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SURVEY OF RESEARCH STUDIES AND TECHNOLOGICAL DEVELOPMENT ON THE PROBLEM OF TSUNAMI IN THE USSR IN 1987-1989

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ABSTRACT

Tsunami research studies in the Soviet Union during the period 1987 to 1989 have been reviewed and a comprehensive list of the publications is provided. The following topics are covered: General research organization; Study of individual tsunamis and tsunamigenic earthquakes; Tsunami wave generation mechanisms; Tsunami propagation in the open ocean; Tsunami propagation in offshore areas; Tsunami run-up; Solving tsunami inverse problems; Impact of tsunami on structures; Improvement of the seismic method for short-term tsunami forecasting; Development of hardware for tsunami recording in the open ocean; Search for new methods of short-term tsunami forecasting; Tsunamiregionalization and Publications

1. GENERAL RESEARCH ORGANIZATION

Work involving the study of the phenomenon of tsunami, the development of short- and long-term tsunami prediction methods and the assessment of tsunami effects on structures has been going on in around 20 organizations: research institutes of the USSR Academy of Sciences and of the Ukrainian Soviet Academy of Sciences, universities and other higher educational institutions, organizations subordinated to the State Committee for Hydrometeorology and Environmental Control and to the USSR Ministry of the Power Industry, and others. In most of these, the problem of tsunami has been studied by small teams or even by single researchers. The institutes in which such studies have been carried out at a steady pace, year in year out, by research teams of five or more specialists are:

- the Institute of Marine Geology and Geophysics (IMGG), the Far-East Branch of the USSR Academy of Sciences, Yuzhno-Sakhalinsk;
- the Computing Centre (CCK), the Siberian Branch of the USSR Academy of Sciences, Krasnoyarsk;
- the Computing Centre (CCN), the Siberian Branch of the USSR Academy of Sciences, Novosibirsk;
- the Institute of Applied Physics (IAP), the USSR Academy of Sciences, Gorki;
- the Leningrad Hydrometeorlogical Institute (LHMI);
- the Marine Hydrophysical Institute (MHI), the Ukrainian Soviet Republic's Academy of Sciences, Sevastopol;
- the Institute of Hydromechanics (IH), the Ukrainian Soviet Republic's Academy of Sciences, Kiev.

The Tsunami Commission, established for research coordination in the field in the late 1960s, is now functioning under the State Committee for Science and Technology and under the USSR Academy of Sciences. The head of the commission is Professor S.L. Soloviev. One of the commission's major concerns is the arrangement of annual All-Union conferences for discussing the current progress of research in the field /195/. The 1987 conference was held at Shushenskoe, on the basis of the CCK, in September 1987; the 1988 conference was held at Obninsk, on the basis of the leading technological organization of the State Committee for Hydrometeorology and Environmental Control in September 1988. In 1989 there will be no annual conference because of a series of international events planned to be held in Novosibirsk. Some 60 to 80 specialists attended the conferences, and several reports, whose abstracts were published, were delivered.

Research in the USSR embraces nearly all aspects of the problem of tsunami (as may be seen from the titles of the sections that follow).

2. STUDY OF INDIVIDUAL TSUNAMIS AND TSUNAMIGENIC EARTHQUAKES

A few very weak tsunamis, of distant origins for the most part, were registered on the Soviet Union's Pacific coast in 1987-1989. Some data showing how the 26 May, 1983, Japan Sea tsunami manifested itself on the Maritime Territory (Primorie) coast in the Soviet Far East are presented in /260/. The tsunami varied in height from 0.5 to 9 m, depending on the offshore relief and other factors. The tsunami observed recently in the western Bering Sea - an area where such events are very rare – is examined in /237/. Some conjectures about the seismic processes that might be at work in the origins of the 1958 and 1964 Alaska tsunamis are offered in /107, 109/. A summary of the recorded Mediterranean tsunamis is given in /189, 191/ – in connection with a tsunami hazard assessment and mitigation project now under development for the Afro-European tsunamigenic belt. Two hitherto unknown tsunamis in the western part of the sea have been revealed /190/. Work on a automatic-access tsunami data bank has been started /29, 112/.

3. TSUNAMI WAVE GENERATION MECHANISMS

Most of the studies were concerned with the elaboration of the classic piston-like model of tsunami excitation /52-56, 82, 180, 249-251/. The spatial distribution of bottom deformations were also studied on model-simulated examples /86, 88/. The effects of the ability of a seismic fault to rupture neither instantaneously nor simultaneously were discussed /32, 44/. The evidence that a purely piston-like movement at the origin of a tsunami tends to give rise to a geostrophic whirl has been borne out.

A program of estimating a complete wave field as excited by a buried seismic focus both in the ocean and in the Earth's crust has been detailized at the CCN as part of the work aimed at elaborating G.S. Podyapol'skiy's ideas, with a seismic moment tensor used to simulate a concentrated source /99, 100/. The relationship between tsunami energy and seismic focus depth was investigated in /238/.

On the other hand, a few works were devoted to mathematical analysis of tsunami excitation processes due to submarine volcanic eruptions and submarine landslides /45, 63, 78, 83/. Among the matters discussed were also the "shock" mechanism of tsunami excitation /87/ and wave generation by violent bottom oscillations during sea-quakes /131/. A procedure of estimating the energy of volcanic eruptions by using offshore tsunami parameters has been proposed (at the IAP).

Some contentions concerning the nature of tsunami origin have been spelled out by specialists who joined in the research of the problem just recently /13, 18, 240/ or in general manuals and surveys /264/. The hypothesis that the excitation of tsunami might be a "resonance" mechanism when the periods and speeds of travel of powerful surface seismic waves and those of tsunami waves coincide was borne out through profound mathematical analysis in /181, 243, 244/. The hypothesis, however, can be challenged: surface seismic waves commonly recorded (Rayleigh and Love waves) in fact propagate much faster than tsunami waves and have too small periods. But the question seems not to have been settled, given the recent discovery /11, 12, 242/ that non-stationary seismic modes differing from Love's waves and travelling with a group speed of less than 0.38 km/s might and indeed do develop as long as the Earth's crust has a vertically layered structure. The speed in fact falls slowly as the mode number grows.

In an effort to find more evidence in support of the piston-like mechanism it was shown in /51, 57/ that tsunami waves may also arise when a displaced section of the ocean bottom is recovering its initial undisturbed position. However, the time taken by the ocean bottom to produce a vertical displacement must be higher than a value commensurable to the period of the tsunami, and the parameters of the waves generated in the process differ from those of the waves produced by the residual piston-like displacements of the ocean bottom (a wave other than the first becomes the maximum one, the negative deviations of the level become more pronounced, etc.).

The late professor S.S. Voit and his co-workers were engaged in developing a mathematical model for the formation of tsunami showing a sharp directivity pattern (which is observed very frequently, in fact) because of the initial agitations taking the form of a field of horizontal velocities or horizontal accelerations through a thickness of water /30, 179, 223, 227, 261, 262/. This approach can be associated with a tectonic thrust. The effect of directivity is enhanced by the Coriolis force and certain relief features of the bottom at the origin of tsunami. A share equal to 0.1 to 1% of the elastic energy of a powerful earthquake appears sufficient to produce a noticeable tsunami. When the mechanism of earthquake origin takes the form of a horizontal shift (and also in the case of a landslide), a doubled whirl (instead of a single whirl as in the case of the piston-like mechanism) occurs in the water thickness.

4. TSUNAMI PROPAGATION IN THE OPEN OCEAN

A great deal of work to create algorithms and programs, computer-independent ones as well, for numerical calculation of the kinematics and dynamics of tsunami travel in basins provided with real bathymetry, at short and long ranges, with the Earth's rotation taken account of , using both the method of finite differences and the method of finite elements, has been accomplished at the CCK and some other organizations /1, 4, 40, 68, 72, 96, 101, 102, 110, 116, 118, 124, 164, 185, 206, 207, 246, 247, 253, 258/. As an example to illustrate the work done, mention may be made of the development of an algorithm and a program for simulation of surface wave propagation for the Green-Nagdi nonlinear-dispersion model (stated in its simplest form as it is), even though, as is well known from the numerous previous publications, for the open ocean it has often been enough to make use of the simplest linear equations of long waves /221, 222/. The stability of different estimation schemes was also studied and errors of numerical estimations were considered.

A series of isochrone maps showing the propagation of tsunami across the Pacific Ocean from 25 sites distributed over the ocean's coastlines was compiled at the CCK on a contract with the Intergovernmental Oceanographic Commission, and more research efforts under the terms of the contract are under way /185, 263/.

Some of the questions already discussed in the literature have been re-evaluated, as, for example, the travel of tsunami over a sea-bottom scarp /217, 220/; the refraction, reflection and dispersion of tsunami waves over bottom unevennesses /21, 58, 61, 62, 77, 122, 145, 182, 184, 197/ (incidentally it was demonstrated that, in the long-wave model, it is essentially important to take into account the effects of multiple surface-wave dispersion in a basin with a statistically uneven bottom); the influence of ocean stratification on the vertical distribution of wave energy /18, 31, 197/; the effects of dispersion /146, 147/; fluctuation of environmental parameters /245/; turbulence /124/. It has been estimated that an overall ice cover may reduce the height of tsunami waves by 20% and make them travel less faster, while drifting ice has little effect on the characteristics of long waves /208, 209, 229, 257, 268/.

The steepness and height of solitary waves /65/ and the interaction between ring nonlinear waves /50/ were also estimated.

5. TSUNAMI PROPAGATION IN OFFSHORE AREAS

When a tsunami travels in shallow water, a host of new factors comes into play, as, for example, the shelf takes up some of the energy of the long waves, the configuration of the coastline and features of the offshore relief affect the parameters of the tsunami, nonlinear-dispersion effects become enhanced, etc. Some of these factors have been studied in the past two years /15, 16, 120, 155, 239/.

For example, the propagation of tsunami from shelf-located sources along the coasts of the Kuril Islands and Kamchatka peninsula was simulated by numerical methods at the LHMI /37/. It was shown that the serial number of the peak oscillation in an incipient edge wave depends on the direction in which the tsunami radiates away from its origin as viewed from the point of observation. The Kuril straits are found to reduce the height of tsunami at a distance from its origin by 20 to 30%. That edge waves can indeed interact with one another in a nonlinear way has been demonstrated at the IAP /119/.

A number of new systems of nonlinear-dispersion equations, as well as other equations, have been set out theoretically and tested experimentally in hydraulic basins /5, 7, 14, 59, 60, 64, 81, 84, 134, 135, 165, 234/.

The ways how long gravitational waves can travel over a sloping bottom have been examined by thorough mathematical analysis /46, 48, 49/.

6. TSUNAMI RUN-UP

This most complicated phase of tsunami existence has been a target of intense research in recent years. Two major trends in it can be distinguished.

First, researchers' efforts were focused on the limits to which models ignoring the breaking of waves (an assumption which is statistically valid for wave heights less than 10 m) can be used in describing a wave run-up for different environmental situations, including bays and variable-section canals. Both nonlinear and linear models, as well as the previously deduced breaking parameter Br, were used for this purpose /75, 76, 89, 90, 93-95, 108, 117, 129, 137-142, 166, 248, 254-256/. One of the particular results of this series of research works is the finding that the onset of a tsunami from the lowering of the sea-level leads to an increase in the height of wave run-up and in the speed of shore flooding. On the other hand, one result of an increase in the effect of nonlinearity is that the time of shore flooding begins to exceed considerably the time of backwash.

Second, numerical methods of run-up estimation applicable to more powerful waves, for which the dissipation of energy plays a significant part, especially in the boundary bottom layers have been developed extensively /225, 267 and others/. But for the dissipative models of tsunami run-up an analytical model has also been suggested, which shows that the dependence of the height of wave run-up on the wave-length is non-monotonous /8, 141/.

Some different schemes of numerical estimation were proposed at four organizations, and after their joint verification in a number of tests, appropriate corrections were put in the schemes.

A comparison of run-up numerical simulation with hydraulic experiments is presented in /121/.

7. SOLVING TSUNAMI INVERSE PROBLEMS

Attempts at reconstructing processes at work at a tsunami source by using shore-based observation data collected by various methods were discussed in /76, 106, 193, 194, 213, 214/.

8. IMPACT OF TSUNAMI ON STRUCTURES

Numerous studies on this subject have been carried out.

The pattern of dynamic pressure on underwater vertical obstacles formed as solids of revolution and the process of washout at the base of obstacles were studied both theoretically and experimentally in large-size trial basins /41, 42, 47, 172, 230-232/. These studies were staged because of the urgency of providing safety for offshore gas and oil drilling platforms under development.

The pattern of dynamic pressure on vertical walls and the impact of tsunami on protection structures (break-waters), and the reaction of a port's water area to the attack of tsunami were also among the matters investigated /3, 6, 17, 67, 91, 92, 97, 130, 133, 148-150, 152-154, 174/.

The results of wide-ranging analytical and numerical studies and basin-based experiments have supplied sufficient material to prepare draft recommendations for construction engineers in tsunami-hazardous areas, to be used later as part of state regulations /43/.

The transport by tsunami waves of bottom sediments and the formation of certain bottom relief features as a result of tsunami passage were also examined, though on a smaller scale /143, 144/.

9. IMPROVEMENT OF THE SEISMIC METHOD FOR SHORT-TERM TSUNAMI FORECASTING

First, studying the efficiency of a new, magnitude-independent indicator of tsunamigenic earthquakes - the duration of amplitude build-up in P waves from start to maximum (the "tau" parameter) was continued, along with some other new relevant indicators /192, 236/.

Second, efforts to develop algorithms and to debug programs for automatic real-time processing of seismograms (determining the time of arrival of P and S waves and wave amplitudes, estimating the epicentre and magnitude of earthquake) were carried on at the IMGG and other organizations /177, 203-205/. These efforts were linked with the attempts to create the United Automized System for tsunami detection in the ocean and population warning (UATS).

As a contribution to the planned new system, the CCN workers designed, on the basis of new methods, some optimum sets of seismic stations which they thought would be useful as part of the UATS for the purpose of determining earthquake hypocentres in the Kuril-Kamchatka area with the lowest possible errors. They have compiled programs for determining the major parameters of earthquake foci in the Kuril-Kamchatka area, on the base of observation data from a network of seismic stations.

That the international seismic code ISC-85 should be used in the operation of seismic stations employed in tsunami warning service was suggested in /39, 216/.

A revision of the threshold values of earthquake magnitude as the levels for tsunami alert signalling was attempted in /228/.

10. DEVELOPMENT OF HARDWARE FOR TSUNAMI RECORDING IN THE OPEN OCEAN

The seismic method (based on earthquake magnitude), used in all present-day tsunami warning services (in Japan, the USA and USSR) is, in effect, a statistical method, leading to a considerable number of false alarms and sometimes to failures to predict an actual tsunami. Back in the 1960s, there were suggestions that tsunamis should be recorded directly at sea. In the USSR, tsunami short-term forecasting came to be termed "the hydrophysical method" /188/.

The hydrophysical method, when used in the Soviet tsunami warning service, in fact formed the backbone of the UATS project, along with the automation of the seismic method /9, 10, 66, 157, 158/.

There were two principal research approaches to dealing with this problem.

At the IMGG, experiments involving the temporary installation of vibrotron and crystal hydrostatic pressure transducers connected with the shore by cable were continued, carrying on the tradition established back in the mid-1960s /34, 35, 125, 126/. In 1987-1989, such experiments were also staged in the south-western and western shelves of the Kamchatka peninsula to ascertain the nature of background oscillations based on open ocean observations in the tsunami period range; in the area of the city of Ust-Kamchatsk in connection with a large scale tsunamiregionalization of the city; and also in Sakhalin Island. The first series of observations at four stations erected in shallow water (depth 7 to 17 m) which were in operation for nearly two years gave an unexpected finding: long-wave background oscillations are stimulated mostly by a nonlinear transformation of the energy of short wind waves, especially during sea storms /127, 128, 132/.

At the State Committee for Hydrometeorology and Environmental Control, a large series of works aimed a developing and testing systems for conveying the readings of bottom pressure transducers to the shore by means of radio relaying buoys was accomplished /28, 79, 80, 113-115, 156, 178, 183, 198, 199, 201, 202/. A host of technical problems such as the problem of designing a power supply unit of sufficient capacity to keep the buoys operating continuously for a long time, had to be dealt with

/163, 200, 224/. The outcome was the conclusion that small-size buoys are not good enough for tsunami warning service, especially in the complicated hydrometeorlogical and ice conditions of the north-western Pacific (which is in agreement with the international findings).

This prompted some authors to suggest that pop-up bottom stations should be used in the tsunami warning service /196, 212/ or that deep-water bottom stations fitted with low-consumption microprocessors capable of transmitting information instantly on the passage of a tsunami to the shore by means of bottom hydroacoustic relaying devices could be used /210, 211, 265, 266/.

Work was also under way at the IMGG to design and apply in practice self-contained bottom tsunami recorders. On the institute's orders, some organizations put to trial their new models of hydrostatic pressure transducers, for example, an electromechanical resonator with a silicon sensitive element.

Considerable attention was also paid to the optimum arrangement of bottom hydrophysical stations /160-162, 167-169/ and the development of algorithms to be used to identify the moment of the onset of a tsunami on bottom-station records by using micro-computers /73, 74, 170, 173/.

A detailed list of algorithms and programs that were up to now proposed for use in the UATS seismic and hydrophysical subsystems can be found in the small monograph /171/.

11. SEARCH FOR NEW METHODS OF SHORT-TERM TSUNAMI FORECASTING

Attempts have been made to see whether magnetic-field agitations produced by approaching tsunami waves could be used as tsunami precursors /19, 20/.

Methods for simultaneous calculation of tsunami and hydroacoustic waves were developed at the CCN in an effort to search for correlations between waves of these types.

On the IMGG's orders, a selection of photographs taken by satellites showing the moments of the origin of a sufficiently powerful earthquake in the Kuril Islands was carried out to make sure whether the previous contention that the origin areas of violent earthquakes could be detected from cavitation effects on the water surface was valid. The possibility of using surface radio location from shore-based stations operating in super-low frequencies of the order of 1 kHz was also discussed.

12. TSUNAMIREGIONALIZATION

Work was continued on developing a procedure for assessing long-term tsunami hazards for the Pacific coasts of Kamchatka and the Kuril Islands and some other Pacific areas /33, 85, 111, 166, 187, 226, 252, 259/. The procedure is based on a numerical simulation of tsunami travel from origin to coast and on the relationship of calculation results to the available fragmentary evidence on previous actual tsunamis.

13. PUBLICATIONS

Around 270 publications on the problem of tsunami have come out in the USSR over the past two-and-a-half years. A list of these publication (probably far from being complete) is enclosed. It contains, for the most part, the abstracts of the reports delivered at the All-Union tsunami conferences in 1987 (CMT) and in 1988 (TMT) and at other scientific meetings (CSO, PHEO), including even those of the CMT and TMT reports which are not concerned directly with the problem of tsunami (marked with an asterisk).

In preparing the list of publications the author received much help from N.P. Konstantinova (IMGG).

ABBREVIATIONS

AISTI – All-Union Institute of Scientific and Technical Information

BHPS – buoy hydrophysical subsystem of the UATS

CMT – All-Union Conference on Numerical Methods in Tsunami Problem, September 1987, Shushenskoe, Abstracts, Krasnoyarsk, 1987, 136 p.

E – English

Ea – English abstract

EGS – European Geophysical Society

IT – Issledovaniya Tsunami (Investigations of Tsunami)

MG – Meteorologiya i Gidrologiya (Meteorology and Hydrology)

OWL - Collected Papers "Oscillations and Waves in Liquid", Gorki, 1988, 118 p.

PhAO Fizika Atmosfery i Okeana (Physics of the Atmosphere and Ocean)

PhE - Fizika Zemli (Physics of the Earth)

R - Russian

SRISTI - Scientific Research Institute of Scientific and Technical Information

TMT - Conference "Theoretical Foundations, Methods and Instrumental Means of Tsunami Forecasting", Abstracts of reports, Obninsk, 1988, 172 p.

UATS (IATS) -United Automized System for Tsunami Prediction

VS - Vulkanologiya i Seismologiya (Vulcanology and Seismology)

CSO - The 3rd Congress of Soviet Oceanologists. Abstracts of reports. Section "Physics and Chemistry of the Ocean", Leningrad, Gidrometeoizdat, 1987, 184 p.

PHEO - Abstracts of reports, Conference "Problems of hydromechanics in exploration of ocean", Kiev, 1987.

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SANAK-KODIAK TSUNAMI OF 1788[1]

S.L. Soloviev

In the years 1799-1867 Russian territories in North America, Kuril Islands and Aleutian Islands were governed by the Russian-American Company. Documents related to the establishment and activities of the company were mostly lost, but some sheets survived in National archives. Examination of these documents during compilation of "Summary of Data on Tsunamis in the USSR" (Soliviev and Ferchev, 1961) disclosed an unpublished and apparently previous unknown description of the 1788 tsunami in the Aleutian Islands.

This new description substantially contributes to the existing seismological literature about this tsunami and the earthquake preceding it. It also moves the boundary of the source further to the east, and by doing this, helps to define the extent of this natural phenomena more confidently.

Information about the 1788 tsunami was published earlier in some Russian and American catalogues (Mushketov and Orlov, 1893; Heck, 1947).

The original source of Mushketov and Orlov catalogues was a monograph by the Russian missionary I. Veniaminov who lived on the Aleutian Islands from 1824 to 1839, and who described details from the Islands of Four Mountains (in the Aleutian Islands west of Umnak I.) to the western part of the Alaska Peninsula (Veniaminov, 1840). In comparing catalogs it is apparent that Mushketov and Orlov adopted almost all of their material for the 1788 tsunami from Veniaminov.

A fuller summary of Veniaminov's monograph follows below (positions of mentioned islands are shown on Fig. 1). "... In one of the notes I have seen, it was told that on July 11, 1788[2] . . . on Unga Island, there was an earthquake so strong that one could not stand on his feet. Many mountains crumbled, and after this event during some time there was a terrible flood" (Veniaminov, op. cit. Chapter I, page 30).

[1]Translated by Peter Ostapiuk for WDC-A from "The tsunami problem, questions about the formation and spreading of disastrous seawaves caused by earthquakes and their prediction", USSR Academy of Science, Moscow, 1967, pp 232-237.

[2]All dates here are Julian dates uncorrected for the International Date Line convention now in use. These are converted to the Gregorian Calendar by adding 10 days rather than 11 days which would be applied to dates from Kamchatka to make them compatible with Gregorian dates from the West Coast of North America.

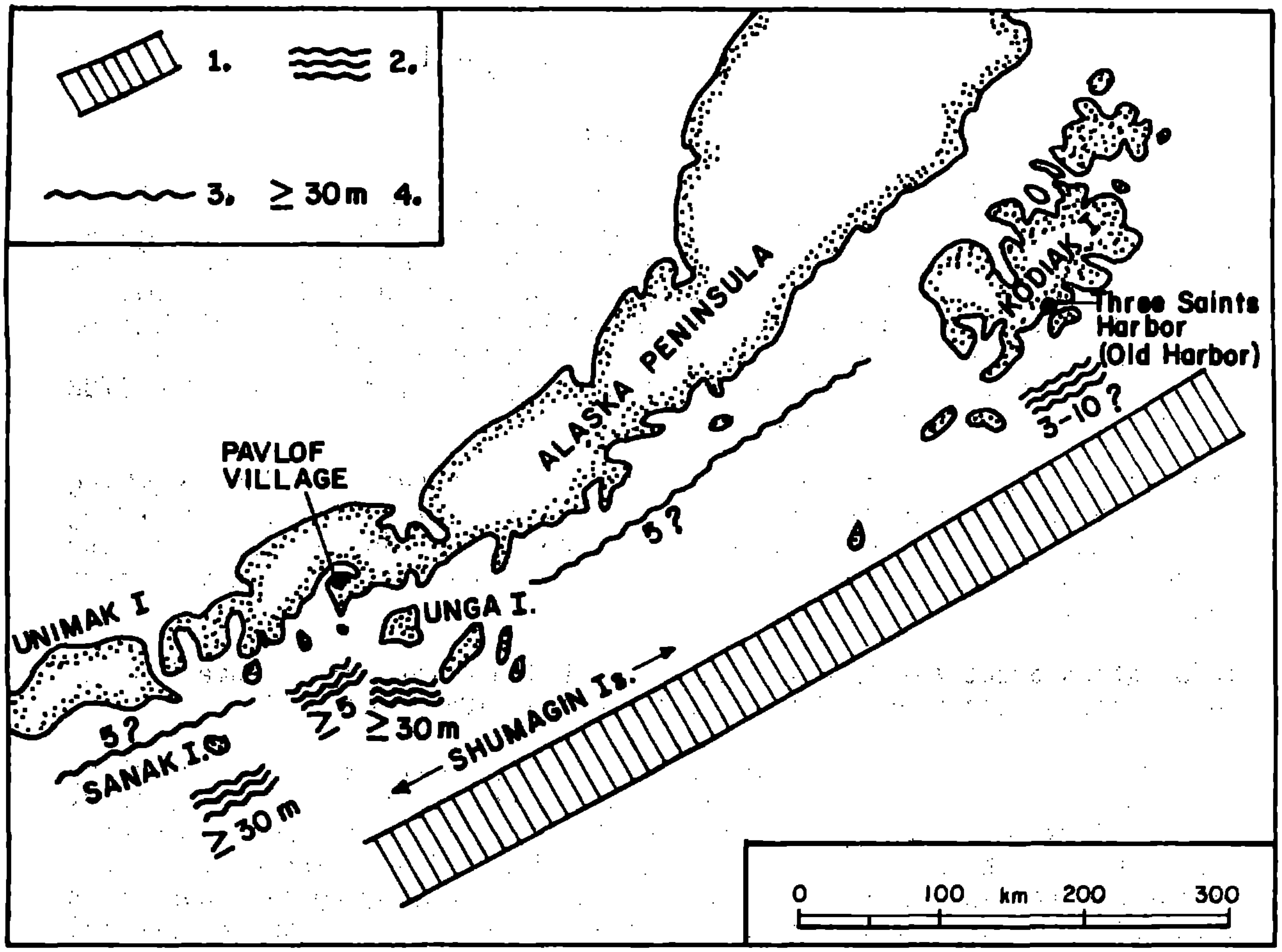

Fig. 1 Source of Earthquake and Tsunami of 1788

1. Presumed location of earthquake rupture zone; 2. doubtless places where tsunami was observed; 3. possible places where occurrences of tsunami was observed; 4. approximate heights of tsunami in meters.

" . . . Legends of the Aleuts say that during the flood on Sanak Island, in about 1790 there were strong but infrequent waves. In addition to this I have seen a note in one of the church books in an old handwriting in which it was told, that on 'July 27, 1788 there was a terrible flood on Unga Island from which many Aleuts died but the Russians were saved by God' and old men say that (this time and later) the water level rose up to 50 sazhens (117 m; a sazhen = 233.6 cm) (Veniaminov, op. cit. Chapter I, page 27).

"The flood which occurred on Sanak Island about 1788 was here too (in the village of Pavlof) but on a much smaller scale" (Veniaminov, op., cit., Chapter I, page 242).

"The deluge or flood which occurred on Unga Island and on the south side of the Alaska Peninsula in 1788 did not have any effect on the north side of Unimak Island" (Veniaminov, op. cit., Chapter I, page 217).

Apart from these descriptions, directly related to the 1788 tsunami, Veniaminov reports a number of indications of recent sharp rising of the land on the southern side of the Alaska Peninsula and on the islands adjoining it in the chapter describing floods on the Aleutian Islands, or what is more probable, indications of recent catastrophic floods in these places probably due to the 1788 tsunami. "In many places, which have long been above the reach of the sea and quite high, there were trees and roots thrown there by the sea, including some which were already rotten, and some still quite strong firm and fresh. The debris seems to be dispersed everywhere to the same height above sea level which is believed to be from 2.5 to 3 sazhens (5.8 to 7 m). On Unga Island on the hill higher than 30 sazhens (70 m), there is a huge tree with roots already turned to stone.

"On many spits consisting of small rocks and sand and on isthmuses, one can notice wave-like mounds or hillocks parallel to the shore, already covered by layers of soil of various thicknesses. The highest of these spits and isthmuses are almost identical and amount to 2 to 3 sazhens (4.7 - 7 m)" (Veniaminov, op. cit., Chapter 1, p. 26-27).

In Heck's catalogue information about the 1788 tsunami was taken from the monograph by Dall (Dall, 1897) and Holden's catalog (Holden, 1898) who took this information from Plummer's catalogue (Plummer, 1896). The original sources which were used by Dall and Plummer can not be traced. In Dall's vast bibliography (about 180 entries, including Veniaminov's work) references in the text are absent and in Plummer's catalogue there is no bibliography at all.

From the list of American works, the most detailed seems to be Dall's monograph where the following is given about the 1788 tsunami:

"In 1788 an earthquake caused a flood wave which moved from the Alaskan peninsula to Sanak Island and caused a big flood on Unga Island from which many natives died". (Dall, 1898; p. 310).

"The 1788 earthquake accompanied by flood wave occurred at Shumagin Island. On the 27th of July, water flooded Sanak Island (the wave at the mentioned part of the island reaches as high as 50 meters), all pigs transported to this island were drowned. From there the flood spread toward the Alaska Peninsula" (Dall, op. cit., p. 467).

The first text, without doubt, seems to be simply a retelling of Veniaminov's story; the second, because of the construction and some details, differs from the first text. This suggests that Dall used some other original sources about the 1788 tsunami. However, this original source, as far as we can judge from Dall's report, does not include any information significantly different from Veniaminov's information.

Now we will pass to the newly found description of the 1788 tsunami. This description is a part of the letter to the distinguished sailor and public figure at the end of the 18th century, one of the discoverers of the Aleutian Islands and founder of the Russian-American Company: G. I. Shelekhov. The letter was written on May 2, 1789 and sent to Shelekhov from Kodiak Island by Vasili Merkuliev.

Listing several reasons why merchandise belonging to Shelekhov was lost or damaged, Merkuliev tells about the earthquake and tsunami with minor editorial changes given below as follows:

"... in 1788 on July 11th, here on Kodiak Island we had a big earthquake and some thought that the earth would collapse. The earthquake was so strong that one could not stand on his feet. We did not have time to recover from this earthquake when a flood came from the sea. We had a deluge in our harbor, and at that time every man was looking for a safe place to save his life. The flood did a lot of damage. First, my barabora (a half sunken hut) was flooded and the merchandise was carried away as were other small structures and the palisade. In your garden all of the soil and vegetation were washed entirely away and at this place water brought in gravel and dug holes in the ground. The raise of the level of water was almost up to the windows in your room. However, the flood lasted only for a very short time, there were two large waves and the rest of them were minor. After this the earth was shaking every day for a month or longer. It was shaking two or three times a day and even more often. Since the time of the earthquake, our place near the harbor subsided". (Archives of the Foreign Affairs of Russia F 339, OP #888, D #774, L #4).

The harbor which is mentioned in the letter seems to be the former "Three Saints Harbor" (now called Old Harbor) because a Russian village was established here during the first visit of Shelekhov to Kodiak Island in 1784-86.

With parallel analysis of all of the known texts it is clear that there are two dates for 1788 tsunamis: 11th and 27th of July. Therefore it can be presumed in connection with this that there were two different tsunamis. The first was connected with the earthquake of July 11 emphazing an extremely vast part of shore with relatively small intensity of waves. The second tsunami we can suppose was connected with a strong aftershock of July 27 and which had a smaller range of effects (Unga Island and Sanak Island), but a much stronger intensity. (Combinations of tsunamis following one after another after more or less small intervals occurred also in the 20th Century. For example, in 1923 near the shores of Kamchatka (Soloviev and Ferchev, 1961) and in 1963 at Urup Island (Soloviev, 1965), both had dual tsunamis).

In contrast one can also presume that the second date is a false one. This kind of mistake happens quite often in seismological literature. However, even if the second tsunami happened it is almost certain that it did not affect Kodiak Island.

The following argument can be used to affirm this hypothesis. On April 30, 1788 the ship Three Saints, under command of Izmailov and Bocharov left Kodiak Island and sailed east. The ship sailed along the shores of North America to Lituya Bay and on July 9th sailed back toward Kodiak. On July 13th it approached the island and on 15th safely sailed into Three Saints Harbor. In the ship's journal there is not a word about a tsunami. It should be this way if the tsunami occurred on July 11, as it is known that a tsunami is not noticeable in the open sea. On the other hand, if a castrophic tsunami had occurred right after the ship sailed into the harbor (July 16 or 27) this would have been noted in the trip journal.

Now we will draw a conclusion from what was presented above. In 1788 a catastrophic earthquake occurred to the south of the Alaska peninsula. Earthquakes of exceptionally high intensity give evidence of a large extent of the rupture zone (from Unga Island to Kodiak Island, a distance of 500 km); of high intensity on the shores ("one could not stand on his feet"); and of large numbers of aftershocks. On the basis of this indirect evidence one can presume that the magnitude of the earthquake was not less than eight. The earthquake was accompanied by a catastrophic tsunami with an average height of 5 meters, extending over 700 kilometers. This tsunami, or one of the tsunamis which was caused by one of the earthquake's aftershocks, caused run-ups on Unga and Sanak Islands of several tens of meters in height.

The source of the 1788 tsunami is located between the sources of other known tsunamis with similar intensity, like the April 1, 1946 tsunami on Aleutian Islands and the March 28, 1964 tsunami on the Alaska peninsula. The two above-mentioned tsunamis caused damage on the Hawaiian Islands. It is possible that the 1788 tsunami also caused damage in the Hawaiian Islands, (however there was no written history of the Islands at that time). Without a doubt the 1788 tsunami was one of the strongest catastrophic tsunamis in the history of the world.

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DATA FOR INVESTIGATING TSUNAMI ACTIVITY IN THE MEDITERRANEAN SEA

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ABSTRACT

The Mediterranean sea has always been the place where major events of culture and civilization have occurred. Some of the greatest ancient civilizations flourished by the coasts of the Mediterranean sea. Thus, any phenomena that could affect and alter the natural status are worthy to be investigated throughly or, at least, to be recorded for future analysis. Tsunamis (seismic sea waves induced by earthquakes, sudden submarine landslides, or submarine volcanic activity) are such events.

This paper has a dual purpose. First to supply, in the form of a catalogue, information about the tsunamis that occurred in the Mediterranean sea from about 1800 AD until today. And secondly, to indicate the places where tsunamis are most frequent and most intense. This will show a high risk zone where tsunamis are likely to occur again.

Many research papers about tsunamis in the Mediterranean sea have been published; however they are of local extent. The author hopes to introduce a total picture of the continuous tsunami activity in the greater area of the Mediterranean Sea based on all the available data.

The recognized zones of great tsunami activity are identified and related to the earthquake activity zones. They must be constantly observed and investigated in order to supply enough and accurate data for designing sea constructions and scheduling sea related activities.

INTRODUCTION

Tsunamis are seismic sea waves usually occurring after an earthquake with its epicenter beneath the sea. Sometimes tsunamis have been associated with earthquakes with epicenters in the mainland, but the tsunami was generated by a submarine landslide. The tsunamis caused by earthquakes can be distributed into three categories; Longitudinal waves, shear waves, and surface waves. The width of the shear waves are bigger than the other ones and are far more destructive. In the open sea, tsunamis are not destructive but when they attack coastal areas and especially closed bays, they may be catastrophic. The Mediterranean Sea, when compared to the oceans, could be considered a big closed bay. Thus tsunamis generated in this area may cause heavy damage to the coastal areas.

Research about tsunamis in the Mediterranean Sea proves that they are not as dangerous as the ones in the Pacific Ocean. However, some tsunamis in the Mediterranean sea have caused great destruction. As a result, further investigation of the tsunamis in the Mediterranean Sea is necessary. Estimating high risk zones is always useful in designing future developments.

In order to reach a sound conclusion, data from 1800 AD until today were chosen. This was done because for this period the international bibliography contains almost all the events, details about the events and even instrumental recordings for some of the events. Thus the data are suitable for further processing and evaluation.

The correlation of the gathered information about the tsunamis that occurred in the Mediterranean Sea was extremely difficult because of the various languages and notations. Most pieces of information were verified by at least two different sources. The sources that have been used are archives, scientific journals, press reports, historical accounts and relevant studies.

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THE CATALOGUE

Dates in the catalogue are given according to the new calendar (Gregorian). It has been constructed in such an order as to introduce clearly the basic characteristics of the event and its cause, where evidence were available and verified by a credit worthy source. The catalogue is arranged in four columns in the following manner. The first column contains the dates of the event. The second one contains the tsunami data including the area of origin, and characteristics of the tsunami. The third column contains data about the earthquake that probably generated the tsunami. Where the focal depth is given by a number and not by the letters s, n, i, this value is in kilometers. The fourth column indicates the references from which the information was obtained.

The letters used are (m) = intensity of the tsunami in small roman letters according to Sieberg's modified scale, (H) = height in meters and (L) = length in meters of the tsunami. (M) = magnitude of the earthquake on the Gutenberg scale, (I) = intensity of the earthquake in the modified Mercalli scale, (r) = focal depth where s = shallow, n = normal, i = intermediate.

CONCLUSIONS

The catalogue shows that the tsunami activity in the Mediterranean Sea is of such an extent that it can not be ignored. The areas where repeated tsunamis are occurring are not irrelevant to the tectonic structure of the Mediterranean basin. Two major conjugated fault systems are dominating the Mediterranean sea and presumably are responsible for the earthquakes which are causing the tsunamis.

There is a high tsunami activity zone which extends from the Ionian islands in west Greece to the coast of Crete and the Rhodus islands. Another zone starts from the northern coasts of the Adriatic sea and ends at the Ionian islands, including the east and the west coasts of the Adriatic sea. A third zone includes the coastal area of Israel and Syria, while a fourth one starts at Marseilles, passes along the west Italian coast and ends at the north coast of Sicily. In the west part of the Mediterranean Sea, the tsunami events are very few and indicate a low risk zone. The seismic activity in the Mediterranean Sea is shown in Figure 1. A qualitative conclusion about the geographic distribution of the tsunami risk in the Mediterranean Sea is show in figure 2, where the zones drawn indicate areas with almost constant seismic and tsunami activity. In order to eliminate the disastrous effects of tsunamis in these areas, harbor protection is compulsory and protective structures must be made. The author claims that further investigation and collection of more instrumental recordings of tsunamis is necessary to obtain a more accurate estimation of the expected areas for future tsunami activity.

No	DATE	TSUNAMI DATA				EARTHQUAKE DATA				REFERENCES
		Area of origin observation place of	m	H	L	M	I	s,n,i r	Latitude Longitude	
1	1802 January 4	Adriatic Sea. Fiume.	iii							1,2,3
2	1804 June 8	Northwest coasts of Peloponnesus. Patras	iii				IX	n	38°1/4N-21°3/4E	1,2,3,7,22,26
3	1804 July 31	Gulf of Napoli (Terra of Greco and Annunziata)								9,4,5,33
4	1805 July 25-26	Costa campana (da Ponza a sorrento)					8		41.25-14.30	9,4,32,29,32
5	1806 July 26	Costa Laziale (de Ardea a Terracina, colli Albans)					3		41.45-12.45	9,4,10,32,29,34
6	1808 April 2	Costa ligure-port of Marseilles					9		44.50-7.12	9,4,10,29,32
7	1809 July 3	Costa Ligure di levante. La Spezia, Lisbon, Napoli.	?				5			9,32,36,34,46
8	1809 July 27	Napoli, near Lisbon.								9,32
9	1812 June 28	Port of Marseilles								9,32,36
10	1813 April 7	Adriatic Sea. Ançona.					5		43.40-13.40	9,4,10,32
11	1813 May 17 and June 20	Gulf of Napoli (Terra of Greco and Resina)								9,4,10,32
12	1816 November 12 and 17	Gulf of Genova								9,
13	1817 January 14	Coast of Sicily. Sciacca.					7		37.30-13.00	9,4,10,32,46,34
14	1817 August 23	Gulf of Corinth. Aigion	iii				X	n	38°1/4N-22°1/4E	1,2,3,20,23
15	1818* January	Athens. Mallet mistakes the event before mentioned								1,2,3

No	DATE	TSUNAMI DATA Area of origin observation place of	m	H	L	EARTHQUAKE DATA M	I	s,n,i r	Latitude Longitude	REFERENCES
16	1818 February 20	Coast of Sicily. Catania, Calabria, Malta.					10		37.35-15.05	9,4,10,32,29,46
17	1818 February 23	Costa ligure occidentale (Savona-Nizza.)								9,4,10,32,36, 29,46
18	1818 December 9	Port of Genova								9,4,20,32,36,29
19	1819 January 8	Gulf of Genova.					7		43.45-18.00	9,4,10,12,36,32
20	1819 March 3	Gulf of Genova.								9,29,36
21	1820 July 23	Gulf of Genova.								9,
22	1821 January 6	Gulf of Corinth. Alcyonic Sea	iv				X	n	37°3/4N-21°1/4E	1,2,3,16,26,31
23	1822 March 20	Near Marsala in Sicily								9,
24	1822 April 10	Coasts of Sicily. Catania, Nicosia.					7		37.45-14.25	9,4,10,32,31, 46,29
25	1823 August 20	Dalmatian coasts. Dubrovnik	iv-							1,2,3
26	1823 March 20	Coasts of Sicily. Cefalu, Palermo.					10		38.15-14.45	9,4,10,32,29
27	1824	Gulf of Napoli								9,
28	1825 January 19	Ionian Islands. Leukas, between the islet of Sessoula and east coasts of the island	iii				XI	n	38°3/4N-20°3/4E	1,2,3
29	1826 March 19	Adriatic coasts of Italy. Pesaro, Sinigallia.					3		43.50-13.00	9,4,10,32
30	1828 July 20	Gulf of Genova.								9,36
31	1828 October 9	Gulf of Genova.					8		44.50-9.10	9,4,10,32,35 29,46
32	1829 May 23	Constantinople	ii							1,2,3,15
33	1831 May 26	Costa ligure di ponente. Ventimiglia-Porto Maurizio.					9		43.50-7.50	9,4,10,32,36,29

No	DATE	TSUNAMI DATA				EARTHQUAKE DATA				REFERENCES
		Area of origin observation place of	m	H	L	M	I	s,n,i r	Latitude Longitude	
34	1831 July 2	Coasts of Sicily. Sciacca							37.05-12.30	9,4,10,32,31, 29,46
35	1832 March 8	Coasts of Calabria. Crotone					10		39.00-17.00	9,4,10,37,34,29
36	1833 January 19	Albanian coasts. Valona and Saseno Isle	iv-							1,2,3
37	1835 July 12	Ionian Islands. Zante	ii							1,2,3,7
38	1836 April 24	Coasts of Calabria. Rossano					9		39.40-16.45	9,4,6,10,32, 29,46,34
39	1837 January 1	Syrian and Israeli coasts of Tiberias	iv							1,2,3
40	1838 August 10	Dalmatic coasts. Trieste, Fiume.								9,32,29
41	1843 September 14	Dalmatia. Dubrovnik, Gruz (Gravosa)	iv							1,2,3
42	1844 March 3	Dalmatia. Dubrovnik	iii							1,2,3
43	1844 March 23	Dalmatia. Dubrovnik	ii							1,2,3
44	1845 June 18	Coasts of Sicily. Messina							36.4-13.44	9,37
45	1845 August 16	Dalmatia. Dubrovnik, Gruz	iii							1,2,3
46	1846 August 14	Costa tirrenica toscana. Pisa, Livorno.					10		43.30-10.30	9,4,6,10,29 46,43
47	1846 August 26	Coasts of Napoli								9,46,34
48	1846 October	Livorno								9,43
49	1846 December 3	Costa Tirreniche. Livorno, Marseilles					5		43.20-10.45	9,4,10,46
50	1847 August 26	Gulf of Napoli								9,40
51	1850 April May and October	Coasts of Toscana. Livorno								9,34

No	DATE	TSUNAMI DATA Area of origin observation place of	m	H	L	EARTHQUAKE DATA M	I	s,n,i r	Latitude Longitude	REFERENCES
52	1851 February 28	Asia Minor. Fetiye	iii	0,60			IX	n	36°1/2N-28°3/4E	1,2,3
53	1851 April 3	Asia Minor, Fetiye	iii	1,80						1,2,3
54	1851 May 23	Khalki Isle, Rhodes	ii							1,2,3
55	1851 October 12	Albanian, coasts, Valona	iii	0,60						1,2,3
56	1851 December 16	Coasts of Toscana. Livorno								9,34
57	1852 February, June and November	Coasts of Toscana. Livorno								9,34
58	1852 May 12	Asia Minor, Smyrna	iii							1,2,3
59	1852 September 8	Asia Minor, Smyrna	iii							1,2,3
60	1853 April 8	Gulf of Salerno								9,34,40
61	1853 August 18	Euboean Gulf	iii+				IX	n	38°1/4N-23°1/2E	1,2,3
62	1854 December 29	Gulf of Genova and coste nizzarde.					8		43.45-7.50	9,4,10,36,29,35
63	1855 February 13	Gulf of Genova.								9,36,29
64	1855 February 13	Asia Minor, Fetiye	iii							1,2,3
65	1856 August 21-22	Coasts of Sardinia. Algeria, Nice, Malta, Mahon, (Ballaries), Carloforte, Iglesias and San Petro Sardinia.								9,4,36.29
66	1856 November 13	Easter Sporades. Chios	iii+				IX	n	38°1/4N-26°1/4E	1,2.3,19
67	1859* October 20	Piraeus. Most probably a strong seiche.	ii-							1,2,3
68	1861 December26	Corinth Culf Northeast coasts South coasts	iv	2,10			XI	n	38°1/4N-22°1/4E	1,2,3,20,23
69	1862 November 24	Gulf of Genova and costa nizzarda								9,36
70	1866 January 2	Albanian coasts. Valona, Himara	iv							1,2,3

No	DATE	TSUNAMI DATA				EARTHQUAKE DATA				REFERENCES
		Area of origin observation place of	m	H	L	M	I	s,n,i r	Latitude Longitude	
71	1866 January 6	Albanian coasts. Valona, Narta	iii							1,2,3
72	1866 February 2	Eastern Sporades, Chios	iii				VIII	n	38°1/4N-26°1/4E	1,2,3
73	1866 February 6	South coasts of Peloponnesus. Island of Kythera	iv	7,18			VIII	n	36°N-23°E	1,2,3,20,22,23
74	1866 March 3	Albanian coasts. Valona	iii							1,2,3
75	1866 March 6	Albanian coasts. Himara, Kanina	iv							1,2,3
76	1866 March 13	Albanian coasts. Himara. Kanina	iii							1,2,3
77	1867 September 20	South coasts of Peloponnesus, Gythion, Crete, Herakleion, Ionian, Islands, Syros, Southeast coasts of Italy, Catania.	iv				IX	n	36°1/2N-22°1/4E	1,2,3,20,23
78	1869 December 28	Albanian coasts. Valona	iii				XI	n	38°3/4N-20°3/4E	1,2,3,18
79	1870 June 24	Alexandria. Italian coasts.	iii							1,2,3
80	1870 October and November	Ionian Sea								9,34
81	1871 January 17	Riviera ligure di ponente. San Remo								9,34,36
82	1875 March 18	Adriatic coasts. Rimini, Cervia.					8		44.12-12.24	9,4,6,10,29
83	1876 December 23	Riviera ligure di ponente. Nice.								9,36
84	1878 April 19	Sea of Marmara. Izmid	iii							1,2,3,20
85	1879 July 29	Adriatic sea. Island of Vis	iii							1,2,3
86	1880 April 25	Riviera ligure di ponente (Lissa)								9,36
87	1883 June 27	Ionian Island. Corfu	iii				VI	n	39°1/2N-20°E	1,2,3,19,22,23
88	1885 January 16	Riviera ligura di ponente (Costa nizzarda)								9,35

No	DATE	TSUNAMI DATA				EARTHQUAKE DATA				REFERENCES
		Area of origin observation place of	m	H	L	M	I	s,n,i r	Latitude Longitude	
89	1886 August 27	South coasts of Peloponnesus. Messenia, Pylos; Asia Minor, Smyrna	iii				XI	i	37°N-21°1/4E	1,2,3,19,22,23
90	1886 November 11	Riviera ligure di ponente. (Costa nizzarda)								9,35
91	1886 December 17	Riviera ligure di ponente. (Costa nizzarda)								9,35
92	1887 February 23	Riviera ligure di ponente.								9,4,6,10,36, 29,46,35
93	1887 October 4	Gulf of Corinth. South coasts, Xylokastro, between Xylokastro and Sykia	iii		20		VIII	n	38°1/4N-22°3/4E	1,2,3,19,22,23
94	1888 July 30	Riviere ligure di ponente. (San Remo)								9,36
95	1889 December 8	Adriatic coasts. Ancona, Isl. Tremiti.					7		42.03-15.30	9,4
96	1892 November 1516	Isl. Ponza					4.50		40.54-13.00	9,4,29
97	1893 February 9	Sporades Islands. North coasts of Samotrace, Alexandroupolis Thracian coasts	iii+	0,90	400		IX	n	40°1/2N-25°3/4E	1,2,3,20,22,23
98	1893 June 14	Albanian coasts. Valona, Himara	iii							1,2,3
99	1894 April 27	Euboean Gulf. Atalanta Bay, West and Northwest coasts of Euboean. Gulf	iv	3,00			XI	n	38,7°N-23,1°E	1,2,3
100	1894 July 10	Constantinople	iii							1,2,3
101	1894 November 16	Coast of Calabria. Palmi, Tropea					- 9		38.15-15.52	9,4,6,13,29, 46,37
102	1894 December 27	Isl. Eolie (Filicudi)								9,12,37
103	1895 January	Costa laziale (Anzio)								9,46

No	DATE	TSUNAMI DATA: Area of origin observation place of	m	H	L	EARTHQUAKE DATA: M	I	s,n,i r	Latitude Longitude	REFERENCES
104	1895 November 1	Costa laziale (Fiumicino)					7		41.41-12.12	9,4,10,29
105	1896 Octomber 16	Costa ligure occidentable (San Remo)					7		43.42-08.03	9,4,10,29
106	1897 December	Ionian Island. Zante	ii-							1,2,3
107	1898 December 3	Ionian Island. Zante	ii+				VII	n	37°3/4N-21°E	1,2,3,22
108	1899 January 22	Messenia, Kyparissia, Marathos	iii				IX	n	37°1/4N-21°3/4E	1,2,3
109	1902 July 5	Salonika	ii-				IX	n	40°1/4N-33°1/4E	1,2,3
110	1903 May 13-14	Coasts of Calabria. Palermo								9,4,6
111	1905 September 8	Coasts of Calabria. Gulf S. Eufemia					11		38.50-16.60	9,6,11,10,27, 29,46,38
112	1906 April 4	Gulf of Napoli (Portici)								9,4,6,5
113	1907 October 23	Coasts of Calabria and Sicily					8		38.02-16.05	9,6,11,10,29,46
114	1908 December 28	Lybian sea, 90 miles north of Alexandrian, Egyptian coasts,							43.30-10.12	9,29,10,29
		Italian coasts	v			4,6	XI	10	38°N-15°1/2E	1,2,3
115	1914 January 15	Costa toscana (Livorno)					6		43.30-10.12	9,29,10,29
116	1914 November 27	Ionian Islands. Leukas	iv+	3,30		6,2	X	n	38°1/2N-20°1/2E	1,2,3,18,20
117	1915 August 7	Ionian Islands. Between Cephalonia and Leukas	iv+			4,9	IX	n	38°1/3N-20°1/2E	1,2,3,20,22,23
118	1916 July 4	Island Eolie (Stromboli)					7		38.48-15.12	9,11,10,29
119	1919 May 22	Stromboli					4,50		37.36-15.12	9,10,39,28,41
120	1919 October 1919	Costa laziale (Anzio-Nettuno)					7,50		41.23-12.35	9,11
121	1920 December 18	Albanian coasts. Valona, Saseno	v-			5,6	IX	n	40°1/2N-19°1/2E	1,2,3
122	1926 August 17	Island Eolie. Malta, Capo, Salina.							38.50-17.45	9,11,10

No	DATE	TSUNAMI DATA				EARTHQUAKE DATA				REFERENCES
		Area of origin observation place of	m	H	L	M	I	s,n,i,r	Latitude Longitude	
123	1928 March 31	Asia Minor. Smyrna	ii			4,9		n	38,1°N-27,1°E	1,2,3
124	1928 April 23-25	Grecian Archipelago; Piraeus Chalkis, Nauplio, Alexandroupolis, Crete, Chania, Karystos	iii+	2,10		4,6	VI	n	42,4°N-25,7°E	1,2,3
125	1928 May 3	Eastern Greece. Strymonic Gulf	ii			4,3	VII	n	40,8°N-26,8°E	1,2,3
126	1930 Septeber 11	Island of Stromboli					5		38.48-15.12	9,28
127	1932 Septeber 26	Gulf of Hierissos. Chalcidice	ii+			6,9	X	n	40°1/2N-23°3/4E	1,2,3
128	1939 January 27	Island Eolie (Filicudi)								9,12
129	1940 January 15	Costa Palermitama (Misilmeri)					8		38.04-13.28	9,4.10,29
130	1941 March 16	Coasts of Sicily. Palermo, Trapani							38.26-12.07	9,14,10
131	1947 October 6	South Peloponneus. Methone in Messenia	ii+			6,9	IX	28	36,9°N-22°E	1,2,3
132	1948 February 9	Dodecanese. Island of Karparthos	iv		1000	7,1	IX	40	35°1/2N-27°E	1,2,3,20,22,23
133	1948 April 22	Ionian Islands. Leukas	iv-	0,90		6,4	X	n	38°1/2N-20°1/4E	1,2,3,20,22,23
134	1949* February 9	Dodecanese. Island of Karpathos						n		1,2,3,23
135	1954 March - February	Island of Stromboli								9,28
136	1956 July 9	Grecian Archipelago. Amorgos, Astipalaea, Pholegandros, Patmos, Kalimmos, Crete, Tinos	v	30		7,8	IX	20;	36,9°N-26°E	1,2,3,21,22,23
137	1956 November 2	Magnessia. Volos	ii+	1,20		3/4	VII	n	39°1/2N-23°E	1,2,3,22,24
138	1959* February 23	North and west coasts of the Grecian Archipelago. Salonika, Salamis, Leros, Crete. No earthquake shok was recorded. Most probably a seiche.								1,2,3
139	1961* May 23	Asia Minor. Sea of Marmara Smyrna.				6,5	VII	n		1

No	DATE	TSUNAMI DATA: Area of origin observation place of	TSUNAMI DATA: m	TSUNAMI DATA: H	TSUNAMI DATA: L	EARTHQUAKE DATA: M	EARTHQUAKE DATA: I	EARTHQUAKE DATA: s,n,i r	EARTHQUAKE DATA: Latitude Longitude	REFERENCES
140	1961* June 6	Grecian Archipelago. Crete, Volos, Leros. Probably strong seiche	ii	0,90						1,2,3
141	1963 February 7	Gulf of Korinth. Possidonia, Patras.								1,2,3
142	1965 July 6	Gulf of Korinth. Itea bay	ii+			6,9	VIII		38,4°N-22,3°E	1,2,3
143	1968 February 19	Island St. Eustratios, Lemnos, Lesvos, Euboea.	ii+	1,20		6,7	IX	31	39,5°N-23,8°E	1,2,3
144	1978 June 20	Salonica, Strymonic Gulf. Most probably a strong seiche.	ii-	-	-	6,5	=	16	40,75°N-23,26°E	
145	1978 June 22	Costa da Giulianova a Mola	0,60							8
146	1979 April 7	Montenegro meridiomale								8
147	1979 April 15	Costa barese								8
148	1979 May 15	South Coasts of Crete. Most probably a strong seiche.	ii-	-	-	5,8	-	58	34,62°N-24,08°E	
149	1981 February 24	Gulf of Corinth, East coasts.	ii?			6,7		10	38,1°N-22,8°E	2,3

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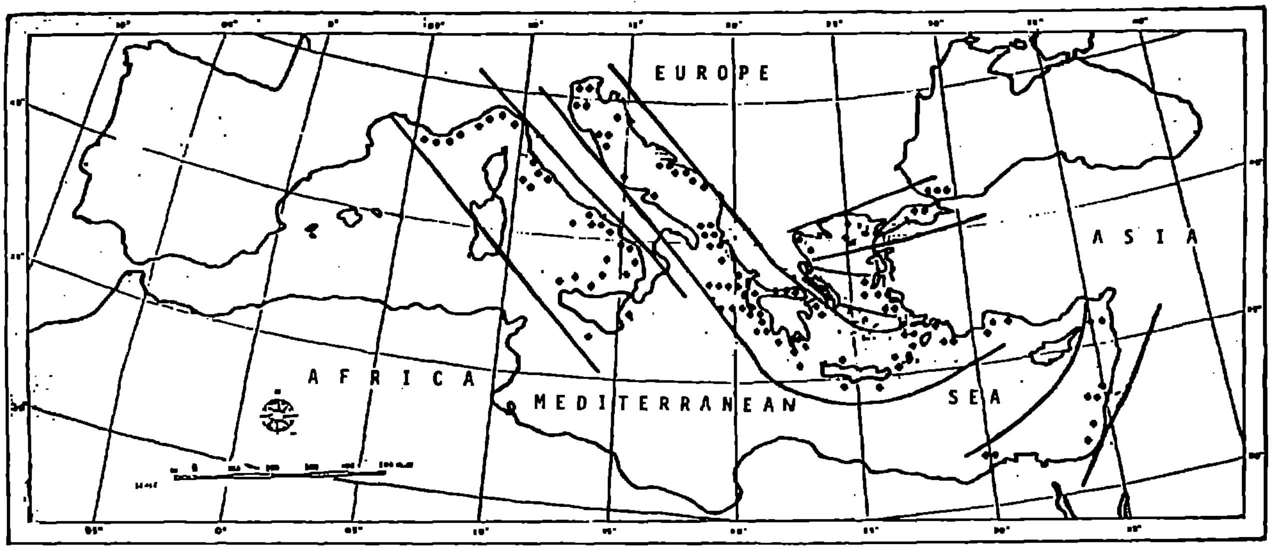

Figure 1. The tsunami activity of the last two centuries is indicated by the black diamonds. The zones show sea areas where tsunami activity is most probable to occur in the future.

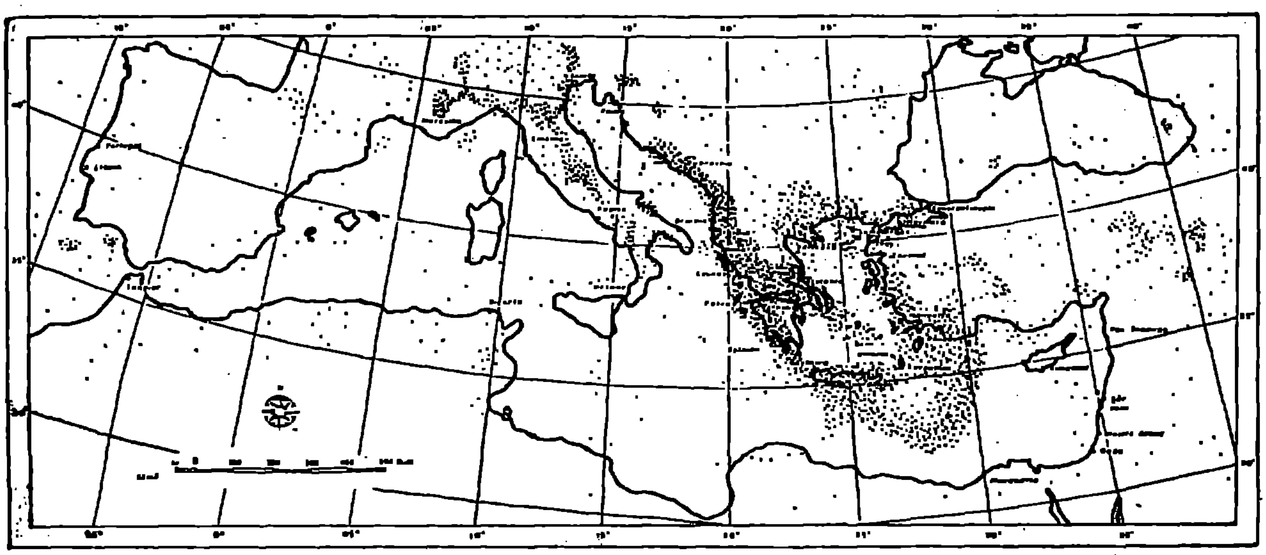

Figure 2. Earthquake epicenters in Mediterranean Sea during the last century.

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FOURTEENTH INTERNATIONAL TSUNAMI SYMPOSIUM
NOVOSIBIRSK, USSR, JULY 31 - AUGUST 3, 1989

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1. Introduction

The fourteenth IUGG-sponsored International Tsunami Symposium was held July 31 through August 3, 1989 in Novosibirsk, USSR. Sixty-five scientists from 13 countries gathered to discuss recent advances in tsunami research. The symposium was a great success due to the enthusiasm of the participants, the quality of research presented, and the great organization provided by the Soviet hosts. Teams of dedicated workers, under the fine leadership of Academician A.S. Alexseev and Dr. V.K. Gusiakov, blended social and scientific activities in a memorable fashion. Besides the hospitality, one other important fact will also be associated with the location of the symposium - it represented the place on the earth farthest from any ocean. So it may be stated that tsunami scientists practice safe meeting attendance.

The 62 presentations of the symposium were divided into six areas of research: generation (7), propagation (12), coastal effects (10), observations (11), seismics and tectonics (10), and hazard mitigation (12). A summary of the research presented was prepared by each session chairman and is provided below. A poster session was held one evening during which 14 additional reports were given. A trend toward more applied, interdisciplinary research was evident in the research presented. This small community of scientists continues to conduct interdisciplinary research in close collaboration, which makes the transfer of new knowledge rapid. These scientists are acutely aware of the importance of their research and clearly demonstrated relevance to the mitigation of the tsunami hazard.

2. Generation

The first sessions of this symposium discussed progress in our attempts to understand the mechanism of tsunami generation and the form of tsunami waves near the source. V.K. Gusiakov examined techniques currently employed at the Novosibirsk Computing Center to model generation using Ward's coupled model. S.I. Iwasaki examined tsunami generation by submarine landslides. He pointed out that, although landslides have caused a number of tsunamis, we know very little about the landslide process itself, and thus have a difficult time building models.

B. Levin and S. Soloviev described laboratory experiments of wave generation by bottom vibrations at seismic frequencies. Their work suggests that the distinctive surface wave patterns developed at the source should be readily observable by airborne sensors.

I. Selezov described analytical investigations of the effect of source rise-time on the initial waves. He has found that longer rise times decrease energy imported to the waves, and that as ocean depth of the source increases the effects of the compressibility of sea water increase. S. Dotsenko and B.

Sergeevsky examined the dependence of dispersive and non-dispersive effects on rise-time and source geometry. They found that dispersive effects can be significant for small, axi-symmetric sources with rapid rise time. They also found that increased rise times decrease both leading wave energy and total wave energy. A. Marchuk and V. Titov discussed the concept of wave focusing and a means of interpreting differences in wave height near the source.

It is clear that these reported efforts show both significant progress in our understanding of generation as well as the limits of that understanding. In particular, we can see the need for more detailed examination of the details of the process in terms of wave-lengths of generated waves, not just total energy. Such studies will not only enhance our understanding of the process but will allow for improved numerical models and improved understanding of the earthquake sources themselves.

3. Tsunami Propagation

Professor N. Shuto led off the sessions on propagation with an invited paper describing the state-of-the-art of tsunami modeling and future directions for modeling. He discussed current aspects of the generation and propagation problems and ways in which numerical models deal with them. He discussed four areas that pose strong challenges for the near future: (1) the need for better observational data, (2) the uses of higher order equations, (3) the need to examine secondary effects such as fire and floating debris, and (4) innovative uses for computer graphics.

Drs. V. Titov, N. Voltzinger, and K. Klevanny discussed various aspects of numerical grid size and generation. Although both papers conveyed much information, it was not clear why the methods described are superior to existing techniques.

Dr. M. Zheleznyak discussed the importance of non-linear and dispersive effects in studying coastal propagation. He indicated that these considerations would be important in examining secondary effects as discussed earlier by Shuto.

Two papers (I. Molotkov and Y. Egorov) discussed coastal propagation modeling. One discussed results in terms of solitary wave considerations, while the other discussed analytical methods for strongly non-linear waves.

V. Bakhteev discussed model studies of wave trapping around islands in the Kuril chain, and how such trapping affects tsunami propagation. G. Kang and J. Ryom discussed an empirical model to allow computation of probable tsunami heights on the Korean coast. Y. Shokin described the development and production of travel time charts for use in the international tsunami warning systems.

A. Gurevich discussed the way in which hydroacoustic waves generated by tsunamis could be generated and could be used to assist in tsunami warnings. Their findings seem to agree with those of B. Levin and S. Soloviev, which indicated that wave patterns during generation should be visible on the surface.

Finally, F. Inamura showed how improved renditions of wave and wave- induced currents could aid in protecting local aquaculture from tsunamis. It seems clear from these papers that questions of open-ocean propagation have rightly become secondary to examinations of waves in the nearshore environment.

4. Coastal Effects

The paper by V. Yakovlev and A. Pyatetsky reported on the construction of solutions to problems of the diffraction effect observed when single and cnoidal waves interact with cylindrical and conical structures. The authors studied the steepness effect of climbing waves on wave loads affecting both single and multiple obstacles of a complicated shape.

The investigation of the tsunami wave run-up on a beach was given by E. Pelinovsky, V. Golinko, and P. Mazova. Control parameters of the problem (in the case of ideal fluid) are the bottom sloping angle and the breaking parameter. Solution of the one-dimensional nonlinear problem was obtained using the Carrier-Greenspan transformations. A stage-by-stage approach for finding run-up characteristics was formulated: the linear calculation of shoreline oscillations and the subsequent nonlinear transformation of the solution according to the Riemann method. A simple way to find the breaking parameter for a wave of arbitrary shape was described. Examples of the wave run-up calculation in the case of pulse perturbation on shelves of various geometries were given, and the influence of dissipation on run-up characteristics was discussed.

H. Yeh (presented by C. Synolakis) discussed the behavior of a single bore propagating into quiescent water. He found that the speed of bore propagation on a uniformly sloping beach decreased faster than the inviscid shallow water wave predictions; that "bore collapse," as predicted from theory, resulted from a momentum exchange with water pushed ahead of the bore; that, contrary to theoretical predictions, pressure must play a role in the early stage of run-up motion; that the maximum run-up height can be predicted by inviscid theory using a reduced value of the initial run-up velocity; that a single incident bore generates two successive run-up motions; and that the behavior of an undular bore is different from that of a fully-developed bore.

V. Davletshin described large-scale studies aimed at comparing experimental and theoretical data concerning long-wave splash and pressure on walls. He presented measurements of splashes and pressures due to solitary waves, bores, and breaking waves. He found that the scale effect for the pressure of breaking waves and bores is due to aeration. The boundaries of the effect were determined and essential formulas were presented.

T. Sokolowski discussed the automated Alaskan Tsunami Warning System, which contains an advanced automatic and interactive computer processing system to provide immediate warnings in Alaska, Canada, and the west coast of the USA. This system has now been instrumental in producing six warnings during the past 2 years. All of these warnings were issued 8-14 minutes after the earthquake, attesting to the effectiveness of the system.

Y. Tsuji demonstrated that tsunamis propagating into rivers could be explained using the theory of an undular bore. Using data from the 1983 tsunami, his theory explained 90% of the observed behavior. K. Fujima and N. Shuto revealed a technique for approximating Manning's friction law in numerical experiments that would save computational costs. H. Watanabe showed that tsunami impact along Japan's coastline depended on the depth of water at the source. Y. Aleshkov gave a theoretical discussion of long waves interacting with cylindrical objects. His approach used a local coordinate system to determine the load on the obstacle. Mironov's theoretical presentation concerning wave impact on objects of a curvilinear shape advanced a coordinate transformation technique to estimate loading forces. From this session, it is again clear that emphasis is increasingly being placed on how waves interact with the shore and with obstacles on the shore.

5. Seismics and Tectonics

Under the session on Seismics and Tectonics, nine very interesting papers were presented. A. Ivashchenko gave a paper entitled "On Modern Seismic Activity and Tsunami Threat near the Kuril Islands," in which he outlined the threat of tsunamis in the USSR, primarily along the Pacific coast of the Kuril Islands and Kamchatka. He discussed the variance of long-term predictions of large tsunamigenic earthquakes in the region.

A.V. Vikulin, in his presentation entitled "Migration of the largest earthquake sources across the Nankai Trench," discussed the source mechanisms of tsunamigenic earthquakes in the Nankai Trench region and forecasted the occurrence of future events. K. Satake presented the results of a novel study undertaken to reconstruct source parameters and displacements from mareographic recordings of tsunamis. This technique is a much more sophisticated and insightful approach to the inverse tsunami problem than has previously been undertaken.

A. Zakhorova presented a joint paper (with O. Starovoit and L. Chepkunas) which described a study of data obtained from broad-band seismograms and focal plane solutions as they relate to tsunami generation.

D. Reymond presented a method for rapidly determining seismic movement as an indication of tsunami potential. This method was developed using the French Polynesia seismic network. V. Ivanov explained an analysis of seismic and tsunami data to infer earthquake source features. T. Zheleznyak described observations of a unique impulse wave recorded by a very long period (240 sec) seismometer during earthquakes that generate tsunamis. Much discussion about the response characteristics of the seismometer followed the presentation since this phenomenon has not been previously measured.

A. Poplavsky and N. Konstantinova presented their criteria for issuing regional tsunami warnings in the Kuril Islands. The research results of geophysical survey methods used to install tsunami recorders in the Sea of Japan were presented by P. Kaplin. This session served to underscore both the gap in our understanding of source mechanisms, and the usefulness of tsunami data in examining seismic problems.

6. Tsunami Observations

M. Okada considered a new method for correcting a waveform deformed by non-linear tide gauge response. This numerical method, based on a simple statistical hypothesis, gave an estimate of the waveform outside the tidewall by correcting the tide gauge records. Y. Shokin, L. Chubarov, and K. Simonov discussed an approach to a local tsunami warning system, and some examples of applied computational experiments were considered. For some areas it was shown that, on the basis of computational experiments, one can reduce the number of false alarms. K. Abe developed a new procedure for identifying reflected waves and explained how they could be clearly observed. This approach uses a simplified model approximating the real wave profile by a three-step function. P. Kovalyov, A. Rabinovich, and G. Shevchenko presented a description of long-wave observations on the northwestern shelf of Kamchatka in the tsunami frequency range. Simultaneous measurements of atmospheric pressure fluctuations were made and small coherence between long waves in the ocean and atmospheric pressure fluctuations was found. Examination of sea activity showed that wind waves and swell are the main sources of background energy in the tsunami frequency band.

A. Rabinovich and G. Schevchenko discussed the problem of estimating extremal sea levels, an important consideration for construction of nuclear power stations and other expensive structures in the coastal zone. The proposed method is based on the analysis of tides, storm surges, and tsunamis, and the calculation of probability densities for each component. The joint distribution of sea level and the return period are computed. This method was used for estimation of maximal sea levels near the northeastern coast of Sakhalin Island.

J. Belokon discussed a nontraditional method of detecting long waves by examining the perturbation of the vertical component of the geomagnetic field induced by tsunami waves. He found this component to be intensified in the region of rapid variation of wave velocity. This variation can be measured on the continental shelf and used to examine both tsunami data and seismic and geophysical data.

K. Minoura and S. Nakaya examined columnar samples of coastal sediment deposits to detect traces of ancient tsunamis. They sampled Lake Jusan, on the Tsugaru Peninsula, and the Sendai Plain of Northeastern Japan. The results of sedimentological and geochemical studies of the samples showed that layers almost coincided with historical ages of tsunamis recorded on ancient documents. This method is quite interesting and worthy of further study. H. Murakami, T. Shimada, and Y. Hosoi discussed a study of the 1946 tsunami in Asakawa Village, Japan using a numerical model.

There were five reports concerning both instrumentation and historical tsunamis in the Pacific Ocean. The importance of deep ocean bottom pressure recorders (BPR) was emphasized in the analysis by F. Gonzalez, E. Bernard, and M. Eble of three small tsunamis generated from 17 November 1987 to 6 March 1988 in the Gulf of Alaska and recorded by a network of three BPRs, as well as by the usual tide gauge stations. The BPR network was able to provide essential information for tsunami analysis and is also an extremely useful tool for validating numerical models on propagation and run-up. Future uses of this instrument were presented in the poster session (see Figure 1). First results of an analysis of the 1985 Chilean tsunami were presented by G. Hebenstreit. Auto- and cross-correlations of the wave time series, recorded by six tide gauges north of the source area, show the three northern stations acting as a separate system, while the three southern stations respond independently. These results will be used to guide numerical simulations of the Chilean shelf as a system, rather than as individual embayments.

A new algorithm for automated tsunami warning based on the mantle magnitude, Mm (calculated from the Rayleigh wave in the 50-300 period range) was shown to be simple and fairly adequate for operational use in French Polynesia (D. Reymond, O. Hyvernaud, and J. Talandier). The role of historical research of past events in establishing present and future threat was emphasized by the analysis by A. An and S. Chun of high-tide records along the Korean coast for a period covering the last six centuries. A catalog of the tsunamis recorded in the last 25 years in Mexico was presented by A. Sanchez and S. Farreras and shown to be a fundamental tool for hazard studies. Complementary tools for hazard assessment, such as the research on historical tools and the study of land use vulnerability, were also illustrated. The depth and variety of papers in this session is an indicator of the growing awareness of the constraints on the research community caused by the relative scarcity of observational data.

7. Tsunami Hazard Mitigation

Assuming the use of the Izutani-Hirasawa method for rapid estimation of fault parameters, F. Inamura and N. Shuto showed that a slight change in the fault orientation may change the wave energy ray direction from shoreward to open seaward, resulting in a maximum error of 60% in run-up predictions. This result is important for the accuracy of predictions based on numerical simulations used by the tsunami warning systems, even for near-field tsunamis.

T.S. Murty and N.K. Saxena considered the tsunami vulnerability of some small islands inside the Exclusive Economic Zone (EEZ) of the USA in the Pacific in view of some major earthquakes predicted to occur in various seismic gaps. They discussed the importance of frequent errors in the computation of tsunami paths and travel times, which may affect the predictions of tsunami warning systems. The main sources of these errors are: use of improper chart projections, lack of consideration of rotational effects, and improper depiction of undulating sea bottom topography.

T.J. Sokolowski, P.M. Whitemore, and W.J. Jorgensen explained the implementation of a new microcomputer system in the Alaska Tsunami Warning Center. This system is used for both automatic real-time earthquake processing and interactive reprocessing-dissemination of critical information to the users. The Center continually receives and processes seismic data from 26 short-period and 6 long-period sites in Alaska and other USA states and automatically determines source parameters, making the information available in tens of seconds after the P-wave arrivals. Selected data and parameters are concurrently available to the interactive system for recomputation, dissemination of information and procedural aids.

S. Tinti detailed his first attempt to develop statistics for a total of 154 tsunamis that affected Italy from the years 1770 to 1908, with earthquakes, landslides, volcanoes and other sources. For this purpose, Italy is regionalized in 8 zones. His main goal is to evaluate probabilities of recurrence for the major events. The main difficulty in accomplishing this goal is the incompleteness of a seismic instrument network in the Mediterranean Basin. He recommends the creation of a Regional and National Warning Center in Italy. This study is important because the tsunami hazard along the Italian coasts has been substantially neglected for a long time, and Italy is one of the Mediterranean regions most affected by tsunami activity.

Two presentations were made on the testing of a satellite-linked early tsunami warning system (Project THRUST) in Valparaiso, Chile. E. Bernard showed high reliability (90%) and fast response times (87 sec) of the system over the past 3 years of testing. He reported on improvements in satellite operations that will reduce the response time to approximately 20 seconds, making this technology appropriate for other rapid onset natural disasters. E. Lorca reported on the development of the standard operations plan for the THRUST Project, including the results of a disaster exercise. The exercise exposed some deficiencies in the present plan which will be corrected.

V. Karstrevko presented a model of tsunami run-up using probability theory. Applying the theory to tsunami run-up in the USSR yielded recurrence curves of specific run-ups. J. Talandier presented the results of recent research to automate the direction, location and sizing of earthquakes in French Polynesia. He urged the use of seismic moment as the indicator of tsunami potential rather than Richter Scale magnitude. I. Tikhonov reported on plans to develop an automated system to locate and size earthquakes in the USSR using a 3-component long-period seismometer. G. Hebenstreit and J. Preuss described a study to integrate tsunami modeling and land use patterns to estimate both wave-based threat and secondary effects (fire, chemical dispersion, etc.) in a specific locality.

The papers in this session probably reflect better than any other the maturing thought process in the tsunami community. The local issues - warming, mitigation, preparedness - are gradually gaining prominence as focal points for continuing study.

Following the symposium, a team of session chairmen nominated 20 of these 65 oral presentations to be published in a special issue of Natural Hazard devoted to the International Tsunami Symposium. Extended abstracts of all the presentations are available from V.K. Gusiakov, Computing Center, Novosibirsk, 630090, USSR.

This contribution was prepared by E.N. Bernard, National Oceanic and Atmospheric Administration (USA) and G.T. Hebenstreit, Science Applications International Corporation (USA), who gratefully acknowledge the input by Session Chairmen A. Alexseev, F. Gonzalez, K. Kajiura, N. Shuto, T. Murty, Y. Tsuji, A. Marchuk, H. Watanabe and S. Farreras.

BOOK REVIEW

UNITED STATES TSUNAMIS (INCLUDING UNITED STATES POSSESSIONS) 1690-1988,
written by James F. Lander and Patricia A. Lockridge
and published by the National Geophysical Data Center
NOAA, U.S. Department of Commerce at Boulder, Colorado
Publication 41-2, 265 pages.

Reviewed by Sydney O. Wigen.

From two of the acknowledged experts in historical tsunamis and data collection comes this much needed catalogue. It is a comprehensive work, detailing not only locally generated events, but those from remote sources which have impacted on the coasts of the United States and of the territories that are or have been under its administration. Geographically it has individual chapters for seven regions, Hawaii, Alaska, West Coast of the United States, American Samoa, Possessions and Trust Territories in the Pacific, East Coast of the United States, and Puerto Rico and Virgin Islands. Events appear in chronological sequence, first drawing on the descriptive accounts that bring tsunami disasters home in terms of their human impact, and then tabular presentations of the sort of data required for research and engineering applications. Throughout, the authors have drawn on the rich store of information available to them through their connections with the National Geophysical Data Center and World Data Center 'A' for Tsunamis. A feature unique in my experience in tsunami cataloguing is a brief background at the opening of each chapter setting forth the history of the region, time of the switch from Julian to Gregorian Calendar, and the date adjustments that were made. Time zones in effect at various periods are also noted. Misunderstandings about these factors have given cataloguers in the past difficulty in reconciling apparently conflicting accounts of the same event from distant shores. Lander and Lockridge frequently in the text are able to clarify these differences, and to cite their sources. The background comments opening each of the seven descriptive chapters also include some description of the tectonic setting of the region, and its tsunamigenerating capabilities. These comments help to put the locally generated tsunamis into perspective.

United States Tsunamis is a book that can be read with enjoyment by anyone with an enquiring mind. But at the same time the authors have produced it for a specific service, to make available a body of knowledge from various sources as a single volume, for the convenience of researchers, planners, and emergency service organizations. They have succeeded admirably. The introductory chapter about tsunami characteristics, warning systems, problems with historical data, and description of texts and tables needs to be read carefully and referred to periodically to achieve the text's full value.

The opening chapter also describes the opening of the Pacific Tsunami Warning Center in Honolulu, and the offer made by the United States to UNESCO to "expand the Center to become the headquarters of the International Pacific Tsunami Warning System, and at the same time to accept the offer of IOC member countries to integrate their existing facilities and communications into the system." It further notes, "Refined historical data are also increasingly useful in predicting future events. The international community has much to gain from its cooperation in increasing the effectiveness of tsunami warnings, thereby reducing tsunami risk." The authors recognize that much historical data are still uncompiled, and hopefully readers discovering accounts not published in the catalogue will submit reports for future compilations. Since the period of active observation and recording of tsunamis is less in many places that the periodicities of tectonic rupture zones, all historical data are needed to help improve the evaluation of tsunami risk. As a corollary, one might well speculate on the ongoing importance of present gauging and recording systems to measure tsunamis wherever and whenever they occur, and for such information from new events to be incorporated accurately, rapidly, and by standardized reporting systems into tsunami records.

HAZARDS '91

Under the umbrella of HAZARDS-91 to be held in Cairo, Egypt during 21-27 April, 1991, several symposia and workshops will be held, dealing with all aspects of natural and technological disasters, with particular emphasis on those occurring in developing countries. Keynote speakers, special invited lectures and contributed papers on current practices and research activities will be grouped into the following themes:

- Cyclones and other severe weather systems
- Storm surges and their coastal effects
- Tsunami generation and propagation
- Biotoxins and other marine natural hazards
- Air and water pollution
- Floods and droughts
- Ice-related hazards
- Earthquakes, landslides and snow avalanches
- Soil erosion
- Deforestation and desertification
- Climatic changes and their impacts
- Risk assessment problems
- Preparedness, mitigation and management
- The IDNDR: a perfect chance to put hazard research

SPONSORSHIP

The International Society for the Prevention and Mitigation of Natural Hazards (NHS) is the principal scientific organization sponsoring HAZARDS-91. The meeting is co-sponsored by the following organizations:

- The Tsunami Society
- The International Association for the Physical Sciences of the Oceans (IAPSO)
- IAPSO Commission on Marine Natural Hazards
- Academy of Scientific Research and Technology, Egypt
- International Tsunami Information Center

CALL FOR PAPERS

The Organizing Committee invites all scientists, engineers and policy makers involved in natural and technological hazards to participate actively in HAZARDS-91. Authors are invited to submit extended abstracts of 2-3 pages (up to 40 lines per page). To maintain a high scientific standard, it is thought that extended abstracts will help in a better screening of the submitted papers. Original and two copies of the extended abstracts should be sent to the chairman of the Scientific Committee, Dr. T.S. Murty before July 31, 1990.

Natural disasters have disrupted the lives of over 820 million people in the past 20 years, causing 2.8 million deaths, billions of dollars in property loss, severe community distress, and untold human misery. The theme for the 1991 meeting is GEOPHYSICAL HAZARDS IN DEVELOPING COUNTRIES AND THEIR ENVIRONMENTAL IMPACTS. This symposium will be held during the start of the International Decade for Natural Disaster Reduction (IDNDR) proclaimed by the United Nations. Through international cooperation, the IDNDR begins a global effort to reduce the loss of life, property damage, and social and economic disruption caused by natural disasters. Another purpose of the 1991 meeting is to establish closer link between research and practice and to bring together not only academic researchers, but also public, private, engineering sector professionals as well as policy makers involved in hazards research or mitigation activities in the world. There is good reason at this time to call on the hazard research and management community to work together and renew its commitment to reducing the threat from natural extremes.

The venue of HAZARDS-91 is Cairo. Egypt has all the necessary ingredients to host this international gathering. Apart from its well known history, it is exposed to several disasters such as floods, drought, storm surges, earthquakes, landslides, soil erosion, desertification, air and water pollution.

Combining with family holidays is recommended.

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