

INFORMAL REPORT

TSUNAMIS AND SEISMIC SEICHES
REPORTED FROM THE WESTERN
NORTH AND SOUTH ATLANTIC
AND THE COASTAL WATERS OF
NORTHWESTERN EUROPE

SEPTEMBER 1968

The opinions and assertions contained in this report are solely those of the author(s) and should not be taken as an official, or inferred official, opinion of the Naval Oceanographic Office, Department of the Navy, Department of Defense, or United States Government.

This document is subject to special export controls and each transmittal to foreign governments or foreign nationals may be made only with prior approval of the Naval Oceanographic Office.

NAVAL OCEANOGRAPHIC OFFICE
WASHINGTON, D.C. 20390

ABSTRACT

Fifty-four tsunamis which have been reported from the western North and South Atlantic Oceans between 1530 and 1964 are included in Part I. These tsunamis have been most frequent in the seismically active regions around the eastern Caribbean. Tsunamis have also been reported in other parts of the area from South Georgia and Cape Horn to Iceland. Thirty-five tsunamis reported from the coasts of northern and western Europe between 842 and 1950 are listed in Part II. This list contains data on the majority of the waves of seismic origin in northwest Europe from Cabo Finisterre on the northwestern tip of Spain to northern Scandinavia.

This Informal Report was prepared by William H. Berninghausen, Geology Section, Marine Environment Branch, Oceanographic Analysis Division.

This manuscript has been reviewed
and is approved for release as an
UNCLASSIFIED Informal Report.


H.W. DUBACH
Division Director

CONTENTS

	<u>Page</u>
Abstract	1
Introduction	1
Part I. Tsunamis and seiches reported from the western Atlantic between 1530 and 1964	5
Part II. Tsunamis and seiches reported from the coastal waters of northwestern Europe between 842 and 1950 . .	26
References	35

FIGURE

1. Travel time chart for tsunami of 18 November 1929	42
--	----

TABLE

I. Tide gage records for Krakatau wave in the Atlantic	43
II. Observed and computed travel times for the tsunami of 18 November 1929	45
III. Locations, periods, and amplitudes of seiches reported in Norwegian waters, 15 August 1950	47

Introduction

The list of tsunamis which forms the main body of this paper is divided into two parts: Part I gives information on tsunamis and other large waves which have been reported from the western North and South Atlantic, while Part II gives similar information for the coastal waters of northwestern Europe.

The data for tsunamis in the eastern Atlantic, south of the Bay of Biscay, are contained in a previously published paper (Reference 3).

Many of the early accounts of large or unusual waves in the Atlantic are incomplete or ambiguous. In some it is impossible to separate destruction caused by tsunamis from that caused by earthquakes. Several reports make reference to a storm occurring at the same time as an earthquake. It is probable that some of the large waves reported from the Atlantic have been storm surges rather than tsunamis.

With comparatively few exceptions the tsunamis in the western Atlantic have been local in origin, though several waves in this region have been caused by distant earthquakes. The waves propagated by the Lisbon earthquake of 1755, for example, were noted in the Caribbean Sea, as well as in European waters; waves which have been attributed to the explosive eruption of Krakatau in Indonesia in 1883 were recorded in Cape Horn, South Georgia, Panama, France, and England (see Table I). At the time of occurrence it was thought that the waves which were recorded in Panama may have been caused by a local earthquake. However, more recent theorizing has attributed the waves in the Atlantic to an airborne shock wave, rather than to a waterborne wave.

The wave caused by the Newfoundland earthquake of November 18, 1929 was reported from numerous locations along the Atlantic coast of North America, as well as from Bermuda, La Martinique, and the Azores. Since this earthquake occurred during a storm, some of the damage attributed to the tsunami may have been caused by storm-generated waves. Figure 1 is a travel time chart showing the progression of the wave front, while Table II gives some of the pertinent facts regarding the wave.

Table II shows that the computed travel time agrees closely with the observed travel time for those locales for which tide gage records were available. Two arrival times are given in the literature for the wave at Burin, Newfoundland, namely, 7:25 Atlantic Standard Time AST (GMT+4) and 7:15 local time, i.e., Newfoundland Standard Time NST (GMT+3.5). Neither of these times agrees with the calculated travel time. If, however, the assumption is made that the 7:25 time should have been NST rather than AST, then the difference between computed and actual travel time is only 7 minutes. This 7-minute difference may be considered a reasonable margin of error. The 54-minute difference between the computed and actual travel times for the wave to Bermuda suggests an untenable margin of error. It is possible that the time of arrival of the wave was not accurately noted nor recorded, or that the wave observed was a storm surge rather than the tsunami.

The arrival times for the tsunami is given in the literature for several other locales in the Newfoundland-Nova Scotia region. Since these times do not fit the pattern set forth by the computed travel times, it is probable that the times noted were those of the arrival

of a large or destructive wave rather than the arrival of the first wave of the tsunami. This first wave may have been masked by the storm which was in force at the time. It would appear that the first wave was noted at St. Lawrence, Newfoundland, since the reports indicate that "the telegraph operator at St. Lawrence was able to warn Burin before the telegraph office at the former place was washed away."

Waves of seismic origin, tsunamis, and seismic seiches in the European region are of minor importance when compared with similar waves which occur along some sectors of the Pacific coast. They are also unimportant when compared with the severe storm waves which frequently occur along the Atlantic and North Sea coasts. For these reasons, it is not surprising that comparatively few data are available on seismically generated waves in northwestern Europe, nor that in much of the early wave data it is impossible to distinguish storm surges from tsunamis or seismic seiches.

Tsunamis have been reported more frequently from southern Ireland, Wales, England, and the opposite coasts of France and the Low Countries than from the other parts of the area. Tsunamis have also been reported from the northern coastal regions of the Iberian Peninsula. The generating earthquakes of the few tsunamis which have been reported from the Scandinavian countries were caused by latent adjustment of the area resulting from the removal of the ice load on the Fennoscandian Shield at the end of the Pleistocene.

Tsunamis in the British Isles, Low Countries, France, and northern Spain for the most part have been generated by local earthquakes during the period 1884 to 1894. These waves may have been caused by

the activity of a submarine volcano which was reported to have erupted on 29 December 1884 at 49°00'N., 34°30'W. One of these waves was reported by the S. S. Diamond while lying-to awaiting daylight to enter port off the west coast of Ireland. Similar waves have been attributed to storm action occurring farther west in the Atlantic.

PART I

TSUNAMIS AND SEICHES REPORTED FROM THE WESTERN ATLANTIC BETWEEN 1530 AND 1964

1530 Sept. 1, Venezuela:* Peninsula de Paria (10°40'N., 62°30'W.), Isla Cubagua (10°49'N., 64°11'W.), and Cumana (10°28'N., 64°10'W.) -- The sea rose more than 20 feet and fell again. Ref. 16, 36.

1543 -- --, Venezuela: Waves noted. Ref. 16.

1688 March 1, Jamaica: Shocks felt throughout the island. Port Royal (17°56'N., 76°51'W.) -- Waves damaged ships in the harbor. Ref. 26, 36.

1692 June 7, Jamaica: Port Royal -- 3,000 persons were killed by the shock and the resulting tsunami. A frigate in the harbor was destroyed.

Along the coast of Liganee (possibly Liguanea Plain, 18°01'N., 76°48'W.) -- The sea withdrew 200 or 300 yards, exposing the bottom; upon returning the water overflowed the greater part of the shore.

Yallahouse (possibly Yallahs, 17°52'N., 76°34'W.) -- "The sea is said to have retired about a mile."

Saint Anns Bay (18°26'N., 77°12'W.) -- A large wave was reported. Ref. 16, 26, 49, 52.

1693 Feb. 13, Iceland: Earthquake accompanied an eruption of Hecla (64°00'N., 19°49'W.). A small wave was noted along the adjacent coast. Ref. 26.

* Major regions affected by the tsunami are underlined.

- ✓ 1751 Oct. 18, Hispaniola: Azua de Compostela was destroyed by the earthquake and overwhelmed by the resulting tsunami. Following the destruction, Azua de Compostela was rebuilt at its present location (18°27'N., 70°44'W.). Santo Domingo (Ciudad Trujillo, 18°28'N., 69°45'W.) -- Wave damage reported. Ref. 16, 36, 48, 53.
- 1755 Nov. 1, West Indies: Earthquake at Lisbon, Portugal (see Part II 1755, Nov. 1). The tsunami struck along the coast of Portugal, Spain, the Azores, and the West Indies. Portsmouth (15°35'N., 61°28'W.) on the island of Dominica and Antigua Island (17°03'N., 61°48'W.) -- Waves 12 feet high were reported.
- Barbados -- The water in Carlisle Bay (13°05'N., 57°37'W.) was black as ink. The wave had a period of 5 minutes and an amplitude of 5 feet.
- La Martinique (14°40'N., 61°00'W.) -- At some places the water was reported to have withdrawn for a mile; at other places the incoming wave flowed into the upper rooms of the houses.
- The lowlands on most of the other French islands were inundated.
- Saba (17°38'N., 63°14'W.) -- The water rose 21 feet above normal.
- St. Martin (18°04'N., 63°04'W.) -- A sloop anchored in 15 feet of water was laid dry on her broadside.
- Ref. 1, 16, 26, 36.

1755 -- --, Cuba: Santiago de Cuba (20°01'N., 75°50'W.) was nearly inundated by a tsunami. (This was possibly from the Lisbon earthquake of Nov. 1.) Ref. 16, 53.

1755 Nov. 18, Epicenter along the east coast of North America at about 43°N., wave noted.

St. Martin -- The water level in the harbor dropped 18 or 24 feet and upon returning rose 6 feet above normal. Ref. 26, 56.

1761 Mar. 31, West Indies: Earthquake at Lisbon, Portugal. (See Part II, 31 March 1761).

Barbados -- The wave was reported as having been 1 1/2 to 4 feet high. Ref. 5, 16, 26, 27, 36.

1767 Apr. 24, Antilles: Earthquake felt at Surinam, La Martinique, and Barbados. At the last two places, the sea ebbed and flowed in an unusual way. Ref. 16, 36.

1769 June 3, Hispanola: Earthquake near Port-au-Prince (18°32'N., 72°20'W.). The sea inundated the country to a distance of a league and a half from the coast. Ref. 26.

1770 June 3, Hispaniola: The earthquake epicenter was probably near Mole Saint-Nicolas (19°48'N., 73°23'W.).

Golfe de la Gonave (19°00'N., 73°30'W.) and Arcahaie (18°46'N., 72°31'W.) -- Waves noted.

La Saline Mountain (Morne Saline Des Cotes, 19°09'N., 72°43'W.) -- The foot of the mountain was partly submerged.

The sea rose a league and a half up into the island.

- Port-au-Prince -- Wave noted by ships in the harbor.
Ref. 16, 48, 50, 53.
- 1774 -- --, Newfoundland: A tsunami swept the southern peninsulas and caused over 300 deaths. Ref. 19.
- 1775 -- --, Hispaniola: Three earthquakes reported. A wave did extensive damage. Ref. 16, 50.
- 1775 -- --, Cuba: Santiago de Cuba -- Large earthquake. Waves caused extensive destruction. Ref. 53.
- 1780 Oct. 2, Jamaica: Probably the same phenomenon reported below for Oct. 22, 1781. Ref. 26, 36.
- 1781 Oct. 22, Jamaica: Savanna La Mar (18°13'N., 78°08'W.) -- An earthquake occurred during a hurricane. The sea rose to a height of 10 feet at half a mile from the beach and swept away a number of houses. Ten persons were killed by the wave, and at least 40 more were killed by the storm.
All the vessels in the bay were dashed to pieces or driven onshore. Ref. 26, 50.
- 1787 Oct. 27, Jamaica: A small local shock was felt at Montego Bay (18°28'N., 77°55'W.). "The vessels in the harbor were agitated." Ref. 26.
- 1799 Jan. 7 and 8, Iceland: An earthquake accompanied by a storm. The sea inundated the country. Ref. 26.
- 1802 Mar. 19, Antigua Island, St. Christopher (17°20'N., 62°45'W.) and other West Indian islands: Earthquakes and tsunamis were reported. Ref. 16, 26.

- 1823 Nov. 30, La Martinique: Strong shock felt at Saint-Pierre (14°45'N., 61°11'W.). The sea rose after the shock and caused some damage in the harbor. Ref. 26, 36.
- 1825 Sept. 20, British Guiana: Demerara County (06°00'N., 58°12'W.), -- Local earthquake. Fluctuations of the sea were noted. Ref. 26.
- 1831 Dec. 3, Trinidad and St. Christopher: The sea was in a state of violent agitation. Ref. 26, 36.
- 1837 July 26, La Martinique: Several shocks accompanied by a large wave occurred during a hurricane. Ref. 26, 36.
- 1840 Nov. 11, Eastern United States: Shock felt at Philadelphia. A large and unusually sudden swell was noted in the Delaware River. Ref. 26.
- 1842 May 7, Hispaniola: Destructive earthquake reported from Mole Saint-Nicolas, Cap-Haitien (19°46'N., 72°13'W.), Port-de-Paix (19°57'N., 72°50'W.), Fort-Liberte (19°40'N., 71°51'W.), and Santiago de los Caballeros (19°30'N., 70°42'W.). A destructive tsunami struck the north coast of the island.
- Port-de-Paix -- The sea withdrew 200 feet and upon returning covered the city with 15 feet of water. Two hundred of the city's 3,000 inhabitants were killed by the earthquake and the tsunami.
- Cap Haitien -- Extensive destruction was caused by the earthquake and tsunami. Ref. 16, 48, 53.

- 1853 July 15, Venezuela: Cumana (10°28'N., 64°10'W.) -- A violent earthquake was followed by a tsunami. Ref. 16.
- 1860 April 8, Hispaniola: Earthquake reported from Port-au-Prince and Anse-à-Veau (18°31'N., 73°31'W.).
Golfe de la Gonaves -- Waves were reported.
Anse-à-Veau -- The sea withdrew and broke with a crash on the shore. Ref. 16, 48, 53.
- 1863 -- --, Newfoundland, southeast peninsula: Small tsunami reported. Ref. 19.
- 1867 Dec. 28, Virgin Islands: Epicenter (18°10'N., 65°30'W.).
St. Thomas (18°21'N., 64°55'W.) -- Charlotte Amalie (18°21'N., 64°56'W.) was destroyed by the earthquake and tsunami. The water receded several hundred feet, returned in a wave 15 to 20 feet high, and swamped small boats in the harbor. The wave went 250 feet inland. A second wave was larger than the first.
Both the USS Susquehanna and De Soto were damaged by the wave, the De Soto quite extensively.
Saint Croix (Santa Cruz, 17°45'N., 64°45'W.) -- At Fredericksted (17°43'N., 64°53'W.) the USS Monongahela was thrown "high and dry" and suffered extensive damage.
Christiansted (Bassin) (17°45'N., 64°42'W.) -- Twenty houses were destroyed by the waves.
Tortola (18°27'N., 64°36'W.) -- The sea level sank and then rose 4 or 5 feet above normal sea level, submerging the lower part of the town and sweeping

away most of the smaller houses.

Peter Island (18°22'N., 64°35'W.) and St. Christopher --
A wave was noted.

Saba, Saint Martin, and Ile Saint-Barthelemy (17°45'N.,
62°50'W.) -- Waves did severe damage.

Antigua Island at St. Johns (17°06'N., 61°51'W.) -- The
sea rose 8 to 10 feet in the harbor.

La Guadeloupe (16°15'N., 61°35'W.) -- At Bass-terre
(16°00'N., 61°44'W.) the sea ebbed and flowed twice.
The swell had a 6-foot range in height from trough to
crest.

Deshayes (16°18'N., 61°48'W.) and Sainte-Rose (16°20'N.,
61°42'W.) -- The sea withdrew and returned with a wave
"at least 60 feet high" which broke over the shore and
carried off all floatable objects. In all, three waves
were reported.

La Martinique and Saint Vincent (13°15'N., 61°21'W.) --
A wave was noted.

Bequia Island (13°01'N., 61°13'W.) -- Three waves about
6 feet high were noted.

Grenada (12°07'N., 61°40'W.): St. Georges (12°10'N.,
61°44'W.) -- The water level suddenly sank 4 or 5 feet,
baring the reef in front of the lagoon, and then rose
to the same height. In all, six waves were reported.

Gouyave (12°10'N., 61°44'W.) -- The sea ebbed and flowed
with a range of 20 feet. Some damage was done.

Isla de Vieques (18°08'N., 65°25'W.): Waves struck the island, first from the south and later from the north.

Puerto Rico, Puerto Yabucoa (18°03'N., 65°49'W.) -- The sea retired about 150 yards and then advanced an equal distance over the land.

Playa de Fajordo (18°20'N., 65°38'W.) -- A wave was noted. Ref. 41.

1868 Mar. 17, Puerto Rico: An earthquake and small wave were reported from Playa de Naguabo (18°12'N., 65°43'W.) and Arroyo (17°58'N., 66°04'W.) on the eastern end of the island. Ref. 41, 53.

1872 Nov. 17 New England: "Fluctuations were registered on the tidegauges at North Haven (44°10'N., 68°52'W.) and on the Fox Islands (44°15'N., 68°52'W.) in Penobscot Bay, Maine (44°15'N., 68°55'W.). The fluctuations continued from midnight until nearly six o'clock in the morning, at somewhat irregular intervals of about seventeen minutes from crest to crest, with an average vertical range of nine inches, the greatest wave being at three o'clock, with a height of twenty inches."

"No corresponding earthquake phenomena have come to the knowledge of the Coast Survey Office, and it is probable that if such was the case, the shock occurred somewhere under the Atlantic Ocean." Ref. 30.

1874 Mar. 11, Lesser Antilles: A submarine shock to the southeast of St. Thomas, Virgin Islands shook the island. Shock was

felt on board ships in the harbor. "Simultaneously the water of the bay, then perfectly still, assumed a turbid appearance, as though clouded by mud and sand; and a little later the surface was agitated by a strong ripple from the south lasting some time."

Dominica (15°25'N., 61°20'W.) -- The Captain of the Royal Mail Steamer Corsica reported a succession of heavy rollers in the harbor that lasted for half an hour and rendered all communication with the shore impossible. No shock was felt on board the Corsica. Ref. 34.

1881 Aug. 12, Jamaica: Earthquake felt on the island. A wave was reported from the north coast.

Kingston Harbor (17°57'N., 76°47'W.) -- Water rose about 18 inches. This wave was probably not caused by the same earthquake which was felt on the island. Ref. 15, 52.

1883 Aug. 27 and 28. Atlantic Ocean. Panama: Waves attributed to the explosive eruption of Krakatau in Sunda Strait between Java and Sumatra on the 26th were recorded on tide gages throughout the world. A resume of the tide gage records in the Atlantic is given in Table I. It has been suggested that some, if not all, of the waves recorded in the Atlantic were generated by the passing of the barometric disturbance (airborne shock wave) which had resulted from the explosive eruption

rather than to a tsunami which was propagated through the water. It is also possible that some waves were seiches generated locally by the seismic waves, analogous to those generated in the gulf coast by the Alaskan shock of 27 March 1964. Ref. 10, 12, 13, 24, 55.

1884 Jan. 14. Uruguay: 7:30 A.M. Montevideo ($34^{\circ}53'S.$, $56^{\circ}11'W.$) -- Wave phenomena lasting about 15 minutes inundated part of the town. The weather was fine; the direction of the wave was from the Patagonian coast. Several people were drowned on the south side of the town. Ref. 31.

1887 Sept. 23, Hispaniola: The epicenter was apparently near the eastern end of the Barlett Trough, a short distance southwest of Mole Saint-Nicolas.

Jeremie ($18^{\circ}39'N.$, $74^{\circ}08'W.$) -- The sea withdrew 65 feet and returned with a rush.

Mole Saint-Nicolas, Anse-D'Haiuault ($18^{\circ}30'N.$, $74^{\circ}27'W.$), and Pointe de Tiburon ($18^{\circ}21'N.$, $74^{\circ}24'W.$), as well as other ports -- Waves noted. Ref. 16, 48, 53.

1907 Jan. 14, Jamaica: Earthquake damaged Kingston ($18^{\circ}00'N.$, $76^{\circ}48'W.$) and surrounding territory. Buff Bay ($18^{\circ}00'N.$, $76^{\circ}40'W.$) was destroyed.

Hope Bay ($18^{\circ}12'N.$, $76^{\circ}34'W.$), Orange Bay ($18^{\circ}14'N.$, $76^{\circ}37'W.$), Sheerness Bay ($18^{\circ}18'N.$, $76^{\circ}48'W.$), and Saint Anns Bay -- Waves noted.

Annotto Bay ($18^{\circ}17'N.$, $76^{\circ}47'W.$) -- One observer reported that the sea receded 80 to 100 yards, dropping 10 to 12 feet below normal sea level. The returning wave raised the water level 6 to 8 feet above normal. This

wave swept into the lower portion of the town destroying houses, and "on the higher land it came up 25 to 30 feet." Another observer said it receded 200 feet, falling 20 feet, and came back about the same distance on land, rising 20 feet above its usual level.

Buff Bay (18°14'N., 76°40'W.) -- The sea withdrew some distance from land.

Port Maria (18°22'N., 76°54'W.) -- The sea withdrew 84 feet.

Ocho Rios (18°25'N., 77°07'W.) near St. Anns Bay -- The sea withdrew about 225 feet.

Port Antonia (18°11'N., 76°28'W.) -- The wave moved a small building near the beach.

South coast of Jamaica -- A wave was also reported and a seiche was set up in Kingston harbor. Ref. 52.

1911 Nov. 3-4, Trinidad, British West Indies: Erin Bay (10°04'N., 61°43'W.) -- Some extraordinary sea waves were noticed on the adjacent coast following an explosion which accompanied the formation of a mud volcano island. Ref. 2.

1916 Apr. 25, Panama: Earthquake reported from Bocas del Toro (9°20'N., 82°15'W.) and Almirante (9°18'N., 82°23'W.). Bocas del Toro -- Waves carried debris and canoes 650 feet inland. Ref. 16, 21, 39.

1918 Oct. 11, Puerto Rico: Epicenter about 18°30'N., 67°20'W., magnitude 7.5.

Punta Borinquen Lighthouse (18°29'N., 67°10'W.) -- The wave was 15 feet above mean sea level. In a low area just southwest of the lighthouse the wave washed 300 feet inland.

Punta Agujereada (18°31'N., 67°08'W.) -- Several hundred palms were uprooted, a few small houses were destroyed, and 8 persons were reported drowned. The waves were estimated as being 18 to 20 feet high.

Aguadilla (18°26'N., 67°09'W.) -- The wave reached heights between 8 and 11 feet above sea level. Thirty-four persons were drowned, and 300 huts along the beach were destroyed.

Near the mouth of the Rio Culebrinas (18°24'N., 67°11'W.) -- The waves moved rectangular blocks of limestone weighing over a ton inland and slightly downhill, a distance of 150 to 250 feet. The waves were at least 12 feet high.

North of the Punta Higuero Lighthouse (18°22'N., 67°16'W.) -- The wave uprooted coconut palms and crossed a railroad track 16 feet above sea level, while 0.5 and 1.0 mile southeast of the lighthouse the water rose 9.0 and 8.5 feet.

Mayaguez (18°22'N., 67°16'W.) -- Water entered the lower floors of buildings near the waterfront and destroyed a few native huts. Watermarks on the houses indicated that the water rose from 1.3 to 5.0 feet above sea level.

About 2.2 miles southwest of Mayaguez --

The wave was 4.5 to 5.0 feet high.

Boqueron (18°02'N., 67°10'W.) -- Receding water dropped about 5 feet, and the incoming wave rose about 3 feet above sea level. A half nautical mile southeast, near the entrance to the bay, the water rose about 18 inches. Playa de Ponce (17°59'N., 66°37'W.) Municipal Dock -- Slight movements of the water were reported.

Cayo Cardona (17°58'N., 66°38'W.) -- Water rose 30 inches on the west side of the island.

Light Station on Isla Caja de Muertos (17°58'N., 66°32'W.) -- The wave rose about 5 feet above sea level and covered about 50 feet of beach above the normal shoreline.

Isabela (18°30'N., 67°01'W.) -- The wave rose about 6 feet above normal.

Puerto Aracibo (18°29'N., 66°42'W.) -- The wave was 1 to 2 feet high.

Rio Grande de Aracibo (18°29'N., 66°42'W.) -- A wave about 4 inches high advanced up the river.

San Juan -- No wave was reported.

Near Loiza Aldea (18°26'N., 65°53'W.) -- The water in the Rio Grande de Loiza (18°26'N., 65°53'W.) receded and then rose about 3 feet above normal.

Isla Mona (18°05'N., 67°54'W.) -- On the west coast of the island, the receding water bared the reef. The returning wave was at least 12 feet above sea level.

Hispaniola, Santo Domingo ($18^{\circ}28'N.$, $69^{\circ}45'W.$) -- The water of the Rio Ozama ($18^{\circ}28'N.$, $69^{\circ}53'W.$) fell about 2 feet and then rose to about the same height. The wave had a period of about 40 minutes.

Tortola -- Waves noted.

St. Thomas -- At Charlotte Amalie, the water in the harbor rose about 18 inches.

Krum Bay ($18^{\circ}20'N.$, $64^{\circ}58'W.$) -- The largest wave was about 4 feet high.

New York, Key West, and Colon, Panama -- No waves were recorded on tide gages. Ref. 40, 53.

1918 Oct. 25, Caribbean: Galveston, Texas -- Wave recorded on the tide gage. Ref. 16.

1922 May 2, Caribbean: Epicenter near the Isla de Vieques, Puerto Rico.

Galveston, Texas -- A wave 2 feet high was recorded on the tide gage. Ref. 35.

1924 Aug. 28, Iceland: An earthquake of 10 seconds' duration was felt at Reykjavik ($64^{\circ}09'N.$, $21^{\circ}57'W.$) and Harnfjord" followed by a tidal wave." Ref. 45.

1928 -- --, Newfoundland: Curling ($48^{\circ}58'N.$, $58^{\circ}00'W.$) on the northwest coast of the island -- A small tsunami was reported. Ref. 19.

1929 Jan. 17, Venezuela: Epicenter $10^{\circ}30'N.$, $64^{\circ}30'W.$ Magnitude 6.9. The entire city of Cumana was thrown into ruins by the

earthquake; 50 persons were killed and 800 injured.

The steamer Commewyne off the coast was endangered by a huge wave, and many sailboats were wrecked. Ref. 46.

1929 Nov. 18, The Grand Banks Earthquake, Epicenter 44°00'N., 56°00'W. Magnitude 7.2. Waves reported from Newfoundland, Saint Pierre (46°50'N., 56°19'W) and Miquelon (47°00'N., 56°20'W.), Nova Scotia, the east coast of the United States, Barbados, La Martinique, and the Azores. Newfoundland: Waves caused major destruction along a 50-mile strip of coast between Lamalin (46°52'N., 55°49'W.) near the west end of the Bruin Peninsula (47°00'N., 55°30'W.) and Rock Harbour (47°11'N., 55°03'W.) well up the peninsula on the west side of Placentia Bay (47°00'N., 54°30'W.). The wave which hit this sector of the coast was 15 feet high, building up to heights of 40 to 50 feet at the heads of narrow inlets and harbors. These waves were probably as much due to the heavy gale at sea as to the tsunami. One report from this area states that 27 lives were lost, 32 houses destroyed, 27 badly damaged, and 168 boats destroyed. Property damage was estimated at \$1,000,000. The following is the summary given in the Saint John Free Press issue of November 26, 1929: Lamaline -- One man died of injuries. All stages and stores along the waterfront were swept away.

Point au Gaul (46°51'N., 55°45'W.) -- Eight lives lost; all fishing property, stages, stores, five cod traps, all provisions, about one hundred tons of coal, three dwelling houses, and seventy other buildings gone.

Taylor's Bay (46°53'N., 55°43'W.) -- Four lives lost and fifteen families homeless; all fishing property with provisions and coal swept away.

Lords Cove -- Four lives lost; all fishing property with provisions and coal swept away.

Lawn (46°56'N., 55°33'W.) -- No lives lost. All fishing properties with most of the boats, dories, provisions, and coal lost.

St. Lawrence (46°54'N., 55°24'W.) -- No lives lost; all flakes (fish drying racks) and stores on both sides of the harbor swept away with all provisions and coal.

Corbin Harbour (46°58'N., 55°15'W.) -- Swept clean; no lives lost.

Lance au Lean -- One dwelling house and all fishing gear lost.

Great Burin Harbour (47°00'N., 55°10'W.) -- Swept but no lives lost.

Step-a-side -- All waterside premises gone. No loss of life.

Kelly's Cove, Ship Cove (47°12'N., 55°10'W.), Burin North, and Burin East -- All waterside premises lost or

damaged; no lives lost.

Port au Bras (47°04'N., 55°07'W.) -- Eight lives lost; eleven dwelling houses, fourteen small schooners, all dories and skiffs, provisions, and all waterside premises gone.

Mortier Bay (47°10'N., 55°05'W.) -- No loss of life.

Considerable damage to waterside premises.

Rock Harbour (47°11'N., 55°03'W.) -- Reported swept.

Bay of Islands (49°10'N., 58°15'W.) on the west coast, a sector of coast northwest of Miquelon between 56°20' and 57°00'W. and from Argentic (47°18'N., 54°00'W.) and Placentia Harbor (47°14'N., 53°58'W.) on the east side of Placentia Bay -- Waves were reported.

Salmonier (47°07'N., 53°32'W.) at the head of Saint

Mary's Bay (47°00'N., 53°40'W.) -- The wave was reported as a 6-foot wall of water which caused considerable damage to floating timber.

Saint Pierre and Miquelon: Waves rose about 12 feet; no damage reported.

Nova Scotia: Cape Breton Island (46°10'N., 60°45'W.) and Halifax Harbour (44°37'N., 63°33'W.) -- Waves were reported.

Sydney (46°09'N., 60°10'W.) -- Water rose 5 feet above maximum high tides.

North Sydney (46°12'N., 60°15'W.) -- Over a foot of water covered the docks, and small boats floated into

the town.

The water advanced inland about 200 yards.

Glance Bay (46°12'N., 59°58'W.) and Mulgrave 45°37'N., 61°24'W.) -- Waves reported.

Canso (45°21'N., 61°00'W.) -- A wave about 2 feet in excess of spring high tide damaged fishermen's wharves and carried ashore the 28-ton Schooner Lena M, which was badly damaged and her cargo destroyed.

Sable Island (43°55'N., 59°55'W.) -- No waves recorded.

East Coast of the United States: Waves were recorded on tide gages at various localities along the east coast. In the New England area the records were complicated by waves produced by a severe storm. Press and other reports mention wave phenomena not necessarily attributable to the storm alone.

Boston -- No tsunami-type fluctuations were recorded on the gage, but some flooding occurred in a northern suburb which was attributed to the tsunami.

Bar Harbor (44°26'N., 68°12'W.), Belfast (44°28'N., 69°00'W.), and Portland, Maine (43°20'N., 70°34'W.) -- Waves reported.

Exeter, N.H. (42°58'N., 70°57'W.), Barnstable, Mass. (41°42'N., 70°18'W.), and Block Island, R. I. (41°10'N., 71°35'W.) -- High tides reported.

Ocean City, Md. (38°20'N., 75°05'W. -- The tide gage recorded a change of approximately 0.9 foot.

Bermuda: Flatts Village (32°19'N., 64°44'W.) -- A dredging plant was violently disturbed. The wave broke the mooring chains of the dredger. This was probably a storm surge, not a tsunami.

A summary of tide gage records is given in Table II.

La Martinique: La Trinite (14°44'N., 60°58'W.) -- Waves were reported. Ref. 8, 11, 14, 16, 19, 25, 42.

1932 Feb. 3, Cuba: Epicenter on the north side of the Bartlett Trough.

Santiago de Cuba -- Small wave was reported to have occurred at the time of the quake. Ref. 17.

1934 June 2, Iceland: Epicenter 66°00'N., 18°15'W., Intensity VIII-IX M. C.* Scale, Magnitude 6 1/4. Dalrik (65°58'N., 18°32'W.) and Eyjafjardhar (65°54'N., 18°15'W.) -- the shock caused considerable damage within 3/5 of a mile of the epicenter. Ships in the neighborhood experienced a powerful blow as if they had suddenly grounded, and an unusual wave disturbance was noted. Ref. 7.

1946 Aug. 4, Hispaniola: Epicenter 19°30'N., 69°00'W. Villa Julia Molina (19°23'N., 69°50'W.) -- The wave, which was estimated as being 12 to 15 feet high, caused very little damage.

Matanzas (18°14'N., 70°25'W.) -- The town was so damaged by the wave that it was abandoned. Approximately 100 persons were killed. The rise of the water probably

* Mercalli-Cancani

did not exceed 8 feet.

Cabo Samana (19°18'N., 69°09'W.) -- Several ebbs and flows were noted; no damage was done by the wave.

The tsunami was recorded on the following tide gages:

<u>Locality</u>	<u>Travel Time</u>
San Juan	0 h 36 m
Bermuda	2 h 07 m
Daytona Beach	3 h 59 m
Atlantic City	4 h 49 m

On the 8th of August an aftershock of the August 4th shock caused a tsunami which was recorded on the following tide gages:

<u>Locality</u>	<u>Travel Time</u>
San Juan	0 h 35 m
Bermuda	2 h 02 m
Daytona Beach	4 h 02 m
Atlantic City	4 h 42 m

Ref. 4, 16, 23.

1954 Oct. .., Southeast Greenland: Aputiteq Point (65°57'N., 35°53'W.) --

A "tidal wave" about 50 or 60 feet above normal sea level demolished the crane and the rails used for hauling the supplies to the stores, as well as several of the boats which could not be brought to safety. Ref. 18.

1955 Jan. 18, Venezuela: La Vela (11°27'N., 69°34'W.) -- A wave was

reported, four ships were wrecked, and a number of

waterfront buildings were damaged. No casualties were reported. The U.S.C.&.G.S. lists no earthquakes in the Atlantic on this date. Ref. 47.

1964 Mar. 27, Gulf of Mexico: Epicenter in northern Prince William Sound, Alaska, at $61^{\circ}06'N.$, $147^{\circ}04'W.$ (March 28, 03:36:12.7 G.M.T.). Magnitude 8.5. Tsunamis were reported from most sectors of the Pacific. Seiches were set up in the Gulf of Mexico and in many lakes in the United States.

Texas and Louisiana -- Waves with amplitudes up to 6 feet were reported from some locales.

Freeport, Texas -- Tide gage records at about 3:50 G.M.T., 28 March showed waves with periods close to those of the seismic surface waves, maximum height about 7 inches. Ref. 10, 24.

PART II

TSUNAMIS AND SEICHES REPORTED FROM THE COASTAL WATERS
OF NORTHWESTERN EUROPE BETWEEN 842 AND 1950

- 842 Oct. 24, Channel Islands (49°30'N., 02°30'W.) and northern France: Local earthquake. The shock "threw down the monuments... and also engulfed the seashore of the neighboring continent." Ref. 28.
- 1099 Nov. 11, Southwestern England: St. Michaels' Mount (50°07'N., 05°29'W.) -- "The sea overflowed the shore, destroying towns and drowning many persons and innumerable oxen and sheep." Ref. 9
- 1134 Oct. 1, Southern North Sea: The sea inundated the coast of England and Netherlands. Ref. 26.
- 1571 Nov. 1, Holland: No local shock mentioned. A disastrous inundation occurred on the coast of Holland. Ref. 26.
- 1580 Apr. 6, English Channel: Epicenter, probably submarine, near the east coast of Kent. Sandwich (51°16'N., 01°21'E.) and Dover (51°08'N., 01°18'E.) -- Sea much agitated. Vessels in the harbors were dashed together. Ref. 26, 32.
- 1609 Jan. 19, England: No shock mentioned. An extraordinary flux and reflux of the tide occurred on the River Thames. Ref. 26.
- 1640 Apr. 4, Holland: Three shocks were felt. The inside waters of Holland were much disturbed. Ref. 16, 26.

1755 Nov. 1, Western Europe and the Caribbean: An earthquake destroyed Lisbon at about 9:40 a.m. Two types of water disturbances were caused by the shock, namely, seiches, which occurred very shortly after the actual shock, and tsunamis, which arrived later.

SEICHES

France: Bordeaux -- The water of the Garonne was greatly agitated. LeHavre -- Wave noted.

British Isles: Portsmouth (50°46'N., 01°05'W.) -- Waves noted 10:35 a.m. and ships rolled and pitched in the dockyard.

Yarmouth (50°42'N., 08°28'W.) -- Sea rose 6 feet a little before noon.

Cork (51°54'N., 08°28'W.) -- Sea was much agitated.

River Thames -- Small waves, like those caused by the launching of a ship, were reported between 11 a. m. and 12 noon.

Lincolnshire (53°10'N., 00°20'W.) and Norfolk (52°40'N., 01°00'E.) -- Waves noted about noon.

Kingston upon Hull (52°42'N., 00°20'W.) -- A wave was reported to be 6 feet high.

Hunstanton (52°57'N., 00°30'E) -- Several people were endangered by the motion of the water.

Firth of Forth -- Agitation of the water was noted at Queen's Ferry (55°59'N., 03°24'W.) at about 10 a.m. The water

rose suddenly and returned again about 12 to 18 inches.

Orkney Islands (59°00'N., 02°00'W.) -- Tides were observed to be much higher than ordinary.

Holland and Friesland (52°40'N., 07°00'E.): -- Waves noted about 11 a.m. Vessels were dashed together by the waves, and moorings were broken.

Many of the lakes in the British Isles, in the Alps, in Germany, and in southern Scandinavia were disturbed, as were some of the fiords in Norway and lochs in Scotland.

Finland: Aurjoki River at Turku (60°26'N., 22°17'E.) -- Waves noted about 12:00 noon.

TSUNAMIS

Great Britain:

Mounts-Bay (50°05'N., 05°29'W.) -- 5- to 6-foot waves were noted a little after 2:00 p.m.

Penzance pier (50°08'N., 05°33'W.) -- The first reflux was observed at 2:45 p.m.; the greatest rise was 8 feet. Activity lasted about 3 hours.

Newlyn pier (50°06'N., 05°33'W.) -- The wave rose 10 feet.

Mousehole (50°05'N., 05°32'W.) -- Activity similar to that at Newlyn.

Hayle (50°11'N., 05°23'W.) -- Waves noted about 3 p.m. The greatest surge was about 7 feet high.

St. Ives (50°12'N., 05°30'W.) -- Waves noted.

Creston, a mile southeast of Plymouth (50°24'N., 04°07'W.) --

At about 5 p.m., the water receded, dropping the level 4 or 5 feet; the returning wave was about 2 feet above normal. Several ships were broken from their moorings. The disturbance lasted more than a half hour. The wave period seems to have been about 10 minutes.

Dartmouth (50°21'N., 03°35'W.) -- Waves noted.

Kinsale Harbor (51°40'N., 08°30'W.) in Ireland: Between 3 and 4 p.m., the water came over the quay with such violence as to throw many people down.

Swansea (51°38'N., 03°58'W.) in Wales, near the mouth of the Bristol Channel -- Wave noted at about 6:45 p.m.

Ref. 1, 16, 26, 27, 36, 38, 43, 44, 54.

1755 Nov. 5, England: No shock mentioned.

Saltholm near Hartlepool (54°41'N., 01°11'W.) in

Durham -- A 3-foot wave caused some damage. Ref. 26.

1756 Feb. 27, England: No shock mentioned.

Ilfracombe (51°13'N., 04°07'W.) -- The water retired, suddenly emptying the quay. The returning wave filled the quay to a height of 6 feet. Ref. 26, 37.

1757 July 15 England: Earthquake felt in the Scilly Islands (49°55'N., 06°20'W.) and Cornwall.

St. Just (50°07'N., 05°42'W.) -- Waves noted. Ref. 26.

1760 Jan. 21, Germany and Denmark: Earthquake felt at Hamburg and Copenhagen.

Helsingor (56°02'N., 12°37'E.) -- Wave noted. Ref. 26.

1761 Mar. 31, Europe and the Caribbean: Possibly more than one earthquake occurred on this date. Shock was felt at Cork, at 12:15 p.m. by ships at sea off Cabo Finisterre in northwestern Spain (42°53'N., 09°16'W.), and in the vicinity of Lisbon about noon.

Cabo Finisterre -- An extraordinary flux and reflux of the sea occurred at about 12:15 p.m.

Amsterdam -- The vessels in the harbor were much agitated.

Kinsale Harbor (Ireland) -- At low water about 5:30 or 6:00 p.m. the sea suddenly rose 2 feet and then retired in about 4 minutes. This event occurred several times.

Carrick (52°14'N., 06°44'W.) -- The waters of the River Suir rose at about 4 p.m. 4 feet in 5 minutes.

Dungarvan Harbor (52°04'N., 07°34'W.) -- Five ebblings and flowings of the sea were observed in 5 hours (4 to 9 p.m.).

Rosslare (52°17'N., 06°23'W.) in County Wexford -- Waves noted on the river about 7 p.m.

Waterford (52°15'N., 07°06'W.) -- The sea advanced 30 feet on the shore.

Mount's-Bay in Cornwall -- About 5 p.m. five 6-foot waves noted in one hour.

Scilly Isles -- About 5 p.m. the sea rose 4 feet; the motion lasted 4 hours.

Fort Augustus in Scotland -- About 2 p.m. the waters of Loch Ness rose and fell about 2 - 2 1/2 feet for about three-quarters of an hour.

- West Indies: Barbados -- See Part I, March 31, 1761.
Ref. 5, 16, 26.
- 1761 July 28, England: No shock mentioned. Mount's-Bay, Falmouth (50°09'N., 05°05'W.), Fowey (50°20'N., 04°38'W.), and Plymouth -- Waves noted. Ref. 6, 26.
- 1761 Aug. 14 English Channel: Earthquake felt in Guernsey (49°27'N., 02°36'W.). A violent swell of the sea set in from the west. Ref. 28.
- 1762 May 26, Norway: No earthquake mentioned. Bergen -- Violent ebb and flow of the sea noted. Ref. 26.
- 1762 Sept. 27, England: No shock mentioned. The Thames rose 10 feet and fell back as suddenly. Ref. 26.
- 1763 Sept. 18 England: No shock mentioned. Weymouth -- The sea rose 10 feet and fell back as suddenly. Ref. 26.
- 1764 Feb. 11 England: No shock mentioned. Bristol and Bristol Channel -- Irregularities were observed in the tides on the Severn. Ref. 54.
- 1765 July 23 Sweden: Both an earthquake and a storm reported from the vicinity of Pitea (65°20'N., 21°32'E.) in Vaster Botten (West Bothnia), Sweden, out of Lulea. More than twenty 3- or 4-foot fluctuations of the sea occurred in a short period. Ref. 26.
- 1767 Sept. 5 Ireland: No earthquake mentioned. The sea at Ostend and the Liffey at Dublin ebbed and flowed suddenly and violently to the extent of 4 or 5 feet. Ref. 26.
- 1767 Nov. 28 England: No earthquake mentioned. London -- The water ebbed and flowed twice in an hour and a half. Ref. 26.

- 1777 Nov. 14 Sweden: Earthquake felt at Sundsvall ($62^{\circ}23'N.$, $17^{\circ}18'E.$).
Vasternorrland -- The shock was succeeded by a sudden
reflux of the sea, which caused the river flowing
through the town to inundate its banks. Ref. 26.
- 1778 Mar. 4 Baltic Sea: No shock mentioned. An extraordinary rise
of the waters of the Baltic was observed. Ref. 26.
- 1788 July 8 Irish Sea: Earthquake on the Isle of Man. On the same
day the sea suddenly receded at Dunbar. Ref. 26.
- 1792 May 21 Holland: No shock mentioned. Zandvoort ($52^{\circ}22'N.$,
 $04^{\circ}32'E.$) -- A sudden fluctuation of the sea noted.
Ref. 26.
- 1798 -- -- England: No shock mentioned. A violent and unusual
motion of the sea on the English coast. Ref. 26.
- 1819 Aug. 31 Norway: Local earthquake at Hemnes ($66^{\circ}14'N.$, $13^{\circ}39'E.$) --
The sea became much agitated as in the most violent
tempest. Ref. 26.
- 1825 Jan. 3, Denmark: No earthquake mentioned. Copenhagen -- The
sea rose and fell in an unusual way. Ref. 26.
- 1830 Jan. 10 Holland: No shock mentioned. The sea rose suddenly
to an unusual height and caused considerable damage
to the dikes. Ref. 26.
- 1883 Aug. 27 Atlantic Ocean, English Channel: Waves attributed to
and 28 the explosive eruption of Krakatau in the Sunda Strait
between Java and Sumatra on the 26th were recorded on
tide gages throughout the world. A résumé of the tide
gage records in the Atlantic is given in Table II. See
Part I, August 27 and 28, 1883.

- 1894 Nov. 21 Ireland: Large waves, possibly caused by submarine volcanic activity in the vicinity of 49°00'N., 34°30'W., were reported from several locales in the Atlantic. Off the west coast of Ireland at 53°09'N., 09°52'W., the ship S.S. Diamond lying-to awaiting daylight to enter port, reported that the wave was heard some time before it was seen and then seemed to be about 40 feet high. The vessel never rose to it but was literally submerged for a time. Ref. 33, 51.
- 1920 Dec. 16 Norway: An earthquake (Mag. 8.4), which occurred in the Kansu Province of China, was recorded at Bergen, Norway at 12:34 p.m. About 12:40 p.m. unusual waves, which were thought by some to have been caused by the Kansu shock, were observed in at least four localities in western Norway.
- Romarheim (60°44'N., 05°39'E.) -- Waves with amplitudes of about 8 inches were seen moving slowly across the fiord.
- Skjeljanger Fyr (60°36'N., 04°57'E.) -- The sea rose 30 inches above high tide.
- Nordfjordeid (61°54'N., 06°01'E.) -- A wave with an amplitude of about 6 inches was observed. Ref. 20, 22.
- 1926 July 30 English Channel: Earthquake felt throughout southern England and northern France.
- Channel Islands -- Small wave noted. Ref. 28.
- 1950 Aug. 15 Norway and England: P waves were recorded at Bergen at 14 h. 20 m. 2 s. G.M.T. Unusual waves were observed

in at least 37 localities in fiords and lakes in Norway at about 14:50 - 15:00 G.M.T. and from reservoirs at Margate ($51^{\circ}23'N.$, $01^{\circ}25'E.$), Portsmouth, and Chichester ($50^{\circ}50'N.$, $00^{\circ}47'W.$) in England at about 14:40 - 15:05 G.M.T. The waves generated in Norway ranged in maximum amplitude from 1 to about 40 inches, and in period from about 1 to 3 minutes. Specific wave heights and the locales affected in Norway are given in Table III. Ref. 22, 24.

References

1. Affleck, Capt., 1809, On the Agitation of the Sea at Antigua:
Nov. 1, 1755: Royal Soc. London, Philos. Trans., Abridged
v. 11, p. 9-10.
2. Arnald, R., and Macready, G. A., 1956, Island-Forming Mud
Volcano in Trinidad, British West Indies: Bull. American
Assoc. Petrol. Geol., v. 40, no. 11, p. 2756.
3. Berninghausen, Wm. H., 1964, Tsunamis and Seismic Seiches
Reported from the Eastern Atlantic South of the Bay of
Biscay: Seismol. Soc. America Bull., v. 54, no. 1,
p. 439-442.
4. Bodle, Ralph R. and Murphy, Leonard M., 1948, Tidal Distur-
bances of Seismic Origin: United States Earthquakes 1946,
U. S. Coast and Geodetic Survey, Washington, U. S. Govt.
Print. Off., Serial No. 714, p. 23.
5. Borlase, Rev. W., 1809, On the Extraordinary Agitation of the
Waters in Mounts Bay, and Other Places, March 31, 1761:
Royal Soc. London Philos. Trans. Abridged v. 11, p. 601-604.
6. -----, 1809, Of a Remarkable Agitation of the Sea,
July 28, 1761.... : Royal Soc. London Philos. Trans.
Abridged, v. 11, p. 621-623.
7. British Admiralty, 1942, Naval Intelligence Division, Geograph.
Handbook Series B. R. 504, Iceland, p. 33.

References (Cont't)

8. Commission Pour l'Etude des Raz de Maree, 1931, Union Geod. Geophy. Internat., Annales, Comm. Pour l'Etude des Raz de Maree, no. 1, p. 64-66.
9. de Beer, Sir Gavin, 1960, Iktin: Geog. Jour., Royal Geog. Soc. London, v. 126 part 2, p. 162.
10. Donn, Wm. L., 1964, Alaskan Earthquake of 27 March 1964: Remote Seiche Stimulation; Science, v. 145, no. 3629, p. 261-262.
11. Doxsee, W. W., 1948, The Grand Banks Earthquake of November 18, 1929: Publications of the Dominion Observatory, Ottawa, v. 7, no. 7, p. 323-335.
12. Evans, F. J., and Wharton, W. L., 1888, On the Seismic Sea Waves Caused by the Eruptions of Krakatoa, Part III of "The Eruption of Krakatoa and Subsequent Phenomena": Royal Soc. London, p. 89-150.
13. Ewing, M. and Press, F., 1953, Tide Gauge Disturbances from the Great Eruption of Krakatoa: Trans. Amer. Geophys. Union, v. 36, no. 1, p. 53-60.
14. Gregory, J. W., 1931, The Earthquake off the Newfoundland Banks of 18 November 1929: Geog. Journ., Royal Geog. Soc. London, v. 77, no. 2, p. 123-234.
15. Hall, Maxwell, 1907, The Great Earthquake of January 14th 1907: Third Report of Earthquakes in Jamaica, Special issue of the Weather Report, No. 337, Govt. Print. Off. Kingston, Jamaica.

References (Con't)

16. Heck, N. H. 1947, List of Seismic Sea Waves: Seismol. Soc. America Bull., v. 37, no. 4, p. 269-286.
17. Hess, H. H., 1932, Interpretation of Gravity Anomalies and Sounding Profiles obtained in the West Indies by the International Expedition to the West Indies in 1932: Trans. Amer. Geophys. Union, v. 13, p. 26-33.
18. ICAO (International Civil Aviation Organization), 1955, ICAO Meteorological Stations in Greenland: ICAO Bull., v. 10, No. 7, p. 7-11.
19. Keith, Arthur, 1930, The Grand Banks Earthquake: Earthquake Notes, Supplement to the Proceedings of the 1930 Meeting, Wash., D. C., Eastern Sect. Seismol. Soc. America, v. 2, no. 2, p. 1-5.
20. Kilderup, Niels-Henr., 1935, Le Raz de Maree du 16 Decembre 1920: Annales de la Commission Pour l'Etude des Raz de Maree, Internat. Union Geod. Geophys., no. 5, p. 32-33.
21. Kirkpatrick, R. Z., 1920, Earthquakes in Panama up to January 1, 1920: Seismol. Soc. America Bull., v. 10, no. 2, p. 121-128.
22. Kyale, Anders, 1935, Seismic Seiches in Norway and England During the Assam Earthquake of August 15, 1950: Seismol. Soc. America Bull., v. 45, no. 2, p. 93-113.
23. Lynch, Joseph H., Bodle, Ralph R., 1948, The Dominican Earthquakes of August 1946: Seismol. Soc. America Bull., v. 38, no. 1, p. 1-18.

References (Con't)

24. McGarr, Arthur, 1965, Excitation of Seiches in Channels by
Seismic Waves: Jour. Geophys. Research, v. 70, no. 4,
p. 847-854.
25. McIntosh, D. S., 1930, The Acadian-Newfoundland Earthquake:
Nova Scotia Inst. Sci. Trans., v. 17, pt. 4, p. 213-222.
26. Mallet, Robert and Mallet, John Wm., 1858, Earthquake Cata-
logue of the British Association: British Assoc. Advance.
Sci. Trans. 1852 to 1858, Reports 3 and 4, Taylor and
Francis, London.
27. Mason, A., 1809, On the Extraordinary Agitation of the Sea at
Barbadoes, March 31, 1761: Royal Soc. London Philos.
Trans., Abridged, v. 11, p. 614-615.
28. Mourant, A. E., 1931, Earthquakes of the Channel Islands, and
Neighbouring Countries: Societe Jersaise (Pub. in Jersey),
p. 50.
29. Mukherjee, S. M., 1955, Lisbon Earthquake of 1 November 1755:
Indian Jour. of Meteorol. and Geophys., v. 6, no. 2,
p. 149-158.
30. Nature, 1873, Earthquake Waves: Nature, v. 7, p. 385.
31. Nature, 1884, v. 29, p. 437.
32. Nature, 1936, British Earthquake of April 6, 1580: Nature,
London, v. 138, p. 472.
33. Neumann Van Padang, M., 1938, Über die Unterseevulkan der
Erde: Ingenieur in Nederl. Ind., Batavia, v. 5, no. 5,
p. 76.

References (Con't)

34. Palgrave, W. G., 1874, Earthquake in St. Thomas: *Nature*, v. 9, p. 483-484.
35. Parker, W. E., 1922, Unusual Tidal Registration of Earthquake: *Seismol. Soc. America Bull.*, v. 12, no. 1, p. 28-30.
36. Perrey, Alexis, 1847, Sur Les Tremblements De Terre Aux Antilles: *Memoires De L'Academie Des Sciences, Artes Et Belles-Lettres De Dijon, Annees 1845-1846*, p. 325-392. (In French).
37. Prince, The Rev. Mr., 1809, Of an Unusual Agitation of the Sea, at Ildfracombe, in Devonshire, February 27, 1756: *Royal Soc. London Philos. Trans. Abridged*, v. 11, p. 7.
38. Reid, H. F., 1914, The Lisbon Earthquake of November 1, 1755: *Seismol. Soc. America Bull.*, v. 4, no. 2, p. 53-80.
39. Reid, Harry F., 1917, Note on the Earthquakes at Almirante, Republic of Panama in April 1916: *Seismol. Soc. America Bull.*, v. 7, no. 1, p. 27-30.
40. Reid, Harry F. and Taber, Stephen, 1919, The Porto Rico Earthquake of 1918: Report of the Earthquake Investigation Commission, 66th Cong. 1st. Sess. House Document no. 269, Washington, U. S. Govt. Print. Off., p. 27-31.
41. Reid, Harry F. and Taber, Stephen, 1920, The Virgin Island Earthquakes of 1867 and 1868: *Seismol. Soc. America Bull.*, v. 10, no. 1, p. 9-30.
42. Romer (no initials given)., 1932, Raz de Maree et Marees de Tempete a La Martinique du XVII Siecle a Nos Jours: *Union Geod. Geophys. Internat., Comm. Pour l'Etude des Raz de Maree Annales*, no. 2, p. 136-141.

References (Con't)

43. Royal Society of London, 1809, Philosophical Transactions,
Abridged: v. 10, (from 1750 to 1755), p. 646-655.
44.,
v. 11, (from 1755 to 1763), p. 7 and p. 138.
45. Seismological Society of America, 1924, Seismological Notes:
Seismol. Soc. America Bull., v. 14, no. 3, p. 214.
46. Seismological Society of America, 1929, Seismological Notes:
Seismol. Soc. America Bull., v. 19, no. 1, p. 55.
47. Seismological Society of America, 1955, Seismological Notes:
Seismol. Soc. America Bull., v. 45, no. 2, p. 160.
48. Scherer, J., 1912, Great Earthquakes in the Island of Haiti:
Seismol. Soc. America Bull., v. 2, no. 3, p. 161-180.
49. Sloane, Hans, 1809, A Letter from Hans Sloane, M. D. and
S. A. S., with General Accounts of the Earthquakes in Peru,
Oct. 20, 1687, and at Jamaica, Feb. 19, 1687-8, and Jan.
7, 1692: Royal Soc. London Philos. Trans., Abridged
v. 3, p. 624-632.
50. Southey, Capt. Thomas V., 1827, Chronological History of the
West Indies: Longman, Rees, Orme, Brown and Green, London
v. 2, p. 407, 422 and 472.
51. Stromeyer, C. E., 1895, Abnormal Atlantic Waves: Nature,
London, v. 51, p. 437-438.
52. Taber, Stephen, 1920, Jamaica Earthquakes and the Bartlett
Trough: Seismol. Soc. America Bull., v. 10, no. 2,
p. 55-89.

References (Con't)

53. Taber, Stephen, 1922, The Great Fault Troughs of the Antilles:
Jour. Geology, v. 30, p. 89-114.
54. Tucker, Josiah, 1809, Of a Remarkable Tide at Bristol: Royal
Soc. London, Philos. Trans. Abridged, v. 12, p. 109.
55. Verbeek, M., 1886, Krakatau: Batavia, Imprimerie de l'Etat.
p. 396-461, (In French).
56. Winthrop, Prof., 1809, Of the Earthquake Felt in New England,
and the Neighboring Parts of America, Nov. 18, 1755: Royal
Soc. London, Philos. Trans., Abridged v. 11, p. 62-63.

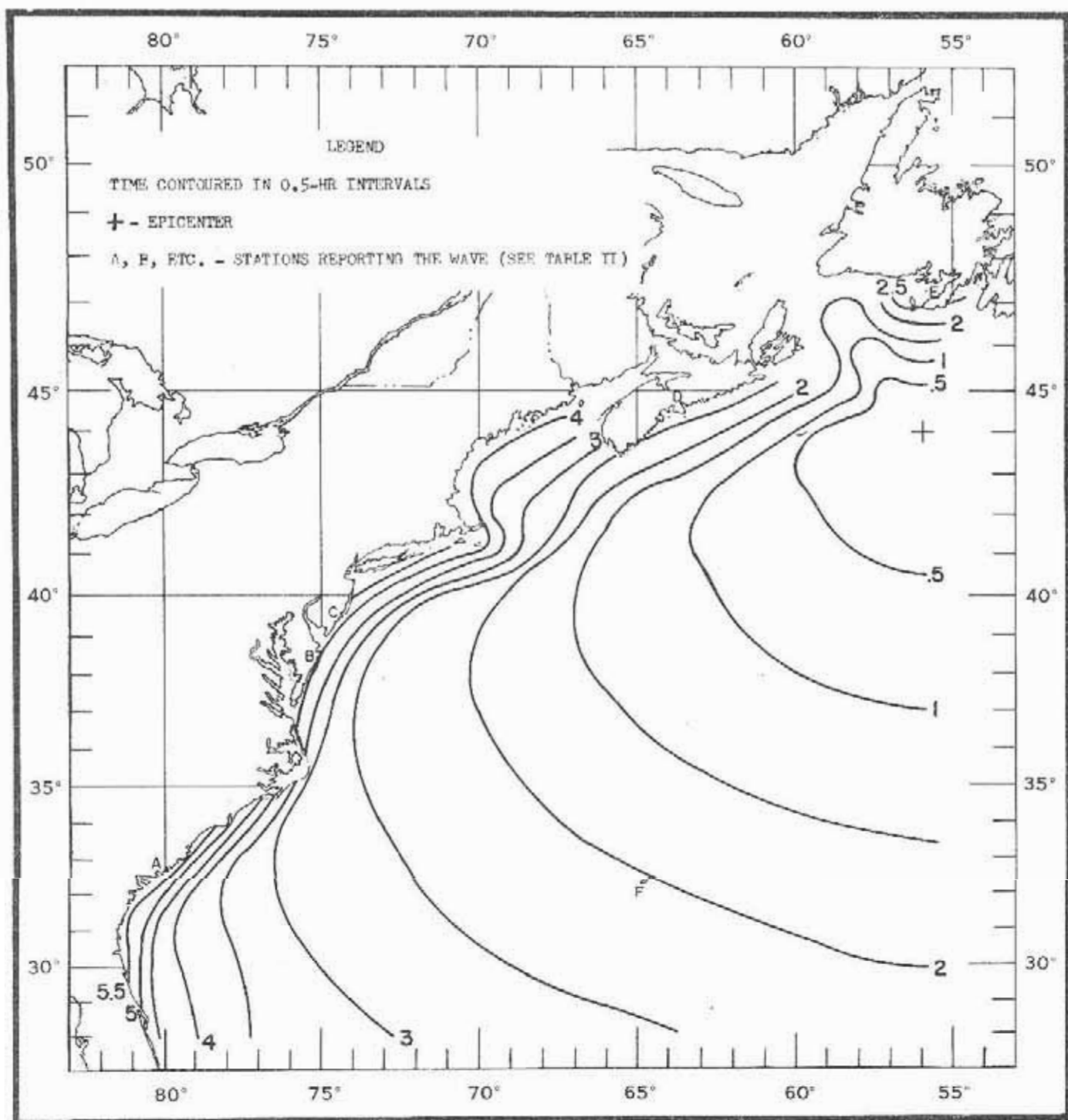


FIGURE 1 TRAVEL TIME CHART FOR TSUNAMI OF 18 NOVEMBER 1929

TABLE I TIDE GAGE RECORDS OF KRAKATAU WAVE
IN THE ATLANTIC

Location	Latitude	Longitude	Distance from Krakatau (Nautical miles)	Commence- ment of disturbance G.M.T. (day/hr/min)	First great wave G.M.T. (day/hr./min)	Height above normal (in.)	Height of max. wave (in.)
Krakatau	06°06'S.	105°25'E.	...	27/02/58	...	...	...
Cape Horn							
Bahia Orange	55°32'S.	68°01'W.	via Pacific 7,520 via Indian 7,818	27/18/52	29/09/29	5	5
South Georgia							
Port Moltke	54°31'S.	35°54'W.	6,676	27/16/27	27/16/55	5	7
Panama							
Colon	09°22'N.,	79°54'W.	11,470	...	27/21/50	7	...
Europe							
Socra	43°24'N.	01°39'W.	10,900	27/05/52	28/04/57	2	3
Rochefort	45°56'N.	00°59'W.	10,900	28/07/44	28/09/24	2	3
Devonport	50°22'N.	04°11'W.	11,040	28/06/20	28/10/45	4	4
Cherbourg	49°39'N.	01°39'W.	11,096	28/09/26	28/09/26	1	2
Portland	50°33'N.	02°26'W.	11,097	...	26/10/15	1	1
LaHavre	49°30'N.	00°08'E.	11,160	28/11/33	28/11/33	1/2	1

TABLE II

Observed and computed travel times for tsunami of 18 November 1922

Time of earthquake 2032 G.M.T., epicenter 44°00'N., 56°00'W.

Location	Latitude	Longitude	Time of arrival G. M. T.	Observed travel time	Approximate distance (nautical miles)	Approximate rate of travel (nautical miles/hour)	Computed travel time	Time difference (Computed minus observed)
A. Charleston, South Carolina	33°47'N.	79°57'W.	2624*	5h 52m	1320	226	5h 44m	-8 m
B. Ocean City, Maryland	38°20'N.	75°05'W.	2420*	3h 48m	915	241	3h 47m	-1 m
C. Atlantic City, New Jersey	39°22'N.	74°26'W.	2450*	4h 18m	880	204	4h 25m	+7 m
D. Halifax, Nova Scotia	44°37'N.	63°33'W.	2330**	2h 58m	330	111	2h 56m	-2 m
E. Burin, Newfoundland	47°03'N.	55°11'W.	2255**	2h 23m	185	78	2h 30m	+7 m
F. Bermuda	32°18'N.	64°45'W.	2330**	2h 58m	780	265	2h 04m	-54 m

* Arrival time based on tide gage records

** Approximate arrival time

Table III

Locations, Periods, and Amplitudes of Seiches
Reported in Norwegian Waters, 15 August 1950

	<u>Locality</u>	<u>Observed Period (minutes)</u>	<u>Maximum Amplitude (Inches)</u>
1.	Jektvikosen (65°18'N., 12°51'E.)	ca. 1	16
2a.	Lake W of Kløftfjellet (65°07'N., 13°04'E.) .....	...	1-2
2b.	Same, Another observer .....	...	4
3.	Byneset (63°23'N., 10°09'E.)	ca. 1.5	22
4.	Riksem (62°21'N., 06°34'E.) .....	...	ca. 40
5.	Stranda (62°19'N., 06°54'E.)	ca. 1	25
6.	Sløgstad (62°19'N., 06°54'E.) .....	...	ca. 40
7.	Ukshag (62°17'N., 06°58'E.) .....	...	ca. 40
8.	Sylte (62°18'N., 07°18'E.) .....	...	...
9.	Fjørå (62°18'N., 07°19'E.) .....	...	...
10.	Geiranger (62°06'N., 07°12'E.) .....	...	...
11.	Innvik (61°51'N., 06°38'E.)	few sec.	ca. 8-12
12.	Saela (61°30'N., 05°42'E.) .....	...	6-8
13.	Slinde (61°10'N., 06°55'E.)	ca. 1	ca. 20
14.	Årdalstangen (61°14'N., 07°44'E.) .....	...	ca. 4-3
15.	Reknesvåg (60°50'N., 05°20'E.) .....	...	×6
16.	Haugsdal (60°51'N., 05°31'E.)	ca. 2	×6
17.	Eidsheimsvag (60°40'N., 05°25'E.) .....	...	...
18.	Askelandsvag (60°39'N., 05°26'E.)	ca. 1-1.5	9
19.	Hjemvik (60°41'N., 05°39'E.)	ca. 1	ca. 20
20a.	Tyssen (60°38'N., 05°53'E.)	ca. 1-2	ca. 10

Table III (continued)

<u>Locality</u>	<u>Observed Period (minutes)</u>	<u>Maximum Amplitude (Inches)</u>
20b. Same, Another observer .....	...	10
21. Stensvik (60°18'N., 05°19'E.)	1-2	12
22. Utskot (60°18'N., 05°19'E.)	1-2	ca. 20
23. Sundvor (60°04'N., 05°48'E.) .....	...	ca. 4-8
24. Indrevågen (60°03'N., 05°46'E.) .....	...	...
25. Sunnfjord (60°02'N., 05°48'E.) .....	...	...
26. Nesbjør (60°04'N., 05°44'E.) .....	...	...
27. Klinkholmen (59°58'N., 05°26'E.) .....	...	...
28. Toftevåg (59°48'N., 05°44'E.) .....	...	...
29. Porsmyr (60°25'N., 06°14'E.) .....	...	ca. 20
30. Vikane (60°26'N., 06°42'E.)	ca. 1	ca. 30
31. Kvandal (60°27'N., 06°36'E.) .....	...	...
32. Bognstrand (60°30'N., 07°00'E.)	15-20 sec?	ca. 12
33. Odda (60°04'N., 06°33'E.) .....	...	...
34. Hatleskårvatn (59°30'N., 06°15'E.)	ca. 0.5	ca. 20
35. Gauselbukt (58°55'N., 05°44'E.)	few sec.	2-4
36. Bottsvatn (59°21'N., 07°13'E.)	1-3	4
37. Rønsjøen (62°12'N., 12°10'E.) .....	...	4-8

The place names used in this listing are those recommended by the U. S. Board on Geographic Names; hence, they may differ in spelling from the form given in the original document.

DOCUMENT CONTROL DATA - R & D

Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified

1. ORIGINATING ACTIVITY (Corporate author)		2a. REPORT SECURITY CLASSIFICATION	
Naval Oceanographic Office Washington, D.C.		Unclassified	
3. REPORT TITLE		2b. GROUP	
TSUNAMIS AND SEISMIC SEICHES REPORTED FROM THE WESTERN NORTH AND SOUTH ATLANTIC AND THE COASTAL WATERS OF NORTHWESTERN EUROPE			
4. DESCRIPTIVE NOTES (Type of report and inclusive dates)			
Informal Report (IR No. 68-85)			
5. AUTHOR(S) (First name, middle initial, last name)			
William H. Berninghausen			
6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF PAGES	
August 1968	50	56	
8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S)		
none	IR No. 68-85		
b. PROJECT NO.	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)		
none	none		
c.			
d.			
10. DISTRIBUTION STATEMENT			
This document is subject to special export controls and each transmittal to foreign governments or foreign nationals may be made only with prior approval of the Naval Oceanographic Office.			
11. SUPPLEMENTARY NOTES		12. SPONSORING MILITARY ACTIVITY	
none		Naval Oceanographic Office	
13. ABSTRACT			
<p>Fifty-four tsunamis which have been reported from the western North and South Atlantic Oceans between 1530 and 1964 are included in Part I. These tsunamis have been most frequent in the seismically active regions around the eastern Caribbean. Tsunamis have also been reported in other parts of the area from South Georgia and Cape Horn to Iceland. Thirty-five tsunamis reported from the coasts of northern and western Europe between 842 and 1950 are listed in Part II. This list contains data on the majority of waves of seismic origin in northwest Europe from Cabo Finisterre on the northwestern tip of Spain to northern Scandinavia.</p>			

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Tsunamis Western North Atlantic Western South Atlantic South Georgia						