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REDUCTION OF NATURAL DISASTERS IN CENTRAL AMERICA

Earthquake Preparedness and Hazard Mitigation

Phase II

**Tsunami Catalogue for Central America
1539-1996**

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**This work is dedicated to the memory of
Dr. Lautaro Ponce**

**TSUNAMI CATALOGUE FOR CENTRAL AMERICA
1539-1996**

CONTENT:

RESUMEN	2
SUMMARY	3
INTRODUCTION	7
CATALOGUE STRUCTURE AND FORMAT	7
FUTURE WORK	9
ACKNOWLEDGEMENTS	10
Part 1: XVI-XVIII CENTURIES	15
Part 2: XIX CENTURY	20
Part 3: XX CENTURY	36
BIBLIOGRAPHY	84

1. The first part of the report is a summary of the work done during the year.

2. The second part is a detailed account of the work done during the year.

3. The third part is a summary of the work done during the year.

4. The fourth part is a summary of the work done during the year.

5. The fifth part is a summary of the work done during the year.

6. The sixth part is a summary of the work done during the year.

7. The seventh part is a summary of the work done during the year.

8. The eighth part is a summary of the work done during the year.

9. The ninth part is a summary of the work done during the year.

10. The tenth part is a summary of the work done during the year.

11. The eleventh part is a summary of the work done during the year.

RESUMEN

El catálogo de tsunamis tiene 50 eventos entre 1539 y 1996 (ver Tabla 1). Todos los eventos sísmicos ocurrieron a lo largo de las costas de Centro América, tanto en el Caribe como el Pacífico, con excepción de dos regionales (de Ecuador y Chile) y un distante (de las Aleutianas). No todos tienen información con igual grado de credibilidad, 9 (20%) de los eventos reportados tienen algún grado de incerteza en cuanto a la ocurrencia del evento sísmico o el tsunami. Entre los eventos hay un posible "seiche" en el Lago de Nicaragua y un curioso caso de un lahar en el volcán Cosiguina generado por un terremoto.

El número de eventos reportados aumenta dramáticamente después de mediados del siglo XIX, 43 (86%) ocurrieron entre 1850 y 1996. Probablemente esto se debe a la baja densidad de población viviendo cerca de la costa antes de esa fecha. La distribución de los eventos en el tiempo es: 4 (8%) en los siglos XVI-XVIII, 11 (22%) en el siglo XIX y 35 (69%) en el siglo XX.

El número de tsunamis mejor documentados es: 34 (68%) locales, un regional y uno distante (de acuerdo a la localización del sismo que los generó). Los tsunamis locales, 22 (65%) están en el Pacífico y el resto 12 (35%) en las costas del Caribe. La identificación sismotectónica preliminar de las fuentes muestra que, en el Pacífico, 16 fueron generados por la Zona de Subducción Cocos-Caribe (COCO-CARIB), 1 (uno) evento por la Zona de Fractura de Panama (PFZ) y 2 eventos por fallamientos superficiales dentro del Bloque de Panama (La Discontinuidad del Canal y el Sistema de Fallas Azuero-Torio). Del lado del Caribe, 5 eventos están relacionados con el Límite entre las placas Norte America-Caribe (NOAM-CARIB) y 7 eventos con el Cinturón Deformado del Norte de Panama (NPDB). Lo anterior muestra el caso poco común de sismos tsunamigenéticos asociados a sistemas de fallas de corrimiento lateral (strike-slip) tanto en el Caribe como en el Pacífico.

Hay diez tsunamis locales con reporte de daños. Siete de ellos en el Pacífico y el resto en el Caribe. Todos tienen magnitud de tsunami (m) en la escala Imamura-Iida (ver Tabla 2) entre 0-2.5.

El número total de muertos debido al impacto de tsunamis locales es menos de 300. Este número podría aumentar a aproximadamente 500 en el caso que se confirme que el evento del 2 de febrero de 1902 fue debido a un terremoto. Los daños reportados van desde la destrucción de embarcaciones e instalaciones costeras, hasta la destrucción de pequeños pueblos. A la fecha, No existe una cuantificación de los mismos.

Los tsunamis locales que más daños han producido son: el de Nicaragua del 2 de septiembre de 1992 ($M_s=7.2$, $m=2.5$, 170 muertos) en la costa del Pacífico, el de El Golfo de Honduras del 4 de agosto de 1856 ($M_s=7-8$, $m=2$) y el de Panamá del 7 de septiembre de 1882 ($M_s=7.9$, $m=1$, 75-100 muertos) en la costa Central y Este del Caribe.

El único reporte de daños por un tsunami no local es el relacionado con el terremoto en las Islas Aleutianas el 10 de marzo de 1957 ($M_s=8.1$) que produjo daños y algunas muertes a lo largo de la costa de El Salvador, y destruyó totalmente una parte del Puerto de Acajutla que estaba en construcción.

SUMMARY

A tsunami catalogue is compiled containing 50 events in the period 1539 to 1996 (see Table 1). All earthquakes occurred along the both Caribbean and Pacific coasts of Central America, except two regional (from Ecuador and Chile) and one distant (from Aleutian). Not all have reliable information, 9 (20%) events reported have some degree of uncertainty in the earthquake and/or tsunami occurrence. Among the events there is one possible seiche in the Nicaragua Lake, and a curious case of a lahar from the Cosiguina volcano crater lake triggered by local earthquake.

The numbers of events reported increased dramatically after the middle of the XIX Century, 43 (86%) occurred between 1850 and 1996. Probably it is a consequence of the lack of population living near the coast before that time. The number of events is 4 (8%) for the XVI-XVIII centuries, 11 (22%) in the XIX, and 35 (69%) in the XX century.

The number of better documented tsunami events are 34 (68%) locals, one regional, and one distant (according to the epicentral location of the tsunamigenic earthquake). The local tsunamis, 22 (65%) are in the Pacific side, and the rest 12 (35%) in the Caribbean coast. A preliminary seismotectonic regionalization of the earthquakes sources shows that, in the Pacific, 16 events could be generated by the Cocos-Caribbean Subduction Zone (COCOS-CARIB), 1 (one) event by the Panama Fracture Zone (PFZ), and 2 events by intraplate (Panama Block) shallow faults (Canal Discontinuity, and Azuero-Torio Fault Zone). In the Caribbean side, 5 events are related with the North American-Caribbean Plates Boundary (NOAM-CARIB), and 7 events with the North Panama Deformed Belt (NPDB). The above shows the non common case of tsunamigenic earthquakes related with a strike-slip fault system both in the Caribbean and Pacific.

There are ten local tsunamis with specific damage report, seven in the Pacific coast, and the rest in the Caribbean. All of them have tsunami magnitude (m) in the Imamura-Iida scale (see Table 2) between 0-2.5).

The total number of casualties due to local tsunamis is less than 300. This number could increase to approximately 500 in case that the February 2, 1902 El Salvador event is confirmed to had been trigger by a earthquake. The damages reported go from coastal and ship damage to small towns destruction, and there does not exist a quantification of them.

The major damaging local tsunamis are: the Nicaragua September 2, 1992 tsunami earthquake ($M_s=7.2$, $m=2.5$, 170 casualties) in the Pacific coast, the Honduras Gulf event of August 4, 1856 ($M_s=7-8$, $m=2$) and the Panama September 7, 1882 ($M_s=7.9$, $m=1$, 75-100 casualties) in the central and eastern Caribbean coast.

The only non-local tsunami that has a damage report is related with the Aleutian earthquake of March 10, 1957 ($M_s=8.1$) that produced damages and some casualties along the El Salvador coast, and total destruction of part of Acajutla's Port, in that moment in construction.

Table 1. Tsunami Catalogue For Central America, 1539-1996, a compact list.

No	DATE	TIME	EARTHQUAKE SOURCE PARAMETERS			TSUNAMI PARAMETERS			TECTONIC REGION	OCEAN
			Lat (°N)	Lon (°W)	Ms/I	T	REGION	m		
1	1539-1124	---	---	---	---	L	Honduras Gulf, HON	--	NO-CA	C
2	1579-0316	---	---	---	---	L	Cano Island, CR	--	CO-CA	P
3	1621-0502	---	8.97	79.5	5.6-6.0	L	Panama la Vieja, PAN	--	CANAL DISCONTINUITY	P
4	1798-0222	---	10.2	82.9	VI-VI+	L	Matina, CR	-1	NPDB	C
5	1822-0507	---	9.5	83.0	7.6	L	Matina, CR	-1	NPDB	C
6	1825-02--	---	---	---	5-5.5	L	Roatan Island, Honduras Gulf, HON	--	NO-CA	C
7	1844-05--	---	11.2	84.8	7.0-7.9	S?	Nicaragua Lake, NIC	--	CO-CA	N-L
8	*1854-0805	05:30	8.5	83.0	7.25	L	Golfo Dulce, CR	1.5	(CO-CA)	P
9	1855-0925	---	---	---	6-6.5	L	Trujillo Bay, Honduras Gulf, HON	--	NO-CA	C
10	*1856-0804	---	---	---	7-8	L	Omoa, Honduras Gulf, HON	2	NO-CA	C
11	*1859-0826	---	13.0	87.5	6-6.5	L	Amapala, Fonseca Gulf, HON	1.5	CO-CA	P
12	*1859-1209	---	13.7	89.8	7-7.9	L	Acajutla Bay, SAL	1.5	CO-CA	P
13	1873-1014	00:05	10.2	80.0	V	L	Colon & Panama, Harbors, PAN	--	NPDB	C
14	*1882-0907	09:18	10.0	79.0	7.9	L	San Blas Coast, PAN	2	NPDB	C
15	1884-1105	---	4.0	76.0	---	L?	Acandí, Colombia	--	Colombia	P
17	1902-0118	23:23	14.7	91.6	6.3	L?	Ocos, GUA	--	(CO-CA)	P
18	*1902-0226	---	13.0	89.0	7.0	?L	Pacific Coast, GUA-SAL	2		P
19	1902-0419	02:24	14.9	91.5	7.5	L?	Ocos, GUA	-1	CO-CA	P
20	1904-0120	14:50	7.0	82.0	7.0	L?		--		P
21	1904-1220	05:42	9.2	82.8	7.45	L	Bocas del Toro, PAN	--	NPDB	C
22	1905-0120	18:23	9.85	84.68	6.8	L?	Coco Island, CR	--	(CO-CA)	P
23	1906-0131	15:36	1.0	81.3	8.2	R	Tumaco, Ecuador San Carlos, PAN Potrero Bay, CR	--	ECUADOR	P
24	1906-----	---	---	---	---	T	El Salvador Coast, SAL	--		P
25	1913-1002	04:23	7.1	80.6	6.7	L	Azuero Peninsula, San Miguel Gulf, PAN	-1	AZUERO-TORIO F.Z.	P
26	1915-0907	01:20	13.9	89.6	7.7	L?	El Salvador Coast, SAL	0.5	CO-CA	P
27	1916-0131	---	---	---	---	T	Panama Canal, PAN	--		P
28	*1916-0426	02:21	9.2	83.1	6.9	L	Bocas del Toro, PAN	0	NPDB	C
29	1916-0525	---	12.0	90.0	7.5	?L?	El Salvador	--		P
30	1919-0629	23:14	13.5	87.5	6.7	L	Corinto, NIC	--	(CO-CA)	P
31	*1919-1212	---	---	---	---	L	El Ostial, NIC	--	(CO-CA)	P
32	1920-1206	---	---	---	---	L	Fonseca Gulf	--		P
33	1926-1105	07:55	12.3	85.8	7.0	L	Offshore, NIC	--	(CO-CA)	P

34	*1934-0718	01:36	8.1	82.6	7.5	L	Chiriqui Gulf, PAN	1.5	FFZ	P
35	1941-1205	20:46	8.7	83.2	7.6	L	Pta. Dominical, CR	-1	CO-CA	P
36	1941-1206	---	10.0	85.2	6.9	L	Nicoya Gulf, CR	-2	(CO-CA)	P
37	1950-1005	16:09	10.0	85.7	7.9	L	Coasts CR-NIC-SAL	-1	CO-CA	P
38	1950-1023	16:13	14.3	91.8	7.3	L	Coasts GUA-SAL	-1	CO-CA	P
39	*1951-0803	00:24	13.0	87.5	6.0	LH	Potosi, Fonseca Gulf, HON	--	(CO-CA)	P
40	1952-0513	19:31	10.3	85.3	6.9	L	Puntarenas, CR	-3	CO-CA	P
41	1956-1024	14:42	11.5	86.5	7.2	L?	San Juan del Sur, NIC	--	CO-CA	P
42	*1957-0310	14:42	51.63	175.41	8.1	D	Acajutla, SAL	--	ALEUTIAN	P
43	1960-0522	19:11	-38.2	73.50	8.5	R?	La Union, Fonseca G., SAL	--	CHILE	P
44	1962-0312	11:40	8.0	89.9	6.7	L	Armuelles, Chiriqui G., PAN	-1	CO-CA	P
45	1968-0925	10:38	15.6	92.6	6.0		Pacific Coast	--		P
46	1976-0204	09:01	15.2	89.2	7.5	L	Cortes, Honduras G., HON	-0.5	NO-CA	C
47	1976-0711	16:54	7.43	78.12	7.0	L	Jaque, Darien, PAN	-1		P
48	1990-0325	13:16	9.8	84.8	7.0	L	Punta Arenas & Quepos, CR	0	CO-CA	P
49	1991-0422	21:56	9.6	83.2	7.6	L	Bocas del Toro, PAN	1	NPDB	C
50	*1992-0902	00:16	11.7	87.4	7.2	L	Nicaragua Coast Bahia de Salinas, and Papagayo G., CR	2.5	CO-CA	P

* = damage Report
 T = tsunami type
 L = local tsunami
 R = Regional Tsunami
 D = Distant Tsunami
 S = seiche
 LH = Lahar
 m = tsunami magnitude
 NO-CA = North America-Caribbean plate boundary
 CO-CA = Cocos-Caribbean subduction zone
 NPDB = North Panama deformed Belt
 I = MM intensity scale
 ? = event included in previous tsunami specific catalogues. But is poor documented, doubtful or are contradictory reports
 before the tsunami symbol refers to the earthquake event and after to tsunami event.
 () = inferred in this study, only when was considered obvious
 C = Caribbean
 P = Pacific
 N-L = Nicaragua lake

TABLE 2. Qualitative Imamura-Iida tsunami magnitude (m) scale
(Horikawa, 1983)

m	H (Tsunami height)	Damage
4	30 m	Considerable damage along more than 500 km of coastline
3	10-20 m	Considerable damage along more than 400 km of coastline
2	4-6 m	Damage and lives lost in certain landward areas
1	2 m	Coastal and ship damage
0	1 m	Very small damage
-1	50 cm	None

1. INTRODUCTION

One of the main goals of the NORAD-CEPREDENAC project "Reduction of Natural Disasters in Central America" Phase II is contributing to the mitigation of tsunami impact in the region.

As a first step, a tsunami catalogue for Central America was compiled with the purpose of improving our knowledge about the frequency, spatial distribution, characteristics, and hazard of the tsunami phenomenon.

The spatial and temporal distribution of the catalogue are: 6-18N and 93-77W, and from 1539 to 1996 respectively. Most of the entries were collected from previous earthquakes and tsunami specific catalogues, both regional and local. A non exhaustive list of them is shown in Table 3, indicating the reference, geographic area, time interval and a short comment about the type of information. Due to time limitation it was not possible to consult original sources, however we put special attention to the original references used for each author in any reported event. It permitted us to recognize catalogues that were collected from other catalogues (secondary information) or from primary sources, and also events reported from independent sources.

Only those parts of the macroseismic information that are or could be related with the tsunami phenomenon were included in the catalogue, with exception of those cases where the rest of the macroseismic report helped to confirm and identify the earthquake source. In any case, textual description was taken avoiding the author's interpretations. The tsunami reports can be in English or Spanish, no translations were done.

The quality of the tsunami reports is variable, as it will be specified below, but as a general rule we included all the events reported as tsunami events in the previous catalogues or in specific studies.

2. CATALOGUE STRUCTURE AND FORMAT

The catalogue was divided in three periods of time: XVI-XVIII, XIX, and XX centuries. Each part contains: a compact list, a map showing the spatial distribution of the tsunami and earthquake events, and the complete information for each event.

2.1 The Compact list

The compact list shows: id number, earthquake source parameters (date, time, lat., lon., Ms/or max. intensity), tsunami parameters (tsunami type: local, regional or distant; tsunami region; tsunami magnitude), the tectonic environment, and the ocean (Caribbean or Pacific). See a example below.

An interrogation simbol "?" before and/or after the tsunami type is used to denote the quality of the event information, its means that the earthquake and/or tsunami occurrence are: poor documented, doubtful or exist contradictory reports, example:

L? = not reliable local tsunami, reliable earthquake occurrence.
 ?L = not reliable earthquake, reliable tsunami phenomenon occurrence.
 ?L? = both earthquake and tsunami occurrence are not reliable.

The same for seiche (S) and regional or distant earthquakes.

Compact list example.

No	DATE	TIME	EARTHQUAKE SOURCE PARAMETERS			TSUNAMI PARAMETERS			TECTONIC REGION	OCEAN
			Lat (°N)	Lon (°W)	Ms/I	T	REGION	m		
1	1539-1124	---	---	---	---	L	Honduras Gulf, HON	--	NO-CA	C
2	1579-0316	---	---	---	---	L	Cano Island, CR	--	CO-CA	P
3	1621-0502	---	8.9	79.5	5.6-6.0	L	Panama la Vieja, PAN	--	CANAL DISCONTINUITY	P
4	1798-0222	---	10.2	82.9	VI-VI+	L	Matina, CR	-1	NPDB	C

2.2 The maps

After the compact list there are maps showing the tsunami area, and the epicentral location of the respective tsunamigenic earthquakes.

2.3 Event information format

The event information include: a header (almost the same as the compact list), earthquake source parameters, earthquake tectonic environment, tsunami magnitude (for the last three, many lines as authors reported it), tsunami report, additional event specific bibliography, and figures and/or tables. See an example below.

Event information format example:

No	DATE	TIME	EARTHQUAKE SOURCE PARAMETERS			TSUNAMI PARAMETERS			O
			Lat (°N)	Lon (°W)	Ms/I	T	REGION	m	
12	*1859-1209	---	13.7	89.8	7-7.9	L	Acajutla Bay, SAL	1.5	P

Epicenter Region:

Guatemala-Salvador Pacific coast

EARTHQUAKE SOURCE PARAMETERS:

1208, 13.7°N-89.8°W, M=7.0 (Murthy, 1995 (ATWC))
 1208, 13.75°N-89.75°W, h=40 Km, M=7 (Soloviev & Go, 1984)
 Magnitude Richter = 8+ (Sucth, 1981)

0912, 13.2°N-90.0°W, h= Intermediate (70-200), 7.0<M<7.7 (Leeds, 1974)

TECTONIC ENVIRONMENT:

COCOS-CARIBBEAN SUBDUCTION ZONE (SHALLOW BENIOFF ZONE) (Sutch, 1981)

Figure 5. Intensity distribution (Grases, 1990)

Tsunami magnitude = -1 (Torai, unpublished)
Tsunami intensity = 3 (Fernandez, 1993, (White & Cifuentes, in preparation))
Tsunami magnitude=1 1/2 (Soloviev & Go, 1984)

TSUNAMI AND/OR MACRO SEISMIC REPORT:

Soloviev & Go, 1984 (Perrey, 1862, 1864; Montessus de Ballore, 1888; Milne 1912; Larde, 1916; Beck, 1934, 1947; Montandon, 1962; Ponysvin, 1965; Iida, et al., 1967);

"There was a destructive earthquake in adjacent regions of Guatemala and El Salvador."

"The earthquake was accompanied by a tsunami. according to a report of the governor of Sonsonate, the sea became very agitated at Acajutla port; the rose to an extraordinary height with a terrible noise; the sea retreated far from shore; the docs and the river boat yards dried up almost to the breakwater; on shore, caves and grottos collapsed; the state warehouses were destroyed; the breakwater and customhouse were flooded; an enormous chain about 70 m long and an anchor disappeared, carries off by waves, and it was impossible to find them; holes of such size were formed in the sand that sailors sank in them up to the waist. Fish floundered on the beach and on the terraces an they were collected in large numbers."

Sutch, 1981 (Perrey, 1864; Milne, 1912; Montando, 1962; Caceres, no date; ING, 1880; Montessus de Ballore, 1888):

"The harbour of Acajutla experienced a tsunami. Milne and Montandon also reporte a tsunami here."

Larde, 1960 (La Gaceta Oficial de El Salvador, 13 diciembre de 1859):

".....A un buque de vela que fondio el sabado en este puerto, le cogio el temblor en alta mar y se paro en su curso, tal que el capitan creyo haber tropezado en la oscuridad contra un banco, hasta que a sus vibraciones irregulares conocio ser el efecto de un terremoto."

SPECIFIC EVENT REFERENCES:

Murty, 1995 (ATWC catalogue)

Guinea et al., 1995 (Alvarez, 1982)

Hatori, 1995 (Iida, et al., 1967; Soloviev & Go, 1985)

Rojas et al., 1993 (Sutch, 1981)

Grases, 1990

Cruz & Wyss, 1983 (Milne, 1911; Montessus de Ballore, 1888; Sutch, 1981)

Carr & Stoiber, 1977 (Montessus de Ballore, 1884)

Leeds, 1973 (Destructive Earthquakes in Nicaragua (Montessus de Ballore, 1888; Jorgensen))

When possible we included figures and tables that summaries the macroseismic information, earthquake location, tsunami affected zones, tsunami observations, near coast permanent soil deformation (liquefaction, uplift, subsidence..), and tide gauge records.

All the items included in the format have the original reference, the only information that was inferred in this study is the tectonic environment and only in the obvious cases. Those underlined references means there were not included in the catalogue bibliography.

Of course not all the tsunami events have complete information for all the format items, specially those from the XVI-XVII centuries. Also there are some events which don't have a tsunami or macroseismic report but they were included in previous tsunami catalogues, and deserve special attention.

3. FUTURE WORK

Following are some recommendations for the future work:

1. The doubtful or poorly documented events have to be re-examined. Especially those with damage reported.
2. The tide gauge records or information obtained from them have to be incorporated. A digital tsunami records data base will be excellent.
3. Its necessary a more dynamic media for the consultation, applications, and updating of the tsunami catalogue. A geographic

information system or specific software for it will be helpful.

4. New tsunami events or re-examined former ones have to be included in the catalogue or data base as soon as possible. They could have an important effect in the tsunami hazard assessment.
5. Some field work could help to improve the interpretation of some historical tsunamis.

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Part of the information was collected during a two weeks trip along Central American countries. We consider it of major importance in order to improve the quality of the catalogue, because it gave us the opportunity to have a personal communication with people of different institutions involved in seismic hazard assessment, and they not only let us have the information but also dedicated time and made helpful comments and suggestions. The author is grateful to: E. Camacho and H. Cowan (Instituto de Geociencias, UPA, Panama), W. Montero, W. Rojas, and M. Fernandez (Escuela Centroamericana de Geologia, UCR, Costa Rica), L. Esquivel and D. Salgado (Comision Nacional de Emergencia, Costa Rica), F. Guendel and E. Malavasi (OVSICORI, UNA, Costa Rica), A. Gutierrez (Instituto Oceanografico, UNA, Costa Rica), L. Muñoz, F. Segura and W. Strauch, A. Morales, A. Agurcia, L. Palacios, and M. Rosales (INETER, Nicaragua), D. Hernandez and R. Torres (Centro de Investigaciones Geotecnicas, El Salvador), L. E. Hernandez (Hidrografia, IGN, El Salvador), G. Cruz (Depto. Física, UNAH, Honduras), M. Marin (Depto. Biologia Marina, UNAH, Honduras). Also I had the opportunity to meet some centralamerican colleagues at the Solid Earth Physics Institute at Bergen University, Norway, where this work was completed, I thank all of them, specially I. Boschini (Costa Rica) who add more information to the catalogue and helped to clear some Costa Rican events, and M. Villagran (Guatemala) for the computer and software advices. Without this help the compilation of the catalogue in this short period of time will not be possible.

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TABLE 3. Regional and local earthquake and tsunami specific catalogues for Central America. Underlined references mean that the complete reference is not included in the catalogue bibliography.

REFERENCE	COVERAGE AREA	TIME PERIOD	COMMENTS
Montessus de Ballore, 1884, 1888	CENTRAL AMERICA	1000-1884	Since XI century, and v. eruptions
<u>Sapper</u> , 1925	CENTRAL AMERICA	1500-1925	volcanic eruptions and earthquakes
<u>Dias</u> , 1930	CENTRAL AMERICA	1469-1930	and v. eruptions
Grases, 1974	CENTRAL AMERICA	1500-1800	deteil macroseismic inf.
Miyamura, 1976	CENTRAL AMERICA	1900-1950	revised magnitude, events not included in in Gutenberg & Richter and Rothe Catalogs.
Carr & Stoiber, 1977	CENTRAL AMERICA	1500-1977	Destructive earthquakes, short macrosiesmic inf.
<u>Cifuentes & White</u> , 1980	CENTRAL AMERICA	1500-1830	and v. eruptions, short macroseismic inf
Cruz & Wyss, 1983	MEXICO & CENTRAL AMERICA	1740-1983	Tsunami specific
Soloviev & Go, 1984	NORTHERN ECUADOR, COLOMBIA & PANAMA MEXICO TO COSTA RICA	1500-1984	Tsunami specific
White & Harlow, 1985	CENTRAL AMERICA	1900-1985	Significant shallow earthquakes
Feldman, 1986	CENTRAL AMERICA	1500-1900	and v. eruptions
Grases, 1990	CARIBBEAN REGION	1500-1990	mainly destructive earthquakes occurred in Caribbean plate boundary
Rojas, 1993	CENTRAL AMERICA	1500-1993	
Fernandez, 1993	CENTRAL AMERICA	1500-1993	Tsunami specific, one line inf.
Murty, 1995	CENTRAL AMERICA	1850-1970	one line information (ATWC)

TABLE 1. Continuation

Ambrasys, 1995	CENTRAL AMERICA	1900-1995	only Ms > 6.0
Hatori, 1995	MEXICO & CENTRAL AMERICA	1900-1995	Tsunami specific, one line inf.
Ambraseys, 1995	CENTRAL AMERICA	1898-1930	Worldwide recorded earthquakes
Ambraseys & Adams, 1996	CENTRAL AMERICA	1898-1996	only Ms > 7.0
Toral, unpublsh	CENTRAL AMERICA & NORTH SOUTH AMERICA	1798-1992	Tsunami specific, one line inf.
Alfaro et al., 1990	SE MEXICO, GUATEMALA & EL SALVADOR	1500-1950	one line inf.
Meyer Abich, 1965	EL SALVADOR & GUATEMALA	1775-1950	
Vassoux, 1978	GUATEMALA	1500-1978	
Tobar, 1982	GUATEMALA	1530-1982	
White, 1988	GUATEMALA	1500-1988	Chixoy-Polochic-Motagua F. System.
Feldman, 1988	GUATEMALA	1800-1900	
Gonzales, inedit	GUATEMALA	1700-1800	Subduction zone earthquakes
Larde, 1960	EL SALVADOR	????-1960	and v. eruptions
Martinez, 1978	EL SALVADOR	1500-1978	
Jordan & Martinez, 1980	EL SALVADOR	1500-1980	Part A: and v. eruptions Part B: damages earthquakes 20th century
Sutch, 1981	HONDURAS	1500-1900	
Leed, 1974	NICARAGUA	1500-1974	one line inf.
INETER, 1993	NICARAGUA	1860-1993	Tsunami specific, one line inf.
INETER, unpublished	NICARAGUA	1500-1972	
Morales, in preparation	NICARAGUA	1870-1997	source: local newspapers

TABLE 1. Continuation

Gonzalez-Viquez, 1910	COSTA RICA	1600-1900	and inundations
Feldman, 1984	COSTA RICA & PANAMA	1892-1948	Earthquake damage
Guendel, 1986	COSTA RICA	1630-1986	1630-1900: damage erathquakes 1900-1986: Ms > 6.0
Montero, 1989	COSTA RICA	1630-1900	
Montero, 1990	COSTA RICA	1730-1990	Tsunami specific, Pacific
Boschini & Montero, 1994	COSTA RICA	1730-1994	Caribbean coast
Peraldo & Montero, 1994	COSTA RICA	1550-1820	Damage earthquakes, Colonial period.
Kirkpatrick, 1920	PANAMA	1500-1900	
Viquez & Toral, 1987	PANAMA	1516-1985	
Camacho & Viquez, 1993a	PANAMA & COSTA RICA CARIBBEAN	1798-1930	Earthquakes related wiht the North Panama Deformed Belt

PART 1:

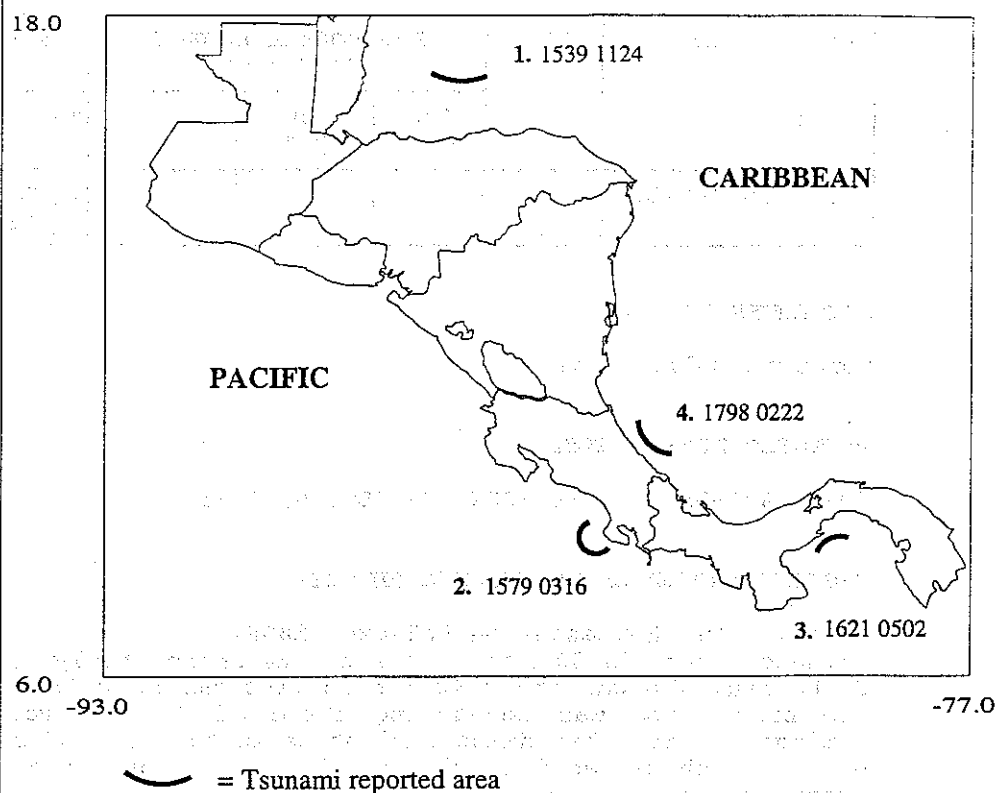
TSUNAMIS DURING THE XVI-XVIII CENTURIES

Part 1: Tsunamis During the XVI-XVIII Centuries

No	DATE	TIME	EARTHQUAKE SOURCE PARAMETERS			TSUNAMI PARAMETERS			TECTONIC REGION	OCEAN
			Lat (°N)	Lon (°W)	Ms/I	T	REGION	m		
1	1539-1124	---	---	---	---	L	Honduras Gulf, HON	--	NO-CA	C
2	1579-0316	---	---	---	---	L	Cano Island, C R	---	CO-CA	P
3	1621-0502	---	8.9	79.6	5.6-6.0	L	Panama la Vieja, PAN	--	CANAL DISCONTINUITY	P
4	1798-0222	---	10.2	82.9	VI-VI+	L	Matina, C R	-1	NPDB	C

*= damage Report
 T= tsunami type
 L= local tsunami
 R= Regional Tsunami
 D= Distant Tsunami
 S= seiche
 LH= Lahar
 m= tsunami magnitude
 NO-CA= North America-Caribbean plate boundary
 CO-CA= Cocos-Caribbean subduction zone
 NPDB= North Panama deformed Belt
 I= MM intensity scale
 ?= event included in previous tsunami specific catalogues. But is poor documented, doubtful or are contradictory reports before the tsunami symbol refers to the earthquake event and after to tsunami event.
 ()= inferred in this study, only when was considered obvious
 C= Caribbean
 P= Pacific
 N-L= Nicaragua lake

LOCAL TSUNAMIS **XVI-XVIII CENTURIES**

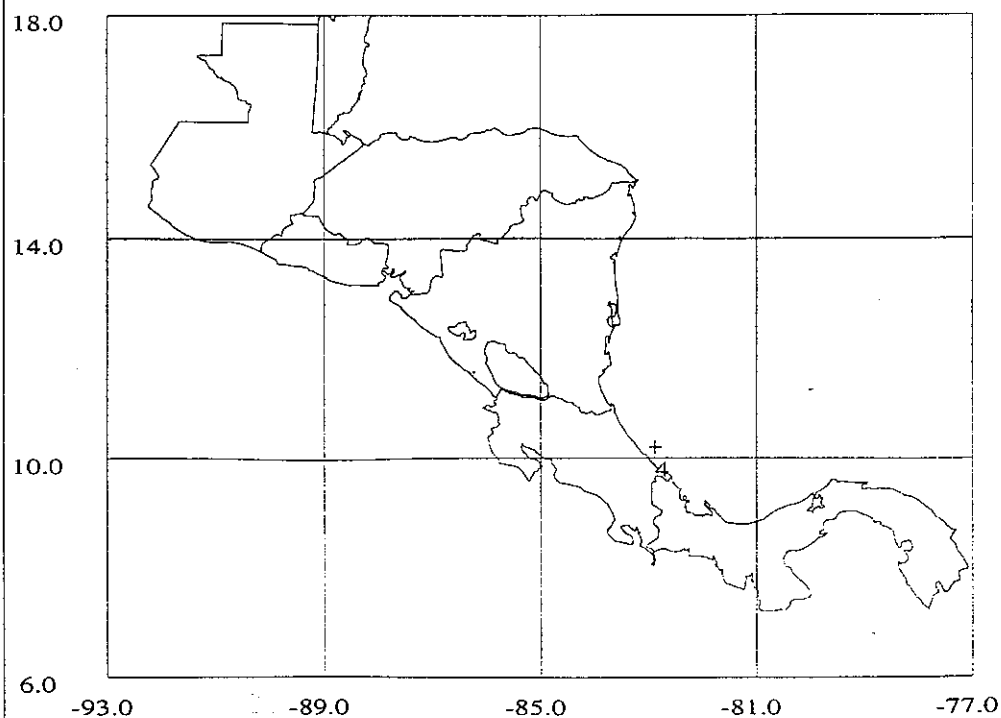


Total events: 4
Selected events: 4

Magnitudes:

M = 0 +

TSUNAMIGENIC EARTHQUAKES **XVI-XVIII CENTURIES**



No	DATE	TIME	EARTHQUAKE SOURCE PARAMETERS			TSUNAMI PARAMETERS			O
			Lat (°N)	Lon (°W)	Ms/I	T	REGION	m	
1	1539-1124	---	---	---	---	L	Honduras Gulf, HON	--	C

EPICENTER REGION:

Honduras Gulf, Caribbean

TECTONIC ENVIRONMENT:

NOAM-CARIBBEAN PLATE BOUNDARY (Sutch, 1981)

TSUNAMI AND/OR MACRO SEISMIC REPORT:

Sutch, 1981 (Montessus de Ballore, 1888):

"Minutes after 23:00 a violent seaquake unexpectedly was encountered by Johan de Lobera, who was about 40 lieues (160 km) away from the Cape of Higueras. The pilot, who was conducting three of Pedro Alvarado's ships to Santo Domingo, feared that damages might be sustained, and brought the flotilla to port. The shock was felt within all of the province of Honduras and caused a great deal of damages."

SPECIFIC EVENT REFERENCES:

Rojas et al., 1993 (Sutch, 1981; Montessus de Ballore, 1888)

Fernández, 1993 (Sutch, 1981)

Grases, 1990 (Montessus de Ballore, 1888)

Grases, 1974 (Montessus de Ballore, 1888)

No	DATE	TIME	EARTHQUAKE SOURCE PARAMETERS			TSUNAMI PARAMETERS			O
			Lat (°N)	Lon (°W)	Ms/I	T	REGION	m	
2	1579-0316	---	---	---	---	L	Cano Island, CR	--	P

EPICENTER REGION:

SE Costa Rica Pacific Coast

TECTONIC ENVIRONMENT:

COCOS-CARIBBEAN SUBDUCTION ZONE (Peraldo & Montero, 1994)

TSUNAMI AND/OR MACRO SEISMIC REPORT:

Peraldo & Montero, 1994 (Gonzalez, 1910):

"We set onward, March the 7, shaping our course towards the island of Caines, with which we fell March 16, setting ourselves for certain days in a fresh river, between the main and it, for the finishing of our needful business, while we abode in this place we felt a very terrible earthquake, the force whereof was such that our ship and pinnacle, riding very near an English mile from the shore were shaken and did quiver as if it had been laid on dry land."

No	DATE	TIME	EARTHQUAKE SOURCE PARAMETERS			TSUNAMI PARAMETERS			O
			Lat (°N)	Lon (°W)	Ms/I	T	REGION	m	
3	1621-0502	---	8.97	79.55	5.6-6,0	L	Panama la Vieja, PAN	--	P

EPICENTER REGION:

Panama Gulf, Pacific

EARTHQUAKE SOURCE PARAMETERS:

0502, 8.97°N-79.55°W, Ms = 5.6-6.0 (Viquez & Camacho, 1994).
 VII-VIII MM, in Veraguas, aprox. 180 km WSW Panama City (Grases, 1990 (Tabor, 1967)).
 IX Rossi-Forel scale, in Veraguas Province (Mendoza & Nishenko, 1989 (Kirkpatrick, 1931; Requejo Salcedo, 1640)).
 VII MM, at Panama City (Viquez & Toral, 1987 (Doc. historicos J.B. Sosa)).

TECTONIC ENVIRONMENT:

SHALLOW INTRAPLATE ON THE CANAL DISCONTINUITY (Viques & Camacho, 1994)
 AZUERO PENINSULA (Viquez & Camacho, 1987 (Nishenko, 1992))

Figure 1. Panama City in 1609 (Viquez & Camacho, 1994)

TSUNAMI AND/OR MACRO SEISMIC REPORT:

Viquez & Camacho, 1994 (Mega, 1957; Requejo Salcedo, 1640):

"El sismo tuvo lugar el día 2 de mayo de 1621 a eso de las 4:30-4:45 de la tarde....."

".....mientras las olas amanazaban con inundar la calle de la Carrera"

SPECIFIC EVENT REFERENCES:

Rojas et al., 1993
 Nishenko, 1992
 Grases, 1990 (Kirkpatrick, 1920; Montessus de Ballore, 1898; Viquez & Toral, 1987; Tabor, 1967)
 Mendoza & Nishenko, 1989
 Viquez & Toral, 1987

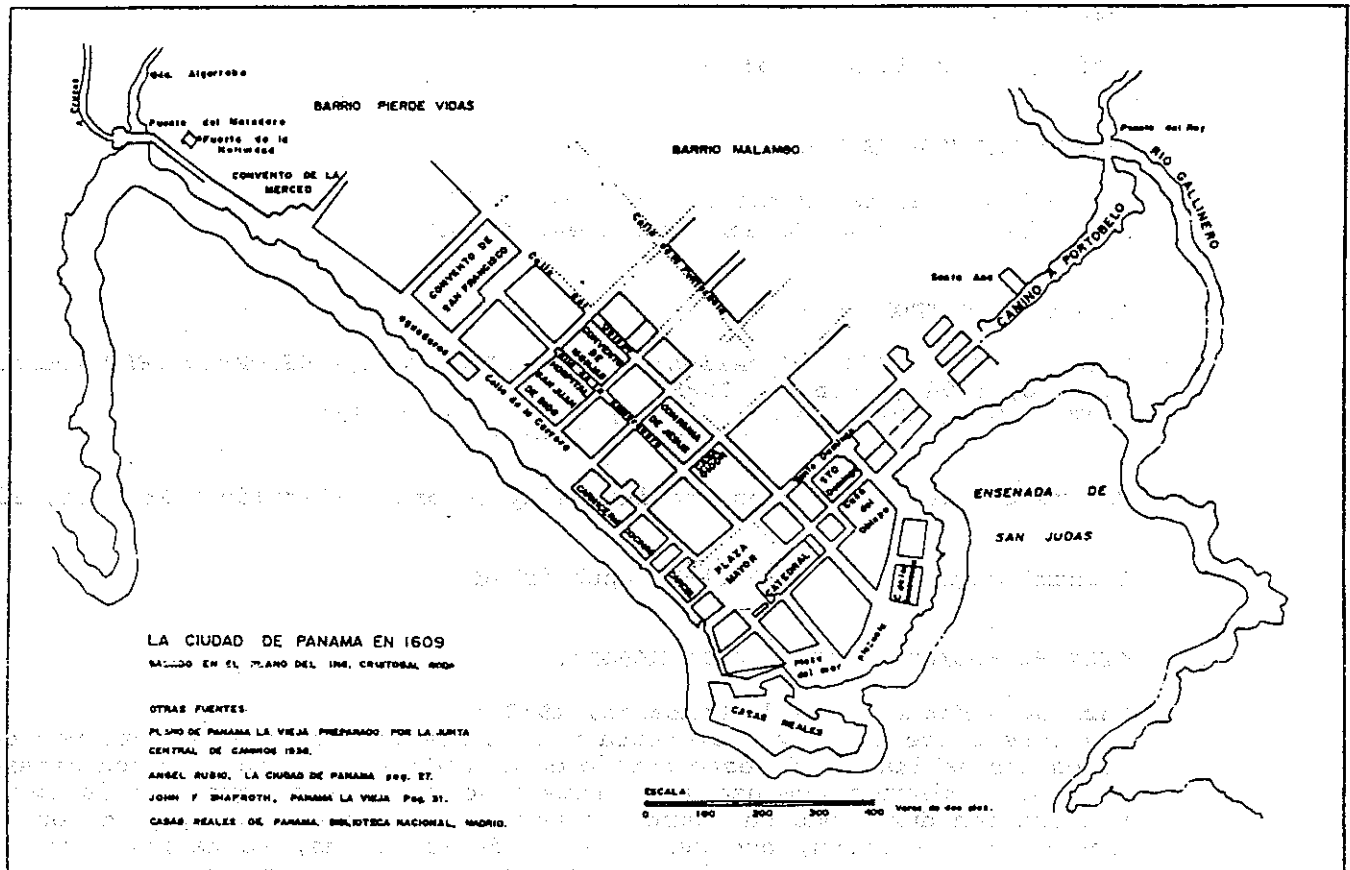


Figure 1. Panama City in 1609 (Panama La Vieja), VII MM reported for the May 2, 1621 earthquake (Viquez & Camacho, 1994)

No	DATE	TIME	EARTHQUAKE SOURCE PARAMETERS			TSUNAMI PARAMETERS			O
			Lat (°N)	Lon (°W)	Ms/I	T	REGION	m	
4	1798-0222	---	10.2	82.9	VI-VI+	L	Matina, CR	-1	C

EPICENTER REGION:

Matina, Costa Rica, Caribbean

EARTHQUAKE SOURCE PARAMETERS:

VI - VI+ at Matina (Peraldo & Montero, 1994)
0221, 10.2°N-82.9°W (Camacho y Viquez, 1993a)

TECTONIC ENVIRONMENT:

SEISMIC NEST NORTH OLD MATINA TOWN OR NORTH PANAMA DEFORMED BELT (Peraldo & Montero, 1994 (Boschini, 1989))
NORTH PANAMA DEFORMED BELT (Camacho y Viquez, 1993a)

Figure 2. Matina location and intensity reported (Peraldo & Montero, 1994)

Tsunami magnitude= -1 (Toral, unpublished)

TSUNAMI AND/OR MACRO SEISMIC REPORT:

Peraldo & Montero, 1994 (Gonzalez, 1910):

" Anoche entre las 7 y 8 dio esta mar un bramido que ciertamente nos dejo a todos los habitantes de este paraje en un todo sorprendidos, y con diferencia de 6 a 8 minutos comenzo a estremecerse la tierra, que sin la mas leve ponderacion duro todo un cuarto de hora; y lo que mas acongoja es que hasta hoy dia de la fecha, que seran las 8 de la mañana, se ha mantenido en un continuo balanceo, esperando por minutos la muerte. A esto se agrega que desde la hora que empezo a temblar se pico la mar en tanta manera que parece que ya se nos viene encima, por lo que participo a Ud. que siendo como es este lugar tan propenso a inundarse y consiguientemente el terreno tan deleznable, pienso yo y todos estos vecinos retirarnos, cuando no a esa ciudad, a buscar altura hasta tanto Dios mejore sus horas."

SPECIFIC EVENT REFERENCES:

Boschini & Montero 1994 (Camacho & Viquez, 1993; Gonzalez, 1910)
Camacho & Viquez, 1993 (Gonzalez, 1910)
Rojas et al., 1993 (Peraldo & Montero, 1994)
Grases, 1990 (Montessus de Ballore, 1888; Gonzalez, 1910; Tabor, 1967)
Boschini, 1989

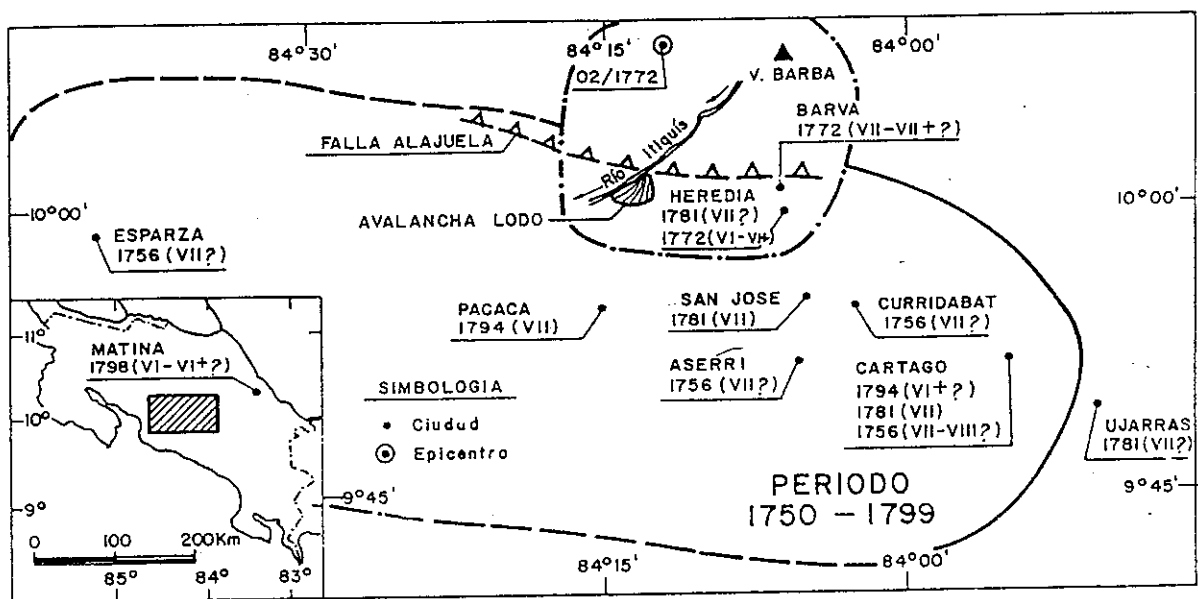


Figure 2. Intensity distribution for earthquakes occurred on the second half of XVIII century at Costa Rica. The inset map shows the Matina location and the estimated intensity for the February 22, 1798 earthquake (Peraldo & Montero, 1994).

PART 2:

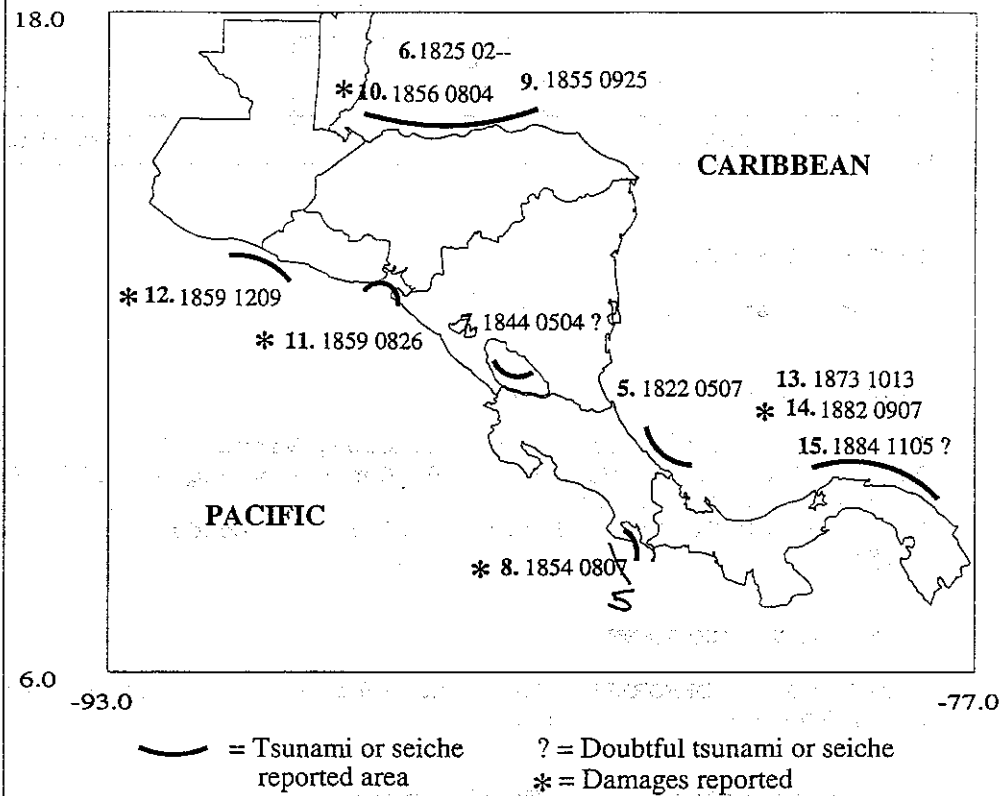
TSUNAMIS DURING THE XIX CENTURY

Part II: Tsunamis During the XIX Century

No	DATE	TIME	EARTHQUAKE SOURCE PARAMETERS			TSUNAMI PARAMETERS			TECTONIC REGION	OCEAN
			Lat (°N)	Lon (°W)	Ms/I	T	REGION	m		
5	1822-0507	---	9.5	83.0	7.6	L	Matina, C R	-1	NPDB	C
6	1825-02--	---	---	---	5-5.5	L	Roatan Island, HON Honduras Gulf, HON	--	NO-CA	C
7	1844-05--	---	11.2	84.8	7.0-7.9	S?	Nicaragua Lake, NIC	--	CO-CA	N-L
8	*1854-0805	05:30	8.5	83.0	7.25	L	Golfo Dulce, C R	1.5	(CO-CA)	P
9	1855-0925	---	---	---	6-6.5	L	Trujillo Bay, HON Honduras Gulf, HON	--	NO-CA	C
10	*1856-0804	---	---	---	7-8	L	Omoa, HON Honduras Gulf, HON	2	NO-CA	C
11	*1859-0826	---	13.0	87.5	6-6.5	L	Amapala, HON Fonseca Gulf, HON	1.5	CO-CA	P
12	*1859-1209	---	13.7	89.8	7-7.9	L	Acajutla Bay, SAL	1.5	CO-CA	P
13	1873-1014	00:05	10.2	80.0	V	L	Colon & Panama, PAN Harbors, PAN	--	NPDB	C
14	*1882-0907	09:18	10.0	79.0	7.9	L	San Blas Coast, PAN	1	NPDB	C
15	1884-1105	---	4.0	76.0	---	L?	Acandí, Colombia	--	Colombia	P

* = damage Report
 T = tsunami type
 L = local tsunami
 R = Regional Tsunami
 D = Distant Tsunami
 S = seiche
 LH = Lahar
 m = tsunami magnitude
 NO-CA = North America-Caribbean plate boundary
 CO-CA = Cocos-Caribbean subduction zone
 NPDB = North Panama deformed Belt
 I = MM intensity scale
 ? = event included in previous tsunami specific catalogues. But is poor documented, doubtful or are contradictory reports before the tsunami symbol refers to the earthquake event and after to tsunami event.
 () = inferred in this study, only when was considered obvious
 C = Caribbean
 P = Pacific
 N-L = Nicaragua lake

LOCAL TSUNAMIS XIX CENTURY

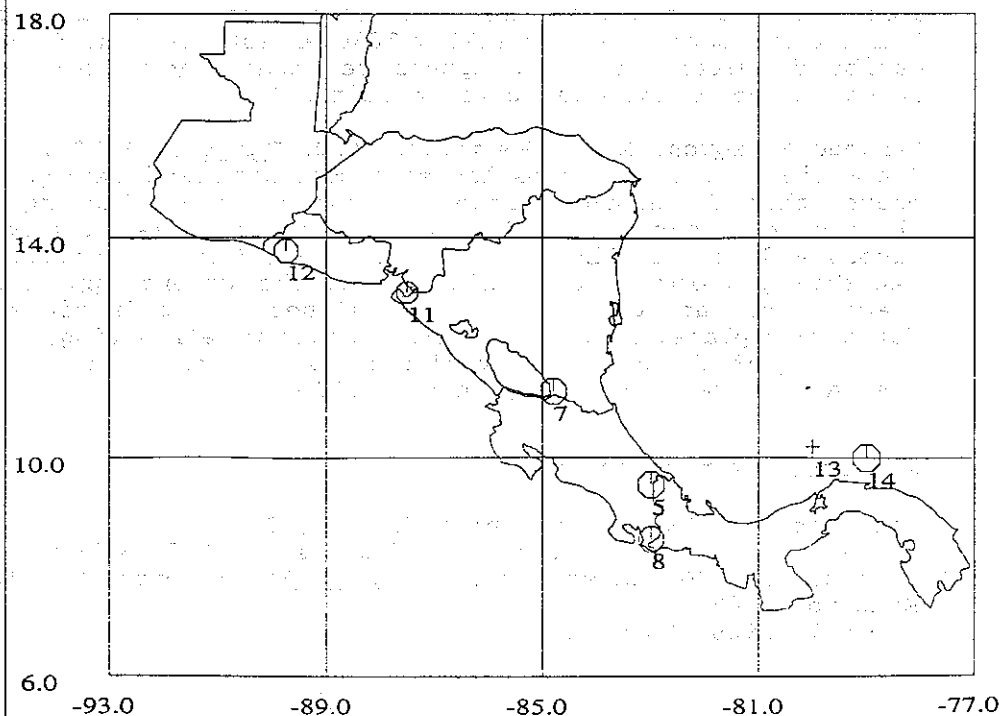


Total events: 15
Selected events: 14

Magnitudes:

M = 0	+
M = 1	.
M = 2	o
M = 3	o
M = 4	o
M = 5	o
M = 6	o

TSUNAMIGENIC EARTHQUAKES XIX CENTURY



No	DATE	TIME	EARTHQUAKE SOURCE PARAMETERS			TSUNAMI PARAMETERS			O
			Lat (°N)	Lon (°W)	Ms/I	T	REGION	m	
5	1822-0507	---	9.5	83.0	7.6	L	Matina, CR	-1	C

EPICENTER REGION.

Matina. Costa Rica, Caribbean

EARTHQUAKE SOURCE PARAMETERS:

0507, 9.5°N-83.0°W, Ms = 7.6 (Camacho y Viquez, 1993)

0507, 9.5°N-83.0°W, Ms = 7.5-8.0 (Camacho y Viquez, 1993 (Montero 1986))

Ms = 7.5 (Rojas, 1993)

0507, 10.0°N-84.0°W, h=Normal, 6.0<M<6.9 (Leeds, 1974 (MDB, 1888; Roberts, 1829))

TECTONIC ENVIRONMENT:

NORTH PANAMA DEFORMED BELT (Camacho & Viquez, 1993a (Montero & Gonzalez, 1990, Montero et al. 1991))

Tsunami magnitude = -1 (Torral, unpublished)

Figure 3. Intensity distribution (Camacho & Viquez, 1993)

TSUNAMI AND/OR MACRO SEISMIC REPORT:

Boschini & Montero 1994 (Montero, 1986; Gonzalez, 1910; Montessus de Ballore, 1888):

"....En Panamá, el sismo causo daños a la iglesia de Santiago de los Caballeros y fue reportado como sentido en el Istmo de Darien. En Bocas del Toro, un residente local menciona la existencia de un reporte acerca de un tsunami que ocurrio entre 1820 y 1830 en esta region. En Monkey Point, costa Caribe de Nicaragua, las lagunas se secaron y se formaron nuevas dunas y hoyos, transformando la costa Mosquitia "

Camacho & Viquez, 1993 (Gonzalez, 1910; Roberts, 1827):

"In Matina:....the shakes lasted almost with no interruption for twenty four hours; that the ground cracked in several sites, leaving deep fissures from which salty water and black sand eruptes; the rivers and bays grew and caused floods and the neighbors decided to leave for Cartago.....

(At Monkey Point, Punta Chica).....the ground appeared rent in various places, the sand on the beach was either raised in ridges, or depressed in furrows; a place, in which several canoes were floating, was now become quite dry; most of the huts were violently cracked and twisted; and the effects of the earthquake, were everywhere visible."

SPECIFIC EVENT REFERENCES:

Rojas et al., 1993 (Boschini & Montero, 1994)

Nishenko, et al., on print 1992 (Gonzalez, 1910; Roberts, 1827)

Grases, 1990 (Gonzalez, 1910; Roberts, 1829; Montessus, 1888)

Montero, 1989

Güendel, 1986 (Gonzalez, 1910)

Carr & Soiber, 1977 (Montessus de Ballore, 1884; Leeds, 1974; BSSA)
Leeds, 1974 (Destructive Earthquakes of Nicaragua)



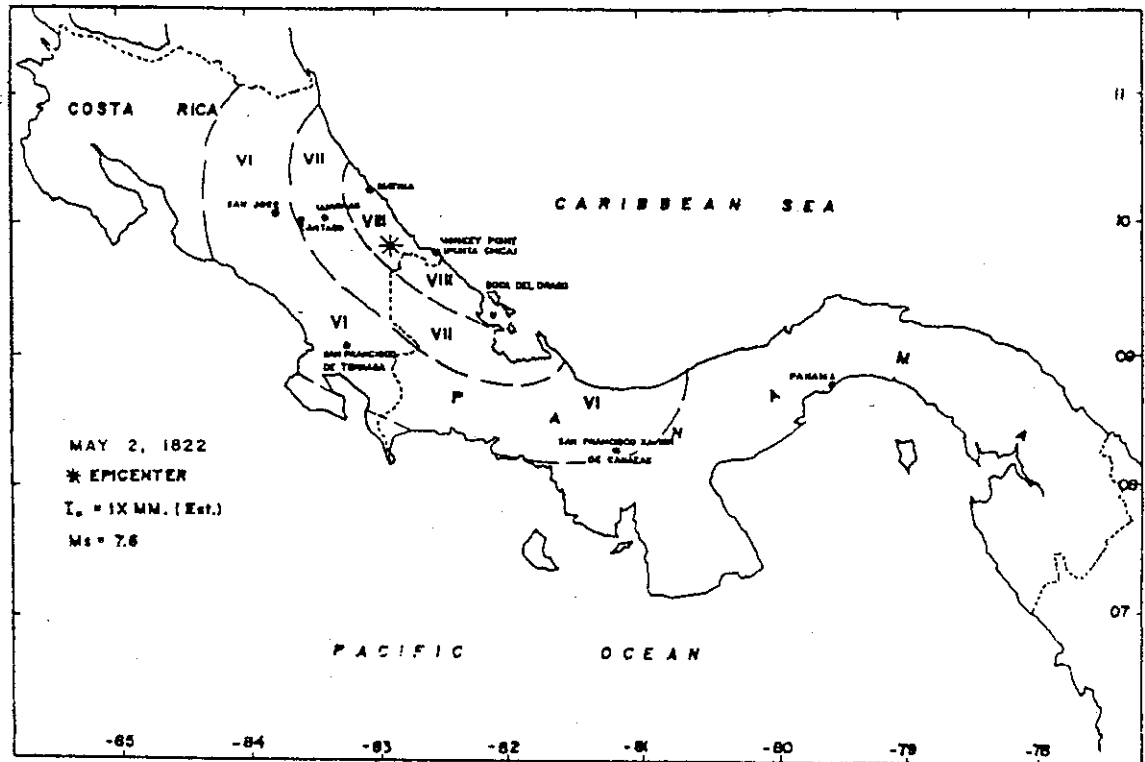


Figure 3. Macroseismic map for the May 7, 1822 event. The proposal epicentre is indicated by a black star (Camacho & Viquez, 1993).

No	DATE	TIME	EARTHQUAKE SOURCE PARAMETERS			TSUNAMI PARAMETERS			O
			Lat (°N)	Lon (°W)	Ms/I	T	REGION	m	
6	1825-02--	---	---	---	5-5.5	L	Roatan Island, Honduras Gulf, HON	--	C

EPICENTER REGION:

Honduras Gulf, Caribbean

EARTHQUAKE SOURCE PARAMETERS:

Magnitude Richter = 5-5.5 (Sutch, 1981)

TECTONIC ENVIRONMENT:

NOAM-CARIBBEAN PLATES BOUNDARY (Sutch, 1981)

TSUNAMI AND/OR MACRO SEISMIC REPORT:

Sutch, 1981 (Mallet & Mallet, 1858; Rockstroch, 1902; Sieberg, 1932; Montessus de Ballore, 1888):

"A shock was reported by passengers on board the ship Recovery on a voyage from Madeira to Honduras. It was felt on the ship and at Belize between 19:00 and 20:00 hr."

"...However, nothing worthy of note occurred till off the island of Roatan. Between 7 and 8 o'clock at night, being quite dark, we were all alarmed by a rumbling noise, as if the vessel had been running over a reef of rocks.....on arriving at Belize, we ascertained that it was the effect of a smart shock of an earthquake which had been experienced there at the very time we felt the confusion."

SPECIFIC EVENT REFERENCES:

Rojas et al., 1993

Grases, 1990 (Perrey, 1847)

No	DATE	TIME	EARTHQUAKE SOURCE PARAMETERS			TSUNAMI PARAMETERS			O
			Lat (°N)	Lon (°W)	Ms/I	T	REGION	m	
7	1844-05--	---	11.2	84.8	7.0-7.9	S?	Nicaragua Lake, NIC	--	N - L

EPICENTER REGION:

Rivas and San Juan del Norte, Nicaragua

EARTHQUAKE SOURCE PARAMETERS:

05--, 11.2°N-84.8°W, h=130, Ms=7.4 (Rojas et al., 1993)

05--, 11.2°N-84.8°W, h=Intermediate (70-200), 7.0<M<7.9 (Leeds, 1974)

TECTONIC ENVIRONMENT:

COCOS-CARIBBEAN SUBDUCTION ZONE (Rojas et al., 1993 (Montero, 1989))

TSUNAMI AND/OR MACRO SEISMIC REPORT:

Rojas et al. 1993 (Jorgensen, 1966; Carr & Stoiber, 1977):

"Desbordamiento del Lago de Nicaragua, muchas replicas"

Carr & Stoiber, 1977 (Montessus de Ballore, 1884):

"Rivas destroyed. seiches (?) in Lake Nicaragua during long swarn."

Leeds, 1974 (Montessus de Ballore, 1888; Crawford 1902; Milne 1912; Montando 1962):

"In May 1944, widespread damage was reported from San Juan del Norte to Grytown. The town of Rivas was destroyed. Rio Negro, closed to navigation in 1835 by Cosiguina, was reopened. Rio Tipitapa (Lake Managua to Lake Niacargua) was reopened, although no previous report indicating it was closed has been found. Lake Nicaragua cascaded through the rapids causing damage. "

No	DATE	TIME	EARTHQUAKE SOURCE PARAMETERS			TSUNAMI PARAMETERS			O
			Lat (°N)	Lon (°W)	Ms/I	T	REGION	m	
8	*1854-0805	05:30	8.5	83.0	7.25	L	Golfo Dulce, CR	1.5	P

EPICENTER REGION:

SE Costa Rica Pacific Coast

EARTHQUAKE SOURCE PARAMETERS:

0805-0530, 8.5°N-83°W, h=33, Ms= 7.3 (Rojas et al., 1993)
0805, 8.5°N-83°W, M=7.25 (Soloviev & Go, 1984).

TECTONIC ENVIRONMENT:

COCOS-CARIBBEAN SUBDUCTION ZONE

Tsunami magnitude=1 1/2 (Soloviev & Go, 1984).

TSUNAMI AND/OR MACRO SEISMIC REPORT:

Soloviev & Go, 1984 (Perrey, 1855, 1856; Montessus de Ballore, 1888):

"On the 4th, at 23:30, there was a very strong earthquake which affected all Costa Rica. It was felt at least from Colon (Aspinwall) in Panama to Pubaqui in Nicaragua....A long stretch of coast on the Pacific at Golfo Dulce sank underwater."

"Shocks were felt again on the 5th at Costa Rica and Nicaragua and on the night of the 6th-7th at Costa Rica. The village of Golfo Dulce on the Pacific coast was flooded by the sea and destroyed."

No	DATE	TIME	EARTHQUAKE SOURCE PARAMETERS			TSUNAMI PARAMETERS			O
			Lat (°N)	Lon (°W)	Ms/I	T	REGION	m	
9	1855-0925	---	---	---	6-6.5	L	Trujillo Bay, Honduras Gulf, HON	--	C

EPICENTER REGION.

Honduras Gulf, Caribbean

EARTHQUAKE SOURCE PARAMETERS:

Magnitude Richter = 6-6.5 (Sutch, 1981)

TECTONIC ENVIRONMENT:

NOAM-CARIBBEAN PLATES BOUNDARY (Sutch, 1981)

TSUNAMI AND/OR MACRO SEISMIC REPORT:

Sutch, 1981 (Perry, 1845-1875; Montessus de Ballore, 1888; Kluge, 1863):

"At 10:45 on 25 September at Trujillo, a very heavy vertical and horizontal shock from ESE to WNW and 15 seconds in duration, the village was heavily damaged."

"....During the first shock on the 25th, the ship Simpronius which was anchored in the Bay, was suddenly lifted up and brusquely dropped as if it were a mass of lead, creating a wake. This phenomenon was repeated several times with more or less force during the next 17 days while the ship was anchored in the Bay at the depth of 7 to 13 brasses (11-24 m.)"

"Our ship, Le P. Cornette added, seemed to raise when we heard the deafening noise come slowly from the ESE, the movement grew rapidly to a degree approaching the level of sound, then seemed to abandon the ship to itself and diminished in intensity as it passed to the WNW."

SPECIFIC EVENT REFERENCES:

Rojas et al., 1993

No	DATE	TIME	EARTHQUAKE SOURCE PARAMETERS			TSUNAMI PARAMETERS			O
			Lat (°N)	Lon (°W)	Ms/I	T	REGION	m	
10	*1856-0804	---	---	---	7-8	L	Omoa, Honduras Gulf, HON	2	C

EPICENTER REGION.

Honduras Gulf, Caribbean

EARTHQUAKE SOURCE PARAMETERS:

Magnitude Richter = 7 to 8 (Sutch, 1981)

TECTONIC ENVIRONMENT:

NOAM-CARIBBEAN PLATES BOUNDARY (Sutch, 1981)

TSUNAMI AND/OR MACRO SEISMIC REPORT:

Tsunami magnitude = -1 (Toral, unpublished)

Tsunami intensity = 2 (Fernandez, 1993 (Sutch, 1981))

Soloviev & Go, 1984 (Perrey, 1872; Montessus de Ballore, 1888; Milne 1912; Sieberg, 1932; Heck, 1947; Montandon, 1962; Ponjavin, 1965; Iida, et al., 1967):

"Suddenly, an earthquake destroyed settlements on the Atlantic coast of Honduras, approximately from Omoa to Beliz....."

"At Omoa, the sea fell and rose to a height of 5 m in still weather; it reached the foot of the fortress and added to the destruction begun by the earthquake. A similar phenomenon was observed on the shore of Criba lagoon."

Cruz & Wyss, 1983 (Montessus de Ballore, 1888; Boscowitz, 1885; Sutch, 1981):

"4 August 1856. This tsunami has been mistakenly associated with the Pacific coast of Honduras in Heck (1947). Omoa is a town on the Atlantic coast of Honduras. The Tsunami affected several town all along the Atlantic coast of that country, like Cortez, Atlantida, Trujillo, and Criba Lagoon. There are accounts of the complete ruin of Omoa, destruction of entire villages and rivers changing direction. This seems to be one of the largest tsunamis to have affected the Atlantic coast of Central America."

Sutch, 1981 (Harp; Rockstroch, 1893; Perrey, 1845-1875; Sieberg, 1932; Boscowitz, 1885):

"The ruin of Omoa. A single shock almost completely destroyed the port. Many cracks opened in the walls of a famous and acient Spanish citadel, and cracks opened up within the region up to a dozen lieues away (48 km), between the Ulua and Tinto Rivers. The sea retreated and then returned from the influence of the shock, greatly increasing the damage. To remark in passing, this is one of the rare examples of a tsunami in Central America that I am acquainted with. This very same one was felt along the shores of the Criba Lagoon according to Boscowitz's commentary..."

".....it was terrible along the coast of Honduras from Omoa to Belize, the sea was elevated 5 meters at the base of the port."

"...While near the mouth of the Poyas River in Criba Lagoon, there came a low rumbling sound, increasing in force as it came sweeping over the land from the south, so unlike thunder that we could not mistake it.A cry of alarm from Jose directed our attention toward the Lagoon... The water was actually receding, leaving the bottom of the lagoon dry. Away it went far

toward the sea....All this time the trembling continued at short intervals....From every direction the waters rushed to a common center, where, meeting, they rose in the air in an immense column, filling the heavens with a ocean to spray. then falling, they came toward the land with the force of a avalanche, threatening us with instant destruction...The Sambo indians informed us that the water had swept back into the interior about fifteen miles."

SPECIFIC EVENT REFERENCES:

Murty, 1995 (ATWC catalogue)
Rojas et al., 1993 (Sutch, 1981)
Grases, 1990 (Montessus, 1888; Boscowitz, 1885; Sutch, 1981; Vassaux, 1969; Milne, 1911; Perrey, 1856)
Carr & Stoiber, 1977 (Montessus de Ballore, 1884)

No	DATE	TIME	EARTHQUAKE SOURCE PARAMETERS			TSUNAMI PARAMETERS			O
			Lat (°N)	Lon (°W)	Ms/I	T	REGION	m	
11	*1859-0826	---	13.0	87.5	6-6.5	L	Amapala, Fonseca Gulf, HON	1.5	P

EPICENTER REGION:

Fonseca Gulf, Pacific

EARTHQUAKE SOURCE PARAMETERS:

0825, 13.0°N-87.5°W, Magnitude = 6.2 (Murty, 1995 (ATWC catalogue))
 0825, 13°N-87.5°W, M=6.25 (Soloviev & Go, 1984)
 Magnitude Reichter = 6-6.5 (Sutch, 1981)

TECTONIC ENVIRONMENT:

COCOS-CARIBBEAN SUBDUCTION ZONE OR SHALLOW FOCUS VOLCANIC (Sutch, 1981)

Tsunami magnitude = -1 (Torai, unpublished)
 Tsunami intensity = 3 (Fernández, 1993 (Sutch, 1981))
 Tsunami magnitude=1 1/2 (Soloviev & Go, 1984)

Figure 4. Tsunami area affected (Carr & Stoiber, 1977)

TSUNAMI AND/OR MACRO SEISMIC REPORT:

Soloviev & Go, 1984 (Perrey, 1864; Montessus de Ballore, 1888; Milne 1912; Heck, 1934, 1947; Ponyavin, 1965; Iida, et al., 1967):

"A strong earthquake in El Salvador and Honduras caused some damaged at La Union and Amapala ports, on the Tigre Island....."

"At La Union, the earthquake was accompanied by tsunami waves, which did some damage. In particular two dug-out canoes and one brigantine were lost."

Sutch, 1981 (Rockstroch, 1893; Montessus de Ballore, 1888):

"Series of earthquakes at La Union. On August 25, one heavy shock caused some damage to the port of Amapala on the island of Tigre and to the villages of San Diego and La Brea. Two vesseles and a brigantine sank from the tsunami following the schok, and there was sligth damage to the port of La Union."

"At 23:00 a heavy shock at La Union, El Salvador. The houses suffered a great deal. Two canoes and one brigantine were lost....."

Larde, 1960:

"Desde antes de anoche (25 de agosto) estamos alarmados con los temblores."
 ".....Tenemos noticias de que en El Viejo, El Tigre y La Brea se sintio el primer temblor del 25 muy fuerte; en el mar ha sido horrible: el capitan del bergantin que esta en la Bahia creyo perderse, dos bangos que se emcontraban haciendo la travesia a Honduras se estrellaron y se hicieron mucho danos."

SPECIFIC EVENT REFERENCES:

Guinea, 1995 (Alvarez, 1979)
 Hatori, 1995 (Iida, et al., 1967; Soloviev & Go, 1984)
 Rojas et al., 1993 (Sutch, 1981);

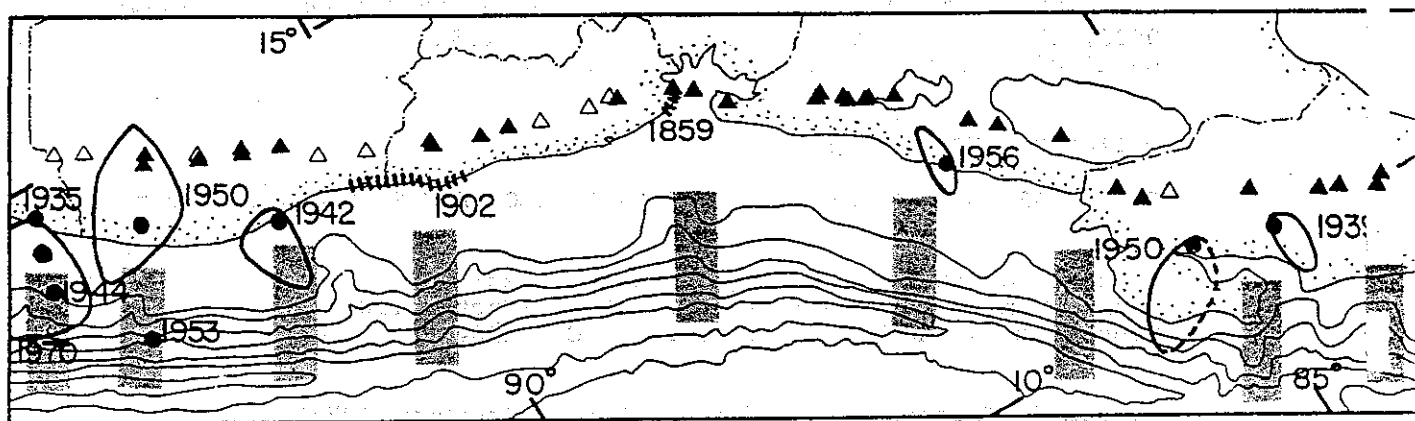


Figure 4. Large earthquakes in Central America, epicentres (solid circles); focal areas (bold lines) estimated by Kelleher and others (1973); hachured coastline represents area affected by tsunamis. It shows the August 8, 1859 and February 26, 1902 tsunamis (Carr & Stoiber, 1977).

Cruz & Wyss, 1983 (Milne, 1911; Montessus de Ballore, 1888; Sutch, 1981)
Carr & Stoiber, 1977 (Montessus de Ballore, 1888)

No	DATE	TIME	EARTHQUAKE SOURCE PARAMETERS			TSUNAMI PARAMETERS			O
			Lat (°N)	Lon (°W)	Ms/I	T	REGION	m	
12	*1859-1209	---	13.7	89.8	7-7.9	L	Acajutla Bay, SAL	1.5	P

EPICENTER REGION:

Guatemala-Salvador Pacific coast

EARTHQUAKE SOURCE PARAMETERS:

1208, 13.7°N-89.8°W, M=7.0 (Murthy, 1995 (ATWC))
1208, 13.75°N-89.75°W, h=40 Km, M=7 (Soloviev & Go, 1984)
Magnitude Richter = 8+ (Sutch, 1981)
0912, 13.2°N-90.0°W, h= Intermediate (70-200), 7.0<M<7.7 (Leeds, 1974)

TECTONIC ENVIRONMENT:

COCOS-CARIBBEAN SUBDUCTION ZONE (SHALLOW BENIOFF ZONE) (Sutch, 1981)

Figure 5. Intensity distribution (Grases, 1990)

Tsunami magnitude = -1 (Torral, unpublished)
Tsunami intensity = 3 (Fernandez, 1993, (White & Cifuentes, in preparation))
Tsunami magnitude=1 1/2 (Soloviev & Go, 1984)

TSUNAMI AND/OR MACRO SEISMIC REPORT:

Soloviev & Go, 1984 (Perrey, 1862, 1864; Montessus de Ballore, 1888; Milne 1912; Larde, 1916; Heck, 1934, 1947; Montandon, 1962; Ponyavin, 1965; Iida, et al., 1967):

"There was a destructive earthquake in adjacent regions of Guatemala and El Salvador."

"The earthquake was accompanied by a tsunami. according to a report of the governor of Sonsonate, the sea became very agitated at Acajutla port; the rose to an extraordinary height with a terrible noise; the sea retreated far from shore; the docs and the river boat yards dried up almost to the breakwater; on shore; caves and grottos collapsed; the state warehouses were destroyed; the breakwater and customhouse were flooded: an enormous chain about 70 m long and an anchor disappeared, carries off by waves, and it was impossible to find them; holes of such size were formed in the sand that sailors sank in them up to the waist. Fish floundered on the beach and on the terraces an they were collected in large numbers."

Sutch, 1981 (Perrey, 1864; Milne, 1912; Montando, 1962; Caceres, no date; ING, 1880; Montessus de Ballore, 1888):

"The harbour of Acajutla experienced a tsunami. Milne and Montandon also reporte a tsunami here."

Larde, 1960 (La Gaceta Oficial de El Salvador, 13 diciembre de 1859):

".....A un buque de vela que fondio el sabado en este puerto, le cogio el temblor en alta mar y se paro en su curso, tal que el capitan creyo haber tropezado en la oscuridad contra un banco, hasta que a sus vibraciones irregulares conocio ser el efecto de un terremoto."

SPECIFIC EVENT REFERENCES:

Murty, 1995 (ATWC catalogue)
Guinea et al., 1995 (Alvarez, 1982)
Hatori, 1995 (Iida, et al., 1967; Soloviev & Go, 1985)
Rojas et al., 1993 (Sutch, 1981)
Grases, 1990
Cruz & Wyss, 1983 (Milne, 1911; Montessus de Ballore, 1888; Sutch, 1981)
Carr & Stoiber, 1977 (Montessus de Ballore, 1884)
Leeds, 1973 (Destructive Earthquakes in Nicaragua (Montessus de Ballore, 1888; Jorgensen))

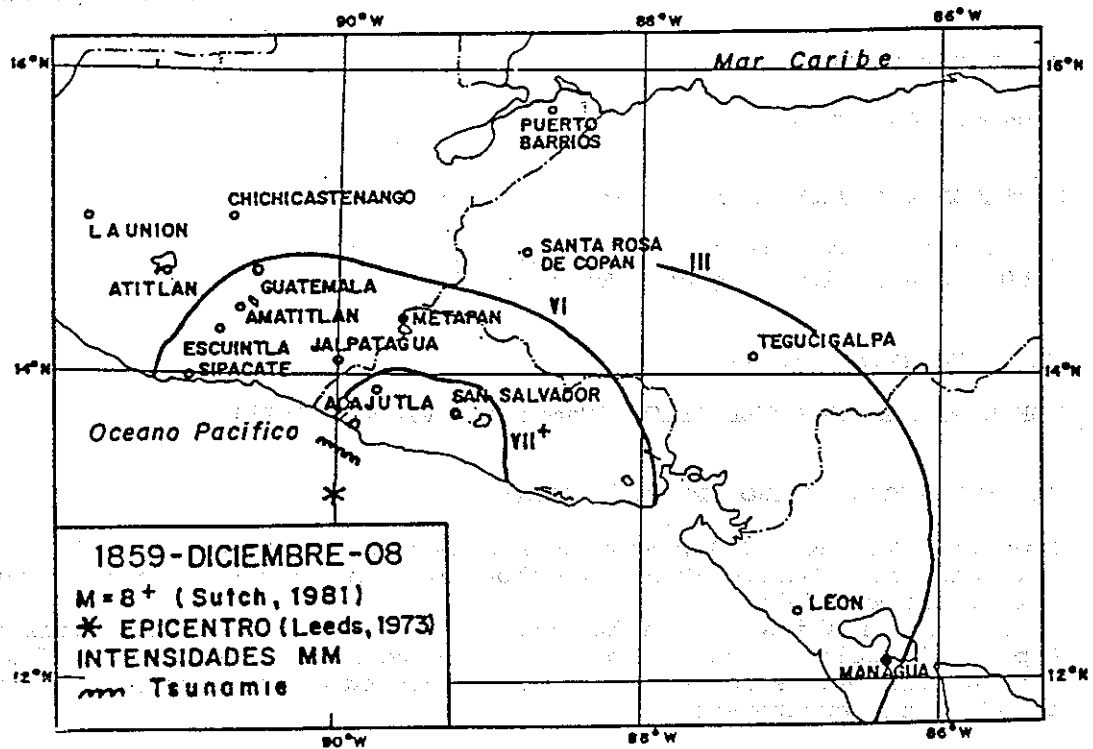


Figure 5. Macroseismic map for the December 8, 1859 earthquake and tsunami (Grases, 1990).

No	DATE	TIME	EARTHQUAKE SOURCE PARAMETERS			TSUNAMI PARAMETERS			O
			Lat (°N)	Lon (°W)	Ms/I	T	REGION	m	
13	1873-1014	00:05	10.2	80.0	V	L	Colon & Panama, Harbors, PAN	--	C

EPICENTER REGION:

Panama, Caribbean

EARTHQUAKE SOURCE PARAMETERS:

1013-1805(local), 10.2°N-80.0°W (Camacho y Viquez, 1993)
V MM, Panama City (Viquez & Toral, 1987)

TECTONIC ENVIRONMENT:

NORTH PANAMA DEFORMED BELT (Camacho y Viquez, 1993)

TSUNAMI AND/OR MACRO SEISMIC REPORT:

Camacho y Viquez, 1993 (Panama Star & Herald on October 16, 1873):

"(In this city (Panama City) the shock was strongly felt about 5 minutes past six.....It was felt on board the ships in the harbour, along the line of the railroad and at Aspinwall (Colon).....In Aspinwall... have been more severely felt than in Panama. The people there were much frightened and the fear of the tidal wave added to the excitement."

SPECIFIC EVENT REFERENCES:

Rojas et al., 1993
Viquez & Toral, 1987 (Nature, 1871);

No	DATE	TIME	EARTHQUAKE SOURCE PARAMETERS			TSUNAMI PARAMETERS			O
			Lat (°N)	Lon (°W)	Ms/I	T	REGION	m	
14	*1882-0907	09:18	10.0	79.0	7.9	L	San Blas Coast, PAN	1	C

EPICENTER REGION.

San Blas Region, Panama, Caribbean

EARTHQUAKE SOURCE PARAMETERS:

M=7.5 Murthy, 1995 (ATWC)
 0907-0318(local), 10°N-79.0°W, Ms=7.9 (Camacho y Viquez, 1993a)
 0907, 10°N-78°W, M=8, thrust-faulting (Mendoza & Nishenko, 1989)
 0907, M=7 1/2 (Soloviev & Go, 1984)
 0907-0920, 9.0°N-82.0°W, h= intermediate (70-200), 7.0<M<7.7 (Leeds, 1974)

TECTONIC ENVIRONMENT:

NORTH PANAMA DEFORMED BELT (Mendoza & Nishenko, 1989)

Tsunami magnitude = 2 (Torai, unpublished)
 Tsunami magnitude=2-2.6 (Mendoza & Nishenko, 1989)
 Tsunami intensity = 1 (Fernandez, 1993 (Viquez & Torai, 1987))
 Tsunami magnitude=1 (Soloviev & Go, 1984)

Figure 6. Intensity distribution (Mendoza & Nishenko, 1989)

Figure 7. Tsunami and liquefaction areas affected (Camacho & Viquez, 1993)

TSUNAMI AND/OR MACRO SEISMIC REPORT:

Camacho y Viquez, 1993b (Cermeise, 1886; A.N.P., 1882a; Canelle-Aillard, 1882; Star & Herald, 1882; Montessus de Ballore, 1888; Ramirez, 1976; Grases, 1974; Mc Cullough, 1979; Nelson, 1971):

"At the village of Rio Indio (Panama) two fresh water lagoons near the coast dried up almost immediately and kind of several sandy islands were formed in their former bed."

"...in Colombia: craters and sand volcanoes appeared at Rio Sucio, in the Atrato river banks, and sandy warm water springs flooded parts of the town of Turbo, in the Uraba Gulf."

"The shocks were also felt by the ships at the ports (in Panama) and it is believed that some got cracks. There was not tsunami. The earthquake was felt in the bay island and the cable to the West Indies broke."

"This event caused a tsunami which affected the San Blas coast, northeastern Panama, with waves 3.0 m high or more. These waves wash most of the islands of the San Blas Archipelago out, which remained submerged for several minutes. Between seventy five and one hundred natives were drowned. Unfortunately the mariogram, of the French Canal Company tide gauge at Colon, with the record of the tsunami, is lost."

Grases, 1990 (Rockwood, 1883; Tabor, 1967; Ramirez, 1969):

"...fue sentido en un area muy extensa que alcanzo a Rivas y Greytown en Nicaragua, Cartagena y Buenaventura en Colombia, Maracaibo en Venezuela, y causo mas de 50 victimas, mayoritariamente ahogados."

Mendoza & Nishenko, 1989 (Star and Herald, 1882; Nelson, 1889, Bulletin du Canal Interoceanique, 1882, Montessus de Ballore, 1888):

"A large tsunami associated with the earthquake swept the San Blas Islands in northern Panama on 7 September 1882, killing about 65 people."

".....the tide ran out a great distance, and on its return, swept away the villages built on the beaches of the different islands of the archipelago and on the mainland. The outflow and inflow occurred four times a day, the greatest damage being done by the third wave. The villages of Rio Coco, Isla Paloma, Napacandi, on the islands of the same name, were swept away, and more than forty persons were drowned. At Playon Grande, every house was washed down, but only two persons were drowned. Playon, Chico, which adjoins it, also suffered. All the produce stored at Rio Mono was swept away, but no lives were lost. The cheif loss of produce, however, has taken place at Aguilí Candi island.....Sixteen persons lost their lives there, and several thousand dollars worth of imported goods were swept into the sea. The villages of Rio Banama and Mosquito have also been flooded, the people left homeless, and their goods destroyed."

"Although the sea was observed to be relatively calm at Colon, the Canal Company tidal gauge located offshore registered a distinct tsunami with a maximum height of 62 cm. At Miguel de La Borda, the tide rose and flooded beach houses. Becouse subsidence was extensive in the area, however, the tsunami effects at Miguel de la Borda cannot be accurately estimated. The submarine telegraph cable between Colon and Jamaica broke during the earthquake."

"In Panama City.....The earthquake was strongly felt on vessels anchored offshore, but no anomaly was observed on the tidal gauge located in Naos, one of the small islands south of the city."

Soloviev & Go, 1984 (Fuchs, 1883, 1885; Montessus de Ballore, 1888; Milne, 1912; Ramirez, 1933, 1969, Sieberg, 1932; Iida, et al., 1967):

"there was a earthquake at Panama.....The underwater cable to Jamica was broke."

"Fuchs adds that the earthquake was felt strongly on the islands in the Gulf of Panama. According to Montessus de Ballore and Ramirez, the HODURAS, situated in a road 3 1/2 km from Panama, felt a seaquake, preceded by a rumbling. Although no visible waves appeared on the surface, the sea began to move rapidly. The vessel began to move, as if at full speed, and ran aground on a bed."

"Sieberg, in giving the basic data on the earthquake, reports that it was accompanied by tsunami waves which were observed from Panama to Guayaquil."

SPECIFIC EVENT REFERENCES:

Murty, 1995 (ATWC catalogue)

Camacho, 1994

Rojas et al., 1993 (Leeds, 1974; Toral, 1992; Mendoza & Nishenko, 1989)

Nishenko, et al., on print, 1992 (Viquez & Toral, 1987; Mensoza & Nishenko, 1989)

Viquez & Toral, 1987

Leeds, 1974 (Destructive Earthquakes of Nicaragua)

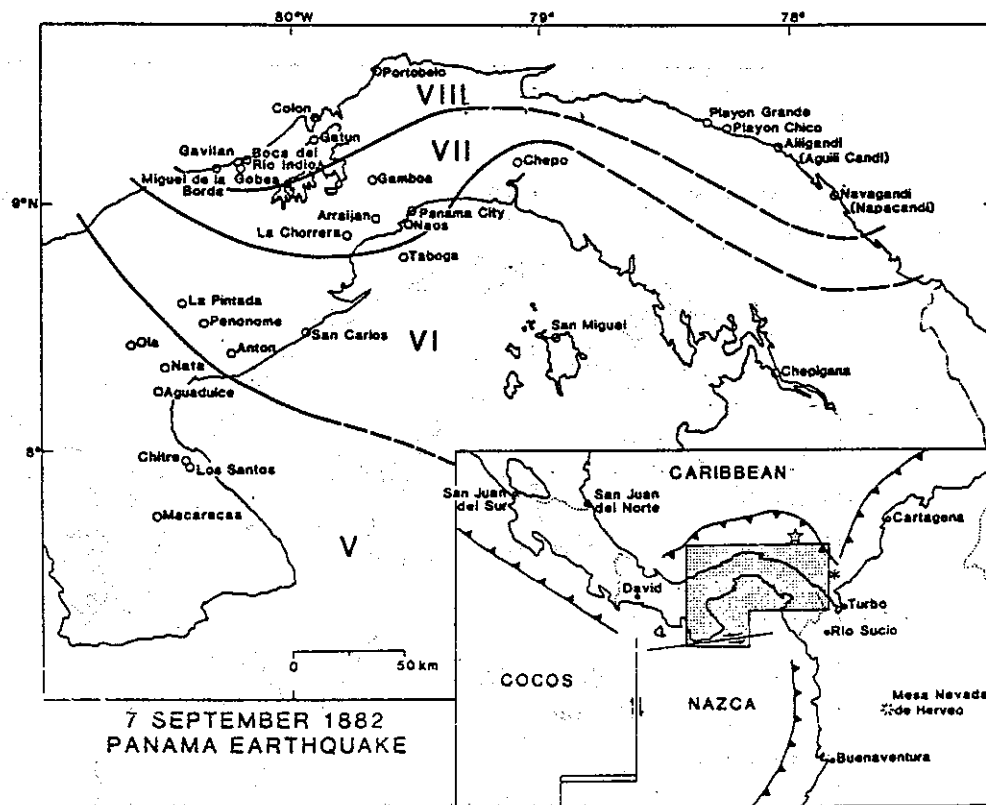


Figure 6. Iseismal map for the September 7, 1882 earthquake. Tectonic features shown in the inset map. Epicentral location proposed by Goberna (1985) (asterisk) and this study (star) (Mendoza & Nishenko, 1989).

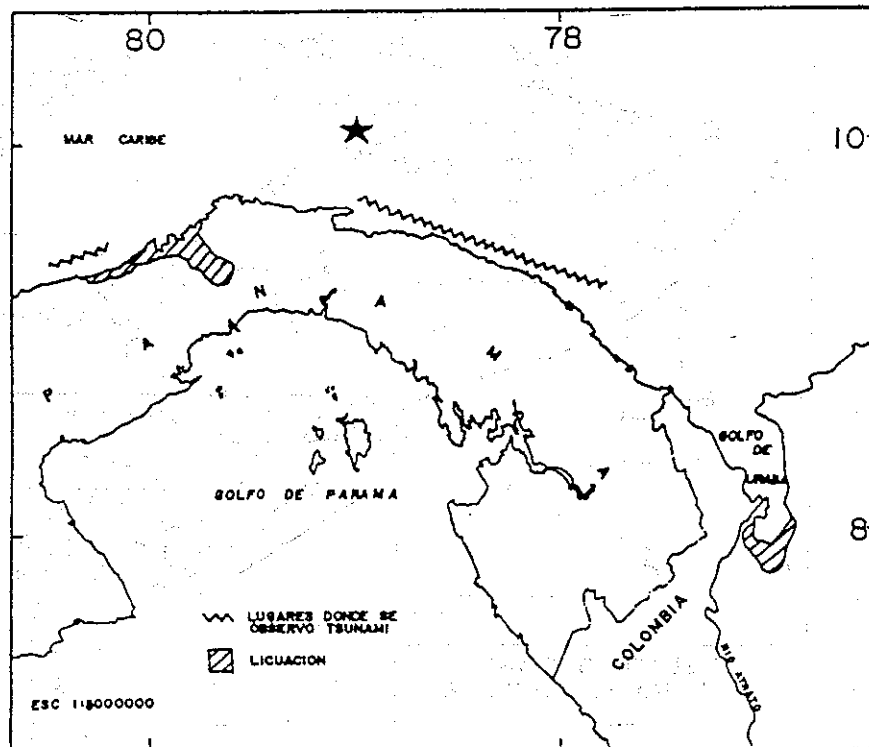


Figure 7. Tsunami area and permanent deformation (liquefaction) related with the September 7, 1882 earthquake (Camacho & Viquez, 1993).

No	DATE	TIME	EARTHQUAKE SOURCE PARAMETERS			TSUNAMI PARAMETERS			O
			Lat (°N)	Lon (°W)	Ms/I	T	REGION	m	
15	1884-1105		4.0	76.0	---	L ?	Acandi, Colombia	--	P

EPICENTER REGION:

Colombia-Panama, Pacific

EARTHQUAKE SOURCE PARAMETERS:

1105, 4N-76W, h=100, Ms=7.5 (Rojas et al., 1993)

TECTONIC ENVIRONMENT:

NORTH PANAMA DEFORMED BELT

TSUNAMI AND/OR MACRO SEISMIC REPORT:

Grases, 1990 (Rockwood, 1885; Tabor, 1967):

"...un sismo destructor en Panama para esta fecha, que afecto principalmente Aguadas y Pacoria.danos en la capital y Pacoria."

Soloviev & Go, 1984 (Fuchs, 1885-1887; Milne, 1912; Sieberg, 1932; Ramirez, 1933; Iida, et al., 1969):

"There was a destructive earthquake on the Panama Isthmus. ...In Panama, Acandi and Paconia suffered especially. There, a seismic wave (it is not clear whether this was an earthquake or a tsunami) destroyed churches, state buildings and private homes."

SPECIFIC EVENT REFERENCES:

Murty, 1995 (ATWC)

Feldman, 1984

PARTE 3:

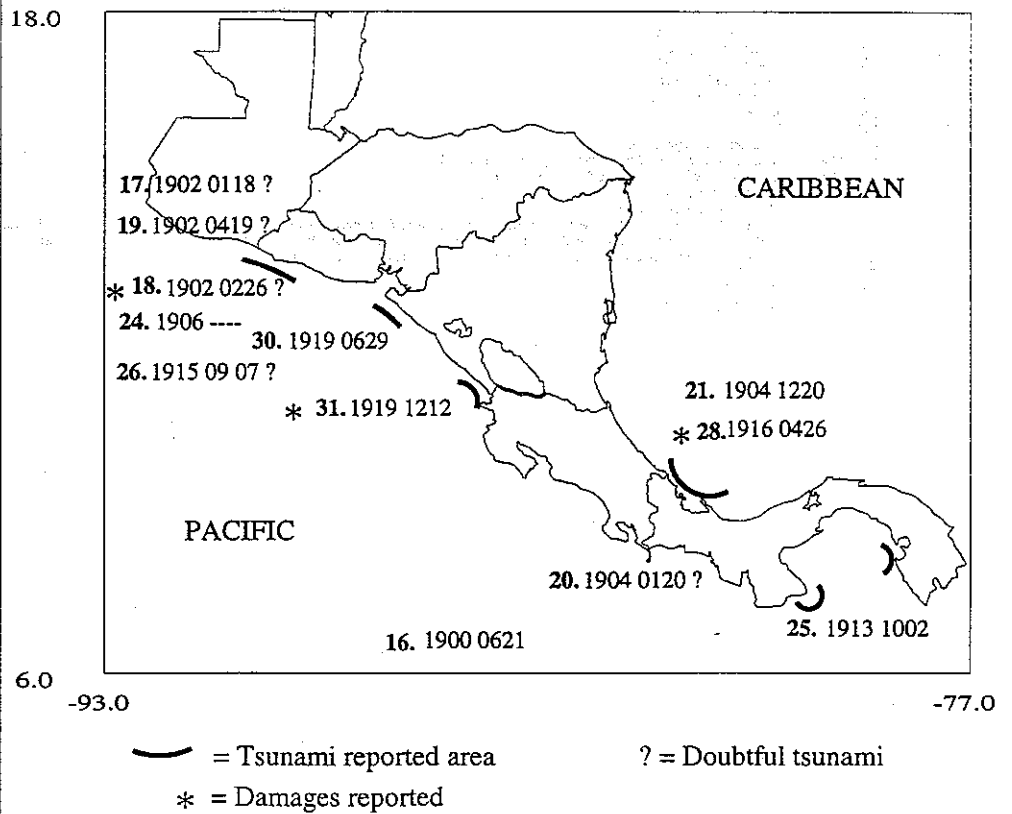
TSUNAMIS DURING THE XX CENTURY

Part 3: Tsunamis During the XX Century

No	DATE	TIME	EARTHQUAKE SOURCE PARAMETERS			TSUNAMI PARAMETERS			TECTONIC REGION	OCEAN
			Lat (°N)	Lon (°W)	M _s /I	T	REGION	m		
17	1902-0118	23:23	14.7	91.6	6.3	L?	Ocos, GUA	--	(CO-CA)	P
18	*1902-0226	---	13.0	89.0	7.0	?L	Pacific Coast, GUA-SAL	2		P
19	1902-0419	02:24	14.9	91.5	7.5	L?	Ocos, GUA	-1	CO-CA	P
20	1904-0120	14:50	7.0	82.0	7.0	L?		--		P
21	1904-1220	05:42	9.2	82.8	7.45	L	Bocas del Toro, PAN	--	NPDB	C
22	1905-0120	18:23	9.85	84.68	6.8	L	Cocos Island, CR	--	(CO-CA)	P
23	1906-0131	15:36	1.0	81.3	8.2	R	Tumaco, ECU-PAN-CR San Carlos, PAN-CR Potrero Bay, CR-PAN	--	ECUADOR	P
24	1906-----	---	---	---	---	T	El Salvador Coast, SAL	--		P
25	*1913-1002	04:23	7.1	80.6	6.7	L	Azuero Peninsula, PAN San Miguel Gulf, PAN	-1	AZUERO-TORIO F.Z.	P
26	1915-0907	01:20	13.9	89.6	7.7	L?	El Salvador Coast, SAL	-0.5	CO-CA	P
27	1916-0131	---	---	---	---	T	Panama Canal, PAN	--		P
28	*1916-0426	02:21	9.2	83.1	6.9	L	Bocas del Toro, PAN	0	NPDB	C
29	1916-0525	---	12.0	90.0	7.5	?L?	El Salvador	--		P
30	1919-0629	23:14	13.5	87.5	6.7	L	Corinto, NIC	--	(CO-CA)	P
31	*1919-1212	---	---	---	---	L	El Ostial, NIC	--	(CO-CA)	P
32	1920-1206	---	---	---	---	L	Ponseca Gulf	--		P
33	1926-1105	07:55	12.3	85.8	7.0	L	Offshore, NIC	--	(CO-CA)	P
34	*1934-0718	01:36	8.1	82.6	7.5	L	Chiriqui Gulf, PAN	1.5	PFZ	P
35	1941-1205	20:46	8.7	83.2	7.6	L	Pta. Dominical, C R	-1	CO-CA	P
36	1941-1206	---	10.0	85.2	6.9	L	Nicoya Gulf, CR	-2	(CO-CA)	P
37	1950-1005	16:09	10.0	85.7	7.9	L	Coasts CR-NIC-SAL	-1	CO-CA	P
38	1950-1023	16:13	14.3	91.8	7.3	L	Coasts GUA-SAL	-1	CO-CA	P
39	*1951-0803	00:24	13.0	87.5	6.0	LH	Potosi, Fonseca Gulf, HON	--	(CO-CA)	P
40	1952-0513	19:31	10.3	85.3	6.9	L	Puntarenas, CR	-3	CO-CA	P
41	1956-1024	14:42	11.5	86.5	7.2	L?	San Juan del Sur, NIC	--	CO-CA	P
42	*1957-0310	14:42	51.63	175.41	8.1	D	Acajutla, SAL	--	ALEUTIAN	P
43	1960-0522	19:11	-38.2	73.50	8.5	R?	La Union, Fonseca G., SAL	--	CHILE	P
44	1962-0312	11:40	8.0	89.9	6.7	L	Armuelles, Chiriqui G., PAN	-1	CO-CA	P
45	1968-0925	10:38	15.6	92.6	6.0		Pacific Coast	--		P
46	1976-0204	09:01	15.2	89.2	7.5	L	Cortes, Honduras G., HON	-0.5	NO-CA	C
47	1976-0711	16:54	7.43	78.12	7.0	L	Jaque, Darien, PAN	-1		P
48	1990-0325	13:16	9.8	84.8	7.0	L	Punta Arenas & Quepos, CR	0	CO-CA	P
49	1991-0422	21:56	9.6	83.2	7.6	L	Bocas del Toro, PAN	1	NPDB	C
50	*1992-0902	00:16	11.7	87.4	7.2	L	Nicaragua Coast, NIC-CR Bahía de Salinas, CR-NIC Papagayo G., CR-NIC	2.5	CO-CA	P

* = damage Report
 T = tsunami type
 L = local tsunami
 R = Regional Tsunami
 D = Distant Tsunami
 S = seiche
 LH = Lahar
 m = tsunami magnitude
 NO-CA = North America-Caribbean plate boundary
 CO-CA = Cocos-Caribbean subduction zone
 NPDB = North Panama deformed Belt
 I = MM intensity scale
 ? = event included in previous tsunami specific catalogues. But is poor documented, doubtful or are contradictory reports
 () = before the tsunami symbol refers to the earthquake event and after to tsunami event.
 C = inferred in this study, only when was considered obvious
 C = Caribbean
 P = Pacific
 N-L = Nicaragua lake

LOCAL TSUNAMIS XX CENTURY 1900-1920

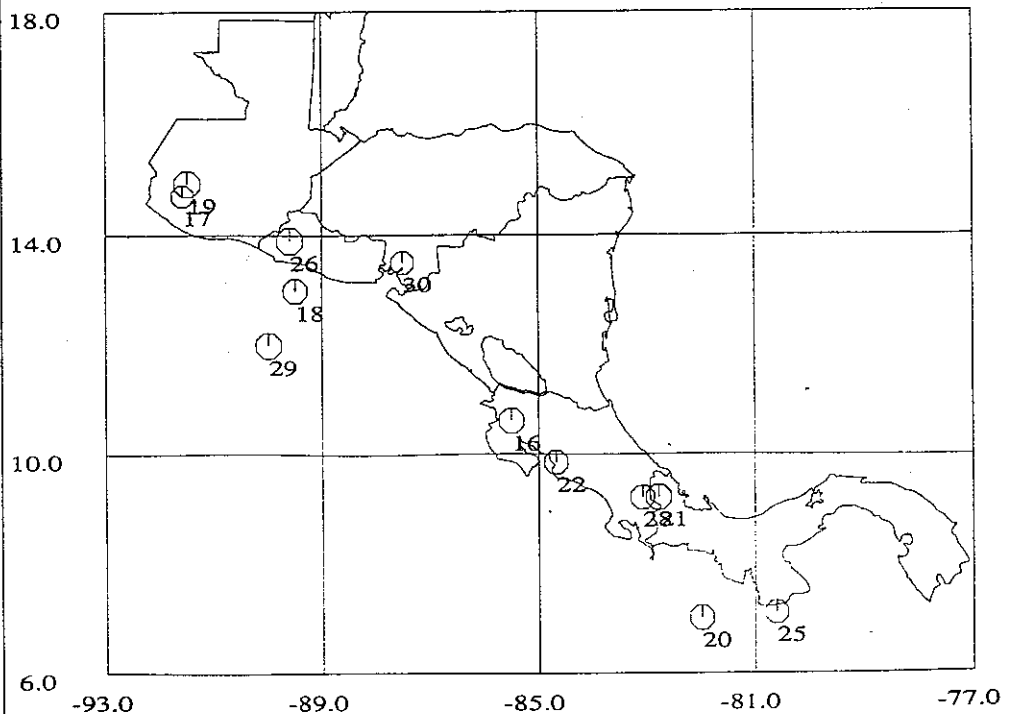


Total events: 32
Selected events: 32

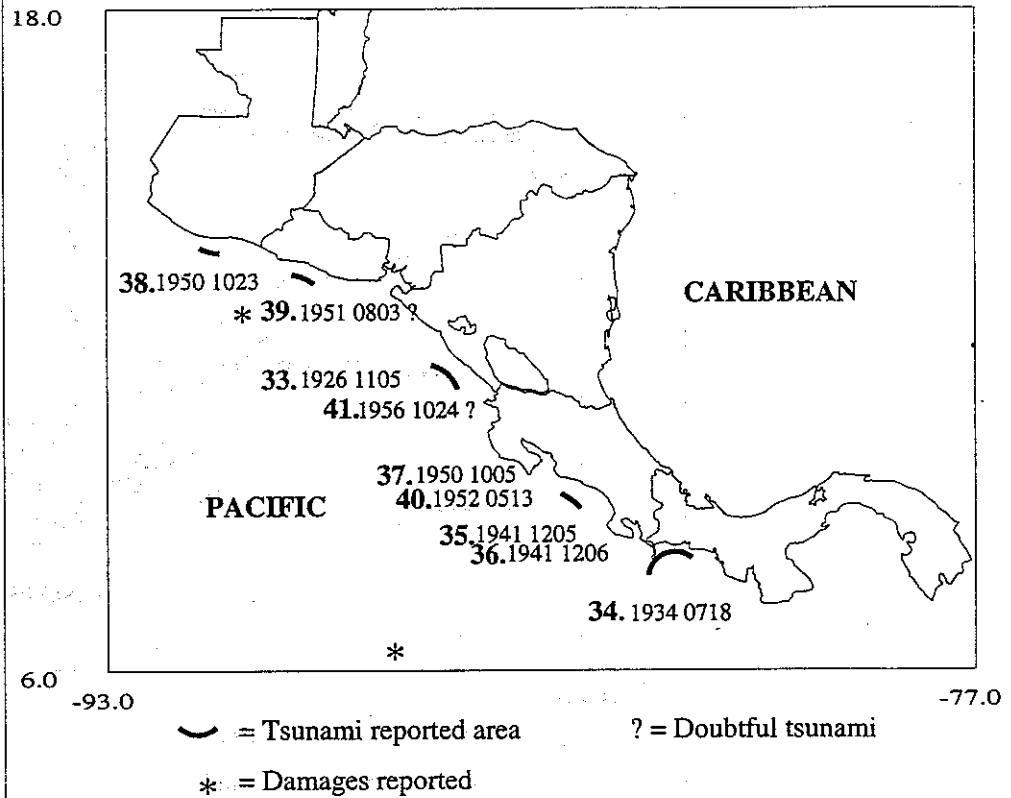
Magnitudes:

M = 0	+
M = 1	.
M = 2	o
M = 3	o
M = 4	o
M = 5	o
M = 6	o

TSUNAMIGENIC EARTHQUAKES 1900-1920



LOCAL TSUNAMIS XX CENTURY 1921-1960

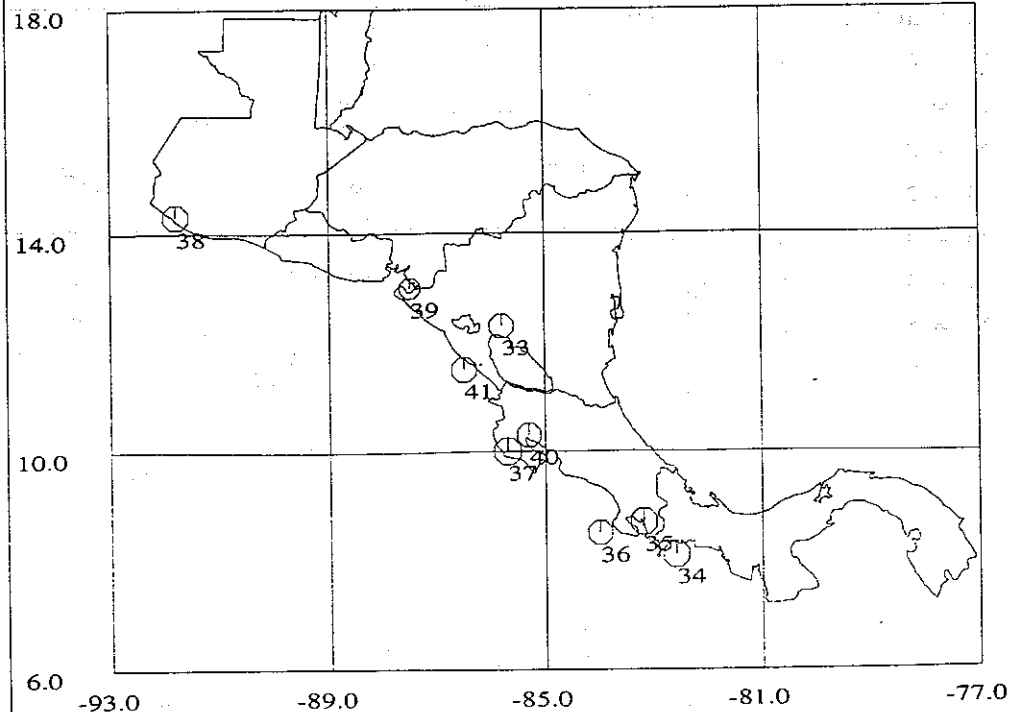


Total events: 50
Selected events: 41

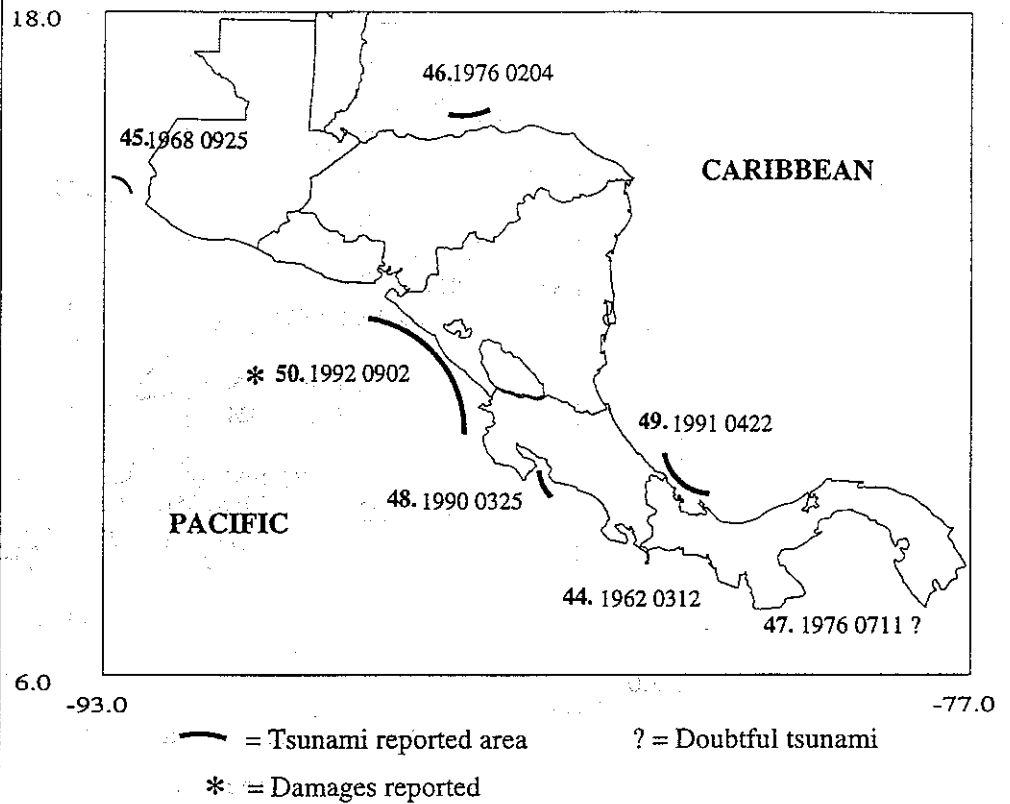
Magnitudes:

M = 0	+
M = 1	.
M = 2	o
M = 3	o
M = 4	o
M = 5	o
M = 6	o

TSUNAMIGENIC EARTHQUAKES 1921-1960



LOCAL TSUNAMIS XX CENTURY 1961-1996

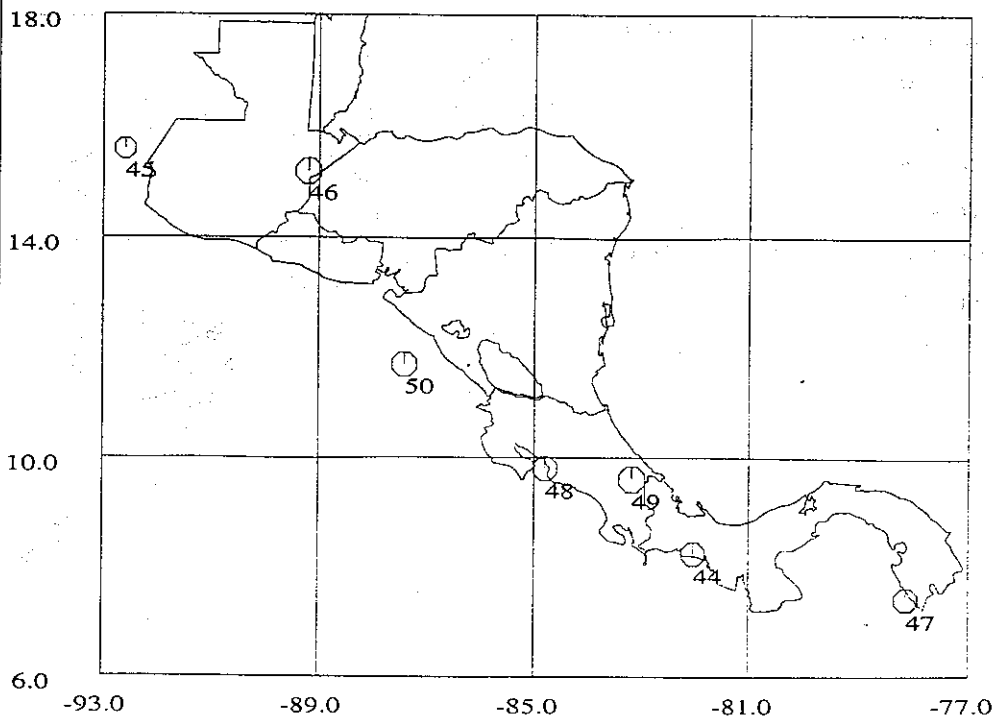


Total events: 59
Selected events: 50

Magnitudes:

M = 0	+
M = 1	.
M = 2	o
M = 3	o
M = 4	o
M = 5	o
M = 6	o

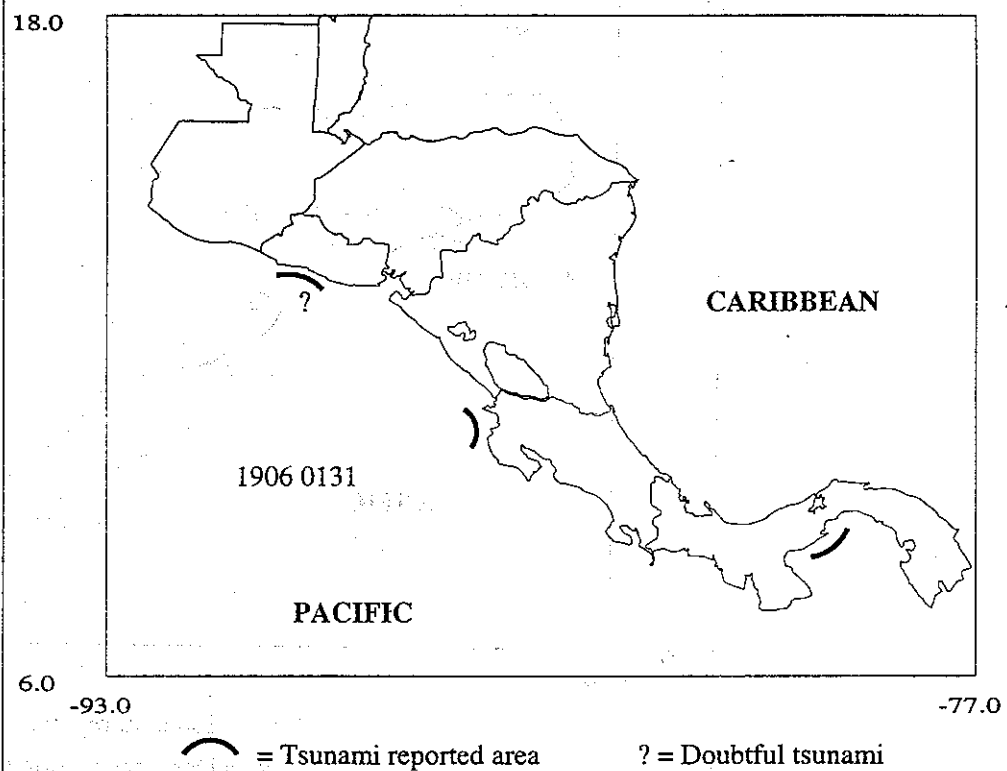
TSUNAMIGENIC EARTHQUAKES 1961-1996



REGIONAL TSUNAMI

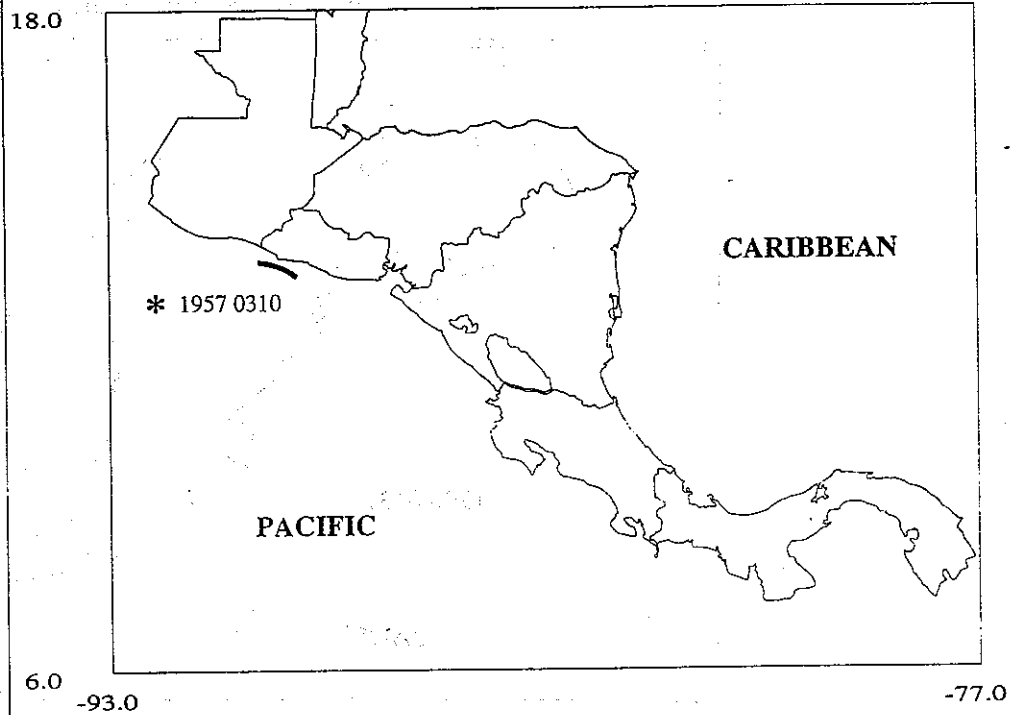
XX CENTURY

Epicentral region: Tumaco, Ecuador



**DISTANT TSUNAMI
XX CENTURY**

Epicentral region: Aleutian

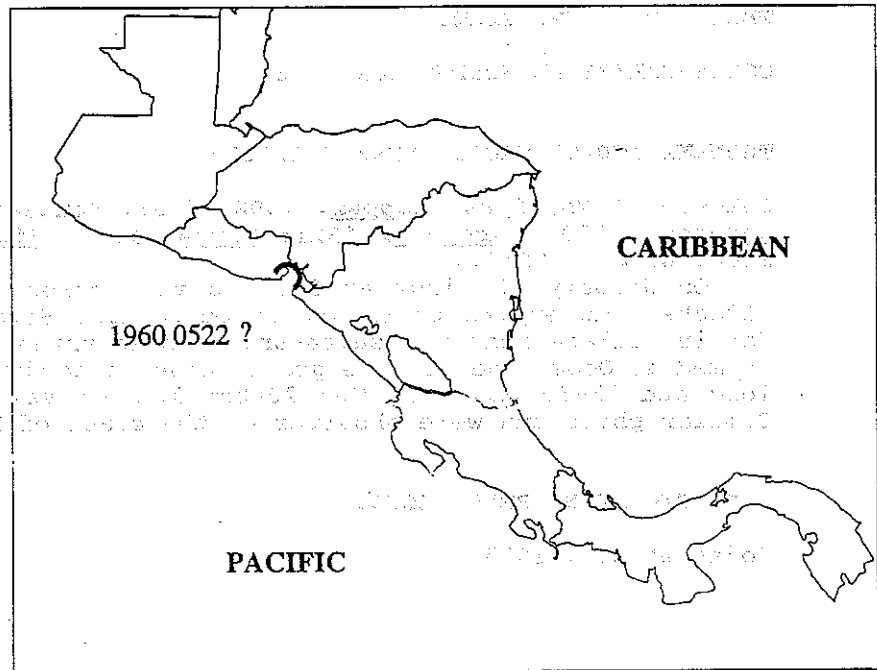


— = Tsunami reported area

* = Damages reported

**REGIONAL TSUNAMI
XX CENTURY
Epicenter region: Chile**

18.0



CARIBBEAN

1960 0522 ?

PACIFIC

6.0

-93.0

-77.0



= Tsunami reported area

? = doubtful tsunami

No	DATE	TIME	EARTHQUAKE SOURCE PARAMETERS			TSUNAMI PARAMETERS			O
			Lat (°N)	Lon (°W)	Ms/I	T	REGION	m	
17	1902-0118	23:23	14.7	91.6	6.3	L?	Ocos, GUA	--	P

EPICENTER REGION:

SW Guatemala Pacific coast

EARTHQUAKE SOURCE PARAMETERS:

0118-2323, 14.71°N-91.59°W, h<40-60 Km, Ms=6.31 (Ambraseys, 1995)

TECTONIC ENVIRONMENT:

COCOS-CARIBBEAN SUBDUCTION ZONE

TSUNAMI AND/OR MACRO SEISMIC REPORT:

Soloviev & Go, 1984 (Sapper, 1902, 1905; Montessus de Ballore, 1906, 1907; Anderson, 1908; Krummel, 1911; Larde, 1916; Sieberg, 1932; Schultz, 1963; Iida, et al., 1967):

"...On January 18, 1902 at 17:20 a very strong earthquake occurred, which affected the entire territory of Guatemala. Several homes collapsed at San Martin village near Quetzaltenango, while three sand ridges about 2 km long formed at Ocos. The visible ground waves according to accounts, were 25-30 m long and 25-30 cm high. Two 20-ton locomotives were shifted 1 1/2 - 2 m. Similar phenomena were observed on the coast of Mexico at San Benito."

SPECIFIC EVENT REFERENCES:

Rojas et al., 1993

No	DATE	TIME	EARTHQUAKE SOURCE PARAMETERS			TSUNAMI PARAMETERS			O
			Lat (°N)	Lon (°W)	Ms/I	T	REGION	m	
18	*1902-0226	---	13.0	89.0	7.0	?L	Pacific Coast, GUA-SAL	2	P

EPICENTER REGION.

Salvador-Guatemala Pacific Coast

EARTHQUAKE SOURCE PARAMETERS:

0226, 13.0°N-89.0°W (Hatori, 1995 (Soloviev & Go, 1985))

0226, 13.0°N-89.5°W, h=30, Ms=7.0 (Rojas et al., 1993 (Carr & Stoiber, 1977))

Tsunami intensity = 2 (Fernandez, 1993 (White & Cifuentes, in preparation))

Tsunami magnitude=2 ((Hatori, 1995 (Soloviev & Go, 1985))

TECTONIC ENVIRONMENT:

COCOS-CARIBBEAN SUBDUCTION ZONE (Rojas et al., 1993)

TSUNAMI AREA (Carr & Stoiber, 1977). See Figure 4.

TSUNAMI AND/OR MACRO SEISMIC REPORT:

Ambraseys & Adams, 1996 (Anderson, 1908; List 1903):

"The seismic sea wave of 1902 February 27 is a spurious event. On 26 February at 19 h local time (27 February 00 h 36 m UT) a tidal wave flooded the coast of Ahuachapan in El Salvador from Garita Palmera to Barra del Paz and beyond, a distance of about 120 km. The height of the wave is not mentioned, but allegedly about 100 persons were drowned at Santiago and 85 at Barra del Paz. Some property damage was caused on the coast of Acajutla an Cara Sucia. Some writers associate this event with a spurious earthquake on 1902 February 26 (Cruz & Wyss, 1983) or with the aerthquake of 1903 April 19. However, there is evidence that this wave was not triggered by an earthquake, but rather that it was the result of a combination of a high tide and abnormal meteorological conditions."

Soloviev & Go, 1984 (Sapper, 1902, 1905; Montessus de Ballore, 1906, 1907; Anderson, 1908; Krummel, 1911; Larde, 1916; Sieberg, 1932; Schultz, 1963; Iida, et al., 1967):

"On February 26, the residents of the Pacific coast border regions of Guatemala and El Salvador heard a loud rumble, like cannon shots, which appered to come from under the botton of the sea. A strong earthquake then occurred. The residents were frightened. Soon they saw the water retreating, exposing the sea botton for a considerable distance. After this, a black wall arose at the sea: this was a large wave, whose might increased as it approached the shore. The wave surge anshore with terrifying force. The residents did not have time to run safety and they perished. The Tsunami was observed on a 120 km strech of coast which included Acajutla. One hundred people died and about the same number were injured at Barra de Santiago settlement. About 85 people died at the village of Barra del Paz. Homes and trees were washed out to sea, and the clothes were ripped from people caught by water. three waves were reported, the first being the smallest."

Carr & Stoiber, 1977 (Sapper, 1937):

"Tsunami along 120 Km of El Salvador and Guatemala Coast."

Larde, 1960:

".....es la marejada sismica que en 1902 invadio las costas de Sonsonate y Ahuachapan.....Frente a la Barra Santiago y no frente a la Barra de San Pedro."

SPECIFIC EVENT REFERENCES:

Rojas et al., 1993 (Cruz & Wyss, 1983; Carr & Stoiber, 1977)

Cruz & Wyss, 1983 (Sieberg, 1932; Sapper, 1905; Schultz, 1962)

No	DATE	TIME	EARTHQUAKE SOURCE PARAMETERS			TSUNAMI PARAMETERS			O
			Lat (°N)	Lon (°W)	Ms/I	T	REGION	m	
19	1902-0419	02:24	14.9	91.5	7.5	L?	Ocos, GUA	-1	P

EPICENTER REGION:

SW Guatemala Pacific Coast

EARTHQUAKE SOURCE PARAMETERS:

0419-0224, 14.93°N-91.5°W, h<40-60 km, Ms=7.5 (Ambraseys & Adams, 1996)
 0419-0223, 14.0°N-91.0°W, h=25 km, Ms=7.4 (Pacheco & Sykes, 1992)
 0419, 14.0°N-91.0°W, h=33 km, M=8.2 (PAS) (Grases, 1990)
 0419-0223, 14°N-91°W, M=8.3 (Soloviev & Go, 1984 (Richter, 1963))

TECTONIC ENVIRONMENT:

COCO-CARIBBEAN SUBDUCTION ZONE (Carr & Stoiber, 1977)

Tsunami magnitude = -1 (Toral, unpublished)

Figure 8. Intensity distribution (Soloviev & Go, 1984)

TSUNAMI AND/OR MACRO SEISMIC REPORT:

Rockstroch, 1902; Sapper, 1902):

"This major earthquake in Guatemala extended the destruction caused by the shock of 18 January (Ms=6.3) and affected a much larger area."

"At the port of Ocos large areas of saturated beach sands liquefied again, and the settlement of the beach extended further inland than on 18 January, causing damage to the railway line."

"The earthquake set up standing waves in the lake of San Cristobal in Alta Verapaz...."

"There is no evidence that the earthquake was associated with a seismic sea wave: modern writers wrongly associate this earthquake with the tidal wave of 27 February in El Salvador."

Soloviev & Go, 1984 (Sapper, 1902, 1905; Montessus de Ballore, 1906, 1907; Anderson, 1908; Krummel, 1911; Larde, 1916; Sieberg, 1932; Schultz, 1963; Tida, et al , 1967):

"...on April 18, a considerably stronger earthquake occurred than on January 18.The greatest destruction occurred at Quetzaltenango, San Pedro and Solola.....The coast in the Ocos region subsided 1 m."

Carr & Stoiber, 1977 (Rockstroh, 1902)):

"Great earthquake devastates western Guatemala. For map see Rockstroh."

SPECIFIC EVENT REFERENCES:

Rojas et al., 1993
 Grases, 1990

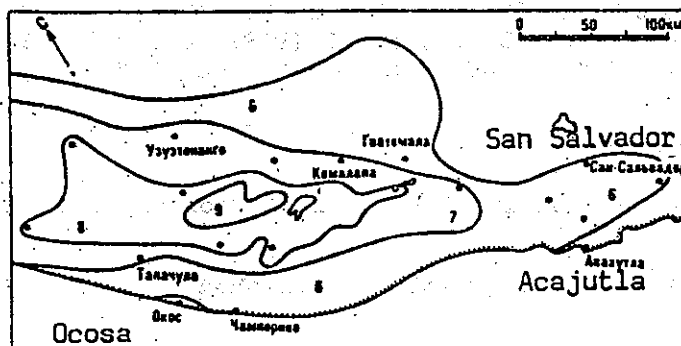


Figure 8. Isoseists of the April 18, 1902 Guatemala SW Pacific coast earthquake on the 12 point scale (Soloviev & Go, 1984).

No	DATE	TIME	EARTHQUAKE SOURCE PARAMETERS			TSUNAMI PARAMETERS			O
			Lat (°N)	Lon (°W)	Ms/I	T	REGION	m	
20	1904-0120	14:50	7.0	82.0	7.0	L?		--	P

EPICENTER REGION:

Panama-Costa Rica, Pacific

EARTHQUAKE SOURCE PARAMETERS:

0120-1450, 7.0°N-82.0°W, h=crustal focus, Ms=7.0 (Ambraseys & Adams, 1996)
 0120, 7°N-79°W, Magnitude = 7.9 (Murty, 1995 (ATWC catalogue))
 0120-1452, 7.0N°-79.0°W, Ms=7.1 (Pacheco & Sykes, 1992)
 0120, 7°N-79°W, M=7.9 (PAS) (Viquez & Toral, 1987 (Gutenberg & Richter, 1954))
 0120-1452, 7°N-79°W, M=7.75 (Soloviev & Go, 1984(Gutenberg & Richter, 1954))

TECTONIC ENVIRONMENT:

PANAMA FRACTURE ZONE

TSUNAMI AND/OR MACRO SEISMIC REPORT:

Ambraseys & Adams, 1996 (Oddone 1907; Viquez 1910):

"This earthquake most probably had an epicentre in the Pacific, south of western Panama. The shock was very strong in the Chiriqui district..."
 "On 21 January a ship sailing near the Revilla Griego Island (20 N, 110W) reported floating tree-trunks and bodies of dead animals, but this is too far away from Chiriqui to be associated with this earthquake."
 "Macroseismic information for this shock is just sufficient to suggest a location off the coast of Chiriqui, near the position adopted by BAAS."

Soloviev & Go, 1984 (Odore, 1907):

"There was an earthquake with an intensity of up 4 degrees (V on R.F. scale) at Panama and Costa Rica. It was felt all over the both countries, but there was no damage. On the 21st, the ship CITY OF PANAMA at 20 N, 110 W, encountered floating trees and animal corpses-possible the result of seismic catastrophe on the 20th."

SPECIFIC EVENT REFERENCES:

Rojas et al, 1993 (Gutenberg & Richter, 1954)
 Viquez & Toral 1987

No	DATE	TIME	EARTHQUAKE SOURCE PARAMETERS			TSUNAMI PARAMETERS			O
			Lat (°N)	Lon (°W)	Ms/I	T	REGION	m	
21	1904-1220	05:42	9.2	82.8	7.45	L	Bocas del Toro, PAN	--	C

EPICENTER REGION:

Panama-Costa Rica, Caribbean

EARTHQUAKE SOURCE PARAMETERS:

1220-0542, 9.2°N-82.8°W, h=crustal focus, Ms=7.3 (Ambraseys & Adams, 1996)
 1220-1201(local), 9.5°N-82.9°W, Ms=7.0 (Camacho y Viquez, 1993a)
 1220-0544, 8.3°N-83.0°W, h=25 km, Ms=7.1, thrust type (Pacheco & Sykes, 1992)
 1220, 8.5°N-83.0°W, h=S, Ms=7.2 (Guendel, 1986 (Gutenberg & Richter, 1954; Abe & Noguchi, 1983; Duda, 1965))
 1220-0544, 8.5°N-83°W, h=25, Ms=7.6 (McNally & Minster, 1981 (Gutenberg & Richter, 1954))

TECTONIC ENVIRONMENT:

NORTH PANAMA DEFORMED BELT (Camacho y Viquez, 1993)
 OSA SEISMIC ZONA (Montero, 1986a; Nishenko, 1992; Boschini & Montero, 1994)

Figure 9. Intensity distribution (Camacho y Viquez, 1993)

TSUNAMI AND/OR MACRO SEISMIC REPORT:

Ambraseys & Adams, 1996 (Oddone 1907; Viquez 1910):

"In the Gulf of Bocas del Toro the shock was very strong on board a man-of-war at anchor. It is also reported that as a result of the earthquake a part of the islet of Sapodilla subsided."

"At Limon....It is said that submerged flat reefs near Limon were uplifted and became visible after the earthquake, but this information is in need of authentication."

Camacho y Viquez, 1993 (Gonzalez, 1910):

"By wireless telegraph we learn that the earthquake was very severe in Bocas del Toro and many houses suffered damage. The United States warship DIXIE at anchor there reported by means of her wireless apparatus that the shock was severely felt on board and the crew alarmed."

SPECIFIC EVENT REFERENCES:

Boschini & Montero, 1994 (Montero & Mora, 1985; Montero, 1986; Boschini, 1989)
 Rojas et al., 1993
 Boschini, 1989
 Viquez & Toral 1986
 Feldman, 1984

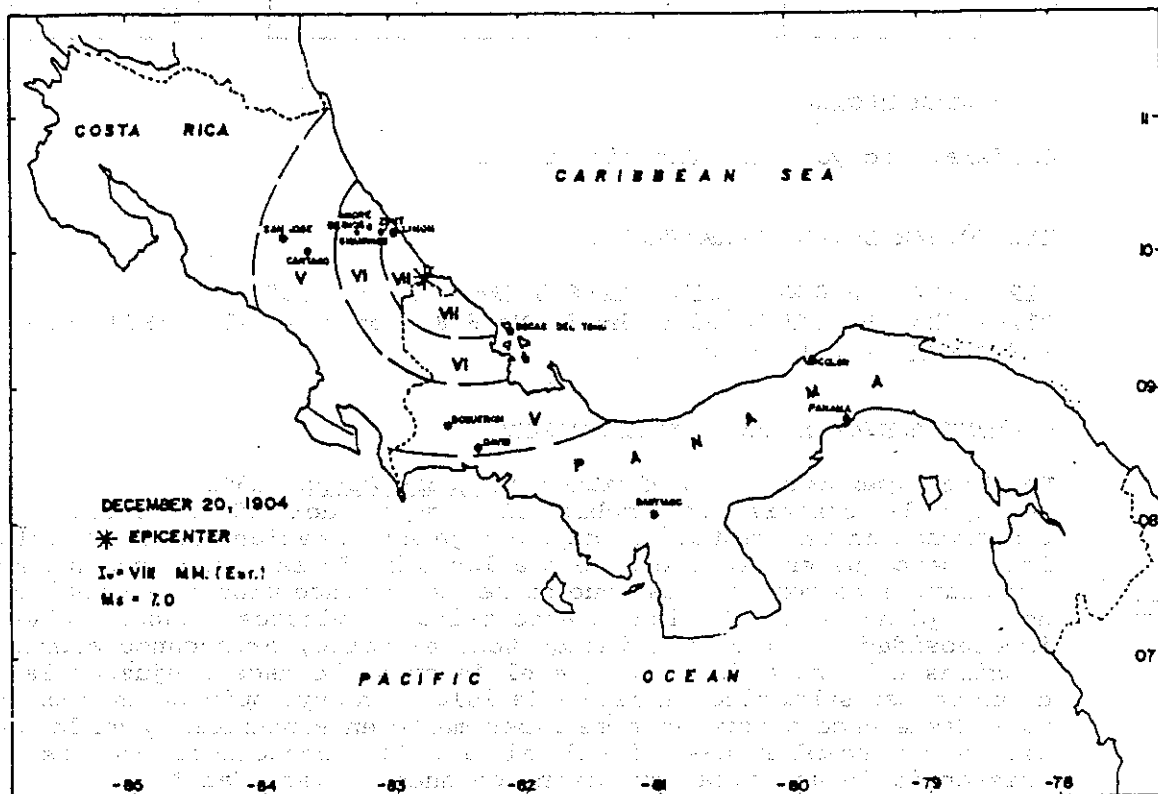


Figure 9. Macroseismic map for the December 20, 1904 Panama event. The proposed epicentre is indicated by a star (Camacho & Viquez, 1993).

No	DATE	TIME	EARTHQUAKE SOURCE PARAMETERS			TSUNAMI PARAMETERS			O
			Lat (°N)	Lon (°W)	Ms/I	T	REGION	m	
22	1905-0120	18:23	9.85	84.68	6.8	L	Coco Island, CR	--	P

EPICENTER REGION:

Caldera, Nicoya Gulf, Pacific, Costa Rica

EARTHQUAKE SOURCE PARAMETERS:

0120-1802, 10.0°N-84.25°W, Ms=6.5 (Ambraseys, 1995)

0120-1823, 9.85°N-84.68°W, h=45, Ms=6.8 (Rojas et al., 1993 (WMR; Gutenberg & Richter, 1954)

TSUNAMI AND/OR MACRO SEISMIC REPORT:

Boschini (personal communication (Agustin Guido, 1905):

"Recayo la conversacion sobre el temblor del 20 de enero, que fue en Puntarenas un terremoto. Nos dijo que jamas se habian sentido temblores en las isla; pero que en esa fecha como a las ocho de la noche, comenzando la marea a vaciar, noto con sorpresa que en menos de cinco minutos se retiro el mar mas de 69 pies; y no habian transcurrido 8 minutos cuando volvio con tal impetuosidad y ruido, que inundo todo el patio, arrancando algunas palmeras proximas a la boca del rio; que el fenomeno le hace prejuizar la existencia de un volcan submarino cercano a la isla, con cuya opinion estamos de acuerdo, pues desde hace cuatro anos se experimento en Puntarenas y en la peninsula de Nicoya un temblor casi igual al del 20, concebimos la sospecha de la existencia de un volcan submarino en nuestra vecindad."

Hatori, 1995 (reported)

Viquez & Toral, 1987:

"Sentido en Costa Rica y moderadamente en Bocas del Toro, V MM en Bocas del Toro."

No	DATE	TIME	EARTHQUAKE SOURCE PARAMETERS			TSUNAMI PARAMETERS			O
			Lat (°N)	Lon (°W)	Ms/I	T	REGION	m	
23	1906-0131	15:36	1.0	81.3	8.2	R	Tumaco, ECU San Carlos, PAN Potrero Bay, CR	--	P

EPICENTER REGION:

Ecuador-Colombia, Pacific coast

EARTHQUAKE SOURCE PARAMETERS:

0131-1536, 1.0°N-81.3°W, Ms=8.1, thrust type (Pacheco & Sykes, 1992)
0131-1536, 1.0°N-81.5°W, M=8.6, (Soloviev & Go, 1984)(Gutenberg & Richter, 1954))
0131, 1.0°N-81.5°W, h=25 Km, M=8.9 (Grases, 1990)

TECTONIC ENVIRONMENT:

NAZCA-SUDAMERICA SUBDUCTION ZONE

Tsunami magnitude=3 (Soloviev & Go, 1984)
Tsunami magnitude = -1 (Toral, unpublished)

Figure 10. Tsunami source area and tide-gauge record at Panama (Hatori, 1983)

TSUNAMI AND/OR MACRO SEISMIC REPORT:

Soloviev & Go, 1984 (Ammon, 1907; Honda, et al., 1908; Sieberg, 1932; Heck, 1934; Gutenberg & Richter, 1949, 1954; Shepard, et al., 1950; Berninghausen, 1962; Pongavin, 1965; Iida, et al. 1967; Hatori, 1968):

"Half an hour after the earthquake, a tidal wave fell on the city (Tumaco). It was 2 1/2 m high (according to other sources, 5 m. It would have been larger had the city not been screened from the sea by two small islands which softened the force of the wave, but one of the islands was half washed away. The wave submerged part of the city and washed away several moorages and homes in the port. There were no casualties. Had it no been ebb tide, the destruction would have been much worse. A second tidal wave followed in 20 minutes, and then a third. Large waves were observed for 4 hours at Tumaco, and flood and ebb tides were supposedly irregular for two weeks."

"The tsunami was observer along the entire coast of Central America, in Mexico and California."

"The wave reached Panama at 17:50. The amplitude of oscillations in level were twice those of regular tide oscillations. At San Carlos the sea retreated, exposing a large beach. The tsunami was cleary registered by the tide gauge on Naos Island, situated 5 km to the south of Panama. The oscillations began with a distinct positive head wave with a period of about 1 hour and an amplitude of 70 cm. Subsequent oscillations were weaker. With the arrival of the tsunami, the water around the island became turbid. By 4:00 on February 1, the amplitude of oscillations in the sea level decreased to 2 cm. Slight oscillations were traced until 15:00."

"A Tsunami occurred at the Pacific coast of Costa Rica about 14:00. A beach 2 km long dried up in Potrero Bay; then the water rushed onshore, tossing up

boats.

SPECIFIC EVENT REFERENCES:

Grases, 1990 (Centeno, 1940; Rudolph and Szirkes, 1906; Perrey, 1858);

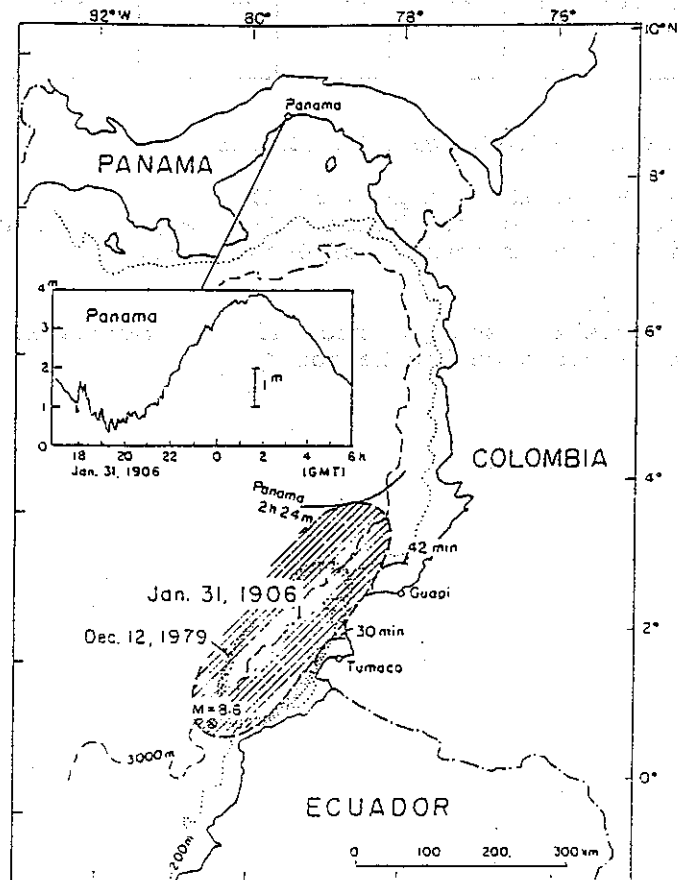


Figure 10. Estimated source area of the Ecuador tsunami on Jan. 31, 1906, and tide-gauge record at Naos Island, Panama Gulf (Hatori, 1983)

No	DATE	TIME	EARTHQUAKE SOURCE PARAMETERS			TSUNAMI PARAMETERS			O
			Lat (°N)	Lon (°W)	Ms/I	T	REGION	m	
24	1906-????	---	---	---	---	T	El Salvador Coast, SAL	--	P

TSUNAMI AND/OR MACRO SEISMIC REPORT:

Soloviev & Go, 1984 (Larde, 1961):

"A tsunami fell on the beach at Los Negros. Apparently, this relates to the Colombian-Ecuador Tsunami of January 31."

Larde, 1960:

".....celebres son por recientes y grandes las olas que.....en 1906 invadio la Playa de los Negros."

No	DATE	TIME	EARTHQUAKE SOURCE PARAMETERS			TSUNAMI PARAMETERS			O
			Lat (°N)	Lon (°W)	Ms/I	T	REGION	m	
25	*1913-1002	04:23	7.1	80.6	6.7	L	Azuero Peninsula, PAN San Miguel Gulf, PAN	-1	P

EPICENTER REGION:

Azuero, Panama, Pacific

EARTHQUAKE SOURCE PARAMETERS:

1002-0423, 7.1°N-80.6°W, h=shallow, Ms=6.7 (Ambraseys & Adams, 1996)

1002-0423, 7°20'N-80°19'W, Ms= 6.5 (Viquez & Camacho, 1993)

1001, 7.5°N, 80.75°W, M=7.5 (Viquez & Toral, 1987 (Miyamura, 1978))

TECTONIC ENVIRONMENT:

INTRAPLATE ASSOCIATE TO AZUERO-ZONA (TORIO) FAULT (Viquez & Camacho, 1993)

Tsunami magnitude = -1 (Toral, unpublished)

Figure 11. Intensity distribution and tsunami areas affected (Viquez & Camacho, 1993)

Figure 12. Liquefaction and landslides areas affected (Viquez & Camacho, 1993)

TSUNAMI AND/OR MACRO SEISMIC REPORT:

Ambraseys & Adams, 1996 (MacDonald & Johnston, 1913):

"This strong earthquake occurred in the Pacific off the coast of Los Santos in Panama. The earthquake was preceded by strong foreshock a 18 h 48 m (UT) on 1 October."

"A few hours after the earthquake a submarine slide ruptured the Central & South American cable near the islet of Frailes del Norte, about 25 km off the south coast of Los Santos province. It has been reported that the broken end of the cable was found at a depth of 1463 m, whereas when the cable was first laid, the depth was only about 305 m. Here the shock caused an abrupt change in the bathymetry, which suggest that submarine sliding occurred. The tide gauge at Balboa showed no abnormal fluctuations of the sea level, and except in the Gulf of San Miguel on the east coast of the Gulf of Panama, from where it was reported that the sea behaved abnormally on the day of the earthquake, there is not evidence of a seismic sea wave."

Viquez & Camacho, 1993 (Estrella de Panama, 1913; Mc Donald, 1913):

"Testigos que viajaban en el vapor Cocle y se encontraba en la entrada del Golfo de San Miguel, costa Pacifica, provincia de Darien, narraron: el mar a una distancia considerable se comportaba extrañamente, presentando la apariencia de agua hirviendo. El agua a sus alrededores estaba haciendo burbujas con pequeñas olas las cuales parecían romperse entre si, sin ninguna direccion definida."

"debido al primero y mas fuertes de los sismos el cable submarino se rompio."

Se descubrió que se había partido a una 15 millas de la costa, en la vecindad de la isla del Fraile del Norte, en donde ocurrió una elevación repentina del nivel del mar."

Feldman, 1984 (La Republica, October 2-8, 1913) :

"Panama, 2. A media noche, a pesar de la lluvia, millares de personas corrieron a la calle a consecuencia del panico que les causaron varios temblores de tierra....."

"Un caballero q'acaba de llegar a esta capital con procedencia de Panama, ha tenido la fineza de suministrarnos algunos datos sobre terres (terremotos) que ultimamente han estado azotando aquella Republica.....Que el lugar denominado Tonosi se hundio totalmente y que fueron numerosas las victimas."

"... las aguas de los rios Joaquin y Flores crecieron hasta el extremo de inundar las montañas, esto sin haber llovido y que han quedado grietas en los alrededores de los rios que puede caber una res."

"Comunican de Tonosi que los edificios de ese pueblo han quedado reducidos a escombros; que se salieron los rios de sus causes y que inundaron considerables porciones de terrenos."

".....Un pequeño poblado llamado Pedaci desaparecio totalmente, pereciendo todos los habitantes. Los temblores en ese lugar vinieron acompañados de grandes crecientes, dos rios se juntaron y Pedaci que quedaba entre ambos, desaparecio..."

SPECIFIC EVENT REFERENCES:

Rojas et al., 1993

Grases, 1990 (Viquez & Toral, 1987; Leeds, 1978)

Viquez & Toral 1986

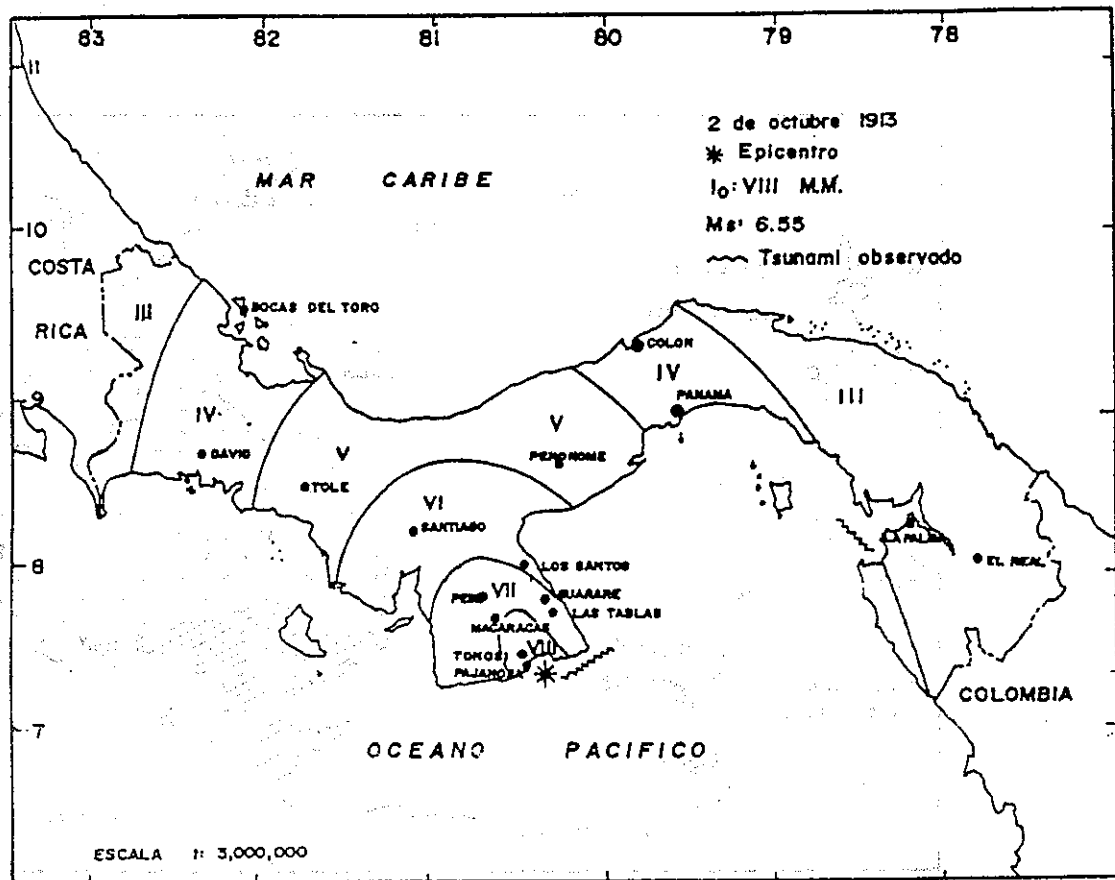


Figure 11. Isoseists and tsunami of the October 2, 1913 Panama earthquake (Viquez & Camacho, 1993).

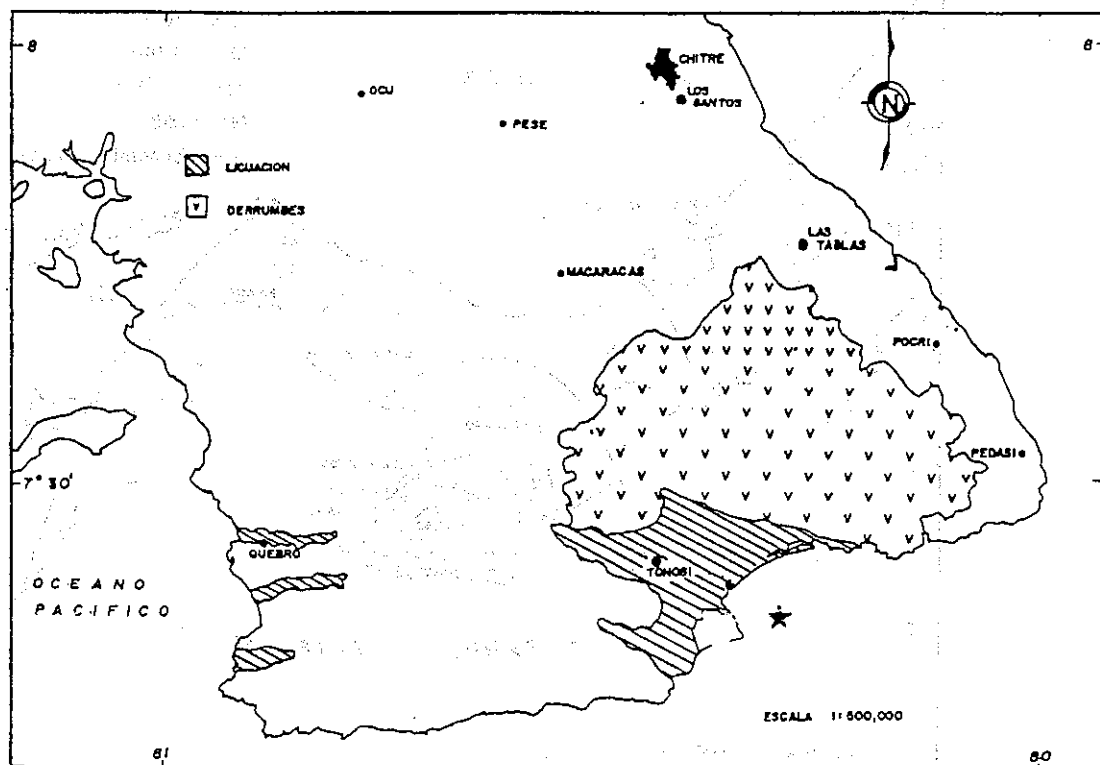


Figure 12. Spatial distribution of permanent deformations, liquefaction and landslides, observer after the October 2, 1913 Panama earthquake (Viquez & Camacho, 1993).

No	DATE	TIME	EARTHQUAKE SOURCE PARAMETERS			TSUNAMI PARAMETERS			O
			Lat (°N)	Lon (°W)	Ms/I	T	REGION	m	
26	1915-0907	01:20	13.9	89.6	7.7	L?	El Salvador Coast, SAL	0.5	P

EPICENTER REGION:

SW El Salvador Pacific coast

EARTHQUAKE SOURCE PARAMETERS:

0907-0120, 13.9°N-89.6°W, h=60 km, Ms=7.7 (Ambraseys & Adams, 1996)
 0907, 14°N-89°W, Magnitude = 7.9 Murty, 1995(ATWC catalogue, no place name)
 0907-0120, 14°N-89°W, 80 Km, M=7 3/4 (Soloviev & Go, 1984 (Gutenberg & Richter, 1954))
 0907-0120, 14N°-89°W, h=80 km, Ms=7.75 (McNally & Minster, 1981(Gutenberg & Richter, 1954))

TECTONIC ENVIRONMENT:

COCOS-CARIBBEAN SUBDUCTION ZONE (McNally & Minster, 1981)

Tsunami magnitude=0.5 (Hatori, 1995)

Figure 13. Intensity distribution (Alfaro et al., 1990)

TSUNAMI AND/OR MACRO SEISMIC REPORT:

Ambraseys & Adams, 1996 (Larde, 1916; Martinez, 1978):

"This was a meyor lower crustal earthquake with an epicentral area extending form southwestern El Salvador to southeastern Guatemala."
 "....It is said that a result of the earthquake the submarine cable on the Costa Rica coast was damaged."

Soloviev & Go, 1984 (Seismological Notes, 1915, vol. 5, N 3; Larde, 1916):

"There was a strong earthquake in El Salvador."
 "There are unreliable reports about a disturbance at sea, arising after the earthquake. The master of Barra de Santiago port reported that during the earthquake an enormous wave appeared at sea. Te residents of the city were seized with panic. However, if we are to believe another eyewitness, situated at the same place, a hurricane raged; the sea was very agitated, but the above mentioned enormous wave did no occur."
 "The weather was bad at nighth at Acajutla, and the sea was stormy; no one noticed any unusual waves."
 "The master of la Libertad port categoricalley denied the occurrence on any unusual phenomena at sea either before or after the earthquake."
 "At El Triunfo Bay, according to a report of the port master, no greater disturbance was observer after the earthquake than that which was observer on the preceding three days, although flood tides were higher than usual all this time."
 "The master of La Union port reported that, bacause of the rain and the hurricane, it could not be seen whether the earthquake affected the state of the sea. One of the observers kept track of the sea from 17:00 to the end of the earthquake. All this time, there were large waves. They reached enormous

size not long before the seismic shock and began to diminish only some time after the earthquake."

SPECIFIC EVENT REFERENCES:

Guinea, 1995 (Alvarez, 1982)
Rojas et al., 1993 (Gutenberg & Richter, 1954)
Grases, 1990 (BSSA; Larde, 1916)
Carr & Stoiber, 1977 (BSSA, v. 5);

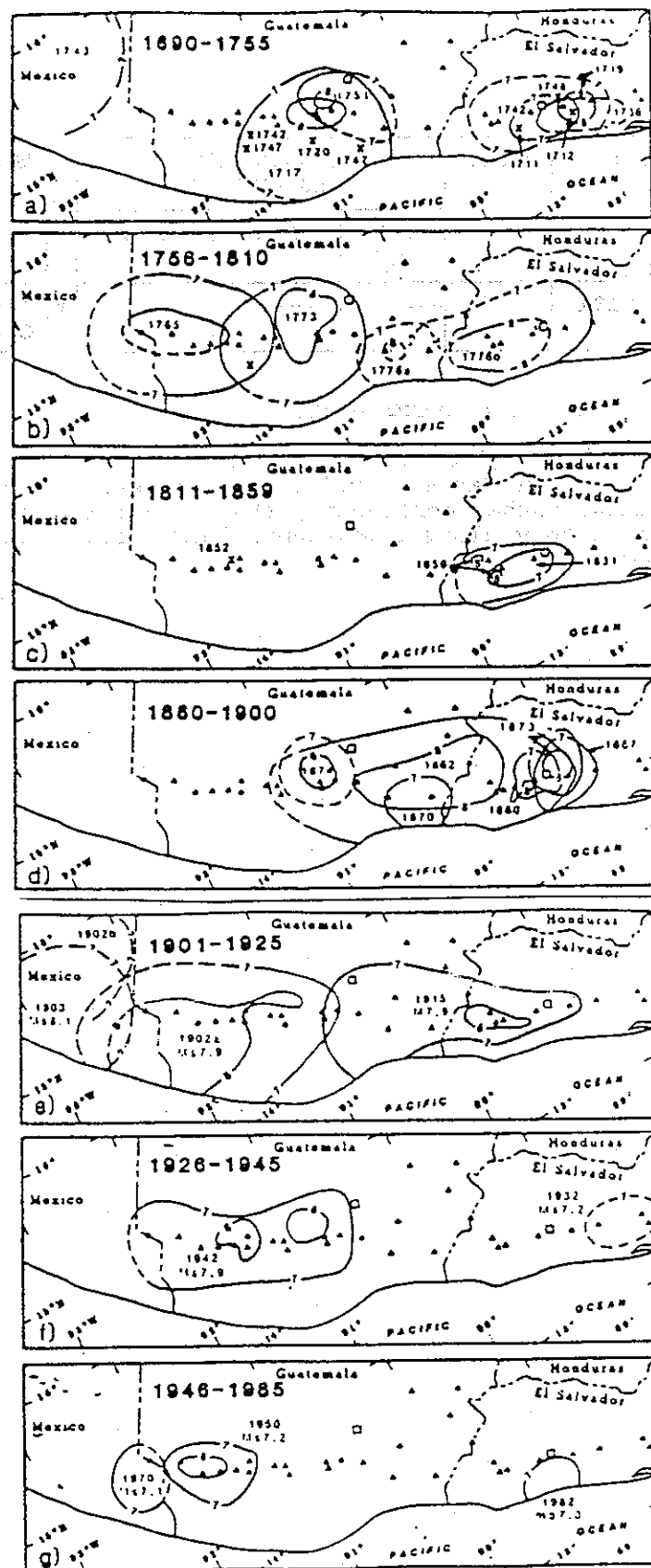


Figure 13. Isoseismal distribution for earthquakes occurred in the subduction zone since 1690. It shows the intensity distribution of the December 8, 1859 and September 7, 1915 El Salvador-Guatemala Pacific coast earthquakes (Alfaro, et al., 1990).

No	DATE	TIME	EARTHQUAKE SOURCE PARAMETERS			TSUNAMI PARAMETERS			O
			Lat (°N)	Lon (°W)	Ms/I	T	REGION	m	
27	1916-0131	---	---	---	---	T	Panama Canal, PAN	--	P

TSUNAMI AND/OR MACRO SEISMIC REPORT:

Soloviev & Go, 1984 (Kirkpatrick, 1920):

"A tide gauge in the Panama Canal zone registered a strange change in level. One can surmise rather confidently that it was due to displacements on the bottom, very likely along a supposed fault running along the coast of the Pacific Ocean."

No	DATE	TIME	EARTHQUAKE SOURCE PARAMETERS			TSUNAMI PARAMETERS			O
			Lat (°N)	Lon (°W)	Ms/I	T	REGION	m	
28	*1916-0426	02:21	9.2	83.1	6.9	L	Bocas del Toro, PAN	0	C

EPICENTER REGION:

Panama-Costa Rica, Caribbean

EARTHQUAKE SOURCE PARAMETERS:

0426-0221, 9.2°N-83.1°W, h=40-60 km, Ms=6.9 (Ambraseys & Adams, 1996)
 0426, 10.0°N, 85.0°W, Magnitude = 7.3 (Murty, 1995 (ATWC catalogue))
 0425, 9.5°N, 82.6°W (Camacho y Viquez, 1993 (Dominion Observatory of Ottawa, Canada))
 M=6.9 Nishenko 1992 (Onda, 1990)
 0426, 9.6°N-82.0°W, M=7.3 (Viquez & Toral, 1987 (Gutenberg & Richter, 1954))
 0426-0221, 10.0°N-85.0°W, h=S, Ms=7.1 (Guendel, 1986 (Abe & Noguchi, 1983))
 0426-0221, 10°N-85°W, Ms=7.3 (McNally & Minster, 1981 (Gutenberg & Richter, 1954))

TECTONIC ENVIRONMENT:

NORTH PANAMA DEFORMED BELT (Camacho & Viquez, 1993)

Tsunami magnitude = 0 (Toral, unpublished)

Tsunami intensity = 0 (Fernandez, 1993 (Viquez & Toral, 1987))

Figure 14. Intensity distribution and tsunami area (Grases, 1990)

TSUNAMI AND/OR MACRO SEISMIC REPORT:

Ambraseys & Admas, 1996 (Camacho & Viquez, 1992; Reid, 1917):

"In the region of Bocas del Toro the earthquake caused considerable damage.....Water and electricity services were disrupted and the submarine telephone cable connecting Almirante with Bocas del Toro was cut."

"A seismic sea wave set up by the earthquake carried canoes and debris 200 m inland and destroyed storage tanks, adding to de damage. The wave flooded Bastimentos, Isla de Carenero and other parts of the coast."

Camacho y Viquez, 1993a (The Star & Herald, 1916):

"This earthquake was particularly strong in Almirante and Bocas del Toro.....The pier in Bocas del Toro was damaged and some houses shifted from their supports and the United Fruit Co. general office, storehouse and workes camp suffer considerable damage. A small tsunami throw litter and canoes some two hundred meters ashore. This wave came form the northeast. The phenomenon of liquefaction was reported."

".....informs that in Bocas del Toro, capital of the Province of the same name: large fissures, which subsequently closed were made and sea flowed over knee deep into the land. The Henriquez aerated water factory at 46 North Avenue came to grief, the large tanks were washed away around the shore and the plant was damaged so badly."

"....in Almirante the earth opened in many places far wider than in Bocas"

"At Bastimentos, Old Bank, the sea flowed beyond the usual limit for some time..."

"At Bocas a slight tidal wave carried canoes and debris two hundred meters in land."

"..... Careening Cay (Carenero) was severely affected, and parts of it were completely covered by water. The same place where he had been standing was submerged and covered by the sea."

Guendel, 1986 (Kirkpatrick, 1920; Feldman, 1984):

"April 26, at 02h 21min (GMT). Damage reported in Santa Barbara and Santo Domingo, with buildings and houses damaged by earthquakes. This damage may be related to a large earthquake that occurred near Bocas del Toro and Almirante in Panama and Sixaola in Costa Rica where major damage was reported. A tidal wave was also associated with this events."

Viquez & Toral 1986:

"Se reporto Seudo-tsunami local que afecto a las islas de Carenero y Colon. La ola alcanzo unos 50 cm altura."

Feldman, 1984(El imparcial, April 1916, La Informacion, April 1916):

"Anoche a las 8.45 un violento y prolongado temblor infundio gran panico en toda la ciudad."

"Acabo de llegar de Bocas del Toro. El gran temblor de antenoche se registro en aquella region de un modo espantoso.....La Isla de Carenero, que esta situada frente al puerto se inundo con 4 pies de agua. Estabamos abordo a la hora del temblor y el movimiento se sintio como si hubieramos estado en tierra. La embarcacion se levanto sobre las olas y fuimos arrastrados por una corriente como la de un rio."

"Bocas del Toro.....Cayeron en Bocas algunos edificios de madera pequeños y que en muchos lugares la tierra se agrieto ligeramente manando de esas cavidades agua dulce en abundancia; y que, en el momento que se produjo el terremoto, las antorchas de las naves de gran calado surtas en aquel puerto, delizaron suavemente un gran trecho como impulsadas por fortisimas corrientes de mar, pero no al extremo de que las embarcaciones caminaran grandes trechos empujadas por esas corrientes marineros extrañas; tambien se me dijo que en diferentes aparajes ribereños de aquella isla se habian notado depresiones may considerables en pequenos trechos de tierra."

SPECIFIC EVENT REFERENCES:

Nishenko, et al., on print (Reid, 1917; Viquez & Toral, 1986; Duda, 1990; Camacho, 1994)

Boschini & Montero 1994

Rojas et al., 1993 (Jorgensen, 1966; Viquez & Toral 1987)

Grases, 1990 (Reid, 1917; Leeds, 1978; Viquez & Toral 1987)

Viquez & Toral, 1987

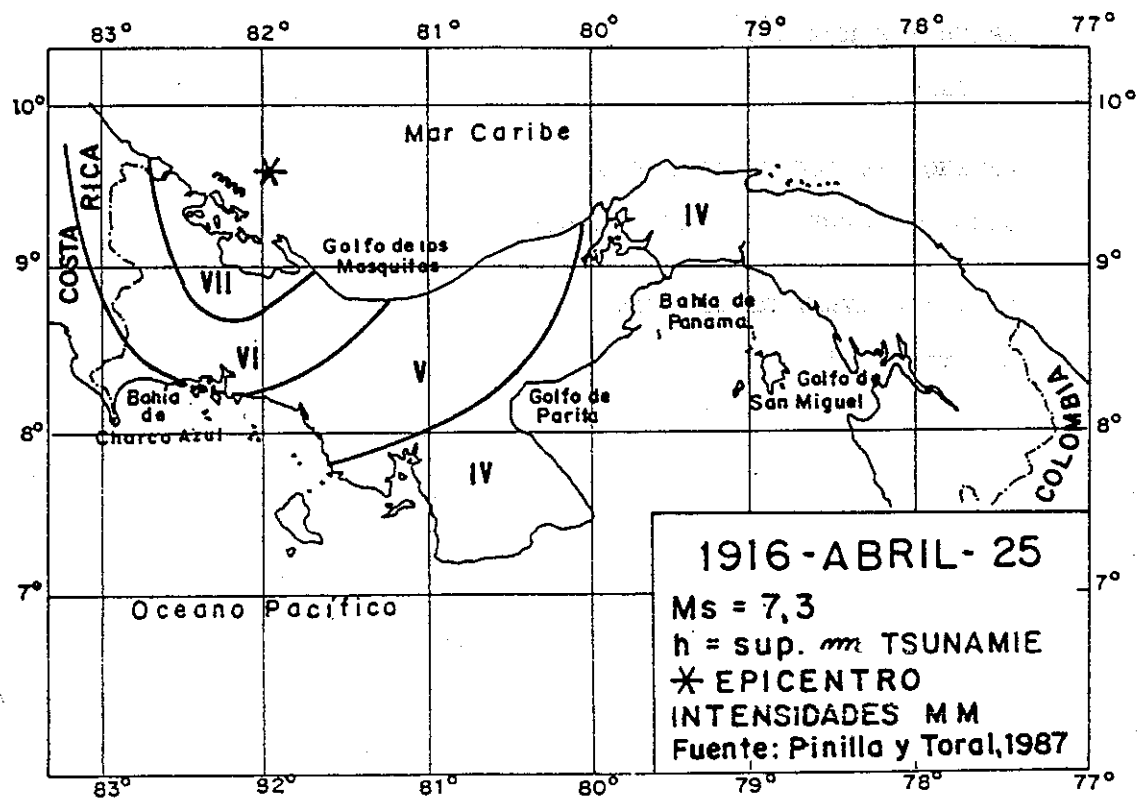


Figure 14. Isoseists, epicentre location (star) and tsunami area of the April 25, 1916 Costa Rica-Panama Caribbean coast earthquake (Grases, 1990).

No	DATE	TIME	EARTHQUAKE SOURCE PARAMETERS			TSUNAMI PARAMETERS			O
			Lat (°N)	Lon (°W)	Ms/I	T	REGION	m	
29	1916-0525	---	12.0	90.0	7.5	?L?	El Salvador	--	P

EPICENTER REGION:

El Salvador

EARTHQUAKE SOURCE PARAMETERS:

0525, 12°N-90°W, Ms=7.5 (Hatori, 1995)

SPECIFIC EVENT REFERENCES:

Hatori, 1995

No	DATE	TIME	EARTHQUAKE SOURCE PARAMETERS			TSUNAMI PARAMETERS			O
			Lat (°N)	Lon (°W)	Ms/I	T	REGION	m	
30	1919-0629	23:14	13.5	87.5	6.7	L	Corinto, NIC	--	P

EPICENTER REGION:

Fonseca Gulf, Pacific

EARTHQUAKE SOURCE PARAMETERS:

0629-2314, 13.5°N-87.5°W, h>40-60 km, Ms=6.69 (Ambraseys, 1995)
0629; 13.5°N, 86.5°W, 90 km, M=6.7 (Leeds, 1974 (HDF; Gutenberg & Richter, 1954))

TECTONIC ENVIRONMENT:

COCOS-CARIBBEAN SUBDUCTION ZONE

TSUNAMI AND/OR MACRO SEISMIC REPORT:

INETER, 1993 (Periodicos El Cronista de Leon y El Comercio de Managua):
"1919, junio 29. Golfo de Fonseca y marejada en Corinto."

SPECIFIC EVENT REFERENCES:

Morales, unpublished
Rojas et al., 1993

No	DATE	TIME	EARTHQUAKE SOURCE PARAMETERS			TSUNAMI PARAMETERS			O
			Lat (°N)	Lon (°W)	Ms/I	T	REGION	m	
31	*1919-1212	---	---	---	---	L	El Ostial, NIC	--	P

EPICENTER REGION:

Nicaragua-Costa Rica, Pacific

TECTONIC ENVIRONMENT:

COCOS-CARIBBEAN SUBDUCTION ZONE

TSUNAMI AND/OR MACRO SEISMIC REPORT:

Morales, unpublished (Periodico El Comercio, Dic. 14 1919; Periodico La Noticia, 1919):

"Antier fue presa del panico el vecindario de El Ostial, puertecito cercano a San Juan del Sur, debido a tres fortisimos temblores que desquisiaron varias casas."

"Momentos despues, la marea subio desproporcionadamente, inundando las habitaciones y han continuado asi, obligando a los vecinos a huir. El agua del mar penetro hasta los rios."

"En el Departamento de Rivas. Del Ostial avisan que han causado alarma tres temblores que se sintieron ayer. "

"El mar, dicen los telegramas, desde hace tres dias esta haciendo grandes crecientes, llegando el agua hasta las primeras casas del valle por el cauce de una quebrada."

"El Ostial es un fondadero que esta al sur de San Juan del Sur, y proximo a la frontera costarricense."

No	DATE	TIME	EARTHQUAKE SOURCE PARAMETERS			TSUNAMI PARAMETERS			O
			Lat (°N)	Lon (°W)	Ms/I	T	REGION	m	
32	1920-1206	---	---	---	---	L	Fonseca Gulf	--	P

EPICENTER REGION:

Fonseca Gulf, Pacific

TSUNAMI AND/OR MACRO SEISMIC REPORT:

INETER, 1993 (Periodico La Notica, Managua)

No	DATE	TIME	EARTHQUAKE SOURCE PARAMETERS			TSUNAMI PARAMETERS			O
			Lat (°N)	Lon (°W)	Ms/I	T	REGION	m	
33	1926-1105	07:55	12.3	85.8	7.0	L	Offshore, NIC	--	P

EPICENTER REGION:

Nicaragua, Pacific

EARTHQUAKE SOURCE PARAMETERS:

1105-0755, 12.3°N-85.8°W, h=135 km, Ms=7.0 (Ambraseys & Adams, 1996)
Ms=7.2 Grases, 1990 (ISC)
1105-0755, 12.3°N-85.8°W, h=135 Km, Magnitude =7.0 (Leeds, 1974)

TECTONIC ENVIRONMENT:

COCOS-CARIBBEAN SUBDUCTION ZONE

TSUNAMI AND/OR MACRO SEISMIC REPORT:

Ambraseys & Adams, 1996 :

"This was a relatively large-magnitude, intermediate-depth earthquake with a focus in Nicaragua. It is said that the worst damage was done at Leon....."
"The shock was very violent on board two ships sailing off the coast of Costa Rica, 330 km from the instrumental epicentre."

Leeds, 1974 (SN, BSSA, Dec. 1926; Richter Elementary Seismology):

"..earthquake is reported as destructive in Managua with more than half the walls houses cracked. The tower of the Cathedral collapsed. Damage was considerable at Granada, Masaya, Chinandega, and San Juan del Sur."
"..the shock was felt at sea on two ships, Eagle and Magician at 10N, 88W."

SPECIFIC EVENT REFERENCES:

Morales, unpublished
Rojas et al., 1993
Grases, 1990 (Bois, 1927; Leeds, 1973);

No	DATE	TIME	EARTHQUAKE SOURCE PARAMETERS			TSUNAMI PARAMETERS			O
			Lat (°N)	Lon (°W)	Ms/I	T	REGION	m	
34	*1934-0718	01:36	8.1	82.6	7.5	L	Chiriqui Gulf, PAN	1.5	P

EPICENTER REGION:

Panama-Costa Rica, Pacific

EARTHQUAKE SOURCE PARAMETERS:

0718-0136, 8.1°N-82.6°W, h=crustal focus, Ms=7.5 (Ambraseys & Ambraseys, 1996)
 0718-0130, 8.14°N-82.38°W, Ms=7.4 (Pacheco & Sykes, 1992)
 0718-0136, 8.12°N-82.61°W, h=25, Ms=7.7, right lateral strike-slip (Camacho, 1991 (1934 ISC Bulletin))
 0718-0136, 8.14°N-82.38°W, h=S, Ms=7.6 (Guendel, 1986 (Kelleher et al, 1973; Abe, 1981))
 0718-0136, 8°N, 82.5°W, M=7.7 (Soloviev & Go, 1984 (Gutenberg & Richter, 1954))

TECTONIC ENVIRONMENT:

PANAMA FRACTURE ZONE (Camacho, 1991)

Tsunami magnitude=1.5 (Hatori, 1995 ((Soloviev & Go, 1984))
 Tsunami magnitude=1 1/2 (Soloviev & Go, 1984)
 Tsunami magnitude = 1 (Torai, unpublished)

Figure 15. Intensity distribution and tsunami area (Grases, 1990)

TSUNAMI AND/OR MACRO SEISMIC REPORT:

Ambraseys & Adams, 1996 (Camacho, 1991):

"This large-magnitude earthquake with an epicentre at sea in the Gulf of Chiriqui was felt throughout Panama and Costa Rica."

"The shock set up a seismic sea wave that flooded the west coast of the Gulf of Chiriqui, causing minor damage. At Armuelles the seaward row of houses in the native village was washed out completely, and the main street was under water several times. At Bahia Honda the tide gauge recorded fluctuations of the sea level of 0.6 m, the disturbance lasting for over five hours. At Puerto Armuelles the tide station was destroyed and no record was obtained. The record made by the tide gauge that was fixed to the dock shows that the shock caused the structure to sink gradually into its foundation, and that the instrument ceased functioning about three minutes after the earthquake."

"The earthquake was also felt on board ships in the Gulf of Chiriqui. SS Nokomis was anchored near the northeast end of Parida Island, SS Tuscaloosa City was sailing off Punta Burica and SS Point Sur was at anchor near Islet of Montuosa. All three vessels reported very violent shaking."

Camacho, 1991 (Lockridge & Smith, 1984):

"The Puerto Armuelles Earthquake also generated a small local tsunami. The tsunami was recorded in Bahia Honda, in the eastern shore of the Gulf of Chiriqui, by a tide gauge aboard the U.S.S. Hannibal. The peak to trough

amplitude was 0.6 m, and the duration of the wave train in Bahía Honda was five hours eighteen minutes. This tsunami only caused minor damage along the western shores of the gulf"

Soloviev & Go, 1984 (Kellar, 1935; Neumann, 1936)):

"A destructive earthquake with its source in Chiriqui Bay (west of Panama) was felt on the coast with a force of about 7 degrees.....A strong seaquake was felt on several American hydrographic ships, riding at anchor in the focal zone, particularly at Punta Burica and Montuosa Island. A crack 1/2-1 m wide and 6 m deep developed along the axis of Montuosa Island..."

"Apparently a tsunami developed during the earthquake. At puerto Armulles, two large anchored buoys were displaced 300 m from the moorage out to sea, in such a way that their relative position did not change. The water level several times passed the mark of the highest high tides, although flood tides should have been small at this time of year. The main street of the Indian village was covered with water several times and a number of homes facing the sea were completely washed out."

"The well of the temporary tide gauge, set up at Puerto Armuelles by the American hydrographic expedition, was also washed away. Ten minutes after the earthquake, this instrument apparently began to register a tsunami beginning with a strong ebb tide wave. During all this, nothing unusual was observed on the surface of the water."

SPECIFIC EVENT REFERENCES:

Murty, 1995 (ATWC catalogue)

Fernandez, 1993 (Viquez & Toral, 1987)

Rojas et al., 1993 (Camacho, 1991);

Grases, 1990 (Viquez & Toral 1987; Rutten and Van Raadshooven, 1940)

Viquez & Toral, 1986

Feldman, 1984

McNally & Minster, 1981 (Gutenberg & Richter, 1954)

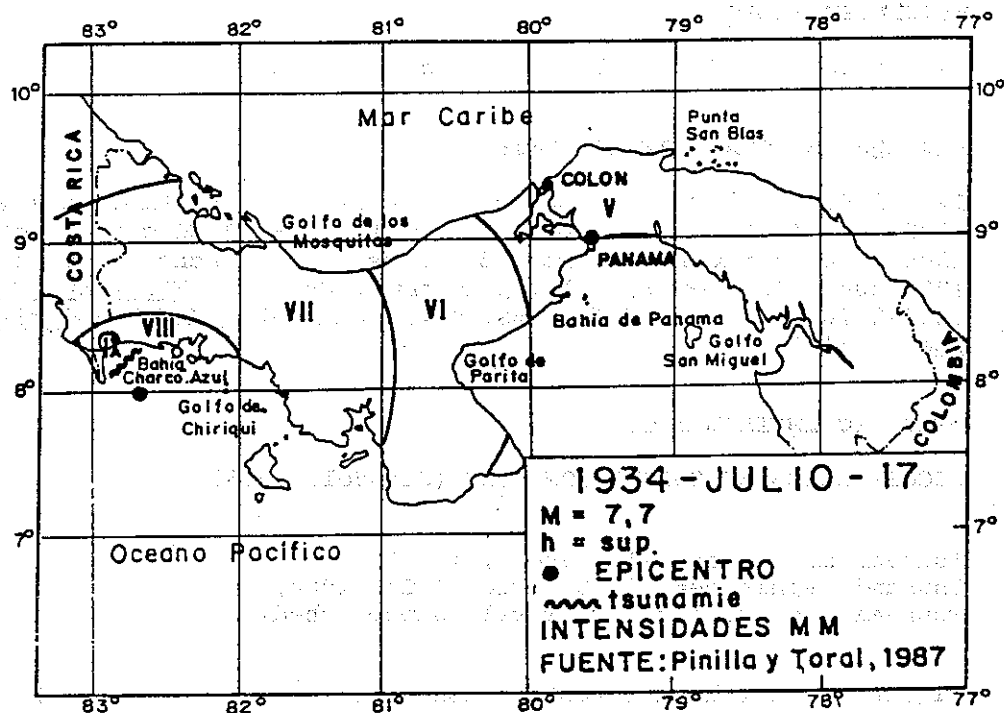


Figure 15. Isoseists, epicentre location (fill circle) and tsunami area of the July 17, 1934 Panama-Costa Rica Pacific coast event (Grases, 1990).

No	DATE	TIME	EARTHQUAKE SOURCE PARAMETERS			TSUNAMI PARAMETERS			O
			Lat (°N)	Lon (°W)	Ms/I	T	REGION	m	
35	1941-1205	20:46	8.7	83.2	7.6	L	Punta Dominical, C R	-1	P

EPICENTER REGION:

Osa Peninsula, Costa Rica, Pacific

EARTHQUAKE SOURCE PARAMETERS:

1205-2046, 8.7°N-83.2°W, h=crustal focus, Ms=7.6 (Ambraseys & Adams, 1996)
 1205, 8.5°N-83°W, Magnitude= 7.5 (Murty, 1995(ATWC catalogue))
 1205-2046, 8.5°N-83.0°W, Ms=7.3, thrust type (Pacheco & Sykes, 1992)
 1205-2046, 8.5°N-83°W, M=7.5 (Soloviev & Go, 1984 (Gutenberg & Richter, 1954))
 1205-2046, 8.67°N-83.16°W, h=S, Ms=7.6 (Guendel, 1986 (Kelleher et al., 1973; Abe, 1981))

TECTONIC ENVIRONMENT:

COCOS-CARIBBEAN SUBDUCTION ZONE (Guendel, 1986)

Tsunami magnitude= -1 (Hatori, 1995)
 Tsunami magnitude= -3 (Soloviev & Go, 1984)
 Tsunami magnitude = -1 (Toral, unpublished)

Figure 16. Earthquake rupture zone (Kelleher et al., 1973)

TSUNAMI AND/OR MACRO SEISMIC REPORT:

Ambraseys & Adams, 1996:

"A mejor earthquake in the Golfo Dulce was felt throughout Costa Rica an in much of Panama."

"The shock was experienced on board a vessel steaming near 8.58N, 84.45W, 160 km from the epicentre."

"The earthquake was recorded on a tide gauge at Puntarenas in Costa Rica. The disturbance began at 21 h 45 m, about one hour after the main shock, and continued for about six hours with an average ranage of 23 cm."

Montero, 1990 (Diario de Costa Rica):

"El rio Balsas hizo una creciente sin haber lluvias; por un momento el agua corrio en sentido contrario."

"...don Victor M. Sibaja, radicado en Punta Dominical describe que despues del temblor el dia 5, se aprecio la marea mas alta y por dos veces seguidas, subio el agua a una altura extraordinaria, quedando el nivel de las medias vacantes.."

".....despues del gran temblor, en Dominical se aprecio una de las mareas mas altas, y bajo en dos movimientos seguidos, como a quedar a media vaciante.."

Soloviev & Go, 1984 (Neumann, 1943):

"An earthquake at Panama and Costa Rica causing oscillations in sea level, was recorded by the tide gauge at Puntarenas (Cost Rica). The record of oscillations began at 15:45, on 90 West meridian time, and lasted 6 hours. The average amplitude of oscillations was 22 cm, the period about 3/4 of an hour."

The oscillations occurred during the flood tide."

SPECIFIC EVENT REFERENCES:

Rojas et al., 1993 (Montero 1986; Viquez & Toral 1987)
Grases, 1990 (Leeds, 1978)
Viquez & Toral 1986
Feldman, 1984
McNally & Minster, 1981 (Gutenberg & Richter, 1954)

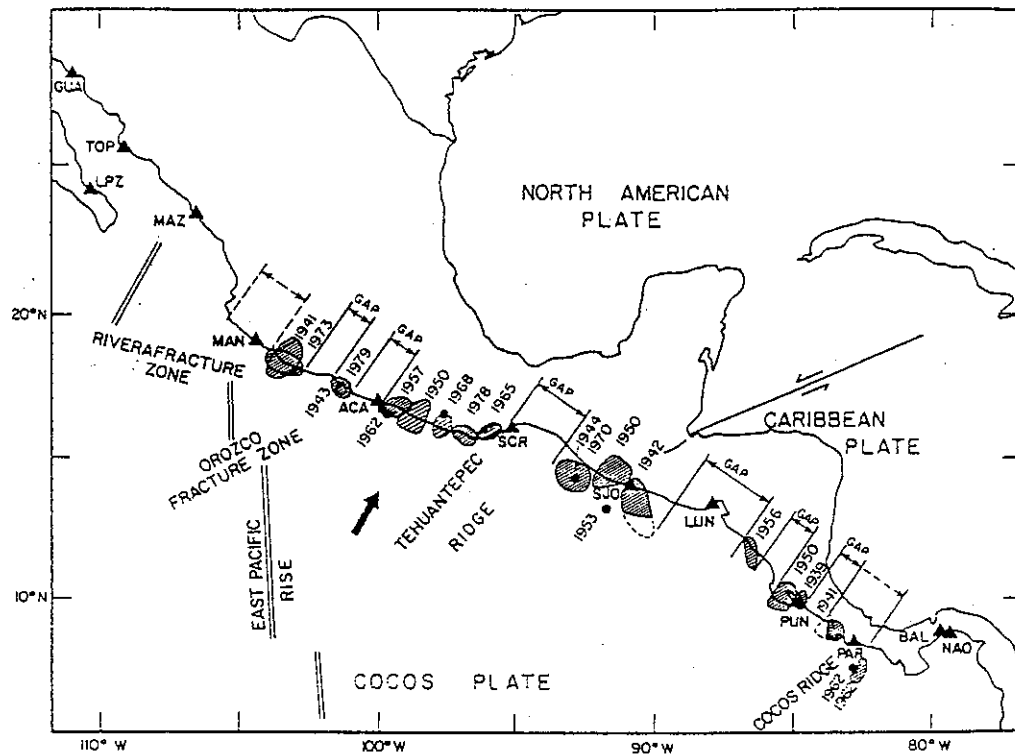


Figure 16. Rupture areas from Kelleher, et al. (1973) for the December 5, 1941 and October 5 1950 Costa Rica Pacific coast earthquakes (Montero, 1990).

No	DATE	TIME	EARTHQUAKE SOURCE PARAMETERS			TSUNAMI PARAMETERS			O
			Lat (°N)	Lon (°W)	Ms/I	T	REGION	m	
36	1941-1206	---	10.0	85.2	6.9	L	Nicoya Gulf, C R	-2	P

EPICENTER REGION.

Pacific coast, Osa Peninsula C. R.

EARTHQUAKE SOURCE PARAMETERS:

0612, 10°N, 85.2°W, Magnitude = 6.9 (Murty, 1995 (ATWC catalogue))
 1206-2124, 8.5°N-84.0°W, h=S, Ms=7.0 (Guendel, 1986 (Gutenberg & Richter, 1954; Abe, 1981))
 1206-2124, 8.5°N-84°W, M=6.9 (Soloviev & Go, 1984 (Gutenberg & Richter, 1954))

TECTONIC ENVIRONMENT:

COCOS-CARIBBEAN SUBDUCTION ZONE

Tsunami magnitude=-2 (Hatori, 1995)
 Tsunami magnitude=-4 (Soloviev & Go, 1984)

TSUNAMI AND/OR MACRO SEISMIC REPORT:

Soloviev & Go, 1984 (Neumann, 1943):

"The tide gauge at Puntarenas registered oscillations in sea level. They began at 16:20, 90 West meridian time and lasted about 8 hours. The mean amplitude of oscillations was less than 8 cm, while the average period was between 10 and 15 minutes. The oscillations occurred during the flood tide."

SPECIFIC EVENT REFERENCES:

Rojas et al., 1993

No	DATE	TIME	EARTHQUAKE SOURCE PARAMETERS			TSUNAMI PARAMETERS			O
			Lat (°N)	Lon (°W)	Ms/I	T	REGION	m	
37	1950-1005	16:09	10.0	85.7	7.9	L	Coasts CR-NIC-SAL	-1	P

EPICENTER REGION:

Nicoya Peninsula Costa Rica, Pacific

EARTHQUAKE SOURCE PARAMETERS:

1005-1609, 10.0°N-85.7°W, h=n+, Ms=7.9 (Ambraseys & Adams, 1996)
 1005-1609, 10.35°N-85.0°W, Ms=7.7, thrust type (Pacheco & Sykes, 1992)
 1005, 10.5°N-85.0°W, M=7.7 (ISC) (Grases, 1990)
 1005-1609; 10.08°N-85.57°W; h=30.7; Ms=7.7, (Guendel, 1986 (Guendel & McNally, 1985, unpublished; Abe, 1981))
 1005-1609, 11°N-85°W, M=7.7 (Soloviev & Go, 1984 (Gutenberg & Richter, 1954))
 1005-1609; 10.35°N-85.20°W; Ms=7.7 (Cruz & Wyss, 1983 (Heck, 1947; Gutenberg & Richter, 1954; NOAA)
 1005-1609, 11.0°N-85.0°W, Ms=7.7 (McNally & Minster, 1981 (Geller & Kanamori, 1977))
 1005-1609, 11.0°N-85.0°W, h=normal (0-60); Ms=7.7 (Leeds, 1974 (HDF; Gutenberg & Richter 265))

TECTONIC ENVIRONMENT:

COCOS-CARIBBEAN SUBDUCTION ZONE (Rojas, et al., 1993)

Tsunami magnitude=-1 (Hatori, 1995)
 Tsunami magnitude= -2(? , author comment) (Soloviev & Go, 1984)
 Tsunami magnitude = 0 (Toral, unpublished)

Figures 4 or 16. Earthquake rupture zones.

TSUNAMI AND/OR MACRO SEISMIC REPORT:

Ambraseys & Adams, 1996 (Cruz & Wyss, 1983):

"This major lower-crustal earthquake in Costa Rica caused disproportionately small damage for its size....."

"The earthquake was associated with a small seismic sea wave, which was reported from the Pacific coast of the Nicoya Peninsula with periods of about 45 min. The tide station at Puntarenas was also shaken and soon after recorded a seiche or possible seismic sea wave. Small oscillation that may have resulted from this earthquake were also recorded on the tide gauges at San Juan del Sur, Nicaragua and at La Union, El Salvador. We could find not evidence to substantiate the statement by Cruz & Wyss (1983) that this earthquake set up a seiche at La Libertad, El Salvador, reaching an amplitude of 8.9 m."

"The seismic sea waves reported from two areas of the coast, 200 km apart, are likely to be due to the local slumping of submarine slopes."

Guendel, 1986 (Feldman, 1984):

"October 5, 1950 at 16h 09min (GMT). Damage reported in Nicoya where churches

and buildings suffered damage. In Puntarenas damage was produced in buildings due to tilting (liquefaction), also reported broken water main."

Soloviev & Go, 1984 (Seismological Notes, BSSA, vol 41, n 1; Murphy & Ulrich, 1952; Iida, et al., 1967):

"There was a strong earthquake at Costa Rica.....In addition, the tide gauge at Puerto Armuelles (Panama) was destroyed by the earthquake. The tide gauge at Puntarenas (Costa Rica) felt a tremor and soon after registered seiches, or possibly a tsunami, with an amplitude of 10 cm and a period of 30 minutes. In El Salvador, the tsunami was registered by the tide gauge at La Union with an amplitude of less than 10 cm and a period of 43 minutes and with a height of 8.9 cm by the tide gauge at La Libertad. A mild tsunami was registered by the tide gauge at San Juan del Sur (Nicaragua) and also at Hilo (Hawaiian Islands) where the amplitude of oscillations was 10 cm, the period 18 minutes."

Cruz & Wyss, 1983 (NOAA):

"5 October 1950: Tsunami had its origin in the Pacific coast of Costa Rica. NOAA Tsunami catalog reports an unusual seiche at La Libertad (El Salvador) reaching an amplitude of 8.9 m."

SPECIFIC EVENT REFERENCES:

Murty, 1995 (ATWC catalogue)

Rojas et al., 1993 (Barquero, 1991; Montero, 1986; Guendel, 1988; Cruz & Wyss, 1983)

Montero, 1990 (Cruz & Wyss, 1983)

Grases, 1990 (BSSA)

Feldman, 1984

No	DATE	TIME	EARTHQUAKE SOURCE PARAMETERS			TSUNAMI PARAMETERS			O
			Lat (°N)	Lon (°W)	Ms/I	T	REGION	m	
38	1950-1023	16:13	14.3	91.8	7.3	L	Coasts GUA-SAL	-1	P

EPICENTER REGION:

SW Guatemala, Pacific

EARTHQUAKE SOURCE PARAMETERS:

1023-1613, 14.3°N-91.8°W, h=crustal focus, Ms=7.3 (Ambraseys & Adams, 1996)
 1023-1613, 14.5°N-91.5°W, Ms=7.2, Thrust type (Pacheco & Sykes, 1992)
 1023-1613, 14.3°N-91.7°W, h=30, M=7.25 (Soloviev & Go, 1984 (Gutenberg & Richter, 1954))
 1023-1613, 14.34°N-91.82°W, h=30; M=7.1 (Cruz & Wyss, 1983 (Gutenberg & Richter, 1954))

TECTONIC ENVIRONMENT:

COCOS-CARIBBEAN SUBDUCTION ZONE (Cruz & Wyss, 1983)

Tsunami magnitude=-1 (Hatori, 1995)
 Tsunami magnitude= -1? (Soloviev & Go, 1984)
 Tsunami magnitude = 0 (Toral, unpublished)

RUPTURE AREA MAP (Carr & Stoiber, 1977). See **Figure 4**.

TSUNAMI AND/OR MACRO SEISMIC REPORT:

Ambraseys & Adams, 1996:

"This was a major earthquake in southwestern Guatemala."
 "The tide gauge at San Jose, Guatemala, recorded a wave of about 30 cm amplitude but at La Union, El Salvador, it was barely noticeable on the tide gauge. The wave was not recorded by other tide gauge in Mexico and Central America."

Soloviev & Go, 1984 (Seismological Notes, 1951, vol. 41, n 1; Murphy & Ulrich, 1952; Iida, et al., 1967):

"There was an earthquake at Guatemala causing heavy destruction at San Marcos."
 "In 2.2 hours after the earthquake, the tide gauge at San Jose (Guatemala) registered a wave with amplitude of 20 cm and a period of 15 minutes. There were barely noticeable oscillations with an amplitude of less than 10 cm and a period of 30 minutes on the record of the tide gauge at La Union (El Salvador). The tsunami was not recorded by other tide gauges in Mexico and Central America, but was registered 9.3 hours later at Hilo, where it had a height of 10 cm and a period of 16 minutes."

SPECIFIC EVENT REFERENCES:

Murty, 1995 (ATWC catalogue)
 Rojas, 1993 (Carr & Stoiber, 1977; Cruz & Wyss, 1983);
 Cruz & Wyss, 1983 (Zerbe, 1953; Murphy & Ulrich, 1952; Gutenberg & Richter, 1954; NOAA)

No	DATE	TIME	EARTHQUAKE SOURCE PARAMETERS			TSUNAMI PARAMETERS			O
			Lat (°N)	Lon (°W)	Ms/I	T	REGION	m	
39	*1951-0803	00:24	13.0	87.5	6.0	LH	Potosi, Fonseca Gulf, HON	--	P

EPICENTER REGION:

Fonseca Gulf, Pacific

EARTHQUAKE SOURCE PARAMETERS:

0803, M(de Bilt surface wave magnitude)=6.0; Ms=6.0 (BKS, Tacubaya) (White & Harlow, 1985 (BSSA, v. 1-45)

0803, 13.0°N, 87.0°W, Provisional magnitude M=6.75 (Miyamura, 1976)

0803-0024, 13.0°N, 87.5°W, h=100, M=6.0 (Leeds, 1974 (BSSA Oct. 1951; Rothe, 1954))

TECTONIC ENVIRONMENT:

COCOS-CARIBBEAN SUBDUCTION ZONE

TSUNAMI AND/OR MACRO SEISMIC REPORT:

Carr & Stoiber, 1977 (BSSA, v. 41, p. 399):

"Destruction at Jinotega and Potosi. Aflood poured out of the crater lake of V. Cosiguina."

Leeds, 1974, Destructive Earthquakes in Nicaragua (BSSA, 59)

"On August 3, 1961, strong earthquakes split open the sides of the long dormant Cosiguina volcano, inactive since 1835, sending tons of water crashing down from a crater in its center and inundating the small Pacific Coast port of Potosi. The town of about 1,000 population was reported virtually destroyed and casualties were believed to be heavy.....this location is near the head of the Gulf of Fonseca."

SPECIFIC EVENT REFERENCES:

Rojas et al., 1993 (Leeds, 1974)

Grases, 1990 (SN, BSSA, 41:4, 1951)

No	DATE	TIME	EARTHQUAKE SOURCE PARAMETERS			TSUNAMI PARAMETERS			O
			Lat (°N)	Lon (°W)	Ms/I	T	REGION	m	
40	1952-0513	19:31	10.3	85.3	6.9	L	Puntarenas, CR	-3	P

EPICENTER REGION.

Tempizque, Costarica, Pacific

EARTHQUAKE SOURCE PARAMETERS:

0513, 10.3°N-85.3°W, Magnitude = 6.9 Murty, 1995 (ATWC catalogue)
 0513-1931, 10.3°N-85.3°W, h=S, M=6.9 (Guendel, 1986 (ISS and ISC; Pasadena))
 0513-1932, 10.3°N-85°W; M=6.7 (Soloviev & Go, 1984)
 0513-1931, 10.30°N-85.30°W, h=32, Ms=7.0 (Cruz & Wyss, 1983 (McNally & Minster, 1981))
 0513, 10.3°N-85.3°W, 0.005R(6371km), Provisional magnitude = 7.0- (Miyamura, 1976)

TECTONIC ENVIRONMENT:

COCOS-CARIBBEAN SUBDUCTION ZONE

Tsunami magnitude= -3 (Soloviev & Go, 1984)

TSUNAMI AND/OR MACRO SEISMIC REPORT:

Soloviev & Go, 1984 (Iida, et al., 1967):

"There was an earthquake at Costa Rica. The tide gauge at Puntarenas registered a single ebb tide wave with an amplitude of less than 10 cm, 12 minutes after the shock."

Feldman, 1984 (La Nacion, 1985):

"El fuerte temblor de ayer...Los detalles que suministramos a continuacion sobre el fuerte temblor que poco despues del medio dia de ayer se sintio en esta capital...Los datos son los siguientes: 13.25, intensidad escala Rossi-Ferrel V, escala Sieber IV, duracion apreciada poco mas de un minuto. Segun informes telegraficos, se sintio con bastante violencia en San Ramon, Palmeras y Esparta."

SPECIFIC EVENT REFERENCES:

Toral, unpublished
 Rojas et al., 1993 (Cruz & Wyss, 1985);

No	DATE	TIME	EARTHQUAKE SOURCE PARAMETERS			TSUNAMI PARAMETERS			O
			Lat (°N)	Lon (°W)	Ms/I	T	REGION	m	
41	1956-1024	14:42	11.5	86.5	7.2	L?	San Juan del Sur, NIC	--	P

EPICENTER REGION:

Pacific Nicaragua

EARTHQUAKE SOURCE PARAMETERS:

1024-1442, 11.5°N-86.5°W, h=crustal focus, Ms=7.2 (Ambraseys & Adams, 1996)
 1024-1442, 11.5°N-86.5°W, Ms=7.2, thrust type (Pacheco & Wyss, 1992)
 1024-1442, 11°47.4N-86°27.6W, Ms=7.3 (McNally & Minster, 1981 (Duda, 1965))
 1024-1442, 11.79°N-86.46°W, h=0-60, M=7.3 (Leeds, 1974 (HDF/ISS, Rothe, 1957))

TECTONIC ENVIRONMENT:

COCOS-CARIBBEAN SUBDUCTION ZONE (McNally & Minster, 1981)

TSUNAMI AND/OR MACRO SEISMIC REPORT:

Ambraseys & Adams, 1996:

"This earthquake was very strongly felt along the Pacific coast of Nicaragua."

INETER 1993 (Inf. from people of the site):

"San Juan Del Sur."

Leeds, 1974 (Rothe, 1957; Hansen, 1972):

"A large magnitude (7.3) earthquake was felt on October 24, 1956 as far away as the south of El Salvador which did slight damage at Managua believes this to be the highest magnitude recorded for a Nicaragua earthquake. He attributes the lack of damage to a deep focus."

SPECIFIC EVENT REFERENCES:

Rojas et al., 1993

No	DATE	TIME	EARTHQUAKE SOURCE PARAMETERS			TSUNAMI PARAMETERS			O
			Lat (°N)	Lon (°W)	Ms/I	T	REGION	m	
42	*1957-0310	14:42	51.63	175.41	8.1	D	Acajutla, SAL	--	P

EPICENTER REGION:

Aleutian, Pacific

EARTHQUAKE SOURCE PARAMETERS:

0309-1422, 51.63°N-175.41°W, Ms=8.1, thrust type(Pacheco & Sykes, 1992(Abe, 1981, 1984))

TSUNAMI AND/OR MACRO SEISMIC REPORT:

Guinea, 1995 (Alvarez, 1979):

"El 10 de marzo de 1957. Un tsunami de regular fuerza, procedente de las islas Aleutianas, causo grandes daños en la costa salvadoreña y la perdida de varias vidas. El entonces naciente puerto de Acajutla, se vio afectado cuando una ola de varios metros de alto destruyo totalmente la segunda celula en construccion."

No	DATE	TIME	EARTHQUAKE SOURCE PARAMETERS			TSUNAMI PARAMETERS			O
			Lat (°S)	Lon (°W)	Ms/I	T	REGION	m	
43	1960-0522	19:11	38.2	73.50	8.5	R?	La Union, Fonseca G., SAL	--	P

EPICENTER REGION.

Chile, Pacific

EARTHQUAKE SOURCE PARAMETERS:

0522-1911, 38.2°N-73.50°W, h=32 km, Ms=8.5, thrust type (Pacheco & Sykes, 1992(Abe, 1981, 1984))

Torres, R., personal communication, 1997

No	DATE	TIME	EARTHQUAKE SOURCE PARAMETERS			TSUNAMI PARAMETERS			O
			Lat (°N)	Lon (°W)	Ms/I	T	REGION	m	
44	1962-0312	11:40	8.0	89.9	6.7	L	Armuelles, Chiriqui G., PAN	-1	P

EPICENTER REGION:

Costa Rica-Panama, Pacific

EARTHQUAKE SOURCE PARAMETERS:

0312, 8°N-82.9°W; M=6.8 (Murthy, 1995)

0312, 8.1°N-82.9°W, h=58 km, Ms=6.8 (ISC) (Grases, 1990)

0312, 8.25°N-83.04°W, h=30, M=6.7 (PAS) (Viquez & Toral, 1987)

0312-1140, 8.25°N-82.04°W, h=0.0, M=6.8 (Guendel, 1986 (Molnar & Sykes, 1969; Rothe, 1969))

0312-1140, 8.1°N-82.9°W, M=6.8 (Soloviev & Go, 1984)

0312-1140, 8.10°N-82.9°W, h=30, Ms=6.7 (Cruz & Wyss, 1983 (Lander & Cloud, 1964; NOAA)

TECTONIC ENVIRONMENT:

COCOS-CARIBBEAN SUBDUCTION ZONE (Cruz & Wyss, 1983; Guendel, 1986)

Tsunami intensity = 0 (Fernandez, 1993 (Viquez & Toral, 1987)

Tsunami magnitude= -3 (Soloviev & Go, 1984)

Tsunami magnitude = -1 (Toral, unpublished)

TSUNAMI AND/OR MACRO SEISMIC REPORT:

Viquez & Toral 1987:

"Sentido fuerte en la zona fronteriza con Costa Rica. Daños leves en David y Puerto Armuelles. Pequeño Tsunami menor de 30 cm fue reportado en Puerto Armuelles y las Islas Galapagos."

Soloviev & Go, 1984 (Lander & Cloud, 1964; Iida, et al., 1967):

"There was an earthquake with source of the coast off Panama and Costa Rica.....A Small tsunami occurred and was registered 2.7 hours later by the tide gauge at San Cristobal (Galapagos) the same height by the tide gauge at Puerto Armuelles."

SPECIFIC EVENT REFERENCES:

Rojas et al., 1993 (Viquez & Toral, 1987; Cruz & Wyss 1983)

Grases, 1990 (Leeds, 1978);

No	DATE	TIME	EARTHQUAKE SOURCE PARAMETERS			TSUNAMI PARAMETERS			O
			Lat (°N)	Lon (°W)	Ms/I	T	REGION	m	
45	1968-0925	10:38	15.6	92.6	6.0		Pacific Coast	---	P

EPICENTER REGION.

Mex-Guat, Pacific

EARTHQUAKE SOURCE PARAMETERS:

0925-1038, 15.6°N-92.6°W, h=138, M(PAS)=6.0, M(BRK)=5.8-6.2 (SN, BSSA, 59, P.1028)

0925-1038, 15.54°N-92.65°W, h=114, Ms=5.8 (Bull. Int. Seism. Center, September 1968)

TSUNAMI AND/OR MACRO SEISMIC REPORT:

Seismological Notes (BSSA 59, p.1028)

"Worst damage was at the village of Acapetahus (Mexico)"

"The Pacific Coast road which is part of the inter-American highway was blocked in several places by landslides and in other places it was reported awash by a six foot tsunami".

No	DATE	TIME	EARTHQUAKE SOURCE PARAMETERS			TSUNAMI PARAMETERS			O
			Lat (°N)	Lon (°W)	Ms/I	T	REGION	m	
46	1976-0204	09:01	15.2	89.2	7.5	L	Cortes, Honduras G., HON	-0.5	C

EPICENTER REGION.

Motagua fault, Guatemala

EARTHQUAKE SOURCE PARAMETERS:

0204-0901, 15.2°N-89.2°W, h=shallow, Ms=7.5 (Ambraseys & Adams, 1996)
 0204-0901, 15.32°N-89.1°W, h=5 km, Ms=7.5, strike slip (Pacheco & Sykes, 1992)
 Ms=7.5 (White and Harlow, 1985 (Espinosa, et al., 1976))

TECTONIC ENVIRONMENT:

NOAM-CARIBBEAN PLATES BOUNDARY (Motagua fault, Plafker, 1976)

Figure 17. Intensity distribution (Espinosa et al., 1976).

Tsunami magnitude= -1 (Ambraseys & Adams, 1996)

TSUNAMI AND/OR MACRO SEISMIC REPORT:

Ambraseys & Adams, 1996 (Buckman, Plafker & Sharp, 1978; Espinosa 1976; Kanamori & Stewart, 1978; Young, Lay & Lynnes, 1989):

"This was a major earthquake in Guatemala. The earthquake was associated with a left-lateral surface break of the Motagua fault, 230 km long"
 "....The shock caused a Tsunami that was recorded on the Puerto Cortes tide gauge with a maximum amplitude of 45 cm."

SPECIFIC EVENT REFERENCES:

Toral, unpublished
 Rojas et al., 1993
Young et al. 1983
Buckman et al., 1978
Kanamori & Stewart, 1978
 Grases, 1990 (Espinosa, 1976)
 Plafker, 1976

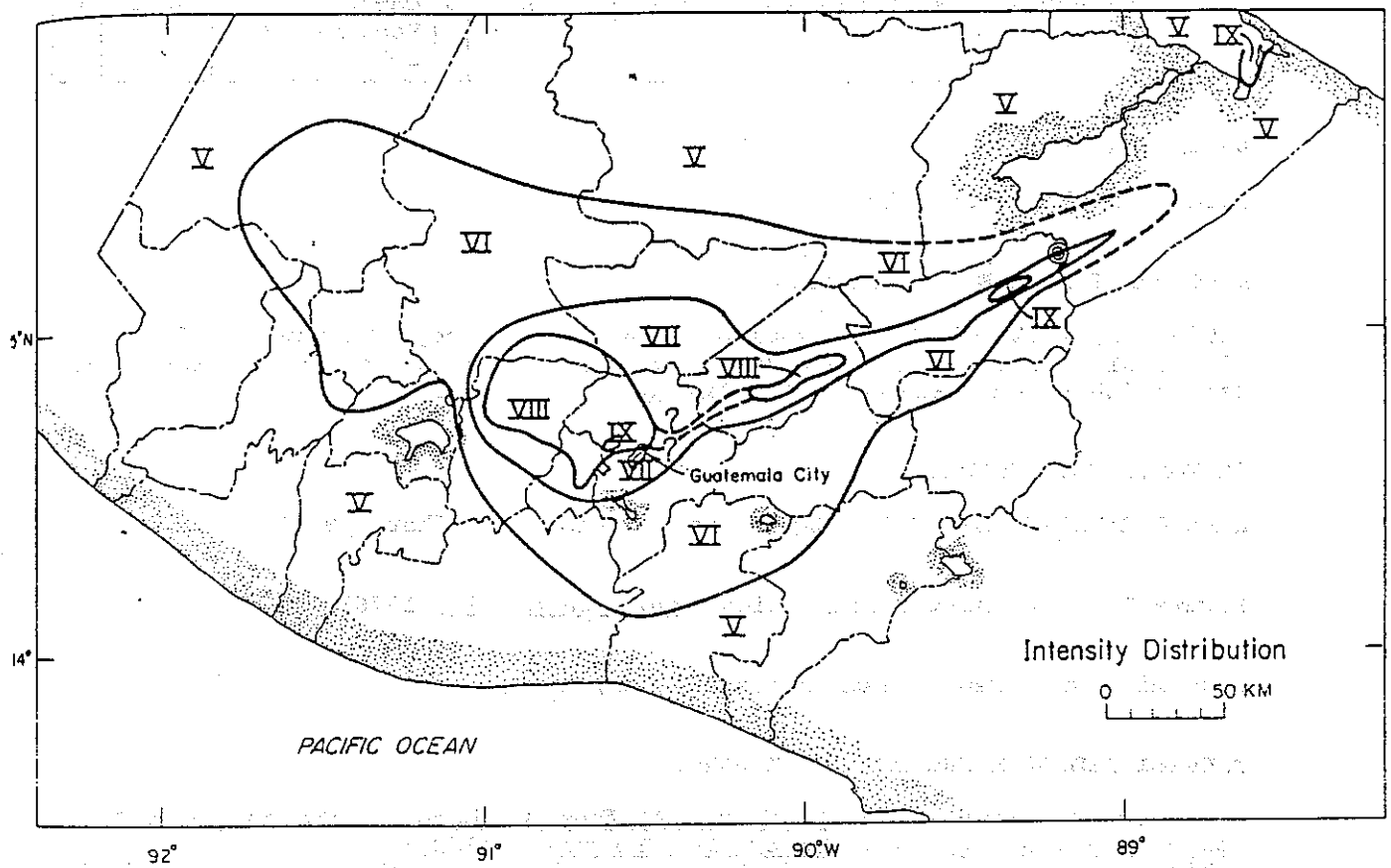


Figure 17. Isoseists of the February 4, 1976 Guatemala Earthquake (Espinosa, 1976).

No	DATE	TIME	EARTHQUAKE SOURCE PARAMETERS			TSUNAMI PARAMETERS			O
			Lat (°N)	Lon (°W)	Ms/I	T	REGION	m	
47	1976-0711	16:54	7.43	78.12	7.0	L	Jaque, Darien, PAN	-1	P

EPICENTER REGION:

Panama, Pacific

EARTHQUAKE SOURCE PARAMETERS:

0711-1654, 7.43°N-78.12°W, h=25, Ms=6.7 (Rojas et al, 1993 (ADS; PDE))
 0711, 7.4°N-78.12°W, h=3, Ms=7.0 (Grases, 1990)

Tsunami magnitude = -1 (Toral, unpublished)

TSUNAMI AND/OR MACRO SEISMIC REPORT:

Grases, 1990:

"Sismo con epicentro en el Pacifico fue sentido en todo el Pais."

"Daños moderados en la Provincia del Darien. Se retiene aqui por los grandes deslizamientos que se reportaron en el pueblo de Jaque, donde hubo muertos y al cual se le asigna una intensidad MM= VIII; en La Palma MM=VII; en Bayano MM=VI, en Ciudad de Panama MM=V".

SPECIFIC EVENT REFERENCES:

Rojas et al., 1993

Viquez & Toral, 1987

Feldman, 1984

No	DATE	TIME	EARTHQUAKE SOURCE PARAMETERS			TSUNAMI PARAMETERS			O
			Lat (°N)	Lon (°W)	Ms/I	T	REGION	m	
48	1990-0325	13:16	9.8	84.8	7.0	L	Puntaarenas & Quepos, CR	0	P

EPICENTER REGION:

Nicoya Gulf, Costa Rica, Pacific

EARTHQUAKE SOURCE PARAMETERS:

0325-1316, 9.8°N-84.8°W, h=crustal focus, Ms=7.0 (Ambraseys & Adams, 1996)
 0325-1322, 9 38.5°N-84 55.6°W, h=20 km, Ms=7.0 (Protti et al., 1995)
 0325, 9.612°N-84.934°W, h=30 km, M=6.5-6.9 Grases, 1990 (Sauter & Cartin, 1990)

TECTONIC ENVIRONMENT:

COCOS-CARIBBEAN SUBDUCTION ZONE (Protti et al., 1995)

Figure 18. Intensity distribution (Grases, 1990)

Figure 19. Epicenter and tide gauge station locations (Gutierrez & Soley, 19919)

Figure 20. Tsunami tide gauge record at Quepos station (Gutierrez & Soley, 19919)

TSUNAMI AND/OR MACRO SEISMIC REPORT:

Ambraseys & Adams, 1996 (Barquero & Rojas, 1994; Montero, et al., 1991):

"This was the main shock in Costa Rica with an epicentre in the Gulf of Nicoya."

"A small seismic sea wave was reported from Quepos and Tambor."

Gutierrez & Soley, 1991:

"El terremoto del 25 de marzo en Cobano, fue detectado por dos mareografos ubicados en Puerto Quepos."

"La hora del evento principal (7:23 hora local), coincide practicamente con la bajamar en Punta Arenas (7:29 hora local). Testigos presenciales reportaron un subito ascenso del nivel del mar en Puntarenas, de aproximadamente 1 metro, presumiblemente asociado al arribo de la cresta de la onda maremoto a este puerto."

"...un analisis pormenorizado de las series de tiempo nos revela un primer ascenso del nivel, superpuesto a la marea, 37 minutos despues de ocurrido el evento principal. Este primer acontecimiento corresponde a la respuesta de la costa (o reflejo continental), al levantamiento de la superficie del agua sobre la plataforma."

"Aproximadamente 50 minutos despues de esta cresta (87 minutos mas tarde del movimiento principal) aparece las cresta correspondiente a la onda principal generada por el sismo. Esto ha sido constatado al estimar el tiempo empleado por la onda maremoto desde su centro de generacion a Puerto Quepos. El resultado concuerda con el tiempo observado. Luego del arribo de la onda principal, se presentan 6 ondulaciones mas, a distintos intervalos, asociadas estas con amplitudes y energias diferenciadas, producto ello de las reflexiones particulares de la costa o desde el borde de la plataforma continental."

Rojas et al., 1993
Grases, 1990 (Sauter & Cartin, 1990)
Guendel, 1990

Grases, 1990 (Sauter & Cartin, 1990).

Guendel, 1990

79

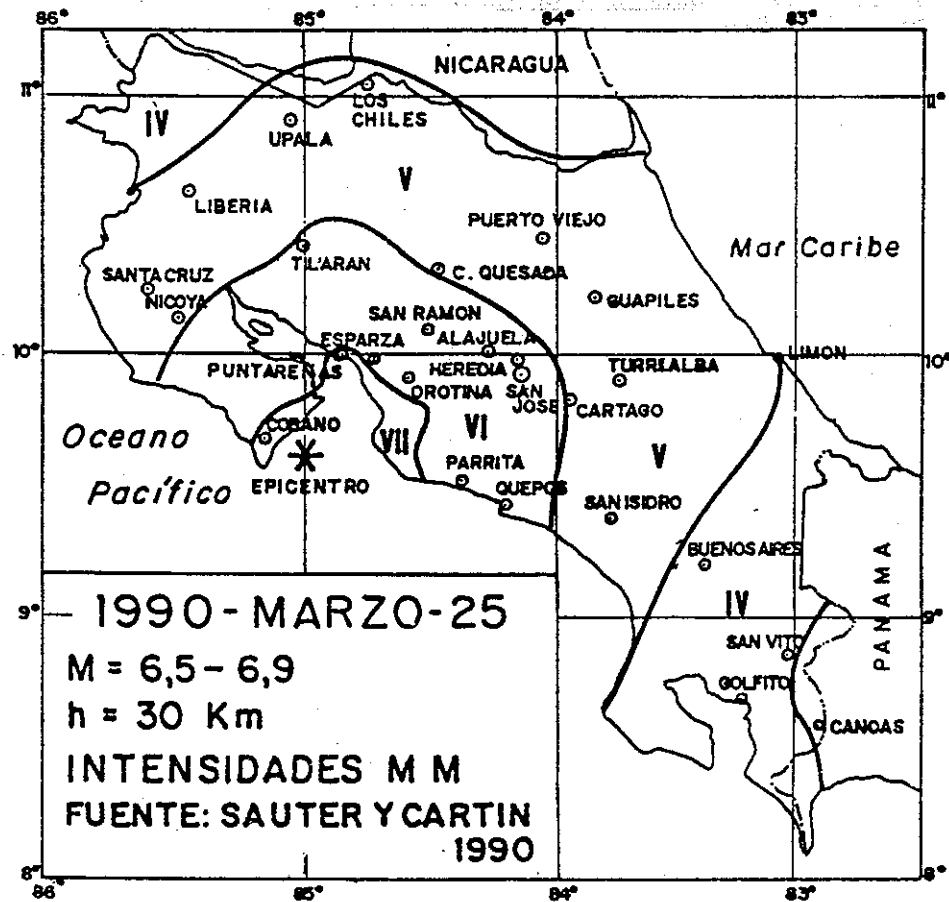


Figure 18. Isoseists of the March 25, 1990 Costa Rica Pacific coast Earthquake (Cobano Earthquake) (Grases, 1990).

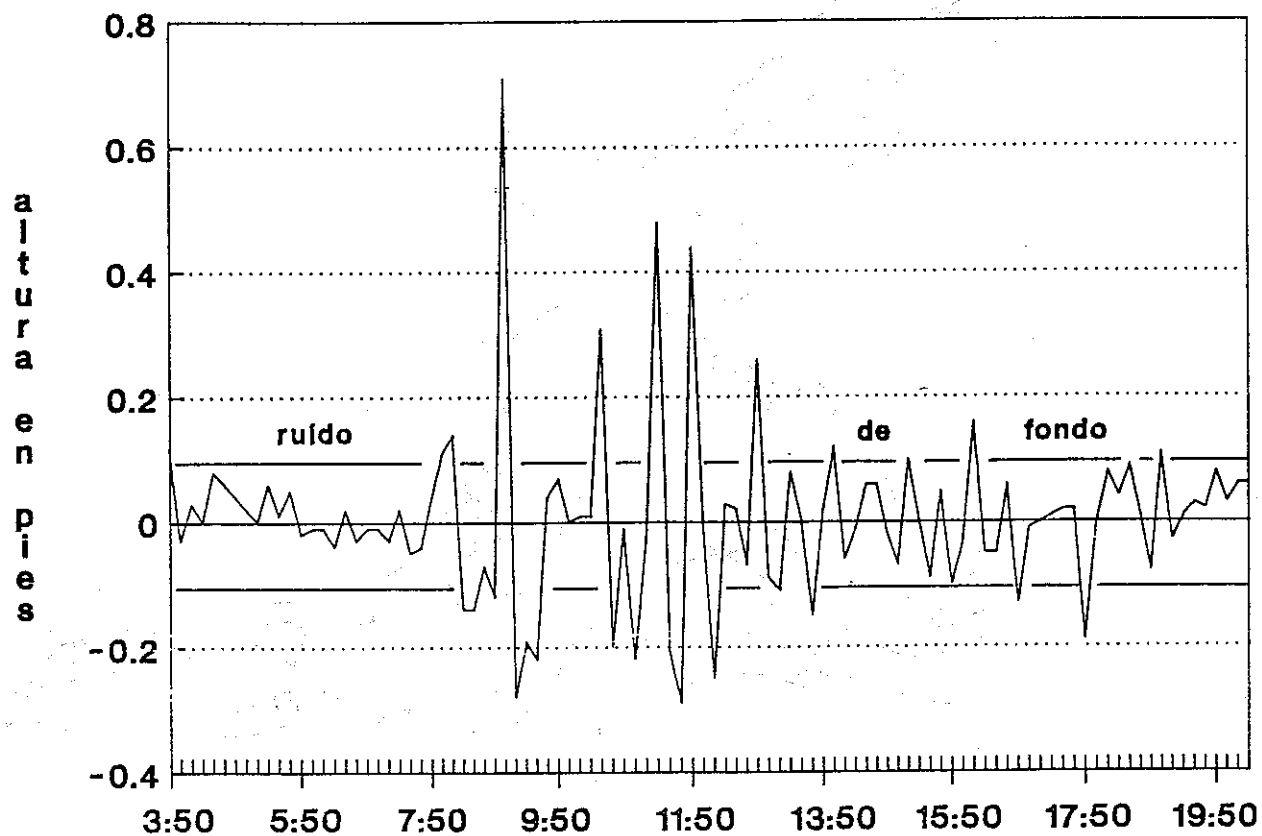


Figure 20. Tsunami record (filtered) of March 25, 1990 at Quepos tide gauge station (Gutierrez, 1991).

No	DATE	TIME	EARTHQUAKE SOURCE PARAMETERS			TSUNAMI PARAMETERS			O
			Lat (°N)	Lon (°W)	Ms/I	T	REGION	m	
49	1991-0422	21:56	9.6	83.2	7.6	L	Bocas del Toro, PAN	1	C

EPICENTER REGION.

Limon, Costa Rica, Caribbean

EARTHQUAKE SOURCE PARAMETERS:

0422-2156, 9.6°N-83.2°W, h=crustal focus, Ms=7.6 (Ambraseys & Adams, 1996)

TECTONIC ENVIRONMENT:

NORTH PANAMA DEFORMED BELT (Camacho, 1994)

Figure 21. Intensity distribution (Mora & Yasuda, 1994)

Figure 22. Landslides and liquefaction near the coast (Mora & Yasuda, 1994)

Figure 23. Co-seismic uplift along Caribbean coast (Plafker, 1991)

Figure 24. Tsunami affected area (Nishenko et al., on print, 1992)

Figure 25. Tsunami record at Coco-Solo, Panama, tide gauge station (Camacho, 1994)

Table 1. Summary of observed tsunami effects (Nishenko et al., on print, 1992)

Tsunami magnitude = 1 (Torai, unpublished; Nishenko, et al., on print)

Tsunami magnitude = 1 (Nishenko, et al., draft, July 1992)

TSUNAMI AND/OR MACRO SEISMIC REPORT:

Ambraseys & Adams, 1996 (Barquero & Rojas, 1994):

"This was a mejor earthquake in the Caribbean side of Costa Rica and Panama."
 "The earthquake was associated with a seismic sea wave that affected the whole coast from north of Limon to Panama, where it was perceptible. It was recorded at Cristobal. The maximum amplitude of the wave was about 2.0 m and in places it caused additional damage."

Camacho, 1994 (Soulas, 1991; Plafker & Ward, 1992):

"El evento del 22 de abril de 1991 tambien produjo un tsunami, estando la marea baja, que fue registrado por el mareografo de Coco Solo, Provincia de Colon. Este instrumento registro una amplitud maxima pico a pico de 76.2 mm alrededor de una hora despues de haber ocurrido el sismo y el tren de ondas duro aproximadamente cinco horas y media."

"Algunas de las localidades, a lo largo de la costa de Bocas del Toro, en donde se observo el tsunami....."

Nishenko, et al., draft July 1992 (Denver, et al., same vol.):

"A tsunami with wave heights of 2 to 3 m was initially reported as being observed by eyewitness following the earthquake along the coast from Cahiuta, Costa Rica, to Bastimentos Island, Panama. This observations indicate a tsunami magnitude, m, of about 1 (where $m = \log_2 h_{max}$, and h_{max} is the waveheight in meters measured at a point 10 a 300 km from the source zone (Iida, 1970). The tide gauge in Coco Solo, Panama (the closest gauge to the

epicenter, proximately 320 km east of the source zone) recorded a maximum peak amplitude of 7.5 cm approximately 1 hour after the earthquake. Approximately three and a half hours later, tide gauges at Mayagueyes Island, Puerto Rico and Limetree, St. Croix, Virgin Islands recorded disturbances of about 7 cm peak to peak. Based on eyewitness observations and tide gauge records, the water disturbance lasted about 4 to 5 hours."

"All of the observers in Costa Rica and Panama notes that the sea was calm before the earthquake. In Costa Rica, the sea receded 20 to 500 m from the shoreline immediately following the earthquake. In Panama, the initial recession began approximately 10 to 15 minutes after the event. The amount of the retreat varied from 100 to 400 m and lasted from 5 to 45 min in places....."

"Following the initial retreat, two principal types of run up behaviour were observed. In some locations, a wave 2 to 3 meters high advanced rapidly to the beach, and flooded from 10 to 100 m inland, according to the location and elevation. Damage resulting from the run-up was not reported by the observers. This type of behaviour was observed at mouths of major rivers in the area, including Boca Matina (#1), Bocas del Pantano (#2), Boca Moin (#5), ... and the Estrella River. Widespread liquefaction along the coast and the compaction induced subsidence of poorly consolidated sediments appear to have locally amplified run up effects at the mouths of large rivers."

"The second type of run up behaviour consisted of a gradual increase in water level without the formation of a large wave. In some locations this occurred an hour after the initial retreat. This behaviour was noted at Seis Millias de Moin (#4), Limon, Cahuita (#7), Punta Uva (#10), Bocas del Toro (#22), and Carenero (#25)....."

".....Along some coastal areas, fringing reefs provided protection against run up effects by damping tsunami waves. Coseismic coastal uplift also helped minimize the impact of flooding....."

"Sand deposition was reported at many sites along the coast. Deposition near Costa Rica-Panama border is similar to accounts associated with an event that occurred on 7 May 1822....."

SPECIFIC EVENT REFERENCES:

Boschini & Montero, 1994

Camacho, 1994

Rojas et al., 1993

Montero C., et al., 1991

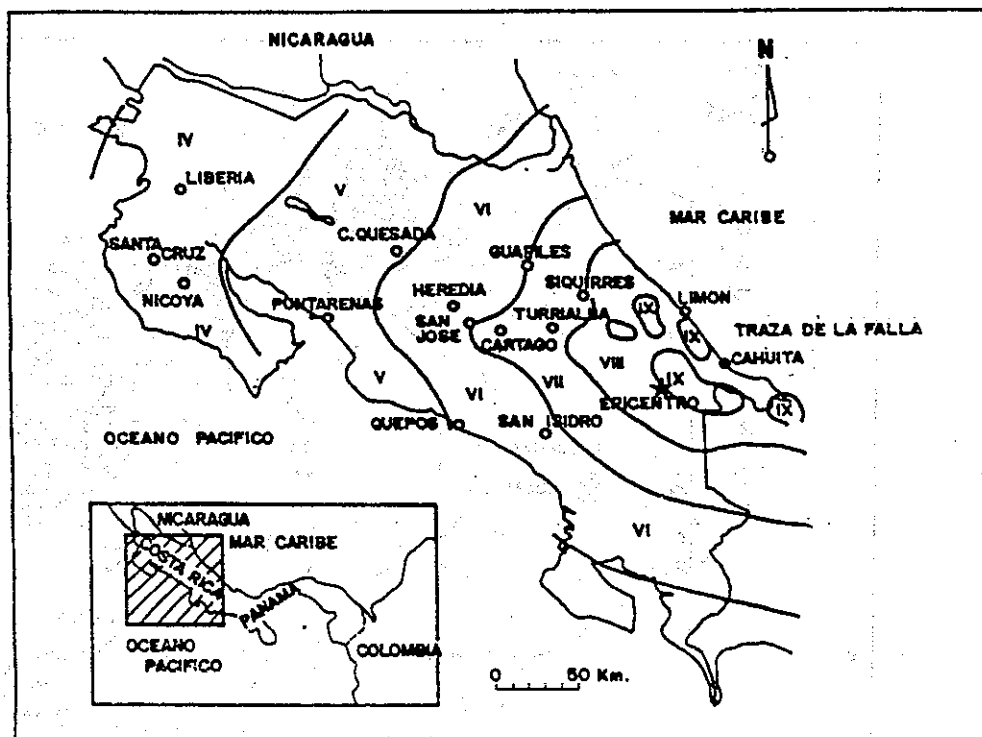


Figure 21. Isoseists and epicentre location (star) of the April 22, 1991 Costa Rica-Panama Caribbean coast earthquake, Limon Earthquake (Mora & Yasuda, 199).

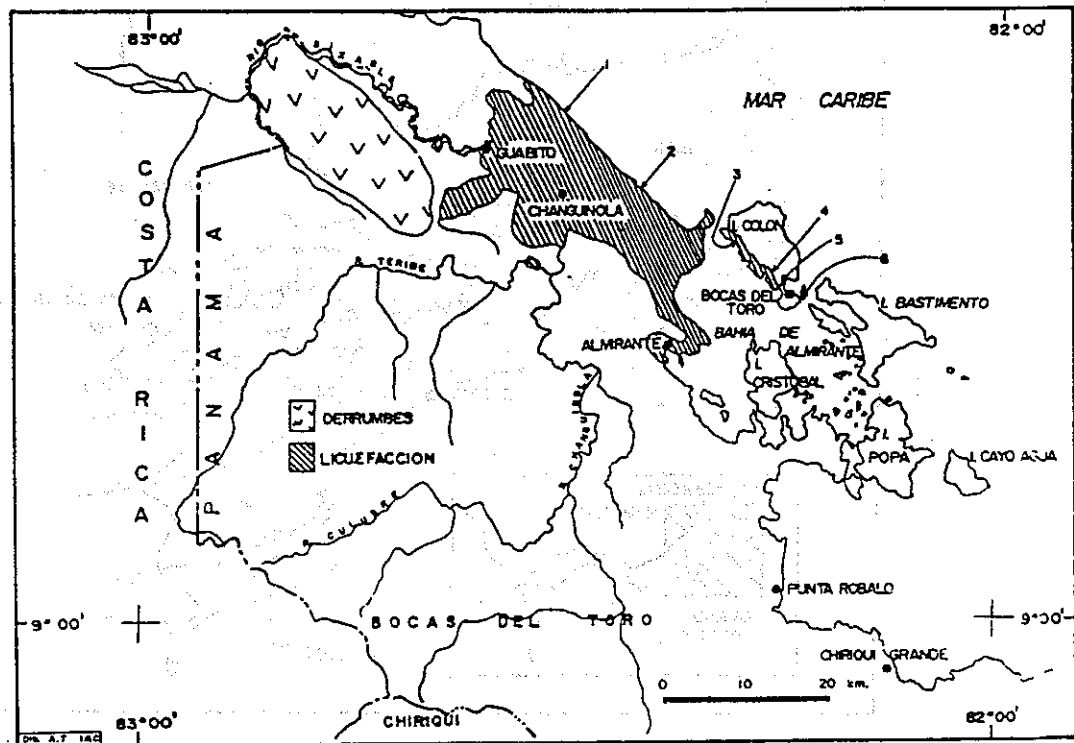


Figure 22. Permanent deformations, landslides and liquefaction near the Caribbean coast related with the April 22, 1981 Limon Earthquake .

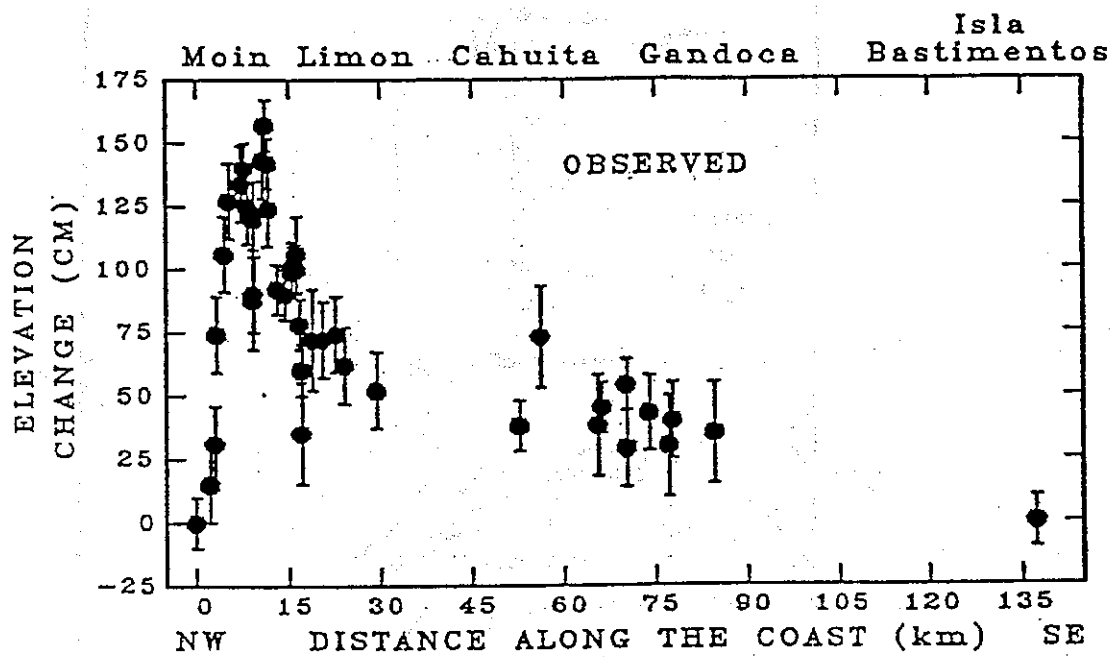


Figure 23. Co-seismic deformation (uplift) along the Caribbean coast related with the April 22, 1991 Limon Earthquake (Plafker & Ward, 1992).

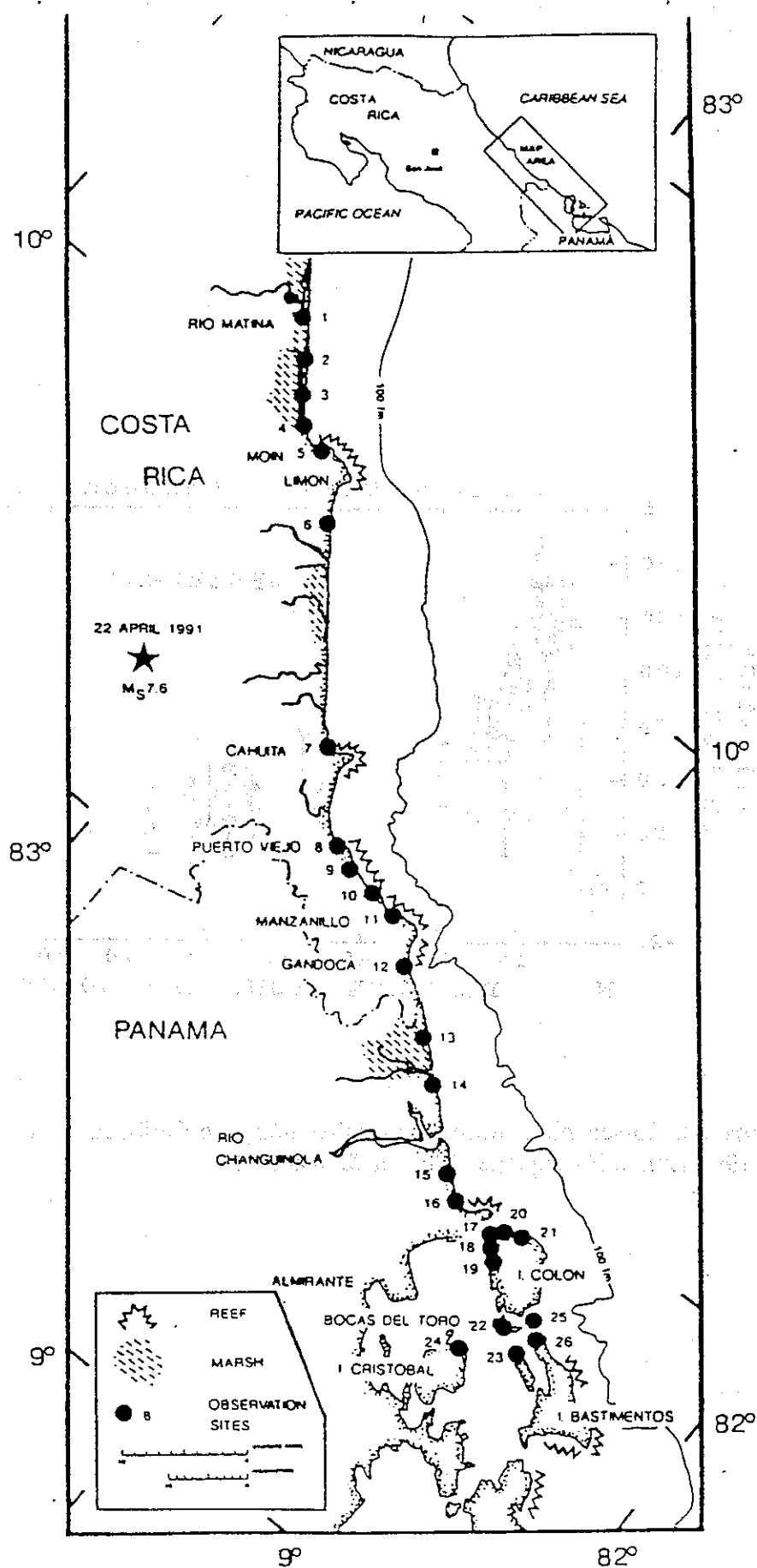


Figure 24. Places along the Costa Rica-Panama Caribbean coast hit by the tsunami of April 22, 1991. The numbers are related with the places mentioned by Nishenko, et al., on print (Nishenko, et al., on print).

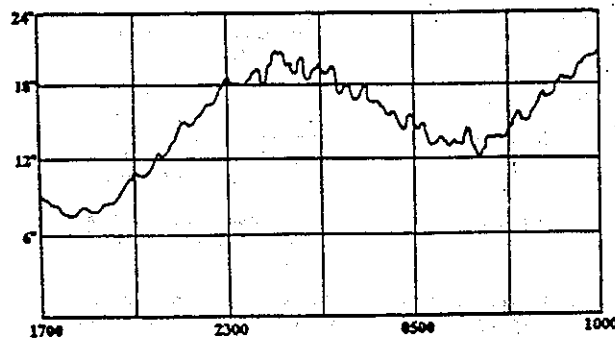


Figure 25. Tsunami record of April 22, 1991 at Coco-Solo tide gauge station, Colon , Panama, (Camacho, 1994).

<u>LOCATIONS</u>	<u>OBSERVED EFFECTS</u>	<u>CHARACTERISTICS</u>
1. Boca del Rio Matina	Water retreats about 400 m 180 m run up	Beach and Rivermouth
2. Boca del Pantano	Water recedes about 100 m. returns within 3 min without flooding	Beach
3. 12 Milla de Moin	2 drown in El Matina channel	
4. 6 Milla de Moin	Water slowly retreats 20 m	Beach
5. Moin	Water recedes about 200 m. sea wave overtoped 3 m dikes in Moin River	Rivermouth
6. Westfalia	Water retreats about 200 m. sand movement	Beach
7. Cahuita	Water recedes rapidly returns slowly after 1 hr. no flooding	Reef
8. Puerto Viejo	Water recedes about 100 m followed seconds later by a large wave, water recedes again. returns with 30 - 70 m run up.	Reef
9. Final de Cocles	Water retreats about 20 m. returns slowly (5-6 min) to previous level	Beach and Cliff
10. Punta Uva	Water retreats 400 - 600 m	Beach
11. Manzanillo	Water retreats about 150 m returns 5 min later with 30 - 70 m run up, sand movement	Beach
12. Gandoca	Water retreats about 300 m returns 5 min later with 70 m run up	Beach
13,14. San-San Natural Refuge	Waves deposit 1 m of sand, created dunes, covered turtle nests	Beach
15. Julio Abrego Beach	Water recedes 3 to 6 times minutes after quake, 100 m runup after last wave	Beach
16. Changuinola River and Tiribibi Pt. Isla Colon	Sand deposition, high energy current	Beach
17. Lime Point	Sea receded 6 time, exposed reefs, water flooded coastal road	Reef
18. West Knapp Hole	Great turbulence observed minutes after quake, strong current, 5 - 10 m runup	Beach on Bay
19. Ground Creek	Water receded, returned as strong current 0.6 m high, 10 m runup	Creek on Bay
20. Punta Cauro	Water receded 5 times Last wave about 2 m high	Beach next to Cliffs
21. Boket Bay	2.5 - 3 m wave 10-15 min after quake	Cove
22. Bocas del Toro	Water receded 10 min after quake, exposed offshore sandbar usually 0.6 m deep, waves runup 10-15 m	Cove
23. Nancy Key	Water receded several time returns as strong current	Point
24. San Cristobal Is.	Sea recedes several meters for 45 min, water returns as slow wave	Creek
25. Carenero Is.	Sea receded 15-20 min after quake, remained out for 15 min returns as gentle wave with 100-150 m runup	Beach
26. Bastimentos Is.	Sea receded 10-15 min after quake, returnsd gently	Reef

No	DATE	TIME	EARTHQUAKE SOURCE PARAMETERS			TSUNAMI PARAMETERS			O
			Lat (°N)	Lon (°W)	Ms/I	T	REGION	m	
50	*1992-0902	00:16	11.7	87.4	7.2	L	Nicaragua Coast, NIC Bahia de Salinas, Papagayo G., CR	2.5	P

EPICENTER REGION.

Nicaragua Pacific coast

EARTHQUAKE SOURCE PARAMETERS:

0902-0016, 11.7°N-87.4°W, h=crust focus, Ms=7.2 (Ambraseys & Adams, 1996)
 0902-0016, 11.742°N-87.34°W, h=45 km, Ms=7.2 (Satake & Imamura, 1995 (PDE))
 0901, 11.6°N-87.3°W, h= 33 km, Ms=7.0 (Murty, et al., 1995 (NEIC))

TECTONIC ENVIRONMENT:

COCOS-CARIBBEAN SUBDUCTION ZONE (Kanamori & Kikuchi, 1993)

Tsunami magnitude=2.5 (Hatori, 1985)

Tsunami magnitude = 3.3 (Torai, unpublished)

Tsunami intensity = 3 for Nicaragua coast and 1 or 2 at the Costa Rica coast (Fernandez, 1993)

Figure 26. Epicenter location and aftershock area (Baptista et al., 1993)

Figure 27. Tsunami tide gauge record at Puerto Corinto station (Baptista et al., 1993)

Figure 28. Tsunami heights at the Nicaragua coast (Satake et al., 1992)

Figure 29. Tsunami observer effects at Costa Rica coast (Fernandez, 1993)

TSUNAMI AND/OR MACRO SEISMIC REPORT:

Ambraseys & Adams, 1996 (Camacho, 1994; Satake et al., 1993):

"This was a major earthquake off the Pacific coast of Nicaragua. Most of the damage and casualties were caused by a seismic sea wave that affected the west coast of Nicaragua and Costa Rica, reaching heights of up to 8.0 m. Wave run-up to 1 km was reported at Nasachapa...."

Murty, et al., 1995:

"Run-up were generally in the three to five meters range, but maximum amplitudes of up to 9.5 m were noted. The horizontal extent of the inundation was typically of the order of a few hundred meters."

"Tsunami was originated by a moderate local earthquake, great destruction to property and took about 170 lives."

"The earthquake occurred in a predicted area (Harlow, et al., 1992)"

"...it was a tsunami earthquake rather than a tsunamigenetic earthquake."

"Both surveys suggest that the largest run-up occurred in the central part of the Nicaragua coast, with attenuation toward the South and the North, this appears consistent with the location of the epicentral area."

Fernandez, 1993:

"Bahia Tamarindo:levantamiento del nivel del mar (de 2 a 3.5 m sobre la altura promedio alcanzada durante la marea alta) aproximadamente unos 15 a 20 minutos despues del sismo, el cual fue percibido con baja intensidad.

Bahia Brasilito: ...el temblor fue percibido parcialmente por la poblacion, el fenomeno que mas impresiono fue el levantamiento del nivel del mar en aproximadamente 3 a 4 m sobre la zona maxima de marea alta. No hubo danos en la zona

.....la zona conocida como Flamingo, la cual fue la mas afectada...., en especial el lugar conocido como La Marina (pequeño atracadero de yates y embarcaciones para la pesca) en donde el nivel del mar ascendio unos 4 mpasando por encima de los diques naturales y provocando que muchos de los yates quedaran montados sobre los diques; ademas hubo danos en los muelles del lugar.

.....despue de percibir el sismo y pasado un cierto tiempo (20 a 30 minutos) se observo un alejamiento del mar, que dejo a la mayoria de las embarcaciones encalladas....

Bahia Potrero:primero fue percibido el movimiento sismico y luego el aumento anormal del nivel del mar. Esta zona no sufrio efectos de ningun tipi.

Bahias El Coco y Hermosa:.....el efecto del levantamiento del nivel del mar que subio a 3.85 m medidos desde la base del muelle(de 2 a 2.5 m por encima de la marea mas alta). El sismo fue sentido con una intensidad baja, entre 15 a 20 minutos despues de este se dio un efecto de retroceso del nivel del mar en aproximadamente 125 m de la zona media de marea (con un tiempo de 1:20 minutos), para luego subir el nivel a la altura antes descrita y medida....Este proceso se observo en 4 ocaciones.

No hubo danos en estructuras,.....

Bahia Panama y Bahia Culebra: ...solo se percibio el moviento sismico.

Bahia Cuajiniquil, Junquillal y Salinas:....asombro al ver el aumento en el nivel del mar."

SPECIFIC EVENT REFERENCES:

Piatanessi & Tinti, 1996

Ihmle, 1996

Kikuchi & Kanamori, 1995

Murthy 1995

Satake, 1995

Satake, 1994

Velasco et al., 1994

Rojas et al., 1993

Kanamori & Kikuchi, 1992

Imamura et al., 1993

Baptista 1993

Satake et al., 1993

Ide et al., 1993

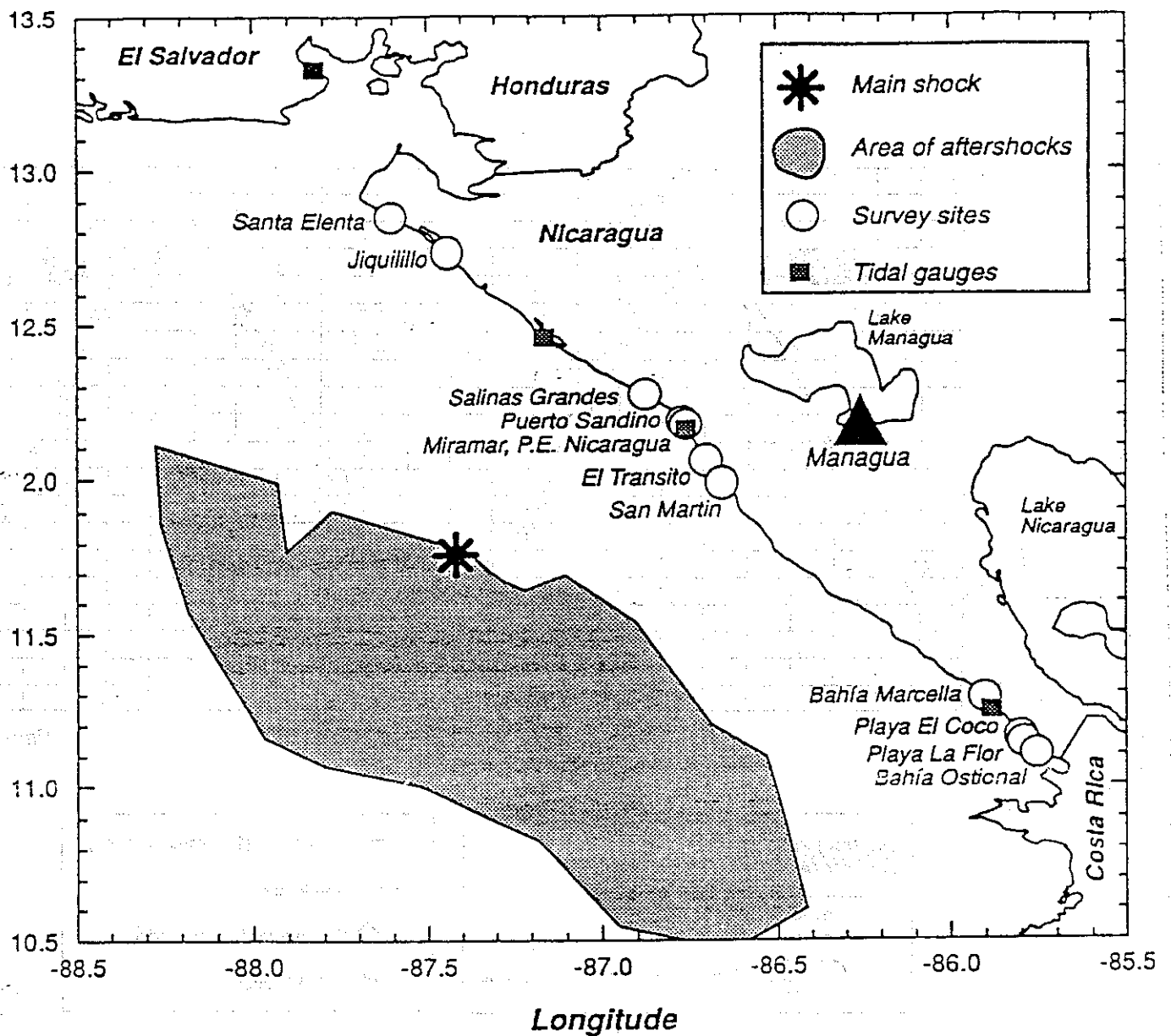


Figure 26. Main shock location, and aftershocks area of the September 2, 1992 Nicaragua Pacific coast earthquake. Also shows the survey sites and the tide gauge stations in the area (Baptista, et al., 1993).

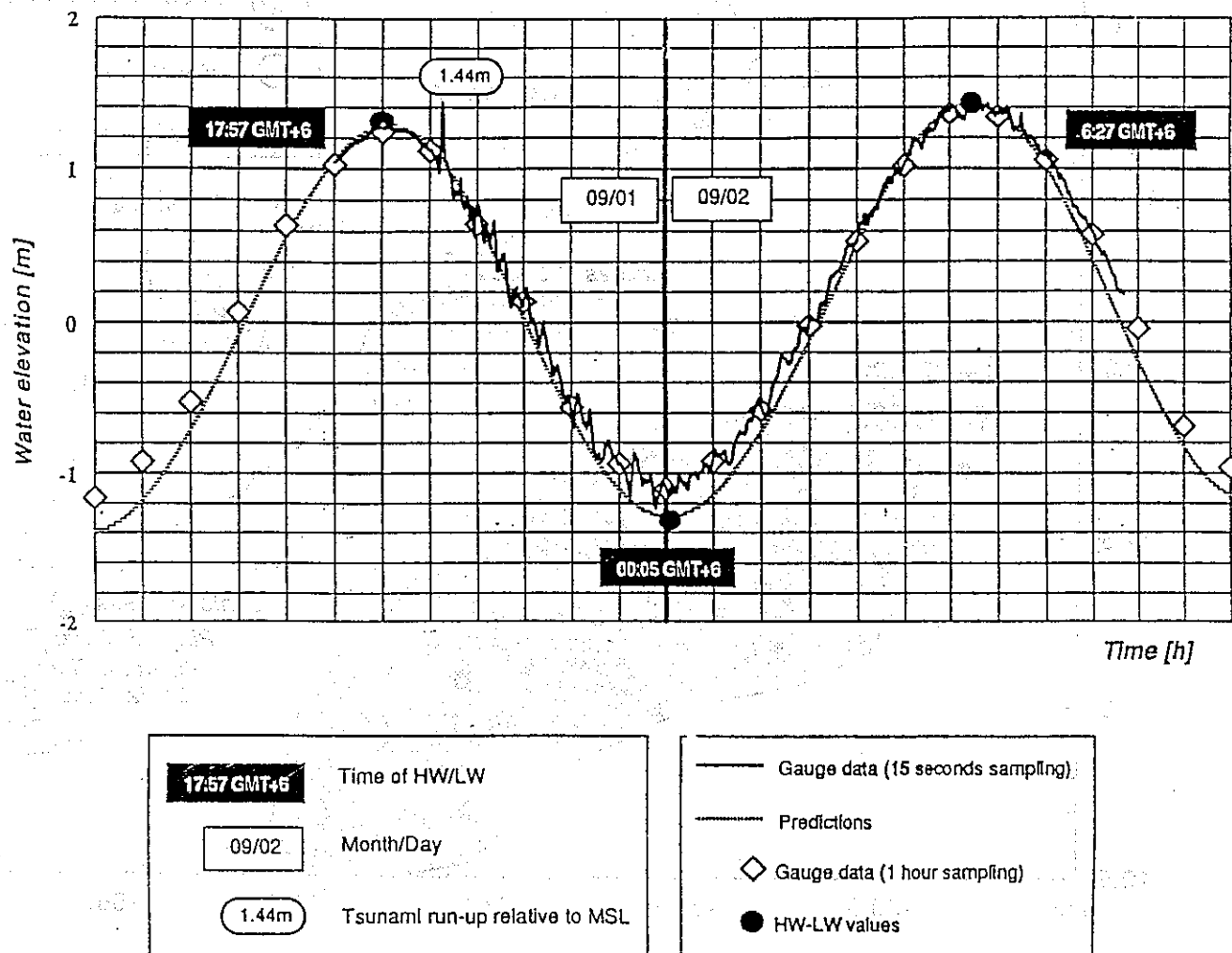


Figure 27. Tsunami record of September 2, 1992 at Puerto Corinto tide gauge station (see Figure 27 for location) (Baptista, et al., 1993).

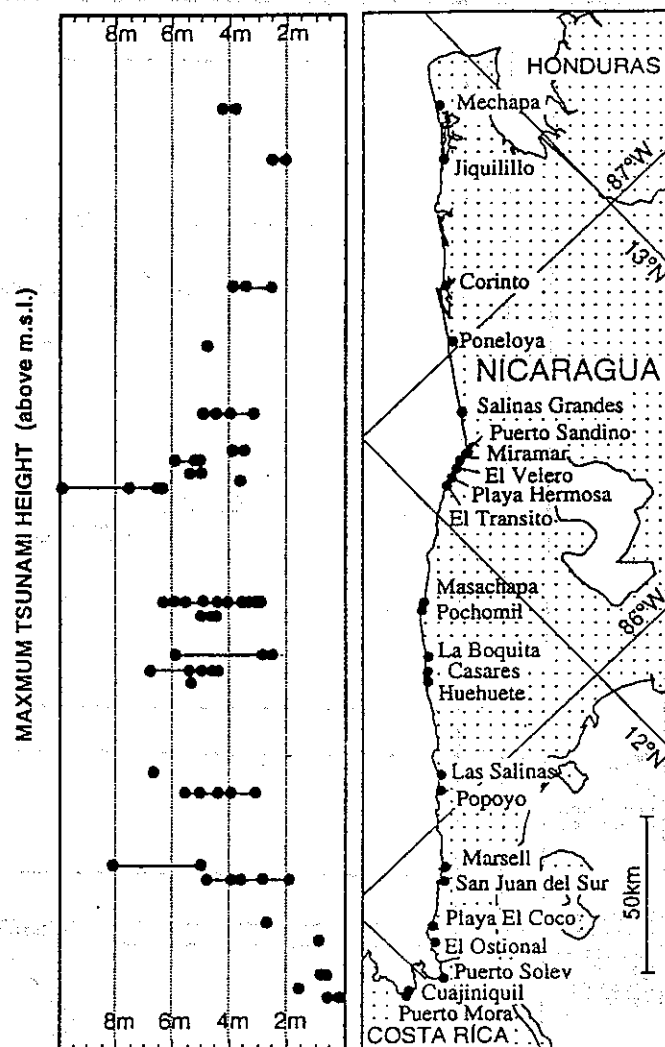


Figure 28. Observer and computed tsunami heights at the coast. The run-up measures are show as a fraction of the maximum elevation (9.1 m at San Martin, see Figure 27 for location) (Baptista, et al., 1993).

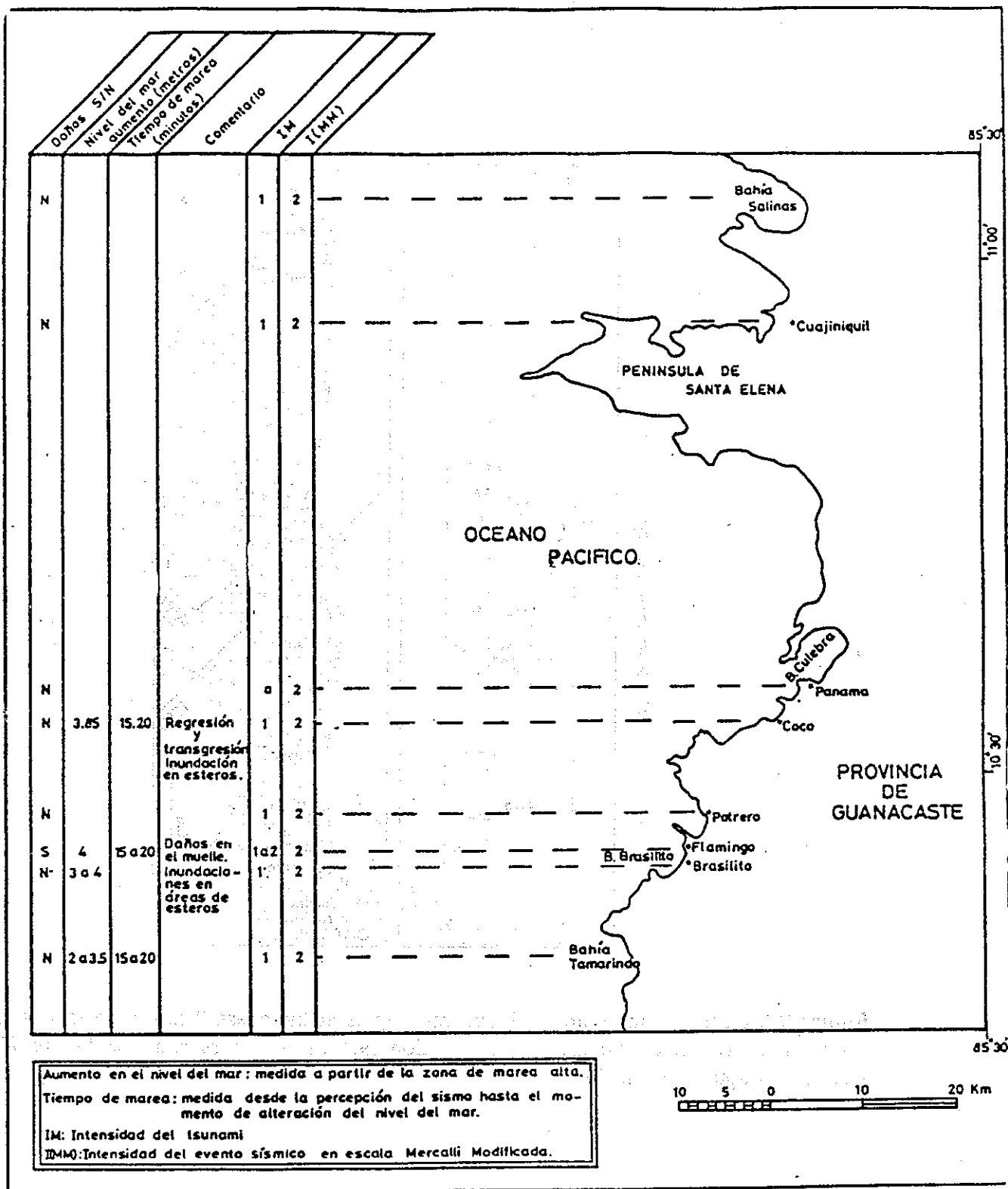


Figure 29. Tsunami observations along the Costa Rica Pacific coast. See above Fernandez (1993) descriptions.

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