

SECTION A – Natural Hazards: Analysis, Vulnerability, Forecasting and Warning

1 CARIBBEAN TSUNAMIS: AN INITIAL HISTORY

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ABSTRACT

Reports of 50 tsunamis of varying certainty are listed for the Caribbean beginning with an event off the coast of Venezuela in 1530. Fifteen of these have reports of damage associated with them and six have reported fatalities. As a thoroughly researched history for the region has not been done, these numbers are approximate and probably low. The author has just learned of but not yet seen, a paper on Caribbean tsunamis by Myrtle Thorm and Compton Deane at the Civil Engineering Department, University of the West Indies, St. Augustine, Trinidad written in the late 1970's. Also, given the increase in coastal development, a repeat of these events today would cause much higher damage and fatalities. Although the history of the Caribbean area is the longest in the Western Hemisphere, the tsunami history has not been studied in detail. The varied colonial past and the number of political divisions make such a study difficult and needing local involvement. Tsunamis have affected the whole area from the northern coast of South America, Costa Rica and Panama, to the whole arc of the Antilles. It is subject to tsunamis of tectonic origin associated with the trench and with structures cutting the arc. Notable is the 1867 tsunami originating in the Anegada trough between St. Thomas and St. Croix, Virgin Islands, which caused 14 to 16 fatalities and was observed throughout the Caribbean. The 1918 tsunami off the northwestern corner of Puerto Rico caused about 40 fatalities and extensive damage. The Caribbean area is also subject to rare but destructive teletsunamis from Atlantic sources. The 1755 tsunami which affected Lisbon, North Africa and England put waves as high as 7 metres at Saba, and 3.7 metres at Antigua and Dominica. Waves reached the second story of buildings in Martinique. The Caribbean may also be subject to tsunamis generated by volcanic activity as seen by the 1690 landslide on Nevis Peak and an explosion of a mud volcano near Trinidad in 1911. Kick-em Jenny, a submarine volcano discovered in 1939, may have generated small, local tsunamis in the 1939 or 1990 eruptions (Sigurdsson, 1996) and may in the future produce a larger wave. Landslides are another source of tsunamis. Each type of source produces tsunamis with different characteristics. The risk should be thoroughly evaluated by a multi-national effort to improve the history and predict effects by using models.

INTRODUCTION

The tsunami hazard in the Caribbean is not as large as some other hazards, notably hurricanes. However, there is a history of destructive tsunamis which, when

viewed against the current state of development in coastal areas and numbers of tourist visitors, would be disastrous if they occurred today. Tsunamis in the future can be expected to be at least as large as those in the past and more destructive. This initial history lists 50

can be expected to be at least as large as those in the past reported tsunamis (Table 1) including 15 which caused and more destructive. This initial history lists 50 damage and six which had reported fatalities.

Table 1.
Preliminary List of Caribbean Tsunamis

1530,	Sep. 1	Venezuela. Sea rose 7.3 m and sank again near coast of Paria and at Cumana and near Island of Cubagua. Ground opened emitting black salt water and asphalt. Mountain at the side of the Gulf of Cariaco was cleft (earthquake). A fort and many houses destroyed but not clear whether due to the wave, the earthquake or both. Berninghausen, 1968; Heck, 1947; Mallet, 1853; Milne, 1912; Robson, 1964.
1543,	(no date)	Venezuela. Waves noted. City of Cumana destroyed by earthquake? Berninghausen, 1968; Centeno-Gran, 1940; Heck, 1947.
1688,	Mar. 1	Jamaica. Shocks felt throughout the island and waves damaged ships in Port Royal. A ship at sea was damaged by a hurricane. Berninghausen, 1968; Mallet, 1853; Milne, 1912; Perry, 1847.
1690,	Apr. 16	Leeward Is. The sea withdrew from Charlotte Amalie, St. Thomas, 16.5 to 18.5m. Robson gives the date as April 5 for Nevis but this is the Julian date. Earthquake of intensity IX caused landslides on volcanic Nevis Peak which caused the sea to withdraw 201m from Charleston before returning in two minutes. Lander, et al., 1989; Mallet, 1853; Olsen, 1988; Robson, 1964, citing Calendar of State Papers, 1689-1692 (1901); Taylor, 1888.
1692,	June 7	Jamaica, Port Royal. Earthquake and subsidence destroyed the city. Ships overturned, frigate washed over tops of buildings. Along the coast of Liganee (possibly Liguanea Plain) the sea withdrew 183 or 274m, exposing the bottom; upon returning the water overflowed the greater part of the shore. At Yallahouse (possibly Yallahs) the sea is said to have retired about 1.6km. At Saint Anns Bay a large wave was reported. 2000 people killed by the earthquake and tsunami. Berninghausen, 1968; Heck, 1947; Mallet, 1853; Milne, 1912; Myles, 1985; Sloane 1809, Taber, 1920.
1751,	Oct. 18	Haiti, Azua de Compostela. The city was destroyed by an earthquake and overwhelmed by the resulting tsunami. Santo Domingo also reported wave damage. Berninghausen, 1968; Heck, 1947; Mallet, 1853; Perry, 1847; Taber, 1922.

1755,	Nov. 1	<p>Teletsunami from the Lisbon, Portugal, earthquake.</p> <p>Waves of amplitude 7m were observed at Saba, 3.6m at Antigua and Dominica, 4.5m at St. Martin, leaving a sloop anchored in 4.6 m of water laying broadside on the dry bottom, 1.5-1.8m at Barbados, where the wave had a period of 5 minutes and the water was black as ink. This could be a local landslide tsunami or seiche triggered by the Lisbon wave. At Martinique, at some places the water was reported to have withdrawn for 1.6 km and at other places it flowed into the upper level rooms of the houses. The lowlands on most of the other French Islands were inundated. There is a report of Santiago de Cuba being nearly inundated in 1755 but the month and day were not given. This is probably from the Lisbon tsunami. Affleck, 1809; Heck, 1947; Lander et al., 1989; Mallet, 1853; Robson, 1964; Scherer, 1912; Southey, 1827; Taber, 1922.</p>
1761,	Mar. 31	<p>Teletsunami from the Lisbon, Portugal, earthquake.</p> <p>A second earthquake near Lisbon, Portugal, caused an extraordinary flux and reflux of the sea at Barbados. Berninghausen, 1968; Davidson, 1936; Mallet, 1854.</p>
1766,	June 11	<p>Jamaica.</p> <p>An earthquake lasting 1 1/2 to 7 minutes hit Cuba. Ships at sea 7.2 km from the coast of Jamaica rolled so much that their gunwales were immersed in the water. Ships in deep water would not experience a tsunami. Either the ships were near the coast or in shoaling water or the wave was a storm wave but no storm was reported. Mallet, 1854.</p>
1766,	Aug. 21	<p>Cumana, Venezuela.</p> <p>Very violent shocks raised Cumana and caused the island of Orinoco to sink and disappear. In many places the water surface was disturbed. This is a possible tsunami report. Mallet, 1854.</p>
1767,	Apr. 24	<p>Martinique and Barbados.</p> <p>The sea was much agitated and ebbed and flowed in an unusual way. Berninghausen, 1968; Mallet, 1854; Robson, 1964.</p>
1770,	June 3	<p>Haiti.</p> <p>Waves noted at Golfe de la Gonave, and Arcahaie. La Saline Mountain foot partly submerged. The sea inundated 7.2km inland. Berninghausen also cites Mallet with a similar report dated 1769 but this is one event. Berninghausen, 1968; Heck, 1947; Mallet, 1854; Milne, 1912; Southey, 1827; Taber, 1922.</p>
1775	no date,	<p>Hispaniola and Cuba.</p> <p>Three earthquakes reported and waves did extensive damage. Berninghausen, 1968; Heck, 1947; Southey, 1827; Taber, 1922.</p>

1781,	Oct. 2	<p>Jamaica, Savanna La Mar.</p> <p>An earthquake occurred during a hurricane. The sea rose to a height of 3m at 0.8 km from the beach and swept away a number of houses. Ten people were killed by the wave and at least 40 more by the storm. All vessels in the bay were dashed to pieces or driven onshore. There is a problem with this date. Berninghausen, Heck and Milne all quote a date of October 2, 1880 for a similar report as reported by Perry. Berninghausen also gives a date of October 22 for this event, citing Mallet who gives the date as October 2. Berninghausen, 1968; Mallet, 1854; Perry, 1845-1846; Southey, 1827.</p>
1787,	Oct. 27	<p>Jamaica.</p> <p>A small local shock was felt at Montego Bay and the vessels in the harbour were agitated. Mallet reports earthquakes in Jamaica on Oct 1 and 21 at Kingston and Port Royal. This would be a low validity report as no wave was cited and the agitation may have been a report of a seaquake effect. Berninghausen, 1968; Mallet, 1854.</p>
1802,	Mar. 19	<p>Antigua I., St. Christopher, and other West Indian Islands.</p> <p>Earthquakes were reported in February and March with the largest on this date. It was accompanied by great agitation of the sea. Intensity IV. Berninghausen, 1968; Heck, 1947; Mallet, 1855; Robson, 1964.</p>
1802,	May 5	<p>Venezuela.</p> <p>Earthquakes at Cumana caused the water of the Orinoco River to rise so high as to leave part of the bed dry. This could describe wave action near the mouth of the river, or bore action. Mallet, 1855.</p>
1812,	Nov. 11 or 12	<p>Jamaica.</p> <p>The sea was much agitated following an earthquake.</p> <p>This could describe wave action or seaquake action. Mallet, 1855.</p>
1823,	Nov. 30	<p>Martinique.</p> <p>At 3:10 P.M. a strong undulation (earthquake) was followed by a tidal wave which caused some damage in Saint-Pierre Harbor. Berninghausen, 1968; Heck, 1947; Mallet, 1855; Perry, 1847; Robinson, 1964.</p>
1824,	Sep. 13	<p>Guadeloupe.</p> <p>Earthquakes were felt at Basse-Terre on the 9th and on the 13th there was a remarkable rise and fall of the tide at Plymouth (Montserrat, British Virgin Islands?). There had been a terrible storm and heavy rain on September 7-9. Mallet, 1855.</p>
1824,	Nov. 30	<p>Martinique.</p> <p>Severe shock at St Pierre. A very high tide threw many ships upon the strand. Heavy rain followed lasting 10 days. Mallet, 1855.</p>

1825,	Sep. 20	British Guiana, Demerara County. Local earthquake and oscillations of the sea were noted. An earthquake was also noted at Trinidad, Tobago, St. Vincent and Barbados. Berninghausen, 1968; Mallet, 185; Milne, 1911; Perry, 1847.
1831,	Dec. 3	Trinidad and St. Christopher. An earthquake occurred. The sea was in a state of violent agitation. Note the large distance between reporting areas. An earthquake was also reported Grenada, St. Vincent, British Guiana. Berninghausen, 1968; Mallet, 1855; Perry, 1847; Robson, 1964.
1837,	July 26	Martinique. Several shocks accompanied by a large wave occurring during a hurricane. Source of wave uncertain. Berninghausen, 1968; Mallet, 1855; Perry, 1847.
1842,	May 7	Guadeloupe. A strong earthquake produced waves with heights reported as follows: Basse-Terre, 0.9m, Deshaies and Sainte Rose, 8.3m and a wave carried away all floatable objects at Gouyave, Grenada, (Charlotte Town). There was some damage, at Bequia I., 1.8m, at Haiti a destructive tsunami struck the north coast, at Mole Saint-Nicholas, Cap-Haitien there was extensive destruction caused by the earthquake and tsunami, at Port-de-Paix the sea receded 60m and the returning wave covered the city with 5m of water. About 200 of the city's 3,000 inhabitants were killed by the earthquake and tsunami. It was observed at Fort-Liberte, Mole-St.-Nicolas and Santiago de los Caballeros. At St. Johns, Virgin Is., the height was 3.1m. At Hispaniola there was destruction on north coast. Note the large area of this event which suggests a teletsunami, but the earthquake was felt at Haiti, Jamaica, Puerto Rico, and other islands. Note also the missing locations such as Puerto Rico for which no tsunami report is available although there are reports from Haiti and the Virgin Islands. Berninghausen, 1968; Heck, 1947; Mallet, 1855; Milne, 1912; Scherer, 1912; Taber, 1922.
1843,	Feb. 8	Antigua. An earthquake was felt at Pointe-a-Pitre, Guadeloupe, St. Lucia, St. Kitts, Monserrat, Martinique and other islands. The sea rose 1.2m but sank again immediately. Robson, 1964.
1853,	July 15	Venezuela. A violent earthquake in Cumana followed by a tsunami. Berninghausen, 1968; Centeno-Grau, 1940; Milne, 1912; Perry, 1847; Robson, 1964.
1860,	Mar. 8	Hispaniola. An earthquake was reported from Port-au-Prince and Anse-a-Veau. Waves were reported from Golfe de la Gonaves, Cayes, and Acquin. At Anse-a-Veau the sea withdrew and broke with a crash on the shore. Berninghausen, 1968; Heck, 1947; Milne, 1912; Taber, 1922.

Table 1 cont'd.

1867, Nov. 18

St. Thomas, Virgin Is.

At Charlotte Amalie the height was 2.4m at the wharf, and the lower part of city was flooded. The water receded nearly 100m and returned as a wave 4.5 to 6m high swamping small boat in the harbor. The wave penetrated 76m inland. The *USS De Soto* was damaged, 11-12 people were killed. At Altona, houses were washed far inland, and there was some damage at Hassel I. At Christensted, St. Croix, waves swept inland 91m, and at Gallows Bay, 20 houses were damaged. At Fredericksted the sea withdrew and returned as a wall of water 7.6m high leaving the *USS Monongahela* stranded. Five were killed, 3-4 injured, and 20 houses were damaged. At Puerto Rico, at San Juan, the river water rose 0.9-1.5m and at Vieques, high waves were observed. At Fajardo, a very small wave was reported, and at Yabucoa the sea retreated and inundated 137m on its return. In the British Virgin Islands, at Peter I., a wave was noted and people fled to Tortola. At Roadtown, Tortola, a 1.5m waves swept some houses away. At Saba, there was some damage. At St. Christopher the wave was also observed. At St. Martin and St. Barthelemy there was some damage. At St. Johns, Antigua, the wave had a height of 3.0m. At Basse-Terre, Guadeloupe, the height was 1.0m with the sea retreated far from coast. At Deshailes, houses in village were destroyed. At Isles des Saintes there was a slight swell, and at Fond du Cure, houses inundated to a depth of 1m. At Pointe-a-Pitre there was a slight swell, and at Sainte-Rose, a 10m wave. The sea withdrew 100m and flooded and damaged houses on return. It was observed at Martinique and St. Vincent had unusually high water. At Grenada, Gouyave (Charlotte Town) the height was 3m and at St. George, 1.5m. At Becquia Island it was 1.8m. Deville, 1867; Lander et al., 1989; Milne, 1912; Paiwonsky, 1979; Reid and Taber, 1920; Robson, 1964.

1868, Mar. 17

Puerto Rico, Arroyo and Naguabo.

An earthquake and tsunami were observed. At St. Thomas, Charlotte Amalie, it was 0.6m, with a small recession and flooding. Berninghausen, 1968; Heck, 1964; Lander, et al., 1989; Milne, 1912; Robson, 1964; Taber, 1922.

1874, Mar. 11

Lesser Antilles.

A submarine shock to the southeast of St. Thomas shook the island and ships in the harbour. Simultaneously the water in the bay, then perfectly still, appeared turbid as though clouded by sand and mud. A little later strong ripples from the south agitated the water surface lasting some time. This probably was the tsunami and the earlier effects from the seismic waves agitating the bottom. At Dominica the steamer *Corsica* reported a series of heavy rollers in the harbor lasting half an hour and rendering communication with the shore impossible. They did not feel the earthquake. The reduced effects at Charlotte Amalie may indicate a source on the eastern side of the island. Berninghausen, 1968; Palgrave, 1874.

1881,	Aug. 12	<p>Jamaica.</p> <p>An earthquake was felt on the island and a wave was reported from the north coast. At Kingston Harbour the water rose about 46cm. Berninghausen felt that this wave was not caused by the earthquake but does not give any reason for his conclusion. Berninghausen, 1968, Hall, 1907; Taber, 1920.</p>
1882,	Sept. 7?	<p>Northeastern Panama, San Blas Archipelago.</p> <p>Milne reports an earthquake for this date observed in Colombia, Panama, Nicaragua, and Ecuador but does not mention a tsunami. Camacho reported the tsunami but did not give details or a date. Eduardo Camacho, 1993; Milne, 1912.</p>
1887,	Sept. 23	<p>Haiti.</p> <p>The epicenter was apparently near the Barlett Trough a short distance southwest from Mole Saint Nicholas. At Jeremie the sea withdrew 20m and returned with a rush. Waves were noted at Mole Saint Nicholas, Anse-D'Haiuault, Pointe Tiburon, and other ports. Heck mistakenly identified the area as in the Philippines. Milne reports the earthquake felt at Port-de-Paix, Haiti and Inagua Island, Bahama Islands. Berninghausen, 1968; Heck, 1947; Milne, 1912; Scherer, 1912, Taber, 1922.</p>
1907,	Jan. 14	<p>Jamaica.</p> <p>Earthquake damage at Kingston, and surrounding territory. Buff Bay was destroyed. Waves noted at Hope Bay, Orange Bay, Sheerness Bay, and Saint Anns Bay. At Annotto Bay, an observer reported the sea receded 73 to 93m, dropping 3 to 3.7m below normal sea level. The returning wave raised the water level 1.8 to 2.4m above normal, sweeping into the lower parts of town destroying houses. On the higher land it came up 7.6 to 9.1m. At Buff Bay the sea receded some distance from the land. At Port Maria the sea withdrew 25.6m. At Ocho Rios near St. Ann's Bay the sea withdrew 69m. At Port Antonio the wave moved a small building near the beach. Waves were also reported from the south coast of Jamaica and seiches were set up in Kingston Harbour. Berninghausen, 1968; Heck, 1946; Taber, 1920.</p>
1911,	Nov. 3	<p>Trinidad.</p> <p>Some extraordinary waves were noticed on the coast following an explosion of a mud volcano island. This is a volcanic-related tsunami. Arnald and Macready, 1956; Berninghausen, 1968.</p>
1916,	Apr. 25	<p>Panama.</p> <p>An earthquake was reported from Bocas del Toro and Almirante, and waves at Boca del Toro carried debris and canoes 198m inland Berninghausen, 1968; Heck, 1947; Kirkpatrick, 1920; Reid, 1917.</p>

1918,	Oct. 11	Puerto Rico.
		<p>A magnitude 7.5 earthquake caused a wave of 2.4 to 3.3m above sea level at Aguadilla which destroyed 300 huts and drowned 34 people. At Cayo Cardona water rose 75 cm on the west side of the island. At El Boqueron the wave droppped 1.5m and rose 90cm above mean sea level. About 800m southeast near the entrance to the bay the water rose only 45cm. At Punta Borinquen Lighthouse the wave was 4.5m above sea level. In a low area just southwest of the lighthouse the wave penetrated 91m inland. Submarine cables were cut in several places. At Gaunica, 45cm waves observed. At Isabela the water rose 1.8m. At Isla Caja de Muertos water rose 1.5m covering 15m of the beach. At Isla Mona the receding water bared the reef and the returning wave was 3.6m above sea level washing a pier washed away, and flooding a cistern. At Mayaguez, a wave entered the first floors of buildings near the waterfront and destroyed a few native huts and a brick wall was overturned. Water levels reached 40 to 150cm above sea level. At Playa Ponce slight water movements were observed. At Puerto Arecido waves 30 to 60cm high were observed and a bore about 10cm went up the Rio Grande. At Punta Agujereada waves estimated at 5.5 to 6m uprooted several hundred palm trees and destroyed several small houses. Eight people drowned. At Punta Higuero Lighthouse waves uprooted coconut palms and crossed railroad tracks 4.9m above sea level while 800m southeast of the lighthouse the water rose 2.6 to 2.7m. At Rio Culebrinas 1000kg blocks of limestone were moved 46 to 76m slightly downhill. Waves were at least 3.7m high. At Rio Grande de Lioza, water receded and rose about 90cm. At St. Thomas, Virgin Islands, Charlotte Amalie the water rose 45cm and at Krum Bay, 1.2m. At Santo Domingo, Hispaniola water of the Rio Ozama fell and rose 60cm with a period of 40 minutes. Waves were noted at Tortola. Berninghausen, 1968; Lander, et al., 1989; Reid and Taber, 1919; Robson, 1964.</p>
1918,	Oct. 25	Puerto Rico, Mona Passage.
		<p>Submarine cables were cut again and a steamer rolled heavily. Waves were recorded on the tide gage at Galveston, Texas. Berninghausen, 1968; Heck, 1946; Lander, et al., 1989.</p>
1922,	May 2	Puerto Rico.
		<p>A wave was recorded on the Galvaston gage which has been associated with a small earthquake in Vieques, but the small earthquake does not seem likely to have produced a recordable tsunami. Lander, et al., 1989, Berninghausen, 1968; Parker, 1922; Campbell, 1991.</p>
1929,	Jan. 17	Cumana, Venezuela.
		<p>City was destroyed by an earthquake and a steamer off shore was endangered by a hugh wave. The tidal wave following the earthquake caused much damage. Many sailboats were wrecked. Berninghausen, 1968; Robson, 1964; Seismological Notes, 1946.</p>

1932,	Feb. 3	Cuba. Small waves were reported at the time of an earthquake at Santiago de Cuba. Berninghausen, 1968; Hess, 1932.
1946,	Aug. 4	Dominican Republic, Matanzas. The town was severely damaged and 100 people killed although the wave probably was only 2.4m. At Villa Julia Molina the wave was estimated to be 3.6 to 4.6m high but caused little damage. At Cabo Samapa several ebbs and flows were observed. It was recorded at San Juan, Puerto Rico, 36 minutes after the earthquake. It was also recorded at Bermuda at 2:07 after the earthquake and at Daytona Beach, 3:59 and Atlantic City, 4:49. Berninghausen, 1968, Bodle and Murphy, 1948; Heck, 1947, Lynch and Bodle, 1948.
1946,	Aug. 8	Puerto Rico, Aquadilla. The sea retreated 24m and returned. At Mayaguez the sea retreated 76m and returned. At San Juan it was recorded on tide gage 35 minutes after the earthquake. It was an aftershock of the August 4 event. The wave was also recorded with travel times of: Bermuda, 2:02, Daytona Beach, 4:02, and Atlantic City, 4:42. Berninghausen, 1968; Bodle and Murphy, 1948; Lander et al., 1989.
1953,	May 31	Dominican Republic. Recorded on the Puerto Plata tide gage at 6cm height. Murphy and Cloud, 1955.
1955,	Jan. 18	Venezuela, La Vela. A wave was reported and four ships were wrecked and four waterfront buildings damaged. No earthquake is listed for this time. Berninghausen, 1968; <i>Seismological Notes</i> , 1955.
1968,	Sept. 20	Venezuela. A report of a tsunami has not been verified. Coffman and Cloud, 1970.
1969,	Dec. 25	Leeward Is. Recorded at Barbados, Antigua, and Dominica with a maximum amplitude of 14cm at Barbados. Von Hake and Cloud, 1971.
1989,	Nov. 1	Puerto Rico, Cabo Rojo. A small tsunami was reported. <i>Preliminary Determination of Epicenters</i> , 1989

1991, Apr. 22

Costa Rica.

At Bocas del Toro, Panama, people reported that Las Delicias sand bank normally covered by 60 to 90cm of water emerged as the sea receded less than ten minutes after the earthquake and remained above water for five to seven minutes. Afterwards several waves entered the bay with great force flooding 50 to 100m in the flat northern part of the town. At Carenero Island violent waves destroyed dwellings. At San Cristobal Island the sea receded several meters for about 45 minutes. People went on the beach to catch trapped fish. It was also observed at Bastimento, Cristobal, 10cm, Puertobelo, W. Panama, 60cm and recorded at Colon. Eduardo Camacho, 1993.

These are plotted in Fig. 1. These have affected 22 countries and administrative groups of islands in Central and South America and the Caribbean Islands This list is undoubtedly incomplete both with respect to the number of events and affected localities.

Tsunamis are instantaneously generated gravity waves in water. In the older literature they may be referred to as tidal waves, or seismic sea waves,

km. The great Lisbon, Portugal, earthquake and tsunami of 1755 sent waves in to the Caribbean with amplitudes of 7m at Saba, 3.6m at Antigua and Dominica, 4.5m at St. Martin, into the upper stories of waterfront buildings in Martinique, and 1.5-1.8m at Barbados. There are no known reports for their effects in other islands in the Caribbean, but with waves of these sizes, they probably affected most of the islands.

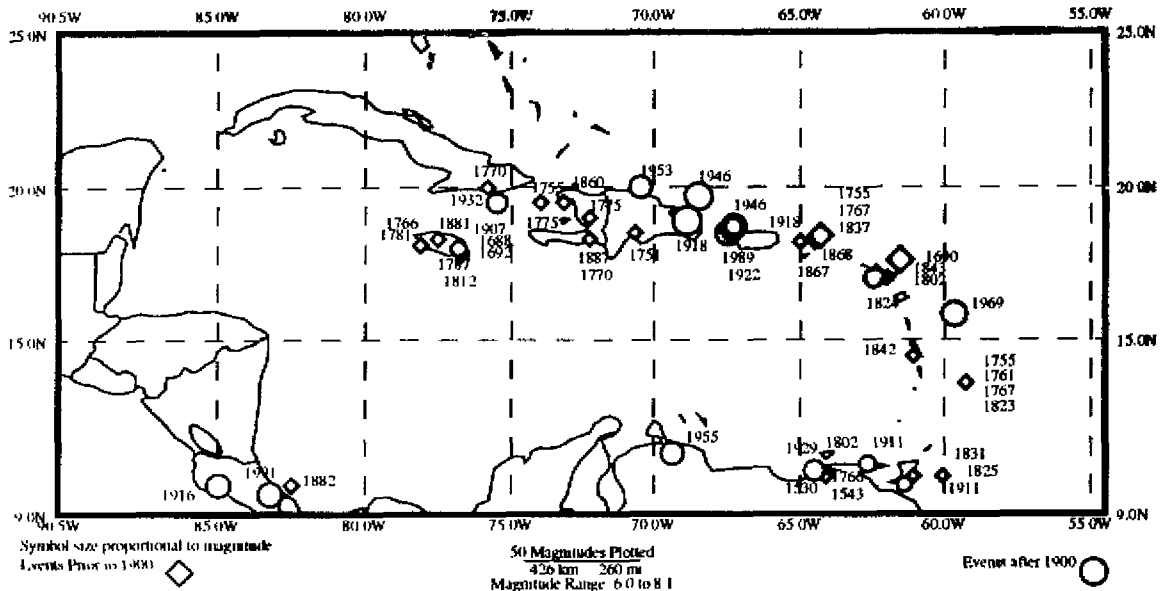


Fig. 1. Location of the source and date of tsunamis reported for the Caribbean except for the teletsunami generated near Portugal in 1755.

maremoto in Spanish, and raz de maree and vagues sismique in French. They are traveling waves whose velocity depends on the square root of the depth of the water such that they slow down and rise up on reaching shoaling depths. Like earthquakes, most are small and recorded mainly on tide gages. Tsunamis are caused by a number of agents and have different characteristics. Teletsunamis originate at distances greater than 1000

The return time for events in the Atlantic is not known, but the Portuguese are concerned enough to be setting up a warning system. Such tsunamis will have about eight hours of lead time before they arrive from the source of the Lisbon tsunami, and have long periods of up to an hour. The dangerous period may last for up to twelve hours. Tsunamis may also be caused by tectonic action in subduction zones. The mechanism is