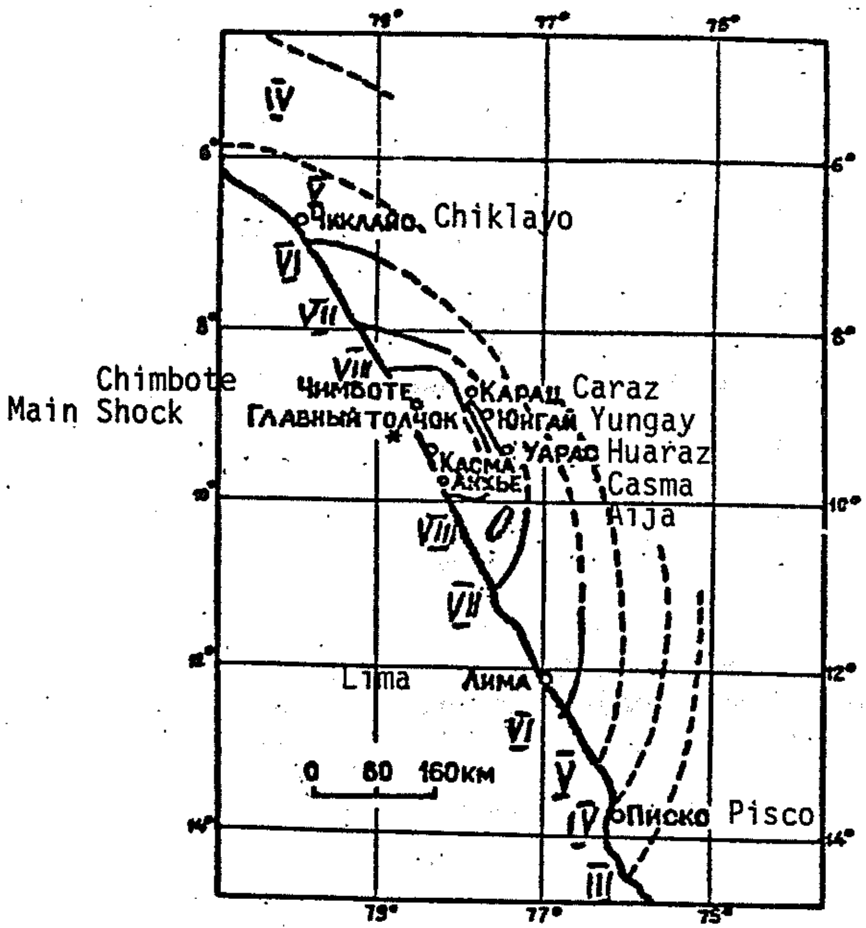

Figure 8: Surface effect of the earthquake of May 31, 1970 (Rossi-Forel scale) [Hatori, 1981a].

July 26, 1970. At approximately 07 hr 41 min an earthquake was felt throughout an extensive area of southern Japan. Railway transportation was temporarily disrupted because of damage to the track. There was no loss of human life, but thirteen people received serious injuries in the town of Miyazaki. The main shock was followed by aftershocks at a maximum intensity of IV points (JMA) (Figure 9). The frequency of the aftershocks soon decreased, and after 1700 hr of that same day, recognizable shocks from this earthquake were not recorded.

After this earthquake, a weak tsunami was observed in the south of Japan. According to tide gauge records, the tsunami began with a rise in water level on the coasts of Kyushyu and Shikoku Islands about 15 min after the earthquake and for the most part had an amplitude of about 10 cm and a period of 20 min. Figure 10 shows the main tsunami records. The parameters deduced from these tide-gauge records are presented in Table 5.

Figure 11 shows the tsunami source, determined by the arrival time of the waves at the tide gauge stations. In dimensions and position, this source matches the source of the tsunami of November 2, 1931 ["Earthquakes and tsunamis...", 1970; NL, Vol. 3, No. 3, 1970; Hatori, 1971; SN, Vol. 61, No. 1, 1971; "The earthquake of July 26, 1970 ...", 1971; Coffman and Von Hake, 1972; Soloviev, 1982; Watanabe, 1983].

[July 25; 22 h 41 m 10 s; 32.2° N. Lat., 131.8° E. Long.; 34 km; M = 7.2; I = -1½].

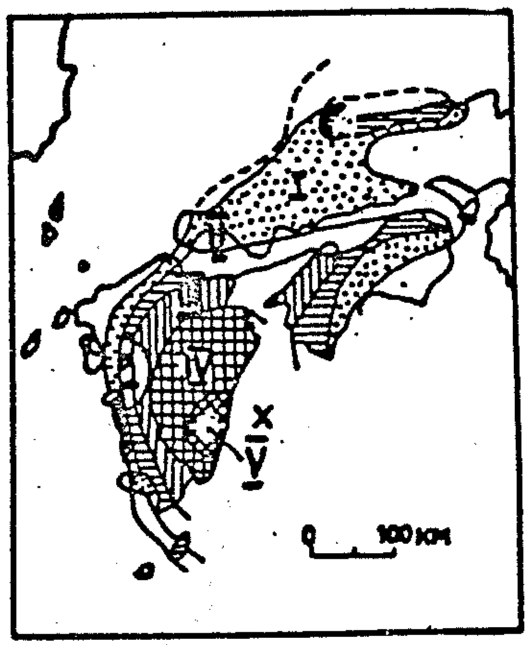

Figure 9: Surface effect of the earthquake of July 26, 1970 [Hatori, 1971]

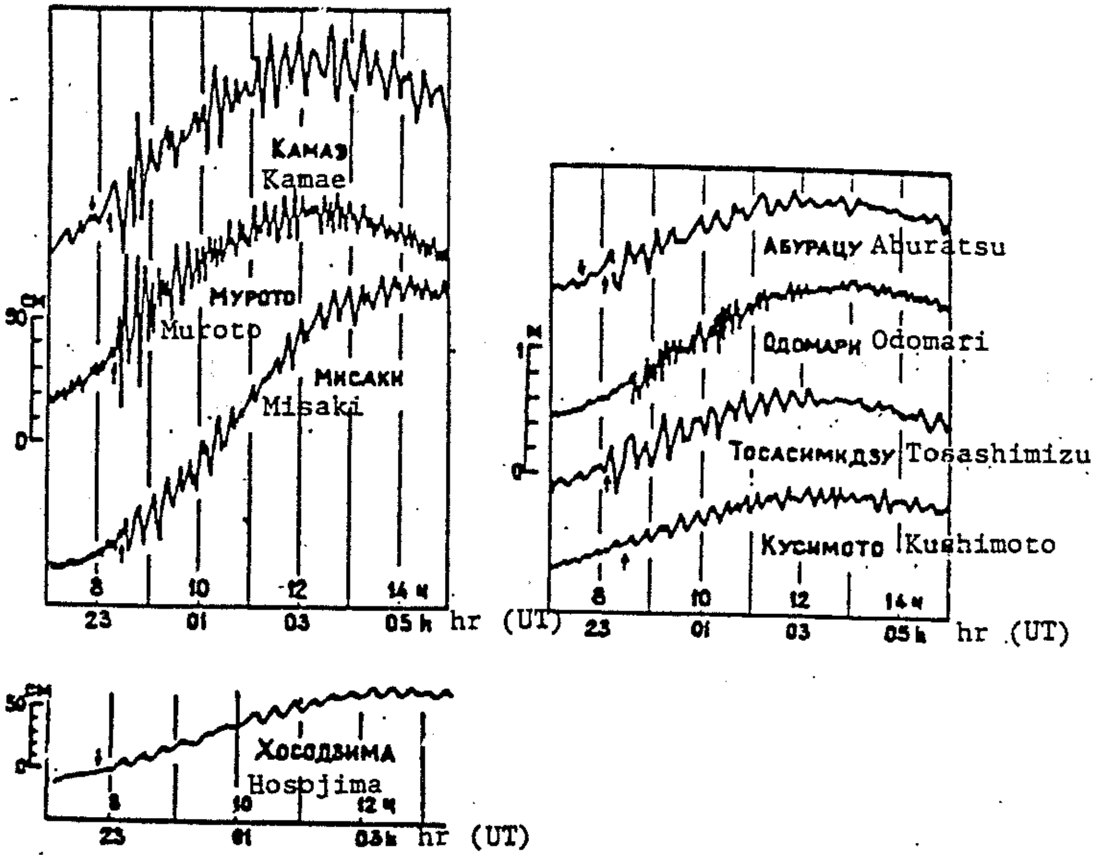

Figure 10: Records of tsunami of July 26, 1970 [Hatori, 1971].

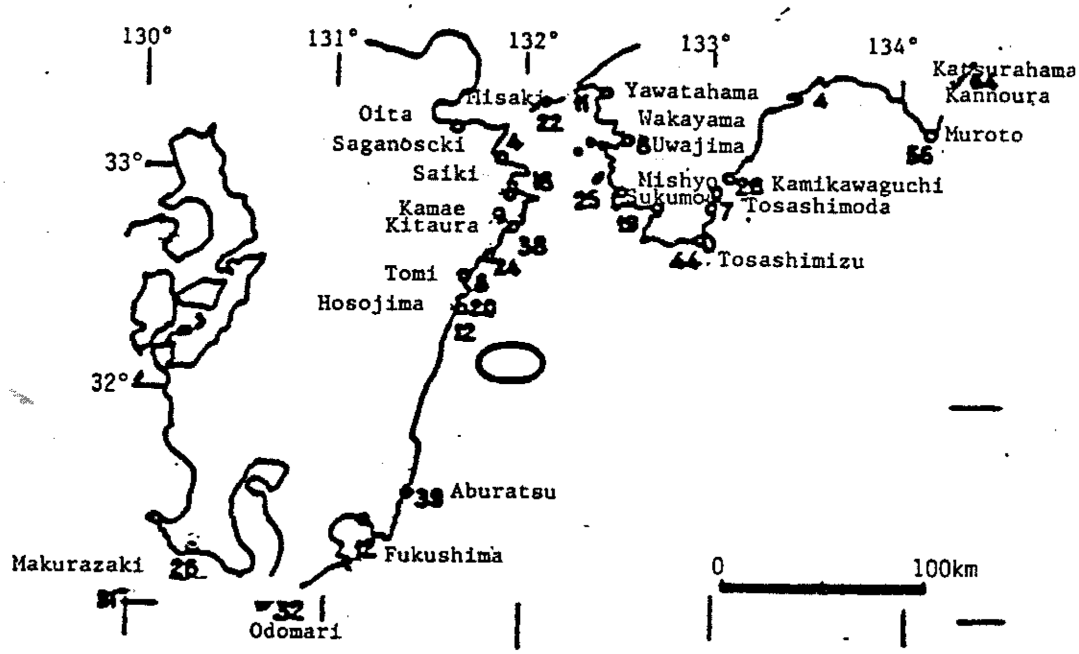

Figure 11: Source and height (in cm) of the tsunami of July 26, 1970 [Hatori, 1971].

Table 5: Tide gauge data for the tsunami of July 26, 1970

Place	First wave: Travel time (min)	First wave: Amplitude (cm)	First wave: Period (min)	Height of the maximum wave (cm)
Nase	-	-	-	8
Makurazaki	75 ?	-	-	26
Odomari	55	10	11	32
Fukushima	-	-	-	12
Aburatsu	24	15	21	39
Hosojima	15	5	20	12
Tomi	19	8	-	8
Kitaura	-	-	-	24
Kamae	20	8	20	38
Saiki	38	5	25	18
Saganoseki	-	-	-	4
Oita (Tsurusaki)	-	-	-	3
Ehime-Misaki	46	7	15	22
Yawatahama	-	-	-	11
Uwajima	-	-	-	8
Mishyo	-	-	-	25
Sukumo	-	-	-	19
Tosashimizu	28	14	22	44
Tosashimoda	40 ?	4	-	7
Kamakawaguchi	38	8	8	26
Kochi (Katsurahama)	-	-	-	4
Muroto	43	12	10	56
Kannoura	42	7	12	64
Kushimoto	49	4	18	17
Uragami	-	-	-	7
Owase	-	-	-	7
Omaezaki	-	-	-	9
Minamiizu	-	-	-	6
Kozu Jima	-	-	-	5
Mera	-	-	-	8

September 30, 1970; 17 hr 52 min. An earthquake occurred in the Philippines. In Basco, Batan Islands, two buildings were destroyed and 60% of the houses were damaged. The maximum intensity of the earthquake was VII points on the Rossi-Forel scale. An insignificant local tsunami was observed [SN, Vol. 61, No. 2, 1971; Coffman and Von Hake, 1972; NL, Vol. 6, 1973; Soloviev, 1982].

[September 30; 09 h 52 m 22.7 s; 20.6° N. Lat., 122.0° E. Long.; 33 km; M = 5.3; I = ½].

November 1, 1970; 03 hr 53 min. A strong earthquake occurred in New Guinea about 30 km north of Madang and was felt on the entire island of New Guinea. This region lies within the well-known seismic zone along the northern part of New Guinea but is not densely populated

The maximum intensity of 8 points and over (MM) occurred within the zone about 20 km from the epicenter. Intensities of 7 points and above were felt 70 km from the epicenter and in distant places outside of this zone. An intensity of 3 points was noted at 500 km from the epicenter.

Fifteen people died and about 20 were injured, mainly as a result of landslides and destruction of wooden huts. Six deaths were due to landslides in localities 150 km south of the epicenter. In the region where the intensity was 8 points and above, the very steepness of the slopes of the hilly terrain facilitated landslides. About 800 wooden, bamboo, and reed/wooden houses were damaged by tremors. Some of the wooden houses and yards were destroyed by the landslides.

Madang, with a population of 11,000 was significantly damaged. Mainly nonreinforced houses and galvanized-iron water tanks were affected. 45% of these water tanks became unserviceable.

In the vicinity of the source, the sea initially receded from the coast followed by a 3 m rise in water level. Three people were drowned when their canoe overturned. On the coast waves did not cause any appreciable damage. As was reported from Madang, the maximum height of the rise of wa. level was 1.2 m. The underwater cable lines connecting Guam Island to Cairns were broken at several places in the region 15 km from Madang. [SI, No. 1049; SN, Vol. 61, No. 2, 1971; Coffman and Von Hake, 1972; NL, Vol. 6, 1973; Everingham, 1975a, 1976, 1977; Soloviev, 1982].

[October 31; 17 h 53 m 09.3 s; 4.9° S. Lat., 145.5° E. Long.; 42 km; M = 7.0; I = ½].

February 8, 1971; 17 hr 04 min. An earthquake occurred in Antarctica. A shock was felt on Argentine Island following rough seas and cracking of ice and land. On February 19, the helicopter from the Argentine icebreaker the *General San Martin* flew over Deception Island. No visible changes could be observed at the English, Chilean, and Argentinean bases, abandoned since the seismic and volcanic activity of February 21, 1969. No changes could be seen in the activity of the penguin colony or in volcanic activity. [SI, No. 1225; SN, Vol. 61, No. 5, 1971; Soloviev, 1982].

The generation of a weak tsunami is not ruled out, but cannot be confirmed by available data.

[February 8; 21 h 04 m 21.8 s; 63.5° S. Lat., 61.2° W. Long.; 33 km; M = 7.0; I = 0?].

<u>May 1, 1971; 18 hr 8 min</u>. An earthquake occurred on the Aleutian Islands. It was felt on Adak Island with an intensity of 6 and on Amchitka Island with an intensity of 3 points. A weak tsunami with a height of 9 cm was observed in Adak. [SN, Vol. 62, No. 1, 1972; Coffman and Von Hake, 1973; Soloviev, 1982].

[May 2; 06 h 08 m 27.3 s; 51.4° N. Lat., 177.2° W. Long.; 43 km; M = 7.1; I = -3].

<u>July 7, 1971; 22 hr 03 min</u>. A catastrophic earthquake of magnitude 7.5 occurred in Chile leaving 84 people dead, 447 injured, and 40,000 homeless. The epicenter was 75 km northwest of Santiago. Thousands of people were stranded without electricity, drinking water, or telephone service. Several communities were isolated by landslides which blocked highways and railroad tracks. The port of Valparaiso suffered the most. The maximum intensity of X points on the Rossi-Forel scale was observed in Ilapel and Salamanca where nearly 30 buildings were destroyed or damaged. In Valparaiso and Viña del Mar the earthquake was felt with intensities of VII and IX points. In La Ligua nearly 80 buildings were destroyed or damaged and in Llay-Llay the number was 90. In Santiago, crowds of frightened people ran through the streets. Building walls cracked and water jets gushed from broken mains. Damage was also reported from Conception Island. Shocks were felt in Mendoza, Tucuman, Bahia Blanca, La Plata, San Juan, Cordoba, and Buenos Aires (Argentina).

This earthquake caused a weak tsunami with a height of 1.2 m which was observed in Valparaiso [SN, Vol. 62, No. 2, 1972; Coffman and Von Hake, 1973; Soloviev, 1982].

[July 8; 03 h 02 m 18.7s; 32.5° S. Lat., 71.2°W. Long.; 58 km; M = 7.5; I = 0].

<u>July 14, 1971; 16 hr 11 min</u>. A strong earthquake with a magnitude of 7.9 occurred at a depth of 50 km in the Solomon Sea near the New Britain, New Ireland and Bougainville Islands. The earthquake was felt strongest on these and neighboring islands. The shock was also felt in Papua, New Guinea. Deep inland on New Britain, the earthquake was felt at an intensity of 8-9 points (MM). In Rabaul the intensity was 7-8 points (MM). Damage was not

significant in the city but was heavy in the region where intensity reached 8 points. In Wide Bay and Wakkunai an intensity of 5 points was recorded and in Kieta the intensity was 5-6 points. In Kobuassan the stylus of the seismograph broke. Precise data are not available for New Ireland and Bougainville. In some regions the earthquake intensity was apparently not less than 8-9 points (MM).

The earthquake caused two deaths, five serious injuries, and considerable damage; coastal highways were blocked by landslides and hydro-electric plants were destroyed. Bii and Hives, two small islands in the Rabaul Gulf, were partially submerged.

The tsunami which followed this earthquake reached the harbor of Rabaul approximately 30 min after the earthquake. The maximum wave height observed in Rabaul was 2 m and arrived 52 min after the earthquake (Figure 13). Waves overflowed the dyke linking Matupi Island with Gazelle Peninsula. In the Rabaul region, buildings did not sustain structural damage from the earthquake; in most cases, damage was caused by inundation.

The tsunami recorded by the tide gauge in Anewa Bay had an amplitude of 48 cm. The wave arrived after 35 min with a period of 10.5 min (Figure 13).

The tsunami was widely reported by all of the small islands of the Solomon Sea. However, the investigation of affected regions was difficult and only a few reports on the tsunami are available.

In Pomio, on the eastern coast of New Britain, the maximum wave was recorded at a height of 3 m. Oscillations of water continued for several hours with an amplitude of up to 1.2 m. No damage was reported.

In Sohano, in the Buka Strait between Buka and Bougainville Islands, water rose to a height of 1.5 m inundating the lower areas near the hospital. No records reporting loss of life or property damage are available.

In Lambon, New Ireland, the first shock caused extensive damage; the primary school was heavily damaged and brick houses were cracked. Waves of 6 m were reported. This was not officially confirmed by subsequent investigations. It is not clear whether the destruction was caused by the tsunami wave or the earthquake.

In the Kunua region of Bougainville Island, a child disappeared from the shore. A tractor left on the coast was overturned and severely damaged.

In Govi, the port storehouse, distillery, and plantations were destroyed, but reliable information on the height of the waves is not available.

The western coast of Bougainville Island was the land closest to the source of the tsunami; however, information from this region is fragmentary. Apparently, private residences sustained most of the damage. A child who had gone fishing did not return home.

There are no reports on the wave from the islands of Trobriand and Woodlark; this is obviously due to the absence of detailed observations.

The tsunami was also recorded outside of the New Britain-New Ireland-Bougainville island region. On Kwajalein Island a wave was recorded at a height of 4 cm; on Truk Island, 6 cm; on Wake Island, 6 cm; at Honolulu, 9 cm; at Kahului, Maui, 4 cm, at Crescent City, California, 15 cm; on Attu Island, Aleutian Islands, 6 cm.

Table 6 presents tide gauge data on the tsunami as observed along the coast of Japan. (The tsunami records are shown in Figure 13). [SI, Nos. 1259-1261, 1426; Cooke, 1971; SN, Vol. 62, Nos. 2, 1972; Braddock, 1973; Coffman and Von Hake, 1973; Everingham, 1975b, 1976, 1977; Hatori, 1982a; Soloviev, 1982; Watanabe, 1983].

Figure 12 shows the epicenters and the aftershock region from the earthquakes of July 14 and 26.

[July 14; 06 h 11 m 29.1 s; 5.5° S, Lat., 153.9° E. Long.; 47 km; M = 7.9; I = 1].

Table 6: Tide gauge data on tsunami of July 14, 1971 on the coast of Japan

	First wave			
Place	Travel time (hr min)	Rise in level (cm)	Period (min)	Height of the maximum wave (cm)
Hanasaki	09 49	6	14	10
Kushiro	12 08	3	15	4
Urakawa	08 39	3	10	6
Hachinohe	09 35	4	32	6
Miyako	09 35	4	20	6
Ayukawa	08 38	4	12	6
Onahama	08 01	5	12	6
Mera	07 14	3	15	4
Uchiura	08 02	4	18	4
Omaezaki	10 29	6	15	6
Owase	08 25	3	12	6
Kushimoto	08 19	3	15	11
Tosashimizu	06 19	-	-	8
Aburatsu	09 49	3	16	8
Nase	06 17	3	16	4

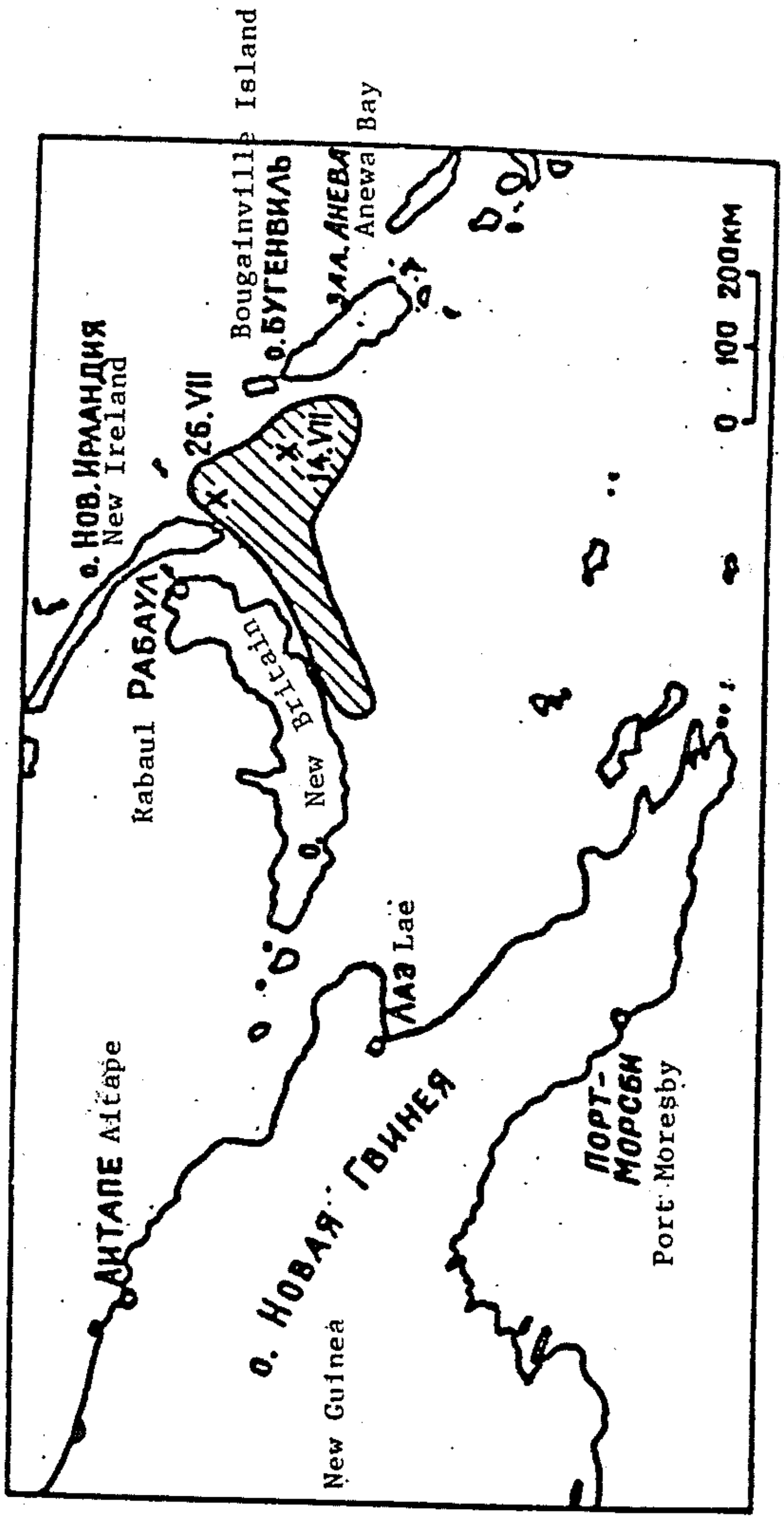

Figure 12: Epicenters and the region of aftershocks from the earthquakes of July 14 and 26, 1971 [Everingham, 1975b].

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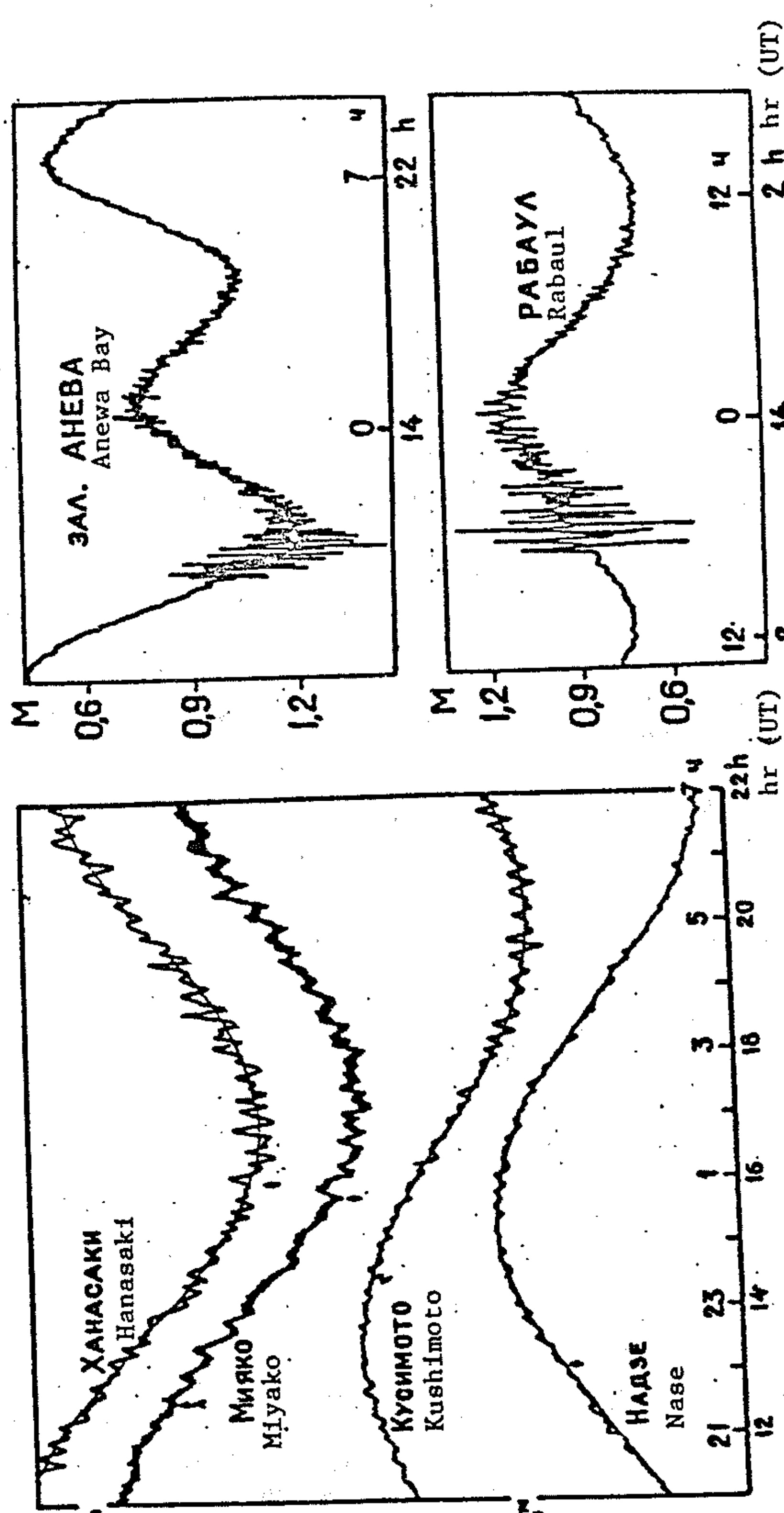

Figure 13: Records of the tsunami of July 14, 1971 on the coast of Japan [Hatori, 1982a] and Papua, New Guinea [Everingham, 1975b]

July 26, 1971; 11 hr 23 min. A strong earthquake occurred on New Ireland at a magnitude of 7.9 and at a depth of 50 km. The epicenter was northwest of the epicenter of the July 14 earthquake (see Figure 12). The epicenters of the main shock and the aftershocks were confined to an unusually large area which stretched from Cape Dampier on the southern coast of New Britain, to the southeastern coast of New Ireland, and to the Buka Island area. The region of aftershocks stretched northeast-southwest, parallel to the coastline of New Britain. In contrast, the aftershock region from the earthquake of July 14 stretched northwest-southeast, parallel to the coastline of New Ireland. (see Figure 12).

In the southern part of New Britain, this earthquake was felt at an intensity of 8-9 points (MM). In Rabaul, the intensity was 7-8 points. On New Ireland and Bougainville Islands, the intensity was not less than 8-9 points.

This earthquake produced a tsunami which was more destructive than the earlier one. The tsunami arrived in Rabaul after approximately 28 minutes, a few minutes before midday. It began with a small ebb and was followed by a series of waves of larger amplitude. The maximum wave height from peak to trough was estimated at 5-6 m [Braddock, 1973], although the tide gauge did not record that level (Figure 14). The period was about 30 min. This tsunami occurred during low-tide, but the maximum rise of water nearly submerged the usual high-tide mark by 1.8 m. Coastal flooding damaged boats, automobiles, and buildings.

The tsunami reached a height of 18 cm and a period of 27 min as registered in the tide gauge records at Alotau (Madang, Papua New Guinea). At Anewa Bay a height of 42 cm and a period of 10 min was recorded (Figure 14).

The tsunami caused damage on the southern coast of New Ireland where coastal villages reported destruction of houses, quays, and plantations. A plantation in Metlika, near the source region, was completely destroyed. Waves penetrated 800 m inland.

Nissan Island which was close to the epicenter also sustained damage. Tsunami destruction was irregularly dispersed along the affected coastline. Some places escaped damage while others were heavily hit.

The tsunami was also observed in places beyond New Britain and New Ireland. The following tsunami heights were reported: 24 cm on Kwajalein, 9 cm on Truk, 6 cm on Wake, 12 cm on Midway, 12 cm in Honolulu, 30 cm on Kahului, 9 cm in Los Angeles, 15 cm in Crescent City, and 6 cm on Attu Island. Table 7 presents data on tide gauge observations in Japan. Figure 14 gives the records of this tsunami.

The Tsunami Warning Center in Honolulu issued a tsunami warning which was lifted four hours after the earthquake. [SI, Nos. 1264, 1268, 1271, 1426; Cooke, 1971; SN, Vol. 62, No. 2, 1972; Braddock, 1973; Coffman and Von Hake, 1973; Everingham, 1975b, 1976, 1977; Hatori, 1982a; Soloviev, 1982; Watanabe, 1983].

[July 26; 01 h 23 m 21.3 s; 4.9° S Lat.; 153.2° E. Long.; 48 km; M = 7; I = 1½].

Table 7: Tide gauge data on the tsunami of July 26, 1971 on the coast of Japan

Place	First wave: Travel time (hr min)	First wave: Rise in level (cm)	First wave: Period (min)	Height of the maximum wave (cm)
Hanasaki	08 10	7	12	13
Kushiro	10 33	5	22	10
Urakawa	08 25	5	10	10
Hachinohe	11 35	7	32	10
Miyako	07 50	3	20	8
Ayukawa	08 24	6	8	13
Onahama	07 07	7	15	10
Uchiura	08 07	5	10	3
Owase	07 30	3	14	15
Kushimoto	07 23	6	18	12
Tosashimizu	09 39	7	-	10
Aburatsu	07 47	5	15	12
Nase	09 54	5	15	9

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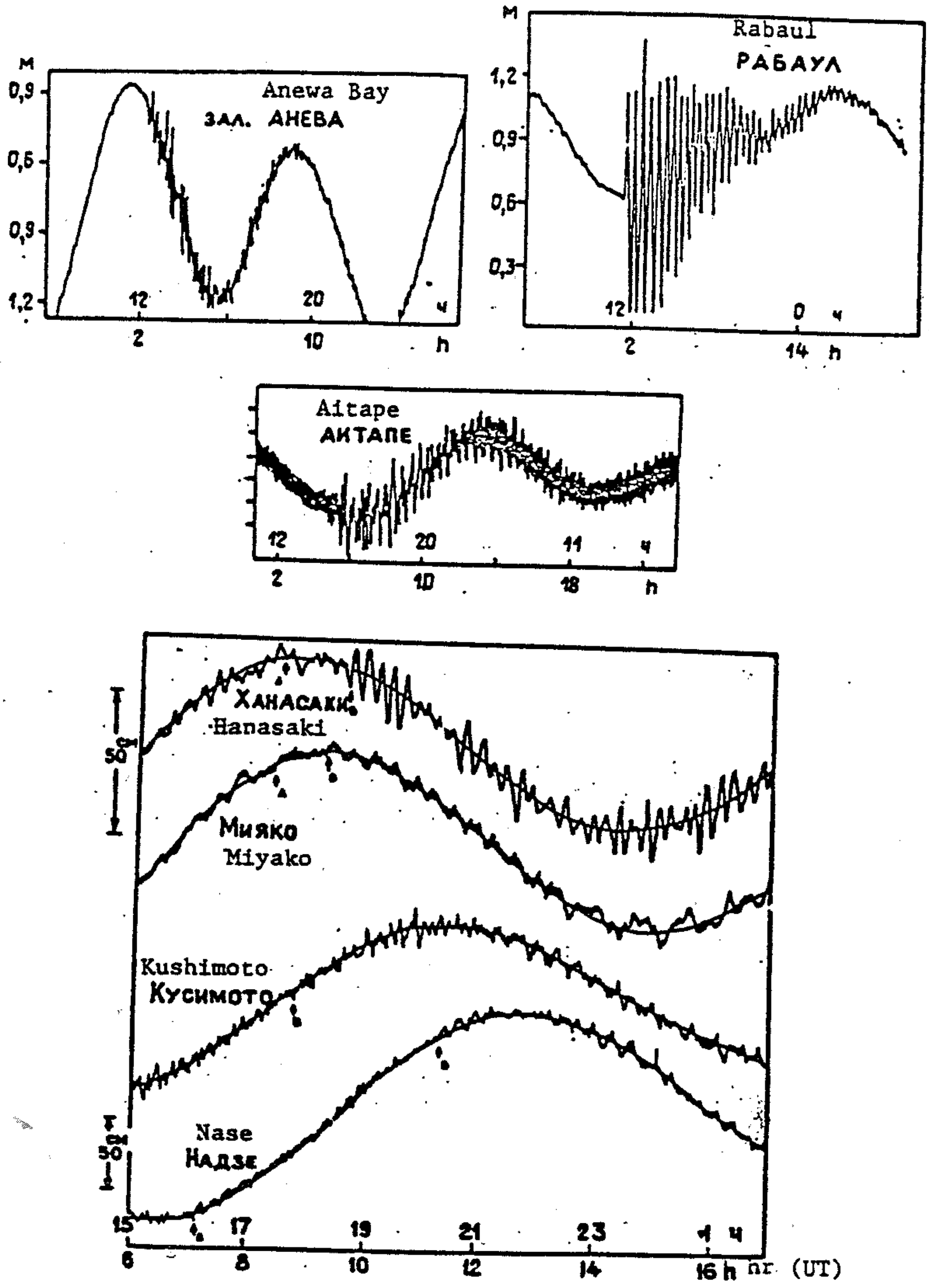

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Figure 14: Records of tsunamis of July 26, 1971 on the coast of Papua New Guinea [Everingham, 1975b] and Japan [Hatori, 1982a]

August 2, 1971; 16 hr 25 min. An earthquake occurred in the region of Cape Erimo, Hokkaido at a magnitude of 7.0. It was felt in Urakawa with an intensity of V points (JMA); it was also felt at an intensity of IV points in the following locations: Kushiro, Nemuro (Hokkaido), and in Hachinohe, Miyako, and Morioka (all on Honshu); it was also felt at II points in the following locations: Sapporo, Hakodate (Hokkaido), and Sendai and Tokyo (both on Honshu). The earthquake occurred at the junction of the Kuril-Kamchatka and Honshu deep-water trenches and produced a weak tsunami on the coasts of Hokkaido and Honshu.

Figure 15 shows the tsunami source; it covers the northeastern part of the source area of the 1968 tsunami. The tide gauge data are presented in Table 8 and the tsunami records are in Figure 16.

As this table shows, the tsunami began in some places with a rise in water level while at other places it began with a drop. [SN, Vol. 62, No. 2, 1972; Hatori, 1972b, 1974; Coffman and Von Hake, 1973; Soloviev, 1982; Watanabe, 1983].

[August 2; 07 h 24 m 56.8 s; 41.4° N. Lat., 143.5° E. Long.; 51 km; M = 7.1; I = -½].

Table 8: Tide gauge data on the tsunami of August 2, 1971

Place	Initial wave			Height of the maximum wave (cm)
	Travel time (min)	Amplitude (cm)	Period (min)	
Hanasaki	53	+ 5	22	13
Kushiro	38 ?	+ 2	-	18
Hiroo	38	+ 4	15	30
Urakawa	31	+ 8	18	23
Tomakomai	55 ?	+ 3	18	8
Muroran	?	-	-	8
Yamasedomari	36	- 3	15	8
Hakodate	58 ?	- 5	20	13
Hachinohe (Same)	42	- 6	18	18
Hachinohe (Minato)	46	- 8	12	24
Miyako	40	- 7	22	14
Ofunato	54	- 9	15	13
Enoshima	56	- 3	22	6
Ayukawa	?	-	-	10

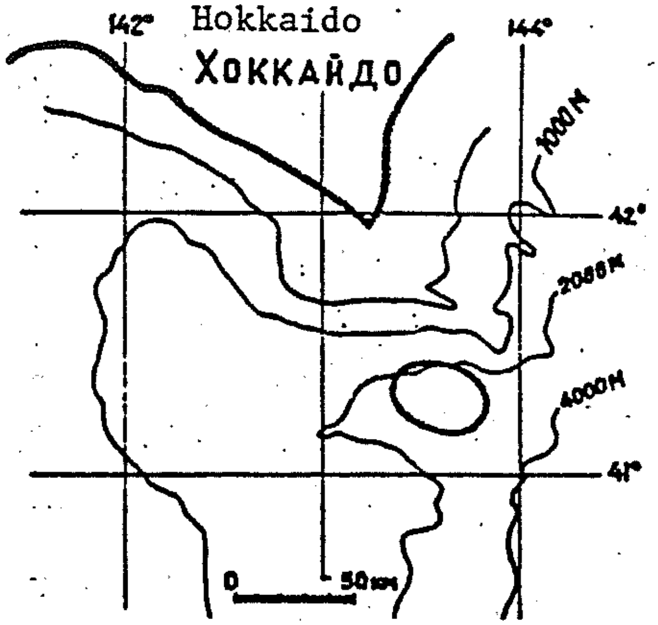


Figure 15: Source of tsunami of August 2, 1971 [Hatori, 1972b].

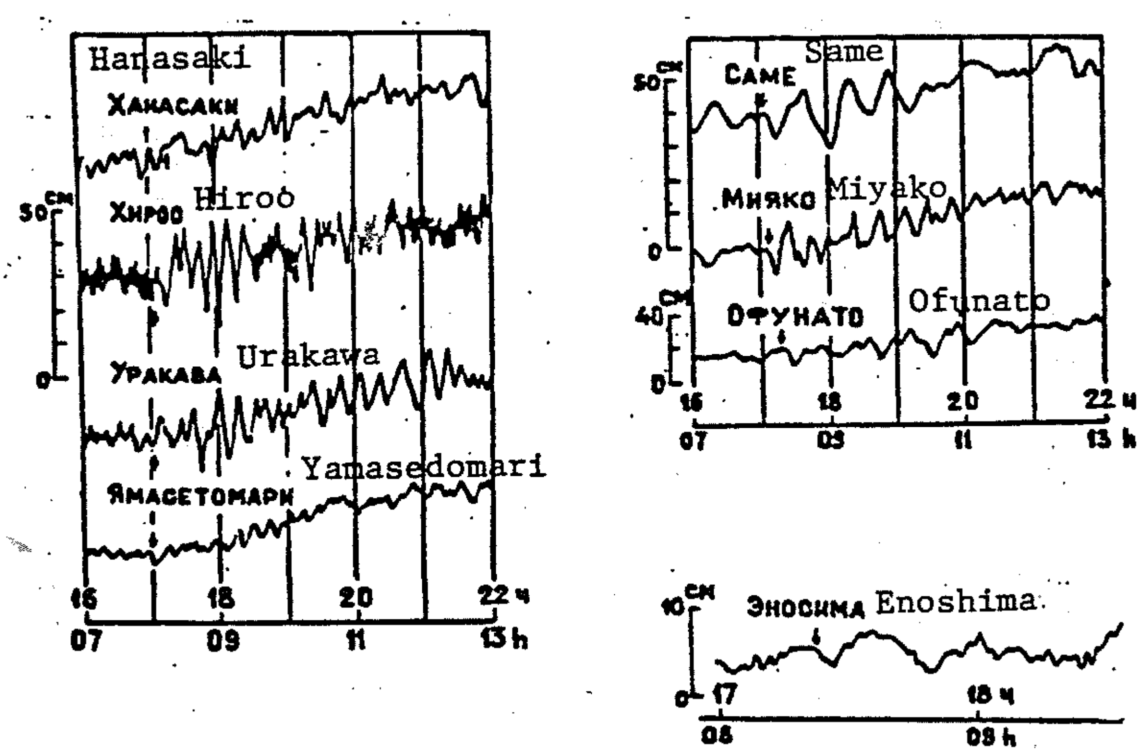


Figure 16: Records of tsunami of August 2, 1971 [Hatori, 1972b].

September 6, 1971; 5 hr 35 min. The southwestern part of Sakhalin experienced a severe earthquake (Figure 17). The maximum intensity of shocks and tremors (7-8 points on MSK-64) were observed on small Moneron Island where rock falls and landslides occurred on steep slopes on the western and eastern coasts. The largest rock falls were at the level of 10,000 m^3 with individual blocks of 30-50 m^3 which occurred on the northwestern coast. Smaller rock falls and landslides occurred on the southern part of the island. Deep inland there was no evidence of any rock falls, landslides, or surface cracks.

In Sakhalin proper, the mining villages of Shebunino and Gornozavodsk were the most severely affected. In Shebunino, up to 75% of the chimneys and ovens in barrack-type buildings were damaged; isolated cracks appeared in the plaster and ovens of newly-built two-story houses of beam construction. In the mine, concrete supports and bulkheads were damaged; the methane level in the air exceeded the permissible level and work had to be stopped for 1½ days. In Gornozavodsk, up to 35% of the structures were damaged. These were primarily frame-plastered houses on the marshy lower river terrace. Building damage was also reported in Nevel'sk, Kholmsk, Sinegorsk, and other places. Primarily, small blocks and shabby frame-plaster structures were damaged. New panel and large-block buildings withstood the shocks well.

The earthquake magnitude was estimated at 7.2. This is the strongest earthquake recorded in Sakhalin since instrument observation began in 1906.

A study of the mechanism of the source leads us to the conclusion that the Moneron earthquake was caused by an upthrust and shift of the eastern wing of the fault to the southwest.

Crustal displacement on the ocean bottom was so pronounced that it caused a 2 m high tsunami which was observed in multiple locations in Shebunino and Gornozavodsk. On Moneron Island, the height of inundation of the bank was estimated at 1.5 m. According to tide gauge data, tsunami height varied from 80 cm in Nevel'sk to 3-5 cm in Adimi (Primor'e), Korsakov, Kuril'sk, and many places in Hokkaido (Figure 18, Table 9). At all locations the tsunami began with a rise in water level which confirms the conclusion that the earthquake was caused by an uplift of the sea bottom in the source region.

The earthquake was followed by numerous aftershocks, four of which produced weak tsunamis which are described later.

[Earthquakes and tsunamis...1972; Hatori, 1972a; SN, Vol. 62, No. 3-4, 1972; Coffman and Von Hake, 1973; Soloviev et al., 1973; Oskorbin et al., 1975; Shchetnikov, 1978, 1981; Soloviev, 1978a, 1982; Watanabe, 1983].

[September 5; 18 h 35 m 29 s; 46.5° N. Lat., 141.1° E. Long.; 15 km; M = 7.5; I = ½].

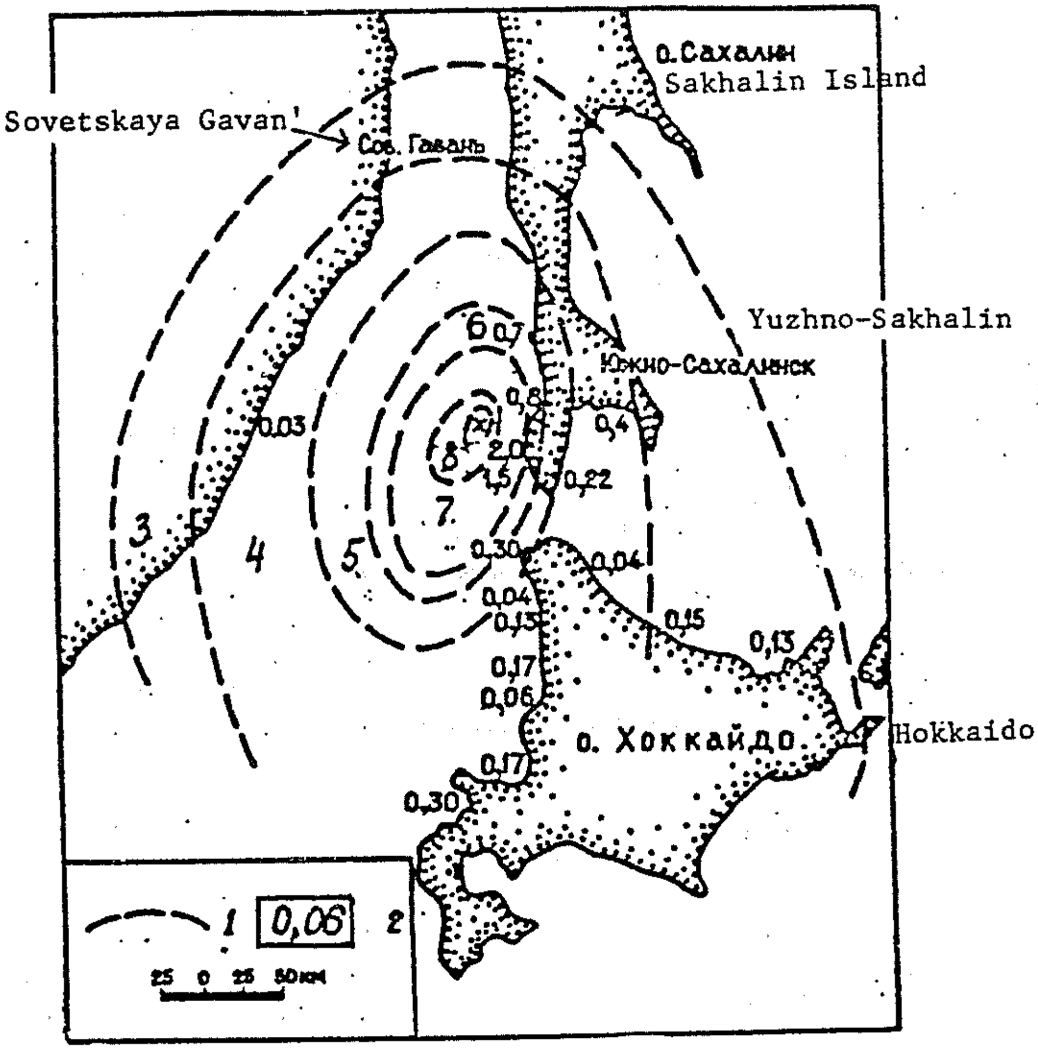
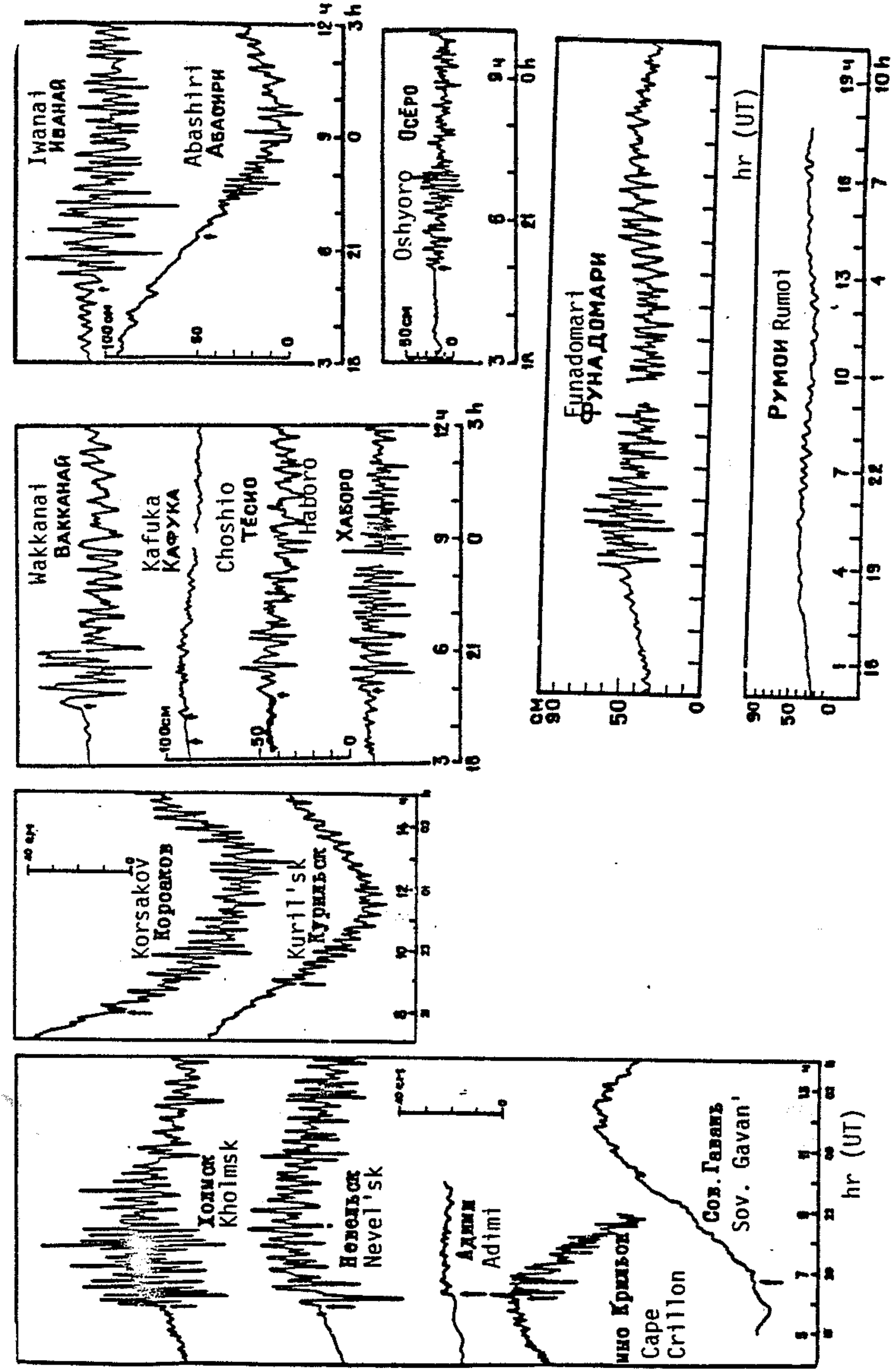


Figure 17: Surface effect of the Moneron earthquake of September 6, 1971 [Shchetnikov, 1978].
(S - isoseismal lines; 2 - height of the tsunami in m)

Figure 18 (opposite page):
Records of the main tsunami of September 6, 1971 at different points in Sakhalin, Primor'e, Kuril Islands and Japan [Hatori, 1972; Shchetnikov, 1978].



Iwanai
ИВАНАЙ
Abashiri
АБАСИРИ
Oshyoro
ОСЁРО
Wakkanai
ВАККАНАЙ
Kafuka
КАФУКА
Choshio
ТЕСИО
Haboro
ХАБОРО
Funadomari
ФУНАДОМАРИ
Rumoi
РУМОИ
hr (UT)
Korsakov
Корсаков
Kuril'sk
Курильск
Холмск
Kholmsk
Невельск
Nevel'sk
Адими
Adimi
мыс Крильон
Cape Crillon
Сов. Гавань
Sov. Gavan'
hr (UT)

Table 9: Principal data on tsunami of September 6, 1971
(September 5, 18 hr 35 min)

Place	Height of the maximum wave (cm)	Travel time (min)	Period (min)
<u>Sakhalin Island</u>			
Moneron Island	1.5 *	0.1	6
Orlovo	0.5 *	-	-
Krasnogorosk	1 *	-	-
Penzenskoe	0.5 *	-	-
Chekhov	0.5 *	-	-
Kholmsk	0.73	0.3	10
Nevel'sk	0.80	0.2	14
Gornozavodsk	2 *	0.3	20-30
Shebunino	2 *	0.3	20-30
Cape Crillon	2 *	0.7	8
Korsakov	0.2	2.4	8
<u>Kuril Islands</u>			
Kuril'sk	0.1	3.3	10
<u>Primor'e</u>			
Adimi	0.04	0.75	5
Sov. Gavan'	0.04	1.2	10
<u>Hokkaido (Japan)</u>			
Rebun Island	0.04	0.7	15
Rishiri Island	0.15	-	-
Wakkanai	0.3	0.9	25
Choshio	0.15	1.3	17
Haboro	0.2	1.4	15
Rumoi	0.06	1.7	23
Otaru	0.2	1.5	15
Oshyoro	0.25	1.4	7
Furuhira	0.2	-	-
Iwanai	0.3	1.3	20
Esashi	0.04	-	-
Mombetsu	0.06	2.7 ?	10

* Visual observations

September 6 - December 11, 1971. The Tinakula Volcano erupted on New Hebrides Islands. The central (main) crater erupted with billowing clouds, weak to moderate explosions, lava flows, and caused strong earthquakes and a tsunami. The height of the ash column was 300 m. The area of volcanic deposition was 1 km^2, the thickness was 10 m at 100 m from the source, and the maximum length of the flow was 300 m. (10° 28' S. Lat., 165° 45' E. Long.) [Gushchenko, 1979; Soloviev, 1982].

September 7, 1971; 00 hr 37 min. A strong aftershock of the Moneron earthquake of September 6 occurred and generated a weak tsunami. In Kholmsk the tide gauge recorded a 7 cm high wave with a period of 10 min. Figure 19 gives the record of this tsunami. [Soloviev, 1978a, 1982; Shchetnikov, 1978, 1981].

[September 6; 13 h 37 m 16 s; 46.6° S. Lat., 141.6° E. Long.; 10 km; M = 6.2; I = -3].

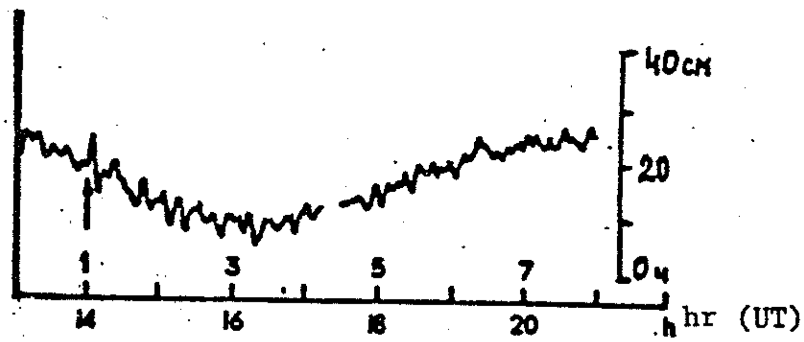


Figure 19: Record of the second tsunami of September, 1971, in Kholmsk [Shchetnikov, 1978].

September 8, 1971; 22 hr 48 min. A second strong aftershock of the Moneron earthquake occurred, generating a weak tsunami. (Figure 20, Table 10). [Soloviev, 1978a; Shchetnikov, 1978, 1981].

[September 8; 11 h 48 m 25 s; 46.4° S. Lat., 141.0° E. Long.; 15 km; M = 6.9; I = -3].

Table 10: Tide gauge data on tsunami of September 8, 1971

Place	First wave			Height of the maximum wave (cm)
	Travel time (min)	Amplitude (cm)	Period (min)	
Kholmsk	34	6	7	9
Nevel'sk	24	2	13	4

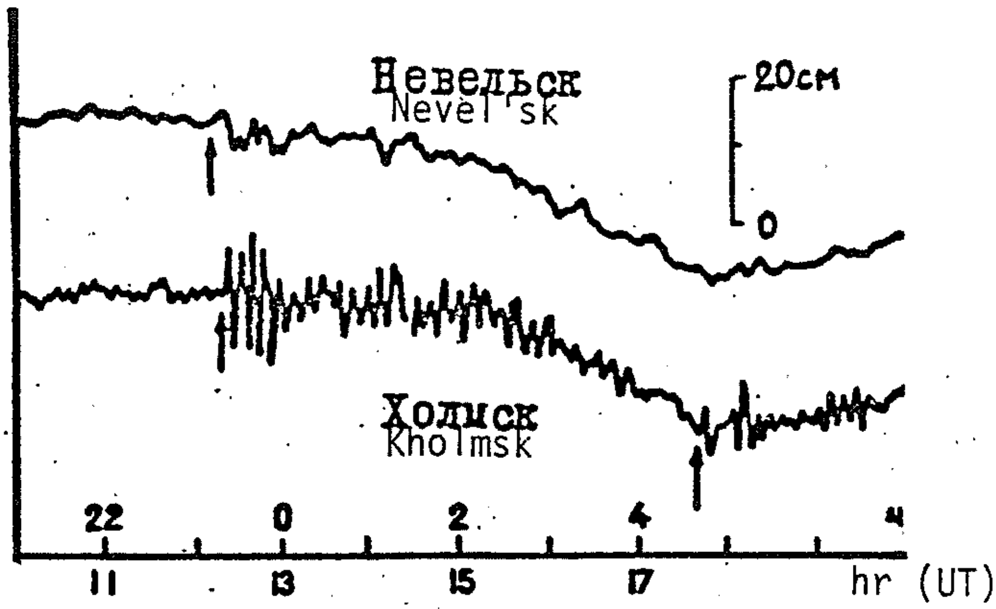


Figure 20: Records of tsunami of September 8, 1971 in Kholmsk and Nevel'sk [Shchetnikov, 1981].

September 9, 1971, 04 hr. A third aftershock of the Moneron earthquake occurred which also generated a weak tsunami. The tide gauge in Kholmsk recorded a wave height of 7 cm and a period of 5 min (Figure 20). [Soloviev, 1978a, 1982; Shchetnikov, 1978, 1981].

[September 8; 16 h 59 m 52 s; 46.2° S. Lat., 141.0° E. Long.; 15 km; M = 6.3; I = -3].

September 25, 1971; 14 hr 36 min. An earthquake alarmed the population of Lae (New Guinea) which was near the epicenter. Because the hypocenter was at a depth of about 115 km, the intensity of the shock was not very high and structures were not damaged. The 30,000 km^2 region near Lae experienced tremors at an intensity of 6 points (MM). In Garain, about 130 km southeast of the epicenter, a steel-frame steel-sheet-covered tea plant suffered light damage. Here, the intensity was local in character and reached 7 points in places. This earthquake was felt in Port Moresby at an intensity of 3 points. [SN, Vol. 62, No. 3, 1972].

According to Everingham (1974), this earthquake was reported as tsunamigenic. However, it is doubtful that an earthquake with a magnitude of 6.7 and a hypocenter depth of 115 km could generate any appreciable tsunami. [Everingham, 1973, 1976, 1977; Soloviev, 1982].

[September 25; 04 h 36 m 14 s; 6.5° S. Lat., 146.6° E. Long.; 115 km; M = 6.7; I = ½].

September 28, 1971; 06 hr 02 min. A fourth strong aftershock of the Moneron earthquake of September 6 occurred, generating a weak tsunami. The tide gauge in Nevel'sk recorded a 3 cm high wave with a period of 8 min (Figure 21). [Soloviev, 1978a, 1982; Shchetnikov, 1978, 1981].

[September 27; 19 h 01 m 43 s; 46.4° S. Lat., 141.1° E. Long.; 10 km; M = 6.2; I = -4].

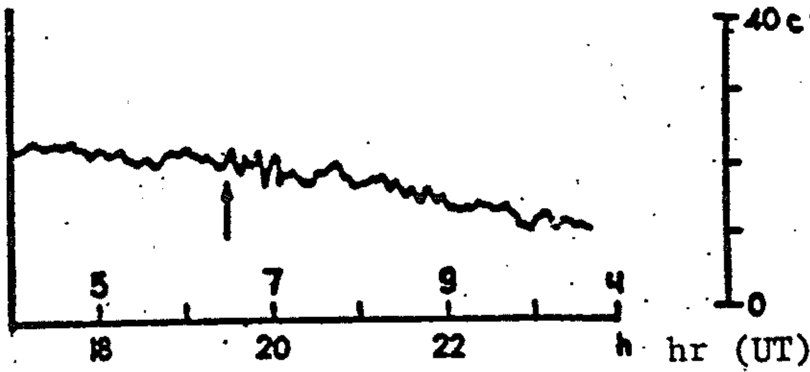


Figure 21: Record of tsunami of September 27, 1971 in Nevel'sk [Shchetnikov, 1981].

December 15, 1971; 20 hr 30 min. A strong earthquake occurred in Kamchatka at a magnitude of 7.7. The epicenter was located south of Cape Kamchatskiy below the Pacific Ocean, at a depth of 20-30 km. The earthquake was felt at an intensity of 7 points in Ust-Kamchatsk and Nikol'skoe. The map of isoseismal lines of this earthquake is presented in Figure 22.

The earthquake generated a weak tsunami in Ust-Kamchatsk. Visual observations are not available, apparently because the onset of the tsunami coincided with low tide and because the tsunami itself was very weak. The tide gauge record shows that the first wave arrived in Ust-Kamchatsk 20 min after the earthquake. The marigram (Figure 23) shows several waves with periods of 20-30 min. The first wave was the maximum with a height of 47 cm. In Severo-Kuril'sk, a wave with a height of 10 cm was observed. This tsunami was also recorded by tide gauges at locations beyond USSR territory:

Place	Height, cm
Aleutian Islands	
Attu Islands	10
Shemya Island	5
Hawaii	
Kahului	18
Hilo	15
Wake Island	9

[SI, No. 1328; SN, Vol. 62, No. 4, 1972; Lazo and Men'shikov, 1973; Coffman and Von Hake, 1973; The Ust-Kamchatskoe Earthquake..., 1975; Soloviev, 1978a, 1982].

[December 15; 08 h 29 m 55.3 s; 56.0° N. Lat., 163.3° E. Long.; 33 km; M = 7.8; I = 0].

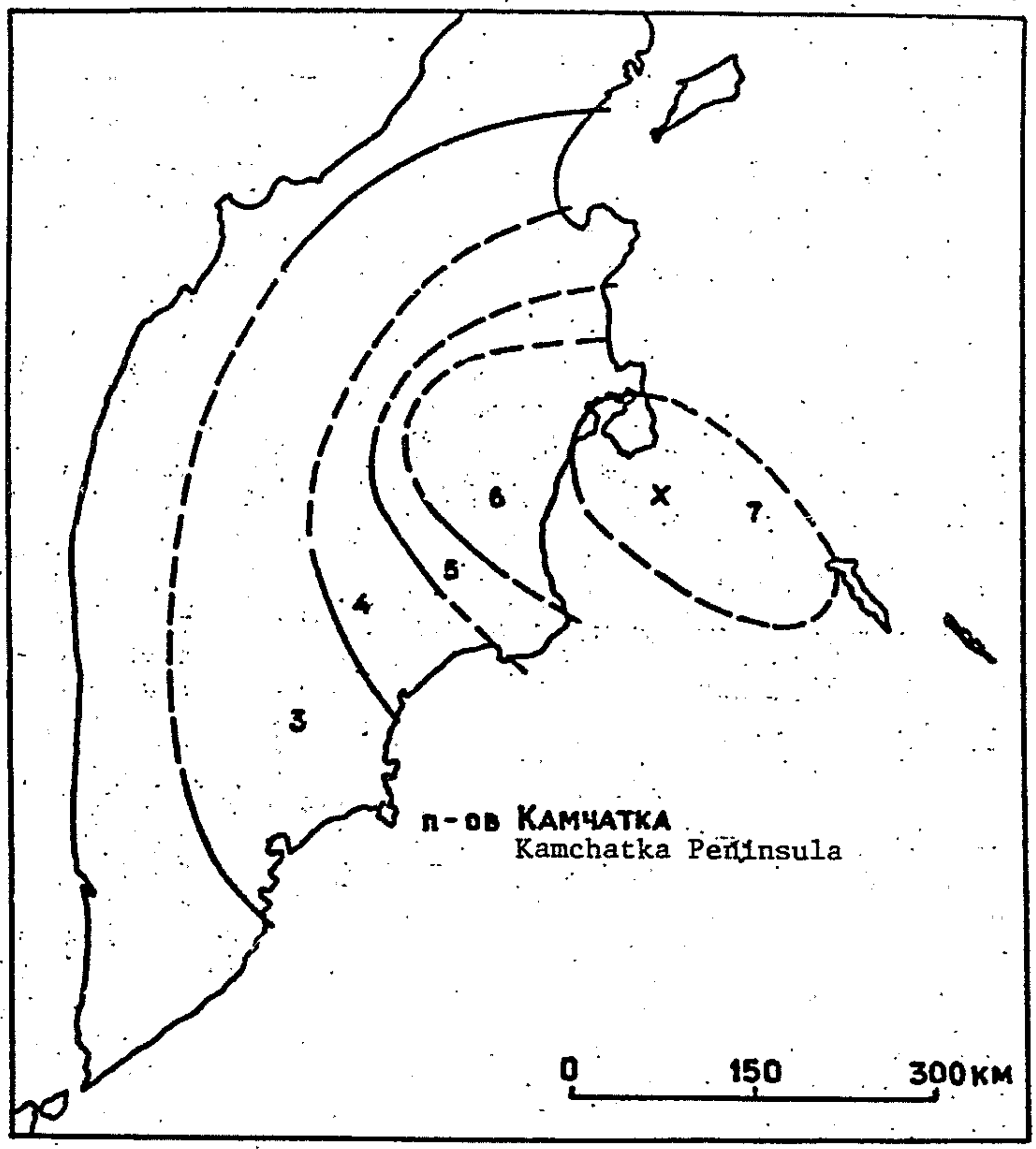


Figure 22: Surface effect and epicenter of the earthquake and source of the tsunami of December 15, 1971.
[The Ust'Kamchatskoe earthquake..., 1975].

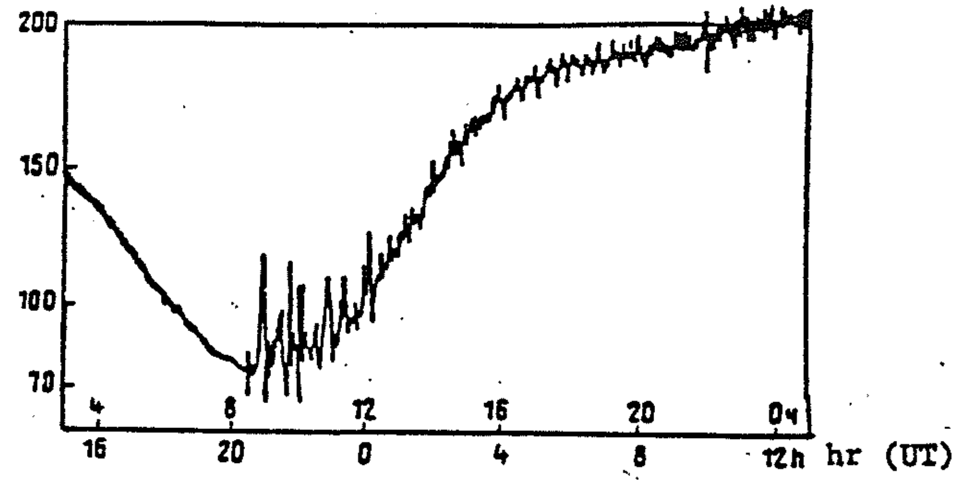


Figure 23: Record of tsunami of December 15, 1971 in Ust'Kamchatsk [Lazo and Men'shikov, 1973].

January 25, 1972; 10 hr 06 min. An earthquake occurred on Taiwan, generating a weak tsunami. It was felt with a maximum intensity of VII points (Rossi-Forel scale). It was also felt in Hong Kong at an intensity of IV and in Basco at V; it was felt at III in Ithayat Island (Batan Islands) and at Tuguegarao and Aparri on Luzon Island; it was felt at III (JMA scale) in the Ryukyu Islands and on Yonaguni Island; it was felt at II on Miyako Island.

A very weak tsunami with a height of 5 cm was recorded on Ishigaki Jima. No other data were available on this tsunami. [SN, Vol. 62, No. 5, 1972; Spaeth, 1974; Observations on Tsunami..., 1977; Soloviev, 1982; Watanabe, 1983].

[January 25; 02 h 06 m 23.3 s; 22.5° N. Lat., 122.3° E. Long.; 33 km; M = 7.0; I = -2].

February 29, 1972; 18 hr 23 min. A strong earthquake at a magnitude of 7.2 occurred in the region of Hachijo Jima and was accompanied by a weak tsunami, the first tsunami in this region since 1953. The earthquake was felt at an intensity of VI (JMA) on Hachijo Jima and caused some damage. In Tokyo it was felt at an intensity of IV which drew the attention of local residents.

The tsunami was observed along the entire coastlines of Honshu, Shikoku, and Kyushu Islands. Table 11 presents data from tide gauge observations and Figure 24 shows marigrams from this tsunami.

As shown in Table 11, the wave began with a rise in water level in some places and a drop in water level in others. Such a distribution of initial recordings is explained by the nature of the first movements at the source of the earthquake. The tsunami source (Figure 25) is located at the junction of the Japanese and Mariana trenches and adjoins the southern part of the 1953 tsunami source. The source is oriented along the Mariana trench. [Hatori, 1972a, 1975a; SN, Vol. 62, No. 5, 1972; Spaeth, 1974; Tsunamis occurring in Japan..., 1973; Soloviev, 1982; Watanabe, 1983].

[February 29; 09 h 22 m 59.8 s; 33.3° N. Lat., 140.8° E. Long.; 56 km; M = 7.2; I = ½].

Table 11: Tide gauge data on tsunami of February 29, 1972

Place	Travel time (min)	Initial wave		Height of the maximum wave (cm)
		Amplitude (cm)	Period (min)	
Hachinohe	?	-	-	7
Miyako	?	-	-	8
Ayukawa	72	+ 5	10	18
Onahama	55	+ 7	20	20
Hitachi	54 ?	+ 4	10	28
Nakaminato	56	+ 7	15	14
Katsuura	23	-22	12	22
Mera	24	-30	16	30
Oshima Island	22	- 3	12	4
Kozu Jima	34	- 5	12	8
Miyake Jima	25	- 7	6	18
Hachijo Jima	29 ?	- 5	-	-
Kurihama	28	+ 4	14	7
Aburatsubo	9 ?	-	-	12
Enoshima	?	-	-	10
Minamiizu	34	- 6	14	23
Omaezaki	53 ?	+ 6	10	24
Nagashima	70	-10	33	18
Owase	73?	- 7	15	16
Uragami	70	- 6	25	18
Kushimoto	71	- 7	17	23
Muroto	80	+10	12	16
Tosashimizu	98	- 4	18	16
Aburatsu	108	+ 6	22	17

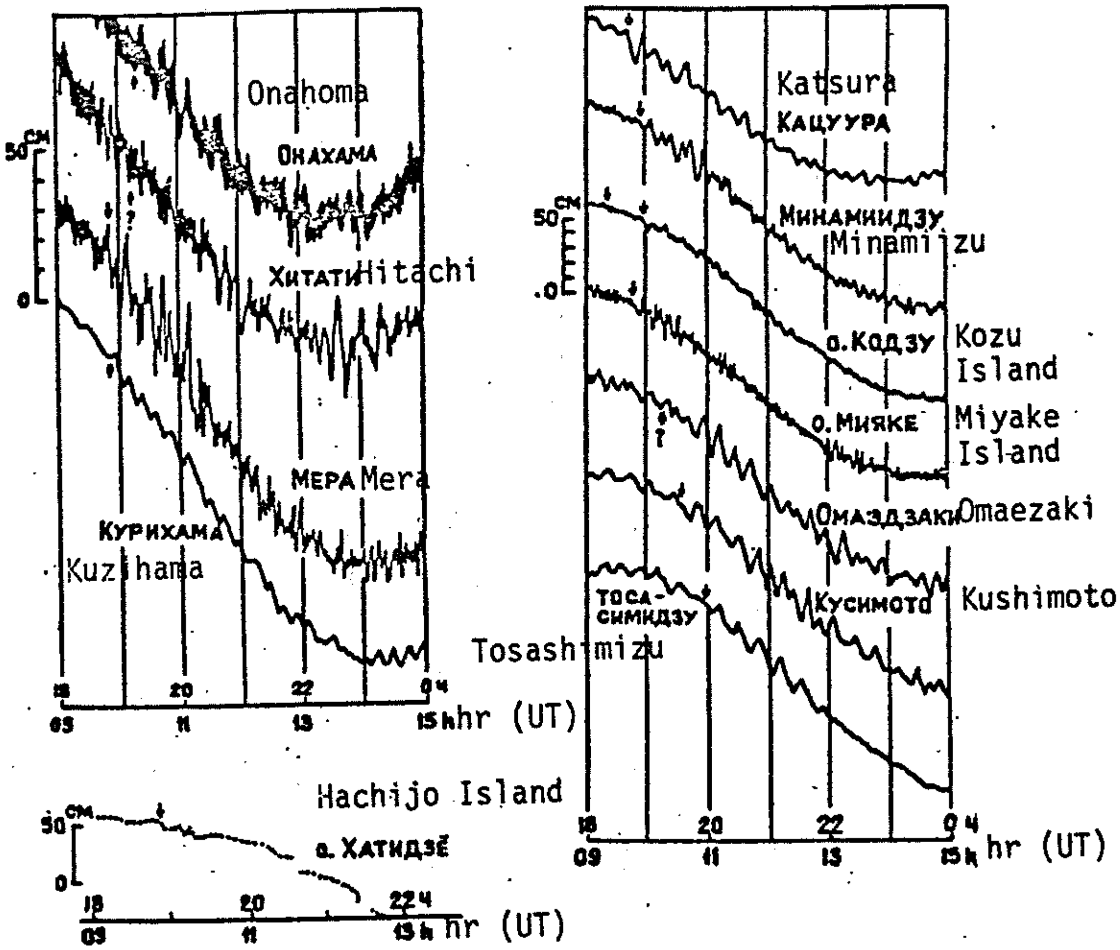


Figure 24: Records of tsunami of February 29, 1972 [Hatori, 1972a].

1509

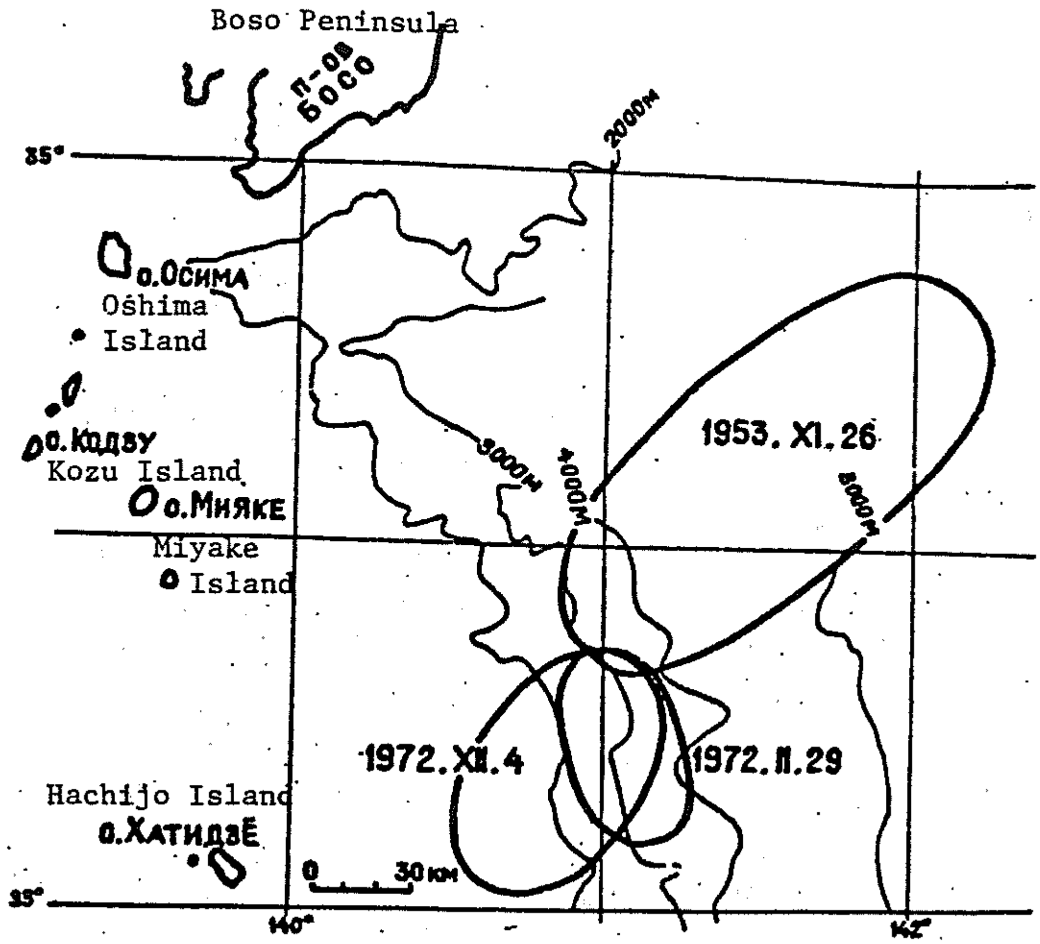


Figure 25: Sources of tsunamis of November 26, 1953, February 29, 1972 and December 4, 1972 [Hatori, 1972a].

<u>July 30, 1972; 12 hr 45 min</u>. A strong earthquake with a magnitude of 7.6 occurred in the region of Sitka, Alaska in the USA. Information obtained from responses to a questionnaire shows that it was felt throughout Alaska over a 50,000 km^2 area.

A maximum intensity of 6 points was recorded at Sitka where chimneys cracked and in isolated cases overturned. Walls vibrated, items fell from grocery store shelves, and water mains were reported as not working. The 6 point shaking was registered in Atoss Lake, 54 km south of Sitka.

A weak tsunami was observed in Sitka and in Juneau. As shown by the tide gauge records (Figure 26) the wave height did not exceed 20 cm and its period was about 10 min. [SN, Vol. 63, No. 2, 1972; NL, Sept. 15, 1972; Spaeth, 1974; Soloviev, 1982]. 1509

[July 30; 21 h 45 m 14.1 s; 56.8° N. Lat., 135.7° W. Long.; 25 km; M = 7.6; I = -2].

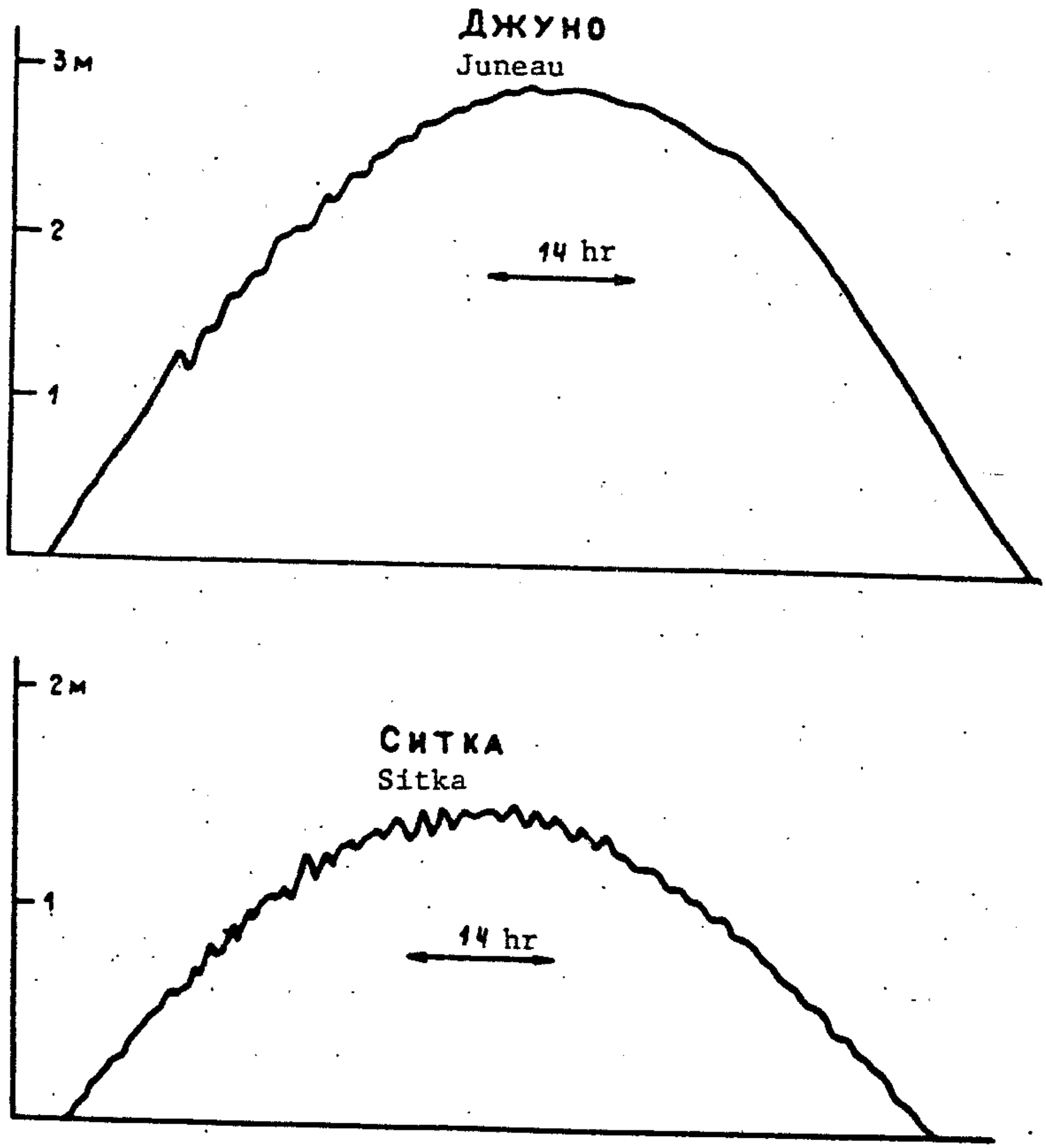


Figure 26 (pages 47 & 48): Records of tsunami of July 30, 1972 [NL, 1972a].

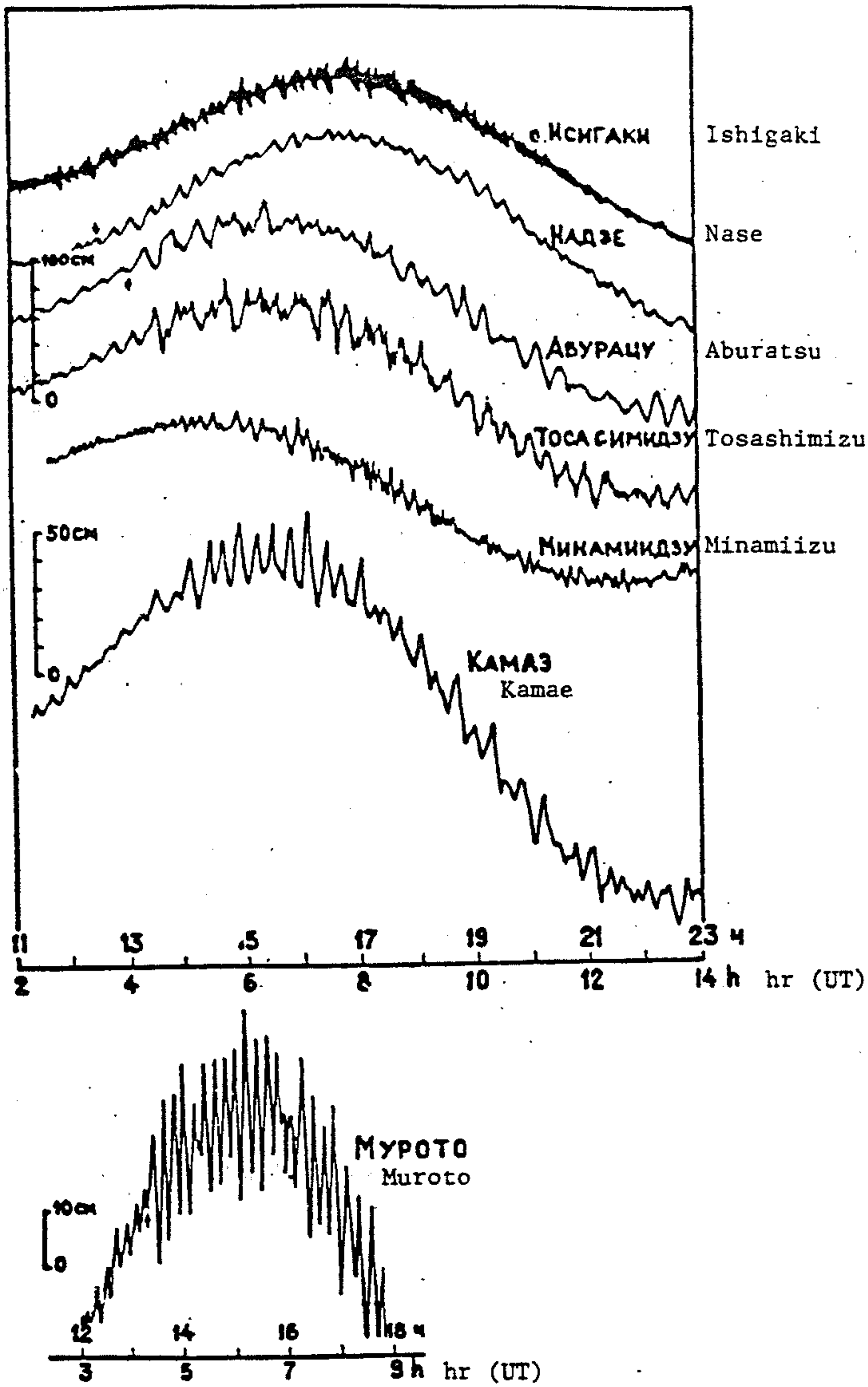


Figure 26 (continued)

August 18, 1972; 09 hr 44 min. A strong earthquake occurred on New Ireland. It was felt at intensities of V points in Rabaul and Pal Malmal, IV-V points in Bahana, IV points in Chuava and Pomia, III-IV points in Ulamona, III points in Bolubolu, Buka, and Arawa, and II points in Port Moresby and Popondette (Rossi-Forel scale).

A tidal wave at a height of 60 cm was recorded in Pomio [SI, No. 1426; SN, Vol. 63, No. 2, 1973; Everingham, 1974, 1976, 1977; Spaeth, 1974; Soloviev, 1982].

[August 17; 23 h 44 m 05.9 s; 6.0° S. Lat., 152.9° E. Long.; 10 km; M = 7.0; I = 0].

August 26, 1972; (about) 18 hr 15 min. Unusual waves were observed in Woko Point Harbor in Lae. According to an eyewitness account, the wave arrived in the open gulf/harbor and passed by; another wave appeared with much greater force, flooded one boat, and threw another boat ashore. The interval between the first and second waves was about 2 min. Sea level rose to 1.5 m above normal, followed by a drop to 0.9 m below normal.

About 3 km from Woko Point, at the main pier of Lae, a drop in sea level was observed at 18 hr 10 min (± 3 min) local time and continued for 10 min. The maximum was 4 cm. The drop in level may have been preceded by a small rise of short duration but the instrument in use was not designed for recording such oscillations.

Between 18 hr 11.5 min and 18 hr 30 min local time, a seismograph positioned 8 km from the coast, near the Technological Institute at Lae, recorded tremors which may not have been caused by the earthquake, but by underwater slumps which may have been the cause of these unusual tsunami-type sea waves. [Everingham, 1977].

December 2, 1972; 08 hr 20 min. An earthquake occurred on the Philippines. In Davao, the earthquake was felt at an intensity of VI points on the Rossi-Forel scale. Damage to structures was reported.

A weak tsunami was observed. Its height on Yap Island was 18 cm; on Guam, 9 cm; on Ryukyu Islands, 50 cm. The tsunami was also observed on the Pacific coast of Japan (Table 12, Figure 27). [SN, Vol. 63, No. 4, 1973; "Tsunamis occurring in Japan...", 1973; Hatori, 1974a; Spaeth, 1974; Soloviev, 1982; Watanabe, 1983].

[December 2; 00 h 19 m 47.2 s; 6.5° N. Lat., 126.6° E. Long.; 33 km; M = 7.4; I = 0].

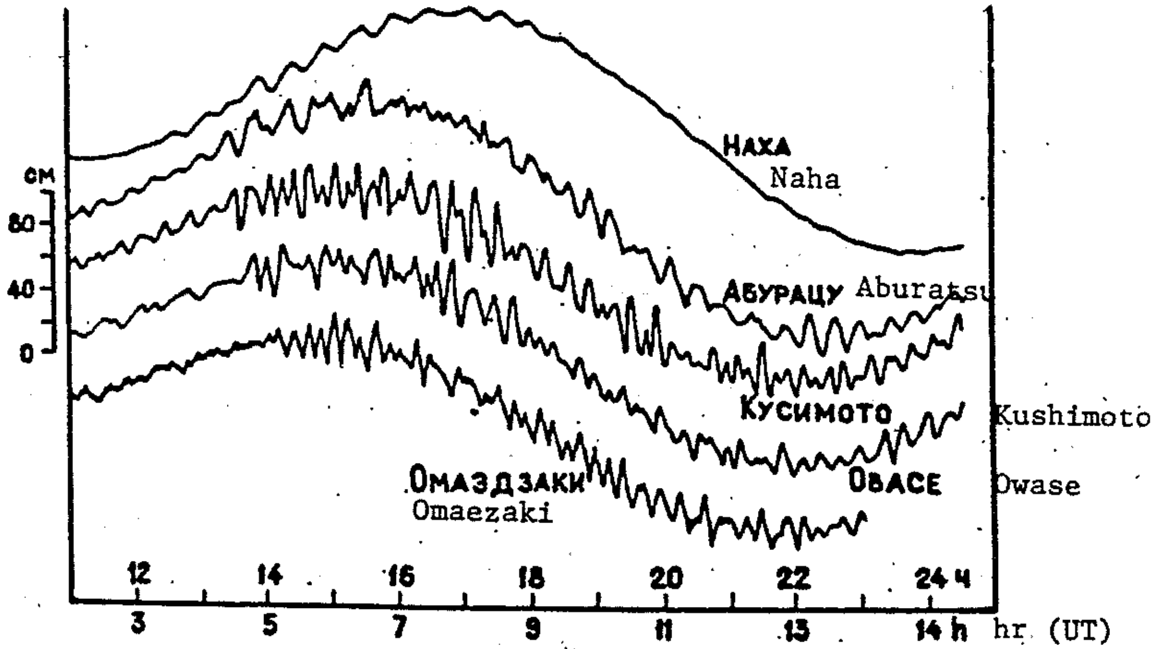


Figure 27: Records of tsunami of December 2, 1972 [Hatori, 1974a].

Table 12: Tide gauge data on tsunami of December 2, 1972 on the coast of Japan

Place	First wave Travel time (hr min)	Rise (cm)	Period (min)	Height of the maximum wave (cm)
Ishigaki Jima	02 35 ?	4	15	14
Nase	03 06	-4	20	12
Nishinoomote	03 45	2	15	16
Aburatsu	03 47	8	25	24
Hosojima	03 48	3	-	12
Kamae	04 02	6	20	26
Tosashimizu	04 00	20	22	44
Muroto	04 00	10	14	33
Kushimoto	04 02	12	18	46
Uragami	04 00	4	15	34
Toba	?	-	-	7
Maisaka	04 35	4	10	8
Omaezaki	04 38	4	10	35

Minamiizu	04 35	4	10	26
Izu-Oshima	?	-	-	-
Kozu Jima	?	-	-	20
Miyake Jima	04 23 ?	4	5	17
Hachijo Jima	04 15	8	13	30
Kurihama	04 40 ?	2	10	13
Mera	04 40	8	12	30
Katsuura	04 42	4	12	11
Choshi	?	-	-	-
Ooarai	04 48	6	12	17
Hitachi	05 10 ?	5	8	23
Onahama	05 00	5	15	22
Ayukawa	05 40 ?	6	8	18
Enoshima	?	-	-	-
Miyako	?	-	10	-
Hachinohe	?	-	9	-
Kushiro	?	-	10	-

<u>December 4, 1972; 19 hr 16 min</u>. An earthquake occurred in the region of Hachijo Jima at approximately the same place as the earthquake of February 29, 1972 (see Figure 25). It was felt at an intensity of VI points (JMA) on Hachijo Jima where landslides and destruction of structures were reported. South of Honshu, the intensity was IV points.

The press reported that in some places roads were damaged. On Hachijo Jima, telephone and electric power lines were severed. Trains in the Tokyo area were delayed for 15 min. Windows were shattered and flower vases fell. High-rise buildings shook. The water supply to 2,500 apartments was affected and nearly 10,000 people evacuated their homes.

The height of the tsunami generated by this earthquake was 50 cm on Hachijo Jima (Figure 28, Table 13). The tsunami was also observed in the southern part of Honshu. Interestingly, the tsunami was weaker than the tsunami caused by the earthquake of February 29, 1972, although the earthquake magnitude was higher than that of the earlier earthquake. This is possibly explained by the source of this earthquake being at a greater depth than the earlier one. [Hatori, 1973; SN, Vol. 63, No. 4, 1973; Tsunami Occurring..., 1973; Spaeth, 1974; Soloviev, 1982; Watanabe, 1983].

[December 4; 10 h 16 m 12 s; 33.3° N. Lat., 140.7° E. Long.; 66 km; M = 7.4; I = -1].

Table 13: Tide gauge data on the tsunami of December 4, 1972 on the coast of Japan

Place	First wave: Travel time (min)	First wave: Amplitude (cm)	Maximum height of the wave (cm)
Hanasaki	?	-	10
Kushiro	?	-	6
Hachinohe	?	-	8
Miyako	72	+ 3	9
Enoshima	70	+ 4	5
Ayukawa	70	+ 7	16
Onahama	55	+10	28
Hitachi	53	+ 9	45
Nakaminato	53	+ 9	16
Ooarai	52	+10	32
Katsuura	23	+ 8	21
Mera	24	+ 9	41
Kurihama	35	+ 4	13
Aburatsubo	32	+ 3	6
Oshima Island	22	+ 3	7
Kozu Jima	32	- 6	27
Miyake Jima	25	- 8	20
Hachijo Jima	24	+14	40
Minamiizu	38	- 8	25
Shimaizu	54	+ 4	5
Omaezaki	55	+10	48
Maisaka	62 ?	+ 3	5
Toba	?	-	3
Owase	73	+ 8	20
Uragami	72	+ 8	44
Kushimoto	68	-20	48
Shirahama	-	-	8
Wakayama	-	-	5
Kochi	-	-	6
Muroto	86	-18	30
Tosashimizu	100 ?	- 6	20
Kamae	110	-10	24
Aburatsubo	118	-	-
Nishinoomote	150	- 6	10

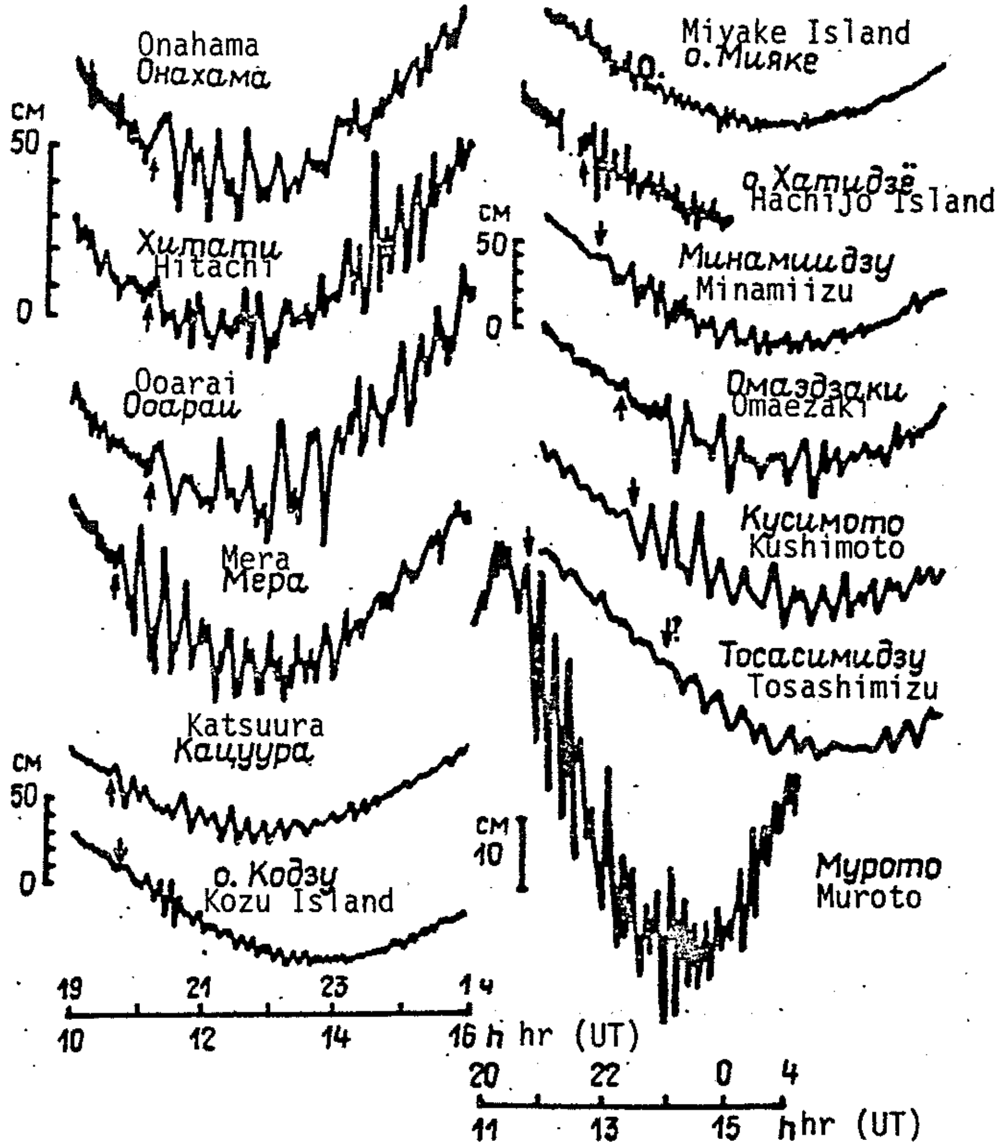


Figure 28: Record of tsunami of December 4, 1972 [Hatori, 1973].

<u>January 30, 1973; 15 hr 01 min</u>. A strong earthquake occurred in Michoacan, a state of west/central Mexico, causing destruction in the valleys of Michoacan, Colima, and western Jalisco. The source region of the earthquake was not densely populated. Due to the inaccessibility of the location, little information was received from the area. In all, 56 people died and a few hundred were injured. The cities of Tecoman and Coahuayana sustained the most severe damage. In Manzanillo, the earthquake injured livestock and damaged roads. Several houses collapsed in the cities of Colima and Ciudad Guzman. In other cities, damage was limited to cracks and falling plaster in houses. Many landslides and ground cracks were discovered over a large but sparsely populated area on the coast of Michoacan. In Mexico City, strong

ground tremors continued for about 40 seconds. Motor vehicle traffic was disrupted on major roads. Damage to windows and decorations on building fronts could be seen, mainly in high-rise buildings located in the commercial area of Mexico City. Strong ground tremors occurred, most of which lasted for periods of 2 seconds.

A weak tsunami with a maximum height of 1 m was observed. Information on the destruction caused is not available. The tsunami was also recorded at locations outside of Mexico. The tide gauge data is listed below.

Place	Height, cm
Mexico	
Manzanillo	116
Acapulco	40
Oceania	
Pago Pago	21
Hawaii	
Hilo	21
Kahului	21
Nawiliwili	6

[SI, No. 1574; NL, Vol. 7, No. 1, 1974; SN, Vol. 63, No. 5, 1973; "1973 earthquakes activity", 1974; Spaeth, 1975; Soloviev, 1982].

[January 30; 21 h 01 m 12.5 s; 18.5° N. Lat., 103.0° W. Long.; 43 km; M = 7.5; I = 0].

February 28, 1973; 17 hr 38 min. A strong earthquake occurred 35 km east of Severo-Kuril'sk (Paramushir Island) causing ground tremors at an intensity of 7 points in the city. The seismic shock, whose epicenter lay at a depth of 70 km below the ocean bottom, produced tsunami waves which reached the coast of the Kuril Islands at a height of 1.5 m.

Isoseismal lines have been drawn according to the macroseismic data (Figure 29). All isoseismal lines are elongated in the northeastern direction, approximately paralleling the direction of the Kuril-Kamchatka island arc, and are somewhat compressed in the west.

The earthquake was also felt in Hiroo and Urakawa (Hokkaido) at an intensity of I point (JMA). [SN, Vol. 63, No. 5, 1973].

Due to stormy weather and snow drifts, eyewitness accounts of the onset of the tsunami are very fragmentary with information available only from Cape

Vasil'eva on the southern tip of Paramushir Island. L.V. Sharov, the head of the local hydrometeorological station, reported that for 20-25 min the waterline receded from 100 to 200 m and that two anomalous rises in water were noticed at heights of 40 cm and 80 cm. According to visual observations, the wave period was between 4 and 6 min. The first wave was noticed at Cape Vasil'eva at 18 hr 30 min, 52 minutes after the initial shock. Considering that the first weak tide of the wave was missed by the observer, the travel time of the wave from its source to the coast may be estimated at 48-49 min. Other visual observations are not available.

A tsunami was recorded at three tide gauge locations: at the hydrometeorological stations at Severo-Kuril'sk, at Shumshu, and at Matua. At the Matua station, the wave record is not easily distinguished from the coinciding wind wave records. The major data on tsunami parameters from the tide gauge records are presented in Table 14.

Figure 29 shows the surface effect of the earthquake; Figure 30 shows the tsunami source as constructed from the tide gauge records; Figure 31 gives the records for this tsunami. The tsunami was also observed at Attu and Shemya Islands at heights of 21 cm and 15 cm respectively. [NL, Vol. 7, No. 1, 1974; Spaeth, 1975; Oskorbin et al., 1976b, 1977b; "New catalog of strong earthquakes...", 1977; Shchetnikov, 1977a; Soloviev, 1978a, 1982].

[February 28; 06 h 37 m 49.5 s; 50.5° N. Lat., 156.3° E. Long.; 70 km; M = 7.5; I = 0].

Table 14: Tide gauge data on the tsunami of February 28, 1973

Place	First wave		Maximum wave		
	Travel time (min)	Amplitude (cm)	Amplitude (cm)	Period (min)	Duration of oscillations (hr)
Severo-Kuril'sk	22	+76	76	40	30
Shumshu Island	07	-(3-4)	60	32	30
Matua Island	42	+ 7	?	?	3

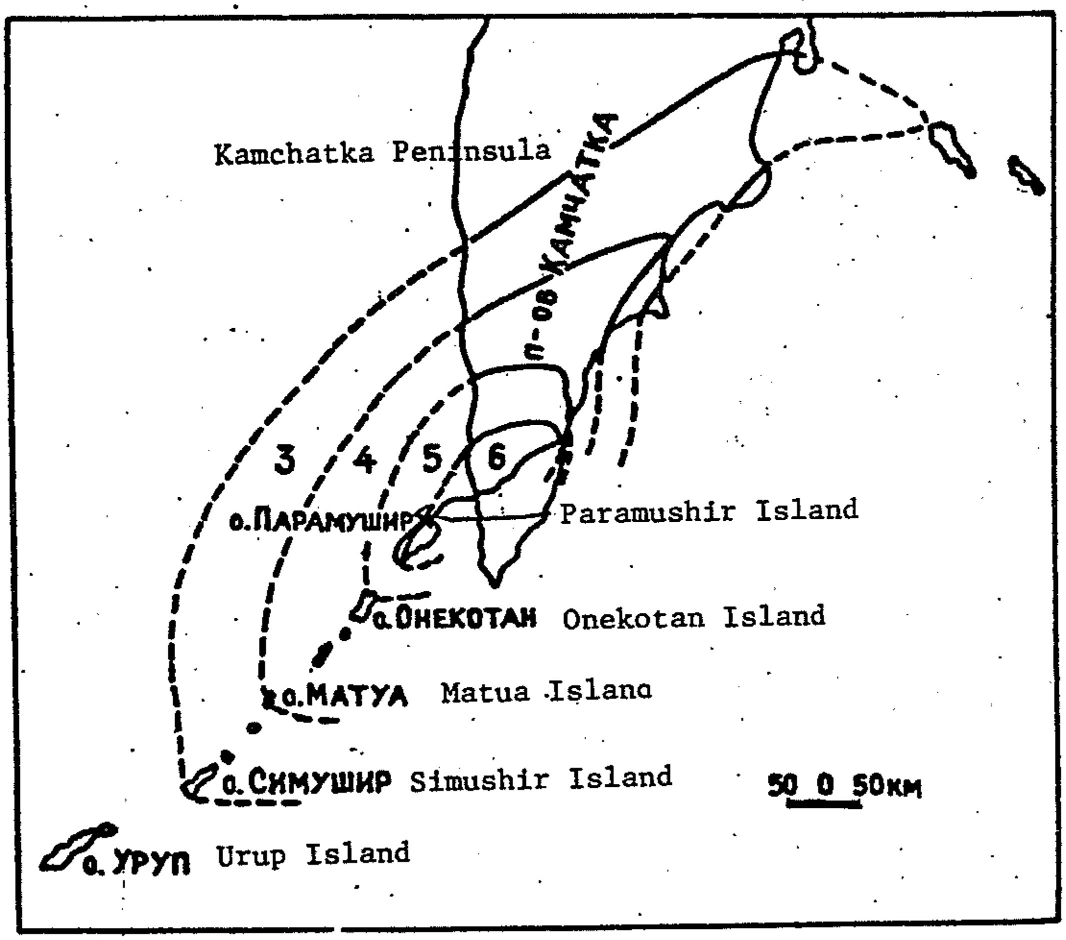


Figure 29: Surface effect of February 28, 1973 earthquake [Oskorbin et al., 1977]

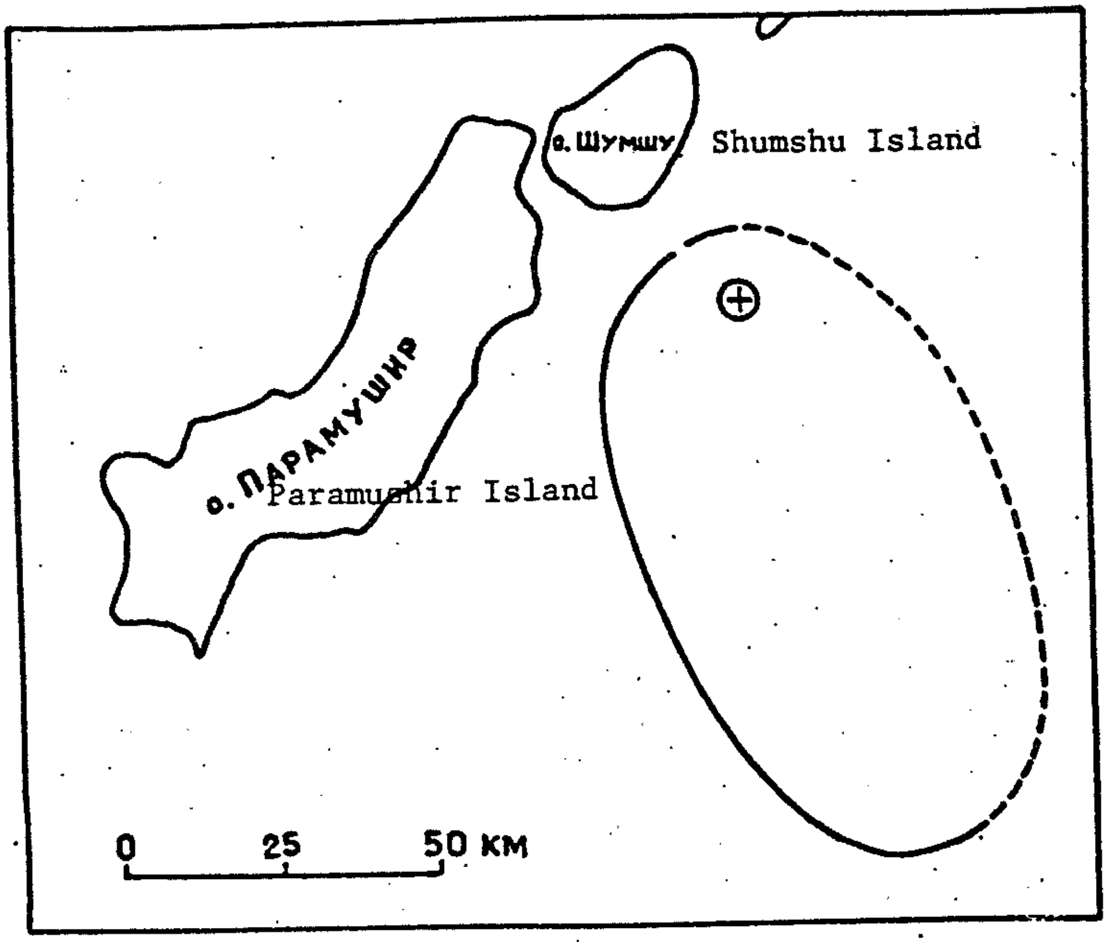


Figure 30: Epicenter of the earthquake and source of the tsunami of February 28, 1973 [Shchetnikov, 1977a]

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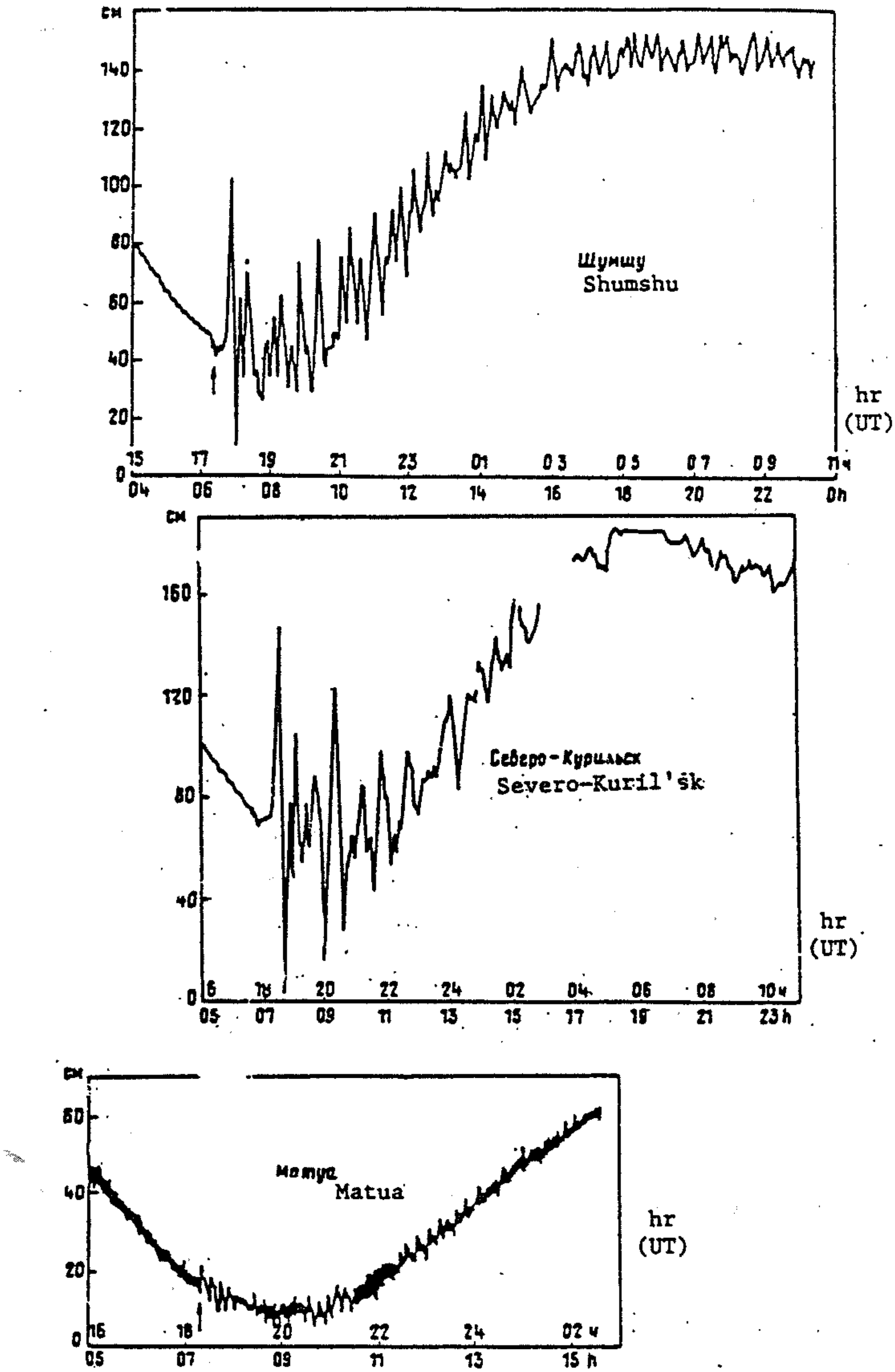

Figure 31: Records of the tsunami of February 28, 1973
[Shchetnikov, 1977a]

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May 30, 1973. A submarine volcano named Nishino-Shima-Shinto (27.15° N. Lat., 140.53° E. Long.) erupted in Japan. The explosion was of the strombolian type. Decolorization of the water occurred. Volcanic ash was thrown to a height of 1.4 km. Lava flows also occurred. The eruption resulted in the formation of an island with an area of 0.12 km^2 and a height of 52 m above sea level. During 1973 the island's size increased to 0.175 km^2 (700 m x 250 m). The active crater, located 40 m above sea level, continued normal activity during the eruption. [Gushchenko, 1979; SI, No. 1712].

June 17, 1973; 14 hr 55 min. Near Tanfil'eva Island (Malyi Kuril Ridge), a magnitude 8.0 earthquake occurred at a depth of 50 km. It produced a tsunami on the coast of the Kuril Islands and Japan. The earthquake began with two strong shocks followed by weaker tremors which continued for 1-1.5 min. The earthquake was preceded by a rumble that was heard on the islands of the Malyi Kuril Ridge and resembled the sound of a jet airplane. Residents of the Kunashir Island village of Golovnino described the rumble as sounding like "underground grinding". It was also heard in Sernovodsk (Kunashir Island), on Iturup Island and on Urup Island where it was heard as a rumble from the sea.

The maximum intensities of 7-8 points were reached on the Zelenyi, Yurii, and Tanfil'eva Islands and on the Veslo Bar near Golovnino village. Domestic ovens cracked, plaster peeled off, and in some places chimneys were damaged.

On Polonskii and Anuchina Islands and in several inhabited areas of the southern part of Kunashir Island the intensity of the tremors was slightly less than 6-7 points. In Yuzhno-Kuril'sk, the earthquake was felt at an intensity of 6 points; on Shikotan Island it exceeded 6 points. In Kuril'sk (Iturup Island) the earthquake was felt by approximately 75% of the population. The highest intensity here was 4-5 points which was felt in the lower areas of the city close to the sea. On Urup Island, the earthquake was felt indoors and on roadways at a force of 3-4 points. The isoseismal lines which are drawn from tide gauge data are shown in Figure 32.

Some destruction was reported from Hokkaido. In Nemuro and Kushiro, the earthquake was felt at an intensity of V points (JMA). In some places the highway was destroyed by cracks. Twenty-seven people were injured, nine of them seriously. Most of the injured had been hurt by falling fragments. The Japan National Railways temporarily discontinued service on some routes to survey for possible damage. Water and electrical power were shut off for some time. On Honshu, the earthquake was felt at an intensity of III points (JMA).

This earthquake produced a tsunami which caused damage to structures on the coast of Nemuro Island. The tsunami was recorded by tide gauges on Kuril Island and the Pacific Coast of Japan (Figure 33). The main parameters of the tsunami are presented in Table 15.

As shown by the analysis of available observation data, the maximum deviation in the ocean level (152 cm) was recorded at Hanasaki (Hokkaido). On the Kuril Islands, the maximum deviation (86 cm) was recorded in

Malokuril'skoye (Shikotan Island). The wave records from Yuzhno-Kuril'sk do not give an accurate representation due to the tide-gauge having a clogged feed pipe. [Shchetnikov, 1977b].

Visual observations reported tsunami heights up to 1 m in Golovnino (Kunashir Island), up to 1.5 m on the Polonskogo and Tanfil'eva Islands, and up to 0.5 m on Zelenyi Island. On the coast of the Nemuro Peninsula the tsunami reached a height of 2 m. A large number of fishing schooners were either damaged or washed out to sea; 26 schooners were destroyed or capsized; 200 houses were flooded; 300 tons of fish were washed away from the stores. The Tsunami Information Center in Honolulu reported that 30,000 residents were evacuated due to a warning; this warning was soon lifted. The tsunami source as constructed from the reverse wave fronts is shown in Figure 34. Tide-gauge records of the first arrivals show a tsunami which indicates a thrust-shift movement at the source of the earthquake. The energy of the tsunami was estimated at 1.65×10^{20} erg. [SI, No. 1657, 1670; Matsumoto, 1974; Shchetnikov, 1977b; Hatori, 1974b, 1975b, 1976b; NL, Vol. 7, No. 1, 1974; SN, Vol. 64, No. 1, 1974; "1973 earthquake activity...", 1974; Spaeth, 1975; Oskorbin et al., 1976a, 1977a; Observations on tsunamis..., 1977; Soloviev, 1978a, 1982; Watanabe, 1983].

[June 17; 03 h 55 m 02.9 s; 43.1° N. Lat., 145.9° E. Long.; 50 km; M = 8; I = 1].

Table 15: Tide gauge data on the tsunami of June 17, 1973

	First wave			
Place	Travel Time (hr min)	Amplitude (cm)	Period (min)	Height of the maximum wave (cm)
<u>Kuril Islands</u>				
Malokuril'skoe	00 27	23	32	140
Yuzhno-Kuril'sk	01 45	23	5	25
Burevestnik	00 54	21	25	68
Kuril'sk	02 18	12	5	33
Severo-Kuril'sk	-	-	-	?
<u>Japan</u>				
Wakkanai	03 06 ?	38	5	8
Mombetsu	02 00	22	4	10
Abashiri	01 34	17	4	10
Hanasaki	00 24	18	150	150
Kushiro	00 31	18	40	48

Hiroo	00 44	20	105	105
Shyoya	?	-	100	100
Urakawa	00 53	10	15	45
Tomokomai	01 10	16	6	21
Muroran	01 22	50	8	14
Yamasedomari	01 05	12	8	17
Hakodate	01 28	30	6	27
Same	01 08	47	10	19
Hachinohe	01 12	12	31	50
Kuji	?	-	44	44
Shimanokoshi	00 40	10	40	40
Taro	?	10	45	45
Miyako	00 53	10	30	40
Kamaishi	01 00	11	30	40
Nagasaki	01 00	12	18	16
Kesennuma	01 00	20	20	30
Enoshima	01 06	10	10	-
Ayukawa	01 11	8	15	22
Matsukawaura	01 25	10	10	24
Onahama	01 25	18	10	17
Hitachi	01 40	12	11	20
Ooarai	01 42	12	12	13
Choshi	01 30	38	8	17
Katsuura	01 20	12	5	6
Mera	01 25	20	4	10
Omaezaki	02 00 ?	20	6	13
Nagashima	02 15	32	8	11
Owase	02 25 ?	26	4	12
Kushimoto	02 20	18	5	24
Tosashimizu	02 57 ?	20	4	10
Kamae	03 20 ?	15	6	10
Aburatsu	03 53 ?	18	4	9
Odomari	03 55	10	8	12

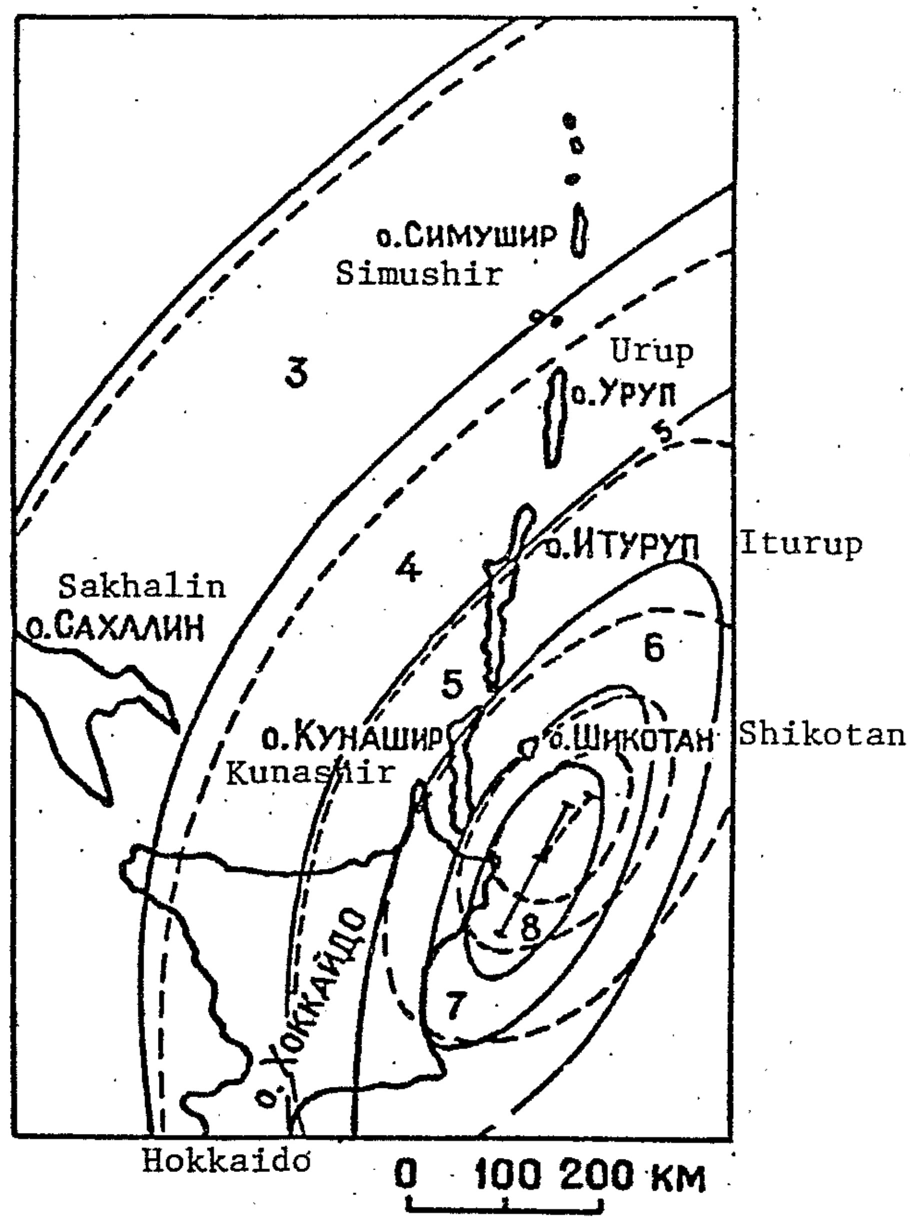

Figure 32: Surface effect of the earthquakes of June 17, 1973 (solid lines) and June 24, 1973 (broken lines) [Oskorbin et al.. 1977a]

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Figure 33 (pages 63 & 64): Records of tsunami of June 17, 1973 on Kuril Islands and in Japan
[Shchetnikov, 1977b; Hatori, 1974b]

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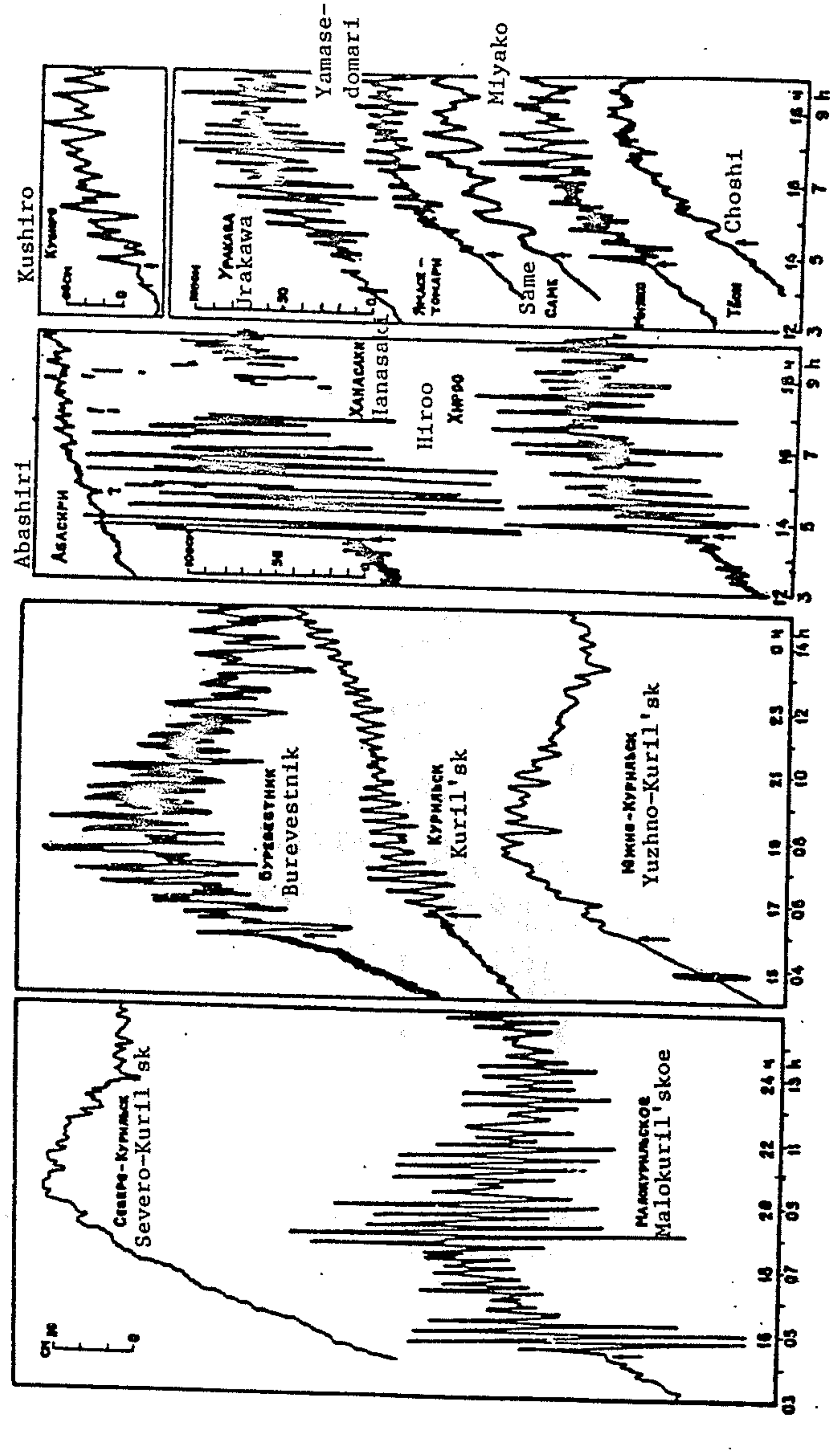
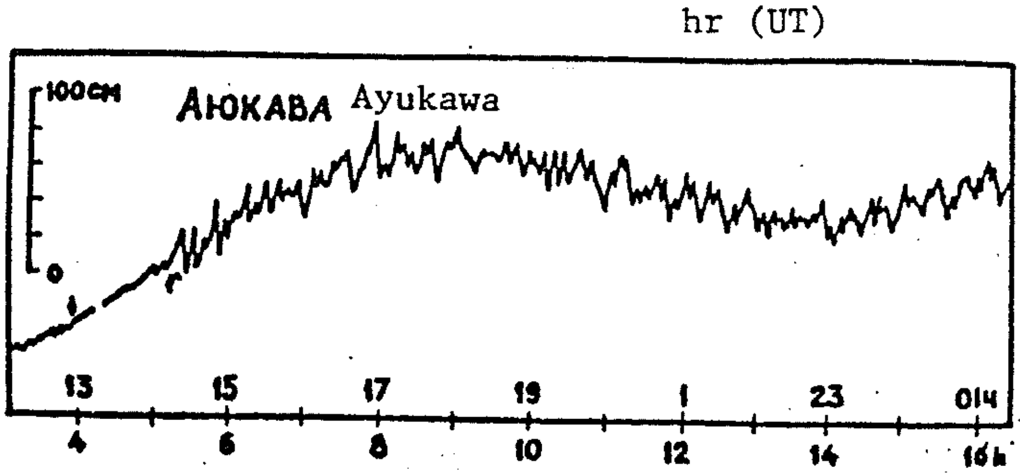


Figure 33 (continued)



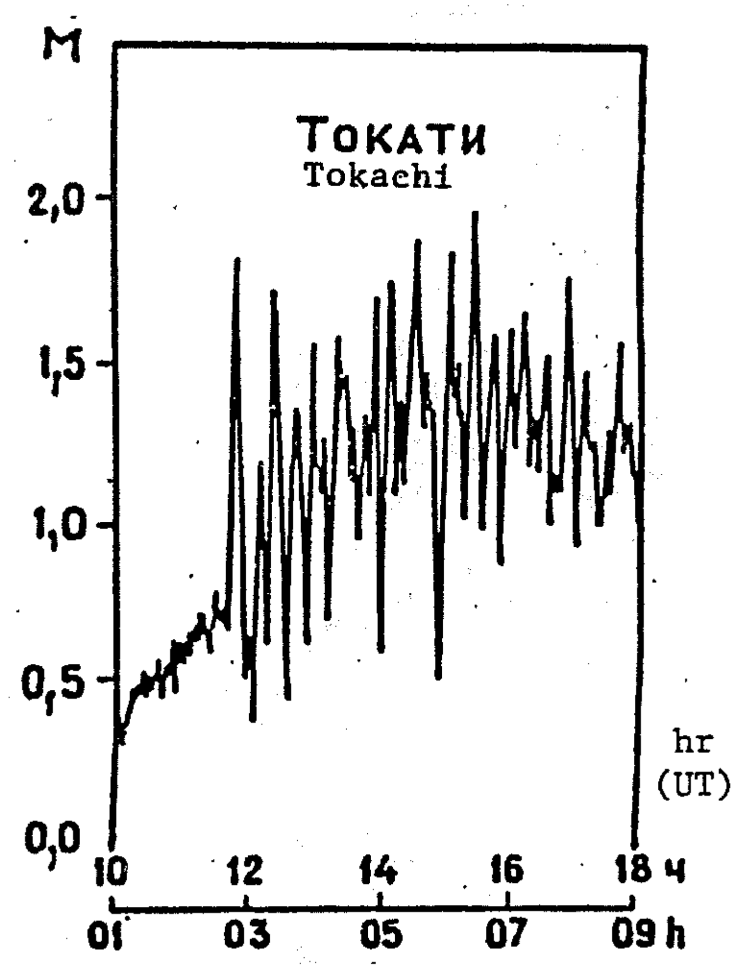


Figure 33 (continued)

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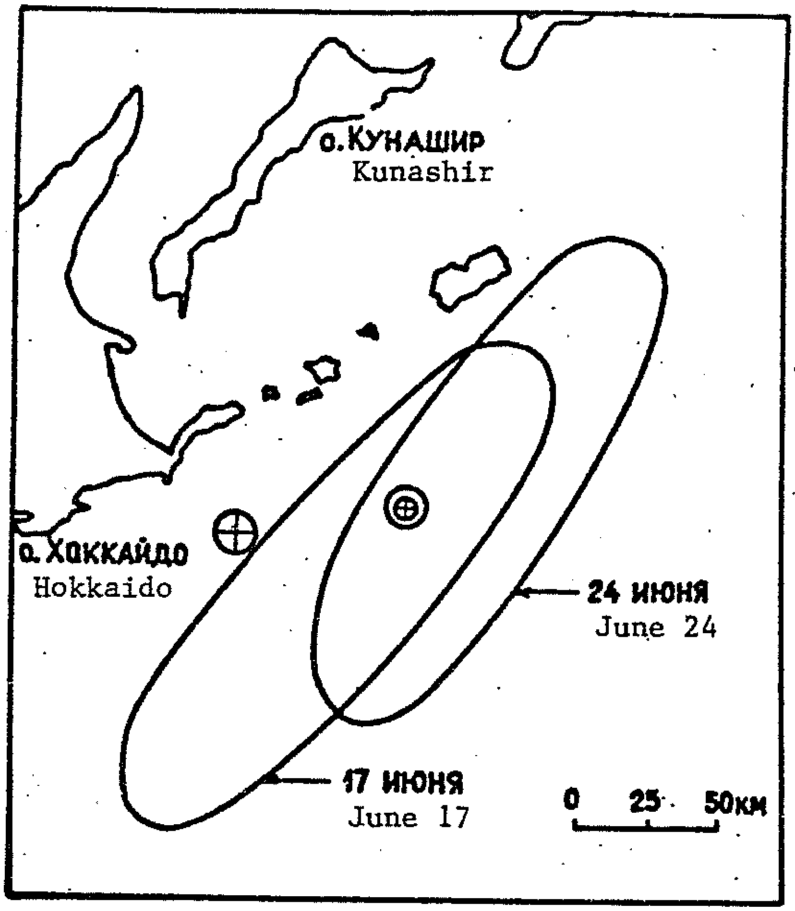

Figure 34: Epicenters of earthquakes and sources of tsunamis of June 17 and 24, 1973 [Shchetnikov, 1977b].

June 24, 1973; 13 hr 43 min. A strong earthquake of magnitude 7.5 occurred near the source region of the earthquake of June 17. Its hypocenter was located 60 km northeast of the hypocenter of the June 17 earthquake and was at a depth of 50 km. This earthquake continued for less than 1 min, a shorter duration than the earlier earthquake.

A comparison of the effects of these two earthquakes shows that the earthquake of June 24 was weaker in many regions and caused virtually no additional destruction of structures. Only in Goryachi Plyazh and Golovnino (Kunashir Island) was the underground shock of June 24 felt at a stronger intensity than that of June 17. In Goryachi Plyazh, the earthquake greatly alarmed the population, causing some frightened people to jump out of windows of their homes. Golovnino residents reported that the second earthquake was stronger than the earlier one. In the region of the Mendeleev volcano, no changes could be noticed in fumarole activity. However, water from the spring became turbid. Bus passengers traveling from Mendeleevo to Yuzhno-Kuril'sk could not feel the earthquake and learned of it only upon arrival at the city center. Data from Japan also indicated that the earthquake was felt at an intensity of not more than 5 points. The rumble from the June 24 earthquake was heard at a lesser distance; for example, it was not even noticed on Urup and Iturup Islands. The underground shock of June 24 was also weaker in magnitude than the June 17 shock, although it happened at the same distance from the island arc. The isoseismal lines from both earthquakes are shown in Figure 32.

The earthquake produced a tsunami which was observed on the coasts of the Kuril Islands and of Japan. It was weaker than the tsunami of June 17. On the tide gauge records (Figure 35), the tsunami begins with a rise in water level. A contour of the tsunami source has been constructed from the tide gauge records (see Figure 34). The principal parameters of the tsunami are given in Table 16.

According to Shchetnikov, the energy of the tsunami was equal to 2.8 x 10^{19} erg. [SI, No. 1665; Matsumoto, 1974; NL, Vol. 7, No. 1, 1974; Hatori, 1974b, 1975b, 1976b; SN, Vol. 64, No. 1 1974; "1973 earthquake activity...", 1974; Spaeth, 1975; Oskorbin et al., 1976a, 1977a; Shchetnikov, 1977b; Soloviev, 1978a, 1982; Watanabe, 1983].

[June 24; 02 h 43 m 25.5 s; 43.1° N. Lat., 146.5° E. Long.; 50 km; M = 7.5; I = 0].

Table 16: Tide gauge data on tsunami of June 24, 1973

	First wave			
Place	Travel time (hr min)	Period (min)	Amplitude (cm)	Height of the maximum wave (cm)
<u>Kuril Islands</u>				
Malokuril'skoe	00 18	23	09	56
Yuzho-Kuril'sk	01 06	26	3	8
Burevestnik	00 47	28	16	23
Kuril'sk	01 22	22	5	8
Severo-Kuril'sk	-	-	-	?
<u>Japan</u>				
Wakkanai	03 06 ?	15	3	8
Mombetsu	02 10	26	5	5
Abashiri	01 36 ?	26	3	3
Hanasaki	00 28	13	52	63
Kushiro	00 38	20	8	14

Hiroo	00 49	-	28	28
Shyoya	?	-	28	-
Urakawa	00 58	10	6	16
Tomakomai	01 14	18	4	8
Muroran	01 32 ?	44	2	6
Yamasedomari	01 12	11	5	7
Hakodate	01 42	16	5	8
Same	01 14	18	2	4
Hachinohe	01 18	12	9	9
Kuji	?	-	15	15
Shimanokoshi	00 45	10	13	13
Taro	?	8	15	15
Miyako	00 58	24	7	7
Kamaishi	01 12	20	12	14
Nagasaki	01 06	10	5	5
Kesennuma	01 15 ?	30	6	12
Enoshima	01 10	8	5	-
Ayukawa	01 20	10	4	10
Onahama	01 30 ?	10	4	12
Hitachi	?	-	-	5
Ooari	?	-	-	5
Choshi	01 37	8	4	4

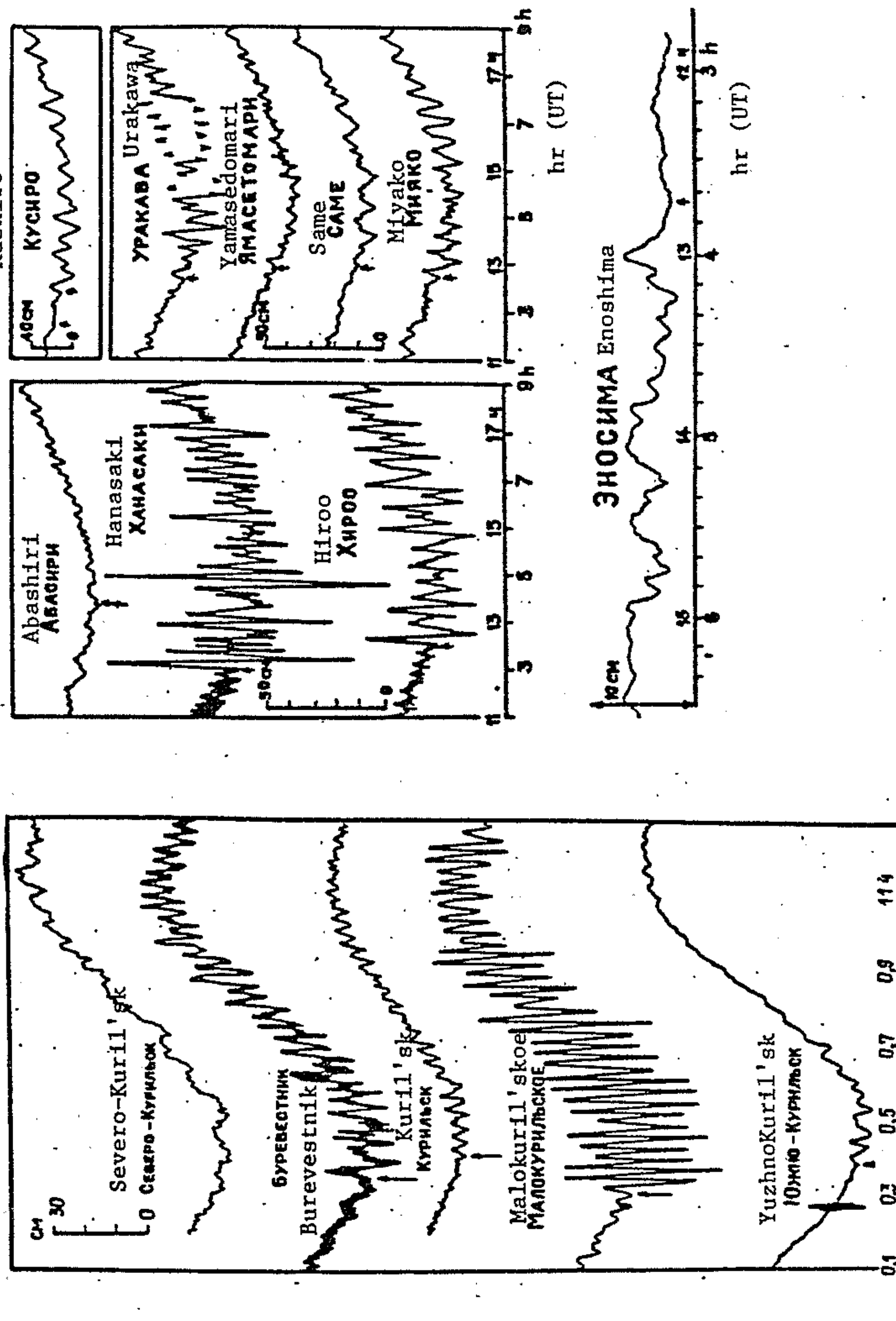

Figure 35: Records of the tsunami of June 24, 1973 on the Kuril Islands and in Japan [Hatori, 1974b; Shchetnikov, 1977b]

October 5, 1973; 00 hr 48 min. An earthquake occurred in central Chile at a magnitude of 6.9. It was felt in the region of La Ligua at an intensity of VII points (Rossi-Forel), in Valparaiso at VI points, and in Santiago at V points. A weak tsunami was observed in Valparaiso at a height of 40 cm. [NL, Vol. 7, No. 1, 1974; SN, Vol. 64, No. 3, 1974; "1973 earthquake activity", 1974; Spaeth, 1975; Soloviev, 1982].

[October 5; 05 h 47 m 51.5 s; 32.5° S. Lat., 71.5° W. Long.; 14 km; M = 6.9; I = -1].

February 1, 1974; 10 hr 30 min. An earthquake occurred on the Solomon Islands with a magnitude of 7.0. It was felt in Arawa at an intensity of V-VI and in Pangun at V points. It was also observed in Korovou and on Shortland Island.

The earthquake produced a local tsunami on the Solomon Islands. The police station at Korovou was flooded to 1.2-1.5 m. The tsunami was recorded by the tide gauges of Loloho, Anewa Bay at an amplitude of 7 to 8 cm (Figure 36). [NL, Vol. 7, No. 1, 1974; Vol. 8, No. 3, 1975; SN, Vol. 64, No. 5; "1974 earthquakes", 1975; Everingham, 1976; Spaeth, 1976; Soloviev, 1982].

[January 31; 23 h 30 m 05.8 s; 7.5° S. Lat., 155.9° E. Long.; 34 km; M = 7.0; I = 1].

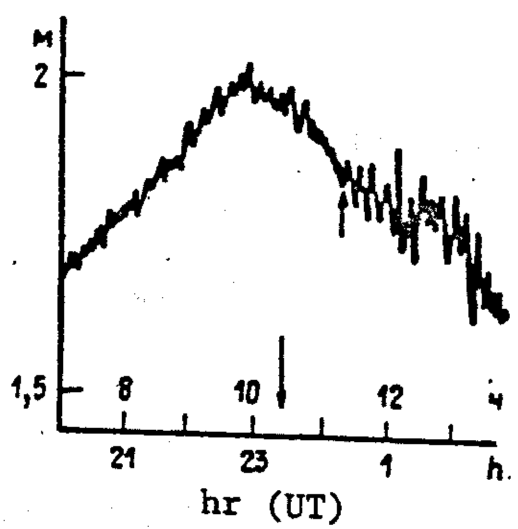

Figure 36: Record of the first tsunami of February 1, 1974 in Loloho [NL, 1974].

February 1, 1974; 14 hr 13 min. A second, stronger earthquake occurred on the Solomon Islands at a magnitude of 7.1. and was felt over an extensive region. The maximum intensity of VI points (Rossi-Forel) was felt on Bougainville Island.

This earthquake produced a tsunami which caused destruction in the Choiseul and Shortland Islands. Wharfs, roads and bridges were destroyed. There was no loss of life. The wave height was 3-4.5 m. Sea level rose approximately 1 m at Torokina, Bougainville Island. The tide gauge in Honiara recorded the wave at a height of about 15 cm (Figure 37). [SI, No. 1799; NL, Vol. 7, No. 1, 1974; Vol. 8, No. 3, 1975; SN, Vol. 64, No. 5, 1974; "1974 Earthquakes", 1975; Spaeth, 1975; Everingham, 1976; Soloviev, 1982].

[February 1; 03 h 12 m 33.1 s; 7.4° S. Lat., 155.6° E. Long.; 40 km; M = 7.1; I = 2].

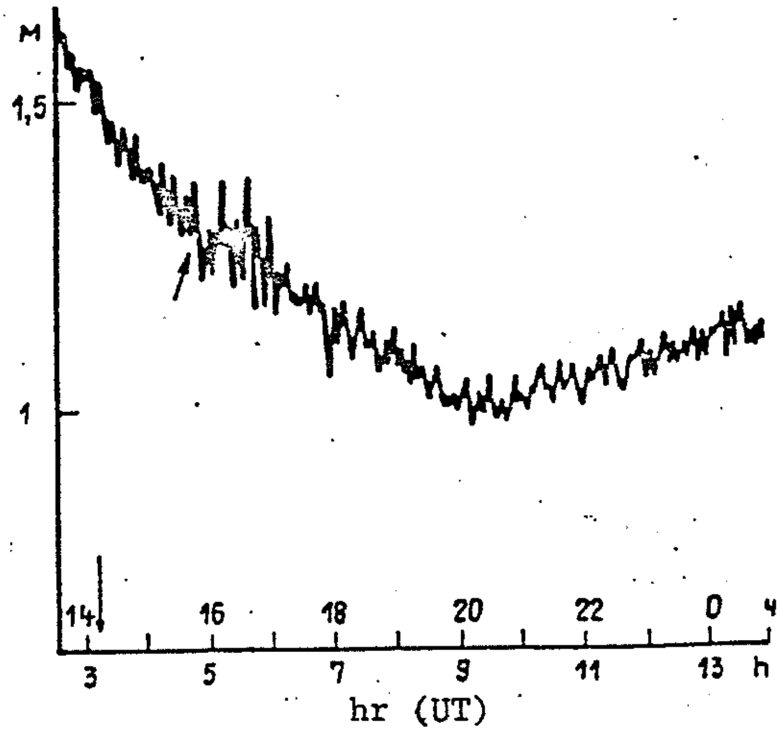

Figure 37: Record of the second tsunami of February 1, 1974 in Loloho [NL, 1974].

<u>May 9, 1974; 08 hr 33 min</u>. An earthquake occurred in the southern Izu Peninsula (Figure 38) with its center in the city of Minamiizu. It caused local destruction and was felt in the entire central part of Japan as well as in such distant regions as Kinki in the northeastern part of Honshu and on Hokkaido. In JMA data, the magnitude of this earthquake was 6.9 and the depth of its source was 10 km. In Minamiizu 30 people died and 102 were injured; 134 houses were completely destroyed and 204 were heavily damaged.

This earthquake produced a very weak tsunami which was recorded by only two tide gauges, at Minamiizu and at Omaezaki near the source (Figure 39). No destruction, caused by the tsunami, was reported. The tsunami data are presented in Table 17. ["Observations on tsunamis in Japan...", 1977; Tsuji, 1975; Report on the Izu-Hanto-Oki Earthquake", 1975; Watanabe, 1983].

[May 8, 23 h 33 m 27.3 s; 34.52° N. Lat., 138.74° E. Long.; 10 km; M = 6.9; I = -2.5].

Table 17: Tide gauge data on the tsunami of May 9, 1974

Place	First wave			Height of the maximum wave (cm)
	Travel time (min)	Rise (+) or fall (-) of level (cm)	Period (min)	
Omaezaki	14	+ 8	20	20
Uchiura	14	+	11	8
Minamiizu	4	-14	10	18
Kozu	11	-	10	12
Okada (Oshima Island)	15	+ ?	?	5
Hiratsuka	80	+ ?	15	5
Aburatsubo	32 ?	-	15	3
Mera	25	+	15	8

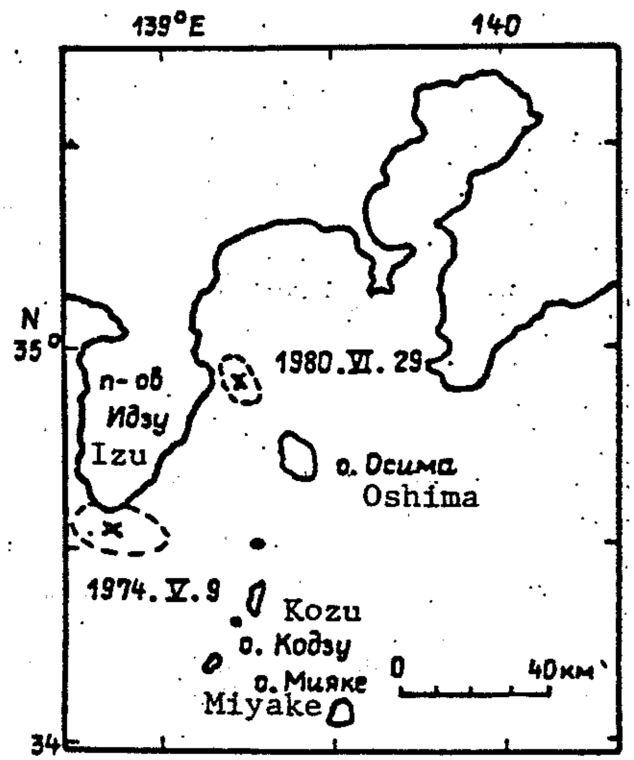

Figure 38: Epicenters of the earthquakes and tsunami sources of May 9, 1974 and June 29, 1980 [Hatori, 1980]

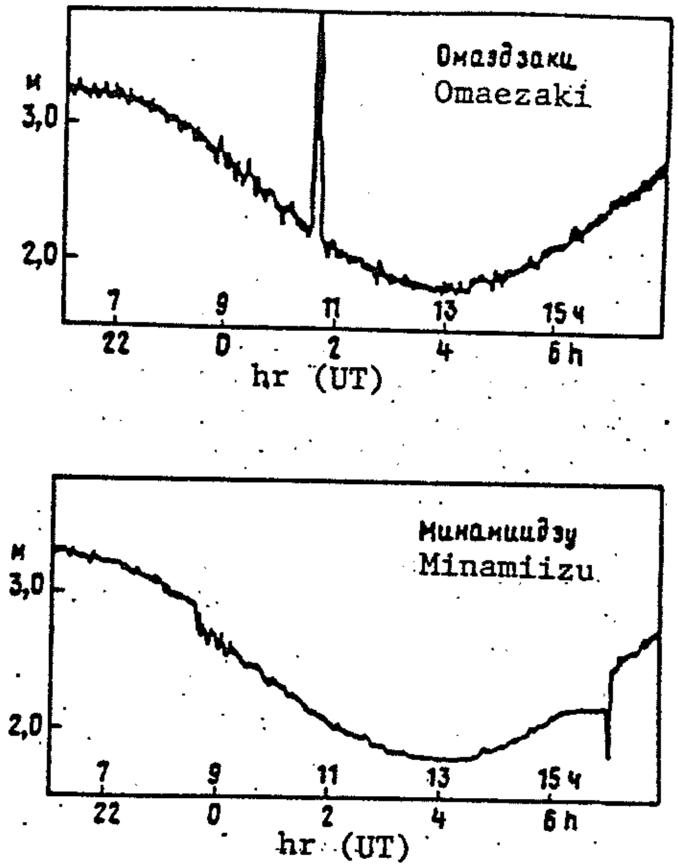

Figure 39: Records of the tsunami of May 9, 1974
["Report on the Izu-Hanto-Oki Earthquake...", 1975]

September 27, 1974; 16 hr 47 min (Sakhalin time) An earthquake with a magnitude of 7.2 shook the southern part of the Kuril Islands. Its macroseismic effect was felt at an intensity of not more than 4-5 points on the nearby islands of Shikotan and Kunashir; the intensity was 3 points on Iturup Island. The earthquake was also felt on Hokkaido, at Nemuro with an intensity of IV points (JMA), at Kushiro at III points, and at Abashiri and Urakawa at II points.

A weak tsunami produced by the earthquake was recorded only on the eastern coast of Hokkaido. Some of these records are shown in Figure 40. In Hanasaki the tsunami began with a rise in water level 34 min after the earthquake. The amplitude of the first wave was 10 cm, the period was 12 min, and the height of the maximum wave was 35 cm. The principal data on the tsunami are given in Table 18. The tsunami was not recorded on the coast of the Kuril Islands. Figure 41 is the map which shows the source location which was determined from the tsunami travel time at three stations. [NL, Vol. 8, No. 3, 1975; SN, Vol. 65, No. 3, 1975; Hatori, 1975b; 1974 Earthquakes..., 1975; Spaeth, 1976; "Observations on tsunamis...", 1977; Takemura, et al., 1977; Soloviev, 1978a, 1982; Watanabe, 1983].

[September 27; 05 h 47 m 29.4 s; 43.2° N. Lat., 146.7° E. Long.; 50 km; M = 7.2; I = -1].

Table 18: Tide gauge data on the tsunami of September 27, 1974

Place	Travel time (hr)	Period (min)	Rise of sea level (cm)
Hanasaki	0.6	15	20
Kushiro	0.6	25	5
Hiroo	0.9	24	10

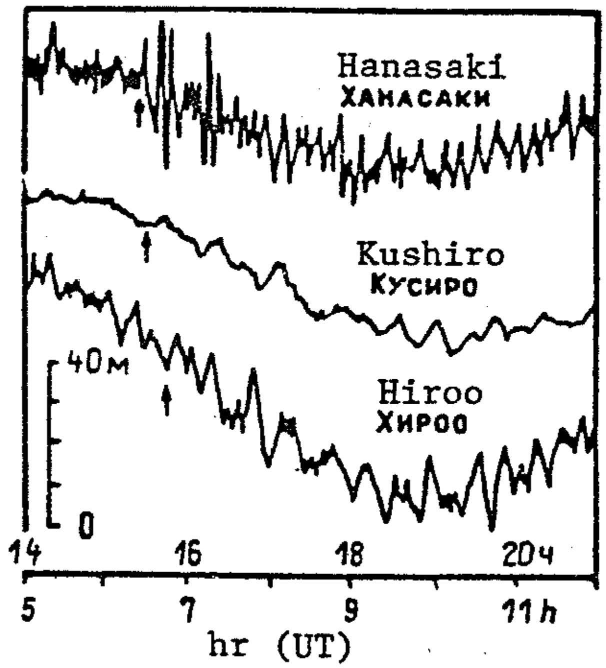

Figure 40: Records of the tsunami of September 27, 1974 [Hatori, 1975b]

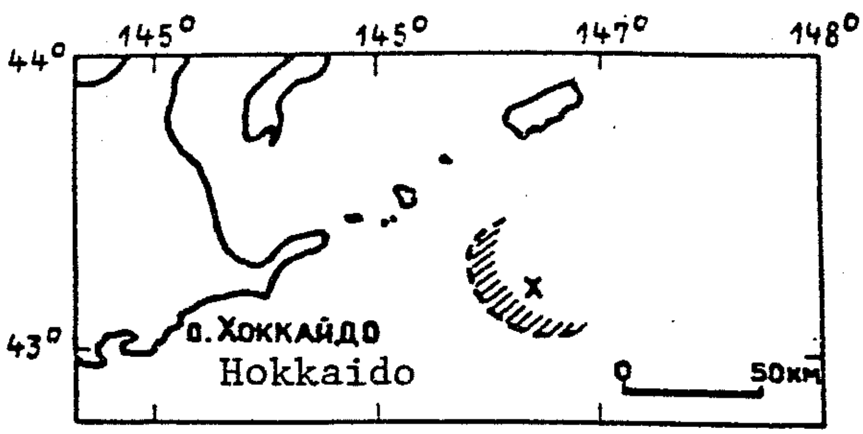

Figure 41: Epicenter of the earthquake and tsunami source of September 27, 1974 [Hatori, 1975b]

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October 3, 1974. The strongest earthquake in Peru for the year 1974 occurred and caused loss of human life and great devastation. Its epicenter was located near the city of Lima. The earthquake caused great destruction in the capital and surrounding area. The intensity was measured at 5 to 8 points (MM) within the city limits. It was reported that at two places in Lima the intensity reached 9 points. In some places there was liquefaction of the ground. Landslides across roads were observed along the sea coast south of Callao. In the Callao region where the intensity was high, liquefaction and subsidence occurred. The better constructed buildings suffered moderate damage. Seventy-eight people were killed and 2,414 were injured.

The earthquake caused a tsunami which was observed over an extensive region. The tsunami records are presented in Figure 42. Tide gauges recorded wave heights of 1.83 m in La Punta (Callao) and 1.2 m in San Juan. Wave heights were also recorded at other locations as follows: 0.37 m in Hilo and Kahului, Hawaii; 0.3 m in Pago Pago, Samoa; 0.15 m in Crescent City, California; 0.06 m on Midway and Wake Island. The tsunami was also recorded at Honolulu and on the Truk Islands. Table 19 presents the data on oscillations on the Pacific Coast of Japan. [SI, No. 1943; NL, Vol. 8, Nos. 1, 2, 3, 1975; Hatori, 1981a; SN, Vol. 65, No. 3, 1975; "The Peru earthquake...", 1975; Spaeth, 1976; Silgado, 1978; Soloviev, 1982; Watanabe, 1983].

[October 3; 14 h 21 m 29.1 s; 12.3° S. Lat., 77.8° E. Long.; 13 km; M = 7.6; I = 1].

Table 19: Tide gauge data on the tsunami of October 3, 1974 in Japan

Place	First Wave: Travel Time (hr min)	First Wave: Rise (cm)	Period (min)	Height of the maximum wave (cm)
Hanasaki	20 33	5	12	12
Kushiro	20 58 ?	4	24	9
Hiroo	21 04	9	25	17
Urakawa	21 09	5	22	12
Hakodate	21 40 ?	2	32	7
Hachinohe	21 13	3	17	12
Miyako	21 35 ?	4	28	10
Ofunato	21 34 ?	4	20	5
Enoshima	21 08	3	15	4
Onahama	21 38	3	15	10

Hitachi	21 30 ?	5	22	10
Chosi	21 42	6	22	13
Mera	?	-	-	6
Minamiizu	21 47 ?	4	12	3
Omaezaki	21 43 ?	4	20	8
Owase	21 42 ?	6	18	7
Uragami	21 52	5	22	8
Kushimoto	22 10	4	18	12
Muroto	22 25 ?	3	12	8
Tosashimizu	22 25	5	18	12
Kamae	22 55	2	22	7
Aburatsu	22 40	4	18	10
Odomari	22 22 ?	4	12	6
Nase	23 00	7	17	14

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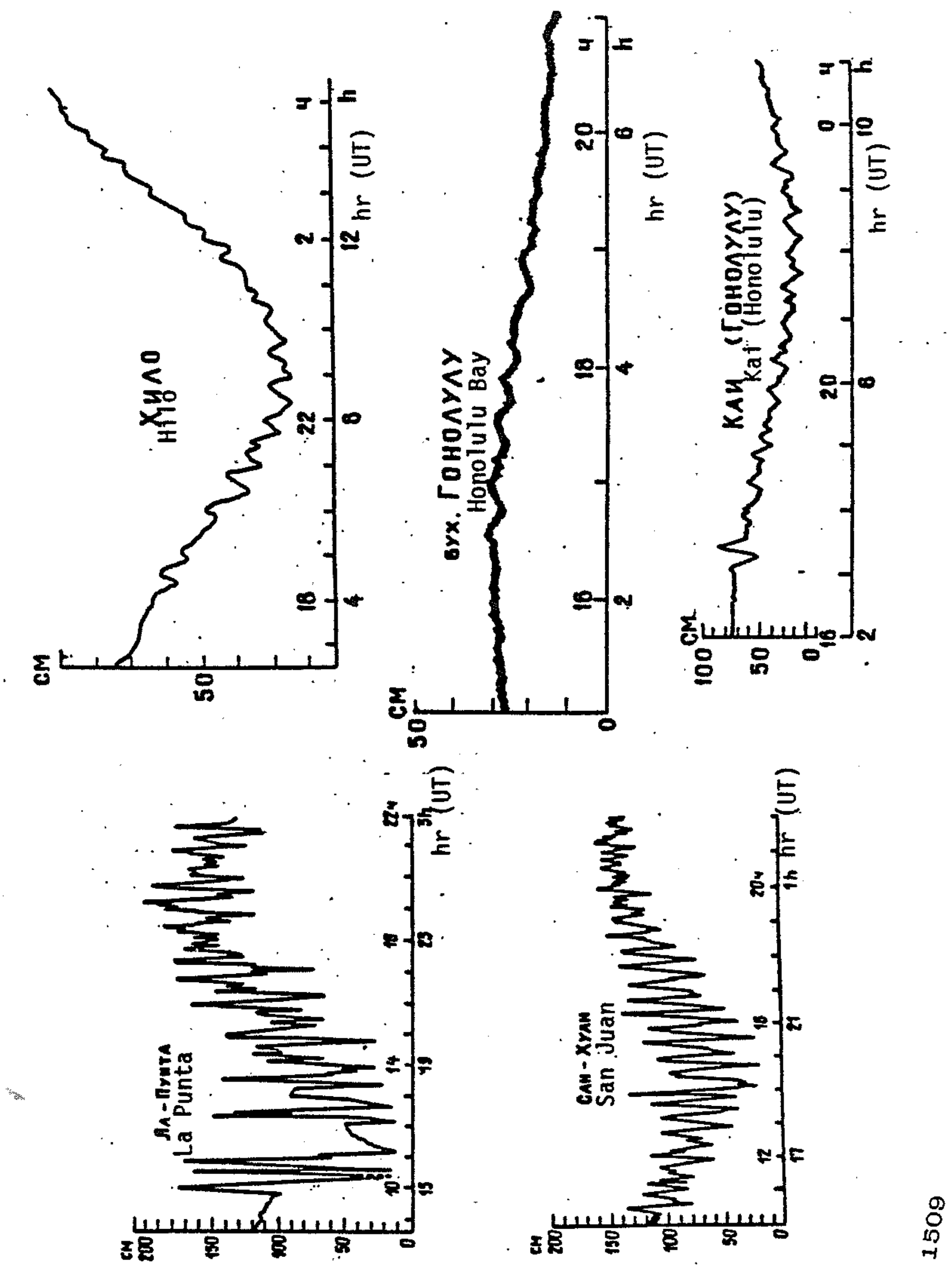

Figure 42 (pages 76 & 77): Records of the tsunami of October 3, 1974 in Peru, on Hawaii and Samoa [NL, 1975] and in Japan [Hatori, 1981.]

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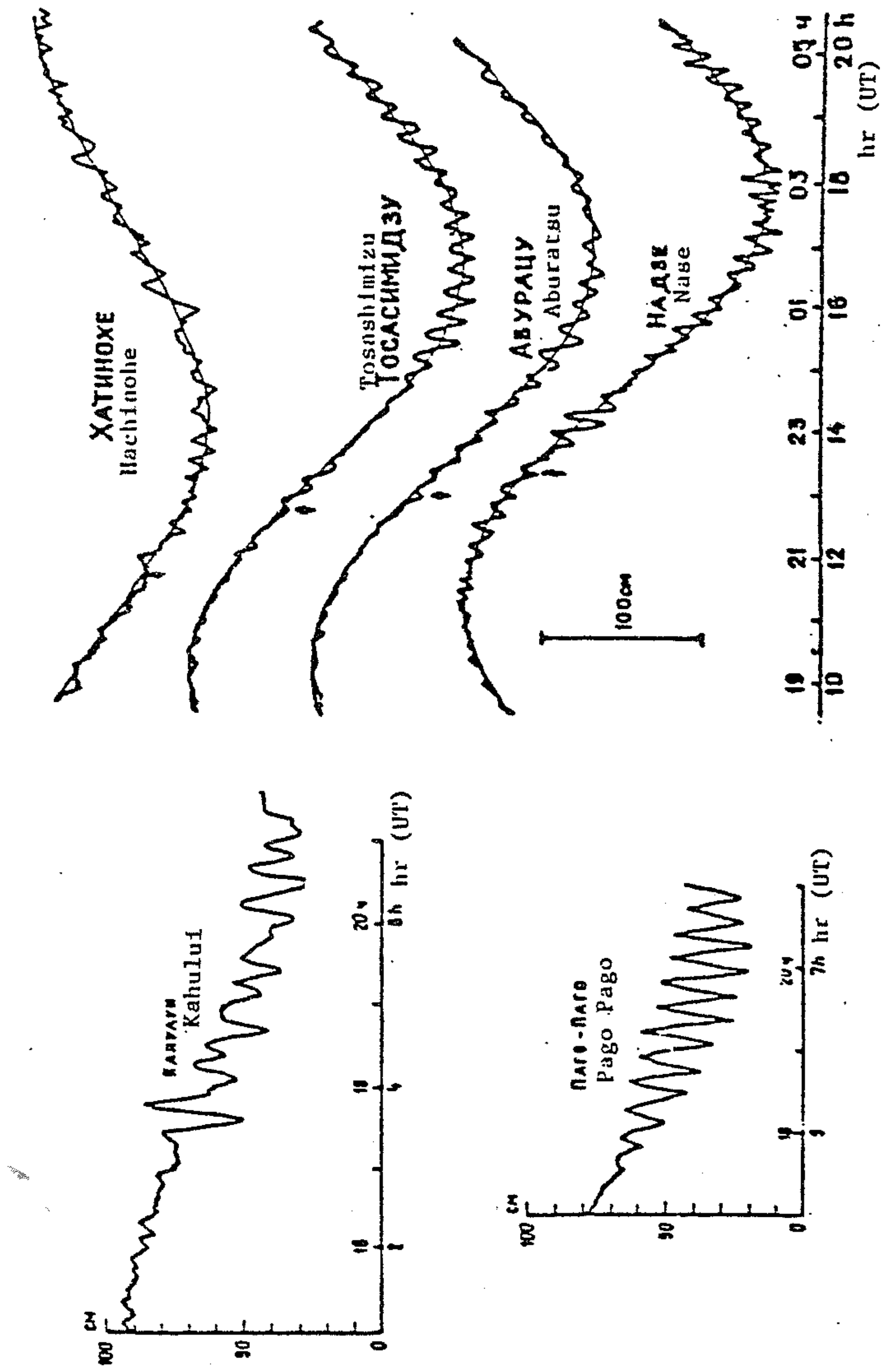

Figure 42 (continued)

October 17, 1974. A submarine volcano erupted in Melanesia, 600-900 miles west of Ritter Island (Sakar). The eruption was preceded by an earthquake followed by almost continuous tremors. The explosion column rose to a height of 400-500 m above sea level. The explosion was of the phreomagmatic or phreatic type. A rumble was heard and a tsunami of low amplitude was generated (5° 31' N. Lat., 148° 7' E. Long.). [Gushchenko, 1979; Soloviev, 1982].

June 11, 1975; 00 hr, 48 min (Sakhalin time). A strong earthquake occurred south of the Kuril Islands at a magnitude of 7.0. It was weakly felt along the entire southern part of the Kuril Islands. In Nemuro, Kushiro, Abashiri, and Urakawa (Hokkaido) its intensity was not more than I point (JMA). Since the magnitude of the earthquake did not exceed 7 points, no tsunami warning was issued in the Kuril Islands or in Japan. However, a fairly strong tsunami was observed on the coast of the southern part of the Kuril Islands and in Hokkaido.

The eastern coast of Kunashir Island was flooded in places up to 5 m mark above sea level. Bridges and roads were damaged. Many fishing camps located near the waterline were destroyed. Supplies, equipment, and belongings were washed away. The tsunami did not play havoc in Kuril'sk and Malokuril'skoye. Visual data on the tsunami are presented in Table 20.

The tsunami was reported along the entire Pacific Coast of Japan, from Nemuro Peninsula (Hokkaido) to Kyushyu Island. It was also reported from Chichijima, the Bonin Islands, and on the Okhotsk Sea coast of Hokkaido. However, it did not cause damage anywhere. The most significant of the tsunami records are given in Figure 43. The values of the principal wave parameters are given in Table 21.

As Table 21 shows, the onset of the tsunami was recorded by all instruments in Japan with a rise in water level while in the southern Kuril Islands it began with a drop in water level. Figure 44 shows the tsunami source drawn from the travel time of the tsunami waves as recorded by the tide gauges.

A tsunami with an amplitude of 12 cm was recorded in Kahului, Hawaii; amplitudes of 9 cm were recorded on Wake and Truk islands, of possibly 12 cm on Kwajalein Island, and of 6 cm in Sitka, Alaska and on Adak in the Aleutian Islands. [SI, No. 2195; Hatori, 1975b; NL, Vol. 8, 1975; Vol. 9, No. 1, 1976; Nagamune and Churei, 1976; Report..., 1976; Spaeth, 1976; SN, Vol. 67, No. 4, 1977; Takemura, et al., 1977; Poplavskaya et al., 1978; Shchetnikov, et al., 1978; Soloviev, 1978a, 1982; Watanabe, 1983].

[June 10; 13 h 47 m 14.5 s; 43.5° N. Lat., 148.5° E. Long.; 40 km; M = 7.0; I = 2].

Table 20: Data of visual observation on the tsunami of June 11, 1975.

Place	Height of water rise (m)	Inundation distance covered by the water on land (m)
Kunashir Island		
Serbryanka River	2-3	250
Otradnoe	2	-
Vinai River	2.5-3	150
Chaika	2	-
Goryachiy Plyazh	2-3	60
Shikotan Island		
Otradnaya Inlet	1.5-2	-
Krabozavodsk	1.5	-
Mayachnaya Inlet	3.5	-
Sennaya Inlet	3.5-4	-
Nepokornyi Cape	5.5	-
Polonskogo Island	2.3	-
Zelenyi Island	1	-
Yurii Island	0.7-1	-

Table 21: Tide Gauge Data on Tsunami of June 11, 1975

Place		First Wave		Height of the maximum wave (cm)
	Travel time (hr min)	Period (min)	Amplitude (cm)	
Kuril Islands				
Paramushir Island				
Severo-Kuril'sk	-	40	3	5
Matua Island	01 03	0.5	10	19
Iturup Island				
Burevestnik	00 46	2.0	45	44
Kuril'sk	01 03	-	1	2

Kunashir Island				
Yuzhno-Kuril'sk	01 11	2.2	-47	55
Shikotan Island				
Malokuril'skoye	00 34	1.7	-58	60
Sakhalin Island				
Cape Crillon	02 42	-	-18	18
Korsakov	04 10	-	-	10
Poronaisk	04 10	-	- 6	11
Japan				
Hokkaido				
Wakkanai	02 52	23	6	6
Abashiri	01 27	12	4	15
Hanasaki	00 43	13	72	96
Kushiro	00 48	24	8	14
Hiroo	00 58	12	33	26
Urakawa	00 59	15	6	42
Muroran	-	-	-	5
Mori	-	-	-	7
Tomakomai	01 39 ?	20	5	7
Hakodate	01 15	25	7	7
Honshu				
Same	01 12	18	4	-
Hachinohe	01 16	8	14	22
Miyako	01 02	10	16	16
Kamaishi	01 05	15	13	14
Ofunato	01 12	13	12	20
Ayukawa	01 24	8	12	12
Matsukawaura	01 42 ?	12	5	11
Onahama	01 38	8	6	13
Hitachi	01 50 ?	8	6	14
Ooarai	01 40	10	4	15
Kushimoto	02 23	12	8	10
Bonin Islands				
Hachijo Jima	02 03	8	7	8
Chichijima	01 51	15	5	12

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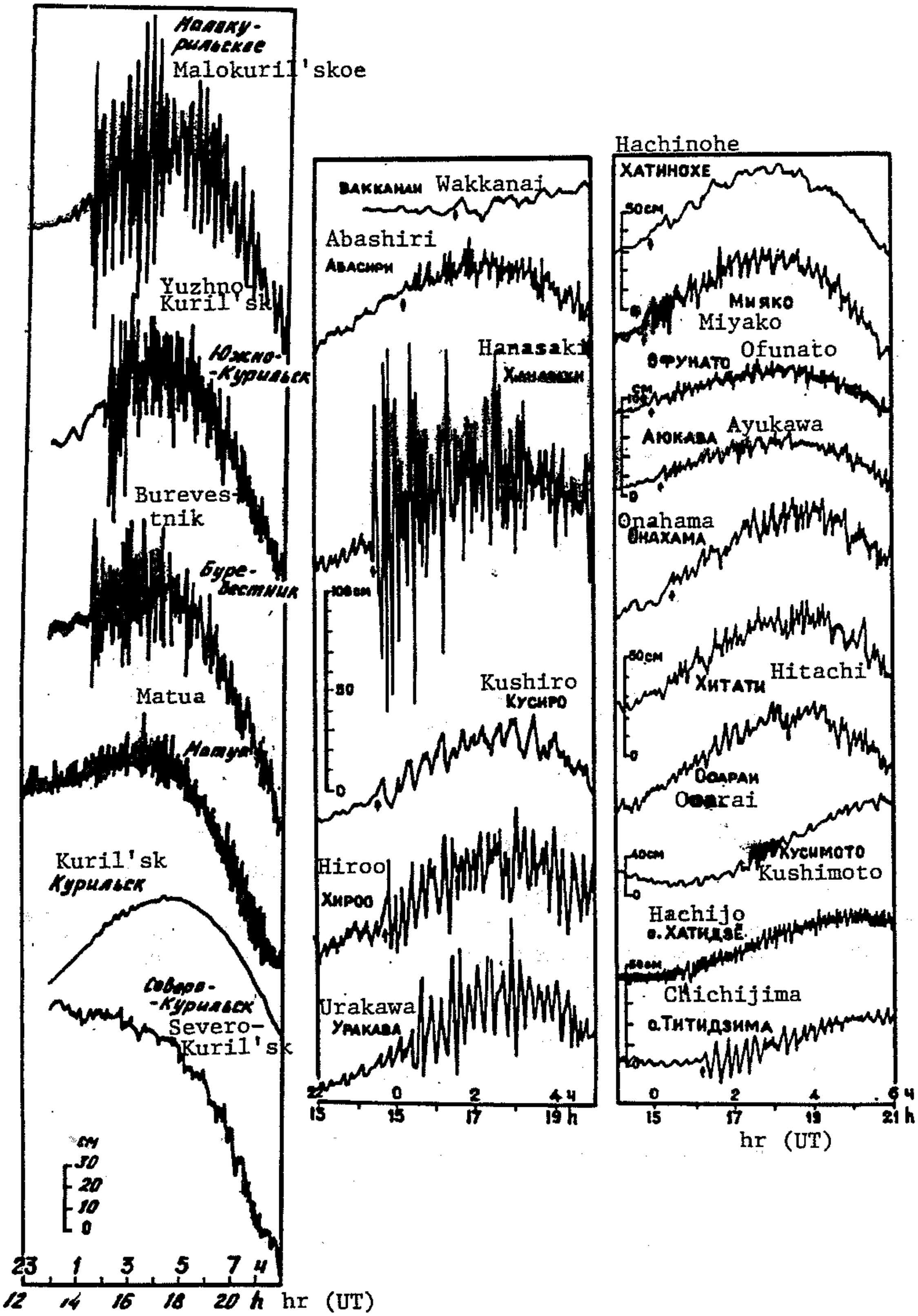

Figure 43: Records of the tsunami of June 11, 1975 on the Kuril Islands [Shchetnikov, et al., 1978] and in Japan [Hatori, 1975b].

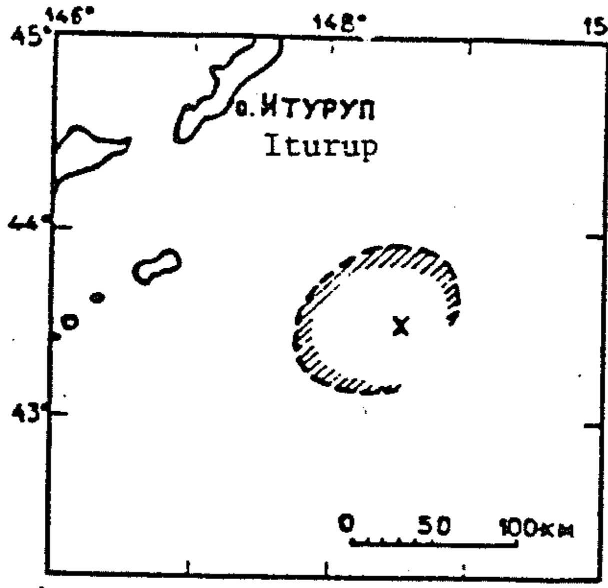

Figure 44: Epicenter of the earthquake and tsunami source of June 11, 1975 [Shchetnikov, et al., 1978].

<u>July 21, 1975; 00 hr 38 min</u>. A strong earthquake occurred in the Solomon Sea. It caused destruction on Bougainville Island where it was felt at an intensity of VIII points (Rossi-Forel scale). In the village of Mamagota, the earthquake destroyed three of the twelve houses. It was also strongly felt on the Shortland Islands.

The tsunami followed close on the heels of the earthquake. On the southwestern and southern coasts of Bougainville Island, over a stretch of 80 km, tsunami waves at heights of 2 m and periods of 5 to 15 min hit the coast several times. The tsunami occurred during the period of 1.2 m maximum high-tide which accented its effect. But there was no loss of life due to the tsunami.

Farmers from the village of Mamagota on the southern coast of the island reported that the rising waves dammed the river and caused it to flood; later normal flow to mouth of the river resumed. Due to several recent tsunamis this village had previously been relocated 1 km inland. This tsunami did not reach the village at its new site but did possibly destroy another village still situated on the coast of the bay. Broken willow trees and scattered grass and leaves on the coastal belt were evidence of this. During the tsunami, water level rose at least 1 m above sea level. Wet particles of coastal sand sticking on the raised end of logs firmly imbedded in the coastal sands also indicate that water level rose to more than 1 m above sea level.

The local hydrologist reported that after the earthquake the measuring instruments on the Yaba River, 7 km from the coast, showed a more than 2 m rise in water level. During the two weeks before the earthquake there had been no rain in this region.

Soon after the earthquake several waves with an amplitude of 10 cm and an interval of 15 min were recorded on the quay at Loloho near Kieta.

A strong tsunami appeared in the village of Torokina. The local residents waited for tsunami waves after the earthquake, having survived the effects of earlier tsunamis caused by the earthquakes of July 1971 and February 1974. Fifteen minutes after the earthquake, they saw the wave approaching; it had the appearance of a long low hump stretching from north to south. Most residents took shelter among shrubs. Some residents reported that the wave spread along the coast as breakers at great speed. One young boy climbed a coconut palm tree and water passed under him. He reported that the wave rose fairly slowly and that he could have ran faster than the wave moved on the coast. The wave passed at a height of 1 m above land and its level remained high until the arrival 5 min later of the second larger wave. The third wave appeared after another 5 min and was lower. Only then did some people return to the village. Yet a fourth wave of ankle-height then appeared.

Water inundated the village which sits 0.5 m above sea level. Two houses were dislodged, possibly by the second wave, to about 30 m inland. Canoes were thrown 50 m beyond the village. A small kitchen was swept from the village into a marsh. Many barrels, full as well as empty, were displaced, some to as far as 60 m. The Spiritual Mission of Torokina building was protected by a 2 m high barrier beyond which lay a ravine into which a large amount of water collected. The water drained into the swamp, about 0.5 km beyond the village.

The tide gauge station was well protected on its south and southwest; however, water flooded the inlet from the north, widely inundating the territory to the northwest, falling 90 m short of the station. In several places covered with creeping plants the tsunami uprooted and carried away the plant cover, leaving the ground almost bare. At the tide gauge station the rise in water level was recorded at the following levels: 17.0, 17.3 and 17.7 cm.

The tsunami was recorded on Kwajalein Island with a maximum amplitude of 6 cm. The tsunami was also observed on the coast of Japan (Table 22). [NL, Vol. 8, Nos. 3, 4; Vol. 9, No. 1, 1975; Everingham, 1976; Everingham, et al., 1977; SN, Vol. 67, No. 4, 1977; Spaeth, 1977; Soloviev, 1982; Watanabe, 1983].

[July 20; 14 h 37 m 39.9 s; 6.6° S. Lat., 155.1° E. Long.; 49 km; M = 7.9; I = 1].

Table 22: Tide gauge data on the tsunami of July 21, 1975 on the coast of Japan

Place	First Wave Travel Time (hr min)	Rise (cm)	Period (min)	Height of the maximum wave (cm)
Hanasaki	12 03	4	12	9
Hiroo	07 51	3	16	6
Urakawa	07 58	3	13	5
Hachinoche	07 11	2	-	6
Onahama	06 25	2	10	4
Chichijima	06 11	3	14	5
Omaezaki	07 55	3	12	5
Owase	09 13	3	10	5
Kushimoto	06 16	4	22	8
Tosashimizu	06 21	3	18	5
Aburatsu	10 33	3	-	8

October 31, 1975. A strong earthquake at a magnitude of 7.2 occurred on the Philippines. Its epicenter was located northeast of Samar Island. In Calbayog the earthquake was felt at an intensity of VI points (Rossi-Forel scale) and in Manila at an intensity of III points.

A tsunami was observed which claimed one life. Nearly 30 houses were washed away on the eastern coast of Samar Island. This tsunami was recorded by Japanese tide gauges on the Pacific Coast of Kyushu Island, in the Kanto region, on the Izu Peninsula, and on the Bonin Islands. In Nase and on Ishigaki Jima (Ryukyu Islands) the tsunami was not recorded by tide gauges. The principal data on the tsunami in Japan, are presented in Table 23. Figure 45 gives the tsunami records.

This tsunami was also recorded at amplitudes of 10 cm on Okinawa, 6 cm on Yap Island, 6 cm on Wake Island, and 3 cm on Truk Island. [NL, Vol. 8 No. 4, 1975; Vol. 9, No. 2, 1976; "Observations on tsunamis in Japan...", 1977; Spaeth, 1977; Hatori, 1982a; Soloviev, 1982; Watanabe, 1983].

[October 31; 08 h 28 m 12.6 s; 12.5° N. Lat., 126.0° E. Long.; 50 km; M = 7.2; I = -1½].

Table 23: Tide gauge data on the tsunami of October 31, 1975 in Japan

Place	First Wave			
	Travel Time (hr min)	Rise (cm)	Period (min)	Height of the maximum wave (cm)
Hanasaki	?	-	-	9
Kushiro	?	-	-	5
Hiroo	05 36	3	18	12
Urakawa	05 44	2	8	10
Miyako	?	-	-	7
Enoshima	04 47	2	20	5
Ayukawa	?	-	-	13
Onahama	?	-	-	10
Hitachi	?	-	-	14
Mera	04 07 ?	6	10	20
Miyako Island	03 34	6	10	24
Hachijo Jima	03 32 ?	8	12	26
Chichijima	03 03	9	13	13
Minamiizu	03 52	4	8	13
Omaezaki	03 58 ?	3	14	32
Owase	03 44	10	14	32
Kushimoto	03 30	11	12	27
Muroto	03 28	5	10	8
Tosashimizu	03 30	13	8	17
Aburatsu	?	-	-	-
Naha	?	-	-	-

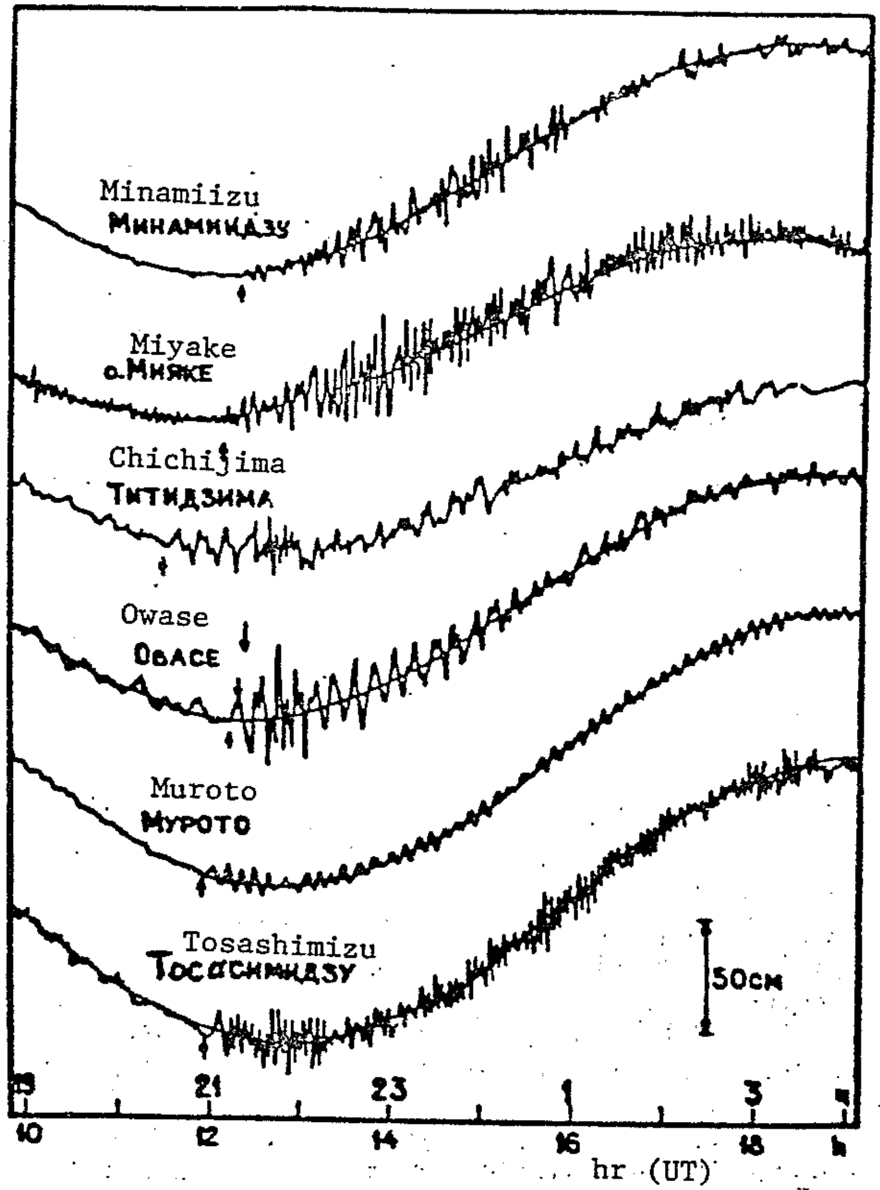

Figure 45: Records of the tsunami of October 31, 1975 on the coast of Japan [Hatori, 1982a].

<u>November 29, 1975</u>. Two earthquakes occurred in the morning on Hawaii Island at 3 hr 35 min local time. The first earthquake was at a magnitude of 5.5 with the epicenter near the Kilauea volcano. The earthquake awakened the entire population of the island. The second earthquake occurred an hour later at a magnitude of 7.2. In Hawaii Island the earthquake was felt at an intensity of 8 points but in the city of Hilo the intensity reached 9 points. In many places houses were severely damaged, roads were breached and became unusable due to landslides; electric power lines were broken. Along the south-eastern coast subsidence was observed from 0.8 m to 3.5 m. A crack in the ground appeared with a maximum width of 1 m. The earthquake was also felt on Oahu, Lanai, Molokai and Maui islands.

The tsunami produced by the main earthquake was observed mainly on the coast of Hawaii Island, particularly in the south. The tsunami was strong and the maximum wave height reached 8 m.

In Halape 6-8 m high waves swept away 36 people. One person died, one was missing, and others were hospitalized with varying degrees of injury.

Seven villages were destroyed in the Punaluu region. Most houses were knocked off of their foundations and swept away by the second and largest wave which carried them considerable distances from the coast. Coconut palm trees were also seriously damaged. In Punaluu itself, where the tsunami penetrated to a distance of 140 m, houses were destroyed. The loss caused by the tsunamis in the Punaluu region was estimated at $1 million dollars.

Waves covered the western and eastern parts of Big Island and flooded inlets and bays in the Kona and Hilo districts. In Keauhou boats and dock equipment were destroyed. In Hilo, where the wave rose in the mouth of the Wailoa River, wave height reached 4 m, flooding and destroying boats.

The wave reached heights of 6.5 m in Honuapo, 7.8 m in Halape, 3.7 m in Napoopoo, and 2.6 m in Hilo. A more detailed distribution of the height of the wave in Hawaii Island is presented in Figure 46.

The tsunami was recorded by tide gauges on the Hawaiian Islands and on other coasts of the Pacific Ocean. The principal tide gauge observation data from Japan are presented in Table 24. Tide gauge data from other regions are given below:

Place	Height of the maximum wave, cm
<u>Alaska</u>	
Yakutat	9
Sitka	21
<u>California</u>	
San Francisco	12
Imperial Beach	37
Los Angeles	30
Port San Luis	79
La Jolla	30
Bodega Bay	43
Long Beach	15
San Diego	12
<u>Hawaiian Islands</u>	
Hilo	174

Kahului	88
Mokuoloe Island	3
Honolulu	18
Nawiliwili	27
<u>Galapagos Islands</u>	
Baltra Island	46
<u>Peru</u>	
Talara	48
La Punta	36
Matarani	35
<u>Chile</u>	
Arica	43
Antofaqasta	27
Caldera	46
Talcahuano	24
<u>Oceania</u>	
Kwajalein	6
Wake	3
Johnston	9

(Figure 47 shows some records of this tsunami.)

In California the rise in water level was 1 m and there were some material losses caused by this tsunami.

From the data from the Hawaiian tide gauge records, Hatori (1976a) constructed the tsunami source (Figure 46). According to his estimate the average rise in water level in the source was 1.2 m. Consequently, the tsunami energy was estimated at 1.6×10^{20} erg. [Loomis, 1975; NL, Vol. 8, No. 4, 1975; Vol. 9, No. 1, 1976; Hatori, 1976a; Cox and Morgan, 1977; Observations on tsunamis in Japan..., 1977; Rojahn and Morrill, 1977; SN, Vol. 67, No. 4, 1977; Spaeth, 1977; Soloviev, 1982; Watanabe, 1983].

[November 29; 14 h 47 m 37 s; 19.3° N. Lat., 155.0° W. Long.; 5 km; M = 7.1; I = 3].

Table 24: Tide gauge data on tsunami of November 29, 1975, observed in Japan on November 30, 1975

Place	Travel time (hr min)	First wave Amplitude (cm)	Period (min)	Height of the maximum wave (cm)
Hanasaki	08 48	6	8	27
Kushiro	?	-	-	12
Hiroo	07 42	15	12	23
Urakawa	09 00	-6	15	12
Hakodate	?	-	-	17
Same	08 56	2	10	5
Miyako	08 50	-8	8	14
Enoshima	08 46	-4	10	-
Ayukawa	09 00	-6	8	55
Onahama	08 10	4	-	21
Hitachi	07 27	5	16	24
Mera	08 28	6	16	19
Miyake Jima	08 22	4	7	24
Chichijima Island	06 53	6	18	18
Minamiizu	07 20	3	-	20
Omaezaki	07 33	4	10	14
Owase	09 14	8	22	22
Kushimoto	10 00	7	12	22
Muroto	08 50	3	8	11
Tosashimizu	08 00	8	22	23
Aburatsu	?	-	-	18
Naha	08 35	3	18	13

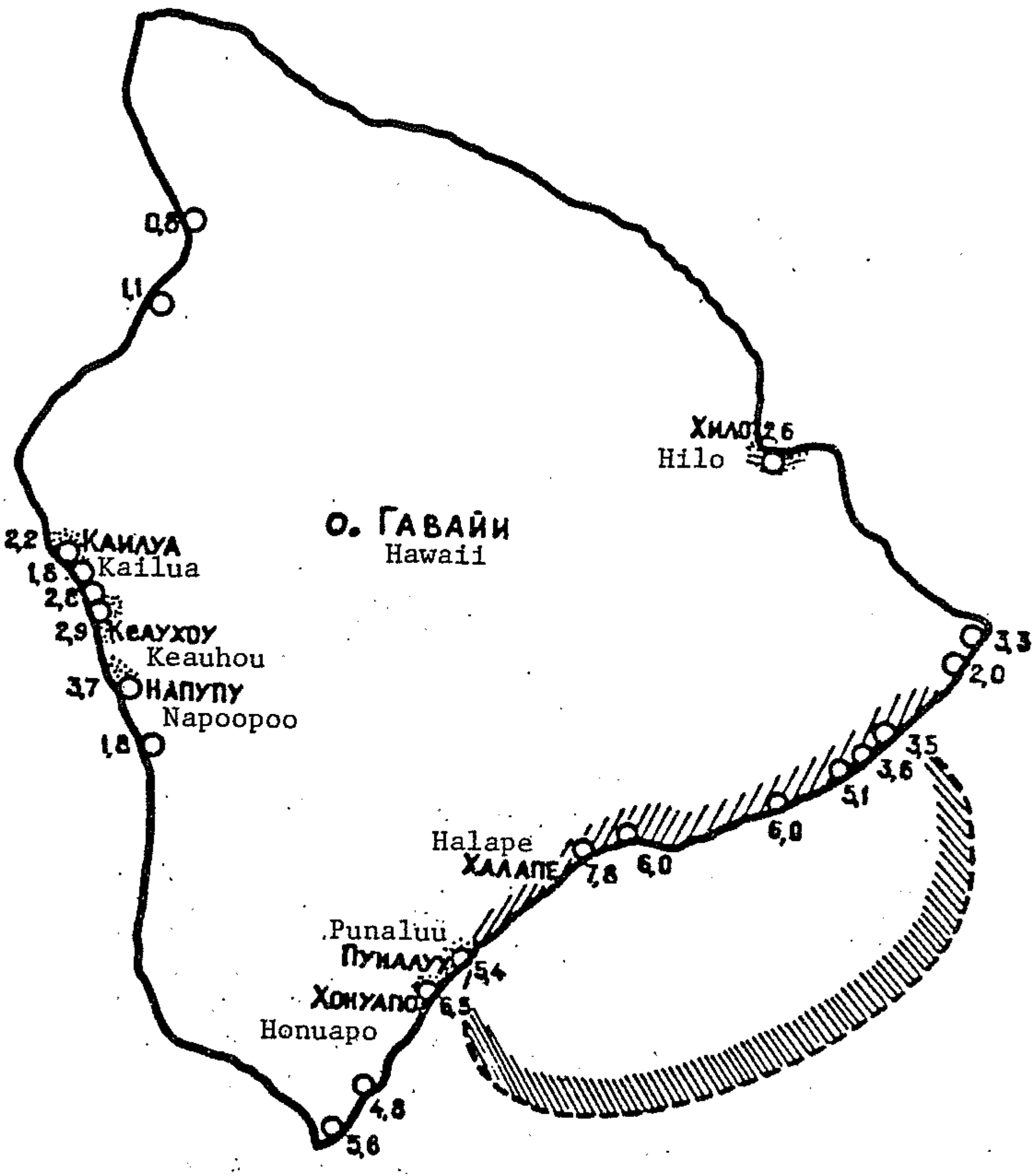

Figure 46: Source of the tsunami of November 29, 1975 and height (in m) of the rise in water level in Hawaii Island [Hatori, 1976a].

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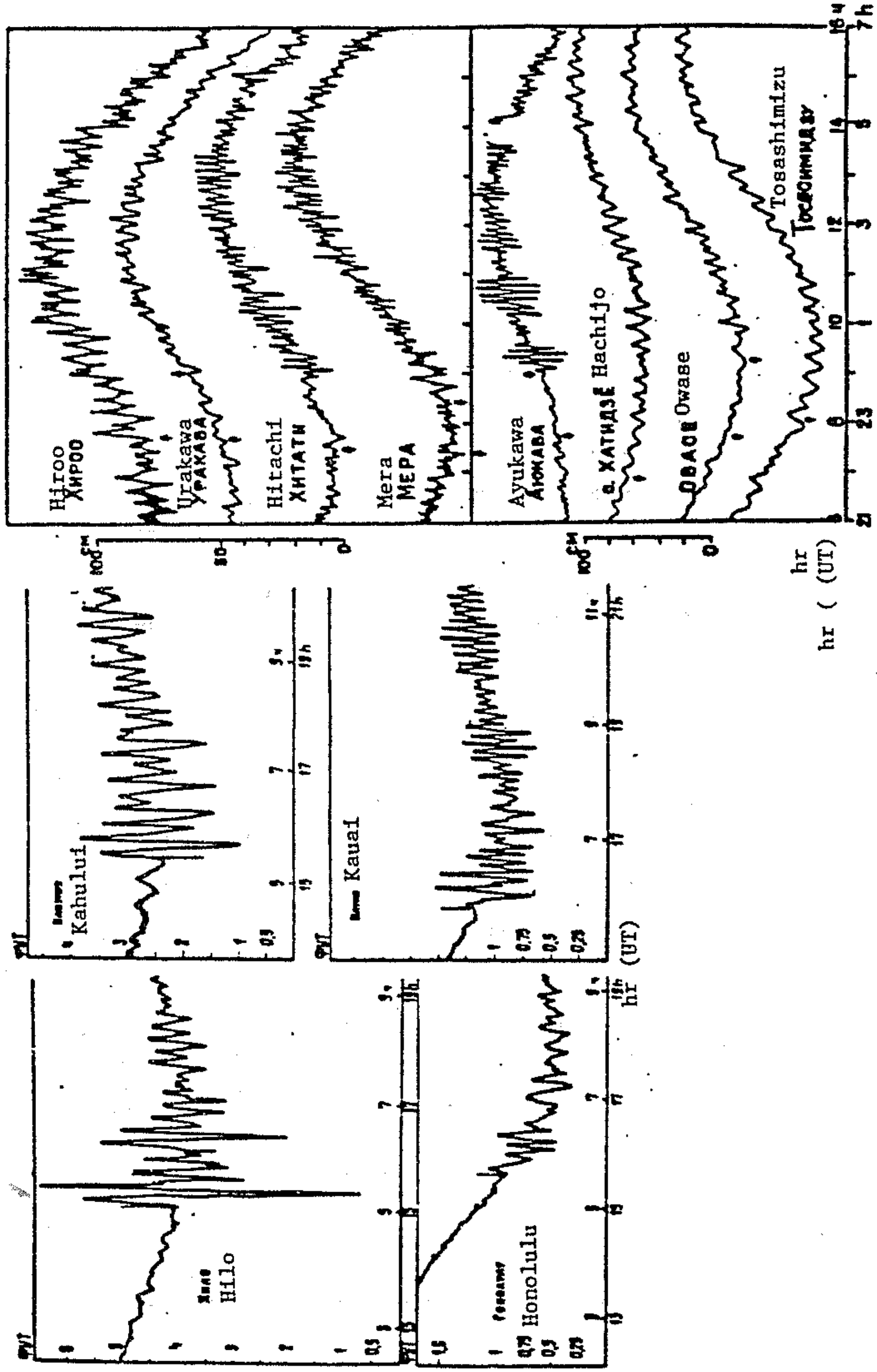

Figure 47: Records of the tsunami of November 29, 1975 on Hawaiian Islands [NL., 1975] and in Japan [Hatori, 1976a].

December 26, 1975; 3 hr 57 min. A strong earthquake at a magnitude of 7.8 occurred in the submarine Tonga Trench. The epicenter was 360 km south of Samoa. It was felt at a force of VI points (Rossi-Forel) on Upolu Island where some insignificant damage was reported.

A tsunami occurred and registered a maximum amplitude of 75 cm in Pago Pago, 15 cm in Apia and 8 cm in Suva.

The International Tsunami Warning Center in Honolulu issued a warning which was soon lifted. [NL, Vol. 8, No. 4, 1975; Vol. 9, No. 1, 1976; SN, Vol. 67, No. 4, 1977; Spaeth, 1977; Soloviev, 1982].

[December 26; 15 h 56 m 38.7 s; 16.3° S. Lat., 172.5° E. Long.; 33 km; M = 7.8; I = 0].

January 14, 1976; 4 hr 48 min. A series of strong earthquakes occurred in early 1976 near the Kermadec Islands north of New Zealand. The strongest of these earthquakes occurred on January 14 at 3 hr 56 min and 4 hr 47 min local time. According to the preliminary estimates from telemetric data of the US Geological Survey, the second earthquake had a greater magnitude; the local magnitude in New Zealand was 7.8 and 7.6 for the first and the second shocks respectively. The first of these two shocks was felt stronger on Raul Island, the only inhabited island of the Kermadec Islands where the meteorological station is manned by 10 people. The strength of the shock on Raul Island was estimated at 7 points (Mercalli scale). Some frame houses were destroyed and things were thrown about in rooms. The water supply was disrupted, and cracks developed on roads which were blocked by landslides and rock falls. No human lives were lost.

The second of these earthquakes caused a tsunami which was recorded as far away as the Hawaiian Islands.

The Australian Service of Home Affairs reported that a 90 cm high tsunami was observed as far south as the Fiji Islands. Waves were recorded at heights of 6 cm in Honolulu, 29 cm in Kahului, 14 cm in Apia, and 15 cm in Suva. A tsunami was also observed on Lord Howe Island (31° S. Lat., 159.4° E. Long.) with a maximum amplitude of about 30 cm. The alignments of anchored boats in the Tutukaka Harbor on the northern coast of New Zealand were disarranged by the tsunamis.

Data confirming that the first of these earthquakes caused the tsunami are not available, although the magnitude of the first earthquake was fairly high. [NL, Vol. 9, Nos. 1, 3, 1976; SN, Vol. 67, No. 5, 1977; Spaeth, 1979: Soloviev, 1982]. 1509

[January 14; 16 h 47 m 32.5 s; 28.4° S. Lat., 177.7° W. Long.; 33 km; M = 8.0; I = 0].

January 21, 1976; 21 hr 05 min (Sakhalin time). A strong earthquake at a magnitude of 7.2 occurred in the southern part of the Kuril Islands east of Iturup Island. It was felt at intensities of 6 points in Reidovo, 5 in Kuril'sk, and 3-4 points in Yuzhno-Kuril'sk. The intensity was III points (JMA) in Nemuro and II points in Urakawa and Hiroo.

The earthquake caused a tsunami which was recorded by tide gauges on the coast of the Kuril Islands and in Hokkaido (Figure 48). At Burevestnik the first wave arrived at 21 hr 40 min (Sakhalin time). According to the report of assistants at the Hydrometeorological Station in Burevestnik, the first wave was followed by a series of waves with periods of 10-20 min and with amplitudes of 25-30 cm. The principal parameters of these waves are presented in Table 25.

Figure 49 shows the estimated tsunami source charted from the travel times of the waves (Table 25). The energy of this tsunami was estimated at 0.35 x 10^{19} erg. [NL, Vol. IX, No. 3, 1976; SN, Vol. 67, No. 5, 1977; Spaeth, 1978; Soloviev, 1978a, 1982; Zhigulina et al, 1980; "Tsunamis observed in Japan...", 1981; Watanabe, 1983].

[January 21; 10 h 05 m 24.1 s; 44.6° W. Lat., 149.2° E. Long.; 40 km; M = 7.3; I = 2½].

Table 25: Tide gauge data on the tsunami of January 21, 1976 in the USSR and Japan

Place	First wave			Height of the maximum wave (cm)
	Travel time (min)	Period (min)	Amplitude (cm)	
Burevestnik	31	10	+13	18
Yuzhno-Kuril'sk	100	6	-10	10
Malokuril'skoye	110	12	-11	37
Matua	97 ?	?	- 5 ?	6-7
Hanasaki	54 ?		+ ?	13

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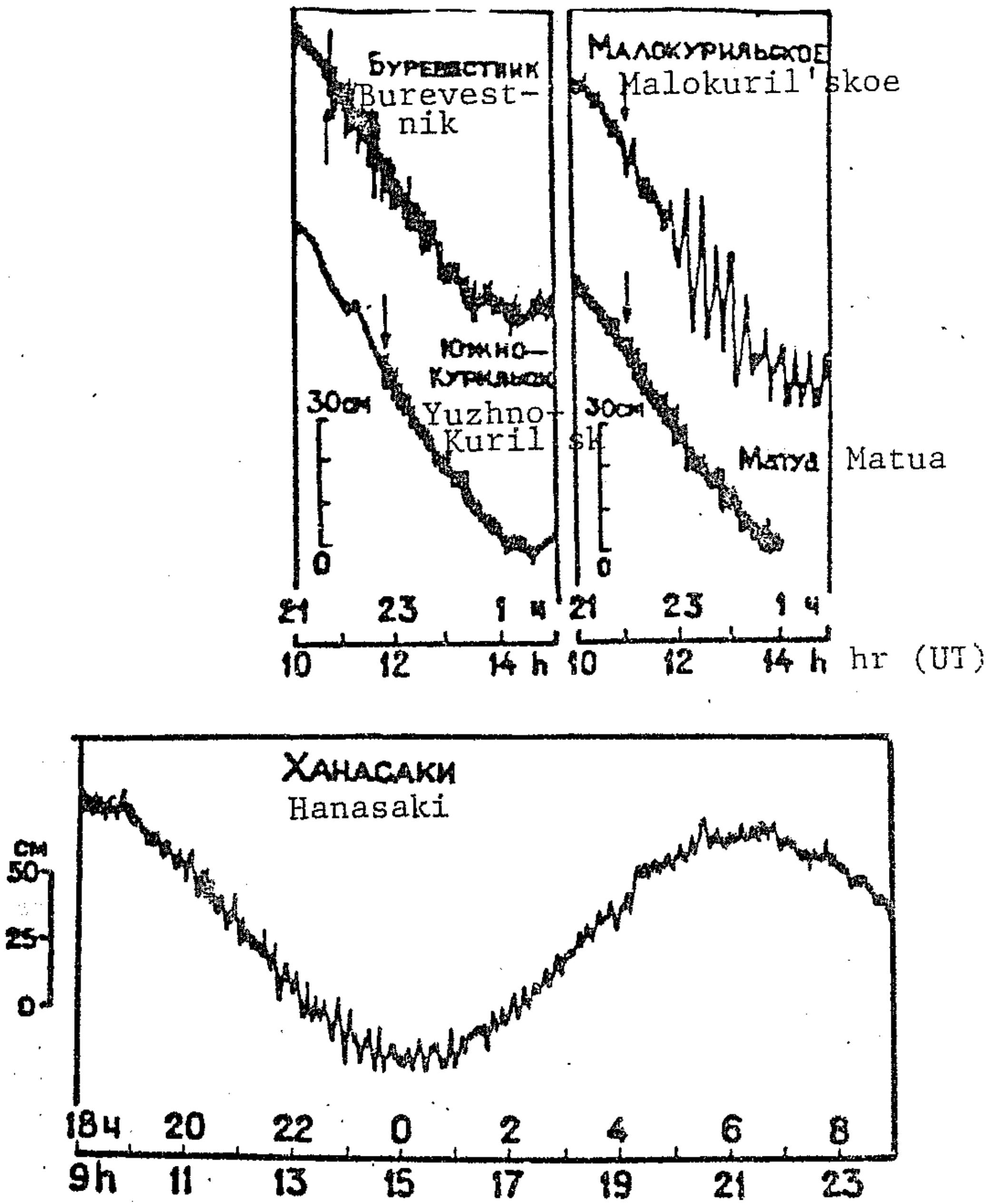

Figure 48: Records of the tsunami of January 21, 1976 on the Kuril Islands [Zhigulina, et al., 1980] **and in Japan** ["Tsunamis observed in Japan...", 1981].

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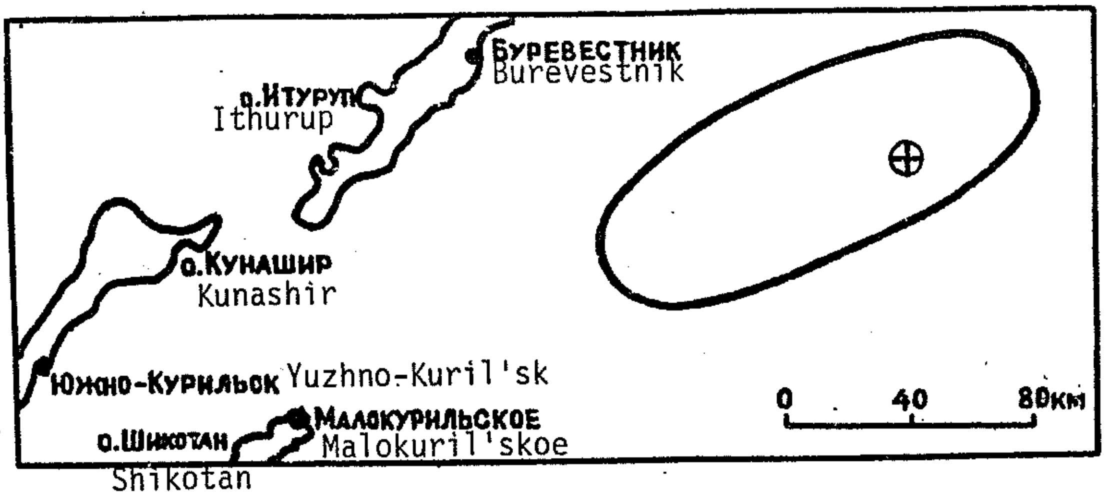

Figure 49: Epicenter of the earthquake and tsunami source of January 21, 1976 [Zhigulina, et al., 1980].

August 17, 1976; 00 hr 11 min. Early in the morning of August 17, 1976 Mindanao Island in the Philippines was shaken by an earthquake at a magnitude of 8.0 with its epicenter in Moro Gulf. It caused a destructive tsunami in the Celebes Sea causing devastation in settlements along the coast of Moro Gulf on Mindanao Island and on the nearby Sulu Islands. This earthquake was felt on all of the central islands of the Philippines Archipelago and in the southern part of Luzon. As a result of the earthquake and tsunami over 8,000 persons were killed or missing, 10,000 were injured, and 90,000 were left homeless making this catastrophe one of the most tragic and distressing disasters in the history of the Philippines.

The earthquake began in the night when offices and schools in Catabato, Zamboanga and other cities were empty; this minimized the number of deaths in these large cities. In the coastal fishing villages, where most houses are built on pilings in the inlets and on the river banks, people were awakened moments after the shock. Unaware of the need to move to higher ground in the event of an earthquake, they were covered by the tsunami wave and pulled into the sea.

The coastal regions of the Celebes Sea suffered a colossal loss to their economy. Soon after, local civil and military units organized rescue operations to help the residents. The Philippine government took prompt measures for the rehabilitation of the affected regions.

1509 Based on the investigation of the affected regions it was concluded that the maximum waves in Moro Gulf reached a height of 4-4.8 m which was much lower than what was reported by the press. Large waves were also observed at heights of 4.3 m in Alicia, Pagadian, and on Bongo Island; 3.4 m on Lebak; and at 3 m on Resa Bay, the eastern coast of Basilan and the Jolo Islands, and on Sacol Island. In Lake Cebu, seiches (standing waves) appeared. A tsunami with a maximum amplitude of 35 cm was recorded by tide gauges in Davao.

Weak tsunami waves were also observed in southern Japan (Figure 50). Table 26 presents data from tide gauge records.

According to data from the International Tsunami Information Center in Honolulu, the tsunami was localized in the Celebes Sea, particularly in Moro Gulf and did not spread to other parts of the Pacific Ocean. Moreover, according to the report from the Indonesian Hydrographic Department, even the Celebes Sea coastlines of Indonesia, including Calimantan Island, were unaffected by the ravages of the tsunami. [NL, Vol. 9, No. 3, 1976; Tsunami Reports, No. 1976-26; Nakamura, 1977; Badillo and Astilla, 1978; SN, Vol. 68, No. 2, 1978; Spaeth, 1978; "Tsunamis observed in Japan...", 1981; Hatori, 1982a; Soloviev, 1982; Watanabe, 1983].

[August 16; 16 h 11 m 07.3 s; 6.3° N. Lat., 123.7° E. Long.; 33 km; M = 8.0; I = 2½].

Table 26: Tide gauge data on the tsunami of August 17, 1986 on the coast of Japan

Place	First Wave		Height of the maximum wave (cm)
	Arrival Time (hr min)	Rise (+) or fall (-) of level	
Ishigaki	06 30	-	-
Tosashimizu	07 20	-	10
Cape Muroto	07 30	-	12
Kushimoto	06 30	-	-
Mera	08 30	+ ?	9
Chichijima	06 15	+ ?	10

1509

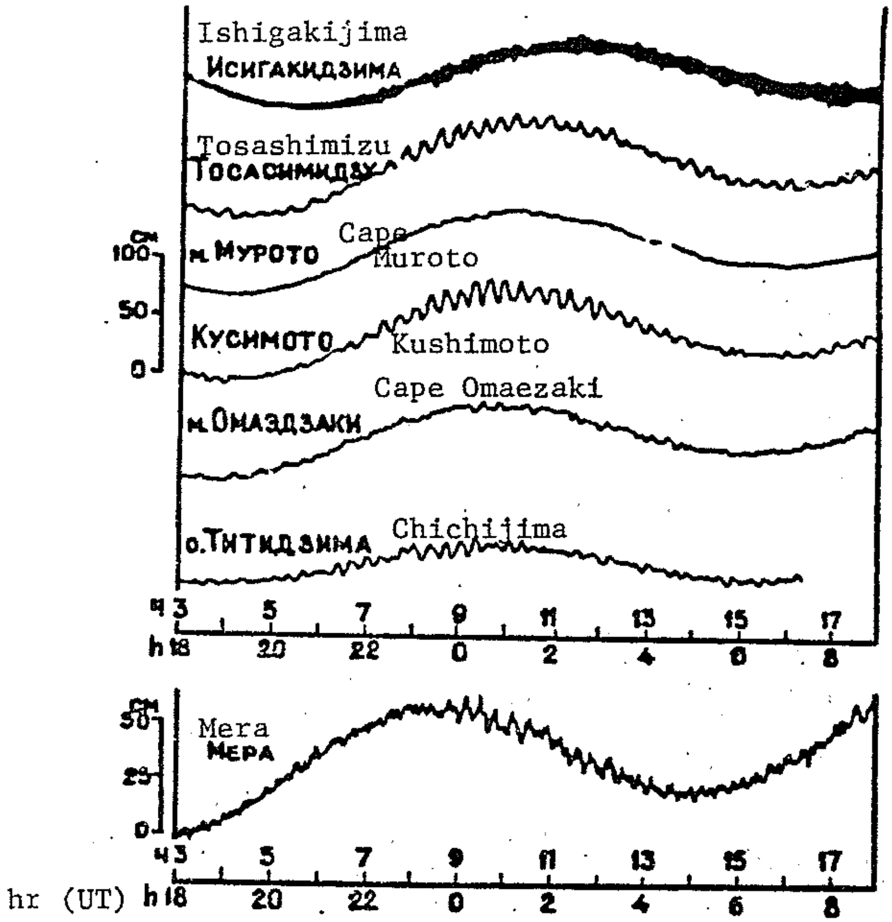

Figure 50: Records of the tsunami of August 17, 1976 on the coast of Japan [Hatori, 1982a]

<u>April 2, 1977; 19 hr 35 min</u>. An earthquake occurred in the deep-water Tonga Trench with its epicenter near Samoa. The earthquake caused some destruction in Apia and Pago-Pago and was felt in Suva on the Fiji Islands.

The earthquake produced a weak tsunami which was recorded in Apia and Pago Pago (Table 27). [NL, Vol. 10, No. 2, 1977; Tsunami Reports, No. 1977-5; Spaeth, 1979; Soloviev, 1982].

[April 2; 07 h 15 m 22.7 s; 16.2° S. Lat., 171.6° W. Long.; 13 km; M = 7.2; I = -2].

Table 27: Tide gauge data on tsunami of April 2, 1977

Place	Travel time (min)	First Wave Period (min)	First Wave Amplitude (cm)	Height of the maximum wave (cm)
Apia	39	12	4	7
Pago Pago	30	18	5	15

April 21, 1977; 10 hr 13 min. An earthquake occurred in the Solomon Islands. This was the first of three earthquakes that occurred in a five hour period in this region. According to press information at least 12 people were killed and 22 were missing as a result of these earthquakes. Severe destruction and landslides were reported from Honiara.

The first earthquake, with a magnitude of 6.5, produced a weak tsunami which was recorded by several tide gauges in Australia and on the Solomon Islands (Table 28). [NL, Vol. 10, No. 2, 1977; Tsunami Reports, No. 1977-6; Spaeth, 1979; Shatornaya, 1981; Soloviev, 1982].

[April 20; 23 h 13 m 10.4 s; 9.5° S. Lat., 160.4° E. Long.; 49 km; M = 6.5; I = -2].

April 21, 1977. The second of the three earthquakes on the Solomon Islands occurred at a magnitude of 7.5, 30 min after the first shock and at almost the same place. It was reported that this earthquake produced a weak tsunami on Rennell Island although it is possible that it was the first earthquake described above which actually caused the tsunami. [NL, Vol. 10, No. 2, 1977; Tsunami Reports, No. 1977-7; Spaeth, 1979; Shatornaya, 1981; Soloviev, 1982].

[April 20; 23 h 42 m 50.5 s; 9.8° S. Lat., 160.8° E. Long.; 19 km; M = 7.1; I = -2].

April 21, 1977; 15 hr 24 min. The third strong earthquake on the Solomon Islands occurred at a magnitude of 7.5, five hours after the first shock in roughly the same region as the two previous shocks. Eighteen people were killed by landslides. Fairly severe destruction was caused in Guadalcanal.

A weak tsunami caused by this earthquake was recorded on the Solomon Islands, northeast of Australia and in the western part of Samoa (Table 29). [NL, Vol. 10, No. 2, 1977; Tsunami Reports, No. 1977-8; Spaeth, 1979; Shatornaya, 1981; Soloviev, 1982].

[April 21; 04 h 24 m 9.6 s; 11.1° S. Lat., 160.7° E. Long.; 33 km; M = 7.5; I = -1½].

Table 28: Tide gauge data on tsunami of April 21, 1977

Place	Travel time (hr min)	Amplitude of the first wave (cm)	Height of the maximum wave (cm)	Period (min)
<u>New Britain</u>				
Rabaul	-	-	7	-
<u>Guadalcanal Island</u>				
Honiara	01 02	7	15	-
<u>Samoa</u>				
Upolu Island	-	-	-	-
Apia	06 37	3	4	13
<u>Australia</u>				
Cairns	07 24	2	2	16
Townsville	06 12	3	6	14
Brisbane	08 50	HEIGHT TOO LOW FOR MEASUREMENTS		

Table 29: Tide gauge data on tsunami of April 21, 1977

Place	Travel time (hr min)	Height of the wave (cm)	Period (min)	Height of the maximum wave (cm)
<u>Upolu Island</u>				
Apia	06 44	2	15	3
<u>Australia</u>				
Townsville	06 21	3	14	4
Cairns	06 25	2	16	3
Brisbane	08 26	Very low height		

June 22, 1977; 00 hr 29 min. An earthquake occurred in the deep water Tonga Trench at a magnitude of 7.0. Two people were reported injured and severe damage was caused on Tonga.

A weak tsunami caused by this earthquake was recorded in a fairly large region (Table 30). [NL, Vol. 10, No. 2, 1977; Tsunami Reports, No. 1977-9; Spaeth, 1979; SN, Vol. 69, No. 1, 1979; Soloviev, 1982].

[June 22; 12 h 08 m 33.4 s; 20.9° S. Lat., 177.4° W. Long.; 65 km; M = 7.0; I =0].

Table 30: Tide gauge data on tsunami of June 22, 1977

Place	Travel time (hr min)	Height of the wave (cm)	Period (min)	Height of the maximum wave (cm)
Fiji Islands				
Suva	01 42	28	30	31
New Caledonia Island				
Noumea	06 05	9	10	9
Samoa				
Apia	01 36	3	20	7
Pago Pago	01 10	10	18	13
Oceania				
Papeete	03 27	27	17	12
Mururoa	05 57	10	12	10
Hawaiian Islands				
Hilo	-	-	-	9
Honolulu	07 38	3	15	12
Kahului	07 47	4	22	25
Lihue	07 27	12	15	16
California				
Port St. Luis	-	-	-	24
San Diego	11 37	4	35	15
Los Angeles	12 24	10	-	10
Long Beach	-	-	-	24

New Zealand				
Whangara	03 42	9	40	13
Auckland	03 37	4	10	10
Tauranga	03 14	10	27	15
Opua	04 02	6	-	15

August 19, 1977. A catastrophic earthquake shook Sumbawa Island. It covered an extensive area from the southern coast of Indonesia to the northwestern coast of Australia. Shocks were felt over a vast territory. In Perth, over 2000 km south of Sumbawa, the shocks caused people to flee from buildings.

A large tsunami was produced. The first press reports announced waves 30 m high in Indonesia and 8 m high in Australia. Apparently, these figures were exaggerated. A group from the International Tsunami Information Center visited the coastal regions of Sumba, Sumbawa, Lombok and Bali Islands to assess the destruction and wave run-ups, and to obtain other detailed information from local people. Inaccessible areas on the southern coast of Sumba and Sumbawa islands were photographed from the air. Information was processed that had been gathered by the Indonesian military, search and rescue parties, provincial administration, and by medical teams visiting accessible areas in the coastal villages to offer help and assess the extent of loss of property and life. These records were supplemented by radio broadcast accounts from individual settlements.

The southern coasts of the islands, with the exception of Bali, is sparsely populated. Villages are generally small and scattered. Hence the loss of human life was not high. According to incomplete data, over 180 people were killed and 3,900 were left homeless. Fishing boats and equipment were lost. For a large part of the Indonesian territory, which had sustained heavy damage from the tsunami, no information is available on the height of the rise in the water level. However, in the accessible region of Sumbawa Island, preliminary information reported that the tsunami reached a height of at least 15 m above the high-tide mark and inundated the island up to 500 m inland.

According to eyewitness accounts, the tsunamis appeared on the Indonesian coast about an hour or two after high tide, beginning with an ebb, which soon left a 100-200 m wide drained belt. This was followed by three large waves with a period of about 5 min or less. The first wave was the highest and most ferocious. Several witnesses noted the duration of agitation of the sea although most made no mention of it. An unusual phenomenon occurred during the time interval between the earthquake and the arrival of the tsunami. Residents of villages in the Sumbawa and Lombok Islands thrice heard a sound at intervals estimated from a few seconds to 1 min and more. It was diversely described as sounding like a bomb explosion or a sonic boom. The sound reportedly emanated from the epicentral area. Nearly every village reported that the water became black and some reported a rise in temperature and an unpleasant smell. The tsunami reached a height of more than 10 m along the coast of Sumbawa. The main destruction was observed on the Sumbawa and Lombok islands.

The tsunami was also observed on the northern and western coasts of Australia. It was reported that on the Australian coast, as on the Indonesian coast, three waves appeared, the first being the largest. Agitation of the sea continued for several hours. In Dampier the wave reached a height of 2 m; in Port Sampson it varied from 2 to 4 m; in Cape Leveque it reached 6 m. The arrival of the tsunami coincided with an observable ebb and a low tide in many places. These factors weakened the overall effect of the tsunami. Evidently, no lives were lost in Australia although there was one report of a person drawn into the sea by waves. [NL, Vol. 10, No. 3, 1977; Tsunami Reports, No. 1977-12; Spaeth, 1979; SN, Vol. 69, No. 1, 1979; Shatornaya, 1981; Soloviev, 1982].

[August 19; 06 h 08 m 55.2 s; 10.5° S. Lat., 118.5° E. Long.; 33 km; M = 7.7; I = 3].

<u>August 29, 1977</u>. An earthquake occurred in the region of the Admiralty Islands. It was felt at an intensity of IV points (Rossi-Forel scale) in the western part of the Manus Island.

According to the report from the Port-Moresby Observatory, a local tsunami was recorded at a height of 0.6 m. [SN, Vol. 62, No. 2, 19].

[August 28; 20 h 10 m 0.5 s; 1.08° S. Lat., 146.23° E. Long., 33 km; M = 5.5; I = O].

<u>October 10, 1977</u>. An earthquake of 6.9 magnitude near Tonga Island caused a weak tsunami which was recorded on the Fiji and Samoan Islands (Table 31). [NL, Vol. 10, No. 4, 1977; Tsunami Reports, No. 1977-16; Spaeth, 1979; Soloviev, 1982].

[October 10; 11 h 53 m 53.8 s; 26.1° S. Lat., 175.4° W. Long.; 33 km; M = 6.9; I = -3].

Table 31: Tide Gauge data on the tsunami of October 10, 1977

Place	Travel time (hr min)	Height of the first wave (cm)	Height of the maximum wave (cm)
Pago Pago	00 54	2	6
Suva	02 13	2	-

January 14, 1978; 12 hr 24 min. A strong earthquake occurred in the Izu region of Japan. The epicenter was located between the Izu Peninsula and Òshima Island. The earthquake caused great destruction. Twenty-five people were killed, 129 were injured, 85 houses were totally destroyed, and 544 were damaged. Roads, railway lines and port structures, etc., were damaged. Landslides were observed and cracks appeared in the ground.

This earthquake produced a weak tsunami which was recorded by many tide gauges (Table 32). Some tsunami records are presented in Figure 51.

Figure 52 shows the source of this tsunami [Aida, 1978a; Hatori, 1978a; Tsunami Reports, No. 1978-1; NL, Vol. 12, No. 2, 1979; SN, Vol 69, No. 5, 1979; Soloviev, 1982; Watanabe, 1983].

[January 14; 03 h 24 m; 34.7° N. Lat., 139.0° E. Long.; 23 km; M = 7.0; I = 0].

Table 32: Tide gauge data on the tsunami of January 14, 1978 in Japan

Place	First Wave			Height of the maximum wave, (cm)
	Travel time, (min)	Amplitude, (cm)	Period, (min)	
Okada	5	+10	4	62
Senzu	5.5	+ 6	3.4	10
Habu	7.5	-10	3.2	18
Minamiizu	13.5	-12	5.5	14
Ito (Futo)	4	- 6	3	7
Oiso	?	-	-	14
Enoshima	?	-	-	14
Kurihama	16 ?	+ 2	12	4
Mera	16	+ 5	10	20
Hachijo Jima	?	-	-	12
Miyake Island	?	-	-	16

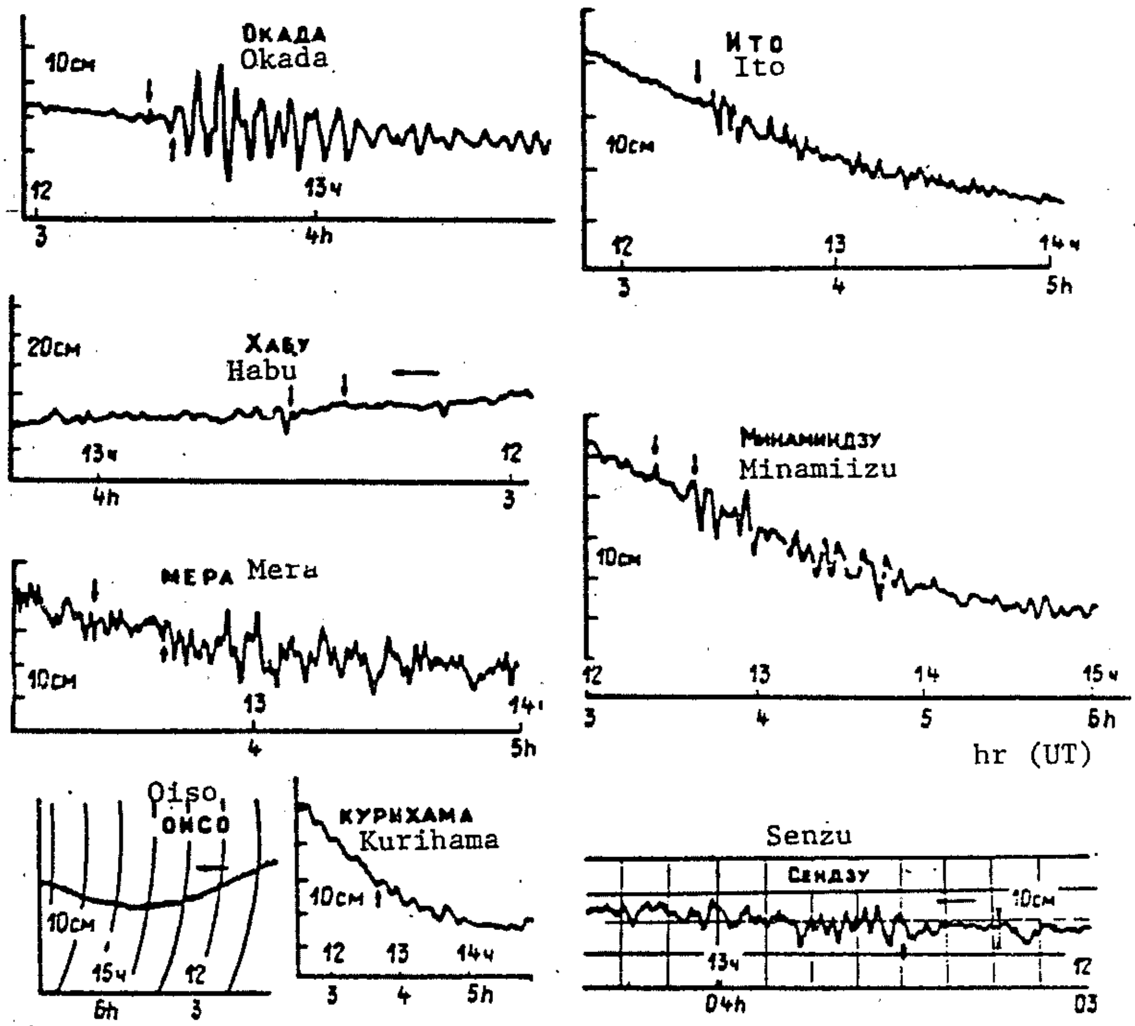

Figure 51: Records of the tsunami of January 14, 1978 [Hatori, 1978a].

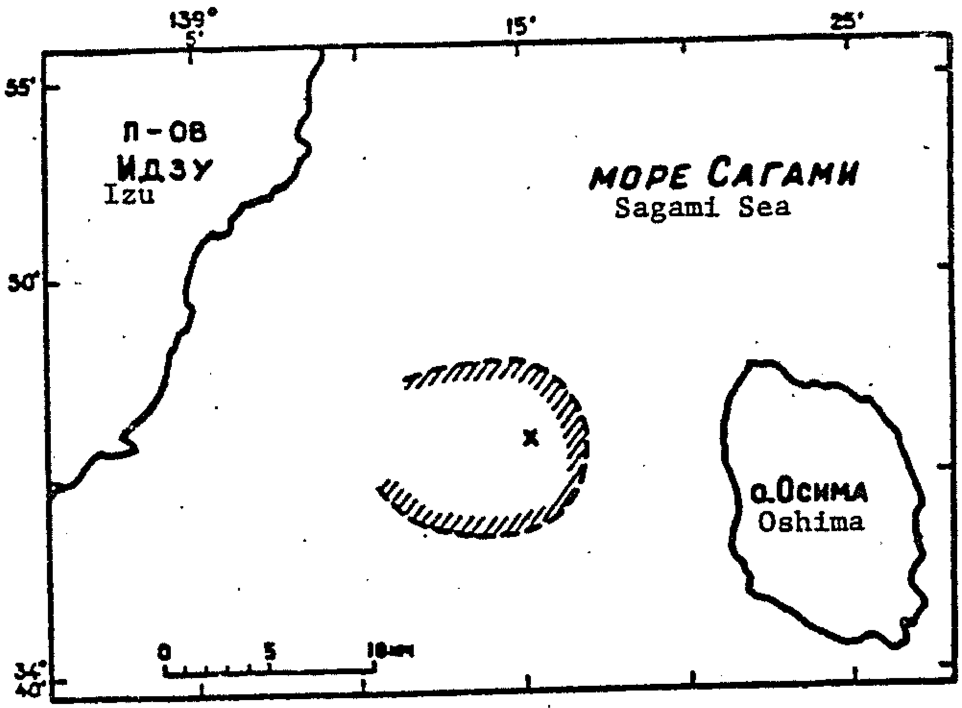

Figure 52: Epicenter of the earthquake and source of the tsunami of January 14, 1978
[Hatori, 1978a]

March 22, 1978. At the end of March 1978, a long series of earthquakes occurred east of Iturup Island, many of which had a magnitude exceeding 7.0. From 00 hr 50 min of March 22 to 19 hr 43 min of March 24 there were as many as seven earthquakes ranging in magnitude from 7.0 to 8.0. This many great earthquakes occurring in succession is unusual. It is also noteworthy that five of the seven earthquakes produced weak tsunamis.

. The first earthquake occurred at 11 hr 32 min (Sakhalin time) at a magnitude of 7.5. It was not felt in the Kuril Islands where a tsunami warning was issued although no sea level oscillations were seen. A tsunami at a height of 7 cm was recorded in Malokuril'skoye. The travel time of the wave was 37 min and its period 20 min (Figure 53). [Shchetnikov et al., 1982; Soloviev, 1982].

[March 22; 00 h 50 m 31 s; 43.8° N. Lat., 149.2° E. Long.; 37 km; M = 7.5; I = -2½].

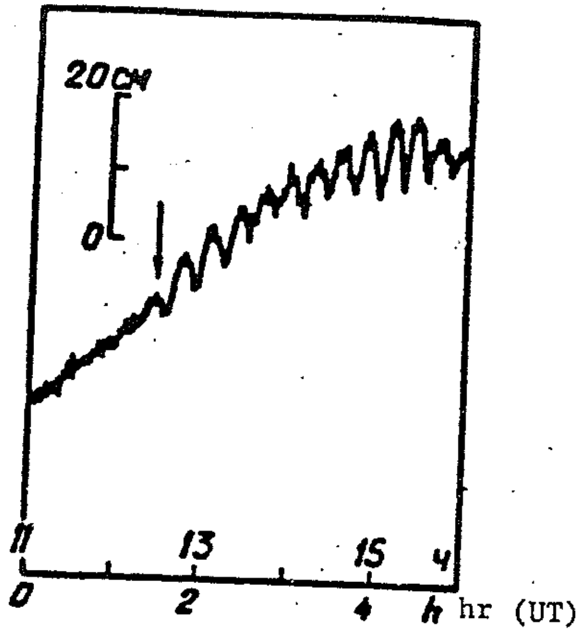

Figure 53: Record of the tsunami of March 22, 1978 in Malokuril'skoye [Shchetnikov et al., 1982].

<u>March 23, 1978</u>. A second earthquake with a magnitude of 7.1 occurred at 8 hr 34 min 31 sec Sakhalin time. This earthquake was not felt on the Kuril Islands. A tsunami warning was issued but substantial sea level oscillations were not reported.

A tsunami was recorded at two hydrometeorological stations: Burevestnik and Yuzhno-Kuril'sk (Table 33). Because the tsunami was a weak one, it did not cause any damage on the coasts of the Kuril Islands or Japan. Figure 54 shows the tsunami records. [Shchetnikov et al., 1982; Soloviev, 1982].

[March 22; 21 h 34 m 31 s; 43.8° N. Lat., 149.3° E. Long.; 36 km; M = 7.1; I = -3].

Table 33: Tide gauge data on the tsunami of March 23,1978 (March 22, 21 h, 34 m)

Place	Travel time (min)	First Wave Period (min)	Amplitude (cm)	Height of the maximum wave (cm)
Burevestnik	44	3	- 4	5
Yuzhno-Kuril'sk	87	3	+ 2	5

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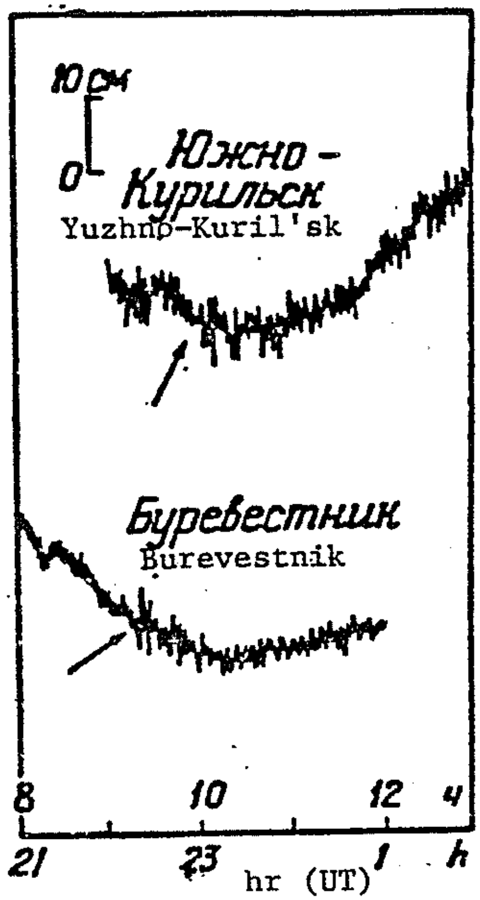

Figure 54: Records of the tsunami of March 23, 1978 (second earthquake) [Shchetnikov et al., 1982].

March 23, 1978. At 11 hr 31 min Sakhalin time the third of the five tsunamigenic earthquakes occurred. Its magnitude was 7.6. There were no visible oscillations in sea level.

A weak tsunami caused by the earthquake was recorded by tide gauges (Table 34).

Figure 55 shows the tsunami records. [Shchetnikov et al., 1982, Soloviev 1982].

[March 23, 00 h 30 m 58 s; 43.8° N. Lat., 149.3° E. Long., 40 km; M = 7.6; I = -1½].

Figure 55: Records of the tsunami of March 23, 1978 (third earthquake) [Shchetnikov et al., 1982].

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Table 34: Tide gauge data on the tsunami of March 23, 1978 (00 h 31 m)

Place	Travel time, (min)	First Wave Period (min)	Amplitude, (cm)	Height of the maximum wave, (cm)
Burevestnik	39	8	+16	17
Yuzhno-Kuril'sk	146	4	- 4	7
Malokuril'skoye	39	12	+ 7	10
Poronaisk	234	17	+ 2	3

March 23, 1978. The fourth of the tsunamigenic earthquakes occurred at 14 hr 16 min Sakhalin time at a magnitude of 7.8. The earthquake was felt at an intensity of 5 points on Shikotan Island and at 3 points on Iturup Island. It was also felt at intensities of II points (JMA) in the Nemuro-Urakawa region (Hokkaido) and in Aomori (Honshu). Visible oscillations in sea level were not observed.

A weak tsunami caused by the earthquake was recorded by tide gauges on the Kuril Islands and in Japan (Table 35).

Figure 56 presents the tsunami records. [Tsunami Reports, No. 1978-7; Hatori, 1979; SN, Vol. 69, No. 6, 1979; Shchetnikov et al., 1982; Soloviev, 1982; Watanabe, 1983].

[March 23; 03 h 15 m 20.3 s; 43.8° N. Lat., 148.9° E. Long.; 40 km; M = 7.8; I = 0].

Table 35: Tide gauge data on the tsunami of March 23, 1978 (03 h 15 m)

Place	Travel time (min)	First Wave Amplitude (cm)	Period (min)	Height of the maximum wave (cm)
Kuril Islands				
Burevestnik	37	+19	9	23
Yuzhno-Kuril'sk	87	+12	9	16
Malokuril'skoye	45	+12	12	30
Sakhalin				
Korsakov	175	- 2	25	-
Cape Crillon	145	- 2	7	-
Poronaisk	253	+ 3	10	-
Japan				
Hanasaki	54	9	13	12
Abashiri	103	1	9	3
Kushiro	?	-	-	6
Hiroo	67	7	8	14
Urakawa	?	-	-	10
Hachinohe	94	4	6	10
Chichijima	163	26	15	28

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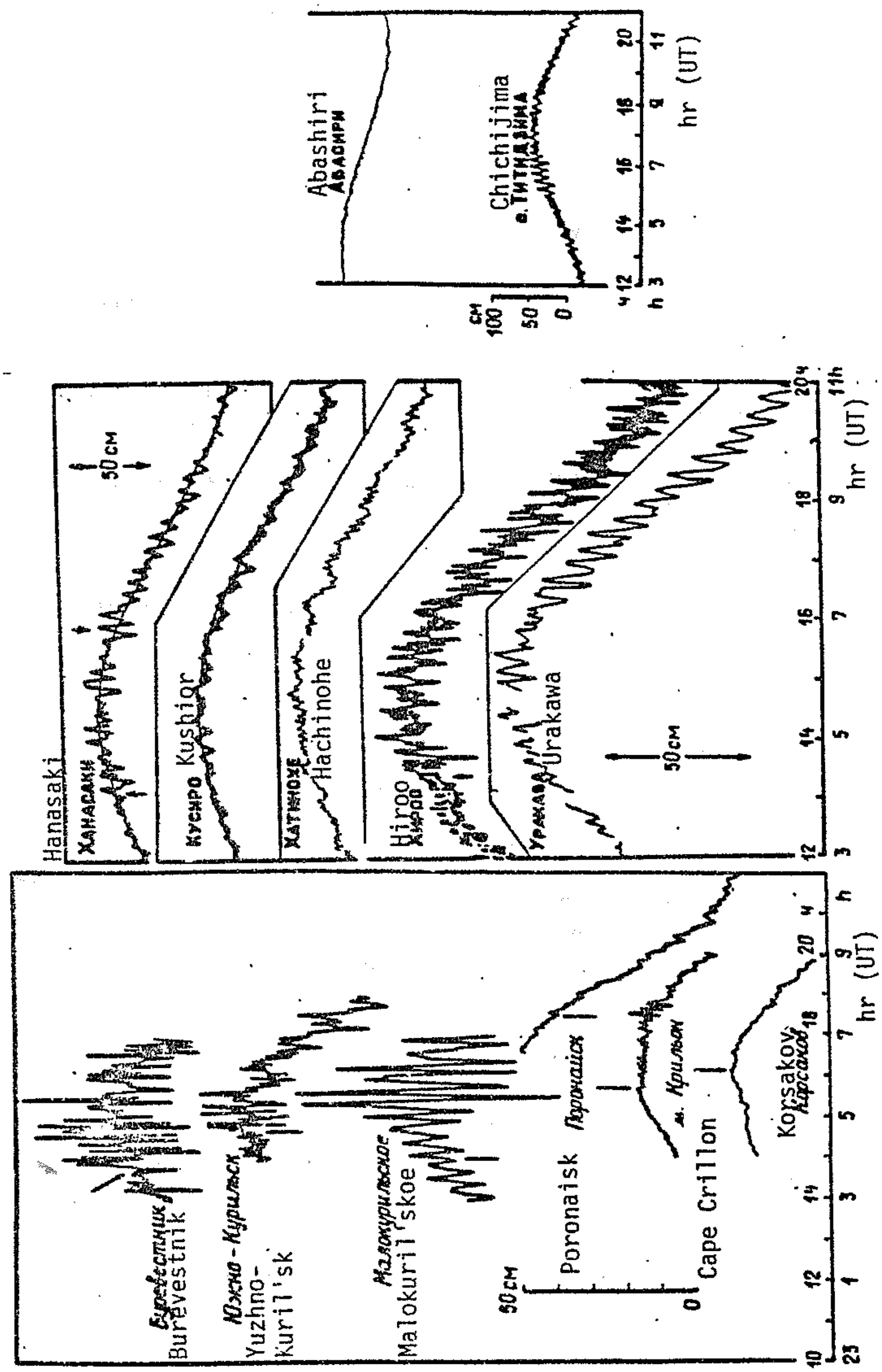

Figure 56: Records of the tsunami of March 23, 1978 on the Kuril and Sakhalin Islands [Shchetnikov et al., 1982] **and in Japan** [Hatori, 1979] <u>(fourth earthquake).</u>

March 25, 1978. The fifth and strongest tsunamigenic earthquake occurred at 06 hr 49 min Sakhalin time. Seismic station "Yuzhno- Sakhalinsk" assessed its magnitude at 7.6. The earthquake was felt at an intensity of 5-6 points on Shikotan Island, at 5 points on Kunashir Island, and at 3 points on Iturup and Urup Islands. The earthquake was felt at an intensity of III points (JMA) in the region of Nemuro-Hiroo-Obihiro (Hokkaido) and at II points in the southwestern part of Hokkaido and in the northern part of Honshu.

The tsunami generated by the earthquake was recorded by instruments on the Kuril Islands and in Japan (Table 36). Data on the visual observations are not available with the exception of a report that for three hours in Kasatka Inlet the sea repeatedly receded about 15-20 m from the coast.

It can be seen from Table 36 that at all stations the tsunami began with a rise in water level. Tsunami tide gauge records from the USSR and Japan are presented in Figure 57. These records were used to draw the sources for the tsunamis of March 23 and 25 (Figure 58). [NL, Vol. 11, No. 1, 1978; Tsunami Reports, No. 1978-9; Hatori, 1979; SN, Vol. 69, No. 6, 1979; Shchetnikov et al., 1982; Soloviev, 1982; Watanabe, 1983].

[March 24; 19 h 47 m 50.7 s; 43.9° N. Lat., 149.1° E. Long.; 39 km; M = 8.0; I = 0].

Table 36: Tide gauge data on tsunami of March 25, 1978 (March 24; 19 h 48 m)

Place	Travel time (hr min)	First wave Amplitude (cm)	First wave Period (min)	Height of the maximum wave (cm)
Kuril Islands				
Matua	42	+ 6	10	10
Burevestnik	32	-14	16	65
Yuzhno-Kuril'sk	01 24	+13	10	18
Malokuril'skoye	32	+16	10	37
Sakhalin				
Korsakov	02 42	+ 1	?	4
Cape Crillon	02 27	+ 2	15	5
Poronaisk	03 40	+ 1	10	3

Japan

Abashiri	01 32	2	9	3
Hanasaki	00 51	16	12	24
Tokachi	01 08	12	9	17
Kushiro	00 56 ?	5	20	9
Hiroo	01 02	14	12	21
Urakawa	?	-	-	17
Hachinohe	01 10	4	17	12
Miyako	01 08	6	12	7
Ayukawa	01 20	5	8	8
Chichijima	02 46	12	15	15
Wake Island	03 58	5	-	5
Midway	04 42	9	-	12

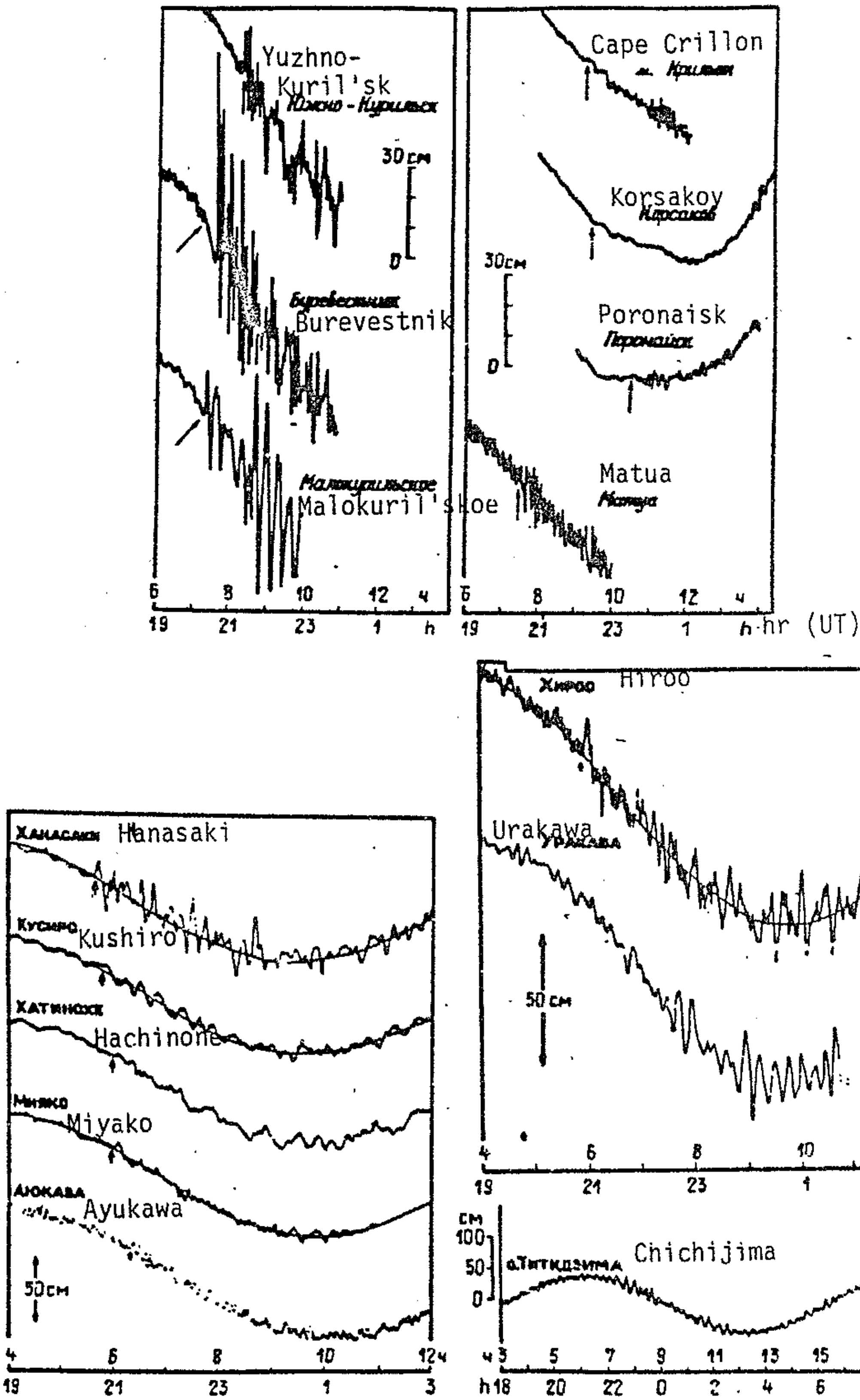

Figure 57: Records of the tsunami of March 25, 1978 on the Kuril and Sakhalin Islands [Shchetnikov et al., 1982] **and in Japan** [Hatori, 1979].

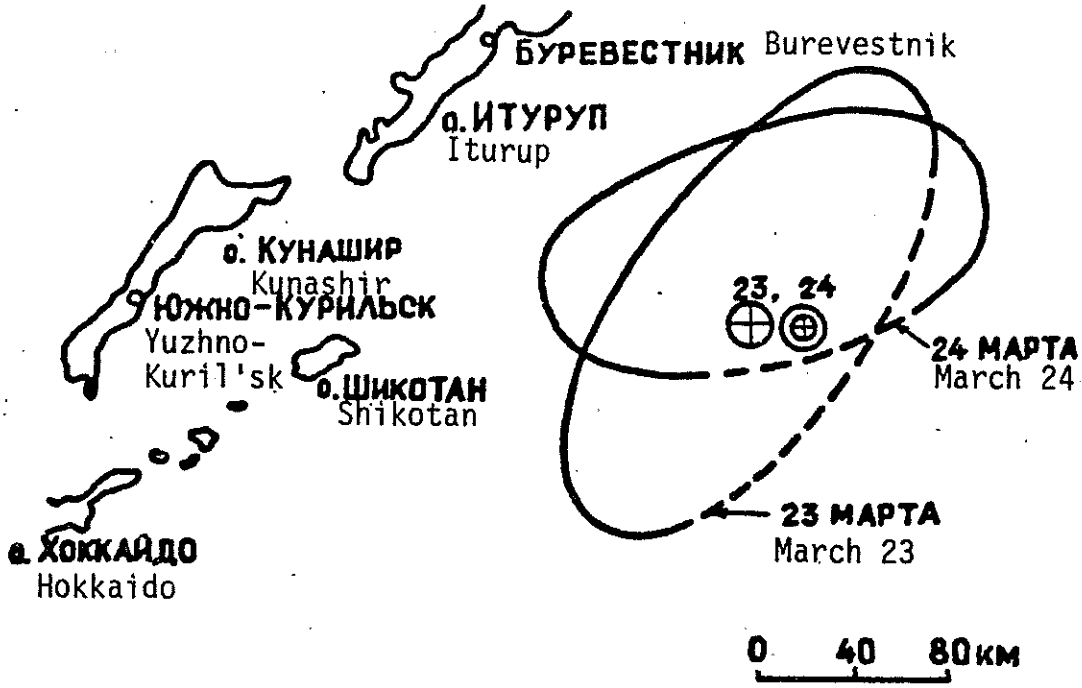

Figure 58: Epicenters of the earthquakes and sources of the tsunamis of March 23 and 25, 1978 [Shchetnikov, 1982].

June 12, 1978; 17 hr 14 min. A strong earthquake of 7.4 magnitude caused extensive destruction in the northeastern part of Honshu. Its epicenter was located in Miyagi Prefecture. Particularly severe destruction was observed in Sendai. As a result of the earthquake 28 people died and nearly 10,000 were injured. Moreover, a tsunami generated by the earthquake caused panic among the people for some time. However, in Onagawa, close to the source, the height of the wave did not exceed 1 m and the tsunami warning was soon withdrawn. Damage caused by the tsunami was not observed.

A tsunami generated by the earthquake was recorded by many tide gauges in Japan (Table 37; Figure 59).

It can be seen from Table 37 that all tsunami records from all tide gauges show the tsunami began with a rise in water level. Figure 60 shows the tsunami source as drawn by Hatori. [Aida, 1978b; Hatori, 1978b; NL, Vol. 12, No. 2, 1978; Tsunami Reports, No. 1978-10; Soloviev, 1982; Watanabe, 1983].

[June 12; 08 h 14 m 26.4 s; 38.5° N. Lat., 141.7° E. Long.; 40 km; M = 7.4; I = ½].

Table 37: Tide gauge data on the tsunami of June 12, 1978 in Japan

Place	First wave Travel time (min)	Amplitude (cm)	Period (min)	Height of the maximum wave (cm)
Hanasaki	-	-	-	8
Kushiro	-	-	-	15
Hiroo	-	-	-	13
Urakawa	-	-	-	12
Tomakomai	-	-	-	12
Hachinohe (Same)	62	6	21	26
Hachinohe	66	7	20	21
Miyako	28	13	25	14
Kamaishi	20	20	26	24
Ofunato	13	22	28	22
Kesennuma	22	65	40	60
Shirahama	14	44	24	30
Tsukihama	14	35	22	35
Enoshima	0	22	25	22
Onagawa	12	50	36	58
Ayukawa	10	20	20	20
Ishinomaki (Kadowaki)	36	26	42	24
Ishinomaki	-	24	38	34
Miyako	-	22	50	18
Shiogama	54	18	25	21
Sendai	44	21	27	18
Soma	45	8	46	-
Matsukawaura	40	10	40	10
Onahama	53	12	28	15
Hitachi	57	9	38	18
Ooarai	60	14	33	16
Mera	-	-	-	11

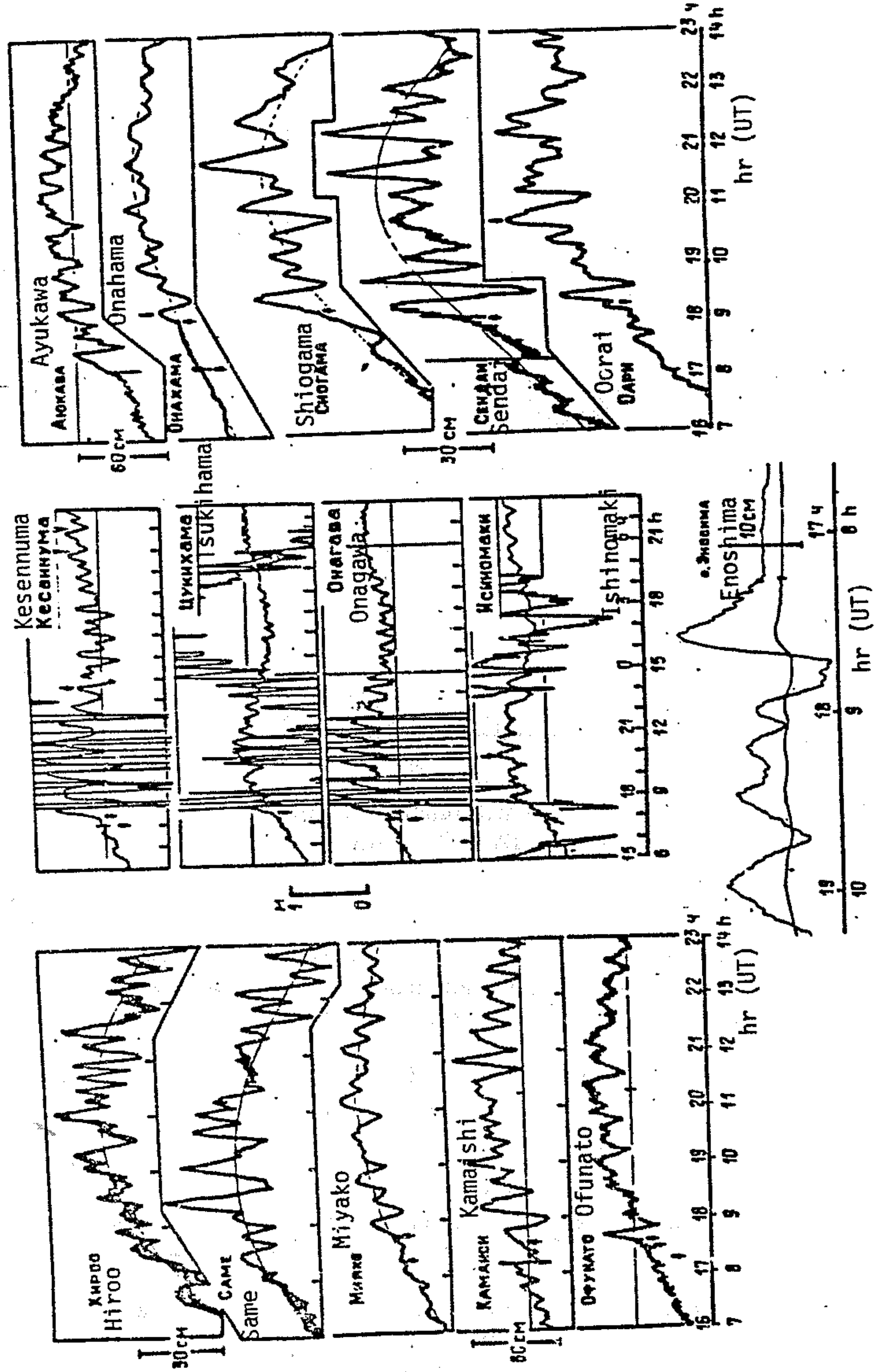

Figure 59: Records of the tsunami of June 12, 1978 [Hatori, 1978b]

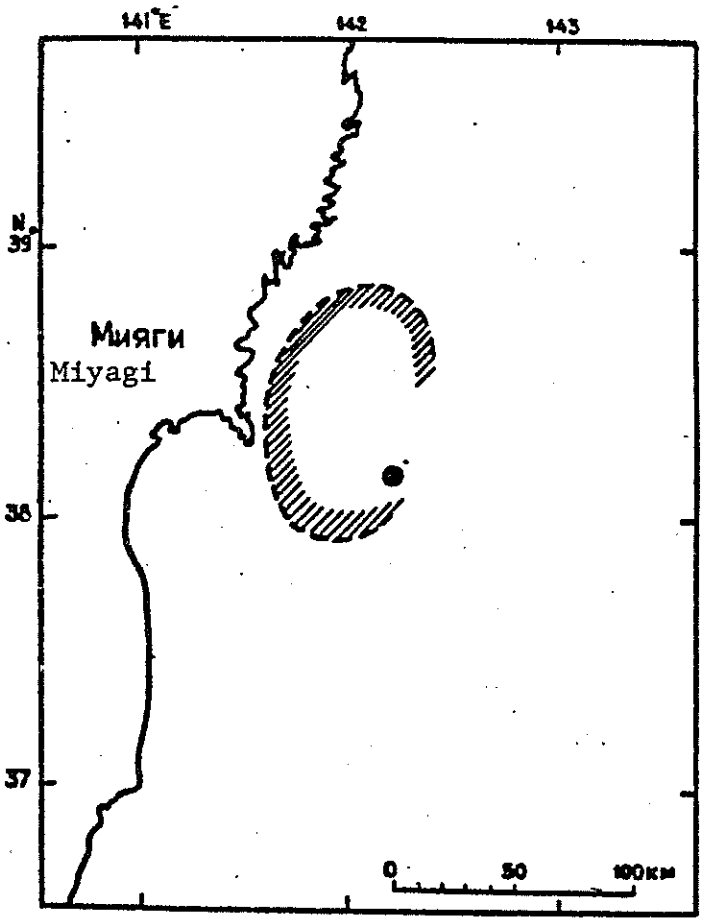

Figure 60: Epicenter of the earthquake and source of the tsunami of June 12, 1978 [Hatori]

June 14, 1978. An earthquake occurred in the Philippines at a magnitude of 6.9. A weak tsunami generated by this earthquake was observed on Hilo Island (3 cm). [Tsunami Reports, No. 1978-2; Soloviev, 1982].

[June 14; 12 h 32 m 33.9 s; 8.8° N. Lat., 122.4° E. Long; 24 km; M = 6.9; I = 0].

July 23, 1978; 23 hr 43 min (Japan time). An earthquake occurred with its source near Bashi Strait, 200 km south of Taiwan. It was felt on Taiwan and in Hong Kong.

A weak tsunami generated by the earthquake was reported from Ishigaki Jima (Ryukyu Islands) at a maximum amplitude of 10 cm and a period of 10 min. [NL, Vol. 11 No. 2, 1978; SN, Vol. 70, No. 2, 1980; "Tsunami observed in Japan...", 1981; Tsunami Reports, No. 1978-2; Soloviev, 1982].

[July 23; 14 h 42 m 36.9 s; 22.3° N. Lat., 121.5° E. Long.; 17 km; M = 7.0; I = -1].

February 20, 1979; 15 hr 32 min. An earthquake with a magnitude of 6.5 occurred east of Iwate Prefecture. It generated a weak tsunami on the coast of Japan (Table 38, Figure 61). [Hatori, 1981b; Watanabe, 1983].

[February 20; 06 h 32 m; 40.13° N. Lat., 143.52° E. Long.; 0 km; M = 6.5; I = 0].

Table 38: Tide gauge data on tsunami of February 20, 1979 in Japan

	First wave			
Place	Travel time (min)	Amplitude (cm)	Period (min)	Height of the maximum wave (cm)
Hanasaki	?	-	-	-
Hiroo	?	-	-	5
Urakawa	41	4	9	5
Hachinohe	48	6	7	6
Kuji	?	-	-	8
Shimanokoshi	30	15	9	15
Miyako	?	-	-	4
Ofunato	?	-	-	7
Enoshima	46	4	5	9
Ayukawa	52	5	8	8
Onahama	?	-	-	4

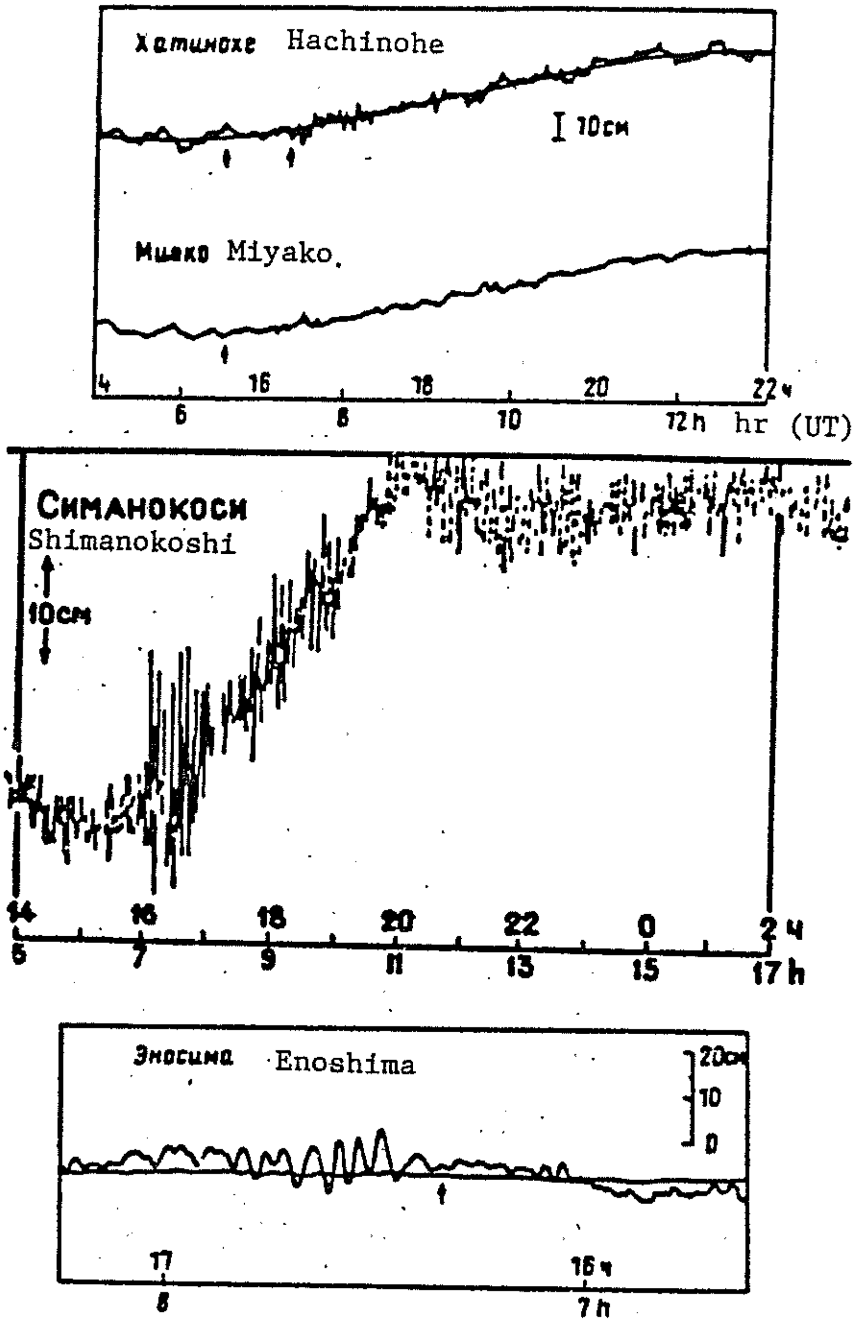

Figure 61: Records of the tsunami of February 20, 1979
[Hatori, 1981b]

<u>March 14, 1979</u>. A strong earthquake occurred not far from Petatlan (Mexico). It generated a weak tsunami which was recorded by the underwater (ocean bottom) tide gauge located 980 km northwest of the epicenter at the exit from the Gulf of California to the Pacific Ocean and sits at a depth of 3,210 m (Figure 62). The wave height was 1 cm, the period was 1.5 hr, and the travel

time was 1.5 hr (Figure 63). The high frequency waves were recorded with a period of 2-4 min. The 0.1 cm amplitude represents the long surface seismic waves. [Filloux, 1982; NL, Vol. 15, No. 2, 1982].

[March 14; 11 h 07 m 16.3 s; 17.81° N. Lat., 101.28° W. Long.; 15-20 km; M = 7.6].

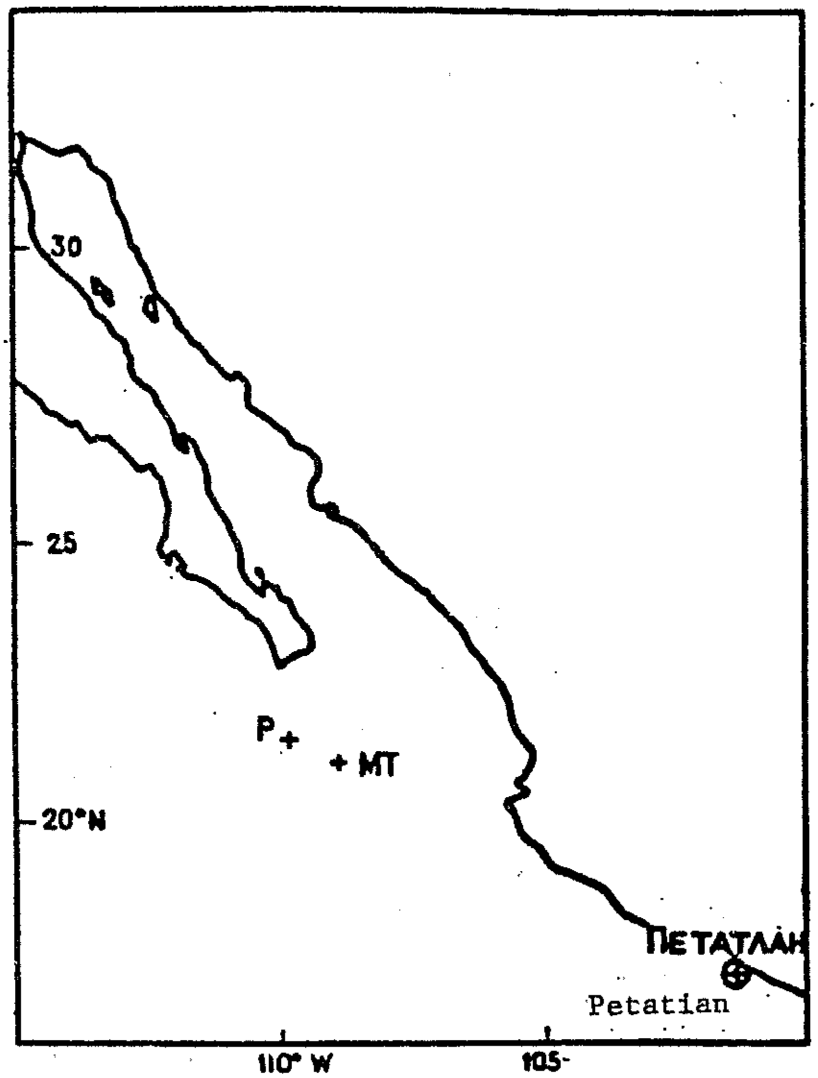

Figure 62: Location of ocean bottom instruments which registered the tsunami of March 14, 1979 [Filloux, 1982, NL, 1982].

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Figure 62 Key: P = Place of observation of ocean bottom pressure gauge,
MT = Extreme of the four points of magnetotelluric observations conducted between P and MT

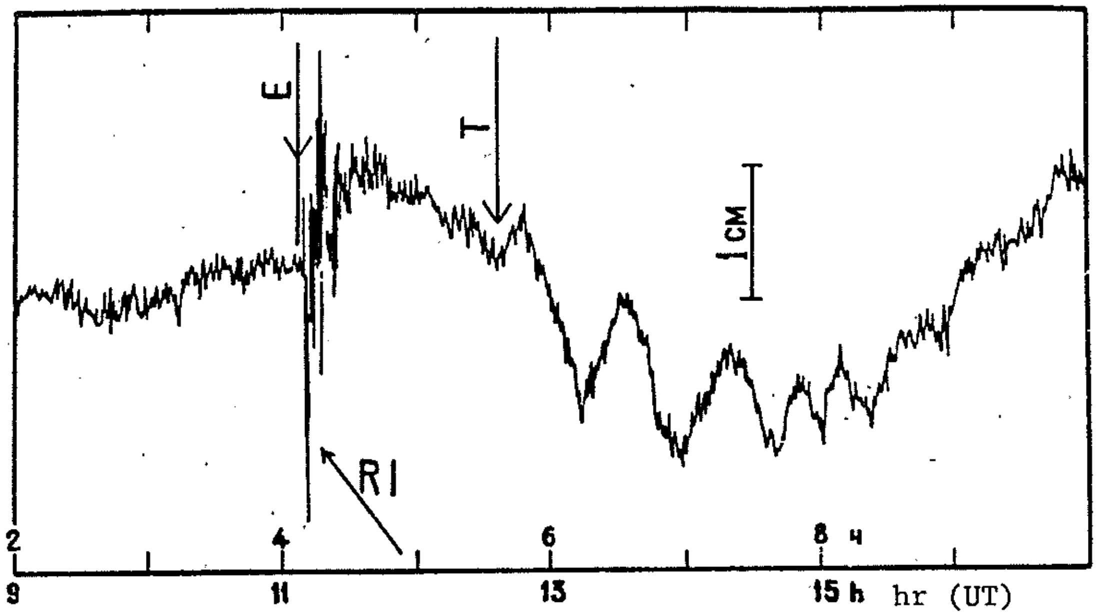

Figure 63: Record of the ocean bottom pressure gauge before and after the beginning of the earthquake of March 14, 1979.
(Key on next page)

Figure 63 Key:

1 - hr
E - Moment of occurrence of the earthquake
RI - Seismic disturbance
T - Moment of appearance of tsunami wave. Change in height by 1 cm corresponds to change in pressure by 100 Pa [Filloux, 1982; NL, 1982].

<u>July 18, 1979</u>. A strong tsunami occurred in Indonesia. According to the preliminary data, a tsunami with a height of 7-9 m was observed on Lomblen Island (8° 35' S. Lat., 123° 30' W. Long.). In four villages 539 people lost their lives and 700 were declared missing. Water covered the land to a distance of 1,500 m. The possible reasons for the generation of the tsunami were the eruption of a volcano, a landslide, or the falling of part of the mountain peak into the sea. An earthquake is ruled out. At first it was erroneously thought that the tsunami was generated by a volcanic eruption. This misperception was due to an incorrect translation from the Indonesian language. 1509

It was later concluded that the cause of the tsunami was a landslide on one of the capes on the southern coast of Lomblen Island. The settlements of Waiteba, located at the neck of the cape on the eastern side of the cape, and Labala-Mulang on the western side suffered the most. The tsunami started with the sea receding from the coast and then returned with tremendous force. Mainly villagers rather than fishermen suffered. [Gushechenko, 1979; NL, Vol. VIII, No. 1, 1980; Marine Science Monthly, No. 7, 1980; Pararas-Carayannis, 1980; Soloviev, 1982].

[July 18; 8.6° S. Lat., 123.5° E. Long.; I = 3].

<u>September 12, 1979</u>. A strong earthquake was recorded in West Irian. Fifteen people died and many were injured. Considerable loss was reported on Japen Island. A tsunami of local significance was observed on Japen and Biak Islands. [EIB, No. 1, 1980; SN, Vol. 70, No. 6, 1980; Soloviev, 1982].

[September 12; 05 h 17 m 51.4 s; 1.68° S. Lat., 136.04° E. Long.; 5 km; M = 7.7; I = 0].

<u>December 12, 1979; 02 hr 59 min</u>. Near the coast of Colombia a very strong earthquake occurred. Its magnitude was estimated at 7.9. The earthquake and tsunami generated by it caused great loss (Figure 64). The earthquake was felt in Bogota, Cali, Papayan, Buenaventura and other places in Colombia and Guayaquil, in Esmeraldas, Quito, and other places in Ecuador.

Tsunami waves washed six fishing villages on the Pacific coast of Colombia. At least 15 coastal towns were affected by the tsunami. People who left their houses were, a few minutes later, carried by the wave into the sea. Six fishing boats were lost at sea, one of them carrying 40 fishermen. The number of dead and lost in the tragedy was in the hundreds.

On Gorgona Island a pier was destroyed but there were no casualties. In the village of Charó, with a population of about 4,000, most houses constructed with bamboo were swept into the lake. The Isquanda River, in which the waves moved upstream, overflowed its banks. The village of Isquanda suffered great loss and at least one person died.

Of the populated places on the coast the fishing village of San Juan suffered the most. Here, the wave destroyed everything in its path and many people died. An eyewitness account reported 3-4 m waves. The first passed about 10 min after the main shock. The tsunami had begun with sea level falling 3 m below normal a few minutes after which the first tide wave arrived. The third wave was the maximum with a height 5 m above sea level at San Juan Island. Fortunately, the moment of arrival of the maximum wave coincided with the maximum low tide phase.

The difference between the maximum high and low tide in this region is about 1.3 m. Had the arrival of the maximum wave coincided with the maximum high tide, the loss of life and property would have been far greater. The maximum wave then would have covered the entire coastal islands since the coastal elevation of these islands is roughly 2-2.5 m relative to high tide. The length of the coastal area affected by the tsunami was roughly 30-35 km and that which was affected by the earthquake was about 225 km, from Guapi to Tumaco.

In Table 39 the data on the loss of life and property due to the earthquake and tsunami is given as reported in the records of the Civilian Defense Service of Colombia. These figures may be on the low side. Most of the deaths (about 80%) were caused by the tsunamis. According to the assessment of the International Tsunami Information Center and also based on data from of unofficial sources, the number of deaths was 500-600 and about 4,000 were injured. At least 10,000 persons were left homeless.

Figure 65 shows the record for Esmeraldas (Ecuador) about 170 km south of the epicenter. The records confirm that the tsunami appeared at the moment of maximum low-tide. It began with a fall in level followed by 3-4 waves. The maximum wave height on the record is about 50 cm. The tsunami did not cause destruction in Tumaco (Colombia) or Esmeraldas (Ecuador). Had the wave arrived at the time of maximum high tide its height would have been more than 1.3 m making it quite likely that these two places would have suffered.

This tsunami was recorded by many tide gauges in Japan (Table 40, Figure 65). [Pararas-Carayannis, 1980; Hatori, 1981a; Soloviev, 1982; Watanabe, 1983].

[December 12; 07 h 59 m; 1.6° N. Lat., 79.4° W. Long.; 24 km; M = 7.9; I = 2½].

Table 39: Loss of life and property caused by the tsunami of December 12, 1979 in Colombia

Place	Died	Lost	Injured	Houses Destroyed
Tumaco	18	7	400	1,280
El Charco	43	50	300	all
San Juan	161	38	70	all
Mosquera	4	-	-	-
Majagual	12	-	28	20%
Salahonda	1	-	-	-

Table 40: Tide gauge data on the tsunami of December 12, 1979 in Japan

Place	First wave Travel time (hr min)	First wave Fall (cm)	First wave Period (min)	Height of the maximum wave (cm)
Hanasaki	19 22	7	15	12
Kushiro	19 36	4	20	10
Hiroo	19 28	4	14	25
Urakawa	20 04	3	20	12
Hakodate	20 20	5	24	9
Mutsu-Ogawara	19 58	4	16	6
Same	20 08	5	18	11
Hachinohe	20 10	7	15	20
Shimanokoshi	19 30	6	16	22
Miyako	19 34	6	15	11
Kamaishi	19 32	6	15	16
Ofunato	19 35 ?	5	15	14
Enoshima	19 27	2	16	4
Ayukawa	19 38	5	18	13
Onahama	19 50	6	20	3
Hitachi	19 50 ?	4	18	13
Mera	20 12	3	18	10
Hachijo Jima	20 30 ?	5	12	-
Minamiizu	19 56 ?	4	17	6
Omaezaki	20 46 ?	4	16	8
Owase	21 03	9	16	12
Uragami	20 56	7	17	12
Kushimoto	20 48	4	15	10
Muroto	?	-	-	5
Tosashimizu	21 32	5	28	10
Aburatsu	21 08	4	22	10
Nase	22 08	4	14	10

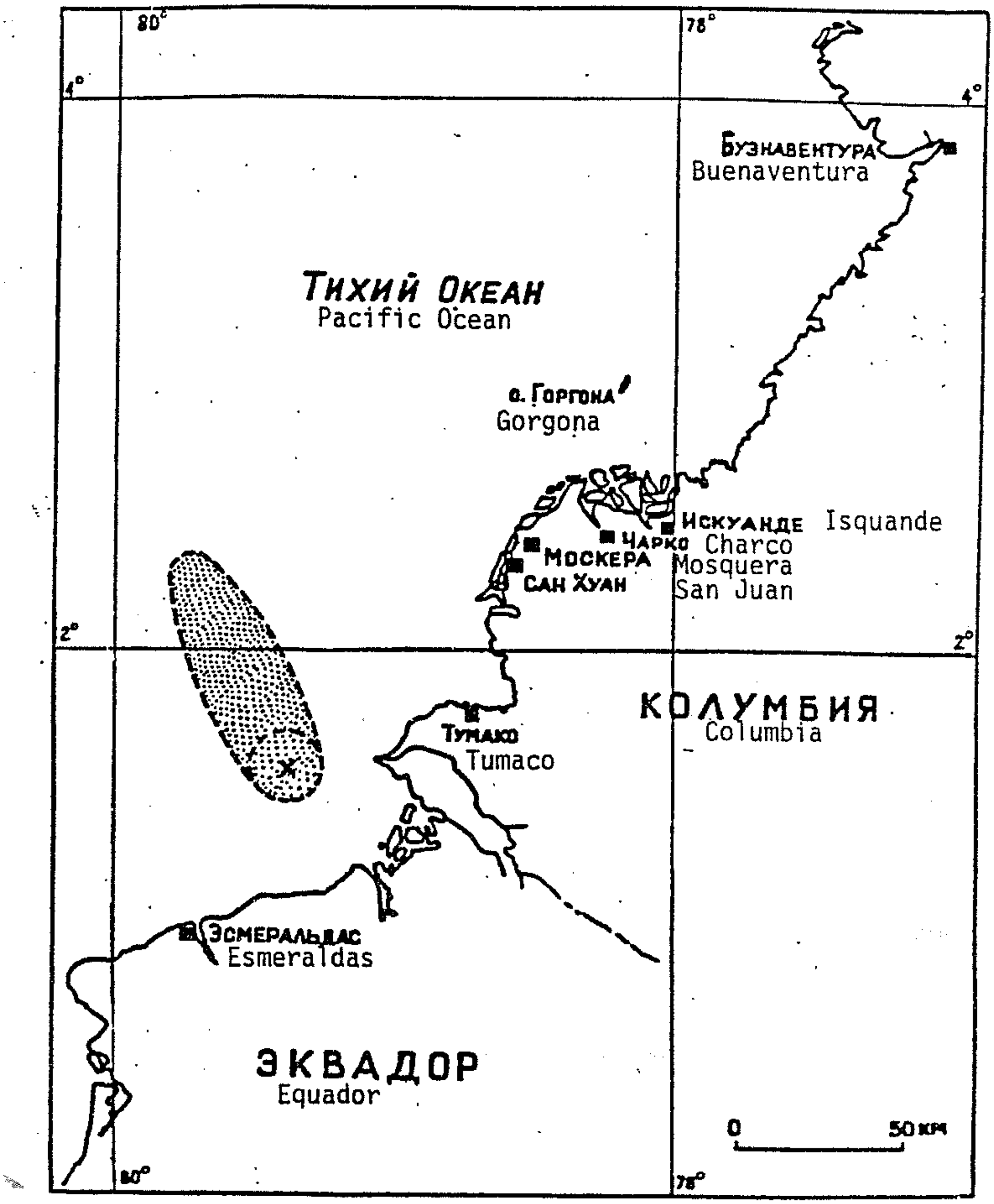

Figure 64: Epicenter and tsunami source for the earthquake and tsunami of December 12, 1979 [Pararas-Carayannis, 1980].

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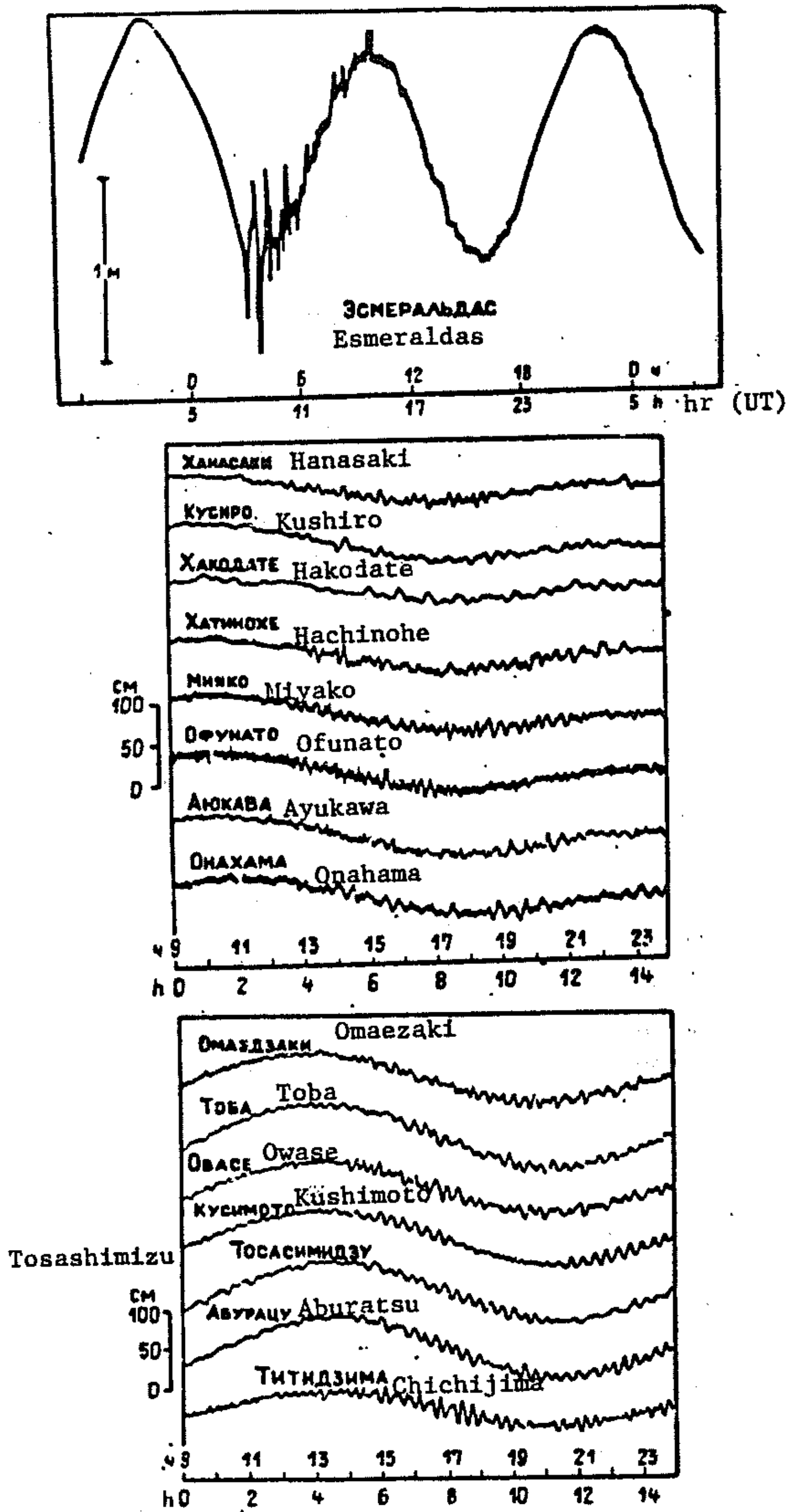

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Figure 65: Records of the tsunami of December 12, 1979 in Esmeraldas [Pararas-Carayannis, 1980] and in Japan [Hatori, 1981a].

February 23, 1980. At 16 hr 50 min Sakhalin time an earthquake occurred at a magnitude of 7.0 southeast of the Malye Kuril and Kuril Islands. It was felt at intensities of 6-7 points in the Malye Kuril Islands and at 6 points in Yuzhno-Kuril'sk, USSR. It was also felt at 6 points (IV on JMA) in Nemuro and Kushiro, at 5 points (III on JMA) in Obihiro and Urakawa (Japan), and at 4 points in Kuril'sk, USSR. A tsunami warning was issued along the southern Kuril Islands.

This earthquake generated a small tsunami which was recorded by tide gauges on the coast from Itupup Island in the north to Honshu in the south (Table 41, Figs. 66 and 67). A tsunami was also recorded by the ocean bottom tide gauge positioned 8 km off of Shikotan Island to SE to the depth 113 m and linked with the observatory "Shikotan" (Malokuril'skoe) by cable (20 km) (Figure 67) an hour before the wave approached populated areas. The staff of the "Shikotan" observatory had an opportunity to observe the entire tsunami passage over the transducer. This was the second case in the world of recording a tsunami away from the waterline. [Dykhan et al., 1981; Soloviev, 1982; Watanabe, 1983].

[February 23; 05 h 50 m; 43.4° N. Lat., 146.8° E. Long.; 30-40 km; M = 7.0; I = -2].

Table 41: Tide gauge data on the tsunami of February 23, 1980

Place	First wave			
	Travel time (min)	Height (cm)	Period (min)	Height of the maximum wave (cm)
Burevestnik	-	4	20	5
Malokuril'skoye	75	30	20	32
Yuzhno-Kuril'sk	65	11	21	11
Ocean bottom tide gauge	15	7	25	7
Nemuro*	39	10	-	10
Kushiro*	-	-	-	8
Hachinohe*	78	7	-	7

*Data of Watanabe

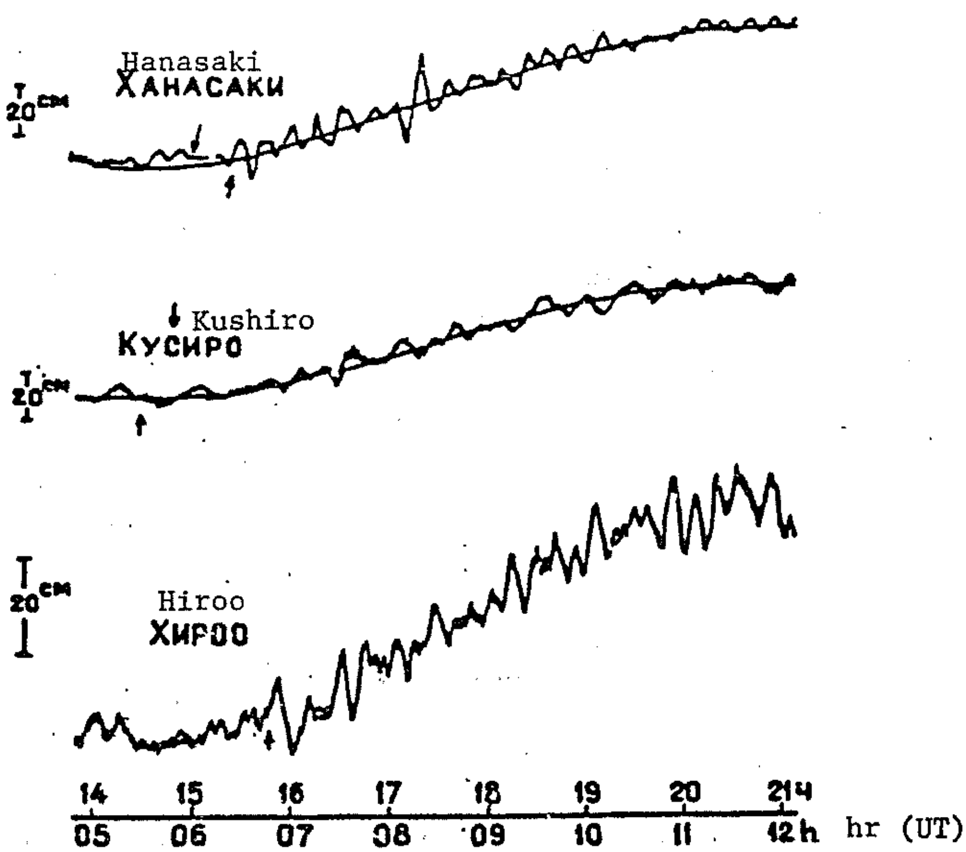

Figure 66: Records of the tsunami of February 23, 1980 in Japan.

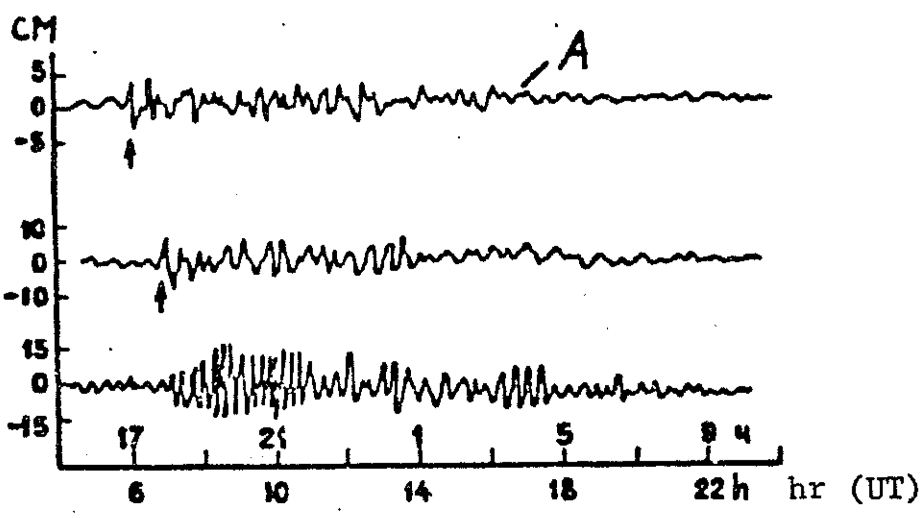

Figure 67: Records of the tsunami of February 23, 1980 made by the ocean bottom tide gauge (A) and by tide gauges in Yuzhno-Kuril'sk and Malokuril'skoye (high tide oscillations not shown) [Dykhan et al, 1981].

June 29, 1980; 15 hr 20 min. An earthquake with a magnitude of 6.7 occurred east of the Izu Peninsula (see Figure 38) and was accompanied by a weak tsunami.

A tsunami warning was issued for the residents of the Kanto region. Four minutes after the main shock a rise in water level was observed at Oshima station (Oshima Island). The tsunami's full height was 56 cm, recorded at Okada on Oshima Island. The maximum height at the coast of Sagami Bay did not exceed 10 cm Figure 68 shows the tsunami records and Table 42 gives the principal data of the tsunami. [Hatori, 1980; Watanabe, 1983].

[June 29; 07 h 20 m; 34.6° N. Lat., 139.1° E. Long.; 10 km; M = 6.7; I = 0].

Table 42: Tide gauge data on the tsunami of June 29, 1980 in Japan

Place	First Wave			Height of the maximum wave (cm)
	Travel time (min)	Amplitude (cm)	Period (min)	
Okada	4.5	23	3.5	56
Senzu	4	6	0.3	10
Minamiizu	16 ?	4	7	8
Manazuru	6	4	4	8
Ito	2.5	6	2.6	9
Oisho	7	7	5	14
Hiratsuka	6	1.5	4	2.5
Enoshima	?	-	-	10
Hayama	?	-	-	10
Aburatsu	11	4	-	4
Kurihama	?	-	-	3
Mera	?	-	-	12
Katsura	?	-	-	3
Kozu Shima	?	-	-	8
Miyake Jima	?	-	-	8

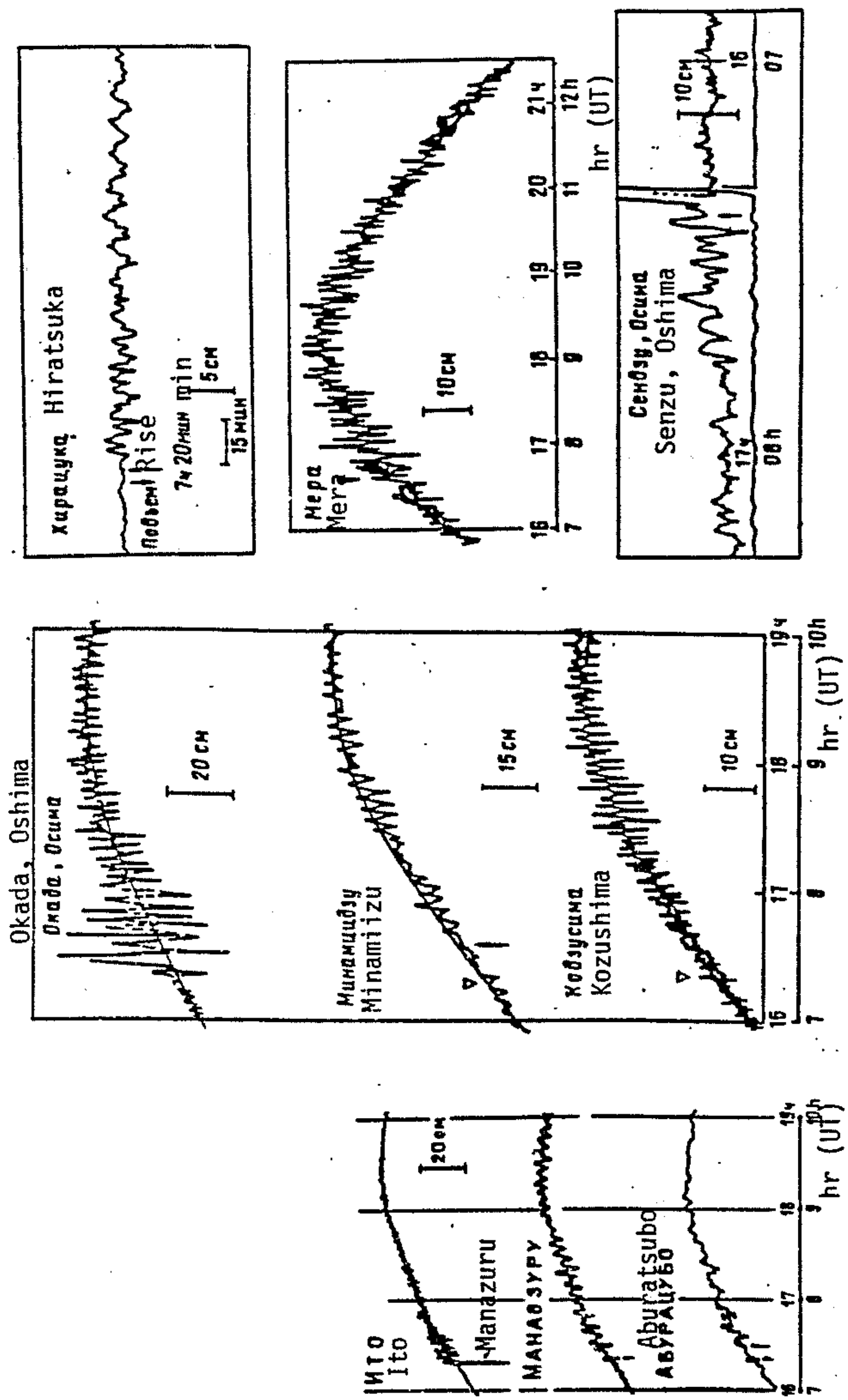

Figure 68: Records of the tsunami of June 29, 1980
[Hatori, 1980].

July 18, 1980; 05 hr 42 min. An earthquake with a magnitude of 7.9 occurred near the Santa Cruz Islands (So. Pacific). The earthquake generated a tsunami. A weak tsunami was registered even on the coast of Japan (Table 43). Figure 69 shows the records of this tsunami [Hatori, 1982a; Watanabe, 1983].

[July 17; 19 h 42 m; 12.5° S. Lat., 166.3° E. Long.; M = 7.9; I = 0].

Table 43: Tide gauge data on the tsunami of July 18, 1980 in Japan

Place	First Wave Travel time (hr min)	First Wave Rise (cm)	Period (min)	Height of the maximum wave (cm)
Hanasaki	8 53 *	3	17	13
Kushiro	10 56	4	20	15
Hiroo	9 22	6	12	19
Urakawa	8 28 *	3	16	18
Hachinohe	9 33	6	15	14
Miyako	8 24 *	4	24	9
Ofunato	9 13	3	16	10
Enoshima	8 48	1	10	3
Ayukawa	8 28 *	3	30	11
Onahama	8 50	3	17	12
Mera	8 58	4	8	13
Hachijo	8 03	3	16	21
Omaezaki	9 18	2	13	13
Toba	9 58	2	18	8
Uragami	8 58	3	20	8
Owase	9 00	4	20	10
Kushimoto	8 58	2	18	11
Muroto	9 11	2	10	7
Tosashimizu	9 38	3	21	10
Aburatsu	8 50	4	15	18
Nase	8 18	4	12	15
Naha				5

*Computed value.

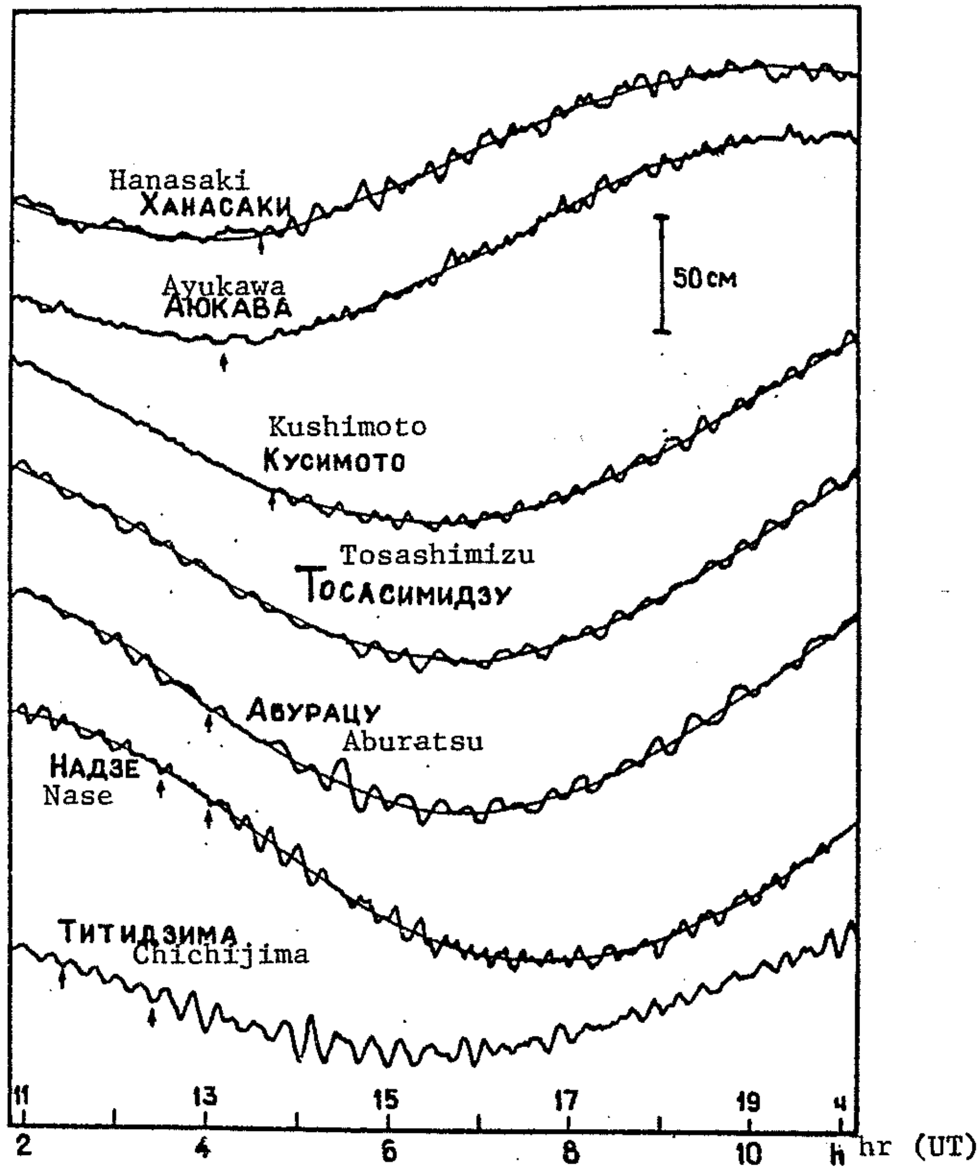

Figure 69: Records of the tsunami of July 18, 1980 on the coast of Japan [Hatori, 1982a].

<u>January 20, 1981; 3 hr 15 min</u>. An earthquake occurred near the Miyagi Prefecture at a magnitude of 7.0. The earthquake generated a weak tsunami on the coasts of the Miyagi and Iwate Prefectures. In Figure 70 and Table 44 we present the records of this tsunami and the principal data from it. [Hatori, 1981b; Watanabe, 1983].

[January 19; 18 h 17 m; 38.6° N. Lat., 142.9° E. Long.; O km; M = 7.0; I = 0].

Table 44: Tide gauge data on the tsunami of January 20, 1981 in Japan

Place	First Wave Travel Time (min)	Amplitude (cm)	Period (min)	Height of the maximum wave (cm)
Hanasaki	?	-	-	5
Kushiro	?	-	-	4
Hiroo	?	-	-	9
Shoya	-	-	-	8
Urakawa	71 ?	4	8	12
Hachinohe	62 ?	3	12	8
Miyako	30	8	12	10
Kamaishi	26	23	11	22
Ofunato	26	20	10	20
Kesennuma	30	15	16	15
Tsukihama	34	22	12	22
Enoshima	25	11	9	10
Ayukawa	33	8	8	8
Ishinomaki	60	6	12	6
Shiogama	76 ?	4	19	4
Sendai	68	4	8	6
Soma	60	3	12	12
Matsukawaura	62	2	23	8
Onahama	54 ?	3	9	8
Hitachi	58	4	8	11
Ooarai	56	7	10	10
Mera	?	-	-	8

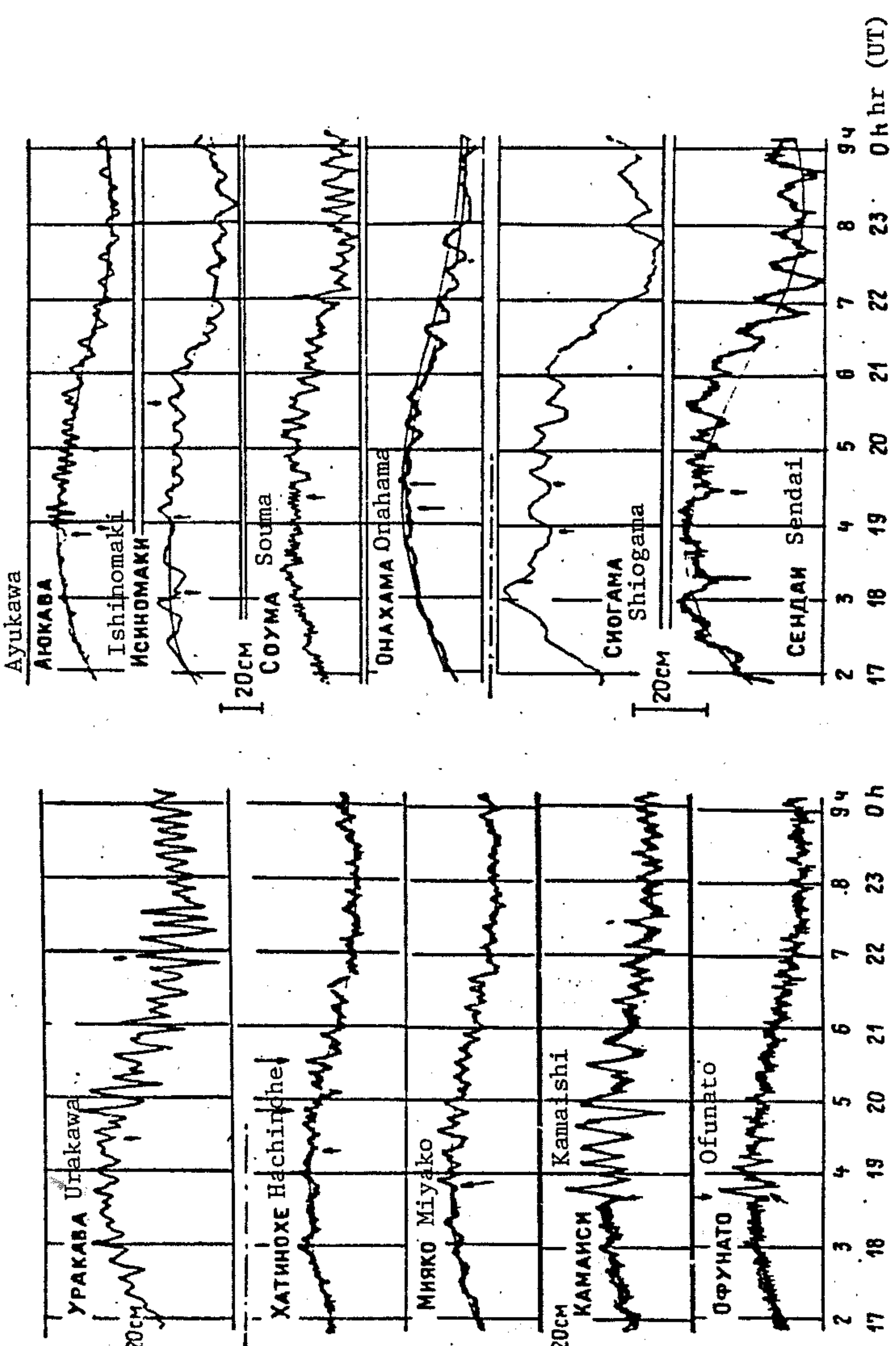

Figure 70: Records of the tsunami of January 20, 1981 [Hatori, 1981b].

September 1, 1981. An earthquake occurred with its source at the northern extremity of the deep water Tonga Trench. The tsunami generated by the earthquake caused destruction on the southwestern coast of Samoa. In the village of Taga on the southern coast of Saai'i Island, women preparing food were swept away along with their household goods. A fishing boat was drawn into the sea. The village well was severely damaged. Two large guest houses were destroyed. The village main street was blocked with piles of rocks and logs.

On Manono Island several houses were damaged and many houses were swept away. No loss of life was reported from the island. The wave height was apparently about 1 m.

In Apia the tide gauge recorded a tsunami height of 21 cm at 09 hr 55 min. In Pago Pago a 24 cm high tsunami was recorded. [NL, Vol. 15, No. 1, 1982].

[September 1; 09 h 30 m; 14.6° S. Lat., 172.7° W. Long.; M = 7.4; I = -2.0].

January 11, 1982. An earthquake occurred in the Philippines. The tide gauge in Legaspi recorded a tsunami at 14 hr 50 min. Oscillations were observed until 15 hr 30 min. The maximum height was 10 cm at 15 hr 00 min. [TWL, January, 1982].

[January 11; 06 h 10 min 10.2 s; 14.6° N. Lat., 124.7° E. Long.; normal; M = 6.9; I < 0].

February 24, 1982. A series of earthquakes occurred near the city of Medan, Indonesia. One of them, which occurred at 10 hr 52 min, generated a small tsunami. [NL, Vol. 15, No. 2, 1982].

[February 24; 04 h 22 m; 4.4° N. Lat., 97.7° E. Long.; M = 5.7; I < 0].

March 21, 1982; 11 hr 32 min. A strong earthquake occurred with its source near Urakawa, Hokkaido. Bridges, roads, and dams were damaged in Urakawa while residential houses suffered little. On the ship *Horonai* (350t), located near Shizunai at the time of the earthquake, the shock was felt with effects suggestive of the beating of logs.

At 11 hr 45 min the regional administration of JMA in Sapporo issued a warning of the tsunami danger along the Pacific coast of Hokkaido. Fortunately, the tsunami was weak. It was recorded along the coast of Hokkaido and on the northeast coast of Honshu (Table 45, Figure 71).

A strong but noiseless low tide was observed during these hours in the port of Urakawa. At the phase of maximum high tide the water rose slightly above the surface of the piers and penetrated 3 m inland. Judging from this the rise of water was 114 cm above the calm sea level. According to the records of a tide gauge at the entry to the port, the maximum rise of water above the calm sea level was 108 cm.

In Mitsuishi, according to an eyewitness account, the tsunami did not reach the surface of the piers. The water withdrawal was appreciable. Some vessels were not able to leave port before this water withdrawal and touched the ground. There was a whirlpool in the port. According to the accounts of fishermen the bottom rose by 15-30 cm and some rocks were visible above water. The maximum rise of water above calm sea level was estimated at 45 cm.

According to the tide gauge records, the tsunami began everywhere with a rise in level.

The tsunami source as drawn by Hatori is shown in Figure 72. It adjoins the coast northwest of Urakawa and is of 40 km long and 20 km wide.

The tsunami rays plotted from the source converge at Cape Erimo and diverge to north of Hiroo and south of Hachinohe, which agrees with the observations. [Hatori, 1982b; NL, Vol. 15, No. 2, 1982; Watanabe, 1983].

[March 21; 02 h 32 m 05.9 s; 42.1° N. Lat., 142.5° E. Long.; 40 km; M = 7.1; I = 0].

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Table 45: Tide gauge data on the tsunami of March 21, 1982 in Japan

Place	First Wave			
	Travel Time (min)	Rise (cm)	Period (min)	Height of the maximum wave (cm)
Hanasaki	?	-	-	14
Kushiro	66 ?	3	30	22
Hiroo	62	10	12	28
Shoya	50 ?	20	26 ?	28
Erimo	24	5	13	55
Horoizumi	-	-	-	-
Urakawa	0	19	16	135
Tomakomai	32	9	18	21
Muroran	48	5	50	16
Mori	52	12	25	30
Hakodate	56 ?	3	33	30
Mutsu-Ogawara	36	6	12	-
Hachinohe (Same)	-	16	-	50
Hachinohe (Minato)	52	25	15	55
Kuji	-	-	-	28
Shimanokoshi	56	8	10	16
Miyako	54	5	16	13
Kamaishi	62	12	14	16
Ofunato	?	-	-	16
Enoshima	78	3	10	8
Ayukawa	90 ?	4	8	16

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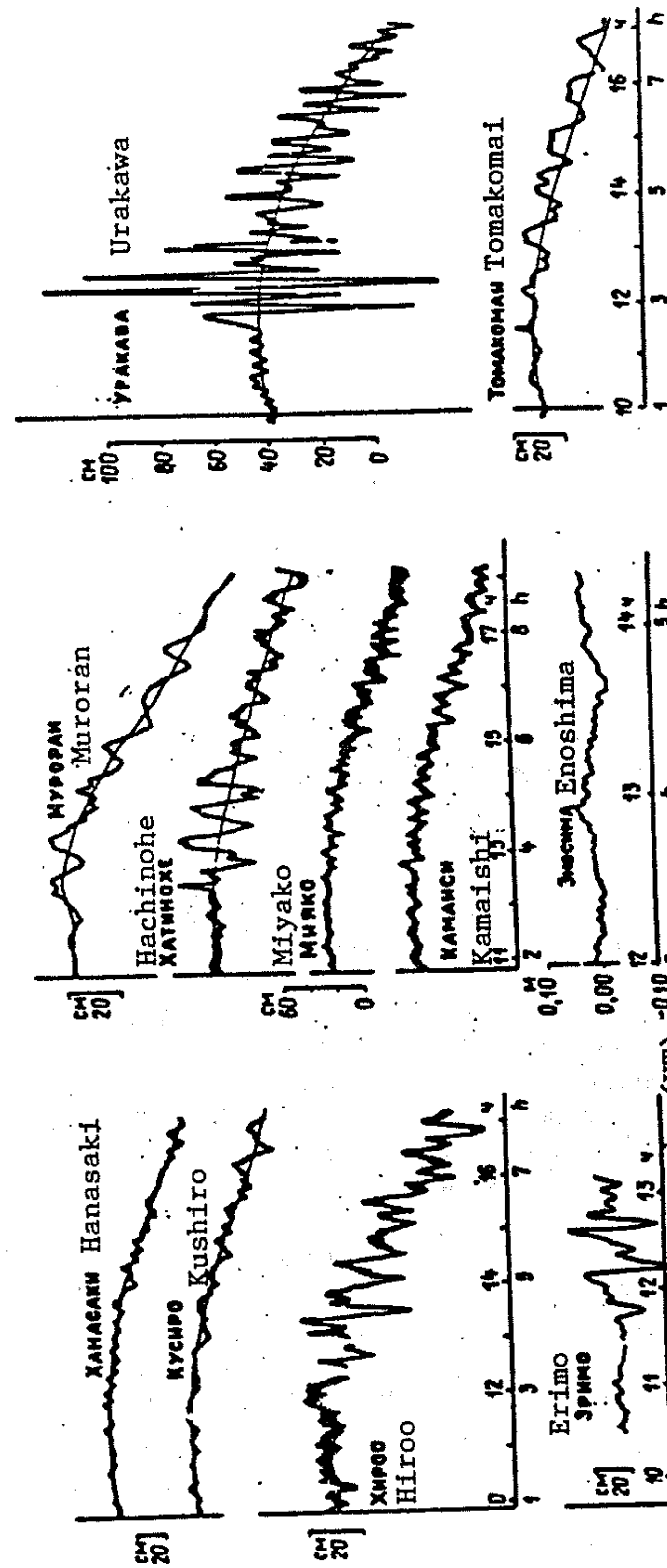

Figure 71: Records of the tsunami of March 21, 1982 [Hatori, 1982b].

Figure 72: Epicenter of the earthquake and source of the tsunami of March 21, 1982 [Hatori, 1982b].

<u>July 23, 1982; 23 hr 23 min</u>. A fairly strong earthquake with a magnitude of 7.0 occurred near the coast of Ibaraki Prefecture. It was felt in Choshi, Mito, Onahama, Shirakawa and Fukushima at intensities of IV points (JMA). Railroad transportation was disrupted. Roughly 30 minutes after the earthquake, the tsunami was recorded on tide gauges on the Pacific Coast of the Tohoku region. The tsunami was registered in records obtained from the coastal area from Hachinohe (Aomori Prefecture) to Mera (Tiba Prefecture) and on Izu islands. Figure 73 presents a part of the obtained marigrams while the principal data of this tsunami are presented in Table 46.

Hatori constructed the source of the tsunami (Figure 74) by the method of reverse fronts using the travel times of the waves. The area of the source appeared to be shifted to the southwest by roughly 30 km from the area of the aftershocks recorded during the course of twenty four hours. The source was 60 km long and had an area of 2.2×10^3 km^2. [Hatori, 1983a; Watanabe, 1983].

[July 23; 14 h 23 m; 36.3° N. Lat., 141.9° E. Long.; 10 km; M = 7.0; I = -1]. 1509

Table 46: Tide gauge data on the tsunami of July 23, 1982 in Japan

Place	First Wave			Height of the maximum wave (cm)
	Travel time (min)	Amplitude (cm)	Period (min)	
Hachinohe	?	-	-	8
Miyako	?	-	-	6
Kamaishi	?	-	-	12
Ofunato	56	4	10	7
Enoshima	50	3	9	-
Ayukawa	54	6	8	36
Ishinomaki	116 ?	2	16	8
Shiogama	98 ?	4	10	8
Sendai	100 ?	4	24	18
Soma	66	6	14	17
Onahama	32	15	12	17
Hitachi	28	10	8	21
Ooarai	?	-	-	26
Kashima	32	5	10	10
Choshi	30	8	9	13
Katsuura	33	2	10	5
Mera	34	6	7	13
Izu-Oshima	37 ?	2	8	-
Minamiizu	40 ?	3	10	9
Kozu Shima	59	5	8	9
Miyake Jima	58 ?	3	8	6
Hachijo Jima	70 ?	2	7	6

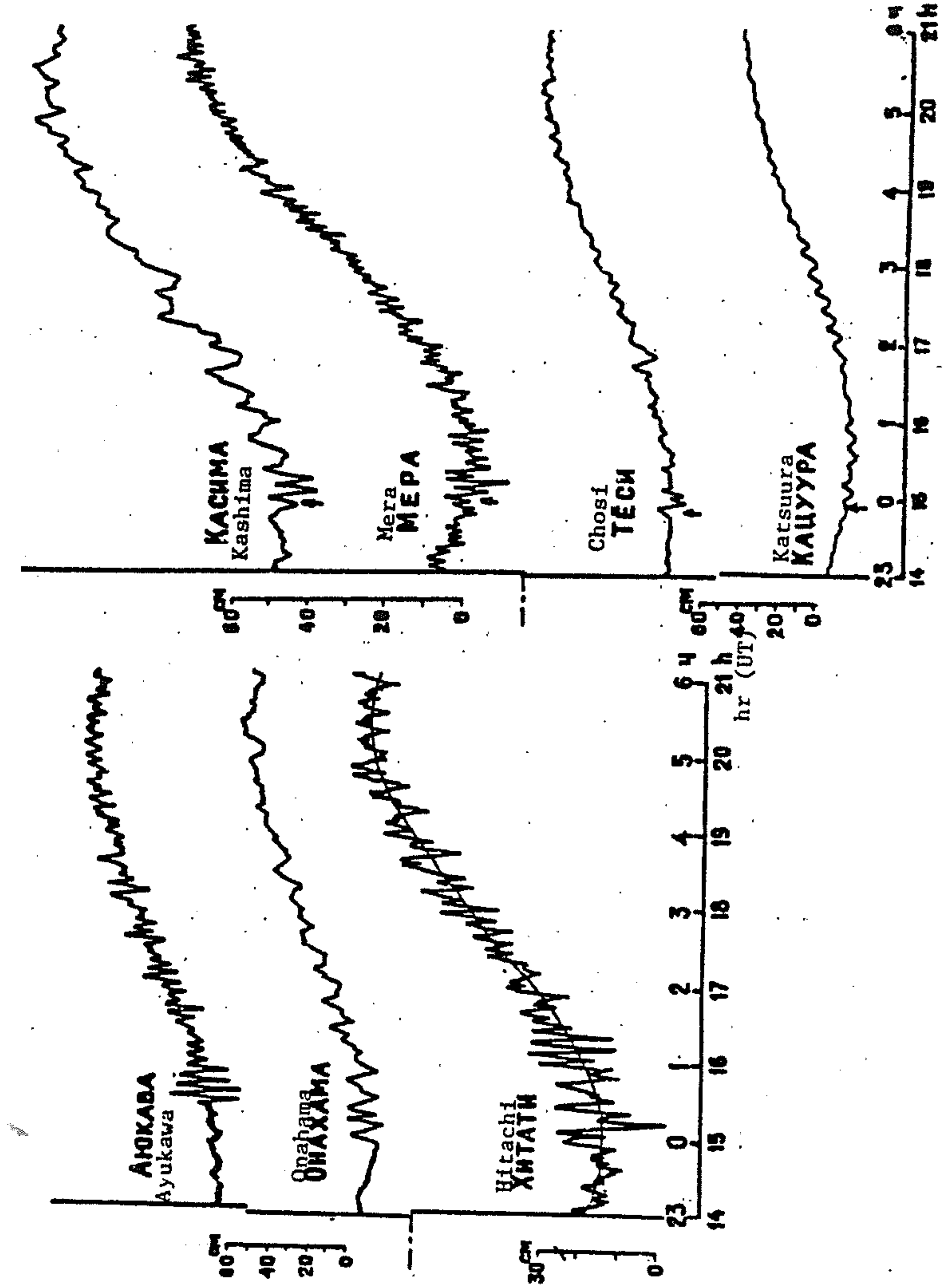

Figure 73: Records of the tsunami of July 23, 1982 [Hatori, 1983a].

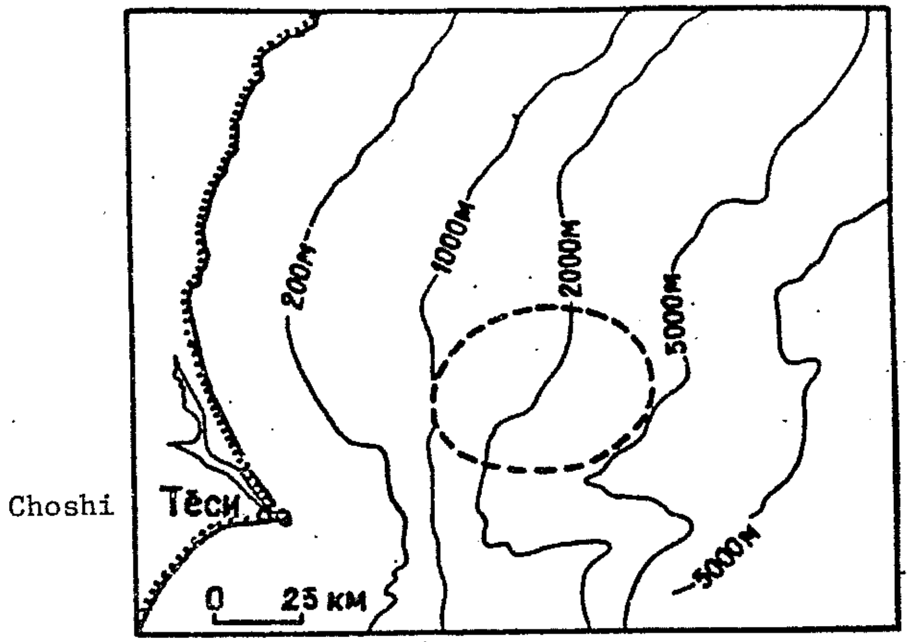

Figure 74: Source of the tsunami of July 23, 1982 [Hatori, 1983a].

December 28, 1982; 15 hr 37 min. An earthquake occurred near Miyake Jima at a magnitude of 6.8. The shock was the strongest of the series of earthquakes in this region which began on December 27. On Miyake and Hachijo Jima the earthquake was felt at an intensity of IV points (JMA). On Miyake, Kozu, and Mikura Islands, landslides were observed, and cracks developed in the water mains. This cluster of earthquakes continued until the middle of January 1983. In all, from December 27, to January 18, 108 earthquakes were felt.

A weak tsunami was observed after this earthquake. The tide gauge at Yaene (Hachijo Jima) recorded the tsunami at a maximum amplitude of 40 cm and a period 8 min (Figure 75). On the records from the instruments on Miyake, Kozu Shima, and Kominato (Hachijo Jima), 20-30 cm high-wind-induced waves predominated. Against the background of these waves it was very difficult to identify the tsunami waves. These wind-induced waves also made it difficult to identify the tsunami waves on the records from other instruments in the coastal area from Ayukawa to Aburatsu.

Figure 76 shows the source of the tsunami as drawn by Hatori on the assumption that the area of the source coincides with the area of the aftershocks. This figure shows the epicenters of the main shock, its foreshocks and its aftershocks observed until the end of December. Southwest of Mikura Island the area of the aftershocks stretches east-west. It has a length of 35 km and an area of 7×10^2 km^2.

From the tide gauge records in Yaene (Hachijo Jima) it is clearly seen that the tsunami began with a rise in water level. [Hatori, 1983b; Watanabe, 1983].

[December 28; 06 h 37 m; 33.9° N. Lat.; 139.5° E. Long.; 20 km; M = 6.8; I = -1].

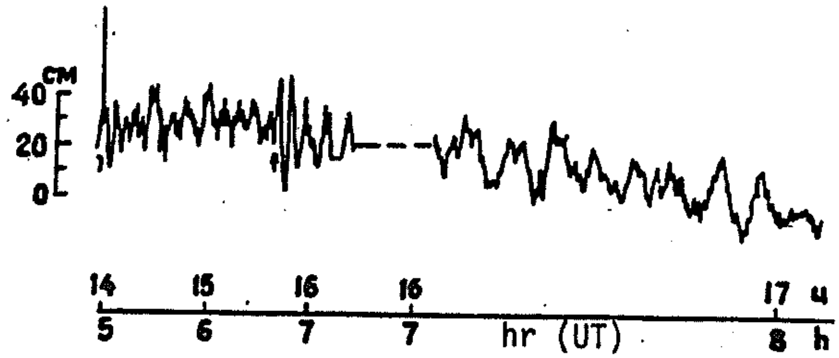

Figure 75: Record of the tsunami of December 28, 1982 in Yaene (Hachijo Jima) [Hatori, 1983b].

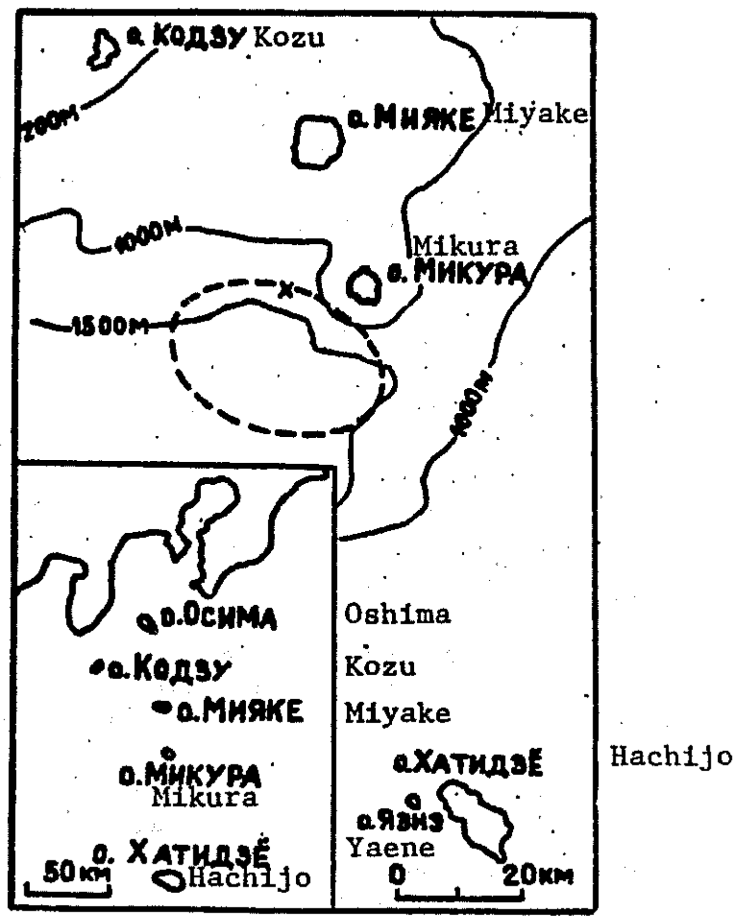

Figure 76: Epicenter of the earthquake and source of the tsunami of December 28, 1982 [Hatori, 1983b].

APPENDICES

and

BIBLIOGRAPHY

APPENDIX 1

LIST OF THE PRINCIPAL PARAMETERS OF TSUNAMIGENIC EARTHQUAKES AND TSUNAMIS IN THE PACIFIC OCEAN DURING 1969-1982

Year	Month	Date	Latitude	Longitude	Depth, (km)	Magnitude of earthquake	Intensity of tsunami
1969	02	23	3.1° S	118.9° E	13	7.0	2
1969	04	21	32.1° N	132.1° E	10	6.5	-3
1969	08	02	6.6° S	146.9° E	17	5.4	-1
1969	08	11	43.5° N	147.4° E	28	8.2	2
1969	11	22	57.8° N	163.5° E	30	7.3	3
1970	01	10	6.8° N	126.7° E	46	7.3	0
1970	04	07	15.8° N	121.7° E	37	7.3	1
1970	05	31	9.2° S	78.8° W	43	7.8	0
1970	07	25	32.2° N	131.7° E	34	7.0	-1½
1970	09	30	20.6° N	122.0° E	33	5.3	½
1970	10	31	4.9° S	145.5° E	42	7.0	½
1971	02	08	63.5° S	61.2° W	33	7.0	0
1971	05	02	51.4° N	177.2° W	43	7.1	-3
1971	07	08	32.5° S	71.2° W	58	7.8	0
1971	07	14	5.5° S	153.9° E	47	7.9	1
1971	07	26	4.9° S	153.2° E	48	7.8	1½
1971	08	02	41.4° N	143.5° E	51	7.0	- ½
1971	09	05	46.5° N	141.1° E	15	7.5	½
1971	09	06	46.6° N	141.5° E	10	6.2	-3
1971	09	08	46.4° N	141.0° E	15	6.9	-3
1971	09	08	46.2° N	141.0° E	15	6.3	-3
1971	09	25	6.5° S	146.6° E	115	6.7	½
1971	09	27	46.4° N	141.1° E	10	6.2	-4
1971	12	15	56.0° N	163.3° E	33	7.8	0
1972	01	25	22.5° N	122.3° E	33	7.0	-2
1972	02	29	33.3° N	140.8° E	56	7.2	½
1972	07	30	56.8° N	135.7° W	25	7.6	-2
1972	08	17	6.0° S	152.9° E	10	7.1	0
1972	12	02	6.5° N	126.6° E	33	7.4	0

Year	Month	Date	Latitude	Longitude	Depth.	Magnitude	Intensity
1972	12	04	33.3° N	140.7° E	66	7.4	-1
1973	01	30	18.5° N	103.0° W	43	7.5	0
1973	02	28	50.5° N	156.6° E	70	7.5	½
1973	06	17	43.2° N	145.8° E	50	7.9	1
1973	06	24	43.4° N	146.5° E	50	7.0	0
1973	10	05	33.0° S	71.9° W	14	6.9	-1
1974	01	31	7.5° S	155.9° E	34	7.0	1
1974	02	01	7.4° S	155.6° E	40	7.1	2
1974	05	08	35.4° N	138.5° E	33	7.0	-2½
1974	09	27	43.2° N	146.7° E	50	7.2	-1
1974	10	03	12.3° S	77.8° W	13	7.6	1
1975	06	10	43.5° N	148.5° E	40	7.0	2
1975	07	20	6.6° S	155.1° E	40	7.9	1
1975	10	31	12.5° N	126.0° E	50	7.2	-1½
1975	11	29	19.3° N	155.0° E	5	7.1	3
1975	12	26	16.3° S	172.7° W	33	7.8	0
1976	01	14	29.2° S	177.9° W	69	7.8	0
1976	01	14	28.4° S	177.7° W	33	8.0	0
1976	01	21	44.6° N	149.2° E	40	7.3	-2½
1976	08	16	6.3° N	123.7° E	33	8.0	2½
1977	04	02	16.2° S	171.6° W	13	7.2	-2
1977	04	20	9.5° S	160.4° E	49	6.5	-1
1977	04	20	11.1° S	160.7° E	33	7.5	-1½
1977	04	21	9.7° S	160.6° E	33	7.1	-1½
1977	06	22	20.5° S	177.4° E	65	7.0	0
1977	08	19	10.5° S	118.8° E	33	7.7	3
1977	08	28	1.1° S	146.2° E	33	5.5	-½
1977	10	10	26.1° S	175.3° W	33	6.9	-3
1978	01	14	34.7° N	139.4° E	23	7.0	0
1978	03	22	43.8° N	149.2° E	37	7.5	-2½
1978	03	22	43.8° N	149.3° E	36	7.1	-3
1978	03	23	43.7° N	149.3° E	40	7.6	-1½
1978	03	23	43.9° N	148.9° E	40	7.8	0
1978	03	24	43.9° N	149.1° E	39	8.0	0
1978	06	12	38.5° N	141.7° E	0	7.7	½
1978	06	14	8.8° N	122.4° E	40	6.6	0
1978	07	23	22.0° N	121.0° E	24	7.0	-1
1979	02	20	40.1° N	143.5° E	17	6.5	0

Year	Month	Date	Latitude	Longitude	Depth	Magnitude	Intensity
1979	03	14	17.8° N	101.3° W	20	7.8	0
1979	07	18	8.6° N	123.5° W	-	-	0
1979	09	12	1.8° S	136.0° E	5	7.7	0
1979	12	12	1.6° N	79.4° W	24	7.9	2½
1980	02	23	43.6° N	146.8° E	35	7.0	-2
1980	06	29	34.6° N	139.1° E	10	6.7	0
1980	07	17	12.5° S	166.3° E	-	7.0	0
1981	01	19	38.4° N	142.6° E	-	7.0	0
1981	09	01	17.7° N	101.4° E	60	7.6	0
1982	01	11	14.6° N	124.7° E	-	6.9	0
1982	02	24	4.4° N	97.7° E	-	5.4	0
1982	03	21	42.1° N	142.5° E	110	6.6	0
1982	07	23	36.3° N	141.9° E	10	7.0	-1
1982	12	28	33.9° N	139.5° E	20	6.8	-1

APPENDIX 2

LIST OF PLACES ON THE PACIFIC COAST EXPERIENCING TSUNAMI EFFECTS DURING 1969-1982

Abashiri (Japan, Hokkaido): Aug. 11, 1969 (26 cm), Jun. 17, 1973 (10 cm); Jun. 24, 1973 (3 cm); Jun. 11, 1975 (15 cm); Mar. 23, 1978 (3cm); Mar. 25, 1978 (3 cm).

Aburatsu (Japan, Miyazaki Prefecture): Apr. 21, 1969; Aug. 11, 1969 (12 cm); May 31, 1970 (4 cm); Jul 26, 1970 (39 cm); Jul. 14, 1971 (8cm); Jul. 26, 1971 (9 cm); Feb. 29, 1972 (17 cm); Dec. 2, 1972 (16 cm); Dec. 4, 1972 (15 cm); Jun. 17, 1973 (9 cm); Oct. 3, 1973 (10 cm); Jul. 21, 1975 (8 cm); Oct. 31, 1975; Nov. 29, 1975 (18 cm); Dec. 12, 1979 (10 cm); Jun. 29, 1980 (4 cm); Jul. 18, 1980 (18 cm).

Aburatsubo (Japan, Kanagawa Prefecture): Feb. 29, 1972 (12 cm).

Acapulco (Mexico): Jan. 30, 1973 (40 cm).

Adak Island (Aleutian Islands): Nov. 22, 1969 (15 cm); May 1, 1971 (9 cm); Jun. 11, 1975 (6 cm).

Adimi (USSR, Primor'e): Sept. 6, 1971 (4 cm).

Admiralty Islands (Bismarck Archipelago): Aug. 29, 1977

Alicia (Philippines, Mindanao Island): Aug. 17, 1976 (4.3 m).

Alotau (Papua New Guinea): Jul. 26, 1971 (18 cm).

Anewa, Bay (Solomon Islands, Bougainville Island): Jul. 14, 1971 (48 cm); Jul. 26, 1971 (42 cm); Feb. 1, 1974 (8 cm).

Antofagasta (Chile): Nov. 29, 1975 (27 cm).

Anuchina, Island (Malyi Kuril Ridge): Aug. 11, 1969 (12 cm).

Apia (Samoa Islands, Upolu Island): Dec. 26, 1975 (15 cm); Jan. 14, 1976 (15 cm); Apr. 2, 1977 (7cm); Apr. 20, 1977 (13 cm); Apr. 21, 1977 (3 cm); Jun. 22, 1977 (7 cm); Sept. 1, 1981 (21 cm).

Arica (Chile): Nov. 29, 1975 (43 cm).

Attu Island (Aleutian Islands): Nov. 22, 1969 (55 cm); Jul. 14, 1971 (6 cm); Dec. 15, 1971 (10 cm).

Auckland (New Zealand): Jun. 22, 1977 (10 cm).

Ayukawa (Japan, Miyagi Prefecture): Aug. 11; 1969 (40 cm); May 31, 1979 (8 cm); Jul. 14, 1971 (6 cm); Jul. 26, 1971 (13 cm); Aug. 2, 1971 (10 cm); Feb. 29, 1972 (18 cm); Dec. 2, 1972 (18 cm); Jun. 17, 1973 (22 cm); Jun. 24, 1973 (10 cm); Jun. 11, 1975 (12 cm); Oct. 31, 1975 (13 cm); Nov. 29, 1975 (55 cm); Mar. 25, 1979 (8 cm); Jun. 12, 1978 (20 cm); Feb. 20, 1979 (8 cm); Dec. 12, 1979 (13 cm); Jul. 18, 1980 (11 cm); Jan. 20, 1981 (8 cm).

Baltra Island (Galapagos Islands): Nov. 29, 1975 (46 cm).

Basco (Philippines, Batan Island): Sept. 30, 1970.

Basilan Island (Philippines): Aug. 17, 1976 (3 m).

Bodega (USA, California): Nov. 29, 1975 (43 cm).

Bongo Island (Philippines): Aug. 17, 1976 (4.3 m).

Bougainville Island (Solomon Islands): Jul. 21, 1975 (2 m).

Brisbane (Australia): Apr. 20, 1977; Apr. 21, 1977.

Burevestnik (Kuril Islands, Iturup Island): Aug. 11, 1969 (103 cm); Jun. 17, 1973 (68 cm); Jun. 24, 1973 (23 cm); Jun. 11, 1975 (44 cm); Jan. 26, 1976 (18 cm); Mar. 22, 1978 (5 cm); Mar. 23, 1978 (17 cm); Mar. 23, 1978 (23 cm); Mar. 25, 1978 (65 cm); Feb. 23, 1980 (5 cm).

Cairns (Australia): Apr. 20, 1977 (2 cm); Apr. 21, 1977 (3 cm).

Caldera (Chile): Nov. 29, 1975 (46 cm).

Celebes Sea (Philippines): Jul. 17, 1976.

Chaika (Kuril Islands, Kunashir Island): Jun. 11, 1975 (2 m).

Charco (Colombia): Dec. 12, 1979.

Chekhov (Sakhalin Island): Sept. 6, 1971 (50 cm).

Chichijima (Japan, Nampo Islands): Jun. 11, 1975 (12 cm); Jul. 21, 1975 (5 cm); Oct. 31, 1975 (13 cm): Nov. 29, 1975 (18 cm); Aug. 17, 1976 (10 cm); Mar. 23, 1978 (28 cm); Mar. 25, 1978 (15 cm).

Chimbote (Peru): May 31, 1970 (76 cm).

Choiseul Island (Solomon Islands): Feb. 1, 1974 (3-4.5 m).

Choshi (Japan, Chiba Prefecture): Aug. 11, 1969 (22 cm); Dec. 2, 1972; Jun. 17, 1973 (17 cm); Jun. 24, 1973 (4 cm); Oct. 3, 1974 (13 cm); Oct. 31, 1975 (50 cm).

Crescent City (USA, California): Jul. 14, 1971 (15 cm); Jul. 26, 1971 (15 cm); Oct. 3, 1974 (0.15 m).

Crillon, Cape (Sakhalin Island): Jul. 11, 1969 (27 cm); Jun. 11, 1975 (18 cm); March 23, 1978; March 25, 1978 (4 cm).

Dampier (Australia): Aug. 19, 1977 (2 m).

Davao (Philippines, Mindanao Island): Aug. 17, 1976 (35 cm).

Dimitrov Inlet (Malyi Kuril Ridge, Shikotan Island): Aug. 11, 1969 (4 m)

Dingalan Bay (Philippines, Luzon Island): Apr. 7, 1970.

Enoshima, Island (Japan, Miyagi Prefecture): Aug. 11, 1969; May 31, 1970 (4 cm); Aug. 2, 1971 (6 cm); Dec. 2, 1972; Jun. 17, 1973; Jun. 24, 1973; Oct. 3, 1974 (4 cm); Oct. 31, 1975 (5 cm); Nov. 29, 1975; Jun. 12, 1978 (22 cm); Feb. 20, 1979 (9 cm); Dec. 12, 1979 (4 cm); Jul. 18, 1980 (3 cm); Jan. 20, 1981 (10 cm).

Enoshima (Japan, Kanagawa Prefecture): Feb. 29, 1972 (10 cm); Jan. 14, 1978 (14 cm); Jun. 29, 1980 (10 cm).

Esmeraldas (Ecuador): Dec. 12, 1979 (50 cm).

Fiji Islands: Jan. 14, 1975 (90 cm).

Fukushima (Japan, Kagoshima Prefecture): Jul. 26, 1970 (12 cm).

Golovnino (Kuril Islands, Kunashir Island): Jun. 17, 1973 (1 m).

Gorgona Island (Colombia): Dec. 12, 1979.

Gornozavodsk (Sakhalin Island): Sept. 6, 1971 (~ 2m).

Goryachi Plyazh (Kuril Islands; Kunashir Island): Jun. 11, 1975 (2-3 m).

Govi (Solomon Islands, Bougainville Island): Jul. 14, 1971.

Guam Island (Mariana Islands): Dec. 2, 1972 (9 cm).

Habu (Japan, Tokyo Prefecture, Oshima Island): Jan. 14, 1978 (18 cm).

Hachijo, Island (Japan): Feb. 29, 1972; Dec. 2, 1972 (30 cm); Dec. 4, 1972 (8 cm); Jun. 11, 1975 (26 cm); Jan. 14, 1978 (12 cm); Jul. 18, 1980 (21 cm).

Hachinohe (Japan, Aomori Prefecture): Aug. 11, 1969 (66 cm); May 31, 1970 (4 cm); Jul. 14, 1971 (6 cm); Jul. 26, 1971 (10 cm); Aug. 2, 1971 (24 cm); Feb. 29, 1972 (7 cm); Dec. 2, 1972; Jun. 17, 1973 (50 cm); Jun. 24, 1973 (9 cm); Oct. 3, 1974 (12 cm); Jun. 11, 1975 (22 cm); Jul. 21, 1975 (6 cm); Mar. 23, 1978 (10 cm); Mar. 25, 1978 (12 cm); Jun. 12, 1978 (21 cm); Feb. 20, 1979 (6 cm); Dec. 12, 1979 (20 cm); Feb. 23, 1980 (7 cm); Jul. 18, 1980 (18 cm); Jan. 20, 1981 (8 cm); Mar. 21, 1982 (24 cm).

Hakodate (Japan, Hokkaido Island): Aug. 11, 1969 (23 cm); Aug. 2, 1971 (13 cm); Jun. 17, 1973 (27 cm); Jun. 24, 1973 (8 cm); Oct. 3, 1974 (7 cm); Jun. 11, 1975 (7 cm); Nov. 29, 1975 (17 cm); Dec. 12, 1979 (9 cm).

Halape (Hawaiian Islands, Hawaii Island): Nov. 29, 1975 (6-8 cm).

Hanasaki (Japan, Hokkaido): Aug. 11, 1969 (150 cm); May 31, 1970 (4 cm); Jul. 14, 1971 (10 cm); Ju. 26, 1971 (13 cm); Aug. 2, 1971 (13 cm); Jun. 17, 1973 (150 cm); Jun. 24, 1973 (63 cm); Sept. 27, 1974 (20 cm); Oct. 3, 1974 (12 cm); Jun. 11, 1975 (96 cm); Jul. 21, 1975 (9 cm); Oct. 31, 1975 (9 cm); Nov. 29, 1975 (27 cm); Jan. 21, 1976 (13 cm); Mar. 23, 1978 (12 cm); Mar. 25, 1978 (24 cm); Jun. 12, 1978 (8 cm); Feb. 20, 1979; Dec. 12, 1979 (12 cm); Jul. 18, 1980 (13 cm); Jan. 20, 1981 (5 cm).

Hayama (Japan, Kanagawa Prefecture): Jun. 29, 1980 (10 cm).

Hilo (Hawaiian Islands, Hawaii Island): Nov. 22, 1969 (5 cm); Dec. 15, 1971 (15 cm); Jan. 30, 1973 (21 cm); Oct. 3, 1974 (.37 cm); Nov. 29, 1975 (4 m); Nov. 29, 1975 (174 cm); Jun. 22, 1977 (9 cm).

Hiratsuka (Japan, Kanagawa Prefecture): Jun. 29, 1980 (2.5 cm).

Hiroo (Japan, Hokkaido): Aug. 11, 1969 (78 cm); May 31, 1970 (4 cm); Aug. 2, 1971 (30 cm); Jun. 17, 1973 (105 cm); Jun. 24, 1973 (28 cm); Sept. 27, 1974 (10 cm); Oct. 3, 1974 (17 cm); Jun. 11, 1975 (26 cm); July 21, 1975 (6 cm); Oct. 31, 1975 (12 cm); Nov. 29, 1975 (23 cm); Mar. 23, 1978 (14 cm); Mar. 25, 1978 (21 cm); Jun. 12, 1978 (13 cm); Feb. 20, 1979 (5 cm); Dec. 12, 1979 (25 cm); Jul. 18, 1980 (19 cm); Jan. 20, 1981 (9 cm).

Hitachi (Japan, Ibaraki Prefecture): Aug. 11, 1969 (25 cm); Feb. 29, 1972 (28 cm); Dec. 2, 1972 (33 cm); Jun. 17, 1973 (20 cm); Jun. 24, 1973 (5 cm); Oct. 3, 1974 (10 cm); Jun. 11, 1975 (14 cm); Oct. 31, 1975 (14 cm); Nov. 29, 1975 (24 cm); Jun. 12, 1978 (18 cm); Dec. 12, 1979 (13 cm); Jan. 20, 1981 (11 cm).

Honiara (Solomon Islands, Guadalcanal Island): Feb. 1, 1974 (15 cm); Apr. 20, 1977 (15 cm).

Honolulu (Hawaiian Islands, Oahu Island): Nov. 22, 1969 (5 cm); Jul. 14, 1971 (9 cm); Jul. 26, 1971 (12 cm); Oct. 3, 1974; Nov. 29, 1975 (18 cm); Jan. 14, 1976 (6 cm); Jun. 22, 1977 (12 cm).

Honuapo (Hawaiian Islands, Hawaii Island): Nov. 29, 1975 (6.5 m).

Hosojima (Japan, Miyazaki Prefecture): Apr. 21, 1969; Jul. 26, 1970 (12 cm); Dec. 2, 1972 (12 cm).

Imperial Beach (USA, California): Nov. 29, 1975 (37 cm).

Iscuande (Colombia): Dec. 12, 1979.

Ishigaki Jima (Ryukyu Islands): Jan. 25, 1972 (5 cm); Dec. 2, 1972 (14 cm); Aug. 17, 1976; Jul. 23, 1978 (10 cm).

Ishinomake (Port) (Japan, Miyagi Prefecture): Jun. 12, 1978 (34 cm); Jan. 20, 1981 (6 cm).

Ishinomaki (Kadawaki) (Japan, Miyagi Prefecture): Jun. 12, 1978 (24 cm).

Ito (Japan, Shizuoka Prefecture): Jan. 14, 1978 (7 cm); Jun. 29, 1978 (9 cm).

Iwashka (Kamchatka): Nov. 23, 1969 (5-7 m).

Johnston Island (Oceania): Nov. 29, 1975 (9 cm).

Jolo Island (Philippines): Aug. 17, 1976 (3 m); Jun. 14, 1978.

Juneau (Alaska): Jul. 30, 1972 (20 cm).

Kahului (Hawaiian Islands, Maui Islauds): Aug, 11, 1969(22 cm); Nov.22, 1969 (20 cm); Jul. 14, 1971 (24 cm); Jul. 26, 1971 (30 cm); Dec. 15, 1971 (18 cm); Jan. 30, 1973 (21 cm); Oct. 3, 1974 (0.37 m); Jun. 11, 1975 (12 cm); Nov. 29, 1975 (88 cm); Jan. 14, 1976 (29 cm); Jun. 22, 1977 (25 cm).

Kamae (Japan, Oita Prefecture): Apr. 21, 1969 (15 cm); Aug. 11, 1969 (12 cm); Jul. 26, 1970 (38 cm); Dec. 2, 1972 (26 cm); Apr. 17, 1973 (10 cm); Oct. 3, 1974 (7 cm).

Kamaishi (Japan, Iwate Prefecture): Aug. 11, 1969 (16 cm); Jun. 17, 1973 (40 cm); Jun. 24, 1973 (14 cm); Jun. 11, 1975 (14 cm); Jun. 12, 1978 (24 cm); Dec. 12, 1979 (16 cm); Jan. 20, 1981 (22 cm).

Kamikawaguchi (Japan, Kochi Prefecture): Jul. 26, 1970 (26 cm).

Kannoura (Japan, Kochi Prefecture): Jul. 26, 1970 (54 cm).

Karaginskii Bay (Kamchatka): Nov. 23, 1969 (5-7 m).

Kasatka Bay (Kuril Islands, Iturup Island): Mar. 25, 1978.

Katsurahama (Japan, Kochi Prefecture): Aug.11, 1969 (8 cm); Jul. 26, 1970 (4 cm).

Katsuura (Japan, Chiba Prefecture): Feb. 29, 1972 (22 cm); Jun. 17, 1973 (6 cm); Jun. 29, 1980 (3 cm); Dec. 2, 1972 (11 cm).

Keauhou (Hawaiian Islands, Hawaii Island): Nov. 29, 1975.

Kesennuma (Japan, Miyagi Prefecture): Aug. 11, 1969 (44 cm); Jun. 17, 1973 (30 cm); Jun. 24, 1973 (12 cm); Jun. 11, 1978 (60 cm); Jan. 20, 1981 (15 cm).

Khailyulya (Kamchatka): Nov. 23, 1969 (5-7 m).

Kholmsk (Sakhalin Island): Sept. 6, 1971 (73 cm); Sept. 7, 1971 (7 cm); Sept. 8, 1971 (6 cm); Sept. 9, 1971 (7 cm).

Kitaura (Japan, Miyazaki Prefecture): Jul. 26, 1970 (24 cm).

Kochi (Japan, Kochi Prefecture): Dec. 2, 1972 (12 cm); Dec. 4, 1972 (6 cm).

Kona District (Hawaiian Islands, Hawaii Island): Nov. 29, 1975.

Korovou (Solomon Islands, Shortland Island): Jan. 31, 1974 (1.2-1.5 m).

Korsakov (Sakhalin Island): Aug. 11, 1969 (26 cm); Jun. 11, 1975 (10 cm); Mar. 23, 1978; March 25, 1978 (5 cm).

Kozu (Japan): Aug. 11, 1969 (6 cm); Jul. 26, 1970 (5 cm); Feb. 29, 1972 (8 cm); Dec. 2, 1972 (20 cm); Dec. 4, 1972 (13 cm); Jun. 29, 1980 (8 cm).

Krabozavodsk (Malyi Kuril Ridge, Shikotan Island): Aug. 11, 1969 (1 m); Jun. 11, 1975 (1.5 m).

Krasnogorsk (Sakhalin Island): Sept. 6, 1971 (1 m).

Kuji (Japan, Iwate Prefecture): Jun. 17, 1973 (44 cm); Jun. 24, 1973 (15 cm); Feb. 20, 1979 (8 cm).

Kunashir Island (Kuril Islands): Jun. 11, 1975 (5 m).

Kunua, Region (Solomon Islands, Bougainville Island): Jul. 14, 1971.

Kurihama (Japan, Kanagawa Prefecture): Feb. 29, 1972 (7 cm); Dec. 2, 1972 (13 cm); Jan. 14, 1978 (4 cm); Jun. 29, 1980 (3 cm).

Kuril'sk (Kuril Islands, Iturup Island): Aug. 11, 1969 (60 cm); Jun. 17, 1973 (33 cm); Jun. 24, 1973 (8 cm); Jun. 11, 1975 (2 cm). 1509

Kushimoto (Japan, Wakayama Prefecture): Aug. 11, 1969 (30 cm); May 31, 1970 (4 cm); Jul. 26, 1970 (17 cm); Jul. 14, 1971 (11 cm); Jul. 26, 1971 (12 cm); Feb. 29, 1972 (23 cm); Dec. 2, 1972 (24 cm); Dec. 4, 1972 (35 cm); Jun. 17, 1973 (24 cm); Oct. 3, 1974 (12 cm); Jun. 11, 1975 (10 cm); Jul. 21, 1975 (8 cm); Oct 31, 1975 (27 cm); Nov. 29, 1975 (22 cm); Aug. 17, 1976; Dec. 12, 1979 (10 cm); Jul. 18, 1980 (11 cm).

Kushiro (Japan, Hokkaido): Aug. 11, 1969 (47 cm); Jul.14, 1971 (4 cm); Jul. 26, 1971 (10 cm); Aug. 2, 1971 (18 cm); Dec. 2, 1972; Jun. 17, 1973 (48 cm); Jun. 24, 1973 (14 cm); Sept. 27, 1974 (5 cm); Oct. 3, 1974 (9 cm); Jun. 11, 1975 (14 cm); Oct. 31, 1975 (5 cm); Nov. 29, 1975 (12 cm); Mar, 23, 1978 (6 cm); Mar. 25, 1978 (9 cm); Jun. 12, 1978 (15 cm); Dec. 12, 1979 (10 cm); Jul. 18, 1980 (15 cm); Jan. 20, 1981 (4 cm).

Kwajalein, Atoll (Marshall Islands): Jul. 14, 1971 (24 cm); Jul. 26, 1971 (24 cm); Jun. 11, 1975 (12 cm); Jul. 21, 1975 (6 cm); Nov. 29, 1975 (6 cm).

La Jolla (USA, California): Nov. 29, 1975 (30 cm).

La Punta (Peru, Callao): May 31, 1970 (61 cm); Oct. 3, 1974 (1.83 m); Nov. 29, 1975 (36 cm).

Labala Mulang (Indonesia, Lomblen Island): Jul. 18, 1979.

Lae (Papua, New Guinea): Aug. 2, 1969; Aug. 26, 1972 (1.5 m).

Lambon (New Ireland Island): Jul. 14, 1971 (6 m),

Lavrova Bay (Kamchatka): Nov. 23, 1969.

Lebak (Philippines, Mindanao Island): Aug. 17, 1976 (3.4 m).

Legaspi (Philippines, Luzon Island): Jan. 11, 1982 (10 cm).

Leveque, Cape (Australia): Aug. 19, 1977 (6 m).

Lihue (Hawaiian Islands, Kauai Island): Jun. 22, 1977 (16 cm).

Loloho (Solomon Islands, Bougainville Island, Anewa Bay): Jan. 31, 1974 (7-8 cm); Jul. 21, 1975 (10 cm).

Lomblen Island (Indonesia): Jul. 18, 1979.

Lombok Island (Indonesia): Aug. 19, 1977.

Long Beach (USA, California): Nov, 29, 1975 (15 cm); Jun. 22, 1977 (24 cm).

Lord Howe Island (Australia): Jan. 14, 1976 (30 cm).

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Los Angeles (USA, California): Jul. 26, 1971 (9 cm); Nov. 29, 1975 (30 cm); Jun. 22, 1977 (10 cm).

Madang (Papua New Guinea): Nov. 1, 1970 (1.2 m).

Maisaka (Japan, Shizuoka Prefecture): Dec. 2, 1972 (8 cm).

Majagual (Colombia): Dec. 12, 1979.

Makurazaki (Japan, Kagoshima Prefecture): Jul. 26, 1970 (26 cm).

Malakal (Caroline Islands, Palau Island): Jan. 10, 1970 (6 cm).

Malokuril'skoe (Malyi Kuril Ridge, Shikotan Island): Aug. 11, 1969 (1 m); Jun. 17, 1973 (140 cm); Jun. 24, 1973 (56 cm); Jun. 11, 1975 (60 cm); Jan. 21, 1976 (37 cm); Mar. 22, 1978 (7 cm); Mar. 23, 1978 (10 cm); Mar. 23, 1978 (30 cm); Mar. 25, 1978 (37 cm); Feb. 23, 1980 (32 cm).

Mamagota (Solomon Islands, Bougainville Island): Jul. 21, 1975 (1 m).

Manazuru (Japan, Kanagawa Prefecture): Jun. 29, 1980 (8 cm).

Manono Island (Samoa Islands): Sept. 1, 1981 (1 m).

Manzanillo (Mexico): Jan. 30, 1973 (116 cm).

Matarani (Peru): Nov. 29, 1975 (35 cm).

Matsukawaura (Japan, Furushima Prefecture): Aug. 11, 1969 (14 cm); Jun. 17, 1973 (24 cm); Jun. 11, 1975 (11 cm); Jun. 12, 1978 (10 cm); Jan. 20, 1981 (8 cm).

Matua Island (Kuril Islands): Aug. 11, 1969 (13 cm); Feb. 28, 1973; Jun. 11, 1975 (19 cm); Jan. 21, 1976 (6-7 cm); Mar. 25, 1978 (10 cm).

Mayachnaya Inlet (Malyi Kuril Ridge, Shikotan Island): Jun. 11, 1975 (3.5 m).

Medan (Indonesia, Sumatra Island): Feb. 24, 1982.

Mera (Japan, Chiba Prefecture): Aug. 11, 1969 (27 cm); May 31, 1973 (4 cm); Jul. 26, 1970 (8 cm); Jul. 14, 1971 (4 cm); Feb. 29, 1972 (30 cm); Dec. 2, 1972 (30 cm); Dec. 4, 1972 (21 cm); Jun. 17, 1973 (10 cm); Oct. 3, 1974 (6 cm); Oct. 31, 1975 (20 cm); Nov. 29, 1975 (19 cm); Aug. 17, 1976 (9 cm); Jan. 14, 1978 (20 cm); Jun. 12, 1978 (11 cm); Dec. 12, 1979 (10 cm); Jun. 29, 1980 (12 cm); Jul. 18, 1980 (13 cm); Jan. 20, 1981 (8 cm).

Metlika (New Ireland Island): Jul. 26, 1971.

Midway Island (Hawaiian Islands): Aug. 11, 1969 (25 cm); Nov. 22, 1969 (5 cm); Jul. 26, 1971 (12 cm); Oct. 3, 1974 (6 cm); Mar. 25, 1978 (12 cm). 1509

Minamiizu (Japan, Shizuoka Prefecture): Aug. 11, 1969 (10 cm); Jul. 26, 1970 (6 cm); Feb. 29, 1972 (23 cm); Dec. 2, 1972 (26 cm); Dec. 4, 1972 (12 cm); May 9, 1974 (11 cm); Oct. 3, 1974 (3 cm); Oct. 31, 1975 (13 cm); Nov. 29, 1975 (20 cm); Jan. 14, 1978 (14 cm); Dec. 12, 1979 (6 cm); Jun. 29, 1980 (8 cm).

Mindanao Island (Philippines): Aug. 17, 1976.

Misaki (Japan, Ehime Prefecture): Jul. 26, 1970 (22 cm).

Mishyo (Japan, Ehime Prefecture): Jul. 26, 1970 (25 cm).

Miyake Jima (Japan): Aug. 11, 1969 (10 cm); Feb. 29, 1972 (18 cm); Dec. 2, 1972 (17 cm); Dec. 4, 1972 (12 cm); Oct. 31, 1975 (24 cm); Nov. 29, 1975 (24 cm); Jan. 14, 1978 (16 cm); Jun. 29, 1980 (8 cm).

Miyako (Japan, Iwate Prefecture): Aug. 11, 1968 (29 cm); Jul. 14, 1971 (6 cm); Aug. 2, 1971 (14 cm); Feb. 29, 1972 (8 cm); Dec. 2, 1972; Jun. 17, 1973 (40 cm); Jun. 24, 1973 (7 cm); Oct. 3, 1974 (10 cm); Jun. 11, 1975 (16 cm).

Miyato (Japan, Miyagi Prefecture): Jun. 12, 1978 (18 cm).

Mokuoloe (Hawaiian Islands; Oahu Island): Nov. 29, 1975 (3 cm).

Mombetsu (Japan, Hokkaido): Aug. 11, 1969 (17 cm); Jun. 17, 1973 (10 cm); Jun. 24, 1973 (5 cm).

Moneron Island (Sakhalin Island): Sept. 6, 1971 (1.5 m).

Mori (Japan, Hokkaido Island): Jun. 11, 1975 (7 cm).

Moro Bay (Philippines): Aug. 17, 1976 (4-4.8m).

Mosquera (Colombia): Dec. 12, 1979.

Muroran (Japan, Hokkaido): Aug. 11, 1969 (12 cm); Aug. 2, 1971 (8 cm); Jun. 17, 1973 (14 cm); Jun. 24, 1973 (6 cm); Jun. 11, 1975 (5 cm).

Muroto (Japan, Kochi Prefecture): Apr. 21, 1969 (20 cm); Aug. 11, 1969 (21 cm); May 31, 1970 (5 cm); Jul. 26, 1970 (56 cm); Feb. 29, 1972 (16 cm); Dec. 2, 1972 (33 cm); Oct. 3, 1974 (8 cm); Oct. 31, 1975 (8 cm); Nov. 29, 1975 (11 cm); Aug. 17, 1976 (12 cm); Dec. 12, 1979 (5 cm); Jul. 18, 1980 (7 cm).

Mururoa Island (Oceania): Jun. 22, 1977 (10 cm).

Mutsu Ogawara (Japan, Aamori Prefecture): Dec. 12, 1979 (6 cm).

Nagasaki (Japan, Iwate Prefecture): Jun. 17, 1973 (16 cm); Jun. 24, 1973 (5 cm).

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Nagashima (Japan, Mie Prefecture): Feb. 29, 1972 (18 cm); Jun. 17, 1973 (11 cm).

Naha (RyukyuIslands, Okinawa Island): Dec, 2, 1972 (6cm); Oct, 31, 1975; Nov. 29, 1975 (13 cm); Jul. 18, 1980 (5 cm).

Nakaminato (Japan, Ibaraki Prefecture): Feb. 29, 1972 (14 cm).

Napoopoo (Hawaiian Islands, Hawaii Island): Nov. 29, 1975 (3.7 m).

Nase (Ryukyu Islands, Amamioshima Island): Aug. 11, 1969 (10 cm); Jul. 26, 1970 (8 cm); Jul. 14, 1971 (4 cm); Jul. 26, 1971 (9 cm); Dec. 2, 1972 (12 cm); Oct. 3, 1974 (14 cm); Dec. 12, 1979 (10 cm); Jul. 18, 1980 (15 cm).

Nawiliwili Bay (Hawaiian Islands, Kauai Island): Aug. 11, 1969 (20 cm); Jan. 30, 1973 (6 cm); Nov. 29, 1975 (27 cm).

Nemuro Peninsula (Japan, Hokkaido Island): Jun. 17, 1973 (2 cm); Feb. 23, 1980 (10 cm).

Nepokornyi Cape (Malyi Kuril Ridge, Shikotan Island): Jun. 11, 1975 (5.5 cm).

Nevel'sk (Sakhalin Island): Sept. 6, 1971 (80 cm); Nov. 8, 1971 (2 cm); Sept. 28, 1971 (3 cm).

New Ireland: Jul. 14, 1971 (3 cm); Jul. 16, 1971 (0.5 m).

Nikol'skoe (Komandorskiye Islands, Bering Island): Nov. 23, 1969 (1.5-2.5 m).

Nishinoomote (Ryukyu Islands, Tanehashima Island): Aug. 11, 1969 (2 cm); Dec. 2, 1972 (16 cm).

Nissan Island (Solomon Island): Jul. 26, 1971.

Noumea (New Caledonia): Jun. 22, 1977 (9 cm).

Odomari (Japan, Kagoshima Prefecture): Apr. 21, 1969; Jul. 26, 1970 (32 cm); Jun. 17, 1973 (12 cm); Oct. 3, 1974 (6 cm).

Ofunato (Japan, Iwate Prefecture): Aug. 11, 1968 (34 cm); Aug. 2, 1971 (13 cm); Oct. 3, 1974 (5 cm); Jun. 11, 1975 (20 cm); Jun. 12, 1978 (22 cm); Feb. 20, 1979 (7 cm); Dec. 12, 1979 (14 cm); Jul. 18, 1980 (10 cm); Jan. 20, 1981 (20 cm).

Oiso (Japan, Kanagawa Prefecture): Jan. 14, 1978 (14 cm); Jun. 29, 1980 (14 cm).

Oita (Japan, Oita Prefecture): Jul. 26, 1970 (3 cm).

Okada (Japan, Tokyo Prefecture, Oshima Island): Jan. 14, 1978 (62 cm); Jun. 29, 1980 (56 cm). 1509

Okinawa Island (Ryukyu Islands): Oct. 31, 1975 (10 cm).

Ol'khovaya River (Kamchatka): Nov. 23, 1969 (12-15m).

Omaezaki (Japan, Shizuoka Prefecture): Aug. 11, 1969 (13 cm); May 31, 1970 (5 cm); Aug. 26, 1970 (9 cm); Jul. 14, 1971 (6 cm); Feb. 29, 1972 (24 cm); Dec. 2, 1972 (16 cm); Dec. 4, 1972 (21 cm); Jun. 17, 1973 (13 cm); May 9, 1974 (15 cm); Oct. 3, 1974 (8 cm); Jul. 21, 1975 (5 cm); Oct. 31, 1975 (32 cm); Nov. 29, 1975 (14 cm); Dec. 12, 1979 (8 cm); Jul. 18, 1980 (13 cm).

Onagawa (Japan, Miyagi Prefecture): Aug. 11, 1969 (31 cm); Jun. 12, 1978 (56 cm).

Onahama (Japan, Fukushima Prefecture): Aug. 11, 1969 (26 cm); May 31, 1970 (3 cm); Jul. 14, 1971 (6 cm); Jul. 26, 1971 (10 cm); Feb. 29, 1972 (20 cm); Dec. 2, 1972 (22 cm); Dec. 4, 1972 (15 cm); Jun. 17, 1973 (17 cm); Jun. 24, 1973 (12 cm); Oct. 3, 1974 (10 cm); Jun. 11, 1975 (13 cm); Jul. 21, 1975 (4 cm); Oct. 31, 1975 (10 cm); Nov. 29, 1975 (21 cm); Jun. 12, 1978 (15 cm); Feb. 20, 1979 (4 cm); Dec. 12, 1979 (13 cm); Jul. 18, 1980 (12 cm); Jan. 20, 1981 (8 cm).

Ooarai (Japan, Ibaraki Prefecture): Dec. 2, 1972 (17 cm); Jun. 17, 1973 (13 cm); Jun. 24, 1973 (5 cm); Jun. 11, 1975 (15 cm); Jun. 12, 1978 (16 cm); Jan. 20, 1981 (10 cm).

Opua (New Zealand): Jun. 22, 1977 (15 cm).

Orlovo (Sakhalin Island): Sept. 6, 1971 (50 cm).

Oshima Island (Japan): Feb. 29, 1972 (4 cm); Dec. 2, 1972

Otradnaya Inlet (Malyi Kuril' Ridge, Shikotan Island): Jun. 11, 1975 (1.5-2m).

Otradnoe (Kuril Islands, Kunashir Island): Aug. 11, 1969 (1.2 m); Jun. 11, 1975 (2 m).

Owase (Japan, Mie Prefecture): Aug. 11, 1969 (17 cm); Jul. 26, 1970 (7 cm); Jul. 14, 1971 (6 cm); Jul. 26, 1971 (15 cm); Feb. 29, 1972 (16 cm); Dec. 2, 1972 (22 cm); Dec. 4, 1972 (20 cm); Jun. 17, 1973 (12 cm); Oct. 3, 1974 (7 cm); Jul. 21, 1975 (5 cm); Oct. 31, 1975 (32 cm); Nov. 29, 1975 (22 cm); Dec. 12, 1979 (12 cm); Jul. 18, 1980 (10 cm).

Ozernoi, Bay (Kamchatka): Nov. 23, 1969 (10-15 m).

Pagadian (Philippines, Mindanao Island): Aug. 17, 1976 (4.3 m).

Pago-Pago (Samoa Islands, Tutuila Island): Jan. 30, 1973 (21 cm); Oct. 3, 1974 (0.3 m); Dec. 26, 1975 (75 cm); Apr. 2, 1977 (15 cm); Jun. 22, 1977 (13 cm); Oct. 10, 1977 (6 cm); Sept. 1, 1981 (24 cm).

Paletoang (Indonesia, Celebes Island): Feb. 23, 1969 (4.0 m).

Palili (Indonesia, Celebes Island): Feb. 23, 1969 (1.5 m).

Papeete (Oceania, Tahiti Island): Jun. 22, 1977 (12 cm).

Parasanga (Indonesia, Celebes Island): Feb. 23, 1969 (1.5 m).

Penzenskoe (Sakhalin Island): Sept. 6, 1971 (50 cm).

Polonskogo, Island (Malyi Kuril Ridge): Aug. 11, 1969 (1.5 m); Jun. 17, 1973 (1.5 m); Jun. 11, 1975 (2.3 m).

Pomio (New Britain Island): Jul. 14, 1971; Aug. 18, 1972 (60 cm).

Poronaisk (Sakhalin Island): Aug. 11, 1969 (12 cm); Jun. 11, 1975 (11 cm); Mar. 23, 1978 (3 cm); Mar. 22, 1978, Mar. 25, 1978 (3 cm).

Port Sampson (Australia): Aug. 19, 1977 (2-4 m).

Port San Luis (USA, California): Nov. 29, 1975 (79 cm); Jun. 22, 1977 (24 cm).

Punaluu (Hawaiian Islands, Hawaii Island): Nov. 29, 1975.

Rabaul (New Britain Island): Jul. 14, 1971 (2 m); Jul. 26, 1971 (6.5 m); Apr. 20, 1977 (7 cm).

Rennell Island (Solomon Islands): Apr. 20, 1977.

Resa Bay (Philippines, Mindanao Island): Aug. 17, 1976.

Ritter Island (Papua New Guinea): Oct. 17, 1974.

Ryukyu Islands: Dec. 2, 1972 (50 cm); Jul. 23, 1978 (10 cm).

Sacol Island (Philippines): Aug. 17, 1976 (3 m).

Saganoseki (Japan, Oita Prefecture): Jul. 26, 1970 (4 cm).

Saiki (Japan, Oita Prefecture): Jul. 26, 1970 (18 cm).

Salahonda (Colombia): Dec. 12, 1979.

Samar Island (Philippines): Oct. 31, 1975.

Same (Japan, Aomori Prefecture): Aug. 2, 1971 (18 cm); Jun. 17, 1973 (19 cm); Jun. 24, 1973 (4 cm); Jun. 11, 1975; Nov. 29, 1975 (5 cm); Jun. 12, 1978 (26 cm); Dec. 12, 1979 (11 cm). 1509

Samoan Islands: Sept. 1, 1981.

San Diego (USA, California): Nov. 29, 1975 (12 cm); Jun. 22, 1977 (15 cm).

San Francisco (USA. California): Nov. 29, 1975 (12 cm).

San Juan (Colombia): Dec. 12, 1979 (5 m).

San Juan (Peru): Oct. 3, 1974 (1.2 m).

Sebu Lake (Philippines): Aug. 17, 1976.

Sendai (Japan, Miyagi Prefecture): Jun. 12, 1978 (18 cm); Jan. 20, 1981 (6 cm).

Sennaya Inlet (Malyi Kuril Ridge, Shikotan Island): Jun. 11, 1975 (3.5-4 m).

Sentyabrskii (Kuril Islands, Iturup Island): Aug. 11, 1969 (1.5 m).

Senzu (Japan, Tokyo Prefecture, Oshima Island): Jan. 14, 1978 (10 cm); Jun. 29, 1980 (10 cm).

Serebryanka River (Kuril Islands, Kunashir Island): Jun. 11, 1975 (2-3 m).

Severo-Kuril'sk (Kuril Islands, Paramushir Island): Aug. 11, 1969 (20 cm); Dec. 15, 1971 (10 cm); Feb. 28, 1973 (76 cm); Jun. 17, 1973; Jun. 24, 1973; Jun. 11, 1975 (5 cm).

Shebunino (Sakhalin Island): Sept. 6, 1971 (2 m).

Shemya, Island (Aleutian Islands): Nov. 22, 1969 (65 cm); Dec. 15, 1971 (5 cm); Feb. 28, 1973 (15 cm).

Shimanokoshi (Japan, Iwate Prefecture): Aug. 11, 1969 (38 cm); Jun. 17, 1973 (40 cm); Jun. 24, 1973 (13 cm); Feb. 20, 1979 (15 cm); Dec. 12, 1979 (22 cm).

Shimizu (Japan, Shizuoka Prefecture): Dec. 4, 1972 (5 cm).

Shiogama (Japan, Miyagi Prefecture): Jun. 12, 1978 (21 cm); Jan. 20, 1981 (4 cm).

Shirahama (Japan, Miyagi Prefecture): Jun. 12, 1978 (30 cm).

Shirahama (Japan, Wakayama Prefecture): Dec. 2, 1972 (18 cm); Dec. 4, 1972 (8 cm).

Shortland Island (Solomon Islands): Feb. 1, 1974 (3-4.5 m).

Shumshu Island (Kuril Islands): Feb. 28, 1973 (60 cm).

Shyoya (Japan, Hokkaido): Jun. 17, 1973 (100 cm); Jun. 24, 1973; Jan. 20, 1981 (8 cm).

Sitka (Alaska): Jul. 30, 1972 (20 cm); Jun. 11, 1975 (6 cm); Nov. 29, 1975 (21 cm).

Sohano (Solomon Islands, Bougainville Island): Jul. 14, 1971 (0.6 m).

Solomon Islands: Jan. 31, 1974; Feb. 1, 1974 (17.7 cm); Apr. 21, 1977.

Soma (Japan, Fukushima Prefecture): Jun. 21, 1978; Jan. 20, 1981 (12 cm).

Sovetskaya Gavan' (USSR, Primor'e): Sept. 6, 1971 (4 cm).

Sukumo (Japan, Kochi Prefecture): Jul. 26, 1970 (19 cm).

Sulu Islands (Philippines): Aug. 17, 1976.

Sumbawa Island (Indonesia): Aug. 19, 1977 (1.5 m).

Suva (Fiji Islands, Viti-Levi Island): Dec. 26, 1975 (8 cm); Jan. 14, 1976 (15 cm); Jun. 22, 1977 (31 cm); Oct. 10, 1977.

Taga (Samoa Islands, Savaii Island): Sept. 1, 1981.

Talara (Peru): Nov. 29, 1975 (48 cm).

Talcahuano (Chile): Nov. 29, 1975 (24 cm).

Tanfil'eva Island (Malyi Kuril Ridge): Aug. 11, 1969 (1 m); Jun. 17, 1972 (1.5 m).

Taro (Japan, Iwate Prefecture): Jun. 17, 1973 (45 cm); Jun. 24, 1973 (15 cm).

Tauranga (New Zealand): Jun. 22, 1977 (15 cm).

Toba (Japan, Mie Prefecture): Dec. 2, 1972 (7 cm); Jul. 18, 1980 (8 cm).

Tokachi (Japan, Hokkaido): Mar. 25, 1978 (17 cm).

Tomakomai (Japan, Hokkaido): Aug. 11, 1969 (20 cm); Aug. 2, 1971 (8 cm); Jun. 17, 1973 (21 cm); Jun. 24, 1973 (8 cm); Jun. 11, 1975 (7 cm); Jun. 12, 1978 (12 cm).

Tomi (Japan, Miyazaki Prefecture); Jul. 26, 1970 (8 cm).

Torokina (Solomon Islands, Bougainville Island): Jul. 14, 1971; Feb. 1, 1974 (1 m); Jul. 21, 1975.

Tosashimizu (Japan, Kochi Prefecture): Jun. 21, 1969 (10 cm); Aug. 11, 1969 (16 cm); May 31, 1970 (8 cm); Jul. 26, 1970 (44 cm); Jul. 14, 1971 (8 cm); Jul. 26, 1971 (10 cm); Feb. 29, 1972 (16 cm); Dec. 2, 1972 (44 cm); Dec. 4, 1972 (12 cm); Jun. 17, 1973 (10 cm); Oct. 3, 1974 (12 cm); Jul. 21, 1975 (5 cm); Oct. 31, 1975 (17 cm); Nov. 29, 1975 (23 cm); Aug. 17, 1976 (10 cm); Dec. 12, 1979 (10 cm); Jul. 18, 1980 (10 cm).

Tosashimoda (Japan, Kochi Prefecture): Jul. 26, 1970 (7 cm).

Townsville (Australia): Apr. 20, 1977 (8 cm); Apr. 21, 1977 (4 cm).

Truk (Oceania): Jul. 14, 1971 (6 cm); Jul. 26, 1971 (6 cm); Oct. 3, 1975; Jun. 11, 1975 (9 cm); Oct. 31, 1975 (3 cm).

Tserkovnaya Inlet (Malyi Kuril Ridge, Shikotan Island): Aug. 11, 1969 (5 m).

Tsukihama (Japan, Miyagi Prefecture): Jun. 12, 1978 (35 cm); Jan. 10, 1981 (22 cm).

Tumaco (Colombia): Dec. 12, 1979.

Tutukana Harbour (New Zealand): Jan. 14, 1976.

Tyatino (Kuril Islands, Kunashir Island): Aug. 2, 1969.

Uchiura (Japan, Shizuoka Prefecture): Jul. 14, 1971 (4 cm); Jul. 26, 1971 (8 cm).

Unalaska Island (Aleutian Islands): Nov. 22, 1969 (10 cm).

Uragami (Japan, Wakayama Prefecture): Aug. 11, 1969 (15 cm); Jul. 26, 1970 (7 cm); Feb. 29, 1972 (18 cm); Dec. 2, 1972 (20 cm); Oct. 3, 1974 (8 cm); Dec. 12, 1979 (12 cm); Jul. 18, 1980 (8 cm).

Urakawa (Japan, Hokkaido): Aug. 11, 1969 (62 cm); Jul. 14, 1971 (6 cm); Jul. 26, 1971 (10 cm); Aug. 2, 1971 (23 cm); Jun. 17, 1973 (45 cm); Jun. 24, 1973 (16 cm); Oct. 3, 1974 (12 cm); Jun. 11, 1975 (42 cm); Jul. 21, 1975 (5 cm); Oct. 31, 1975 (10 cm); Nov. 29, 1975 (12 cm); March 23, 1978 (23 cm); Mar. 25, 1978 (17 cm); Jun. 12, 1978 (12 cm); Feb. 20, 1979 (5 cm); Dec. 12, 1979 (12 cm); Jul. 18, 1980 (18 cm), Jan. 20, 1981 (12 cm); Mar. 21, 1982 (80 cm).

Ust'-Kamchatsk (Kamchatka): Nov. 22, 1969 (20 cm); Dec. 15, 1971 (47 cm).

Uwajima (Japan, Ehime Prefecture): Jul. 26, 1970 (8 cm).

Valparaiso (Chile): Jul. 7, 1971 (1.2 m); Oct. 5, 1973 (40 cm).

Vasil'eva, Cape (Kuril Islands, Paramushir Island): Feb. 28, 1973 (80 cm).

Vinai, River (Kuril Islands, Kunashir Island): Jun. 11, 1975 (2.5-3 m).

Visayan Sea (Philippines): Apr. 7, 1970.

Wai Teba (Indonesia, Lomblen Island): Jul. 18, 1979.

Wakayama (Japan, Wakayama Prefecture): Dec. 4, 1972 (5 cm).

Wake Atoll (Oceania): Aug. 11, 1969 (12 cm); Jul. 14, 1971 (6 cm); Jul. 26, 1971 (6 cm); Dec. 15, 1971 (9 cm); Oct. 3, 1974 (6 cm); Jun. 11, 1975 (9 cm); Oct. 31, 1975 (6 cm); Nov. 29, 1975 (3 cm); March. 25, 1978 (5 cm).

Wakkanai (Japan, Hokkaido): Aug. 2, 1969 (13 cm); Jun. 17, 1973 (8 cm); Jun. 24, 1973 (8 cm); Jun. 11, 1975 (6 cm).

Whangara (New Zealand): Jun. 22, 1977 (13 cm).

Yaba River (Solomon Islands, Bougainville Island): Jul. 21, 1975 (2 m).

Yakutat Bay (Alaska): Nov. 29, 1975 (9 cm).

Yamasedomari (Japan, Hokkaido): Aug. 2, 1971 (8 cm); Jun. 17, 1973 (17 cm); Jun. 24, 1973 (7 cm).

Yap Island (Caroline Islands): Dec. 2, 1972 (18 cm); Oct. 31, 1975 (6 cm).

Yawatahama (Japan, Ehime Prefecture): Apr. 21, 1969 (10 cm); Jul. 26, 1970 (11 cm).

Yurii Island (Malyi Kuril Ridge): Aug. 11, 1969 (1 m); Jun. 11, 1975 (0.7-1 m).

Yuzhno-Kuril'sk (Kuril Islands, Kunashir Island): Aug. 11, 1969 (195 cm); Jun. 17, 1973 (25 cm); Jun. 24, 1973 (8 cm); Jun. 11, 1975 (55 cm); Jan. 21, 1976 (10 cm); Mar. 22, 1978 (5 cm); Mar. 23, 1978 (16 cm); Feb. 25, 1978 (18 cm); Feb. 23, 1980 (11 cm).

Zelenyi Island (Malyi Kuril Ridge): Aug. 11, 1969 (2 m); Jun. 17, 1973 (0.5 m); Jun. 11, 1975 (1 m).

APPENDIX 3

ADDITIONS TO "CATALOG OF TSUNAMIS ON THE WESTERN COAST OF THE PACIFIC OCEAN"

(Soloviev and Go, 1974)

February, 1878; night of 4th-5th. A very strong earthquake occurred on the Coast of Blanche Bay (New Britain), in Rabaul, and on Matupi Island (Figure 77). Five tsunami waves were observed with heights of up to 4 m, which washed a considerable area of the coast of Matupi Island [Hydrographische..., 1879].

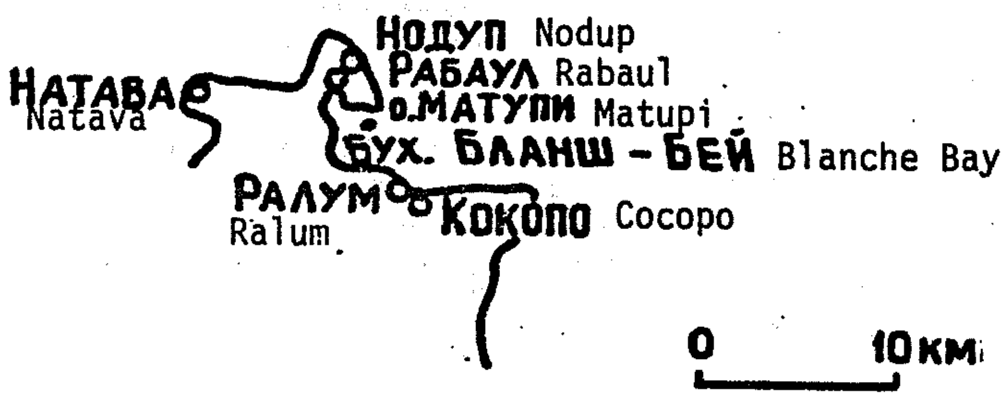

Figure 77: Some population centers in the north of New Britain where tsunami waves were observed [Everingham, 1977].

March 6, 1895; 18 hr 25 min. A strong earthquake occurred with its source in the western part of the Solomon Sea.

It was felt on the ship anchored in the region of the Trobriand Islands at 8° 32.5' S. Lat. and 151° 02.5' E., Long. The ship oscillated for over a minute. The movements were not very strong but resembled ship movements when the propeller is in reverse gear or when the ship's nose runs aground.

In Kavataria* trees swayed and near the villages a four feet (1.2 m) deep cavity was formed. On Simsim Island residents felt the shock and then a loud noise was heard which evidently emanated from not far away; this was followed by yet another shock.

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* (indicates, throughout this catalog, places where coordinates are unknown)

Several shocks were felt on Kawa Island* situated about 20 km southwest of Simsim Island.

After the second shock on Simsim Island there was a short lull followed by the sound of an advancing wave which almost immediately hit the western side of the island and swept over the tongue of low coastal ground on the island's northern end. The waters destroyed frail native houses and swept portions of them into the sea along with household goods. One little child was drowned and one man received severe skin abrasions. Residents who were unable to grasp the trunk of a tree were swept into the sea. One man reported that as he held onto a coconut tree the water reached his armpits. A large number of fish were left on the island.

The most noteworthy phenomenon associated with this wave was the force with which the water swept the sea bottom before reaching land. A large quantity of coral and marine debris had been thrown onto land. More telling, crawfish, crabs, bêche-de-mer, and ground-feeding fish had also been thrown onto the island. On the coast a large block of coral, which in its previous offshore position must have been totally submerged at least once every 24 hours, was lying on the beach several feet from the water's edge. According to various estimates this block weighed from half a ton to over one ton. About 1-2 m from the waterline there was a mushroom-shaped piece of coral whose stem was about 0.3 m in diameter and must have weighed a hundred kilograms or more. The column of hard coral which formed this stem had snapped in two. A solid block of bluish gray stone block of about 27 dm^3 appeared to have been raised about 0.6 m off of the ground. This was evident from the length of a deep cut into a tree against which the stone was resting. Although some of the shrubs and plants were broken or washed out, none of the coconut palms or large trees had been uprooted or injured.

Apparently, no waves hit Kawa Island* although shocks from the earthquake were felt there. A great wave did hit the coast of New Guinea in Porlock Bay (9° 0.2' S. Lat., 149° 03' E. Long.) at the foot of Mount Victory. The local residents said that four small villages which are close to each other in Porlock Bay were washed away and that some people had drowned.

In Buna village 26 people died. People ran into the bushes and were overtaken by the water. Some of them were dashed against trees and others were carried out in the backwash. [This information regarding Buna village was apparently collected 11 years later from a local resident who was apparently contrasting a smaller and more recent inundation (1906) with the one of 1895, which is here described].

In Gona Bay water penetrated the island southward roughly to Ononda* about 7 km inland and left pieces of coral over the flooded area. The wave height was possibly 6 m. The wave scattered the people [Everingham, 1977a].

<u>September 11, 1900</u>. On Cocopo (Herbertshohe) at 7 hr 30 min an earthquake of great intensity occurred (Figure 77). It felt as though the ground

suddenly rose by about 1 m ("several feet"), then dropped with a thud. This disturbance lasted about 3 min. During this rise of the land, the sea receded to about 15 m from the shoreline then, after a 10 min interval, rushed back in again. The German mail steamer *Stellin* lying at anchor touched bottom several times greatly alarming those on board. [Everingham, 1977a].

[September 10; 21 h 30 m; 4.0° S, Lat., 152.0° E. Long.; M = 6.8].

September 18, 1900. [Note: Sept 18 is the date given for this event by the AAAS Seismological Committee (1902) as reported in the 1977 catalog by I.B. Everingham. However, the catalog by Everingham itself lists Sept. 11 as the correct date of the event and offers the following explanation: *"The report stated that the event occurred on Sep. 18 but the description of weather and time of occurrence suggest that the date given is one week in error."*]. In Ralum, an earthquake shock was experienced on board a ship and continued for nearly one minute (Figure 77). All on board thought that the ship had run aground. Looking towards the shore they saw people rushing out of their houses. After a 20 min interval a second shock was felt which lasted for 20 sec. Shocks continued intermittently throughout the day until 9 P.M. In all there were 32 distinct shocks.

After the first shock water receded from the bay (Blanche Bay), leaving boats on dry bottom. The local residents hurried for the fish lying on the dry ground but were soon met by an incoming wave which fortunately was not of great force or volume. After the first shock the sea gage on stern showed a depth of 5.5 m; however the water returned gradually and after half an hour the depth recorded was 11 m. The ship then sailed 1 km into deep water. Oscillations of water continued up to 10 hr 30 min. [Everingham, 1977a].

May 7, 1907. A tsunami occurred in Aitape. Details are not known. [Everingham, 1977a].

[May 7; 10 h 16 m 00 s; 2.8° S. Lat., 144. 5° E. Long.; M = 7.0].

December 16, 1907. An earthquake occurred on Aitape early in the morning. On the coast the land subsided, so that in places where there had been villages there now appeared lakes and lagoons. The earthquake was associated with a great tsunami. [Everingham, 1977a].

[December 15; 17 h 35 m; 3.1° S. Lat., 142.5° E. Long.; M = 7.4].

August 1915. A strong earthquake occurred in the region of Huon Bay and particularly in Salamaua. The tsunami washed almost the entire village. It is quite possible that this report refers to the event of October 11, 1913. [Everingham, 1977a].

July 30, 1917; 7 hr 58 min. In Aitape the sea rose to about 1 m. [Everingham, 1977a].

[July 29; 21 h 52 m 24 s; 3.05° S. Lat., 143.8° E. Long.; M = 7].

February 2, 1920; 21 hr 12 min. A strong earthquake occurred on Gasmata Island (south of New Britain). Its intensity was about 8 or 9 points and it continued for 1 min 10 sec. Residents rushed from their houses. The newly rebuilt dock was half destroyed; in some parts of the island cracks about 5 cm wide appeared; many bottles of drugs and medicines in the hospital were broken. In the middle of the island an old soldier bungalow had jumped forward off its studs and broke stringers and cross pieces. Then for several minutes in the hilly inland part of the island the sound of rumbling and trees crashing and breaking could be heard. In Lindenhafen two houses (European construction) collapsed like a pack of cards and the manager just managed to escape unhurt.

For 48 hours after the main shock (which caused all of the damage) tremors of 30-40 sec duration occurred at half-hour intervals. Afterwards, the tremors continued to occur six times a day.

After the main shock in Gasmata, the harbor water receded into the sea in a swift torrent through the main inlet but did not return. As a result of this the tides thereafter stopped 50-60 cm lower than the previous high-water mark. Many dead fish were left on the reefs and their stench was carried by the sea wind to the shore. On the morning of the 2nd [before the earthquake occurred], although the weather was good, a very strong swell set in from SSW and continued throughout the day. [Everingham, 1977a].

[February 2; 11 h 22 m 18 s; 6.5° S. Lat., 150.0° E. Long.; M = 7.7].

January 20, 1922; 8 hr. An earthquake occurred at Sumai "about 8 in the morning" with the first shock being the worst. It shook the houses in the village and broke some of the coconut trees. A 1.8 m high wave directly entered the village and then receded. The mortally afraid residents abandoned their huts and ran inland to escape the incoming tide. Around midday there were two small shocks and people again left their houses. About 5 P.M. a very strong shock was felt. Some canoes were flooded and sank. As a result of this or the previous shocks, the roofs of some of the houses caved in and one house was totally destroyed. [Everingham, 1977a].

January 19; 21 h 58 m 50 s; 7.0° S. Lat., 143.0° E. Long.; M = 7.5].

November 3, 1923; 7 hr 18 min. After the first shock in Blanche Bay and Simpson Harbor (Rabaul) the water [which was at high tide] quickly receded to the low water mark and returned again after 15 minutes. Within half an hour this process repeated itself. [Everingham, 1977a].

[November 2; 21 h 08 m 06 s; 4.5° S. Lat., 151.5° E. Long.; 50 km; M = 7.2].

November 4, 1923; 10 hr 20 min. At Natawa plantation (northern coast of New Britain) several earthquakes occurred. The sea receded a few seconds after the first shock. This occurred many times with the water surface being highly agitated. After the second shock no further disturbance of the water at Rabaul was recorded, but a similar disturbance was reported on the northern coast of New Britain, roughly 28 km from Rabaul. [Everingham, 1977a].

[November 4; 00 h 04 m 30 s; 5° S. Lat., 152.0° E. Long.; M = 7.2].

October 1, 1930; 07 hr 21 min. It was reported that a tsunami was observed on the western coast of Karkar Island in the Bismarck Sea. The sea rose and fell about four times, finally dropping to roughly 0.6 m below the previous level. [Everingham, 1977a].

[September 30; 21 h 20 m 45 s; 4.5° S. Lat., 146.0° E. Long.; M = 7.0].

December 24, 1930; 7 hr 30 min. A strong earthquake shook Mal Island and its neighboring islands followed immediately by two tsunami waves (Figure 78). The house of the plantation manager was lifted off of its piles and dropped down again. A huge water tank by the side of this house was thrown from its supports and fell against the house. A loud hissing sound similar to that made by escaping steam was heard from the southeastern end of the island and two large clouds of dense smoke or steam were observed hanging over the sea. At the same time two large waves appeared, one of which was coming towards the southeastern end of the island from the southwest while the other appeared to be going due east.

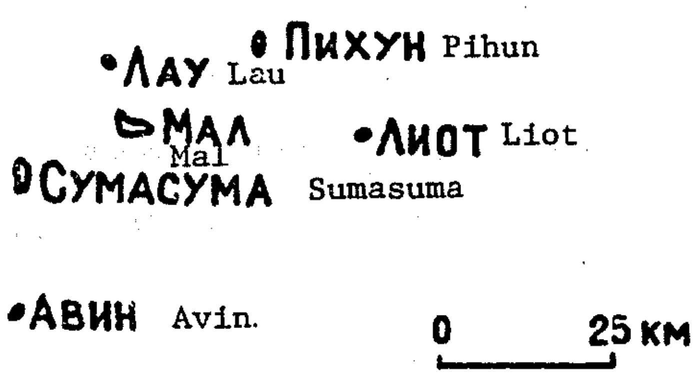

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Figure 78: Location of islands in the pleistoseismal region of the earthquake of December 24, 1930
[Everingham, 1977a].

The wave from the southwest struck the end of the island washing away everything in its way and uprooted coconut palms and large trees over a distance of 2 km. The second wave moved almost due east towards Numu, a small uninhabited island with an area of 0.8 ha. [2 acres]. It was completely washed away to its coral base. On it were some very large casuarina trees which were uprooted, broken to pieces, and thrown into the sea. All this happened during low tide. No doubt, because of this very few people died. Nearly 200 palms were destroyed.

On neighboring Lau Island some residents were cutting copra and since they were close to the end of the island they were trapped by the waves. Two of these residents drowned. Local fishermen were also caught in the wave but all survived although some of them received cuts and bruises from floating fragments. As these people were being swept along the island, some of them tried to save themselves by clutching the branches of coconut palms. As these palms are 9-12 m tall, one can get some idea about the wave height. Survivors of the wave reported an interesting phenomenon. The water in the wave was fresh water rather than salt water.

The shocks continued throughout the day of December 24 and numbered about thirty. They continued for days gradually decreasing in frequency and intensity until they had become small tremors. They ceased altogether by the beginning of January.

On Sumasuma Island the wave traveled along the cape and destroyed houses (built of local material). The copra cutters were caught in the tail end of the wave and had to swim. All of them were rescued.

On Avin Island the sea receded and then the wave (4 m?) hit from the east.

In the middle of Lau Island a blow hole was discovered which had appeared at the time of the disturbance. All around it the foliage was killed, just as though it has been subjected to a blast of hot air, and there was a deposit of yellowish whitish sandy clay.

A similar condition on a larger scale occurred on Pihun Island whose population had abandoned the island and was then living on Amot Island. These people said that they could not return to their island because of the awful stench of dead fish. They also reported that their swamp taro (hula) gardens had been destroyed. Three people died and four were injured, the most serious injury being a broken leg.

In early January Pihun Island was surveyed [along with other affected islands] by a government official from Rabaul. He estimated that roughly one tenth of the island (primarily the southern end) had been seriously affected. Wherever the wave passed, all types of vegetation were destroyed. The official likened the effects to what might be produced by "a blast of hot air." All plants were withered and dead except for some foliage which possibly had remained above water.

Liot Island also suffered from the wave. On its southwestern end some gardens (plantations) were destroyed. On a reef close to where the island of Numu had been, a large rock was found which was possibly brought from the bottom of the sea by the wave since no one had seen it before at this place.

The islands of Mati (Wuvulu), Aua (Durour) and Allison (Manu) were not hit by the tsunami. Karkar Island was affected on its eastern, northern and western parts. Waves destroyed a bridge and washed away a part of the coastal belt together with the palms and at other places thousands of fish were stranded on the coast. One man said that he was thrown together with his boat onto the dry coast. Fifteen residents were reported lost at sea. Whether the rough sea was due to weather conditions or caused by the earthquake was uncertain.

At Sapara, on the northern coast of New Guinea (Figure 79) one of the eyewitnesses, a missionary by the name of Father Van Baar, stepped outside of the mission school at the time of the earthquake and saw that the sea was receding. He went to the beach where residents had gathered, and observed the water receding into the bay, leaving the place where the *Stella Maris* usually anchored, and all the reefs, quite dry. Some locals began to search for fish in the pools left by the receding water.

As soon as the sea receded to 500 m, it halted and began moving back towards the shore line. A "general call" was sounded to run for safety and everyone scattered. Father Van Baar ran back towards Meriman. Looking back, he saw his own house and the newly constructed church collapsing. Continuing on towards Meriman, he was met by a wave coming from that direction; he turned and ran to the bushes. Up to his waist in swirling water, he managed to reach high ground, which soon became an island.

As soon as the water subsided locals began searching for their families and for victims among the debris. Under the wreckage of houses in Sapara they found the body of a woman from the inland village of Pipoura. Two women found under the wreckage were seriously wounded but died soon after rescue. Under the debris about 230 m from the coast they found the body of a student of the missionary school. The next day in Sapara the body of another woman was found under the debris of a hut. Moreover one small child was lost. All places were thoroughly searched but he could not be found. It was presumed that the child was dragged into the sea by the receding water and drowned.

In the village Meddibur and Tawulti there was no loss of life; only some injuries were received. In the former village three elderly people and in the latter a young girl were injured.

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Some signs indicate that in Sapara water rose to a height of 6-7.5 m and rushed 200-300 m inland, scattering a hose of coral fragments on the coast and destroying everything in its path except the tall coconut palms and large trees. Thirty-two structures in the Sapara Mission and village were completely demolished and swept away, the debris scattered over the entire affected area, leaving a scene of utter devastation.

North of Sapara the village of Simbini sustained the worst damage. 24 houses were destroyed. Other places with houses destroyed were: Meriman (2), Ruranat* (7 houses and a newly constructed bridge), Mere (2), Malala (3 houses and a newly constructed bridge), Busip (4), Kelaua Plantation (2 labor houses and a foot bridge across the river), Wangol (3), and Bimat* (3).

In Bogia the wave gushed through the wharf and passed through the plantation and copra store but did not destroy anything.

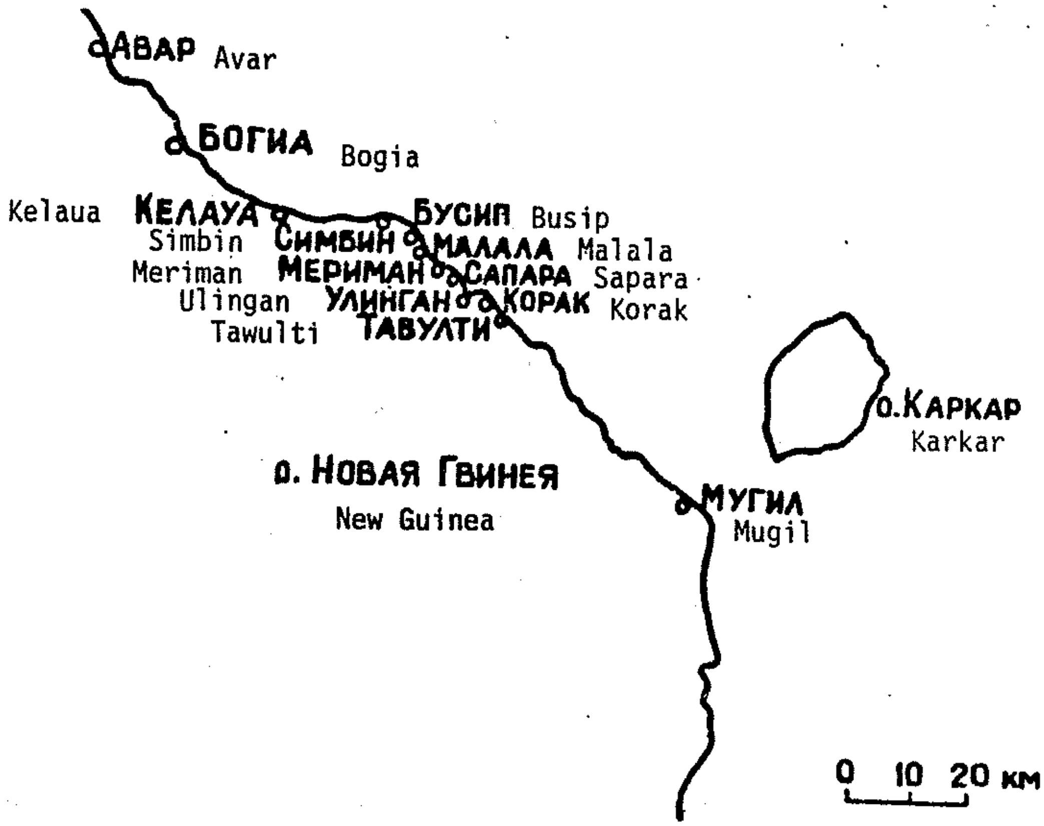

Figure 79: Habitations on the northern coast of New Guinea affected by the tsunami of December 24, 1930 [Everingham, 1977a].

At Awar plantation, according to any eyewitness account, the wave height was 3.6 m. It washed the platforms for drying copra, passed through the copra store where there were 300 sacks full of copra and carried them through the labor house carrying away the front and back walls, the partitions, and deposited beds, blankets, and effects 150 m inland. A small boat was thrown onto the plantation. On the coast a huge mass of coral fragments was deposited above the high water mark. Canoes from the villages of Nubia and Sisimungan were destroyed.

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Madeibur*, which is south of Sapara and situated on the southern side of the bay south of Sapara Mission, was hit by the backwash from the receding wave. 12 houses were destroyed, and yet a section of bush between the villages of Sapara and Madeibur were undamaged. In Madeibur three people were injured.

At Ulingan the villages of Torto* and Meiwak*, situated on the north and south capes of the harbor were unaffected by the water. At the head and to the northern side of the harbor, the 13 houses comprising the village of Ulingan, together with the mission school and house at the immediate head of the bay were completely demolished and washed inland. Lumps of coral reef were washed up on the shore and the road was washed away.

A small bay and several acres of land north of Korak evidently took the full brunt of the force of the wave which penetrated 350-450 m inland, laying waste the brush and trees to completely block the roads for nearly a mile. Huge masses of coral reefs were cast up on the beach. Water destroyed the copra store, left a trench where a shed had stood, and uprooted full grown trees.

18 houses were destroyed in Korak and 7 in Tawulti. South of Tawulti no houses were destroyed, at the Mugil Mission a small anchored boat was cast ashore into the bushes and was damaged.

In places exposed to the action of the waves practically all boats were either destroyed or damaged and many domestic cattle died.

Except for minor instances, the orchards and gardens of local residents were not damaged, but all kapiaks, betelnuts, bananas, paw-paws, and other natural products growing on the flooded area have died from the effects of the salt water.

Three canoes carrying 18 local residents on a trading trip from Karkar Island were wrecked at Murakanuma*. The canoes were smashed but all on board got ashore uninjured. [Everingham, 1977a].

August 7, 1931; 11 hr 40 min. As a result of the earthquake from Aitape to Ulau cracks were observed on the shore and water entered inland. [Everingham, 1977a].

[August 7; 02 h 11 m 30 s; 4.0° S. Lat., 142.6° E. Long.; M = 7.1].

1509 August 12, 1931; 22 hr 00 min. In Namatanai (New Ireland) an earthquake occurred. An eyewitness present on the stony wharf noticed a strong agitation of the water on the shallow-water reef and waves reaching from there to the wharf. Possibly this was not tsunami. [Everingham, 1977a].

December 13, 1934; 00 hr 15 min. A strong earthquake occurred in Rabaul. The first tremor was "of an up-and-down nature" and was followed by spasmatic shocks from different directions (Figure 77). On many main roads there were landslides and a small tsunami was reported from Nondup (Nodup). [Everingham, 1977a].

September 20, 1935. J. C. McCarthy who visited Aitape observed the earthquake and tsunami. He narrated that he heard locals shout, "The sea! Look at the sea!", as he saw that the ocean seemingly receding from the beach. After the first series of shocks, the tremors diminished until they became barely discernible. The sea receded until the entire foreshore was dry. Then the tide began to return. It came in great breakers although further out to sea the sea was calm. Large waves swept up over the coast and at places flooded inland. Where the land was lower, the sea moved several hundred meters inland. [Everingham, 1977a].

[September 20; 01 h 46 m 33 s; 3.5° S. Lat., 141.8° E. Long.; M = 7.9].

May 13, 1938; (early morning). The entire northeastern section of the New Guinea mainland experienced a strong earthquake. The Morobe region suffered the most from the shock. Small tsunami waves inundated the northern tip of Salamaua and bulk stores sustained considerable damage. Numerous houses of local residents collapsed and the locals fled in terror to higher ground. For a time flood waters had cut off Salamaua from the airport. Many instances of minor damage occurred, including disruption of telephone service. Numerous oil barrels were swept by water from waterfront stores into the swamp. Boats and launches ran aground. [Everingham, 1977a].

[May 12; 15 h 38m 57 s; 6.0° S. Lat., 147.8° E. Long.; M = 7.5].

April 30, 1939. [12 people drowned at unspecified locations as a result of the tsunami described here which was experienced in the Solomon Islands, the Russell Islands, and Guadalcanal]. This tsunami destroyed the Lavoro Plantation House in Guadalcanal and reached a height of 10 m on the coast of Beaufort Bay. At the same time the wave passed without any damage in Visale Mission, a few kilometers north on the same coast. Here, the tsunami height was only 1.8 m. In Tulagi between 13 hr and the end of April 30, twelve waves were observed with heights of 1.2 m (from crest to trough). Goods lying on the floor in some Chinese shops were damaged. [Everingham, 1977a].

[April 30; 02 h 55 m 30 s; 10.5° S. Lat., 158.5° E. Long.; M = 8.1].

November 8, 1950. An earthquake generated a 1.2 m high wave on the southwestern coast of Guadalcanal; it did not cause any damage. In Honiara there was a vertical rise of water at the coast, possibly only about 30 cm and would have passed unnoticed by all who were not familiar with a tsunami. [Grover, 1955]. 1509

[November 7; 5 h 59 m 41 s; 14.00° S. Lat., 167.0° E. Long.; 60 km; M = 6¾].

1950-1953. After the end of 1950 seafaring vessels began noticing the eruption of a volcano 35 km south of Vangunu Island, New Georgia Archipelago. The scattering of pumice stone was also reported. In the night of April 15-16, 1952 the crews of cruising ships witnessed flame tongues and the water within a half kilometer radius boiled. In the village of Bili in southern Gatanai Island, on May 31, 1952 from 9 hr 22 min to 9 hr 47 min, more than 20 explosions could be heard near the volcano. Seaquakes were felt fairly frequently.

Aborigines from the village of Penjuku on the extreme southeastern Marovo Lagoon frequently observed different phases of the underwater eruption. Sometimes a dome was formed on the water surface, at other times there was a column of great height and at still other times a mushroom cloud of smoke. By the end of 1951 small tsunamis were quite frequently observed; later they ceased when the volcanic structure apparently reached the water surface.

A small new island was noticed for the first time on November 11, 1952 but by January 19, 1953 it could no longer be located. Apparently it was washed out by waves. Eruptions continued and explosions followed every 2 min.

On January 20, 1953, J.C. Grover overflew the site of the eruption on a regular flight of a passenger aircraft. He was able to observe two explosions at an interval of 3¾ min. There were no above water structures. The site of the volcano was clear from the patch of yellowish green water in place of the usual deep blue color. It extended 13 km on the 100° azimuth.

During the final eruption a white column of water, with a diameter of 360 m and several hundred meters high, was thrown up. On all sides of the rising cylindrical front sea waves were propagated, initially reaching a height of 12-15 m which then disappeared fast. The column fell on the patch of discolored water and after some time small breakers appeared at the eastern edge of the patch, evidently the spot where the exploded material fell. [Grover, 1955].

[09.01° S. Lat., 157.57° E. Long.].

1951, beginning of the year. An event occurred early in 1951 and was described by an eyewitness as follows: "There had been intermittent earth
1509 tremors all day. The wave came up suddenly in the afternoon, swept away three wards of the old hospital, which was built of native materials. Waves approximately 20 ft. [6 m] high. No casualties".

The Assistant District Officer remembered only the gradual rise of water to a maximum of 1.8 m during the morning; this could be a separate event from the one described above. In the International Seismological Summary there is a record of an earthquake on February 22 at 01:46 (Greenwich time) which is probably related to the tsunami. [Everingham, 1977a].

[February 22; 01 h 45 m 42 s; 3.7° S. Lat., 142.2° E. Long.].

<u>October 11, 1955; 10 hr 00 min</u>. There were reports of small tsunami waves at Sulfur Creek and along the northern border of Simpson Harbor. These were first noticed about one hour after the main shock. [Everingham, 1977a].

[October 10; 08 h 57 m 47 s; 5.0° S. Lat., 152.5° E. Long.; M = 7.3].

<u>August 18, 1959; 08 hr 05 min</u>. A seismic sea wave was generated somewhere off of the west coast of Ranongga Island (Ghanongga) (Figure 80). In Vori*, on the northern coast of Ranongga Island, large sea waves were observed soon after the strong shock. They were in the deep sea beyond the reefs traveling northward at right angles to the shoreline. The sea receded by 15 m and then returned to its original position. The waves then passed by without otherwise affecting the bay. Having passed the northern tip of Ranongga Island the tsunami continued down the eastern coast, swept the shoreline, and entered Emu Harbor*. The western coast only caught the backwash. At the inner narrow end of Emu the wave was about 1.2 m high and many fish were left behind on the coast between the first and second lines of coconut palms.

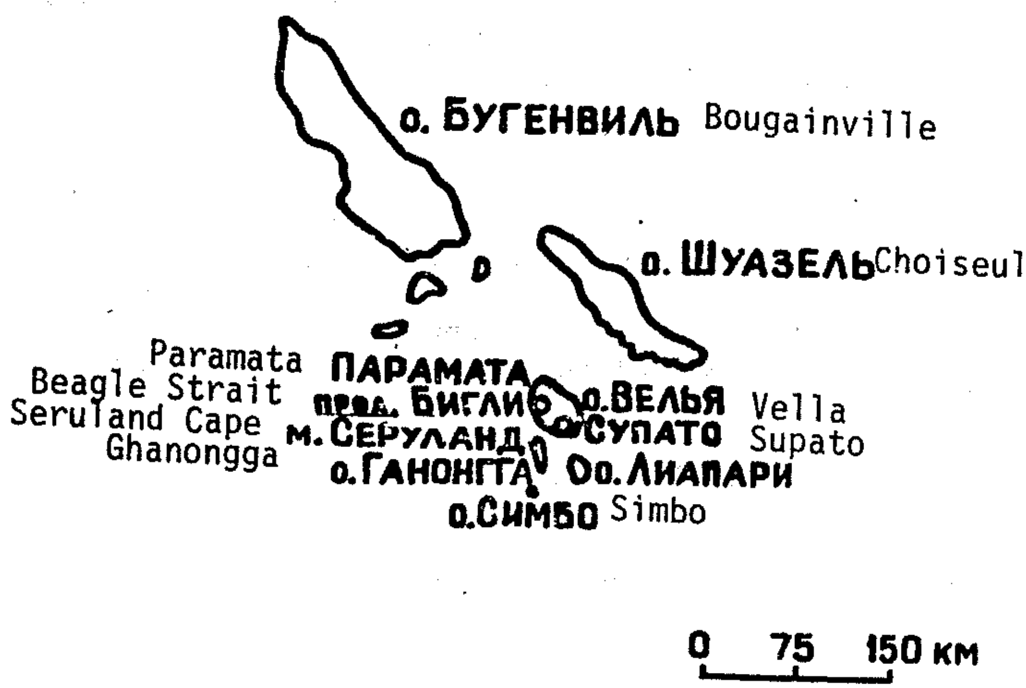

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Figure 80: Geographic points near the source region of the tsunami of August 18, 1959.

Through Beagle Strait, on the southern coast of Vella Island, the tsunami passed Serulando Point to the village Supato, where residents saw waves traveling swiftly out at sea which were square to the coastline while the fringes of the waves which passed over shallow areas were slowed by friction; here the waves appeared to be about 15 m apart. On the western side of Supato Bay and along the coastline for about three miles farther northwest the sea had subsided by about 30 cm when the wave swept the coast damaging houses on the shore. On Liapari Plantation the sea had receded from the coast by "a few feet", but the wave passed behind the reef without touching the bay. The wave was not observed on the east, north, or west coasts of Vella Island although one shipboard eyewitness, Garner [who apparently feared his vessel was endangered], reported that there were "confused and dangerous tide rips off the east coast later that morning". Although wishing to get out of it, Garner could not risk turning his ship around. Simbo Island also reported "a heavy and confused sea" that morning.

On Binskin Island* (or Inia), south of Vella Island and off the northern coast of small Baga Island, the wave approached from Supato on the east, passing through Beagle Strait. Mrs. Binskin, who has been in the area since 1910, reported that this earthquake was much worse than others before. To the accompanying rumble from the mountain on Vella Island her house shook north-and-south, then east-and-west, throwing everyone to the ground where they crawled on their hands and knees. Everything on the shelves and tables fell to the ground except for the items in two small kitchen shelves which had "earthquake" bars affixed across the front. People watched the two quays in the harbor gradually subside into the water. All of the coral boulder retaining walls disintegrated. A small seed box (30 x 20 x 20 cm) containing soil was thrown from its 1.2 m high position in the branches of a small tree for a distance of about 5 m.

About a minute later the islanders raised a cry in their local language: "everyone stand by their canoes, the water is coming". The sea receded and then returned so rapidly that some people did not have time to undo their canoe ropes and had to cut them adrift with their "pangas". The water rose to about 105 cm above the present [since the earthquake] low water mark, or roughly 255 cm above the low water mark in use at the time of the earthquake. Water entered Mrs. Binskin's house through open doors, one of which had been shaken off its hinges, reaching a depth of 22.5 cm, then quickly receded carrying out nearly all of her household effects. Two quays were destroyed, although the well-built and firmly-anchored shore section of one of them remained intact.

From this location it was possible to compare the water levels from before and after the earthquake. Where the depth was 150 cm earlier it now showed 298 cm, which means the level of submergence was 148 cm.

The current low water mark is higher than the old [pre-earthquake] high water mark and there are now freshwater lakes on the island. The area of the island has been reduced to less than the original 5 acres and is yet being further eroded. One other observation is of importance: during the two week period in which these earthquakes continued, the sea beyond the harbor was continuously disturbed and sea level was 15 cm above the present level. When the shocks ceased in early September, sea level fell by 15 cm and has remained constant since then.

Not all of Binskin Island sank as much as 1.5 m. The more solid coral rock section adjoining Beagle Channel appeared to sink by 30 cm. A partial explanation for the submergence of the mainland side of this small island is that it is 'made' land, reclaimed from mangrove swamp and protected by retaining walls [dikes]. Consolidation of the underlying materials and lateral spreading of that loose material above water level by the severe shaking, and the erosion effects of the seismic sea wave are also contributing factors.

The force of the current during the sudden subsidence of each wave was strong enough to snap off coral heads in the channel between the island and the mainland mangroves. The growing stag horn coral (Acropora) was also broken and laid down on the channel bed pointing in one direction. As a result of this tsunami the strait became deeper and safer.

Further to the northwest of Paramata, on the mainland, the sea receded approximately 15 m and the sea wave rose to the high water mark, but there was no damage.

Off the western coast of Ranongga, where it began, the wave appeared to observers to be "a few feet high". It caused no serious damage and passed by those inlets that were sheltered by coastal reefs and facing away from the oncoming wave. [Everingham 1977a].

[August 17; 21 h 24 m 40 s; 7.5° S. Lat., 156° E. Long.; M = 7.25].

<u>August 1, 1961; 15 hr 40 min</u>. On the southern coast of the Solomon Islands a small tsunami swept the coast. Its height was nearly 1 m. [Everingham, 1977a].

[August 1; 05 h 39 m 49 s; 9.8° S. Lat., 160.5° E. Long.; 50 km; M = 6.6].

<u>November 17, 1964</u>. In Rabaul the tide gauge recorded a small seismic sea wave generated by an earthquake; its height was about 5 cm. [Everingham, 1977a].

[November 17; 08 h 15 m 39 s; 5.7° S. Lat., 150.7° E. Long.; 45 km; M = 7.3].

August 14, 1967; 8 hr 15 min. Tidal effects measured in Rabaul after an earthquake were very small. The maximum height of the tidal rhythm was only 10 cm and the effects lasted for less than two hours [Everingham, 1977a].

[August 13; 22 h 15 m 10 s; 4.4° S. Lat., 152.5° E. Long.; 30 km; M = 6.4].

APPENDIX 4

LIST OF PLACES EXPOSED TO THE ACTION OF THE TSUNAMIS DESCRIBED IN APPENDIX 3

(Places whose coordinates are not known are not listed)

Aitape (New Guinea): May 7, 1907; Dec. 16, 1907; Jul. 30, 1917 (1 m); Aug. 7, 1931; Sept. 20, 1935; Beginning of 1951.

Awar (New Guinea): Dec. 24, 1930 (3.6 m).

Awin Island (Bismarck Archipelago): Dec. 24, 1930 (4 m?).

Beagle Strait (Solomon Islands): Aug. 18, 1959.

Beaufort Inlet (Solomon Islands, Guadalcanal Island): Apr. 30, 1939 (10 m).

Blanche Bay (New Britain): Feb. 4-5, 1878; Sept. 18, 1900 (5.5 m); Nov. 3, 1923.

Bogia (New Guinea): Dec. 24, 1930.

Buna (New Guinea): Mar. 6, 1895.

Busip (New Guinea): Dec. 24, 1930.

Gasmata (New Britain): Feb. 2, 1920.

Gatanai Island (Solomon Islands): 1950/1953.

Gona Inlet (New Guinea): Mar. 6, 1895 (6 m).

Guadalcanal (Solomon Islands): Apr. 30, 1930; Nov. 8, 1950 (1.2 m).

Honiara (Solomon Islands, Guadalcanal Island): Nov. 8, 1950 (30 cm).

Karkar Island (New Guinea): Nov. 1, 1930; Nov. 1930 (-0.6 m); Dec. 24, 1930.

Kelaua (New Guinea): Dec. 24, 1930.

Kokopo (New Britain): Sept. 11, 1900.

Korak (New Guinea): Dec. 24, 1930.

Lavoro (Solomon Islands, Guadalcanal Island): Apr. 30, 1939.

Lau Island (Bismarck Archipelago): Dec. 24, 1930 (9-12 m).

Liapari Island (Solomon Islands): Aug. 18, 1959.

Liot Island (Bismarck Archipelago): Dec. 24, 1930.

Madeibur (New Guinea): Dec. 24, 1930.

Mal Island (Bismarck Archipelago): Dec. 24, 1930.

Malala (New Guinea): Dec. 24, 1930.

Matupi Island (Bismarck Archipelago): Feb. 4-5, 1878.

Mere (New Guinea): Dec. 24, 1930.

Meriman (New Guinea): Dec. 24, 1930.

Mugil (New Guinea): Dec. 24, 1930.

Murakanum (New Guinea): Dec. 24, 1930.

Namatanai (New Ireland): Aug. 12, 1931.

Natava (New Britain): Nov. 4, 1923.

Nodup (New Britain): Dec. 13, 1934.

Numu Island (Bismarck Archipelago): Dec. 24, 1930.

Ononda (New Guinea): Mar. 6, 1895 (6 m).

Paramata (Solomon Islands, Vella Island): Aug. 18, 1959.

Pihun Island (Bismarck Archipelago): Dec. 24, 1930.

Porlock Inlet (New Guinea): Mar. 6, 1895.

Rabaul (New Britain): Feb. 4-5, 1878; Nov. 3, 1923; Octo. 11, 1955; Nov. 17, 1964 (5 cm); Aug. 14, 1967 (10 cm).

Ranongga Island (Solomon Islands): Aug. 18, 1959.

Rurunat (New Guinea): Dec. 24, 1930.

Salamaua (New Guinea): Aug. 1915; May 12, 1938.

Sapara (New Guinea): Dec. 24, 1930 (6-7.5 m).

Seruland Cape (Solomon Islands, Vella Island): Aug. 18, 1959.

Simbini (New Guinea): Dec. 24, 1930.

Simbo Island (Solomon Islands): Aug. 18, 1959

Simsim Island (Trobriand, New Guinea Islands): Mar. 6, 1895.

Simpson Harbor (New Britain): Nov. 3, 1923; Oct. 11, 1955.

Solomon Islands: Aug. 1, 1961 (1 m).

Sulphur Inlet (New Britain): Oct. 11, 1955.

Sumai (New Guinea): Jan. 20, 1922 (1.8m).

Sumasuma Island (Bismarck Archipelago): Dec. 24, 1930.

Supato (Solomon Islands, Vella Island): Aug. 18, 1959.

Tawulti (New Guinea): Dec. 24, 1930.

Tulagi (Solomon Islands, Guadalcanal): Apr. 30, 1939 (1.2 m).

Ulau (New Guinea): Aug. 7, 1931.

Ulingan (New Guinea): Dec. 24, 1930.

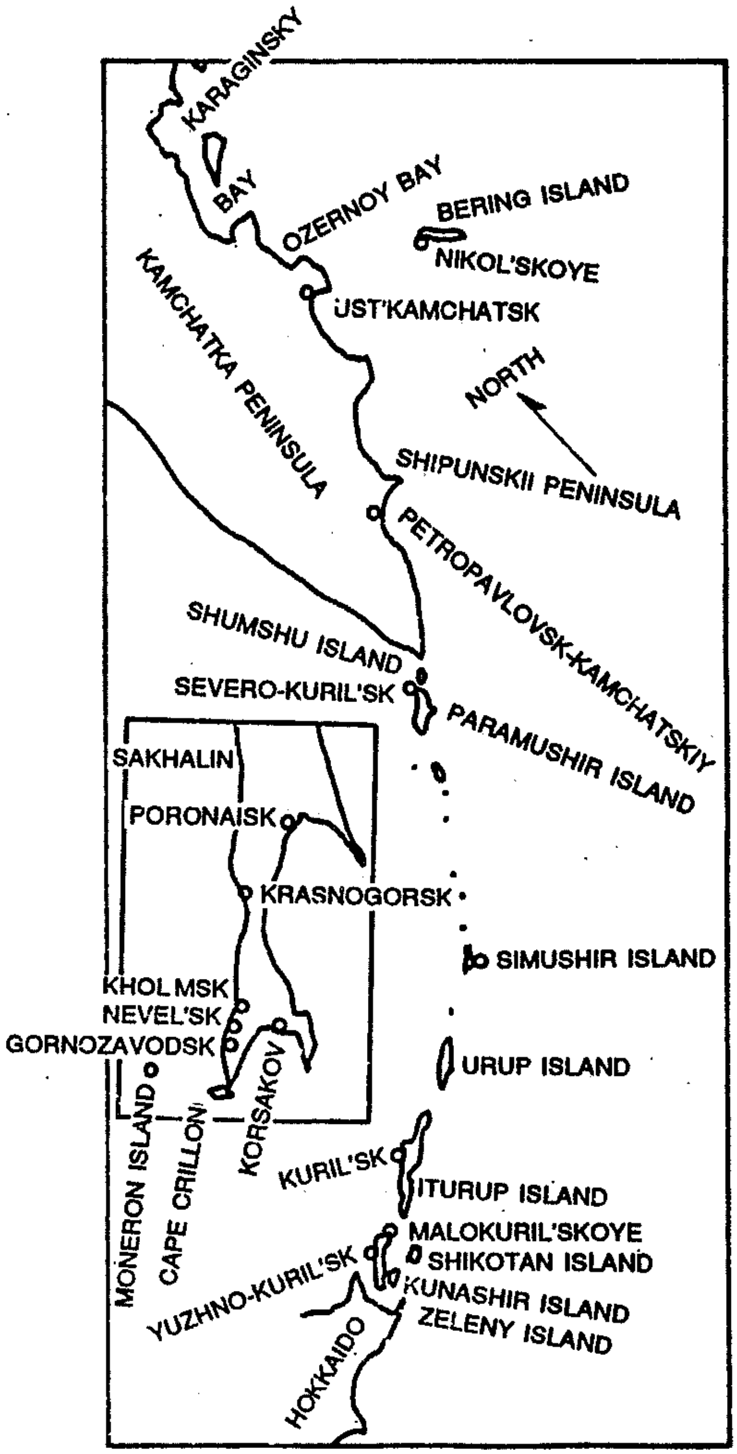
Vangunu Island (Solomon Islands): 1950/1953.

Vella Island (Solomon Islands): Aug. 18, 1959.

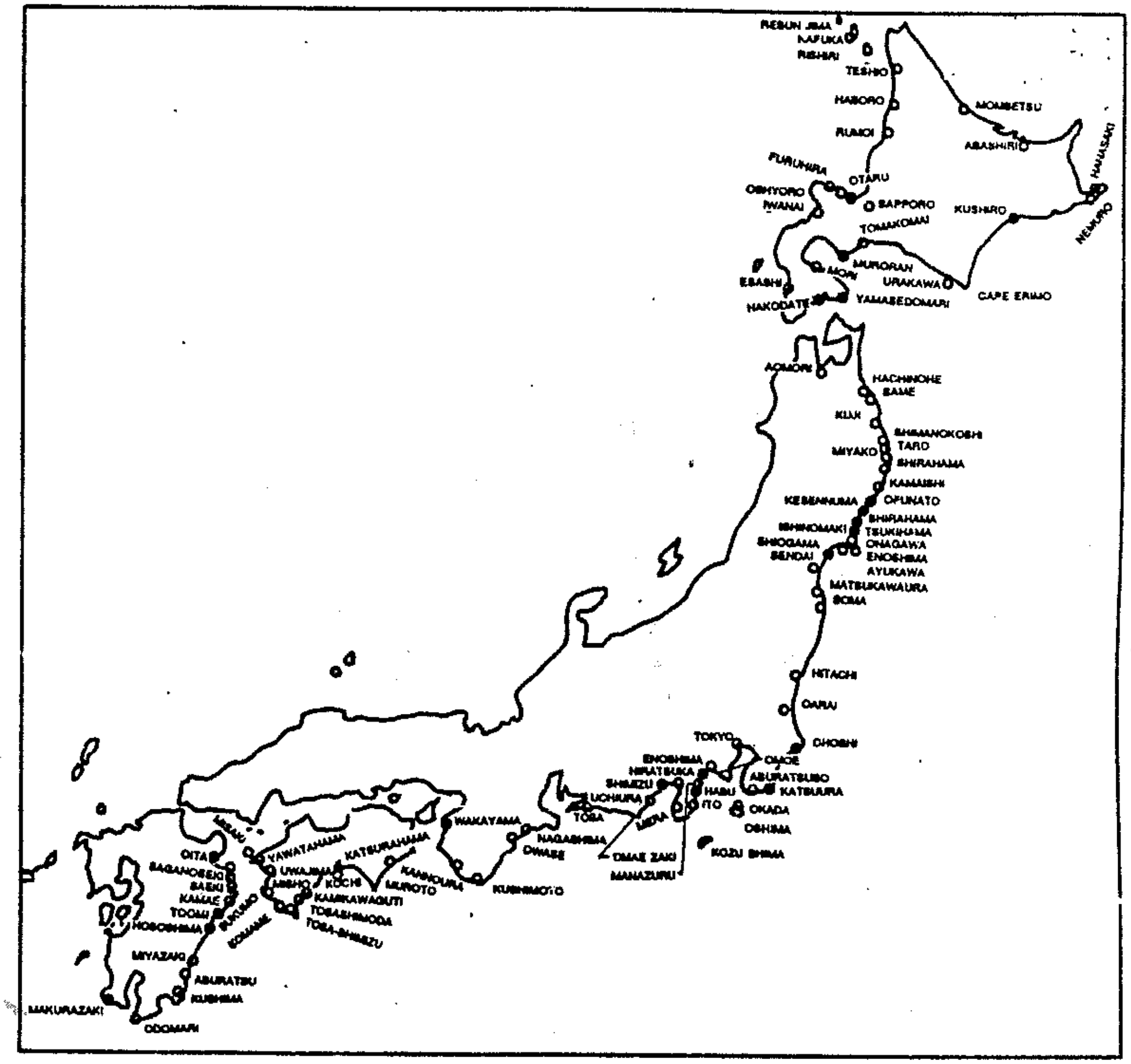
APPENDIX 5

GEOGRAPHIC MAPS

Map I. Far-East USSR

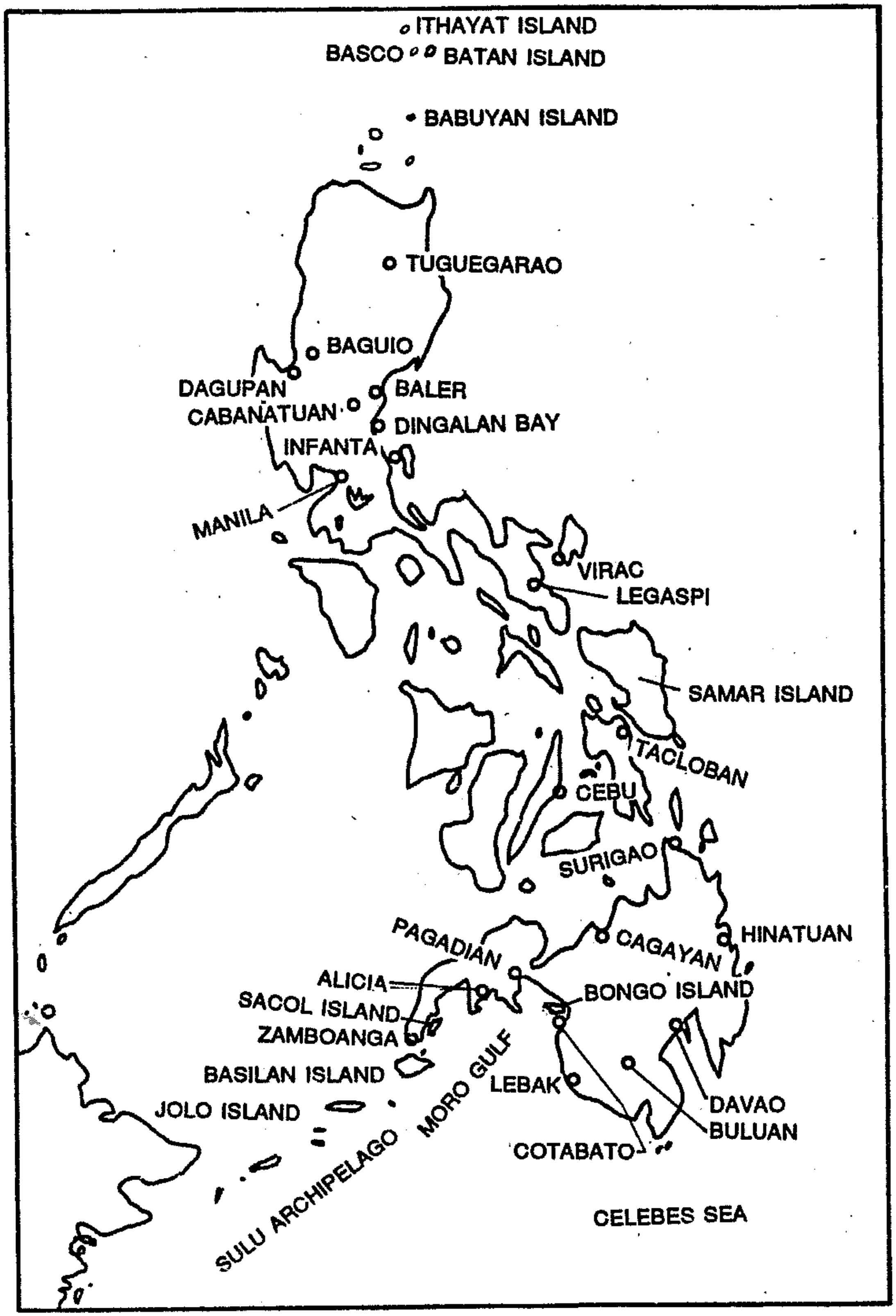


Map II. Japan



REBUN JIMA
NAFUKA
RISHIRI
TESHIO
HABORO
RUMOI
MOMBETSU
ABASHIRI
HANASAKI
FURUHIRA
OTARU
OSHYORO
IWANAI
SAPPORO
KUSHIRO
NEMURO
TOMAKOMAI
MURORAN
MORI
URAKAWA
ESASHI
HAKODATE
YAMASEDOMARI
CAPE ERIMO
AOMORI
HACHINOHE
SAME
KUJI
SHIMANOKOSHI
TARO
MIYAKO
SHIRAHAMA
KAMAISHI
KESENNUMA
OFUNATO
SHIRAHAMA
ISHINOMAKI
TSUKIHAMA
SHIOGAMA
ONAGAWA
SENDAI
ENOSHIMA
AYUKAWA
MATSUKAWAURA
SOMA
HITACHI
OARAI
TOKYO
CHOSHI
ENOSHIMA
OHOE
HIRATSUKA
ABURATSUBO
SHIMIZU
KATSUURA
UCHIURA
HABU
TOBA
ITO
OKADA
MERA
OSHIMA
NAGASHIMA
OWASE
OMAE ZAKI
KOZU SHIMA
MANAZURU
WAKAYAMA
KUSHIMOTO
YAWATAHAMA
KATSURAHAMA
OITA
SAGANOSEKI
UWAJIMA
SAEKI
KOCHI
MUROTO
KAMAE
KAMIKAWAGUTI
TOOMI
TOSASHIMODA
HOSOSHIMA
TOSA-SHIMIZU
MIYAZAKI
ABURATSU
KUSHIMA
MAKURAZAKI
ODOMARI

Map III. The Philippines



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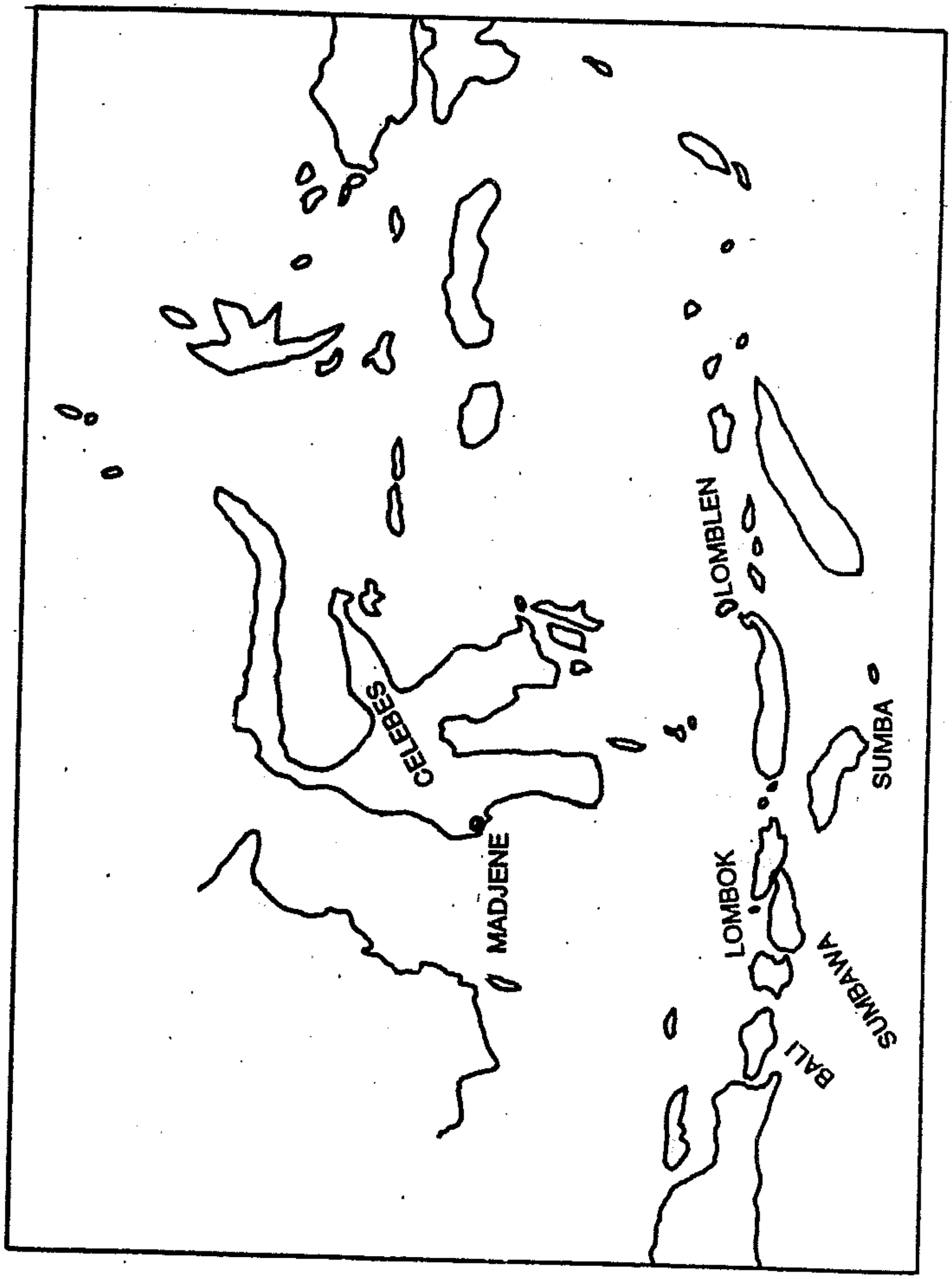
Map IV. Eastern Part of Indonesia



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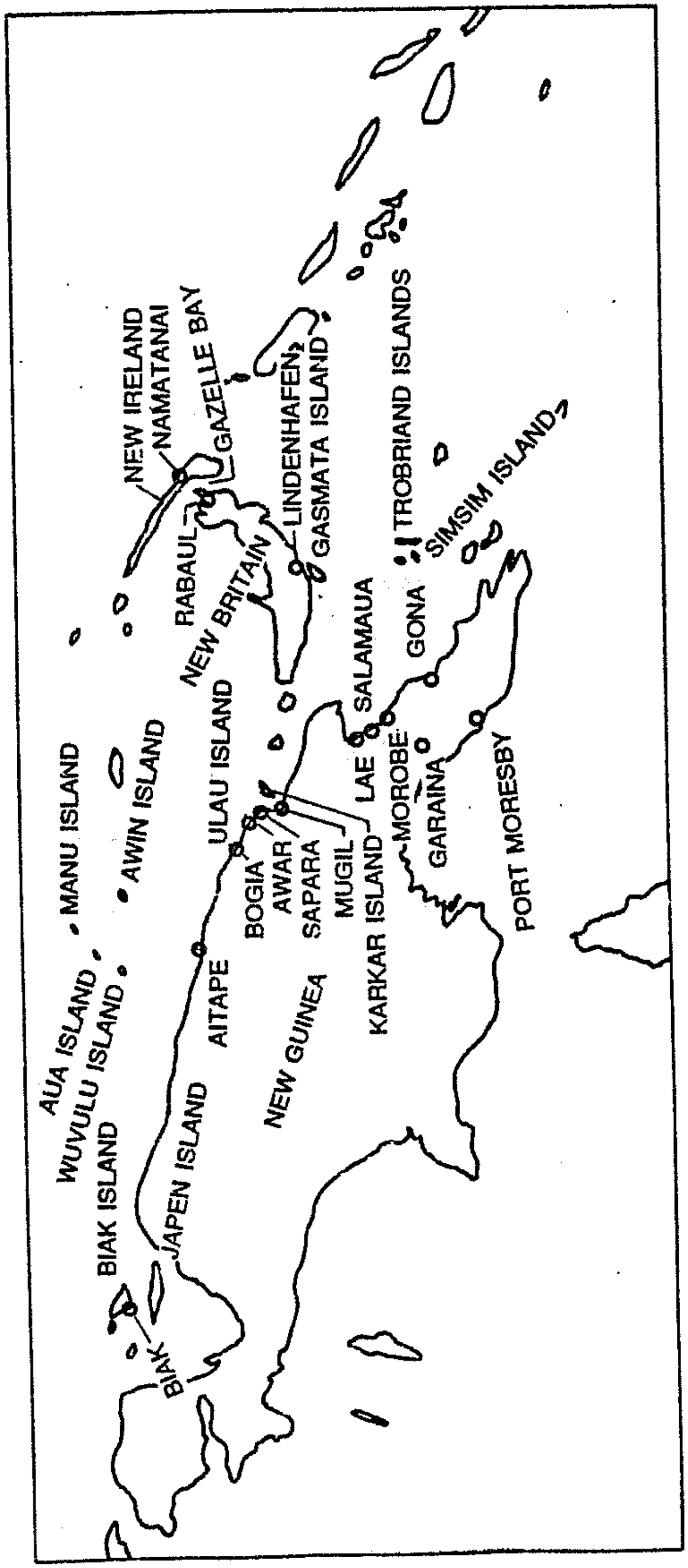
Map V (a). New Guinea and Bismarck Archipelago



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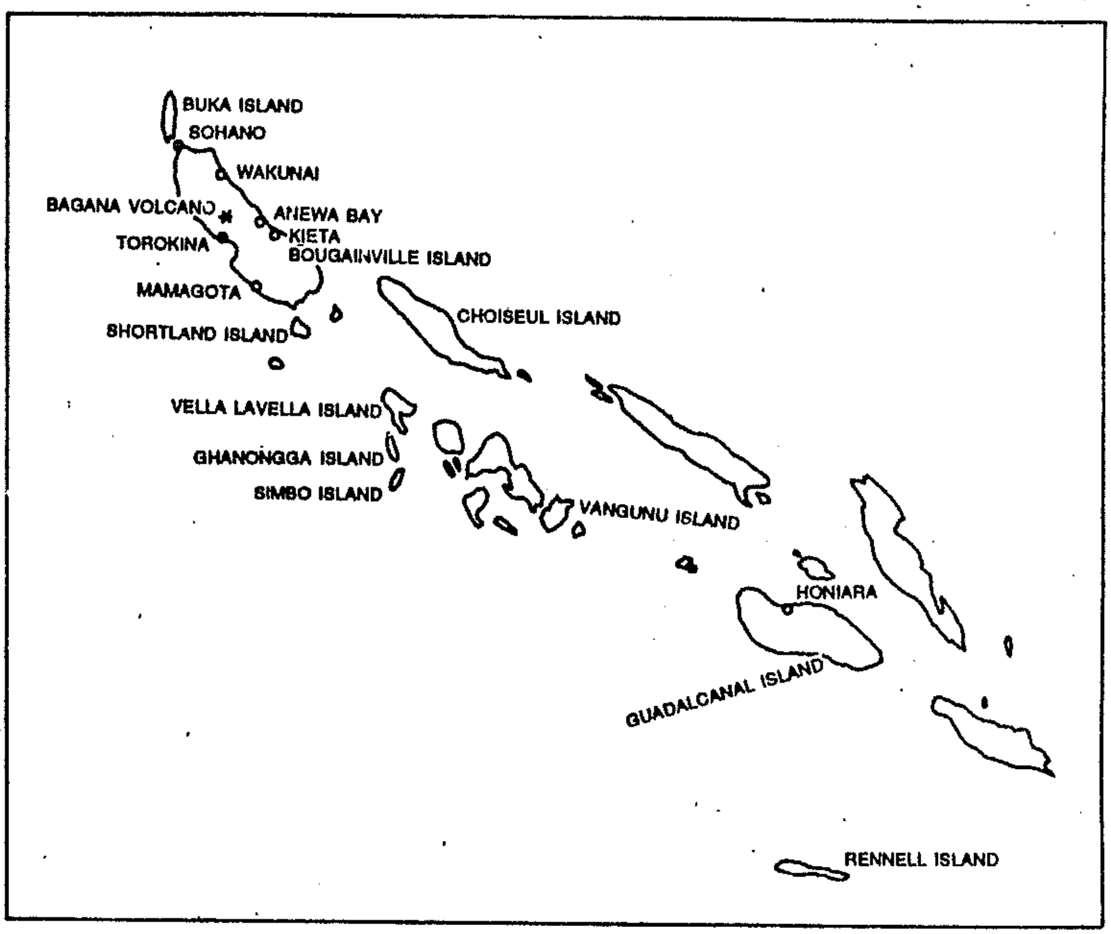
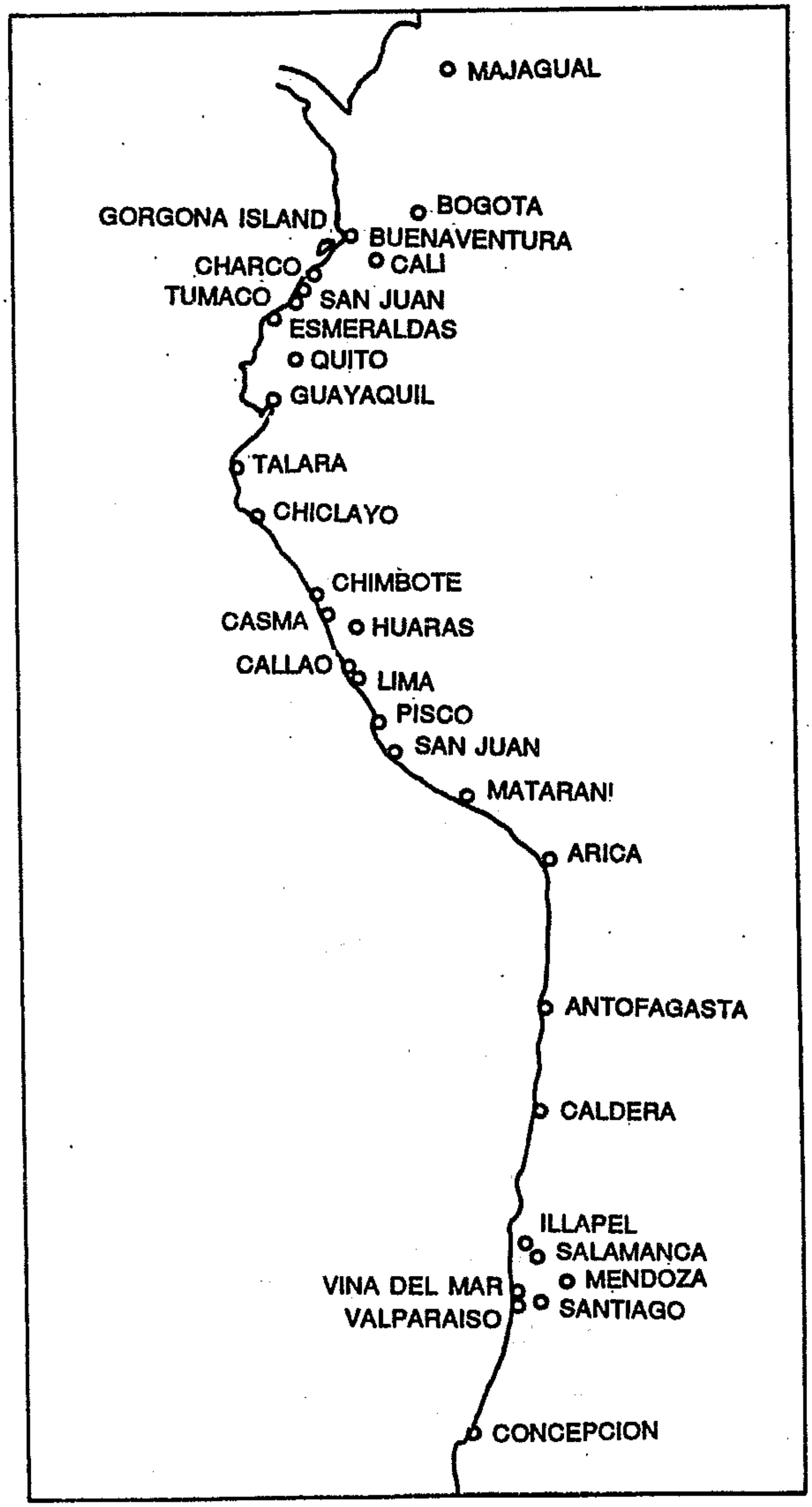
Map V (b). Solomon Islands



Map VI. South America



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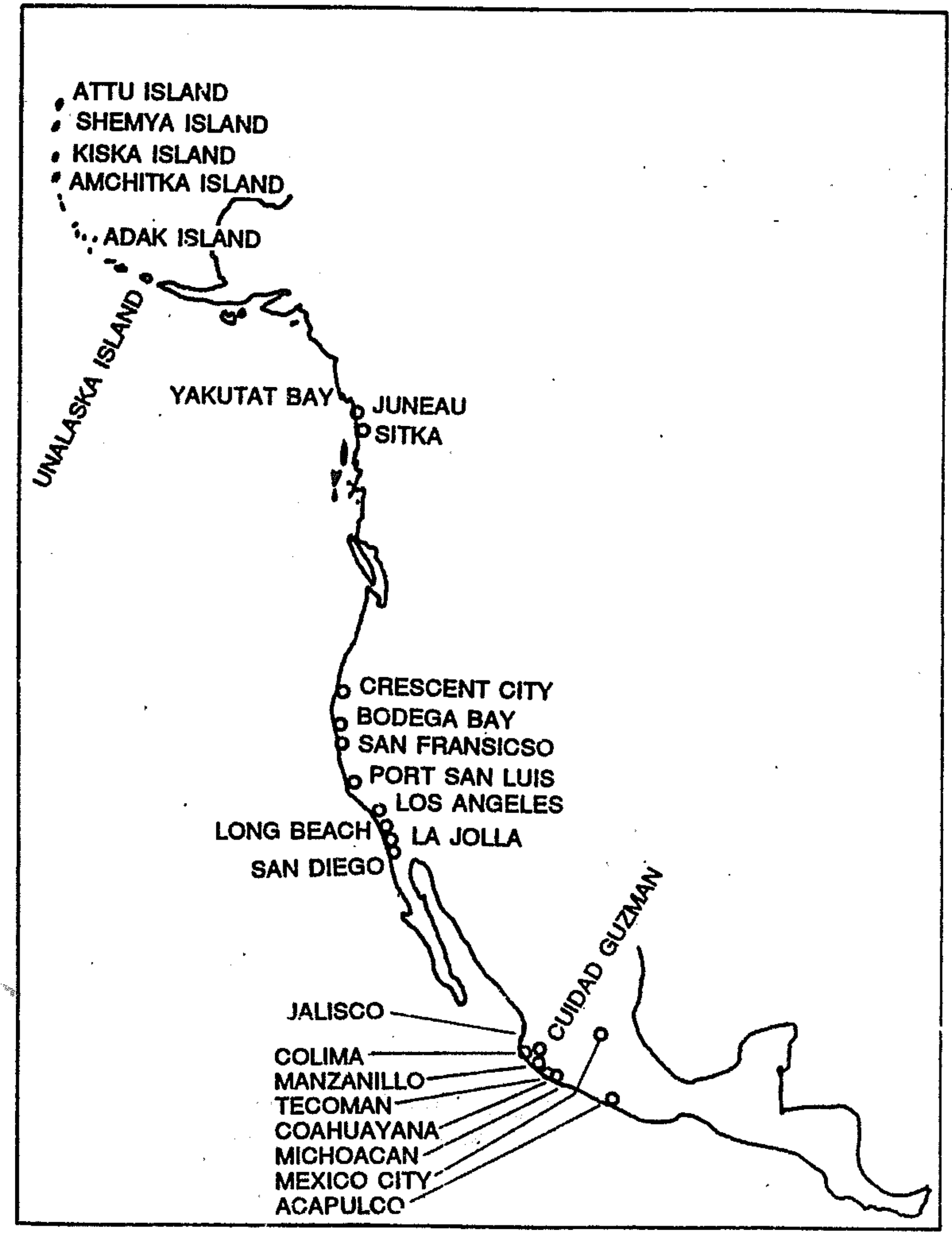
Map VII. North America



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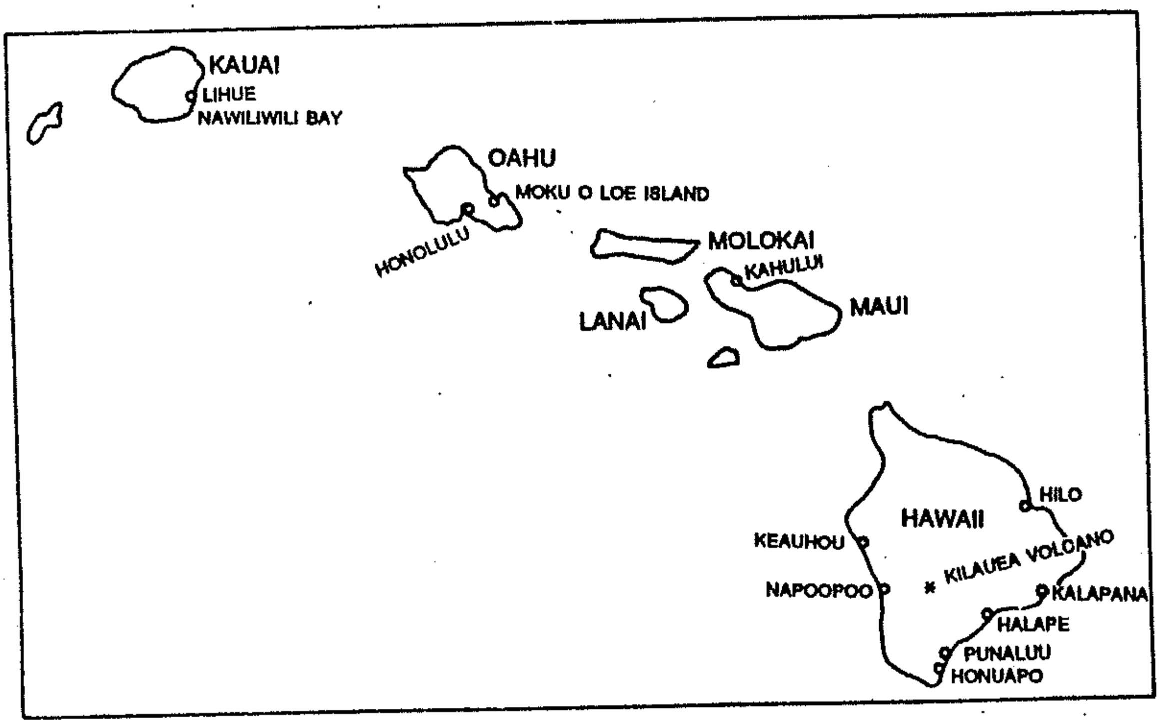
Map VIII. Hawaiian Islands



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ABBREVIATIONS USED IN BIBLIOGRAPHIC CITATIONS

BERI Bulletin of the Earthquake Research Institute, University of Tokyo

EIB Earthquake Information Bulletin

NL Newsletter, International Tsunami Information Center, Honolulu

QJS Quarterly Journal of Seismology, Japan Meteorological Agency, Tokyo

SI Smithsonian Institution, Center for Short-lived Phenomena. Event Notification Reports, Washington

SN Seismological Notes, Bulletin of the Seismological Society of America

TWL Tsunami Warning Log

Zisin Journal of the Seismological Society of Japan, Tokyo

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Каталог цунами в Тихом О
С.Л. Соловьев, Ч.Н.Го, Х.С.Ким
Каталог цунами в Тихом океане 1969–1982 (англ.)

Сдано в набор 13.03.92 В печать 02.04.92
Формат 70x108 1/16 Печать офсетная
Усл. печ. л. 13,0 Усл. кр.-отт. 18,38 Уч.-изд. л. 12,70
Тир. 300 экз. Зак. 1509

Производственно-издательский комбинат ВИНИТИ
140010, Люберцы 10, Московской обл.,
Октябрьский проспект, 403