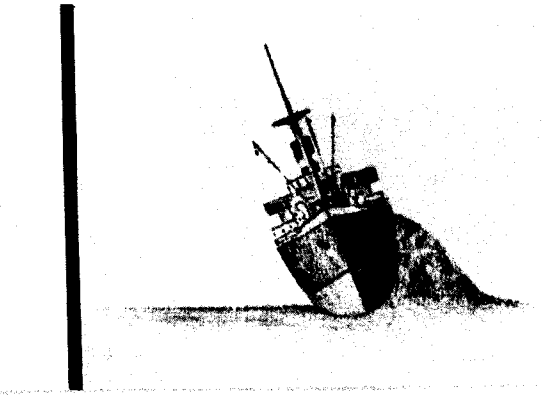
REPORT SE-39

WORLD DATA CENTER A
for
Solid Earth Geophysics

TSUNAMIS IN PERU-CHILE

JULY 1985

National Geophysical Data Center



COVER ILLUSTRATIONS: (Left) Cascade formed on East side of Banco Tres Hermanas during withdrawal of the water. Higher side is upstream.

(Center) Tugboat El Pacifico falls into trough that formed opposite Corral. The tug has never been found.

(Right) Sand accumulated on starboard side of the Carlos Haverbeck while she was aground on Banco Tres Hermanas.

Illustrations above, from accounts of the May 22, 1960, tsunami in Chile, were furnished by Pierre St. Amand.

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TSUNAMIS IN PERU-CHILE

by

Patricia A. Lockridge

JULY 1985

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National Geophysical Data Center

Boulder, CO 80303 USA

DESCRIPTION OF WORLD DATA CENTERS

World Data Centers conduct international exchange of geophysical observations in accordance with the principles set forth by the International Council of Scientific Unions (ICSU). They were established in 1957 by the International Geophysical Year Committee (CSAGI) as part of the fundamental international planning for the IGY program to collect data from the numerous and widespread IGY observational programs and to make such data readily accessible to interested scientists and scholars for an indefinite period of time. WDC-A was established in the U.S.A.; WDC-B in the U.S.S.R.; and WDC-C in Western Europe, Australia, and Japan. This new system for exchanging geophysical data was found to be very effective, and the operations of the World Data Centers were extended by ICSU on a continuing basis to other international programs; the WDC's were under the supervision of the Comite International de Geophysique (CIG) for the period 1960 to 1967 and are now supervised by the ICSU Panel on World Data Centres.

The current plans for continued international exchange of geophysical data through the World Data Centers are set forth in the *Fourth Consolidated Guide to International Data Exchange through the World Data Centres*, issued by the ICSU Panel on World Data Centres. These plans are broadly similar to those adopted under ICSU auspices for the IGY and subsequent international programs.

Functions and Responsibilities of WDC's

The World Data Centers collect data and publications for the following disciplines: Meteorology; Oceanography; Rockets and Satellites; Solar-Terrestrial Physics disciplines (Solar and Interplanetary Phenomena, Ionospheric Phenomena, Flare-Associated Events, Geomagnetic Phenomena, Aurora, Cosmic Rays, Airglow); Solid Earth Geophysics disciplines (Seismology, Tsunamis, Gravimetry, Earth Tides, Recent Movements of the Earth's Crust, Rotation of the Earth, Magnetic Measurements, Paleomagnetism and Archemagnetism, Volcanology, Geothermics), and Marine Geology and Geophysics. In planning for the various scientific programs, decisions on data exchange were made by the scientific community through the international scientific unions and committees. In each discipline, the specialists themselves determined the nature and form of data exchange, based on their needs as research workers. Thus, the type and amount of data in the WDC's differ from discipline to discipline.

The objects of establishing several World Data Centers for collecting observational data were: (1) to insure against loss of data by the catastrophic destruction of a single center, (2) to meet the geographical convenience of, and provide easy communication for workers in different parts of the world. Each WDC is responsible for: (1) endeavoring to collect a complete set of data in the field or discipline for which it is responsible, (2) safe-keeping of the incoming data, (3) correct copying and reproduction of data, maintaining adequate standards of clarity and durability, (4) supplying copies to other WDC's of data not received directly, (5) preparation of catalogs of all data in its charge, and (6) making data in the WDC's available to the scientific community. The WDC's conduct their operation at no expense to ICSU or to the ICSU family of unions and committees.

World Data Center A

World Data Center A, for which the National Academy of Sciences through the Geophysics Research Forum and its Committee on Geophysical Data has overall responsibility, consists of the WDC-A Coordination Office and seven subcenters at scientific institutions in various parts of the United States. The GRF periodically reviews the activities of WDC-A and has conducted several studies on the effectiveness of the WDC system. As a result of these reviews and studies, some of the subcenters of WDC-A have been relocated so that they could more effectively serve the scientific community. The addresses of the WDC-A *subcenters and Coordination Office are given inside the front cover.*

The data received by WDC-A have been made available to the scientific community in various ways: (1) reports containing data and results of experiments have been compiled, published, and widely distributed; (2) synoptic-type data on cards, microfilm, or tables are available for use at the subcenters and for loan to scientists; (3) copies of data and reports are provided upon request.

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TSUNAMIS IN PERU-CHILE

BY

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Boulder, Colorado

INTRODUCTION

The National Geophysical Data Center (NGDC) and its collocated World Data Center-A for Solid Earth Geophysics (WDC-A) are responsible for acquiring, archiving, and disseminating three types of tsunami data: tide gage records (marigrams), photographs of wave action and property damage, and digital data on the occurrence and effects of tsunamis. This responsibility includes the provision of information on this hazard to local officials who are responsible for warning inhabitants endangered by tsunamis, and to scientists who are engaged in research to mitigate the effects of tsunamis.

A tsunami is a series of ocean waves generated by an impulsive disturbance in the ocean or in a small, connected body of water. Defined in this way, the term includes waves generated by abrupt ocean-bottom displacements caused by earthquakes, submarine or shoreline landslides, volcanic eruptions, and explosions. These long-period, low-amplitude waves pose a threat to no one in the open ocean, but their speed decreases as they reach shallow water and their height increases. Property damage and casualties in coastal cities may therefore result.

The project for Tsunami Hazard Reduction Using System Technology (THRUST), sponsored by the Office for U.S. Foreign Disaster Assistance/Agency for International Development (AID), is a comprehensive program to mitigate destruction from tsunamis in developing countries. As part of this project, NGDC/WDC-A has compiled several sets of data that contain historical information about tsunamis in the Peru-Chile area. This area of South America was chosen for the project because it is one of the most highly seismic regions in the world. Tsunamis spawned by earthquakes in this region have caused considerable destruction along the coast of South America and elsewhere.

To show the differences in seismicity and vulnerability to tsunami damage that exist in the Peru-Chile coastal area, we have divided the coastline into several regions to facilitate the examination and comparison of the data in each region.

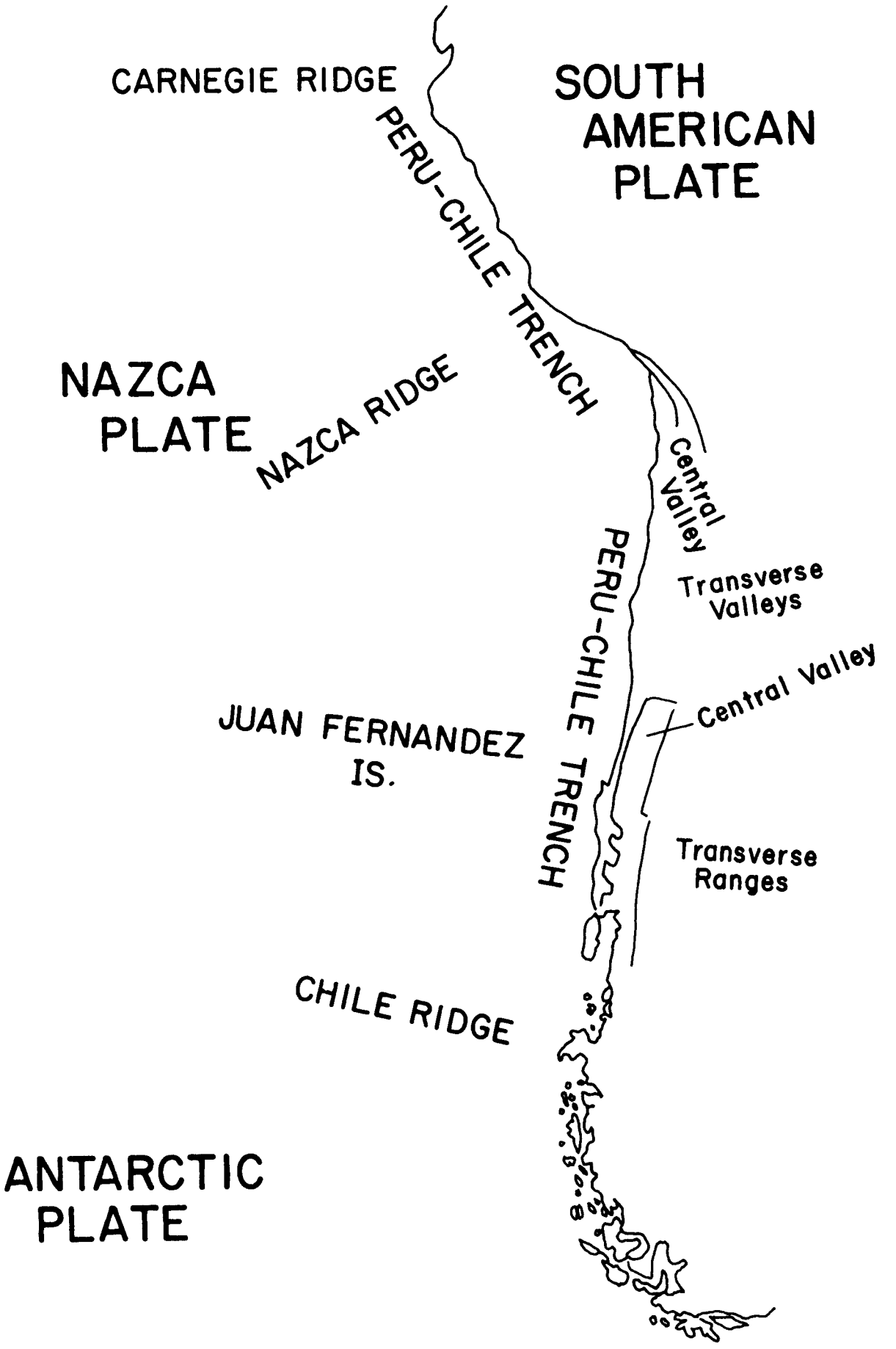

FIGURE 1. GEOLOGIC FEATURES OF PERU-CHILE

These regions are:

1) Peru (3° S. latitude to <18° S. latitude),
2) North Chile (18° S. latitude to <27° S. latitude),
3) North Central Chile (27° S. latitude to <33° S. latitude),
4) Central Chile (33° S. latitude to <37° S. latitude),
4) South Central Chile (37° S. latitude to <41° S. latitude), and
5) South Chile (41° S. latitude to 60° S. latitude).

This report contains maps that show major geologic features of the entire region (fig. 1), as well as locations of major coastal cities in Peru-Chile (fig. 2). In addition, each region includes five tables that contain the following information:

1) list of earthquakes that both occurred and generated tsunamis in the region,
2) effects in Peru-Chile of tsunamis generated in the region,
3) effects outside Peru-Chile of tsunamis generated in the region,
4) damage and number of deaths from tsunamis in the region,
5) coastal cities in the region that reported tsunamis from all sources.

The chapters describing the above regions contain: bar graphs depicting the number of tsunamigenic earthquakes that have occurred at each degree of latitude; maps showing the extent of affected coastline for several of the larger earthquakes; and maps showing areas throughout the Pacific Ocean Basin where major tsunamis were reported.

BACKGROUND

The historical data in this report were taken from catalogs in the "Reference" list, which follows table 1. Where the sources differ markedly, separate entries for each source are included in the table. Further, some reports of tsunami events that do not fit the definition of a tsunami as given on page 1 also are included in table 1. However, if known to be spurious, data for these events appear only in table 1, not in the tables and maps elsewhere in this report.

A historical study of the tsunamis in this area and of the earthquakes that generated them will benefit not only the inhabitants of Chile and Peru, but also those of other nations in the Pacific Ocean Basin. Many areas outside the Continent of South America have reported damage from tsunamis generated in the Peru-Chile area. For example, only those tsunamis that originated in the Peru-Chile and Aleutian trenches have historically caused significant wave runup along the Pacific coast of the United States (Garcia, 1976).

Earthquakes that have generated tsunamis in the Peru-Chile area have hypocenters off the coast at a shallow depth. The seismic zone in Western South America is a continuous boundary along which the Nazca Plate underthrusts the South American Plate, producing the Peru-Chile trench (Garcia, 1976). Most earthquake hypocenters in this area lie on the shoreward side of this trench--in the most highly seismic region between latitudes 12° S. (Lima, Peru) and 40°S. (Valdivia, Chile) (Berninghausen, 1962). Contemporary studies indicate that large-magnitude earthquakes in this area cause motion along the boundary of the Nazca-South American Plates. Any segment of the boundary that has not ruptured for many decades is considered to be a zone of high seismic risk (Garcia, 1976).

One of every three Pacific-wide tsunamis in the 20th century was generated in Peru or Chile. An earthquake of sufficient magnitude to generate a tsunami that would affect the entire Pacific Basin (mag. = 8.2) occurs in Chile once every 25 years on the average. Further, 40 percent of all damaging tsunamis in the 20th century were generated in Chile.

Major differences in seismicity, in morphology of the coast, and in potential for generation of large tsunamis exist along the coastline of Peru-Chile. For example, the maximum dimension of rupture zones caused by large South American earthquakes varies considerably along the trench. These variations may be related to the rate of subduction of the Nazca Plate as well as to variations in the morphology of the inner wall of the trench.

The southern coast of Chile south of 40° S. latitude differs markedly from the northern portion of the coast. From Northern Peru to Southern Chile the coast is regular and has few indentations, but from 41° S. to Tierra del Fuego the coast is penetrated by a complex system of inlets (Murty and others, 1975) and the Peru-Chile trench is less well defined. The Chile Ridge (a bathymetric feature of the Pacific Basin) intersects the South American coast at about 46°S. latitude, where it forms the southern boundary of the Nazca Plate. A decrease in seismicity occurs south of that southern boundary (McCann and others, 1979). Although a map plot of instrumentally determined epicenters of medium-size earthquakes shows a rather even distribution from north to south, major shocks appear to be restricted to a few discrete source areas. Each of these source areas displays a characteristic pattern of seismic and tsunami effects (Lomitz, 1970).

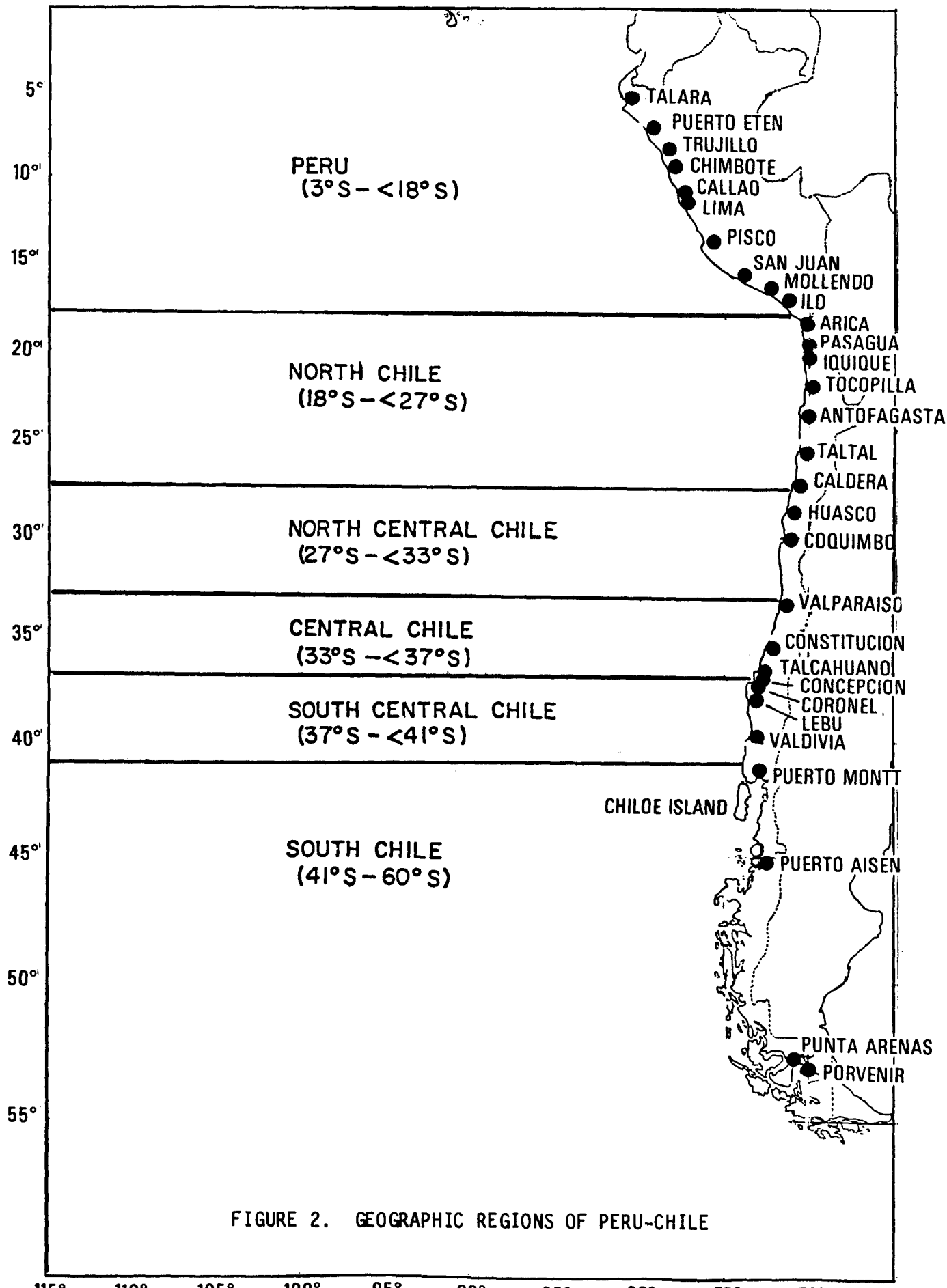

FIGURE 2. GEOGRAPHIC REGIONS OF PERU-CHILE

TABLE 1. TSUNAMIGENIC EARTHQUAKES OF PERU-CHILE

	YEAR	MONTH	DAY	ORIGIN TIME	LATITUDE (°)	LONGITUDE (°)	MAGNITUDE	FOCAL DEPTH (KM)	RUNUP HEIGHT (M)	TSUNAMI MAGNITUDE	TSUNAMI INTENSITY	SOURCE REGION	VALIDITY	CAUSE	REFERENCE
*	1562	10	28	1000	38.0	73.5	8.0	16.0	4.0	3.5		S. CENTRAL CHILE	4	T	1,9,10,31,38,52
*	1570	02	08	1300	37.0	73.0	8.8	4.0	2.0	3.0		S. CENTRAL CHILE	4	T	1,9,10,31,38,51
	1575	03	17	0600	33.4	70.6	7.3	4.0	2.0	2.5		CENTRAL CHILE		T	9,10,31,52
	1575	12	06		(40.0	74.0)						S. CENTRAL CHILE			9
	1575	12	16	1900	40.0	74.0	7.8	4.0	2.0	2.5		S. CENTRAL CHILE		T	1,10,31,38,51
*	1575	12	16	1830	39.8	73.2	8.5					S. CENTRAL CHILE	4	T	52
	1575	12	16		40.0	70.0						S. CENTRAL CHILE		T	9
*<	1586	07	09		12.2	77.7	8.5	26.0	4.0			PERU	4	T	9,10,38
	1604	11	24	1613	18.0	71.5	8.4	16.0	4.0			PERU		T	1,9,10,31
*	1604	11	24		17.0	72.0	8.5	8.0		3.5		PERU	4	T	38
	1604	11	26		(18.0	71.5)						PERU			9
	1604	11	29		(18.0	71.5)						PERU			9
	1605	11	26		(18.0	71.5)						PERU			9
	1605	11	29		(18.0	71.5)						PERU			9
	1615	09	16	2400	18.6	71.0	7.5	4.0	2.0	1.5		NORTH CHILE	4	T	1,9,10,31,38,51
*	1633	05	14		(41.8	74.0)		2.0		1.5		SOUTH CHILE		T	9,38
*	1647	05	07		(14.2	75.7)		2.8		2.0		PERU	3	T	9,10,38
	1647	05	13		(14.2	75.7)						PERU			9
	1651	00	00					22.6		5.0		NORTH CHILE			9,10
	1657	03	15	2330	37.0	73.0	8.0	8.0	3.0	2.5		S. CENTRAL CHILE	3	T	1,31,38,51
	1657	03	15		33.3	70.4						CENTRAL CHILE			9
	1657	07	09		(33.3	70.4)		0.7		0.0		CENTRAL CHILE		T	9,38
	1681	03	10		(18.5	70.3)	7.5					NORTH CHILE	3	T	31,51
	1682	10	19		13.5	76.5						PERU		T	10,38
	1686	00	00		(12.0	77.0)						PERU			9,10
	1687	07	12		(32.2	70.8)						N. CENTRAL CHILE			31,51
	1687	07	12	0700	32.8	70.7	7.3					N. CENTRAL CHILE	4	T	52
*<	1687	10	20		13.5	76.5	8.5	8.0		3.5		PERU	4	T	9,38
	1705	11	16		(18.6	70.2)						NORTH CHILE			9
*	1705	11	26		18.6	70.2		8.0	3.0			NORTH CHILE			9,10,38
	1715	08	22		(18.5	70.3)	7.5					NORTH CHILE	3	T	31,51
	1725	03	27		(16.6	72.7)		2.0		1.5		PERU		T	9,38
*<	1730	07	08	1300	32.5	71.5	8.7	16.0	4.0	3.5		N. CENTRAL CHILE	4	T	1,9,10,31,38,51
	1737	12	24		43.0	74.0						SOUTH		T	9,31,38
	1742	03	23		(36.8	73.0)						CENTRAL CHILE		T	9,38
*<	1746	10	28		12.0	77.0	8.0	24.0	4.6	3.5		PERU	4	T	9,10,38
	1750	05	24		(36.5	74.0)						CENTRAL CHILE			9
	1751	03	25	0530	(36.9	73.0)	8.5					CENTRAL CHILE			9
	1751	05	02									S. CENTRAL CHILE			9
	1751	05	24		37.0	73.0	8.2	3.5	1.8	3.5		S. CENTRAL CHILE		T	9,38
*<	1751	05	25	0500	36.5	74.0	6.0					CENTRAL CHILE	4	T	1,9,10,31,38,51
	1765	00	00					2.8		2.0		N. CENTRAL CHILE		T	9,38
	1806	12	01		(12.1	77.1)		1.0		0.5		PERU	3	T	9,10,38
	1811	11	19		(33.0	71.4)		4.0	2.0	2.0		CENTRAL CHILE		T	9,38
	1819	04	03		(27.4	70.3)						N. CENTRAL CHILE			9,31
	1819	04	04		(27.4	70.3)						N. CENTRAL CHILE			9,31
	1819	04	11		27.2	71.2			2.0			N. CENTRAL CHILE			10
*<	1819	04	11	0300	27.0	71.5	8.5	4.0		2.0		N. CENTRAL CHILE	4	T	1,5,9,31,38,51
	1819	04	13		(27.2	71.2)						N. CENTRAL CHILE			9
	1819	05	00		(27.2	71.2)						N. CENTRAL CHILE			9
	1822	11	19		33.0	72.0			2.0			CENTRAL CHILE			10,38
*	1822	11	19	0230	33.0	71.6	8.5					CENTRAL CHILE	4		52
	1822	11	19	0300	33.0	71.4	8.5	3.5		2.0		CENTRAL CHILE		T	1,9,31,51
	1829	09	26		(33.1	71.7)						CENTRAL CHILE		T	9,31,38
	1835	02	20	1626	37.0	73.0	8.2	24.0	4.6	3.0		S. CENTRAL CHILE		T	1,5,9,31,38,51

TABLE 1. TSUNAMIGENIC EARTHQUAKES OF PERU-CHILE (CONT.)

	YEAR	MONTH	DAY	ORIGIN TIME	LATITUDE (°)	LONGITUDE (°)	MAGNITUDE	FOCAL DEPTH (KM)	RUNUP HEIGHT (M)	TSUNAMI MAGNITUDE	TSUNAMI INTENSITY	SOURCE REGION	VALIDITY	CAUSE	REFERENCE
	1835	02	20		36.5	74.0						CENTRAL CHILE			10
*<	1835	02	20	1530	36.8	73.0	8.2	15.0	4.0			CENTRAL CHILE	4	T	52
	1836	02	20		(37.0	73.0)						S. CENTRAL CHILE			9
	1836	06	03		(22.6	70.3)	7.5				1.0	NORTH CHILE		T	9,10,38
	1836	07	03	1306	(22.6	70.3)	7.5	2.0	1.0		1.0	NORTH CHILE			9,10,38,51
	1836	07	03	2230	22.5	70.3	7.5					NORTH CHILE	3		52
*<	1837	11	07	1130	42.5	74.0	8.5	8.0	3.0		3.0	SOUTH CHILE	4	T	1,5,9,10,31,38,52
	1838	05	07		(36.7	73.1)		0.7			0.0	CENTRAL CHILE		T	9,38
	1839	02	12		33.6	76.8						CENTRAL CHILE		V	9,38
	1847	05	23		(12.1	77.1)		2.0			1.5	PERU		T	38
	1847	10	19		(29.9	71.4)						N. CENTRAL CHILE			9
	1849	06	17		(30.0	71.5)						N. CENTRAL CHILE			9,38
	1849	11	17		(30.0	71.5)	6.8	5.0	2.3		2.5	N. CENTRAL CHILE		T	9,31,38
	1849	11	18		30.0	71.5	6.7					N. CENTRAL CHILE		T	9,38
	1849	11	28		(30.0	71.5)						N. CENTRAL CHILE			9
	1849	12	17	0610	(30.0	71.5)	7.5	4.0	2.0			N. CENTRAL CHILE		T	9,10,51
	1849	12	17	1010	29.9	71.4	7.5	5.0	2.3			N. CENTRAL CHILE	4		52
	1851	04	02		(33.0	71.5)						CENTRAL CHILE		T	9,10,31,38
	1851	04	13		(33.0	71.7)						CENTRAL CHILE			9
	1851	05	26		28.0	70.5	7.2	2.8			2.0	N. CENTRAL CHILE			38
	1851	05	26	1814	27.0	71.6	7.2	3.0	1.6			N. CENTRAL CHILE	4	T	9,10,31,51
	1855	08	11		(33.0	71.7)		0.7			0.0	S. CENTRAL CHILE		T	9,38
	1858	04	24		(30.0	71.4)	6.5	1.4			1.0	N. CENTRAL CHILE		T	9,38
*	1859	10	05	1500	27.0	70.0	7.7	5.5	2.5		2.5	N. CENTRAL CHILE	4	T	1,9,10,31,38,51
	1859	10	11									N. CENTRAL CHILE			9
	1860	04	23		(12.0	77.1)		0.7			0.0	PERU	3	T	9,10,38
	1861	03	20									S. CENTRAL CHILE			9
*	1865	01	08		(12.0	77.1)		2.0			1.5	PERU	3	T	9,38
	1868	08	08		(18.6	71.0)						NORTH CHILE			9
	1868	08	11		(18.6	71.0)						NORTH CHILE			9
	1868	08	13	1645	18.6	71.0	8.5	15.0	4.0		3.5	NORTH CHILE		T	1,4,5,9,10,31,38,51
*<	1868	08	13	2045	18.6	71.0	8.5	21.0	4.3			NORTH CHILE	4	T	52
	1868	08	14		(18.5	71.0)						NORTH CHILE			9
	1868	08	15		(18.6	71.0)						NORTH CHILE		T	9
	1868	09	14		(36.7	73.2)		1.0			0.5	CENTRAL CHILE		T	9,38
	1868	10	02		17.0	72.5		1.0			0.5	PERU		T	9,38
	1868	10	16		(33.1	71.7)		1.0			0.5	CENTRAL CHILE	3	T	9,38
	1869	01	27		(36.6	72.9)		0.7			0.0	CENTRAL CHILE	3	T	9,38
	1869	02	06		(39.9	73.4)		0.7			0.0	S. CENTRAL CHILE		T	9,38
	1869	04	22		(12.1	77.1)		1.4			1.0	PERU		T	9,38
	1869	06	25		(19.6	70.2)		0.7			0.0	NORTH CHILE		T	9,38
	1869	08	09		(30.0	71.4)		3.0	1.6		1.5	N. CENTRAL CHILE	3	T	9,38
	1869	08	19		16.0	73.5	6.5					PERU		T	1,9,10,38
	1869	08	21		21.0	70.0	6.8	0.7			0.0	NORTH CHILE		T	9,38
	1869	08	21		19.0	70.5	6.8	2.0			1.5	NORTH CHILE		T	38
*	1869	08	24	1710	18.6	70.0	6.8	2.0	1.0			NORTH CHILE	4	T	52
	1869	08	24		18.6	70.0	7.8	2.0	1.0			NORTH CHILE		T	9,10,31
	1869	08	24	1710	19.0	71.0	7.8	2.0	1.0			NORTH CHILE		T	51
	1871	03	25	1454	35.0	72.5	7.5	1.0			0.5	CENTRAL CHILE	3	T	9,38,52
	1871	08	20		(33.1	71.7)		1.0			0.5	CENTRAL CHILE		T	9,38
	1871	08	21		12.0	76.6						PERU			9
	1871	08	21		13.0	77.0	7.0	2.0	1.0		1.0	PERU		T	1,9,10,38
	1871	10	05	0050	20.1	71.3	7.5					NORTH CHILE		T	9,38,51
	1871	12	28		(41.5	73.0)		1.0			0.5	SOUTH CHILE		T	9,38
	1873	07	07									CENTRAL CHILE			9,10

TABLE 1. TSUNAMIGENIC EARTHQUAKES OF PERU-CHILE (CONT.)

	YEAR	MONTH	DAY	ORIGIN TIME	LATITUDE (°)	LONGITUDE (°)	MAGNITUDE	FOCAL DEPTH (KM)	RUNUP HEIGHT (M)	TSUNAMI MAGNITUDE	TSUNAMI INTENSITY	SOURCE REGION	VALIDITY	CAUSE	REFERENCE
	1873	11	19		(23.6	70.4)			2.8		2.0	NORTH CHILE		T	9,38
	1877	05	09		21.5	70.5			24.0	4.6	3.5	NORTH CHILE			38
	1877	05	09	0100	21.6	71.0	8.5		16.0	4.0		NORTH CHILE	4	T	1,5,9,10,31,51
*<	1877	05	10	0216	19.6	70.2	8.3		24.0	4.5		NORTH CHILE	4	T	52
	1877	05	15						0.7		0.0	NORTH CHILE		T	9,38
	1877	06	15		(19.6	70.2)			0.7		0.0	NORTH CHILE		T	9,38
	1877	08	23		(20.2	70.1)			1.0		0.5	NORTH CHILE	3	T	9,38
	1877	09	02						1.0		0.5	S. CENTRAL CHILE		M	9,38
	1877	10	09		23.7	70.4			1.0		0.5	NORTH CHILE		T	9,38
	1878	01	23		16.3	71.3	7.0		2.0	1.0		PERU		T	9,10,38
	1878	02	03		(16.3	71.3)						PERU		T&M?	9
•	1878	02	14		(36.8	73.0)			0.7		0.0	CENTRAL CHILE			9,38
	1878	02	15		(16.3	71.3)						PERU			9
	1878	03	12		(20.2	70.1)			0.7		0.0	NORTH CHILE		T	9,38
	1878	04	12		(20.2	70.1)			1.0		0.5	NORTH CHILE		T	9,38
	1878	04	13		(20.2	70.1)						NORTH CHILE			9,38
	1878	06	12		(23.6	70.4)			0.7		0.0	NORTH CHILE		T	9,38
	1878	06	16		(23.6	70.4)						NORTH CHILE		T	9,38
	1878	09	15									N. CENTRAL CHILE			9
	1878	11	23		(33.1	71.7)			1.0		0.5	CENTRAL CHILE		M	9,38
	1879	08	08		(33.1	71.7)			2.0		1.5	CENTRAL CHILE		M	9,38
	1880	08	15	1248	31.0	71.5	7.0		1.0		0.5	N. CENTRAL CHILE		T	9,38
	1881	07	14		(20.2	70.1)			1.4		1.0	NORTH CHILE	3	T	9,38
	1881	10	27		(19.6	70.2)			0.7		0.0	NORTH CHILE		T	9,38
	1882	02	23		(27.9	70.1)			0.7		0.0	N. CENTRAL CHILE			9,38
	1882	09	14		(19.6	70.2)			0.7		0.0	NORTH CHILE		T	9,38
	1885	11	12	0740	(20.2	70.1)			1.0		0.5	NORTH CHILE	3	T	9,38,51
	1886	08	29		(20.2	70.1)						NORTH CHILE			9,38
	1896	03	13									S. CENTRAL CHILE			9,38
	1898	07	23		37.0	74.0	6.5		0.7		0.0	S. CENTRAL CHILE		T	9,38
	1899	08	08									CENTRAL CHILE			9
	1903	09	26		(20.2	70.1)			0.7	-0.5	0.0	NORTH CHILE		T	9,38,51
	1903	12	07	1509	28.5	71.0	6.5		0.7	-0.5	0.0	N. CENTRAL CHILE	3	T	9,38,51
	1906	05	07		(18.5	70.3)			1.5	0.6	0.0	NORTH CHILE		T	9,38
	1906	08	07		(33.0	72.0)						CENTRAL CHILE			9,
*<	1906	08	17	0040	33.0	72.0	8.6	25	3.6	1.8	2.0	CENTRAL CHILE	4	T	9,10,20,31,38,51
	1906	12	26	0653	18.0	71.0	7.9	33				NORTH CHILE		T	51
	1908	12	12	1208	14.0	78.0	8.2	33				PERU		T	51
	1909	06	08	0546	25.0	73.0	7.6	33				NORTH CHILE		T	9,10,13,51
	1909	06	08		26.5	70.5						NORTH CHILE			38
	1911	09	15		20.0	72.0	7.3					NORTH CHILE		T	51
	1913	07	28	0539	17.0	74.0	7.0		0.7		0.0	PERU		T	9,38,51
	1913	08	06	2214	17.0	74.0	7.9	33				PERU		T	51
•	1914	01	12		12.0	76.6			1.0	0.0	1.5	PERU	4	T	1,9,10,38,51
	1914	02	26	0458	18.0	67.0	7.2					PERU	4		9,52
	1918	05	20	1755	28.5	71.5	7.9	80				N. CENTRAL CHILE		T	51
•	1918	12	04	1148	26.0	71.0	7.8	33	5.0	2.3	2.5	NORTH CHILE	4	T	1,9,10,38,51
	1918	12	04		27.0	71.0						N. CENTRAL CHILE			38
	1918	12	18		(27.4	70.3)						N. CENTRAL CHILE		T	9,31
	1920	08	20	1615	38.0	73.5	5.5	15				S. CENTRAL CHILE		T	51
	1920	08	20	1615	38.0	73.5	7.0	15	1.4		1.0	S. CENTRAL CHILE		T	1,9,10,38
	1922	01	06	1411	16.5	73.0	7.2	33				PERU		T	51
	1922	11	07	2300	28.0	72.0	7.0	33				N. CENTRAL CHILE		T	51
	1922	11	10	0433	29.0	71.0	8.2		9.0	3.2	2.5	N. CENTRAL CHILE	4	T	1,5,10,20,31
*<	1922	11	11	0432	28.5	70.0	8.3	25				N. CENTRAL CHILE	4	T	38,51

TABLE 1. TSUNAMIGENIC EARTHQUAKES OF PERU-CHILE (CONT.)

	YEAR	MONTH	DAY	ORIGIN TIME	LATITUDE (°)	LONGITUDE (°)	MAGNITUDE	FOCAL DEPTH (KM)	RUNUP HEIGHT (M)	TSUNAMI MAGNITUDE	TSUNAMI INTENSITY	SOURCE REGION	VALIDITY	CAUSE	REFERENCE
	1923	02	17		(35.3	72.4)			1.5	0.6	1.5	CENTRAL CHILE		M	9,38
	1923	05	04	2227	28.7	71.7	7.0	60				N. CENTRAL CHILE		T	9,10,38,52
	1923	05	07	2227	28.8	71.8	7.0	60				N. CENTRAL CHILE		T	51
	1923	08	12	1211	(18.5	70.3)			0.7	-0.5	0.0	NORTH CHILE		T	9,38,51
	1925	05	15	1157	26.0	71.5	7.1	50				NORTH CHILE		T	51
	1926	12	09	2242	28.0	71.0	6.0		1.5	0.6	0.5	N. CENTRAL CHILE		T	9,38,51
•	1927	11	21	2312	44.6	73.0	7.1	33	2.8	1.0	2.0	SOUTH CHILE	4	T	1,9,10,20,38,51
	1928	03	31		(23.6	70.4)						NORTH CHILE		M	9,10,38
	1928	04	27	2035	13.0	69.5	6.7					PERU		T	9,10,51
	1928	07	18	1905	5.5	79.0	7.0	33				PERU		T	51
	1928	11	20	2035	22.5	70.5	7.1	33				NORTH CHILE		T	51
	1928	12	01	0406	35.0	72.0	8.4	25	1.5	0.6	0.5	CENTRAL CHILE	3	T	1,9,31,38,51
	1929	08	09		(23.6	70.4)			4.0	2.0	2.5	NORTH CHILE		M	9,38,51
	1930	12	28		28.5	71.0	6.0		1.0	0.0		N. CENTRAL CHILE		T	1,9,10,51
	1930	12	29	0326	28.5	71.0	6.0		1.0	0.0	0.5	N. CENTRAL CHILE	3	T	1,10,38
	1931	03	18	0802	32.5	72.0	7.1	33				N. CENTRAL CHILE	3	T	51
	1933	01	23		(20.0	71.0)						NORTH CHILE			9
	1933	02	23	0809	20.0	71.0	7.6	40				NORTH CHILE		T	9,22,38,51
	1934	12	04	1725	19.5	69.5	6.9	130				NORTH CHILE		T	9,22,38,51
	1936	07	13		24.5	70.5			1.0		0.5	NORTH CHILE			38
	1936	07	13	1112	24.5	70.0	7.3	60	1.0	0.0		NORTH CHILE	4	T	1,9,10,22,51,52
	1939	01	25	0332	36.3	72.3	8.3	60				CENTRAL CHILE		T	51
	1939	04	18	0623	27.0	70.5	7.4	100				N. CENTRAL CHILE		T	51
	1940	05	24	1634	10.5	77.0	8.4	60	2.0	1.0	1.5	PERU	3	T	9,13,38,51
	1940	10	04	0755	22.0	71.0	7.3	75				NORTH CHILE		T	51
	1940	10	11	1841	41.5	74.5	7.0	33				SOUTH CHILE		T	51
*	1942	08	24	2250	15.0	76.0	8.6	60	2.0	1.0		PERU	3	T&L	1,9,10,38,47,51
*	1943	04	06	1607	30.8	72.0	8.3	33	1.0	0.0	0.0	N. CENTRAL CHILE	4	T	1,5,9,10,20,31,38,47,51
	1946	08	02	1919	26.5	70.5	7.9	60				NORTH CHILE		T	51
	1946	09	30	0100	13.0	76.0	7.0	70				PERU		T	51
	1948	04	06									N. CENTRAL CHILE	4		9
	1948	12	26	0712	22.5	69.0	7.0		0.7	-0.5	0.0	NORTH CHILE	3	T	9,38,51
	1949	04	20	0329	38.0	73.5	7.3	70				S. CENTRAL CHILE	4	T	51
	1949	12	17	1508	54.0	71.0	7.7	33	0.7		0.0	SOUTH CHILE		T	51,38
	1949	12	17	0653	54.0	71.0	7.7	33	0.7		0.0	SOUTH CHILE		T	51
	1950	01	30	0057	53.5	71.5	7.0	33				SOUTH CHILE		T	51
	1950	12	10	0250	14.6	76.3	7.0	80	0.7		0.0	PERU		T	9,38
	1953	02	15	0932	12.0	77.5	5.5		0.7		0.0	PERU		T	9,38
	1953	05	06	1717	36.5	72.5	7.6	60				CENTRAL CHILE		T	51
	1953	12	12	1635	3.5	81.0	7.3	33	0.5	-1.0	0.5	PERU	4	T	9,10,38
	1955	04	19	2024	29.9	71.6	7.0		1.4		1.0	N. CENTRAL CHILE	4	T	38
*	1955	04	19	2024	30.0	72.0	7.1	33	1.0	0.0	1.0	N. CENTRAL CHILE	4	T	1,5,9,10,47,51
	1956	01	08	2054	19.0	70.5	7.1	55				NORTH CHILE		T	51
	1956	12	18	0231	25.5	71.0	7.0	33				NORTH CHILE		T	51
	1957	07	29	1715	23.5	71.5	7.0	33				NORTH CHILE		T	51
	1959	02	07	0937	4.0	81.5	7.3		0.2		-2.0	PERU		T	9,10,38
	1960	01	13	1541	15.8	72.8	7.8	160	5.7		3.0	PERU	4	T	9,38
	1960	05	21	1002	37.5	73.5	7.3	33	1.0	0.0	-1.0	S. CENTRAL CHILE	4	T	5,9,10,38,47,51
	1960	05	22		41.0	73.5	8.5					SOUTH CHILE			10
*<	1960	05	22	1911	39.5	74.5	8.6	33	25.0	4.7		S. CENTRAL CHILE		T	51
	1960	05	22	1033	37.5	73.0	8.5	33	11.3	4.5	4.0	S. CENTRAL CHILE	4	T	1,4,5,9,17,47
	1960	05	22	1911	38.0	73.5						S. CENTRAL CHILE	4	T	
	1960	05	22	2333	41.0	73.5	8.5		25.0			SOUTH CHILE			38
	1960	05	24		45.0	76.0	6.8					SOUTH CHILE		T	9,10
	1960	11	01	0846	38.5	75.1	7.4	55				S. CENTRAL CHILE		T	51

TABLE 1. TSUNAMIGENIC EARTHQUAKES OF PERU-CHILE (CONT.)

	YEAR	MONTH	DAY	ORIGIN TIME	LATITUDE (°)	LONGITUDE (°)	MAGNITUDE	FOCAL DEPTH (KM)	RUNUP HEIGHT (M)	TSUNAMI MAGNITUDE	TSUNAMI INTENSITY	SOURCE REGION	VALIDITY	CAUSE	REFERENCE
*<	1960	11	20	2202	6.8	80.7	6.8	93	0.7	-0.5	-1.0	PERU	4	T	9,10,38
	1961	10	18	1652	36.7	73.0	6.5	15				CENTRAL CHILE		T	51
	1963	09	24	1630	10.6	78.0	7.0	80				PERU		T	51
	1965	02	23	2211	25.7	70.5	7.0	80				NORTH CHILE		T	51
	1965	03	22	2256	31.9	71.5	6.0	58				N. CENTRAL CHILE		T	51
	1965	10	03	1615	42.9	75.2	6.5	31				SOUTH CHILE		T	51
	1965	11	06	0921	22.2	113.8	6.2	100				NORTH CHILE		T	51
*	1966	10	17	2142	10.7	78.8	8.0	40	3.0	1.6	1.5	PERU	4	T	9,38
	1966	12	28	0818	25.5	70.6	7.8	32	1.0	0.0	0.5	NORTH CHILE	4	T	5,9,38,47,51
	1966	12	28		24.1	68.6	7.6		0.4	-0.4		NORTH CHILE			10
	1967	09	03	2107	10.6	79.8	7.0	40	2.0	1.0	1.5	PERU	4	T	9,10,38,47,52
	1967	11	15	2132	28.7	71.2	6.2	15				N. CENTRAL CHILE		T	51
	1967	12	21	0225	21.7	70.0	7.5	33	0.7	-0.5	0.0	NORTH CHILE	4	T	9,27,38,51
	1970	06	14	0000	52.0	73.8	6.6	10				SOUTH CHILE		T	51
	1970	06	19	1056	22.2	70.5	7.0	52				NORTH CHILE		T	51
	1970	11	28	1109	20.9	69.8	6.0	33				NORTH CHILE		T	51
	1971	04	04	1016	56.2	122.5	6.2	33				SOUTH CHILE		T	51
	1971	05	09	0825	39.8	104.8	6.2	33				S. CENTRAL CHILE		T	51
	1971	07	09	0303	32.5	71.2	7.5	58	1.2	0.3		N. CENTRAL CHILE		T	9,47,51
	1970	05	31		9.2	78.8	6.6		1.8		1.0	PERU	4	T	9,47
*	1971	07	09	0303	32.5	71.2	6.6	58	1.2	0.3		N. CENTRAL CHILE			52
	1972	06	08	1854	30.5	71.8	6.6	39				N. CENTRAL CHILE		T	51
	1972	12	29	0451	30.6	71.0	6.0	60				N. CENTRAL CHILE		T	51
	1973	10	05	0548	32.9	71.9	6.5	14	0.4	-1.0	0.5	N. CENTRAL CHILE	4	T	9,22,27,38,47,51
	1974	06	25	0505	54.6	131.6	6.1	37				SOUTH CHILE		T	51
	1974	08	20	1044	38.4	73.4	7.0	36				S. CENTRAL CHILE		T	51
	1974	10	03		12.3	77.8	8.1	13	1.8		1.0	PERU	4	T	5,9,27,47
	1975	03	13	1527	26.0	75.0	6.7					NORTH CHILE		T	51
	1975	05	10	1429	35.7	74.6	7.8					S. CENTRAL CHILE		T	51
	1983	10	04	1852	26.5	70.6	7.4	15	0.2	-2.3	0.2	NORTH CHILE	4	T	45
	1985	03	03	2247	33.2	72.0	7.8	SH	1.1	0.1		CENTRAL CHILE	4	T	35

EXPLANATION OF TABLE

* indicates that the earthquake caused a destructive tsunami.
< indicates that the tsunami was reported outside the South American coast.
() around the latitude and longitude indicate that the epicenter was derived from the coordinates of a city name given in the reference.

Event Date: Where the time is given, the date and time are Universal Time Coordinated (UTC). Where no time is given, the event date is the local date at the source of the tsunami.

Earthquake Magnitude: Where more than one value was found in the literature, the largest value is listed in the table. Pre-1900 magnitude values are noninstrumental.

Focal Depth: Measurement is in kilometers. SH = shallow (depth 70 km or less).

Runup Height: The maximum water height above sea level. Where more than one value was found in the literature, the largest value is used in the table. If no value was found in the literature, the runup height was approximated from the reported tsunami magnitude or the tsunami intensity using the formulae below (see Tsunami Magnitude and Tsunami Intensity).

Tsunami Magnitude: $M = \log_2 H$, where M is the tsunami magnitude and H is the maximum runup height in meters, and measured at a coast from 10 km to 250 km from the origin of the tsunami (Cox and others, 1967).

Tsunami Intensity: $I = \log_2(\sqrt{2})H$, where I is the tsunami intensity and H is the average height of the flood or the average amplitude of the tsunami based on the tide gage records from the given area of coast (Solov'ev and Go, 1975).

TABLE 1. TSUNAMIGENIC EARTHQUAKES OF PERU-CHILE (CONT.)

Explanation of Table (Cont.)

Source Area:

Peru = 3° S. latitude - <18° S. latitude;
North Chile = 18° S. latitude - <27° S. latitude;
North Central Chile = 27° S.latitude - <33° S. latitude;
Central Chile = 33° S.latitude - <37° S. latitude;
South Central Chile = 37° S. latitude - <41° S. latitude;
South Chile = 41° S. latitude - 60° S. latitude (see fig. 2).

Validity: Probability of actual tsunami occurrence is indicated by a numerical rating of the validity of the reports of that event: 4 = definite tsunami, 3 = probable tsunami.

Cause: T = tsunami; V = volcanic; M = meteorological; L = landslide

Reference: Numbers correspond to the list of references below and refer to the major references used for a particular event.

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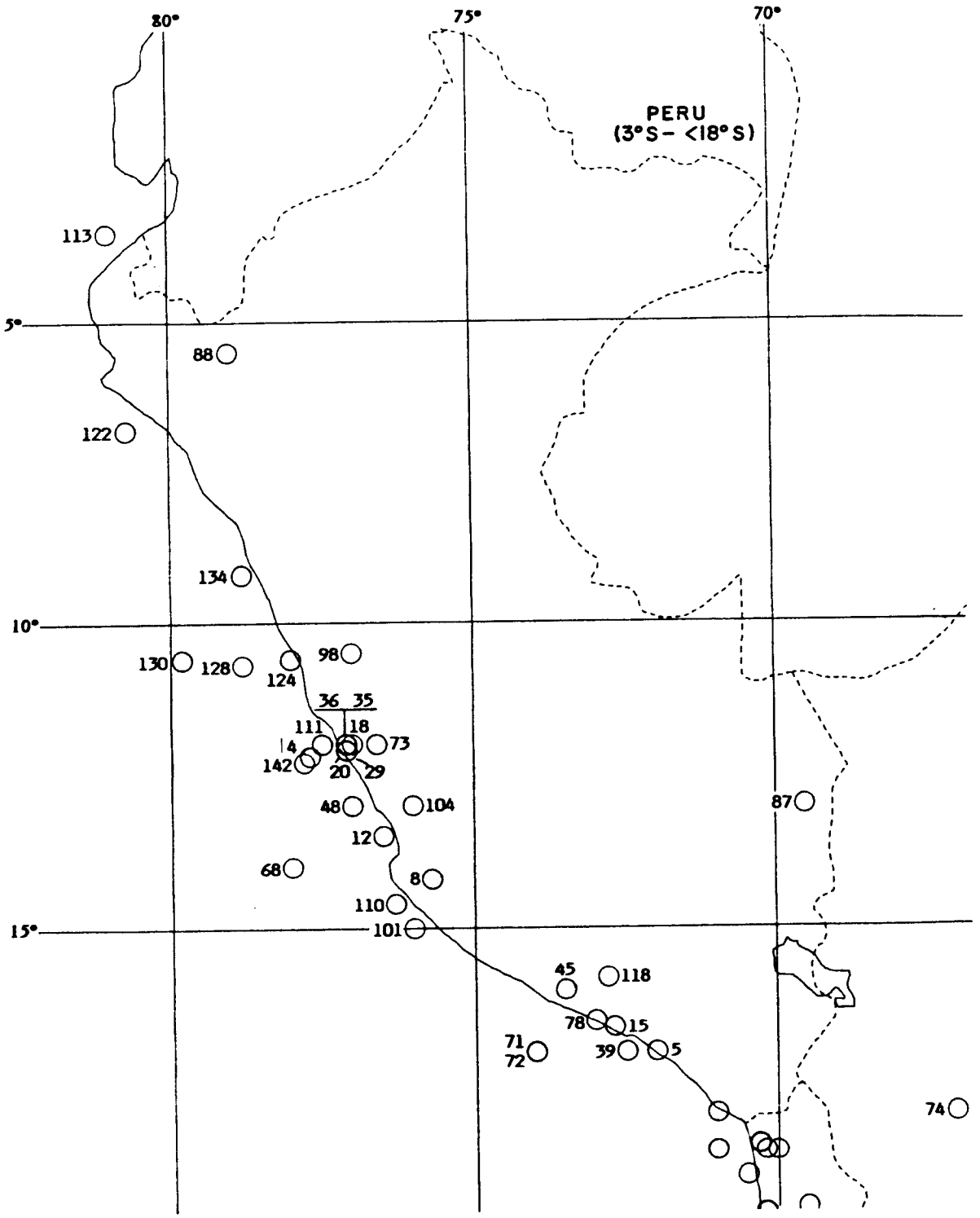


FIGURE 3. EPICENTERS OF TSUNAMIGENIC EARTHQUAKES OF PERU
[NUMBERS REFER TO EVENT NO. IN TABLE 2.]

PERU

[3° S. - <18° S.]

Three regions, each having a different seismic potential, exist in Peru. The first region extends from 3° S. to <9° S. latitude; the second from 9° S. to <15° S. latitude; and the third from near 15° S. to <18° S. latitude.

Region from 3° S. - <9° S.

This part of the Peru-Chile trench is consuming the Carnegie Ridge, an aseismic feature (McCann, 1979). The interaction between the Carnegie Ridge and the subduction zone may explain the fact that only three tsunamigenic earthquakes have been reported in this area (table 2). One of these, the Nov. 20, 1960, event (mag. 6.8) caused considerable damage along the Peru coast. Although an earthquake of magnitude ≥8.0 has not occurred in this area, earthquakes of lower magnitude have the potential to produce damaging tsunamis.

Region from 9° S. - <15°S.

This region has a history of "great" earthquakes (those of mag. 8 or larger); however, the length of the rupture zone has historically been 150 km or less. Eight such earthquakes have produced tsunamis on this section of the Peru coast. An area near 12° S. was the site of a large earthquake in 1974. This earthquake generated a tsunami that was recorded, but was not destructive, in Hawaii and California. Having ruptured recently, this region probably has a low seismic potential (McCann, 1979).

Region from 15° S. - <18° S.

A change in the seismicity pattern occurs near 15° S. latitude. Here, a collision of the Nazca Ridge with the Peru-Chile trench appears to be responsible for a tear in the descending Nazca Plate (McCann, 1979). The following tsunamigenic earthquakes have occurred in the Peru-North Chile area: a magnitude 8.5 event at 17° S. latitude in 1604, a large earthquake at 18.6° S. latitude in 1705, a magnitude 8.5 event at 18.6° S. latitude in 1868, and a magnitude 8.3 event at 19.6° S. latitude in 1877. Since a large-magnitude event has not occurred in this area since 1877, a seismic gap exists in the region from South Peru to North Chile (15° S. to 23° S. latitude). This region is known to have the potential to produce large earthquakes (mag. 8.0 - 8.5) and damaging tsunamis in the future.

Table 2 lists the tsunamigenic earthquakes that have occurred in Peru, together with information about the tsunamis they produced. (See table 1 for alternate data, erroneous dates, and events that appeared in the literature but are not believed to have been tsunamis.) The data included in table 2 are believed to be the most accurate available. Of the 34 events listed, 10 were damaging locally and five were reported in areas of the Pacific outside the west coast of South America. Nineteen of the events are given a "3" (probable) or a "4" (definite) validity rating, but the validity of the remaining events is uncertain. The events listed in table 2 are plotted on a map of Peru in figure 3.

TABLE 2. TSUNAMIGENIC EARTHQUAKES OF PERU

EVENT NO.		EVENT DATE YEAR	MO	DA	TIME	EARTHQUAKE DATA S. LAT. °	W. LONG. °	MAGNITUDE	DEPTH (KM)	TSUNAMI DATA RUNUP (M)	MAGNITUDE	INTENSITY	VALIDITY	REFERENCES
4	*<	1586	07	09		12.2	77.7	8.5		24.0	4.0		4	9,10,38
5	*	1604	11	24	1613	17.0	72.0	8.5		16.0	4.0	3.5	4	38
8	*	1647	05	07		14.2	75.7)			2.8		2.0	3	9,10,38
12	*<	1687	10	20		13.5	76.5	8.5		8.0		3.5	4	9,38
15		1725	03	27		16.6	72.7)			2.0		1.5		9,38
18	*<	1746	10	28		12.0	77.0	8.0		24.0	4.6	3.5	4	9,10,38
20		1806	12	01		12.1	77.1)			1.0		0.5	3	9,10,38
29		1847	05	23		12.1	77.1)			2.0		1.5		38
35		1860	04	23		12.0	77.1)			0.7		0.0	3	9,10,38
36	*	1865	01	08		12.0	77.1)			2.0		1.5	3	9,38
39		1868	10	02		17.0	72.5			1.0		0.5		9,38
45		1869	08	19		16.0	73.5	6.5						1,9,10,38
48		1871	08	21		13.0	77.0	7.0		2.0	1.0	1.0		1,9,10,38
68		1908	12	12	1208	14.0	78.0	8.2	33	2.0				51
71		1913	07	28	0539	17.0	74.0	7.0		0.7		0.0		9,38,51
72		1913	08	06	2214	17.0	74.0	7.9	33					51
73	*	1914	01	12		12.0	76.6			1.0	0.0	1.5	4	1,9,10,38,51
74		1914	02	26	0458	17.9	67.0	7.2					4	9,52
78		1922	01	06	1411	16.5	73.0	7.2	33					51
87		1928	04	27	2035	13.0	69.5	6.7						9,10,51
88		1928	07	18	1905	5.5	79.0	7.0	33					51
98		1940	05	24	1634	10.5	77.0	8.4	60	2.0	1.0	1.5	3	9,13,38,51
101	*	1942	08	24	2250	15.0	76.0	8.6	60	2.0	1.0		3	1,9,10,38,47,51
104		1946	09	30	0100	13.0	76.0	7.0	70					51
110		1950	12	10	0250	14.6	76.3	7.0	80	0.7		0.0		9,38
111		1953	02	15	0932	12.0	77.5	5.5		0.7		0.0		9,38
113		1953	12	12	1635	3.5	81.0	7.3	33	0.5	-1.0	0.5	4	9,10,38
118		1960	01	13	1541	15.8	72.8	7.8	160	5.7		3.0	4	9,38
122	*<	1960	11	20	2202	6.8	80.7	6.8	93	1.2		1.0	4	9,10,38
124		1963	09	24	1630	10.6	78.0	7.0	80					51
128	*	1966	10	17	2142	10.7	78.8	8.0	40	3.0	1.6	1.5	4	9,38
130		1967	09	03	2107	10.6	79.8	7.0	40	2.0	1.0	1.5	4	9,10,38,47,52
134		1970	05	31		9.2	78.8	6.6	43	1.8	1.0		4	9,47
142		1974	10	03		12.3	77.8	8.1	13	1.8	1.0		4	5,9,27,47

NOTE: * Indicates that the earthquake caused a destructive tsunami.

< Indicates that the tsunami was reported outside the South American coast.

() Parentheses around the latitude and longitude indicate that the epicenter was derived from the coordinates of a city name given in the reference.

See footnotes at end of table 1 for explanation of column headings.

The literature gives some information about the size of the tsunami for two-thirds (26) of the events in table 2. The size may have been indicated by a tsunami magnitude, a tsunami intensity, or a measured or estimated runup height. Of the 26 events that had such information, only six had reported runup heights of less than 1 meter. The reason that some events that had significant runup heights were not considered to be probable tsunamis is that they do not clearly fit the definition of a tsunami described in the introduction to this report. Figure 4 shows the frequency of occurrence of the tsunamigenic earthquakes for each degree of Peru's coastline. Shaded areas indicate the number of tsunamigenic earthquakes that caused damage.

Table 3 lists the dates of 19 tsunamis that were generated in Peru and the cities that reported each event. If a value is not given for the runup height and an "X" does not appear in the damage column, then the reporting city or region was given in the literature but descriptive effect information was not given. Figures 5-9 show graphically the extent of the coastline affected by five events listed in table 3. Modern methods of reporting and measuring runup heights have greatly expanded the amount of data available for more recent tsunamis. Tsunamis originating in Peru have been reported on two occasions as far south as Talcahuano, Chile.

Of all the tsunamis listed in table 3, that on October 17, 1966, was the most damaging and affected the largest extent of South American coastline (fig. 9). The largest runup height (24 meters) was reported from Callao, Peru, as result of the tsunami on October 28, 1746. Only rubble remained where the town once stood, according to the literature.

Table 4 gives dates of seven tsunamis generated in Peru and the names of towns outside the Peru-Chile coastal area that reported the events. Peru tsunamis have repeatedly been reported in the Northwest and Northeast Pacific, but seldom in the Southern Pacific Basin. Interestingly, Japan observed four of the seven events. The tsunamis in 1586 and 1687 that were reported in Japan were undoubtedly experienced elsewhere, but accounts that these tsunamis affected other countries could not be found. Maps showing the extent of the effects of the tsunamis of 1586, 1687, 1746, and 1960 are given in figures 10 and 11.

Table 5 is a summary of damage and number of deaths caused by tsunamis in Peru. More than 600 people have been killed by tsunamis in Peru, and Callao has been destroyed at least three times (1586, 1687, and 1746). Tsunamis occurring in this century appear to be less damaging than those in the 19th century. But when the increase in population in the area and the length of time since a devastating tsunami has struck Southern Peru are considered, the potential for destruction in the future is apparent.

Table 6 lists the names of cities in Peru that have reported tsunamis, the dates of the tsunamis, the runup heights, and whether damage occurred. The table shows that Callao has reported 18 tsunamis, seven of which have been damaging. Figure 12, a bar graph of the data in table 6, shows the number of tsunamis per degree of coastline. Although most of the serious effects reported in Peru have resulted from Peru-generated tsunamis, earthquakes in North Chile have also generated tsunamis that reportedly damaged property in this area. There also are reports of tsunamis from sources outside South America (Alaska and Kamchatka), but none of these was damaging.

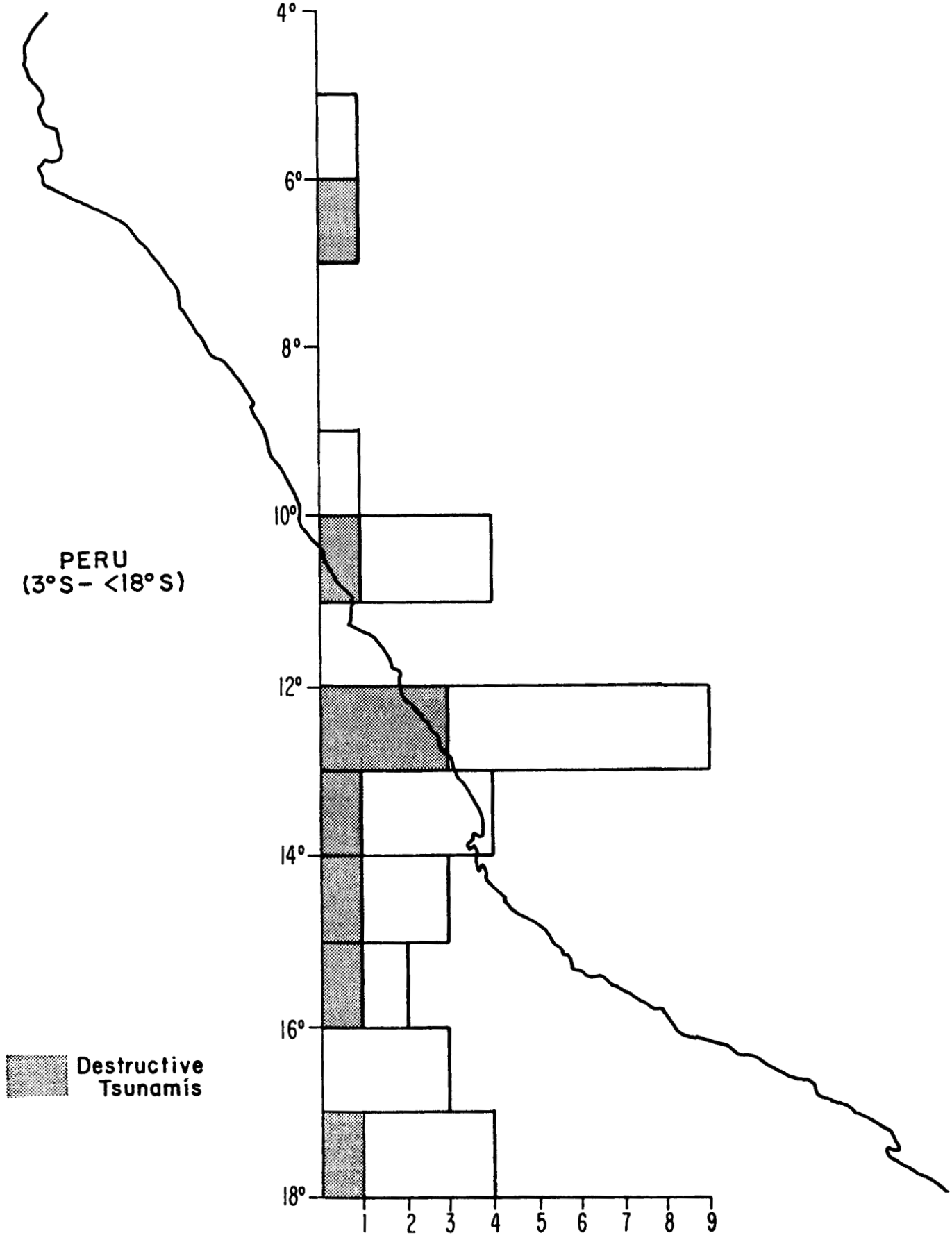


FIGURE 4. NUMBER OF TSUNAMIGENIC EARTHQUAKES PER DEGREE OF PERUVIAN COASTLINE

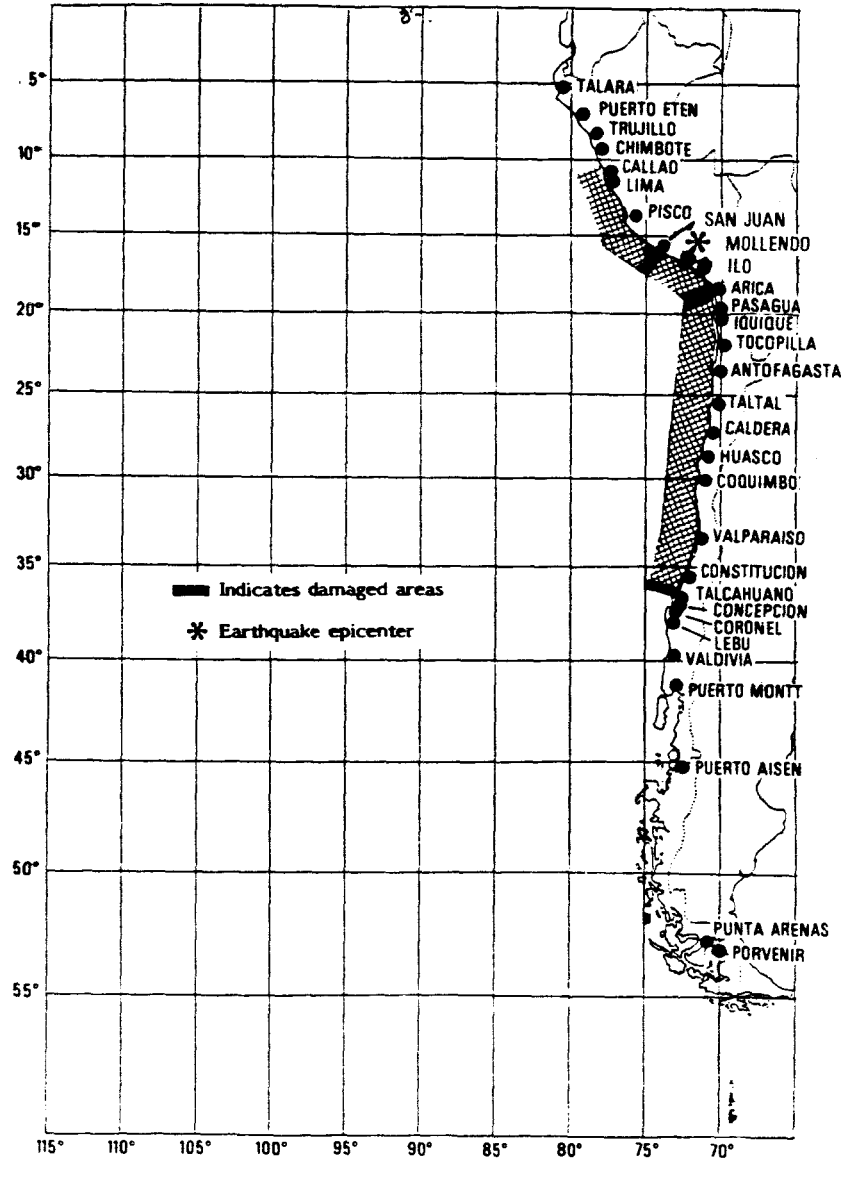


FIGURE 5. AREA OF PERU-CHILE COAST AFFECTED BY PERU TSUNAMI OF NOV. 24, 1604

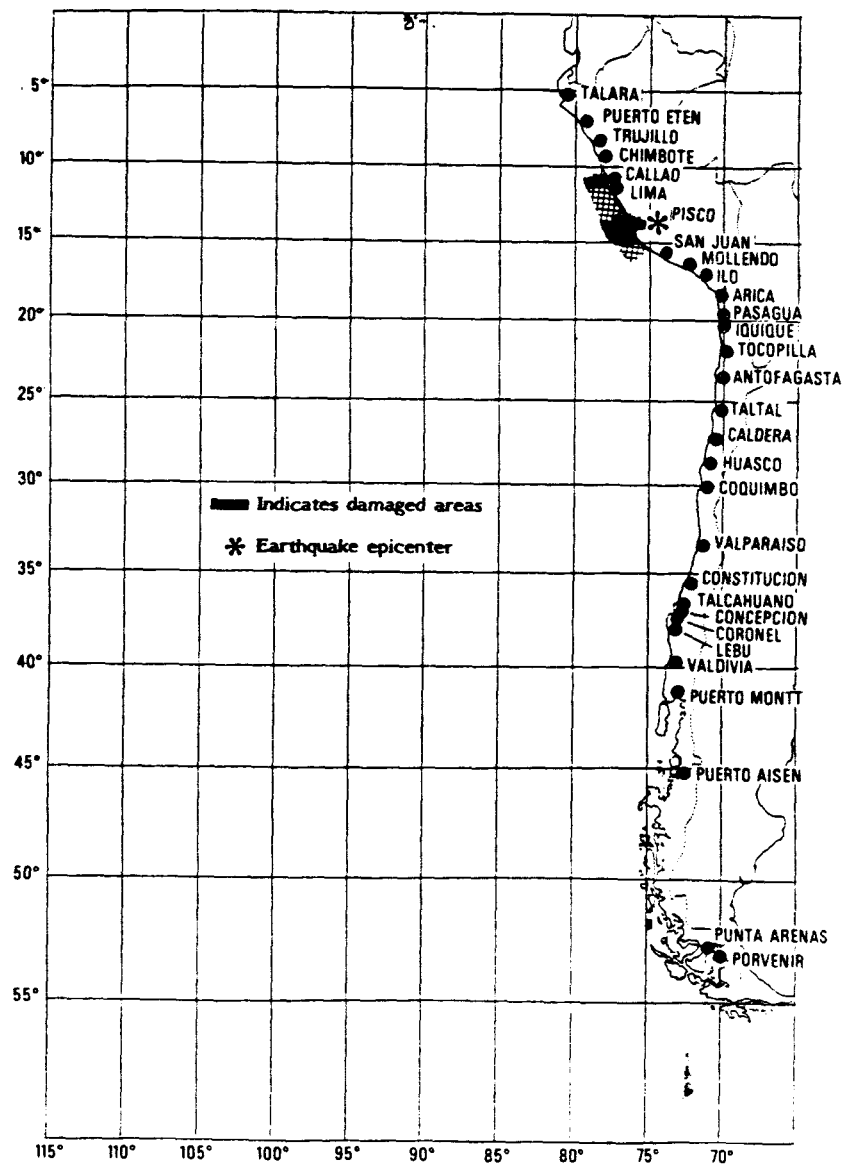


FIGURE 6. AREA OF PERU-CHILE COAST AFFECTED BY PERU TSUNAMI OF OCT. 20, 1687

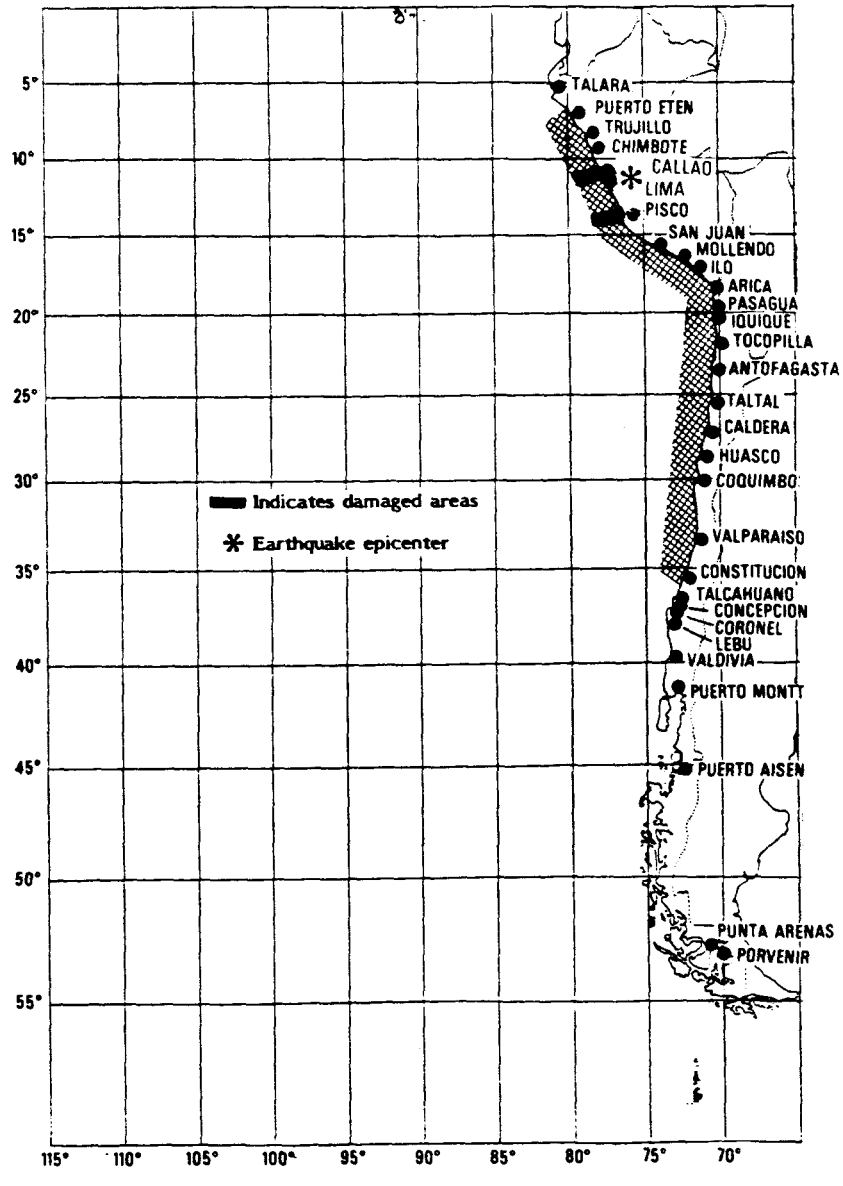


FIGURE 7. AREA OF PERU-CHILE COAST AFFECTED BY PERU TSUNAMI OF OCT. 28, 1746

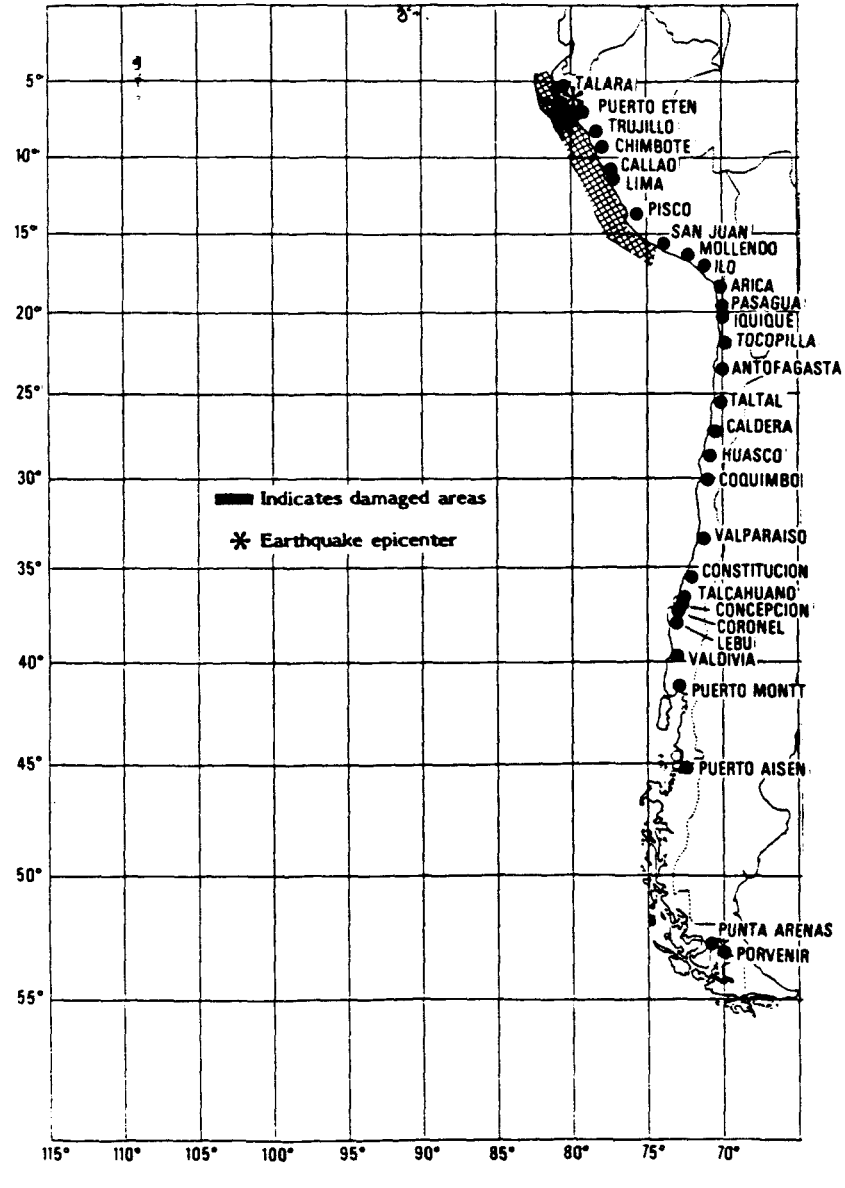


FIGURE 8. AREA OF PERU-CHILE COAST AFFECTED BY PERU TSUNAMI OF NOV. 20, 1960

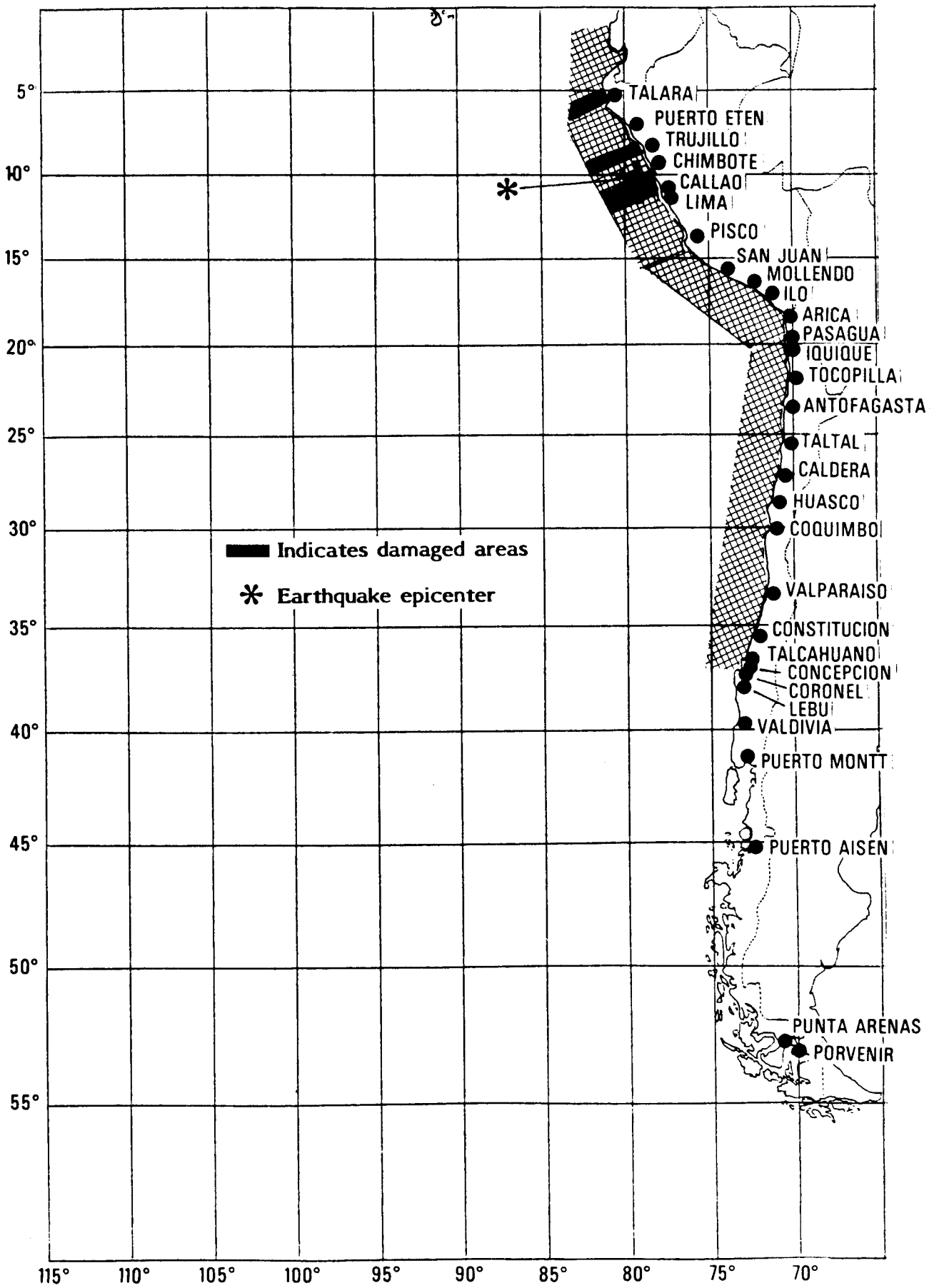


FIGURE 9. AREA OF PERU-CHILE COAST AFFECTED BY PERU TSUNAMI OF OCT. 17, 1966

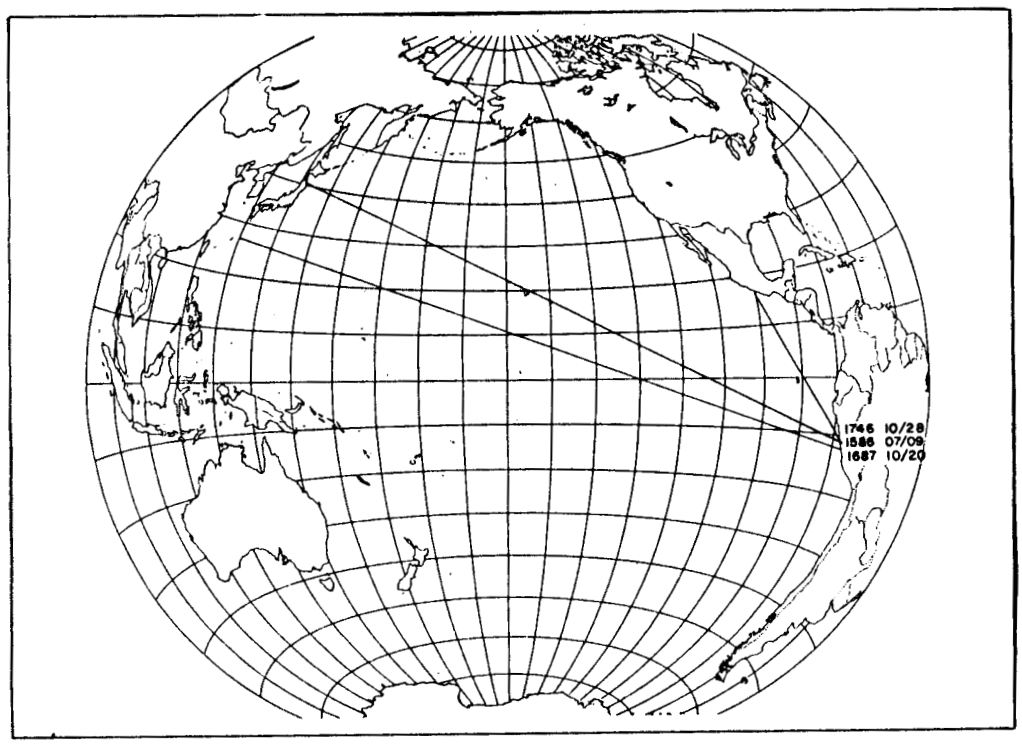


FIGURE 10. AREAS OUTSIDE PERU-CHILE REPORTING TSUNAMIS OF JULY 9, 1586; OCT. 20, 1687; AND OCT. 28, 1746

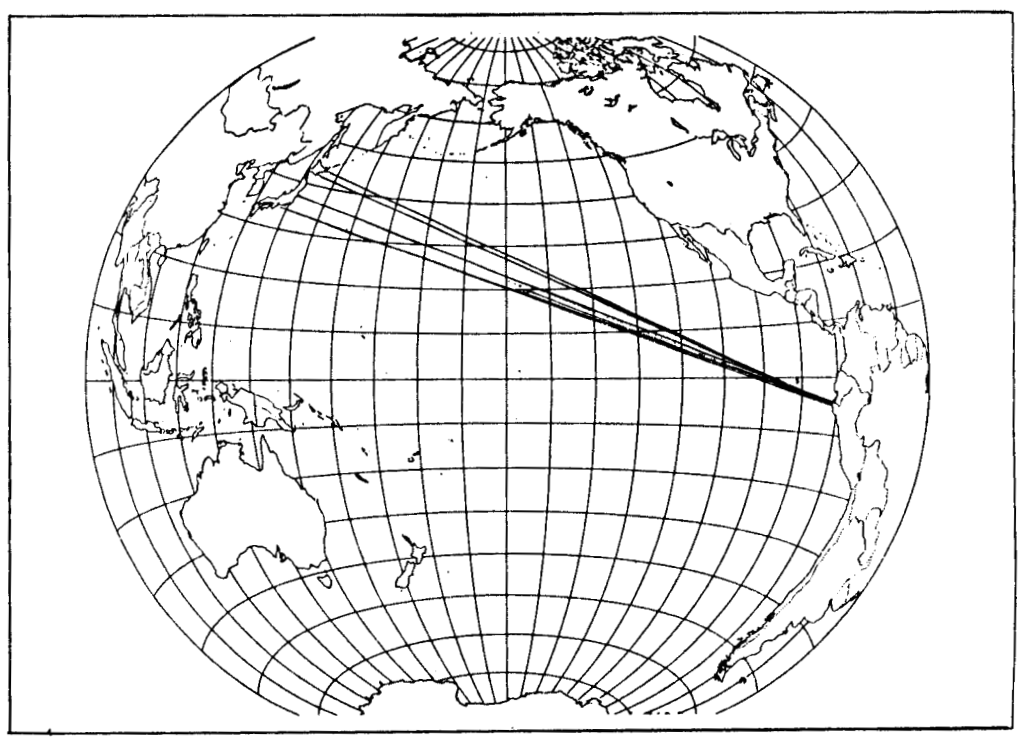


FIGURE 11. AREAS OUTSIDE PERU-CHILE REPORTING TSUNAMI OF NOV. 20, 1960

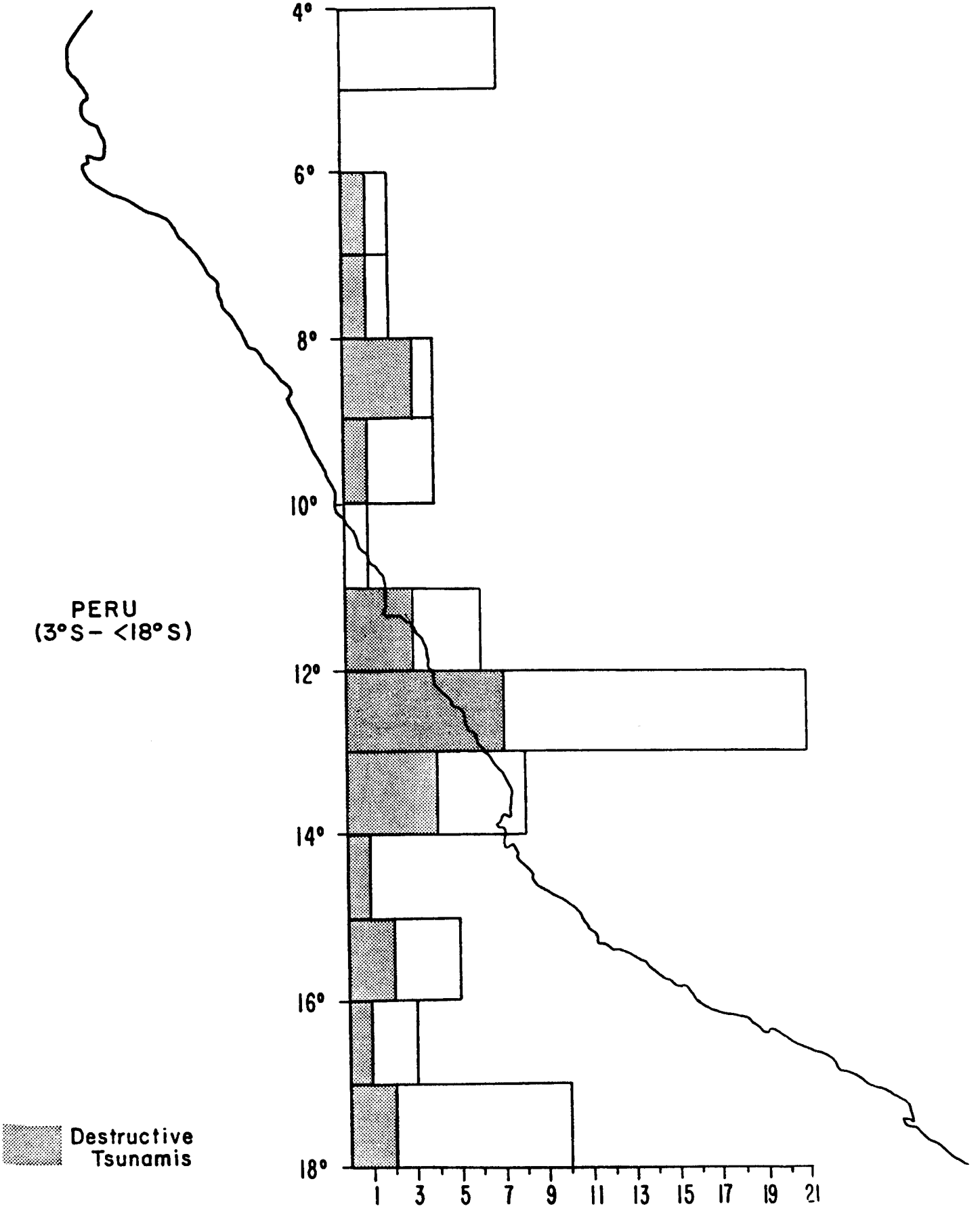


FIGURE 12. NUMBER OF REPORTED OBSERVATIONS OF TSUNAMI EFFECTS PER DEGREE OF PERUVIAN COASTLINE

TABLE 3. EFFECTS IN PERU-CHILE OF TSUNAMIS GENERATED IN PERU

EVENT DATE YEAR MO DA	COUNTRY	REPORTING CITY OR REGION	S. LAT. °	W. LONG. °	RUNUP (M)	DAMAGE
1586 07 09	PERU	CALLAO	12.08	77.13	24.0	X
1604 11 24	PERU	CALLAO	12.08	77.13		
	PERU	PISCO	13.77	76.70		
	PERU	CAMANA	16.63	72.48		X
	PERU	ILO	17.70	71.33		
	CHILE	ARICA	18.48	70.33		X
	CHILE	CONCEPCION	36.83	73.05		X
1647 05 07	PERU	CALLAO	12.08	77.13		
	PERU	CUSCO (CUZCO)	13.53	71.95		
	CHILE	ARICA	18.48	70.33		X
1687 10 20	PERU	CHANCAY	11.60	77.23		
	PERU	CALLAO	12.08	77.13		X
	PERU	SAN VINCENTE DE CANETE	13.10	76.38		
	PERU	CHINCHA ISLANDS	13.65	76.40		
	PERU	PISCO	13.77	76.70		
	PERU	AREQUIPA	16.40	71.55		
1725 03 27	PERU	CAMANA	16.63	72.48		
1746 10 28	PERU	GUANAPE	8.53	78.98		X
	PERU	SANTA	8.95	78.62		X
	PERU	CHANCAY	11.60	77.23		X
	PERU	CALLAO	12.08	77.13	24.0	X
	PERU	PISCO	13.77	76.70		X
	CHILE	CONCEPCION	36.83	73.05		
1860 04 23	PERU	CALLAO	12.08	77.13		
1865 01 08	PERU	CALLAO	12.08	77.13		X
1868 10 02	CHILE	TALCAHUANO	36.67	73.17		
1913 07 28	CHILE	MOLLENDO	17.00	72.00		
1914 01 12	PERU	CALLAO (LA PUNTA)	12.08	77.13		X
1942 08 24	PERU	CALLAO	12.08	77.13	1.6	
	PERU	LOMAS	15.55	74.83	2.0	X
	PERU	MATARANI	17.00	72.12	0.5	
1950 12 10	PERU	PISCO	13.77	76.70		
1953 02 15	PERU	CHANCAY	11.60	77.23		
1953 12 12	PERU	TALARA	4.58	81.42	0.5	
1960 01 13	PERU	ANCON	11.78	77.11		
1960 11 20	PERU	TALARA	4.58	81.42	1.2	
	PERU	PIMENTEL	6.85	79.88	9.0	X
	PERU	PUERTO ETEN	6.92	79.83	9.0	X
	PERU	CHIMBOTE	9.08	78.60	0.6	
	PERU	CALLAO	12.08	77.13	2.2	
	PERU	SANTA ROSA	14.63	70.75		X
	PERU	SAN JOSE	14.72	70.22		X
	PERU	LOBOS DE AFUERA ISLANDS				X
	PERU	SAN JUAN	15.36	75.12	0.3	
	PERU	MATARANI	17.00	72.12	0.4	

TABLE 3. EFFECTS IN PERU-CHILE OF TSUNAMIS GENERATED IN PERU (CONT.)

EVENT DATE YEAR MO DA	COUNTRY	REPORTING CITY ON REGION	S. LAT. °	W. LONG. °	RUNUP (M)	DAMAGE
1966 10 17	PERU	TORTUGA I. (GALAPAGOS IS.)	1.00	90.92	3.0	X
	PERU	TALARA	4.58	81.42	0.1	
	PERU	TRUJILLO	8.10	79.00	3.0	X
	PERU	CHIMBOTE	9.08	78.60	-1.0	
	PERU	CASMA	9.50	78.30		X
	PERU	CULEBRAS	9.88	78.22		X
	PERU	HUACHO	11.23	77.58		X
	PERU	ANCON	11.78	77.11		X
	PERU	CALLAO (LA PUNTA)	12.08	77.13	2.1	X
	PERU	SAN JUAN	15.37	75.12	0.3	
	PERU	MATARANI	17.00	72.12	0.4	
	CHILE	HUARA	20.00	69.75		X
	CHILE	VALPARAISO	33.08	71.67	0.4	
	CHILE	TALCAHUANO	36.67	73.17	0.3	
	CHILE	LEBU	37.62	73.72	0.3	
	PERU	PUERTO-CHIMU				X
1974 10 13	PERU	CALLAO	12.08	77.13	1.8	

TABLE 4. EFFECTS OUTSIDE PERU-CHILE OF TSUNAMIS GENERATED IN PERU

EVENT DATE YEAR MO DA	COUNTRY OR STATE	REPORTING CITY OR REGION	LAT. °	LONG. °	RUNUP (M)	PACIFIC QUADRANT
1586 07 09	JAPAN	MIYAGI (NE. HONSHU)	(38.25	141.00)	2.0	NW. PACIFIC
1687 10 20	JAPAN	NE. HONSHU				NW. PACIFIC
	JAPAN	OKINAWA	26.50	128.00		NW. PACIFIC
1746 10 28	MEXICO	ACAPULCO	16.85	- 99.92		NE. PACIFIC
1953 12 12	ECUADOR	LA LIBERTAD	-2.20	- 80.92	0.1	SE. PACIFIC
1960 11 20	HAWAII	HILO	19.70	-155.07	0.1	NE. PACIFIC
	JAPAN	HACHINOHE	33.10	139.78	0.25	NW. PACIFIC
	JAPAN	ONAHAMA	36.95	140.90		NW. PACIFIC
	JAPAN	HAKODATE	41.77	140.72	0.15	NW. PACIFIC
	JAPAN	KUSHIIRO	42.97	144.40	0.16	NW. PACIFIC
	JAPAN	AYUKAWAHAMA	(38.50	141.50)	0.34	NW. PACIFIC
1966 10 17	HAWAII	HILO	19.70	-155.07	0.27	NE. PACIFIC
	HAWAII	KAHULUI	20.93	-156.48	0.37	NE. PACIFIC
	CALIFORNIA	CRESCENT CITY	41.76	-124.22	0.06	NE. PACIFIC
	JAPAN	OFUNATO	39.07	141.72	0.24	NW. PACIFIC
	JAPAN	HAKODATE	41.77	140.72	0.15	NW. PACIFIC
	JAPAN	HACHINOHE	40.50	141.50	0.38	NW. PACIFIC
1974 10 03	HAWAII	HILO	19.70	-155.07	0.37	NE. PACIFIC
	HAWAII	KAHULUI	20.93	-156.48	0.37	NE. PACIFIC
	HAWAII	MIDWAY ISLAND	28.22	-177.37	0.06	NE. PACIFIC
	CALIFORNIA	CRESCENT CITY	41.76	-124.22	0.15	NE. PACIFIC
	PACIFIC	WAKE ISLAND	19.30	166.62	0.06	NW. PACIFIC
	AM. SAMOA	PAGO PAGO	-14.27	-171.72	0.30	SW. PACIFIC

TABLE 5. SUMMARY OF DAMAGE AND NUMBER OF DEATHS CAUSED BY PERUVIAN TSUNAMIS

EVENT DATE YEAR MO DA	REPORTING CITY OR REGION	EFFECTS	NO. OF DEATHS
1586 07 09	CALLAO, PERU	DESTRUCTION REACHED 250 METERS INLAND	
1604 11 24	ARICA AREA, CHILE	CITY INUNDATED AND DESTROYED	34
	CAMANA, PERU	WATER DESTROYED ALL IN ITS PATH	40
	CONCEPCION, CHILE	MONASTERY FLOODED	
1647 05 07	ARICA, CHILE	200,000 FRANCS DAMAGE	14
1687 10 20	CALLAO, PERU	CITY SUBMERGED	500
1746 10 28	CALLAO, PERU	TOWN INUNDATED AND DESTROYED	MANY
	CHANCAY, GUANAPE, PISCO, AND SANTA, PERU	TOWNS DESTROYED	MANY
1865 01 08	CALLAO, PERU	BATH HOUSE WASHED AWAY	5
1914 01 12	CALLAO, PERU	HOTELS FLOODED	
1942 08 24	LOMAS, PERU	SETTLEMENT FLOODED	
1960 11 20	LOBOS DE AFUERA ISLANDS	ISLANDS DEVASTATED	
	SANTA ROSA, PUERTO ETEN, PIMENTAL, AND SAN JOSE, PERU	DAMAGE	3
1966 10 17	CASMA, PERU	$2 MILLION DAMAGE	
	CULEBRAS, PUERTO-CHIMU, AND TORTUGA, PERU	SERIOUS DAMAGE	
	HUARA, TRUJILLO, ANCON, AND HUACHO, PERU	TOWNS PARTIALLY FLOODED	

TABLE 6. CITIES AND AREAS ALONG COAST OF PERU THAT REPORTED TSUNAMIS FROM ALL SOURCE REGIONS

EVENT DATE YEAR MO DA	SOURCE	REPORTING CITY OR REGION IN PERU	S. LAT. °	W. LONG. °	RUNUP (M)	DAMAGE
1966 10 17	PERU	TORTUGA I., GALAPAGOS IS.	1.00	90.92	3.0	X
1877 05 10	N. CHILE	TUMBES	3.62	80.45		
1953 12 12	PERU	TALARA	4.58	81.42	0.5	
1959 02 07	PERU	TALARA	4.58	81.42		
1960 11 20	PERU	TALARA	4.58	81.42	1.2	
1946 04 01	ALEUTIANS	TALARA	4.58	81.42	0.5	
1957 03 09	ALEUTIANS	TALARA	4.58	81.42	0.8	
1964 03 27	ALASKA	TALARA	4.58	81.42	1.0	
1966 10 17	PERU	TALARA	4.58	81.42	0.1	
1877 05 10	N. CHILE	PIMENTEL	6.85	79.88		
1960 11 20	PERU	PIMENTEL	6.85	79.88	9.0	X
1960 11 20	PERU	PUERTO ETEN	6.92	79.83	9.0	X
1877 05 10	N. CHILE	PACASMAYO	7.45	79.55		
1868 08 13	N. CHILE	TAMBO	7.58	78.70		X
1877 05 10	N. CHILE	TAMBO	7.58	78.70	4.0	
1877 05 10	N. CHILE	HUANCHACO	8.05	78.10		X
1868 08 13	N. CHILE	TRUJILLO	8.10	79.00		X
1966 10 17	PERU	TRUJILLO	8.10	79.00	3.0	
1877 05 10	N. CHILE	SALAVERRY	8.23	78.92	0.8	
1746 10 28	PERU	GUANAPE	8.53	78.98		X
1746 10 28	PERU	SANTA	8.95	78.62		X
1877 05 10	N. CHILE	SANTA	8.95	78.62	3.0	

TABLE 6. CITIES AND AREAS ALONG THE COAST OF PERU THAT REPORTED TSUNAMIS FROM ALL SOURCE REGIONS (CONT.)

EVENT DATE YEAR MO DA	SOURCE	REPORTING CITY OR REGION IN PERU	S. LAT. °	W. LONG. °	RUNUP (M)	DAMAGE
1877 05 10	N. CHILE	CHIMBOTE	9.08	78.60	2.0	
1960 11 20	PERU	CHIMBOTE	9.08	78.60	0.6	
1966 10 17	PERU	CHIMBOTE	9.08	78.60	1.0	
1877 05 10	N. CHILE	SAMANCO	9.22	78.55	3.5	
1868 08 13	N. CHILE	CASMA	9.50	78.30	2.5	
1877 05 10	N. CHILE	CASMA	9.50	78.30	2.0	
1966 10 17	PERU	CASMA	9.50	78.30		X
1966 10 17	PERU	CULEBRAS	9.88	78.22		X
1877 05 10	N. CHILE	SUPE	10.82	77.67	6.0	
1966 10 17	PERU	HUACHO	11.23	77.58		
1877 05 10	N. CHILE	SALINAS (PTA)	11.33	78.50	6.0	
1687 10 20	PERU	CHANCAY	11.60	77.23		X
1746 10 28	PERU	CHANCAY	11.60	77.23		X
1953 02 15	PERU	CHANCAY	11.60	77.23		
1877 05 10	N. CHILE	ANCON	11.78	77.11	1.5	
1960 01 13	PERU	ANCON	11.78	77.11		X
1966 10 17	PERU	ANCON	11.78	77.11		
1586 07 09	PERU	CALLAO	12.08	77.13	24.0	X
1604 11 24	PERU	CALLAO	12.08	77.13		
1647 05 07	PERU	CALLAO	12.08	77.13		
1687 10 20	PERU	CALLAO	12.08	77.13		X
1730 07 08	NC. CHILE	CALLAO	12.08	77.13		
1746 10 28	PERU	CALLAO	12.08	77.13	24.0	X
1751 05 25	C. CHILE	CALLAO	12.08	77.13		
1860 04 23	PERU	CALLAO	12.08	77.13		
1865 01 08	PERU	CALLAO	12.08	77.13		X
1868 08 13	N. CHILE	CALLAO	12.08	77.13	4.0	X
1877 05 10	N. CHILE	CALLAO	12.08	77.13	3.0	X
1914 01 12	PERU	CALLAO (LA PUNTA)	12.08	77.13		X
1922 11 11	NC. CHILE	CALLAO	12.08	77.13	2.4	
1942 08 24	PERU	CALLAO	12.08	77.13	1.6	
1946 04 01	ALEUTIANS	CALLAO	12.08	77.13	0.6	
1952 11 05	KAMCHATKA	CALLAO	12.08	77.13	0.3	
1957 03 09	ALEUTIANS	CALLAO	12.08	77.13	0.3	
1960 11 20	PERU	CALLAO	12.08	77.13	2.2	
1964 03 27	ALASKA	CALLAO	12.08	77.13	2.0	
1966 10 17	PERU	CALLAO (LA PUNTA)	12.08	77.13	2.1	
1974 10 03	PERU	CALLAO	12.08	77.13	1.8	
1687 10 20	PERU	SAN VICENTE DE CANETE	13.10	76.38		
1835 02 20	C. CHILE	SAN VICENTE DE CANETE	13.10	76.38		X
1647 05 07	PERU	CUSCO (CUZCO)	13.53	71.95		
1687 10 20	PERU	CHINCHA ISLANDS	13.65	76.40		
1868 08 13	N. CHILE	CHINCHA ISLANDS	13.65	76.40		X
1877 05 10	N. CHILE	CHINCHA ISLANDS	13.65	76.40	3.0	
1604 11 24	PERU	PISCO	13.77	76.70		
1687 10 20	PERU	PISCO	13.77	76.70		X
1746 10 28	PERU	PISCO	13.77	76.70		X
1868 08 13	N. CHILE	PISCO	13.77	76.70		X
1877 05 10	N. CHILE	PISCO	13.77	76.70	3.0	
1950 12 09	PERU	PISCO	13.77	76.70		
1960 11 20	PERU	SANTA ROSA	14.63	70.75		X
1960 11 20	PERU	SAN JOSE	14.72	70.22		X
1960 11 20	PERU	SAN JUAN	15.36	75.12	0.3	
1966 10 17	PERU	SAN JUAN	15.37	75.12	0.3	
1942 08 24	PERU	LOMAS	15.55	74.83	2.0	X
1868 08 13	N. CHILE	CHALA	15.85	74.22	15.0	X
1877 05 10	N. CHILE	CHALA	15.85	74.22	3.0	

TABLE 6. CITIES AND AREAS ALONG THE COAST OF PERU THAT REPORTED TSUNAMIS FROM ALL SOURCE REGIONS (CONT.)

EVENT DATE YEAR MO DA	SOURCE	REPORTING CITY OR REGION IN PERU	S. LAT. °	W. LONG. °	RUNUP (M)	DAMAGE
1687 10 20	PERU	AREQUIPA	16.40	71.55		
1604 11 24	PERU	CAMANA	16.63	72.48		X
1725 03 27	PERU	CAMANA	16.63	72.48		
1868 08 13	N. CHILE	MOLLENDO	17.00	72.00		X
1877 05 10	N. CHILE	MOLLENDO	17.00	72.00	3.0	X
1913 07 28	PERU	MOLLENDO	17.00	72.00		
1942 08 24	PERU	MATARANI	17.00	72.12	0.5	
1946 04 01	ALEUTIANS	MATARANI	17.00	72.12	0.5	
1957 03 09	ALEUTIANS	MATARANI	17.00	72.12	0.8	
1960 11 20	PERU	MATARANI	17.00	72.12	0.4	
1964 03 27	ALASKA	MATARANI	17.00	72.12	1.0	
1966 10 17	PERU	MATARANI	17.00	72.12	0.4	
1868 08 13	N. CHILE	ISLAY	17.03	72.10	12.0	
1877 05 10	N. CHILE	ISLAY	17.03	72.10	3.0	
1604 11 24	PERU	ILO	17.70	71.33		
1868 08 13	N. CHILE	ILO	17.70	71.33		X
1877 05 10	N. CHILE	ILO	17.70	71.33	6.0	X

NORTH CHILE

[18° S. - <27° S.]

Northern Chile can be separated into three distinct seismic regions. The northernmost region comprises the area between 18° S. and 20° S. latitude; the second region includes the area between 20° S. and 22° S. latitude; and the third region includes the area between 22° S. and 27° S. latitude.

Big Bend Area, 18° S. - <20° S.

The northernmost region, sometimes called the "big bend" area in the South American coastline, has a history of destructive earthquakes and tsunamis. It is characterized by a rather steeply dipping seismic zone and a high concentration of Neocene volcanism (McCann, 1979). Also in this region is the Range Fault, which intersects the coastline at the Chile-Peru border--the terminus of the Central Chilean Valley (Lomitz, 1970). Great earthquakes in 1604 (Southern Peru), 1705, 1868, and 1877 destroyed Arica (located at 18.5° S. latitude) as well as other coastal towns, and generated Pacific-wide tsunamis that were destructive. Studies of the source areas of major historical tsunamis in this region shows that they tend to line up along the Peru-Chile trench (Hatori, 1983).

Two major tsunamis of the 19th century (1868 and 1877) occurred in this area. They were reported throughout the Pacific Basin, and were damaging in Hawaii, Japan, New Zealand, and several islands in the South Pacific Ocean. Of the two events, that in 1868 appears to have been the most damaging both locally and in areas outside South America.

A seismic gap exists in the region from South Peru to North Chile (15° S. to 23° S. latitude), where a tsunamigenic earthquake has not occurred since that in 1877. The scanty earthquake history of this "big bend" region suggests the recurrence interval for "great" tsunamigenic earthquakes may be as long as 200 years, and so this area may continue to accumulate tectonic strain for another century before a great tremor occurs. Even so, this region has the highest seismic and tsunamigenic potential of any region along the coast of South America, and therefore should be monitored carefully (McCann, 1979).

Region from 20° S. - <22° S.

The second region in North Chile lies between 20° S. and 22° S. latitude. Here, the Central Chilean Valley is well developed, and earthquakes have occurred both offshore and on the Range Fault. The offshore earthquakes have produced several tsunamis, but none has been destructive.

Region from 22° S. - <27° S.

The Province of Antofagasta includes much intermediate-depth activity, but lacks major shallow shocks (Lomitz, 1970) of the type that generates destructive tsunamis. The largest events in this area occurred on Dec. 4, 1918, and on Dec. 28, 1966. Both were magnitude 7.8 earthquakes, but only the 1918 event gener-

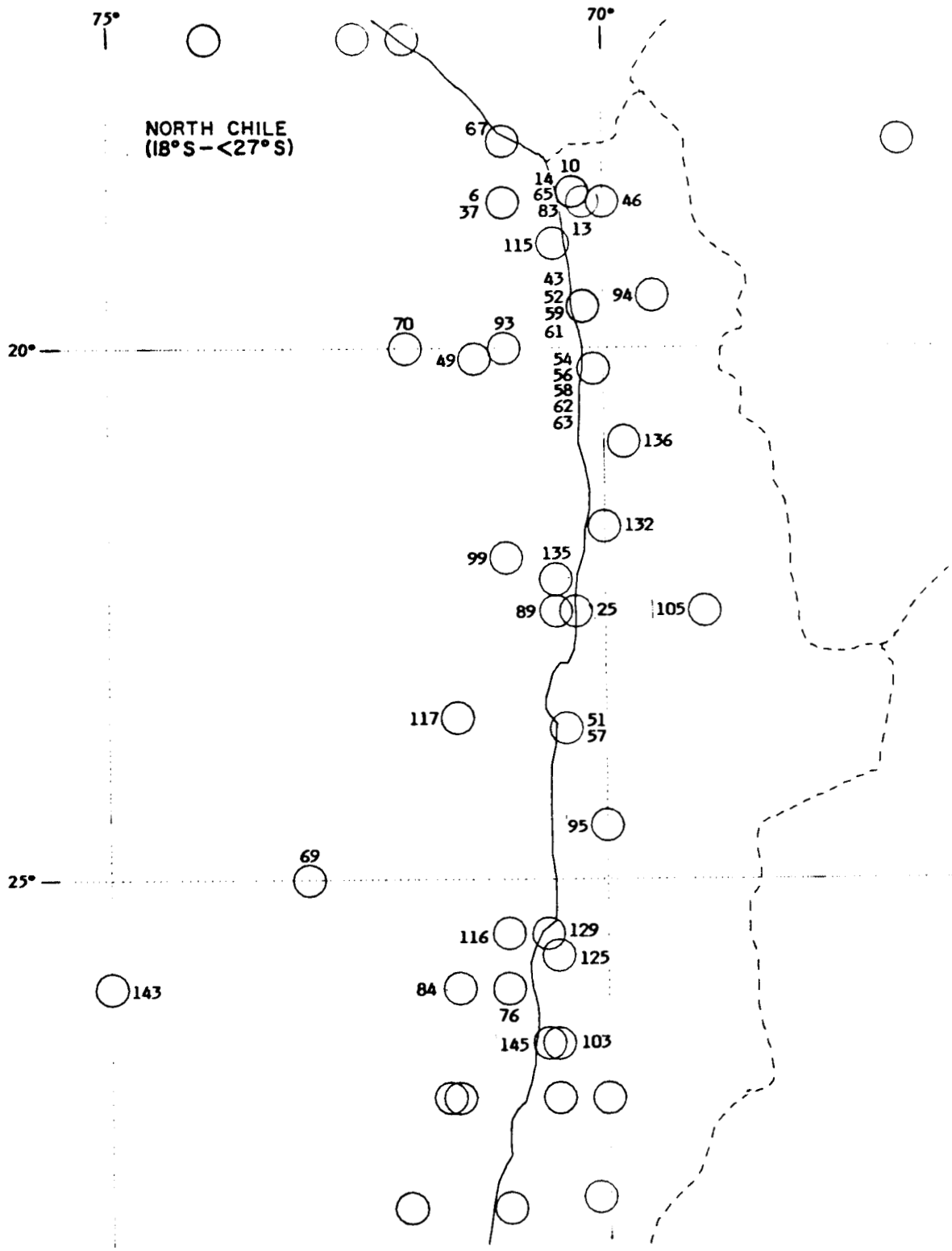


FIGURE 13. EPICENTERS OF TSUNAMIGENIC EARTHQUAKES OF NORTH CHILE [NUMBERS REFER TO EVENT NO. IN TABLE 7.]

ated a damaging tsunami. No tsunamigenic earthquake of magnitude $\geq$8.0 has been reported in the coastal region between 20° S. and 27°S. latitude.

Table 7 lists the tsunamigenic earthquakes of North Chile, and gives other data about the tsunamis they produced (see table 1 for alternate data, erroneous dates, and events that appeared in the literature but are not believed to have been tsunamis). The data included in table 7 are believed to be the most accurate available. Of the 44 events listed, five were damaging locally and two were reported in areas of the Pacific outside the west coast of South America. Ten of the events have a validity rating of "4," indicating that a tsunami definitely occurred. An additional seven events have been given a "3" (probable) validity rating, but the validity of the remaining events is less certain. The events listed in table 7 are plotted on a map of North Chile in figure 13.

The literature provides information about the size of the tsunami for 25 of the events in table 7. This size may have been indicated by a tsunami magnitude, a tsunami intensity, or a measured or estimated runup height. Of the 25 events that had such information, 12 had runup heights reported to be less than 1 meter. The reason that some events that had significant runup heights were not considered to be probable tsunamis is that they do not clearly fit the definition of a tsunami as described in the introduction. Tsunamis in the 20th century have not been as large or as destructive as those occurring last century. Figure 14 shows the frequency of occurrence of the tsunamigenic earthquakes for each degree of the North Chile coastline. Shaded areas indicate the number of tsunamigenic earthquakes that caused damage.

Table 8 lists the dates of 20 tsunamis generated in North Chile and the names of the cities that reported each event. An "X" in the damage column indicates that damage occurred at that city. If a value is not given for the runup height and an "X" does not appear in the damage column, then the event was reported in the literature but descriptive effect information was not given. The areas reporting each tsunami are listed by increasing latitude (north to south). Figures 15 and 16 show the extent of the coastline affected by the 1868 and 1877 events (hatched area) and the locations where damage occurred (shaded areas). These events caused the most extensive damage ever reported along the Peru-Chile coast.

Table 9 lists the dates of two major tsunamis in North Chile and the cities outside Peru-Chile that reported each event. These events are the only tsunamis generated in North Chile that were widely reported outside the west coast of South America. They were destructive in Hawaii, Japan, New Zealand, and on several Pacific islands. The 1868 event appears to have been more widely felt in the South Pacific Basin even though its epicenter was located 1° north of the 1877 event. Maps showing the extent of the effects of these tsunamis are shown in figures 17 and 18.

Table 10 is a summary of damage and number of deaths caused by tsunamis in North Chile. More than 26,000 people have been killed by tsunamis generated in this region. However, during the 20th century no severely damaging tsunamis has occurred in the area.

Table 11 lists the names of cities in North Chile that have reported tsunamis, the dates of the tsunamis, the runup heights, and whether damage occurred. The table shows that Arica and Iquique, located in the "big bend" of South America, have been especially vulnerable both to local tsunamis and to those generated

TABLE 7. TSUNAMIGENIC EARTHQUAKES OF NORTH CHILE

EVENT NO.	EVENT DATE YEAR	MO	DA	TIME	EARTHQUAKE DATA S. LAT. °	W. LONG. °	MAGNITUDE	DEPTH (KM)	TSUNAMI DATA RUNUP (M)	MAGNITUDE	INTENSITY	VALIDITY	REFERENCES
6	1615	09	16	2400	18.6	71.0	7.5		4.0	2.0	1.5	4	1,9,10,31,38,51
10	1681	03	10		(18.5	70.3)	7.5					3	31,51
13	*1705	11	26		18.6	70.2			8.0	3.0		4	9,10,38
14	1715	08	22		(18.5	70.3)	7.5					3	31,51
25	1836	07	03	2230	22.5	70.3	7.5		2.0	1.0	1.0	3	52
37	*<1868	08	13	2045	18.6	71.0	8.5		21.0	4.3		4	52
43	1869	06	25		(19.6	70.2)			0.7		0.0		9,38
46	*1869	08	24	1710	18.6	70.0	6.8		2.0	1.0		4	52
49	1871	10	05	0050	20.1	71.3	7.5						9,38,51
51	1873	11	19		(23.6	70.4)			2.8		2.0		9,38
52	*<1877	05	10	0216	19.6	70.2	8.3		24.0	4.5		4	52
53	1877	05	15						0.7		0.0		9,38
54	1877	08	23		(20.2	70.1)			1.0		0.5	3	9,38
56	1878	03	12		(20.2	70.1)			0.7		0.0		9,38
57	1878	06	12		(23.6	70.4)			0.7		0.0		9,38
58	1881	07	14		(20.2	70.1)			1.4		1.0	3	9,38
59	1881	10	27		(19.6	70.2)			0.7		0.0		9,38
61	1882	09	14		(19.6	70.2)			0.7		0.0		9,38
62	1885	11	12	0740	(20.2	70.1)			1.0		0.5	3	9,38,51
63	1903	09	26		(20.2	70.1)			0.7	-0.5	0.0		9,38,51
65	1906	05	07		(18.5	70.3)			1.5	0.6	0.0		9,38
67	1906	12	26	0653	18.0	71.0	7.9	33					51
69	1909	06	08	0546	25.0	73.0	7.6	33					9,10,13,51
70	1911	09	15		20.0	72.0	7.3						51
76	*1918	12	04	1148	26.0	71.0	7.8	33	5.0	2.3	2.5	4	1,9,10,18,38,51
83	1923	08	12	1211	(18.5	70.3)			0.7	-0.5	0.0		9,38,51
84	1925	05	15	1157	26.0	71.5	7.1	50					51
89	1928	11	20	2035	22.5	70.5	7.1	33					51
93	1933	02	23	0809	20.0	71.0	7.6	40					9,22,38,51
94	1934	12	04	1725	19.5	69.5	6.9	130					9,22,38,51
95	1936	07	13	1112	24.5	70.0	7.3	60	1.0	0.0	0.5	4	1,9,10,22,51,52
99	1940	10	04	0755	22.0	71.0	7.3	75					51
103	1946	08	02	1919	26.5	70.5	7.9	60					51
105	1948	12	26	0712	22.5	69.0	7.0		0.7	-0.5	0.0	3	9,38,51
115	1956	01	08	2054	19.0	70.5	7.1	55					51
116	1956	12	18	0231	25.5	71.0	7.0	33					51
117	1957	07	29	1715	23.5	71.5	7.0	33					51
125	1965	02	23	2211	25.7	70.5	7.0	80					51
129	1966	12	28	0818	25.5	70.6	7.8	32	0.4	0.0	0.5	4	5,9,38,47,51
132	1967	12	21	0225	21.7	70.0	7.5	33	0.7	-0.5	0.0	4	9,27,38,51
135	1970	06	19	1056	22.2	70.5	7.0	52					51
136	1970	11	28	1109	20.9	69.8	6.0	33					51
143	1975	03	13	1527	26.0	75.0	6.7						51
145	1983	10	04	1852	26.5	70.6	7.4	15	0.4	-2.3	0.2	4	45

NOTE: * Indicates that the earthquake caused a destructive tsunami.
< Indicates that the tsunami was reported outside the South American coast.
( ) Parentheses around the latitude and longitude indicate that the epicenter was derived from the coordinates of a city name given in the reference.
See footnotes at end of table 1 for explanation of column headings.

elsewhere in the Pacific Ocean Basin. However, these "remote source" tsunamis have seldom caused damage in this section of North Chile. Figure 19, a bar graph of the data in table 11, gives the number of tsunamis per degree of coastline.

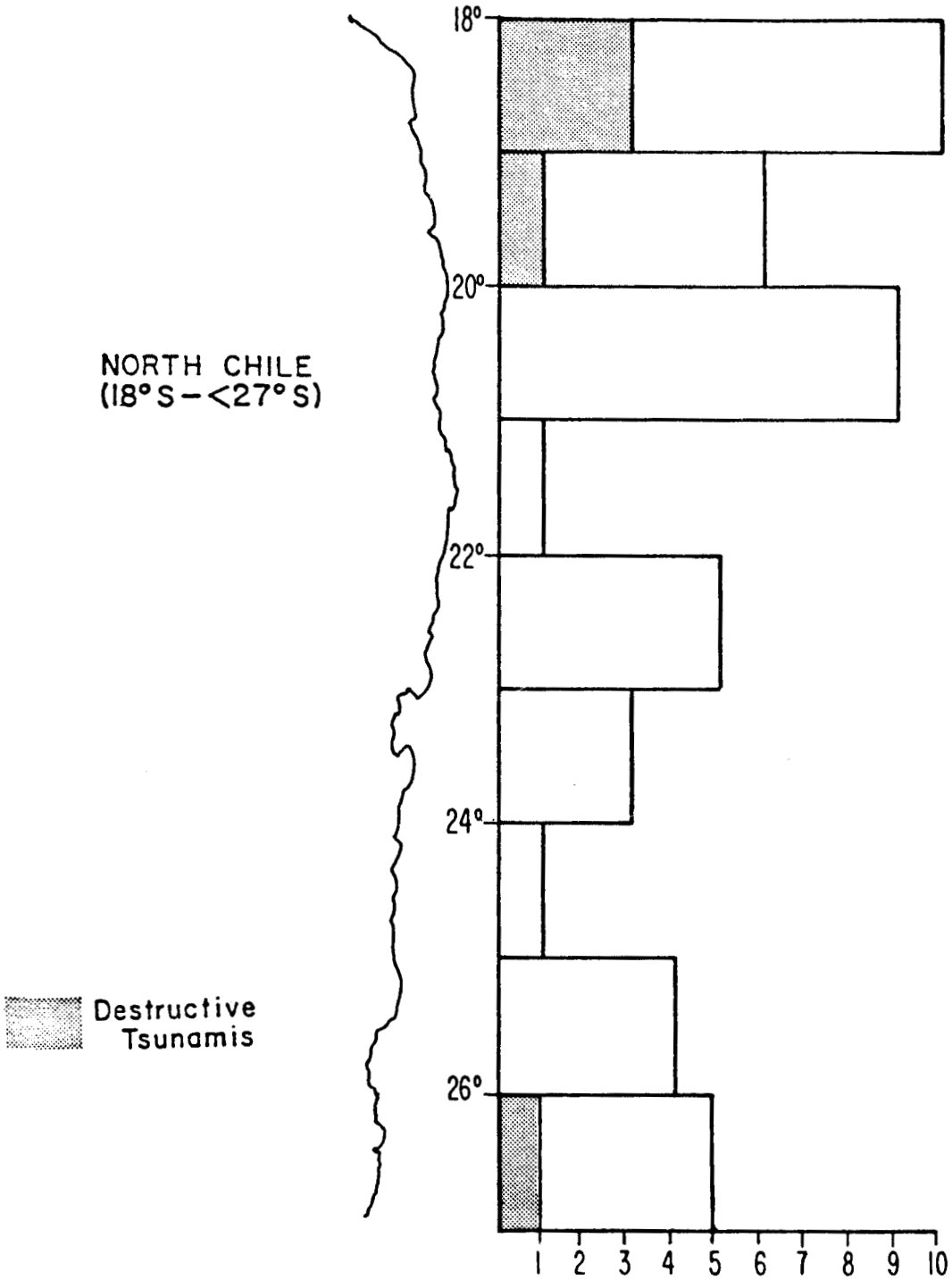


FIGURE 14. NUMBER OF TSUNAMIGENIC EARTHQUAKES PER DEGREE OF NORTH CHILE COASTLINE

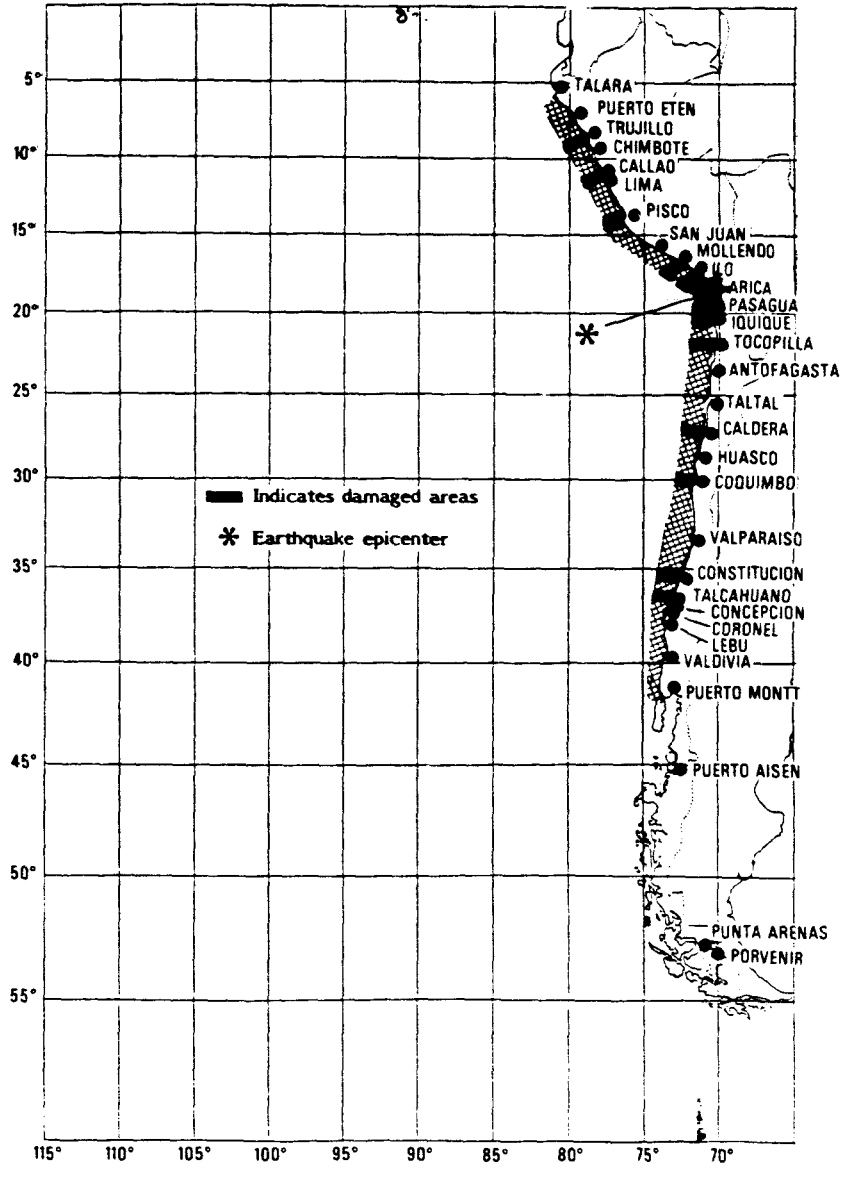


FIGURE 15. AREA OF PERU-CHILE COAST AFFECTED BY CHILE TSUNAMI OF AUG. 13, 1868

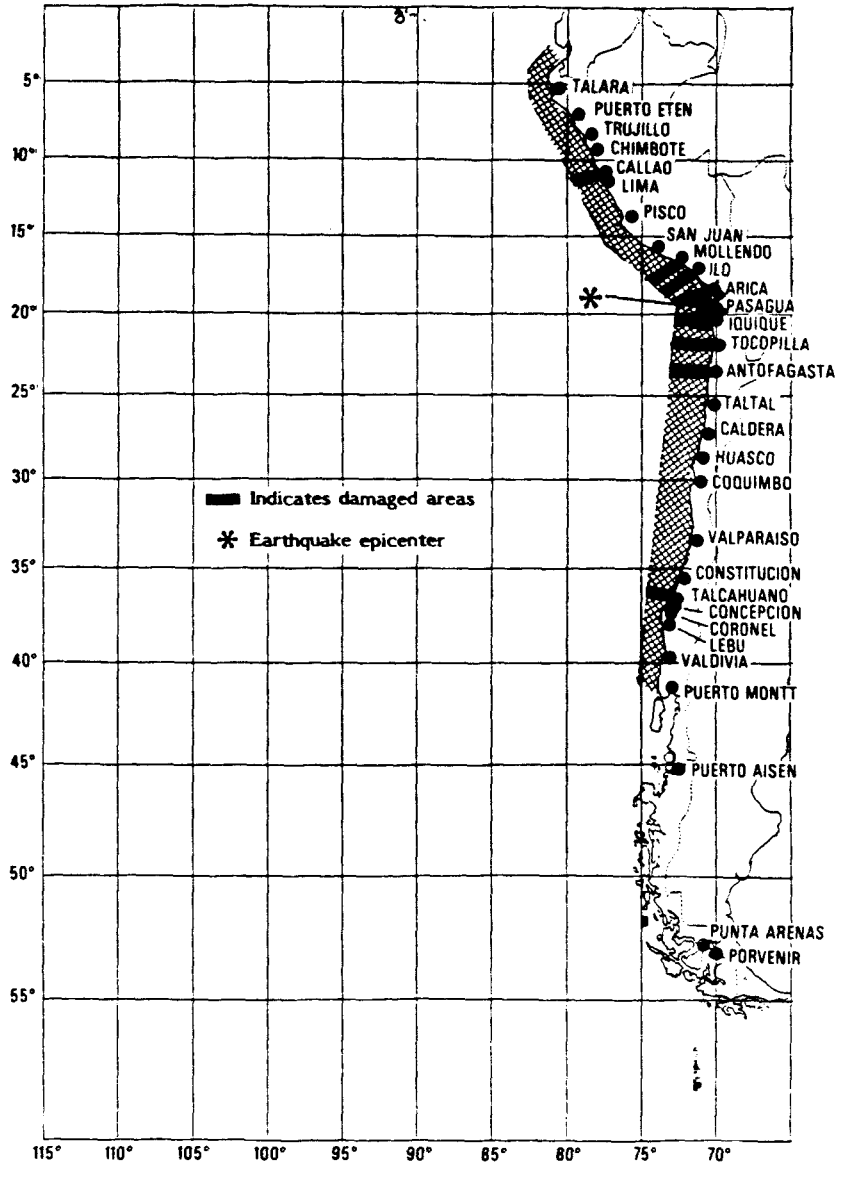


FIGURE 16. AREA OF PERU-CHILE COAST AFFECTED BY CHILE TSUNAMI OF MAY 10, 1877

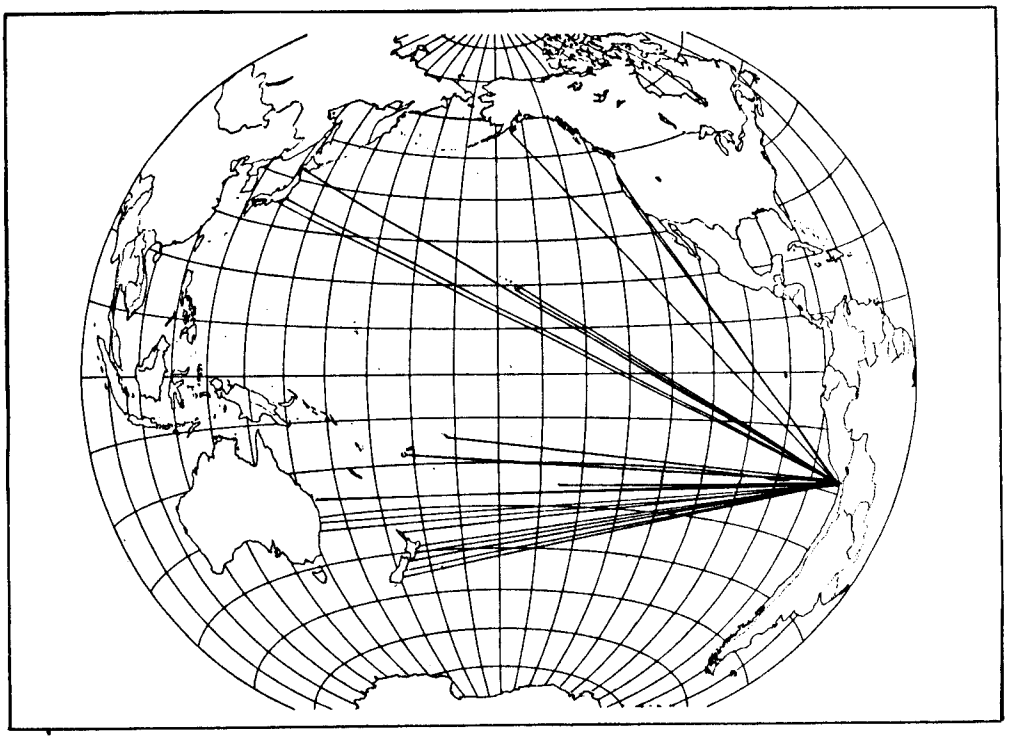


FIGURE 17. AREAS OUTSIDE PERU-CHILE REPORTING CHILE TSUNAMI OF AUG. 13, 1868

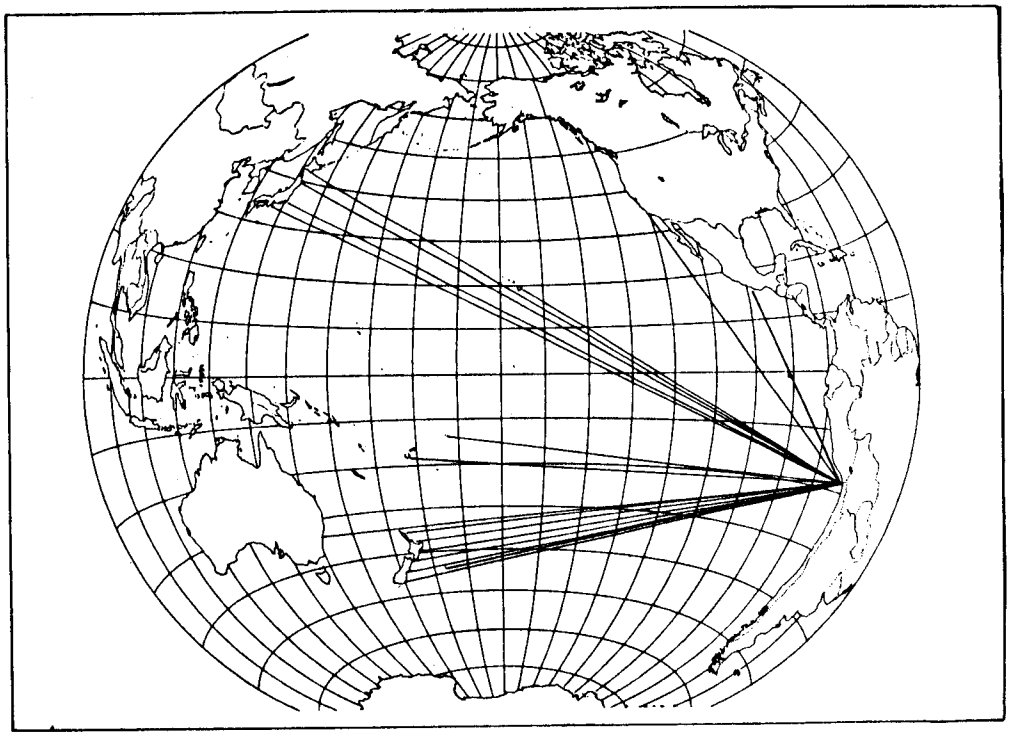


FIGURE 18. AREAS OUTSIDE PERU-CHILE REPORTING CHILE TSUNAMI OF MAY 10, 1877

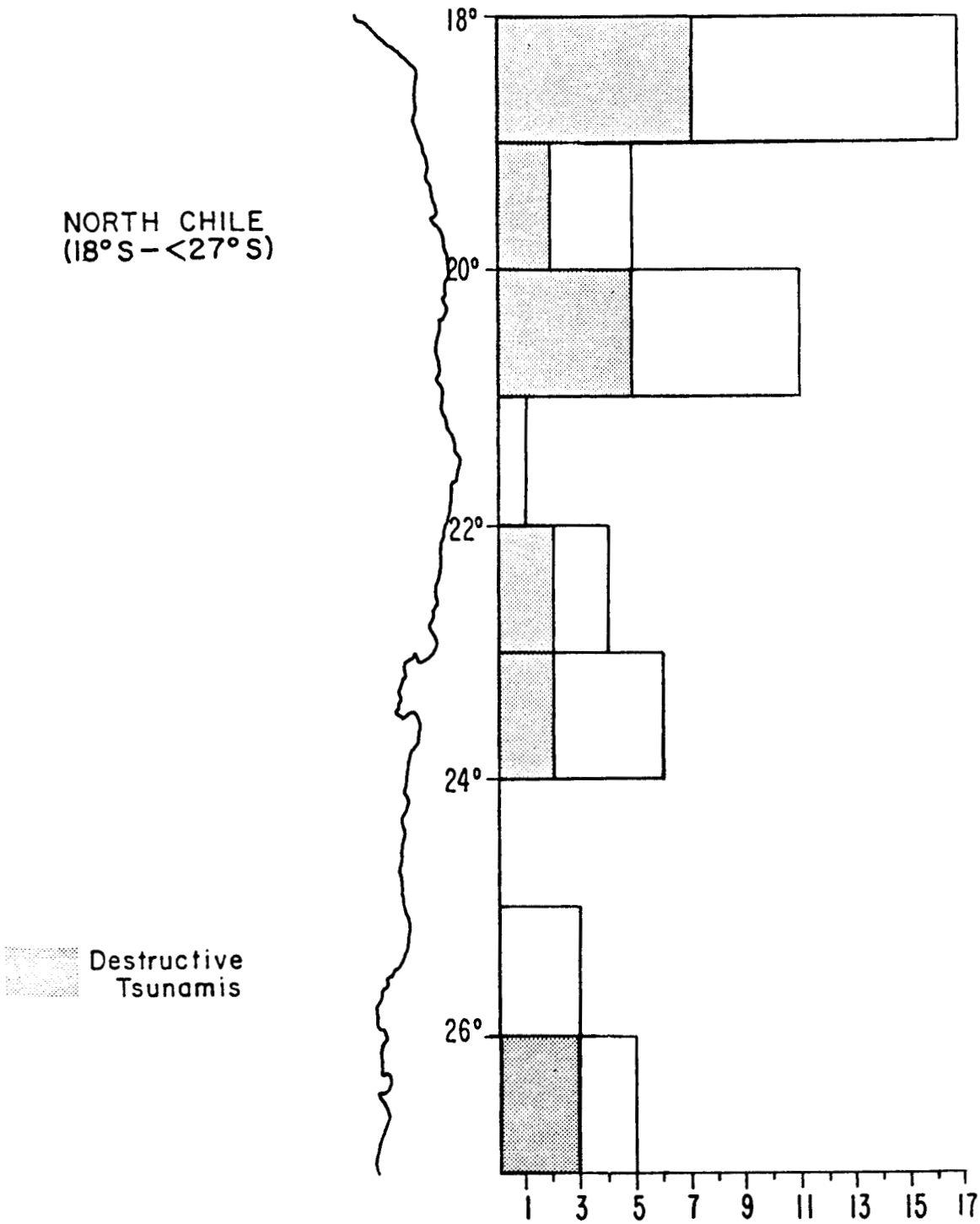


FIGURE 19. NUMBER OF REPORTED OBSERVATIONS OF TSUNAMI EFFECTS PER DEGREE OF NORTH CHILE COASTLINE

TABLE 8. EFFECTS IN PERU-CHILE OF TSUNAMIS GENERATED IN NORTH CHILE

EVENT DATE YEAR MO DA	COUNTRY	REPORTING CITY OR REGION	S. LAT. °	W. LONG. °	RUNUP (M)	DAMAGE
1615 09 16	CHILE	ARICA	18.48	70.33		
1705 11 26	CHILE	ARICA	18.48	70.33		X
1836 07 03	CHILE	COBIJA	22.55	70.27		
1868 08 13	PERU	TAMBO	7.58	78.70		X
	PERU	TRUJILLO	8.10	79.00		X
	PERU	CASMA	9.50	78.30	2.5	
	PERU	CALLAO	12.08	77.13	4.0	X
	PERU	CHINCHA ISLANDS	13.65	76.40		X
	PERU	PISCO	13.77	76.70		X
	PERU	CHALA	15.85	74.22	15.0	X
	PERU	MOLLENDO	17.00	72.00		X
	PERU	ISLAY	17.03	72.10	12.0	
	PERU	ILO	17.70	71.33		X
	CHILE	ARICA	18.48	70.33	15.0	X
	CHILE	PISAGUA	19.57	70.23		X
	CHILE	IQUIQUE	20.25	70.13	12.0	X
	CHILE	TOCOPILLA	22.08	70.17		X
	CHILE	COBIJA	22.55	70.25		X
	CHILE	MEJILLONES	23.05	70.42	6.0	X
	CHILE	TALTAL	25.43	70.55		
	CHILE	CHANARAL	26.38	70.67		X
	CHILE	CALDERA	27.07	70.83		X
	CHILE	CARRIZAL BAJO	28.13	71.25		X
	CHILE	COQUIMBO	29.95	71.42	7.5	X
	CHILE	JUAN FERNANDEZ ISLANDS	33.00	80.00	2.0	X
	CHILE	VALPARAISO	33.08	71.67		
	CHILE	SAN VINCENTE	34.45	71.08		
	CHILE	CONSTITUCION	35.33	72.42	3.5	X
	CHILE	TOME	36.63	72.95	4.5	X
	CHILE	TALCAHUANO	36.67	73.17	4.0	X
	CHILE	CORONEL	36.98	73.17		
	CHILE	LOTA	37.12	73.17		
	CHILE	ARAUCO	37.25	73.32		
	CHILE	LEBU	37.63	73.72		
	CHILE	SAN VINCENTE DE CANETE	37.80	73.42		X
	CHILE	CORRAL	39.86	73.42	4.0	
	CHILE	ANCUD	41.87	73.83		
	CHILE	CHILOE ISLAND	42.50	73.92		X
1869 08 24	CHILE	PISAGUA	19.57	70.23	2.0	X
	CHILE	IQUIQUE	20.25	70.13	2.0	X
	CHILE	ARICA	18.48	70.33	2.0	X
1877 05 10	CHILE	HUANILLOS			18.0	X
	PERU	TUMBES	3.62	80.45		
	PERU	PIMENTEL	6.85	79.88		
	PERU	PACASMAYO	7.45	79.55		
	PERU	TAMBO	7.58	78.70	4.0	
	PERU	HUANCHACO	8.05	78.10		X
	PERU	SALAVERRY	8.23	78.92	0.8	
	PERU	SANTA	8.95	78.62	3.0	
	PERU	CHIMBOTE	9.08	78.60	2.0	
	PERU	SAMANCO	9.22	78.55	3.5	
	PERU	CASMA	9.50	78.30	2.0	
	PERU	SUPE	10.82	77.67	6.0	

TABLE 8. EFFECTS IN PERU-CHILE OF TSUNAMIS GENERATED IN NORTH CHILE (CONT.)

EVENT DATE YEAR MO DA	COUNTRY	REPORTING CITY OR REGION	LAT. °	LONG. °	RUNUP (M)	DAMAGE
1877 05 10	PERU	SALINAS (PTA)	11.33	78.50	6.0	
	PERU	ANCON	11.78	77.11	1.5	
	PERU	CALLAO	12.08	77.13	3.0	X
	PERU	CHINCHA ISLANDS	13.65	76.40	3.0	
	PERU	PISCO	13.77	76.70	3.0	
	PERU	CHALA	15.85	74.22	3.0	
	PERU	MOLLENDO	17.00	72.00	3.0	X
	PERU	ISLAY	17.03	72.10	3.0	
	PERU	ILO	17.70	71.33	6.0	X
	CHILE	ARICA	18.48	70.33	20.0	X
1877 05 10	PERU	PISAGUA	19.57	70.23	5.0	
	CHILE	IQUIQUE	20.25	70.13	6.0	X
	CHILE	CHANABAYA	20.89	70.15	10.0	X
	CHILE	CALETA PABELLON DE PICA	20.90	70.16	10.0	X
	CHILE	PUNTA LOBOS	21.02	70.17	10.0	
	CHILE	GUANILLO DEL NORTE	21.20	70.08	15.0	
	CHILE	TOCOPILLA	22.08	70.17	24.0	X
	CHILE	COBIJA	22.55	70.27	9.0	X
	CHILE	MEJILLONES	23.08	70.43	21.0	X
	CHILE	ANTOFAGASTA	23.65	70.42	6.0	X
	CHILE	CHANARAL	26.38	70.67	5.0	X
	CHILE	CALDERA	27.07	70.83	2.0	
	CHILE	CARRIZAL BAJO	28.07	70.58	1.5	
	CHILE	COQUIMBO	29.95	71.42	2.0	
	CHILE	JUAN FERNANDEZ ISLANDS	33.00	80.00		
	CHILE	VALPARAISO	33.08	71.67	1.1	
	CHILE	LLICO	34.76	72.17		
	CHILE	CONSTITUCION	35.33	72.42	5.0	
	CHILE	TOME	36.63	72.95	0.8	
	CHILE	TALCAHUANO	36.67	73.17	15.0	X
	CHILE	PENCO	36.75	73.00		X
	CHILE	CORONEL	37.02	73.15	3.0	
	CHILE	LOTA	37.08	73.17	1.5	
	CHILE	ARAUCO	37.25	73.32		
	CHILE	VALDIVIA	39.77	73.25		
	CHILE	CORRAL BAY (ENSENADA)	39.96	73.42	0.6	
	CHILE	PUERTO MONTT	41.47	73.00		
	CHILE	ANCUD	41.87	73.83		
1877 08 23	CHILE	IQUIQUE	20.25	70.13		
1878 03 12	CHILE	BUCHUPUREO	36.08	72.77		
1878 06 12	CHILE	ANTOFAGASTA	23.65	70.42		
1881 07 14	CHILE	IQUIQUE	20.25	70.13		
1881 10 27	PERU	PISAGUA	19.57	70.23		
1882 09 14	PERU	PISAGUA	19.57	70.23		
1885 11 12	CHILE	IQUIQUE	20.25	70.13		
1903 09 26	CHILE	IQUIQUE	20.25	70.13		
1906 05 07	CHILE	ARICA	18.48	70.33		
	PERU	TACNA	18.00	70.25		
1918 12 04	CHILE	CALDERA	27.07	70.83	5.0	
1923 08 12	CHILE	ARICA	18.48	70.33		

TABLE 8. EFFECTS IN PERU-CHILE OF TSUNAMIS GENERATED IN NORTH CHILE (CONT.)

EVENT DATE YEAR MO DA	COUNTRY	REPORTING CITY OR REGION	LAT. °	LONG. °	RUNUP (M)	DAMAGE
1934 12 04	CHILE	ARICA	18.48	70.33		
1936 07 13	CHILE	ANTOFAGASTA	23.65	70.42		
	CHILE	TALTAL	25.43	70.55	0.8	
	CHILE	TALCAHUANO	36.67	73.17	1.0	
1948 12 26	CHILE	TOCOPILLA	22.08	70.17		
1966 12 28	PERU	CHIMBOTE	9.08	78.60	0.1	
	PERU	SAN JUAN	15.37	75.12	0.2	
	PERU	MATARANI	17.00	72.12	0.1	
	CHILE	ARICA	18.48	70.33	0.3	
	CHILE	ANTOFAGASTA	23.65	70.42	0.4	
	CHILE	CALDERA	27.07	70.88	0.4	

TABLE 9. EFFECTS OUTSIDE PERU-CHILE OF TSUNAMIS GENERATED IN NORTH CHILE

EVENT DATE YEAR MO DA	COUNTRY	REPORTING CITY OR REGION	LAT. °	LONG. °	RUNUP (M)	DAMAGE	PACIFIC QUADRANT
1868 08 13	HAWAII	MOLOKAI (KANAIO)			1.2	X	NE. PACIFIC
	HAWAII	HILO	19.73	-155.05	4.5	X	NE. PACIFIC
	HAWAII	MAUI (KAHULUI)	20.93	-156.48		X	NE. PACIFIC
	HAWAII	HONOLULU	21.30	-157.87	1.6		NE. PACIFIC
	HAWAII	WAIMEA BAY	21.63	-158.07	1.8		NE. PACIFIC
	CALIFORNIA	SAN DIEGO	32.70	-117.17	0.6		NE. PACIFIC
	CALIFORNIA	LOS ANGELES	33.71	-118.27			NE. PACIFIC
	CALIFORNIA	SAN FRANCISCO	37.80	-122.47	0.5		NE. PACIFIC
	OREGON	ASTORIA	46.20	-123.77	0.22		NE. PACIFIC
	ALASKA	KODIAK ISLAND	57.82	-152.50			NE. PACIFIC
	PHILIPPINES	SAN PEDRO					NW. PACIFIC
	JAPAN	NAKA RYUKYU					NW. PACIFIC
	JAPAN	SHIMODA	34.67	138.95			NW. PACIFIC
	JAPAN	YOKOHAMA	35.45	139.65		X	NW. PACIFIC
	JAPAN	HAKODATE	41.77	140.72	1.5		NW. PACIFIC
	FIJI IS.	VITI-LEVU ISLAND	-18.00	178.00			SW. PACIFIC
	AUSTRALIA	SANDGATE	-27.30	153.00			SW. PACIFIC
	AUSTRALIA	NEWCASTLE	-32.93	151.78			SW. PACIFIC
	AUSTRALIA	SYDNEY	-33.92	151.17	1.2		SW. PACIFIC
	NEW ZEALAND	OCAIN BAY					SW. PACIFIC
	NEW ZEALAND	WHITE'S BAY					SW. PACIFIC
	NEW ZEALAND	OTAGO BAY			0.3		SW. PACIFIC
	NEW ZEALAND	LE BON BAY				X	SW. PACIFIC
	NEW ZEALAND	MANGONUI	-35.00	173.57	1.2		SW. PACIFIC
	NEW ZEALAND	PORT CHARLES	-36.52	175.50	1.8		SW. PACIFIC
	NEW ZEALAND	CAPE RUNAWAY	-37.53	177.98	3.0		SW. PACIFIC
	NEW ZEALAND	OPOTIKI	-38.00	177.30	2.0		SW. PACIFIC
	NEW ZEALAND	NAPIER	-39.48	176.97	1.0		SW. PACIFIC
	NEW ZEALAND	PIGEON BAY	-41.25	175.25		X	SW. PACIFIC
	NEW ZEALAND	NELSON PORT	-41.28	173.28	1.2		SW. PACIFIC
	NEW ZEALAND	WELLINGTON	-41.28	174.78			SW. PACIFIC
	NEW ZEALAND	WESTPORT	-41.77	171.63	1.5		SW. PACIFIC
	NEW ZEALAND	KAIAPOI	-43.40	172.67	1.2	X	SW. PACIFIC
	NEW ZEALAND	LYTTLETON	-43.62	172.72	5.4		SW. PACIFIC

TABLE 9. EFFECTS OUTSIDE PERU-CHILE OF TSUNAMIS GENERATED IN NORTH CHILE (CONT.)

EVENT DATE YEAR MO DA	COUNTRY	REPORTING CITY OR REGION	LAT. °	LONG. °	RUNUP (M)	DAMAGE	PACIFIC QUADRANT
1868 08 13	NEW ZEALAND	AKAROA	-43.83	172.98			SW. PACIFIC
	NEW ZEALAND	TIMARU	-44.38	171.23	3.0		SW. PACIFIC
	NEW ZEALAND	OAMARU	-45.10	170.97	4.5		SW. PACIFIC
	NEW ZEALAND	PORT CHALMERS	-45.82	170.65	3.3		SW. PACIFIC
	NEW ZEALAND	BLUFF	-46.64	168.35			SW. PACIFIC
	MARQUESAS ISLAND		-9.00	-139.50		X	SE. PACIFIC
	W. SAMOA	APIA	-13.80	-171.75	3.0	X	SE. PACIFIC
	AUSTRAL IS.	RAPA	-26.80	-144.33		X	SE. PACIFIC
	CHATHAM ISLAND		-44.00	-176.58		X	SE. PACIFIC
	ANTARCTICA					X	SE. PACIFIC
1877 05 10	MEXICO	ACAPULCO	16.85	- 99.93	1.0	X	NE. PACIFIC
	HAWAII	COCONUT ISLAND			4.2	X	NE. PACIFIC
	HAWAII	KEALAKEKUA	(19.45	-155.87)	9.0		NE. PACIFIC
	HAWAII	HILO	19.70	-155.07	4.8	X	NE. PACIFIC
	HAWAII	KAWAIHAE	20.03	-155.83	1.5		NE. PACIFIC
	HAWAII	KAHULUI	20.93	-156.48	1.5		NE. PACIFIC
	HAWAII	LAHAINA	20.95	-155.68	3.6		NE. PACIFIC
	HAWAII	WAIAKEA	21.20	-157.88		X	NE. PACIFIC
	HAWAII	HONOLULU	21.32	-157.83	1.45		NE. PACIFIC
	HAWAII	NAWILIWILI BAY (KAUAI)	21.95	-159.35	1.0		NE. PACIFIC
	CALIFORNIA	GAVIOTA	(34.50	-120.30)	4.0		NE. PACIFIC
	CALIFORNIA	SAN FRANCISCO	37.80	-122.47	0.15		NE. PACIFIC
	JAPAN	BOSO PENINSULA	(34.90	-139.90)		X	NW. PACIFIC
	JAPAN	TOKYO BAY	35.50	139.90	0.70		NW. PACIFIC
	JAPAN	KAMAISI	39.27	141.90	3.0		NW. PACIFIC
	JAPAN	HAKODATE	41.77	140.72	2.4	X	NW. PACIFIC
	AUSTRALIA	SYDNEY	-33.92	151.17			SW. PACIFIC
	NEW ZEALAND	LE BON BAY			2.0	X	SW. PACIFIC
	NEW ZEALAND	AUCKLAND	-36.92	174.78	2.7		SW. PACIFIC
	NEW ZEALAND	TAURANGA	-37.70	176.18	1.0		SW. PACIFIC
	NEW ZEALAND	GISBORNE	-38.68	178.03	2.5	X	SW. PACIFIC
	NEW ZEALAND	WAIROA	-39.05	177.42			SW. PACIFIC
	NEW ZEALAND	PIGEON BAY	-41.25	175.25	2.0		SW. PACIFIC
1877 05 10	NEW ZEALAND	WELLINGTON	-41.28	174.78	1.5		SW. PACIFIC
	NEW ZEALAND	KAIAPOI	-43.40	172.67	0.9		SW. PACIFIC
	NEW ZEALAND	LYTTLETON	-43.62	172.72			SW. PACIFIC
	NEW ZEALAND	AKAROA	-43.83	172.98	3.0	X	SW. PACIFIC
	NEW ZEALAND	TIMARU	-44.38	171.23			SW. PACIFIC
	NEW ZEALAND	OAMARU	-45.10	170.97		X	SW. PACIFIC
	NEW ZEALAND	PORT CHALMERS	-45.82	170.65	6.0		SW. PACIFIC
	NEW ZEALAND	BLUFF	-46.64	168.35			SW. PACIFIC
	W. SAMOA	APIA	-13.80	-171.75	1.8		SE. PACIFIC
	FIJI ISLANDS	S. COAST VANUA LEVU	-16.80	-179.50	2.0	X	SE. PACIFIC
	CHATHAM ISLAND		-44.00	-176.58		X	SE. PACIFIC
1966 12 28	HAWAII	KAHULUI	20.93	-156.48	0.3		NE. PACIFIC
	HAWAII	HILO	19.70	-155.07	0.3		NE. PACIFIC

TABLE 10. SUMMARY OF DAMAGE AND NUMBER OF DEATHS CAUSED BY NORTH CHILE TSUNAMIS

EVENT DATE YEAR MO DA	REPORTING CITY OR REGION	EFFECTS	NO. OF DEATHS
1705 11 26	ARICA, CHILE	TOWN DESTROYED	
1868 08 13	ARICA, CHILE	MANY SHIPS DESTROYED	25,000
	CALDERA, CHILE	SHIPS DAMAGED	
	IQUIQUE, CHILE	CITY COMPLETELY SUBMERGED	150
	CORONEL, CONSTITUCION, COQUIMBO, BAJO, COBIJA, TOCOPILLA, TALCAHUANO MEJILLONES, PISAGUA, AND JUAN FERNANDEZ IS., CHILE	CONSIDERABLE DAMAGE	
	TOME, CHILE	WAREHOUSE, CUSTOM HOUSE FLOODED	
	TRUJILLO, PERU	SOME DAMAGE	
	ILO, PISCO, PERU	ALL WASHED AWAY	20
	CALLAO, PERU	CONSIDERABLE DAMAGE	
	TAMBO, PERU	SETTLEMENT WASHED AWAY	500
	MOLLENDO, PERU	SETTLEMENT, WAREHOUSES WASHED AWAY	
	HILO, HAWAII ISLAND	SEVERE DAMAGE	
	MAUI AND MOLOKAI ISLANDS	SOME DAMAGE	
	RAPA, AUSTRAL ISLANDS	SETTLEMENTS DESTROYED	
	ANTARCTICA	BREAKUP OF ICE FLOW	
	APIA, WESTERN SAMOA	CHURCH AND BRIDGE DESTROYED	
	PIGEON BAY AND LEBON BAY, NEW ZEALAND	SOME DAMAGE	
	YOKOHAMA, JAPAN	HARBOR FLOODED	
1869 08 24	ARICA, IQUIQUE, AND PISAGUA, CHILE	TOWNS FLOODED	
1877 05 10	ARICA, CHILE	LOSS OF SHIPS	277
	IQUIQUE, CHILE	CITY PARTIALLY FLOODED,	30
	IQUIQUE, CHILE	$1.6 MILLION IN DAMAGE	
	TALCAHUANO, CHILE	CONSIDERABLE DAMAGE	
	CALETA PABELLON DE PICA, CHILE	LOWER CITY COMPLETELY DESTROYED	40-200
	CHANABAYA, CHANARAL, CHILE	CITIES FLOODED	
	HUANILLOS, TOCOPILLA, COBIJA AND MEJILLONES, CHILE	CITIES MOSTLY DESTROYED	MANY
	ANTOFAGASTA AND, PENCO, CHILE	SOME DESTRUCTION	
	ILO, PERU	EXTENSIVE DAMAGE	
	CALLAO, PERU	SOME DESTRUCTION	HUNDREDS
	MOLLENDO, PERU	RAILWAY WASHED OUT	
	HILO, HAWAII ISLAND	57 HOUSES DESTROYED	5
	ACAPULCO, MEXICO	SOME DESTRUCTION	
	CHATHAM ISLANDS	BRIDGE AND HOMES WASHED AWAY	
	LE BON BAY, NEW ZEALAND	TWO BRIDGES DESTROYED	
	AKAROA, NEW ZEALAND	COASTAL HOMES FLOODED	
	OMARU, NEW ZEALAND	PIER DESTROYED	
	HAKODATE, JAPAN	PART OF CITY FLOODED	
1918 12 04	CALDERA, CHILE	SOME DAMAGE	

TABLE 11. CITIES AND AREAS ALONG COAST OF NORTH CHILE THAT REPORTED TSUNAMIS FROM ALL SOURCE REGIONS

EVENT DATE YEAR MO DA	SOURCE	REPORTING CITY OR REGION IN N. CHILE	S. LAT. °	W. LONG. °	RUNUP (M)	DAMAGE
1906 05 07	N. CHILE	TACNA, PERU	18.00	70.25		
1960 05 22	SC. CHILE	ARICA	18.47	70.32	2.0	
1604 11 24	PERU	ARICA	18.48	70.33		X
1615 09 16	N. CHILE	ARICA	18.48	70.33		
1647 05 07	PERU	ARICA	18.48	70.33		X
1705 11 26	N. CHILE	ARICA	18.48	70.33		X
1868 08 13	N. CHILE	ARICA	18.48	70.33	15.0	X
1869 08 24	N. CHILE	ARICA	18.48	70.33	2.0	X
1877 05 10	N. CHILE	ARICA	18.48	70.33	20.0	X
1888 03 13	BISMARCK SEA	ARICA	18.48	70.33		X
1906 05 07	N. CHILE	ARICA	18.48	70.33		
1923 08 12	N. CHILE	ARICA	18.48	70.33		
1934 12 04	N. CHILE	ARICA	18.48	70.33		
1952 11 05	KAMCHATKA	ARICA	18.48	70.33	1.2	
1955 04 19	NC. CHILE	ARICA	18.48	70.33	0.2	
1957 03 09	ALEUTIAN IS.	ARICA	18.48	70.33	1.3	
1964 03 27	ALASKA	ARICA	18.48	70.33	2.1	
1975 11 29	HAWAII	ARICA	18.48	70.33	0.4	
1868 08 13	N. CHILE	PISAGUA	19.57	70.23		X
1869 08 24	N. CHILE	PISAGUA	19.57	70.23	2.0	X
1877 05 10	N. CHILE	PISAGUA	19.57	70.23	5.0	
1881 10 27	N. CHILE	PISAGUA	19.57	70.23		
1882 09 14	N. CHILE	PISAGUA	19.57	70.23		
1966 10 17	PERU	HUARA	20.00	69.75		X
1868 08 13	N. CHILE	IQUIQUE	20.25	70.13	12.0	X
1869 08 24	N. CHILE	IQUIQUE	20.25	70.13	2.0	X
1877 05 10	N. CHILE	IQUIQUE	20.25	70.13	6.0	X
1877 08 23	N. CHILE	IQUIQUE	20.25	70.13		
1881 07 14	N. CHILE	IQUIQUE	20.25	70.13		
1885 11 12	N. CHILE	IQUIQUE	20.25	70.13		
1903 09 26	N. CHILE	IQUIQUE	20.25	70.13		
1906 08 16	C. CHILE	IQUIQUE	20.25	70.13		
1933 03 03	JAPAN	IQUIQUE	20.25	70.13	0.4	
1964 03 28	ALASKA	IQUIQUE	20.25	70.13		X
1877 05 10	N. CHILE	CHANABAYA	20.89	70.15	10.0	X
1877 05 10	N. CHILE	CALETA PABELLON DE PICA	20.90	70.16	18.0	X
1877 05 10	N. CHILE	PUNTA LOBOS	21.02	70.17	10.0	
1877 05 10	N. CHILE	GUANILLO DEL NORTE	21.20	70.08	15.0	
1868 08 13	N. CHILE	TOCOPILLA	22.08	70.17		X
1877 05 10	N. CHILE	TOCOPILLA	22.08	70.17	24.0	X
1948 12 26	N. CHILE	TOCOPILLA	22.08	70.17		
1868 08 13	N. CHILE	COBIJA	22.55	70.25		X
1836 07 03	N. CHILE	COBIJA	22.55	70.27		
1877 05 10	N. CHILE	COBIJA	22.55	70.27	9.0	X
1868 08 13	N. CHILE	MEJILLONES	23.05	70.42	6.0	X
1877 05 10	N. CHILE	MEJILLONES	23.08	70.43	21.0	X
1877 05 10	N. CHILE	ANTOFAGASTA	23.65	70.42	6.0	X
1878 06 12	N. CHILE	ANTOFAGASTA	23.65	70.42		
1922 11 11	NC. CHILE	ANTOFAGASTA	23.65	70.42		
1936 07 13	N. CHILE	ANTOFAGASTA	23.65	70.42		
1960 05 22	SC. CHILE	ANTOFAGASTA	23.65	70.42	1.4	
1966 12 28	N. CHILE	ANTOFAGASTA	23.65	70.43		
1868 08 13	N. CHILE	TALTAL	25.43	70.55		
1906 08 16	C. CHILE	TALTAL	25.43	70.55		
1936 07 13	N. CHILE	TALTAL	25.43	70.55	0.8	

NORTH CENTRAL CHILE

[27° S. - <33° S.]

This region, known as the Transverse Valley because of its east-west-trending transverse structures, is characterized by a shallow dipping seismic zone and by a lack of Neogene volcanism (McCann, 1979). Destructive tsunamis this century have occurred in this area at the rate of about one event every 20 years.

The 1922 and 1943 events, both of magnitude 8.3, demonstrate that this region has a potential for destructive earthquakes. Both the 1955 and 1971 earthquakes did not have large magnitudes, when compared to magnitudes of other earthquakes that generated damaging tsunamis, yet both produced locally damaging tsunamis. The 1730 and 1922 events generated tsunamis that were damaging as far away as Japan, indicating that Japan may be vulnerable to future tsunamis generated in this area of Chile.

Table 12 lists the tsunamigenic earthquakes that have occurred in this region, together with information about the tsunamis they produced. (See table 1 for alternate data, erroneous dates, and events that appeared in the literature but are not believed to have been tsunamis.) The data included in table 12 are believed to be the most accurate available. Of the 27 events listed, seven were damaging locally and three were reported in areas of the Pacific outside the west coast of South America. About one-half the events (14) are given at least a "3" (probable) validity rating, and the validity of other events is less certain. The events listed in table 12 are plotted on a map of North Central Chile in figure 20.

The literature gives some information about the size of the tsunami for 16 of the events listed in table 12. The size may have been indicated by a tsunami magnitude, a tsunami intensity, or a measured or estimated runup height. Of the 16 events that had such information, only three had reported runup heights of less than 1 meter. The reason that some events that had significant runup amounts were not considered to be probable tsunamis is that they do not clearly fit the definition of a tsunami as described in the introduction. Figure 21 gives the frequency of occurrence of the tsunamigenic earthquakes for each degree of coastline of North Central Chile. Shaded areas indicate the number of tsunamigenic earthquakes that caused damage.

Table 13 lists the dates of 18 tsunamis that were generated in North Central Chile and the cities that reported each event. If a value is not given for the runup height and an "X" does not appear in the damage column, then the event was reported in the literature but descriptive effect information was not given. The areas of Peru-Chile coast affected by the tsunamis of July 8, 1730, Feb. 20, 1835, and Nov. 11, 1922, are shown in figures 22, 23, and 24. The sites where damage occurred are shaded.

Table 14 gives the dates of three tsunamis in North Central Chile and the names of several cities where the tsunamis were observed. Figure 40 shows the area affected by the 1730 and 1819 tsunamis outside the Peru-Chile coastal area, and figure 25 shows the extent of the effects of the 1922 tsunami outside Peru-Chile Tsunamis from North Central Chile have been observed as far distant as Hawaii and Japan. Of the tsunamis observed in those areas, property damage was most extensive from the Nov. 11, 1922, event.

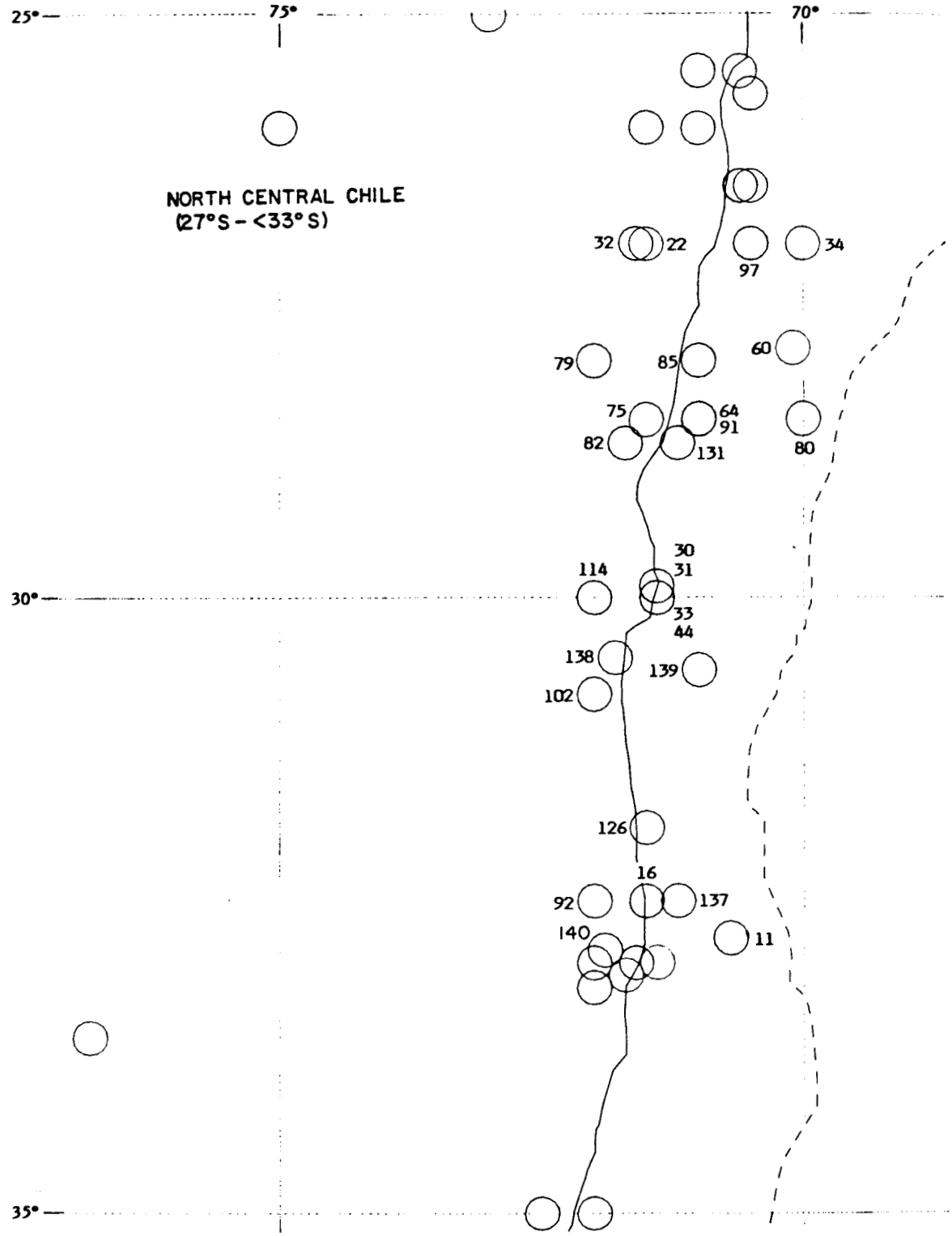


FIGURE 20. EPICENTERS OF TSUNAMIGENIC EARTHQUAKES OF NORTH CENTRAL CHILE
[NUMBERS REFER TO EVENT NO. IN TABLE 12.]

TABLE 12. TSUNAMIGENIC EARTHQUAKES OF NORTH CENTRAL CHILE

EVENT NO.		EVENT DATE YEAR	MO	DA	TIME	EARTHQUAKE DATA S. LAT. °	W. LONG. °	MAGNITUDE	DEPTH (KM)	TSUNAMI DATA RUNUP (M)	MAGNITUDE	INTENSITY	VALIDITY	REFERENCES
11		1687	07	12	0700	32.8	70.7	7.3					4	52
16	*<	1730	07	08	1300	32.5	71.5	8.7		16.0	4.0	3.5	4	1,9,10,31,38,51
22	*<	1819	04	11	0300	27.0	71.5	8.5		4.0	2.0	2.0	4	1,5,9,31,38,51
30		1847	10	19		(29.9	71.4)							9
31		1849	12	17	1010	29.9	71.4	7.5		5.0	2.3		4	52
32		1851	05	26	1814	27.0	71.6	7.2		3.0	1.6	2.0	4	9,10,31,51
33		1858	04	24		(30.0	71.4)	6.5		2.0	1.0			9,38
34	*	1859	10	05	1500	27.0	70.0	7.7		5.5	2.5	2.5	4	1,9,10,31,38,51
44		1869	08	09		(30.0	71.4)			3.0	1.6	1.5	3	9,38
60		1882	02	23		(27.9	70.1)			0.7		0.0		9,38
64		1903	12	07	1509	28.5	71.0	6.5		0.7	-0.5	0.0	3	9,38,51
75		1918	05	20	1755	28.5	71.5	7.9	80					51
79		1922	11	07	2300	28.0	72.0	7.0	33					51
80	*<	1922	11	11	0432	28.5	70.0	8.3	25	9.0	3.2	2.5	4	38,51
82		1923	05	04	2227	28.7	71.7	7.0	60					9,10,38,52
85		1926	12	09	2242	28.0	71.0	6.0		1.5	0.6	0.5		9,38,51
91		1930	12	29	0326	28.5	71.0	6.0		1.0	0.0	0.5	3	1,10,38
92		1931	03	18	0802	32.5	72.0	7.1	33				3	51
97		1939	04	18	0623	27.0	70.5	7.4	100					51
102	*	1943	04	06	1607	30.8	72.0	8.3	33	1.0	0.0	0.0	4	1,5,9,10,20,31,38,47,51
114	*	1955	04	19	2024	30.0	72.0	7.1	33	1.0	0.0	1.0	4	1,5,9,10,47,51
126		1965	03	22	2256	31.9	71.5	6.0	58					51
131		1967	11	15	2132	28.7	71.2	6.2	15					51
137	*	1971	07	09	0303	32.5	71.2	6.6		1.2	0.3			52
138		1972	06	08	1854	30.5	71.8	6.6	39					51
139		1972	12	29	0451	30.6	71.0	6.0	60					51
140		1973	10	05	0548	32.9	71.9	6.5	14	0.4	-1.0	0.5	4	9,22,27,38,47,51

NOTE: * Indicates that the earthquake caused a destructive tsunami.

< Indicates that the tsunami was reported outside the South American coast.

() Parentheses around the latitude and longitude indicate that the epicenter was derived from the coordinates of a city name given in the reference.

See footnotes at end of table 1 for explanation of column headings.

Table 15 is a summary of the property damage and number of deaths that accompanied tsunamis in North Central Chile. Caldera has been repeatedly damaged by these giant waves (1859, 1918, 1922); in 1922, the tsunami inundated the coast at Caldera as much as 100 meters and destroyed many houses. The 1922 tsunami was damaging not only locally, but also in Hawaii, American Samoa, Japan, and Taiwan.

Table 16 lists the names of cities in North Central Chile that reported tsunamis from all source regions. Figure 26, a bar graph of the data given in table 16, shows the number of tsunamis per degree of coastline.

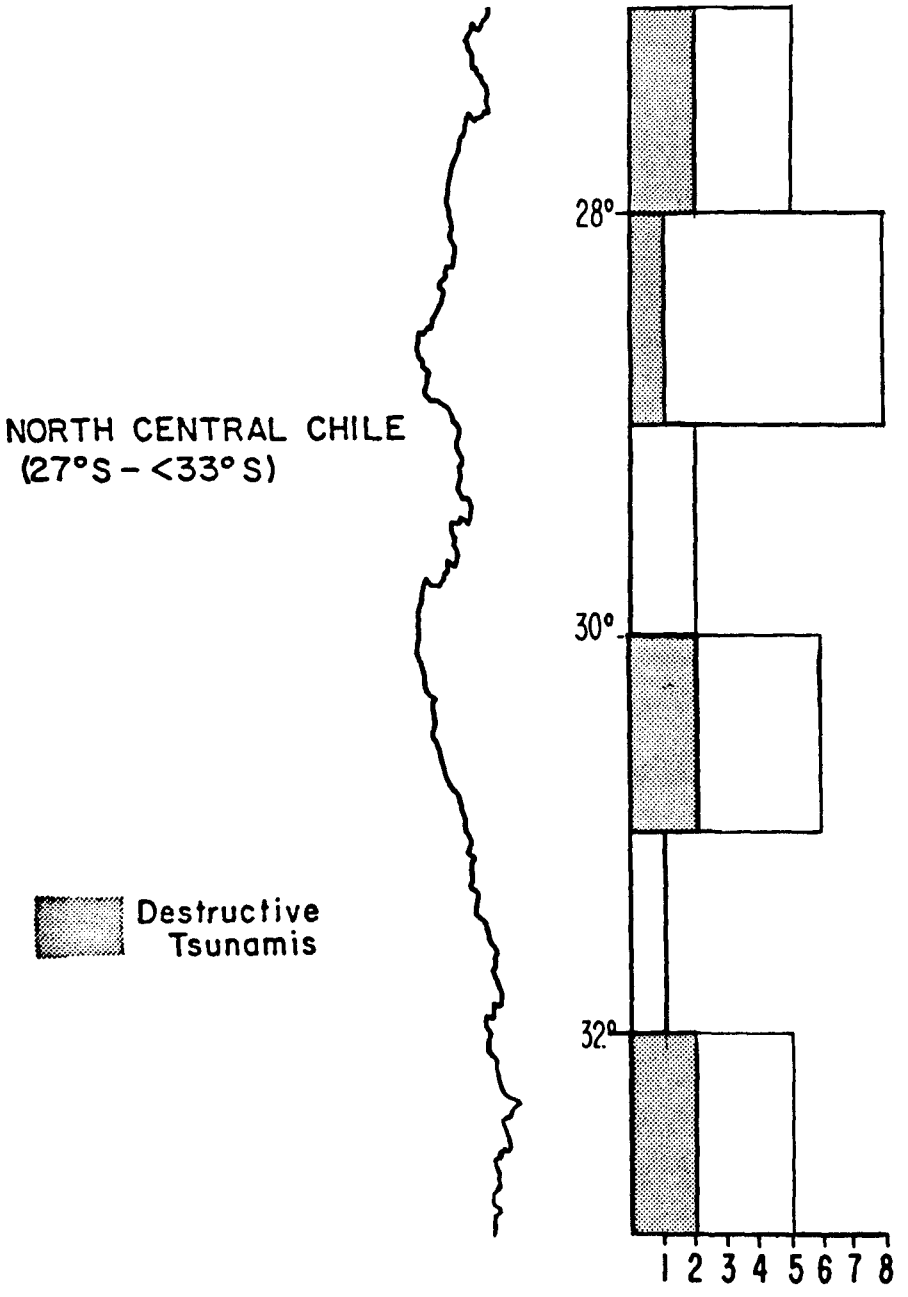


FIGURE 21. NUMBER OF TSUNAMIGENIC EARTHQUAKES PER DEGREE OF NORTH CENTRAL CHILE COASTLINE

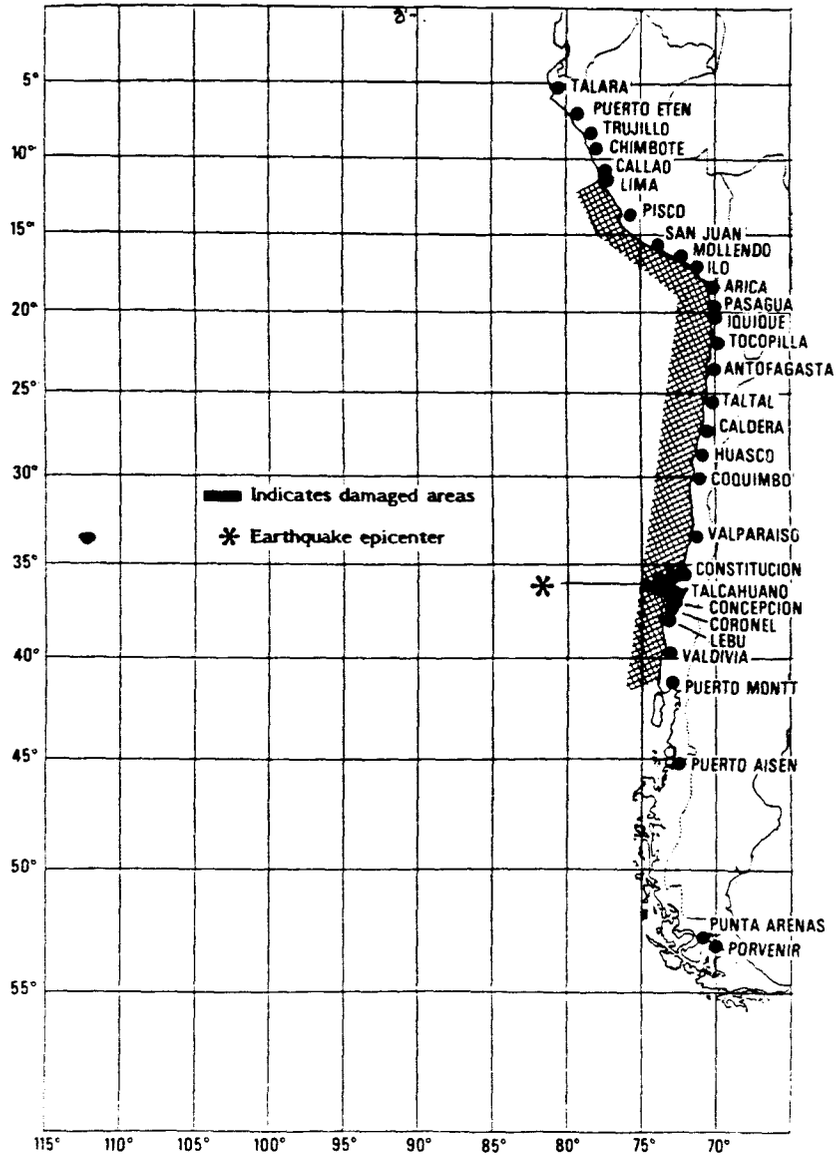


FIGURE 22. AREA OF PERU-CHILE COAST AFFECTED BY CHILE TSUNAMI OF JULY 8, 1730

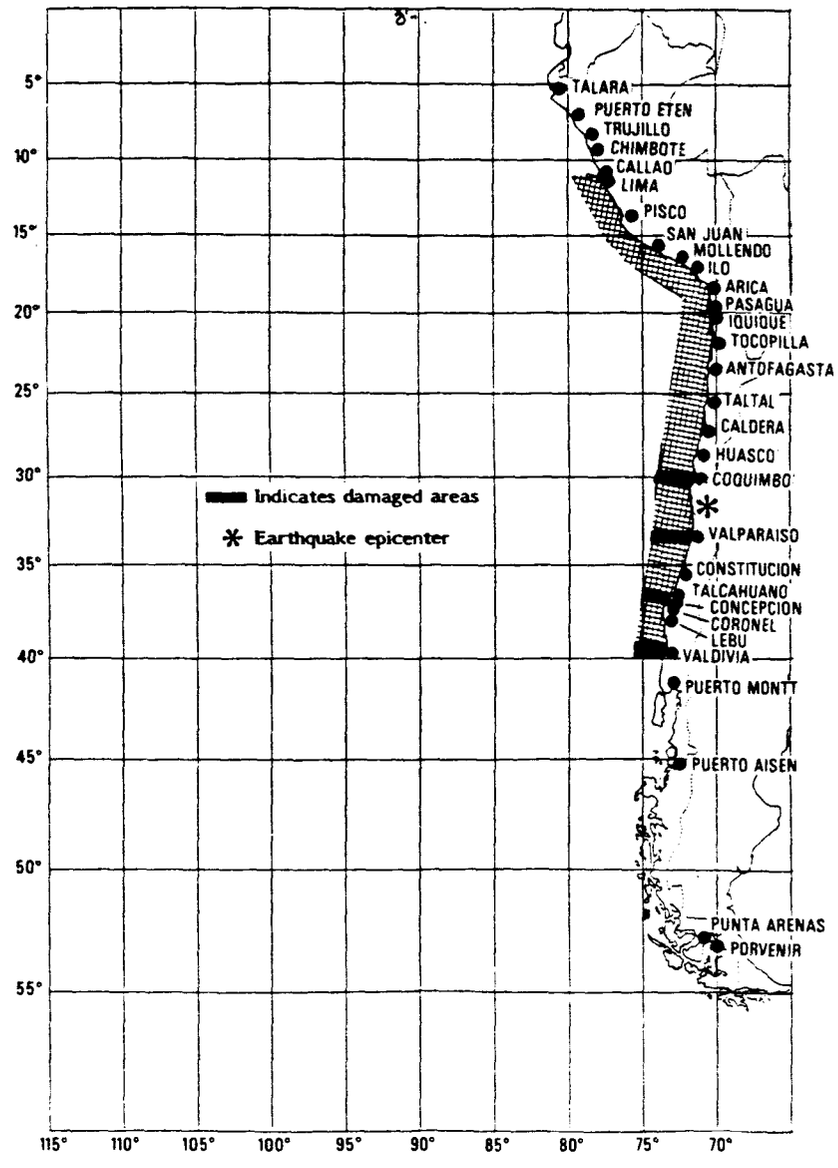


FIGURE 23. AREA OF PERU-CHILE COAST AFFECTED BY CHILE TSUNAMI OF FEB. 20, 1835

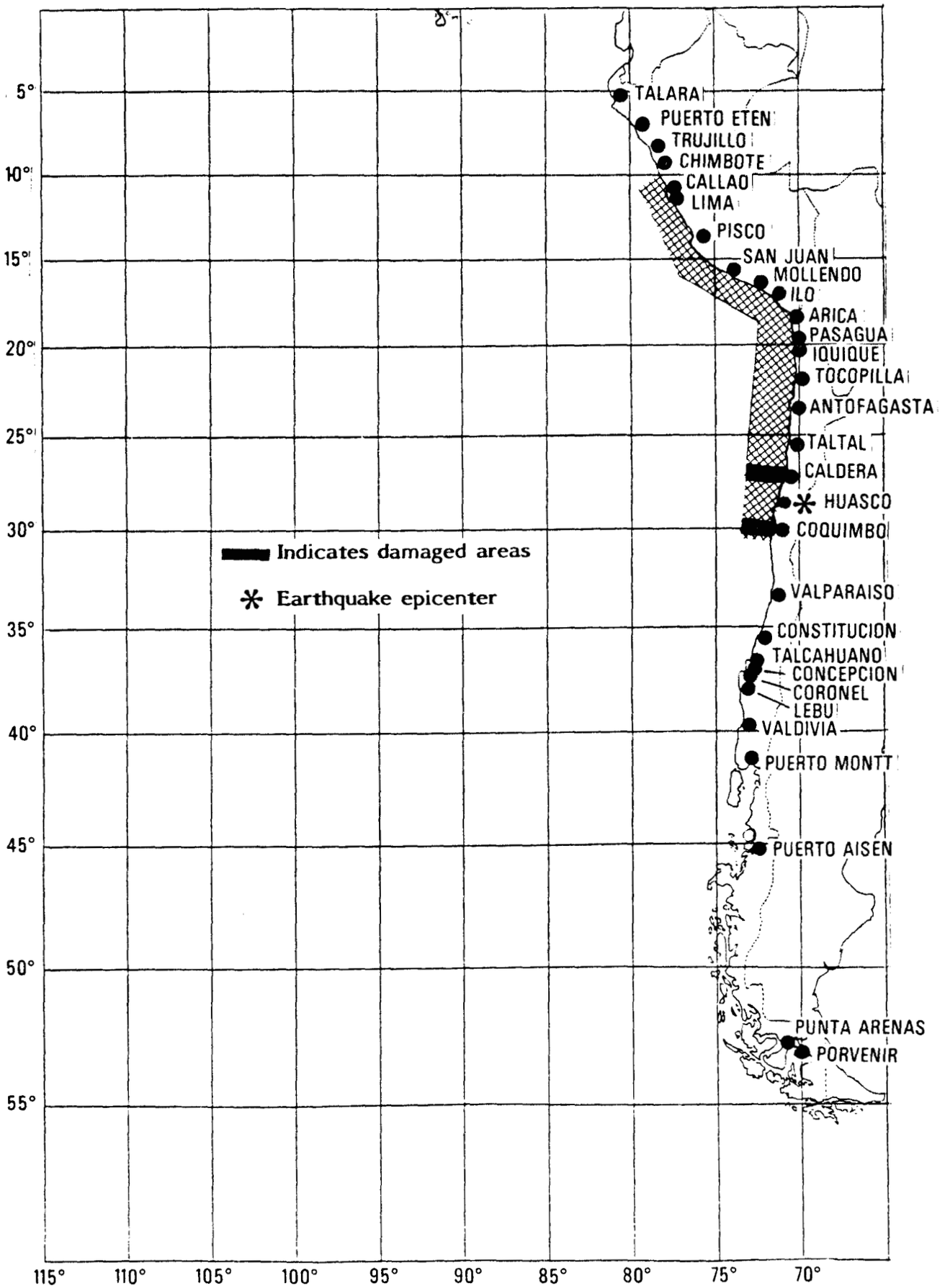


FIGURE 24. AREA OF PERU-CHILE COAST AFFECTED
BY CHILE TSUNAMI OF NOV. 11, 1922

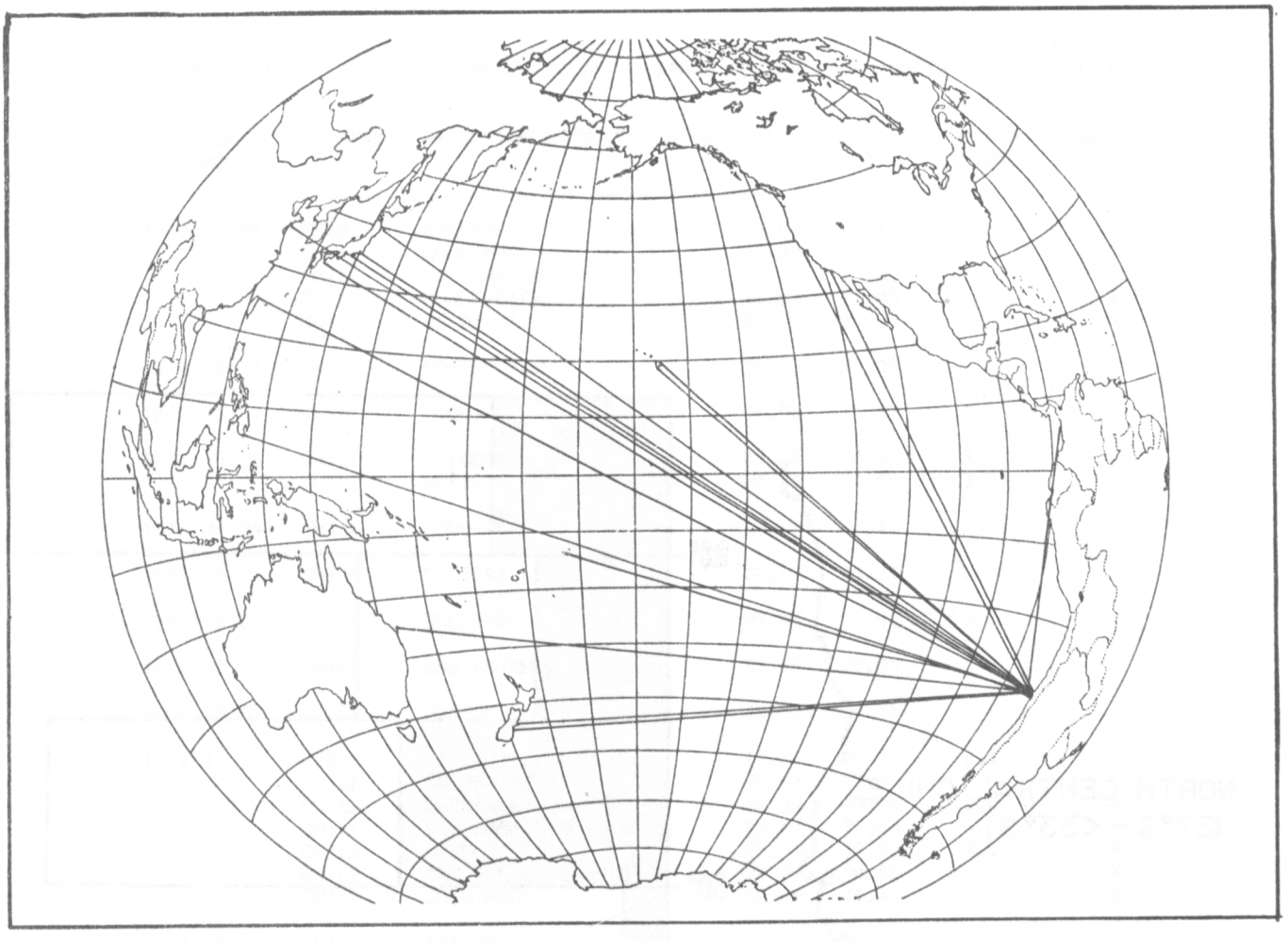


FIGURE 25. AREAS OUTSIDE PERU-CHILE REPORTING CHILE TSUNAMI OF NOV. 11, 1922

CORRAL BAJO, CHILE, AFTER TSUNAMI OF MAY 22, 1960

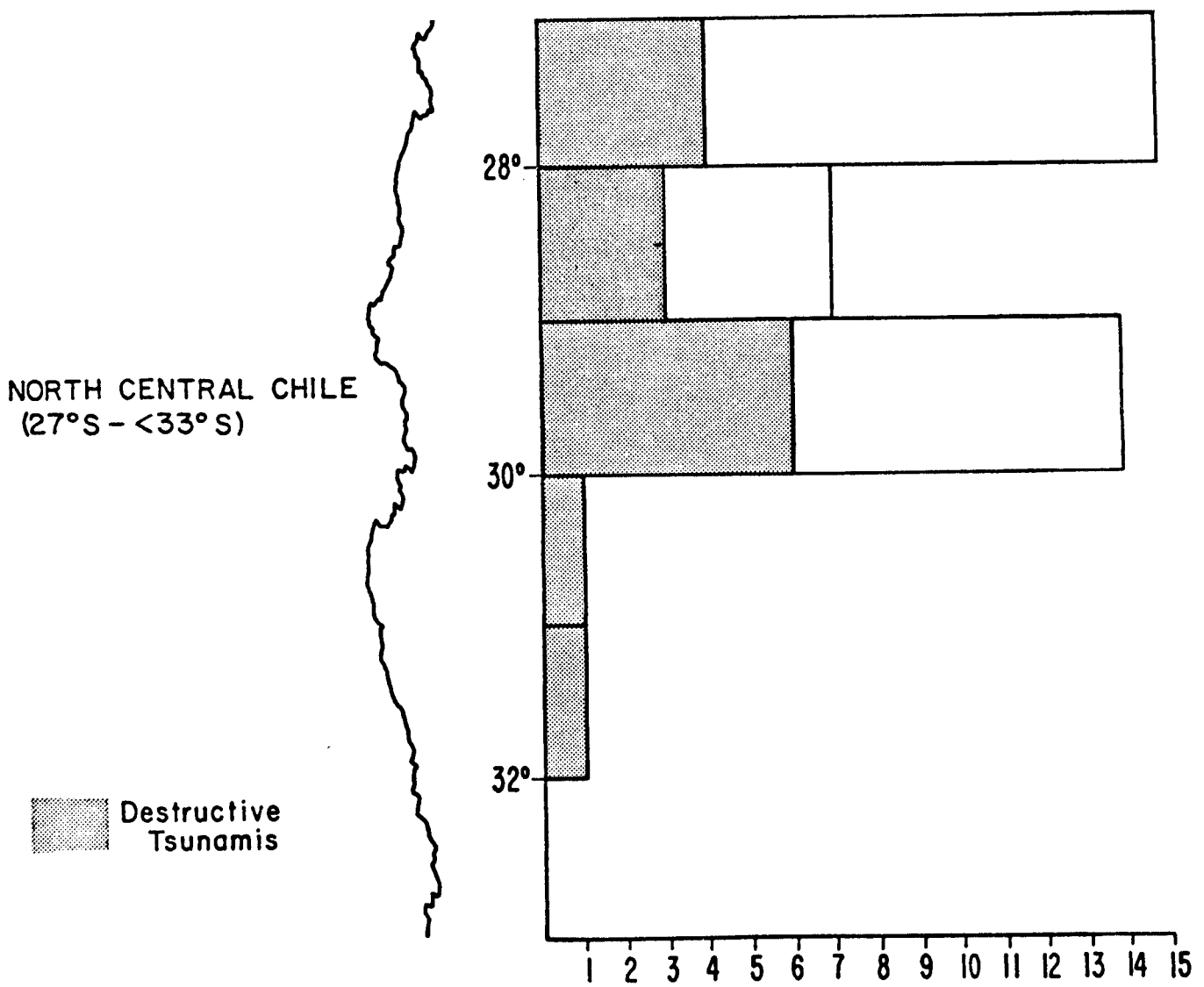


FIGURE 26. NUMBER OF REPORTED OBSERVATIONS OF TSUNAMI EFFECTS PER DEGREE OF NORTH CENTRAL CHILE COASTLINE

TABLE 13. EFFECTS IN PERU-CHILE OF TSUNAMIS GENERATED IN NORTH CENTRAL CHILE

EVENT DATE YEAR MO DA	COUNTRY	REPORTING CITY OR REGION	S. LAT. °	W. LONG. °	RUNUP (M)	DAMAGE
1730 07 08	PERU	CALLAO	12.08	77.13		
	CHILE	COQUIMBO	29.95	71.42		X
	CHILE	VALPARAISO	33.08	71.67		X
	CHILE	CONCEPCION	36.83	73.05		X
	CHILE	VALDIVIA	39.77	73.25		X
1819 04 11	CHILE	CONCEPCION	36.83	73.05		X
1849 12 17	CHILE	COQUIMBO	29.95	71.42	5.0	
1851 05 26	CHILE	CALDERA	27.07	70.83	1.5	
	CHILE	HUASCO	28.50	71.25	3.0	
1858 04 24	CHILE	COQUIMBO	29.95	71.42		
1859 10 05	CHILE	CALDERA	27.07	70.83	5.5	X
1869 08 09	CHILE	COQUIMBO	29.95	71.42	3.0	
1882 02 23	CHILE	SAN ANTONIO	27.88	70.05		
1903 12 07	CHILE	HUASCO	28.50	71.25		
1922 11 11	PERU	CALLAO	12.08	77.13	2.4	
	CHILE	ANTOFAGASTA	23.65	70.42		
	CHILE	CHANARAL	26.38	70.67	9.0	X
	CHILE	SAN AMBROSIO ISLANDS	26.47	79.88		
	CHILE	CALDERA	27.07	70.83	7.0	X
	CHILE	SAN FELIX ISLANDS	28.97	70.50		X
	CHILE	COQUIMBO	29.95	71.42	7.0	X
1923 05 04	CHILE	ATACAMA	27.50	70.00		
1926 12 09	CHILE	CHANARAL	26.38	70.67		
	CHILE	CALDERA	27.07	70.83		
	CHILE	HUASCO	28.50	71.25		
1930 12 29	CHILE	COQUIMBO	29.95	71.42		
1943 04 06	CHILE	LOS VILOS	31.93	76.58		X
	CHILE	VALPARAISO	33.08	71.67	0.8	
1955 04 19	CHILE	ARICA	18.48	70.33	0.2	
	CHILE	LA SERENA	29.90	71.30	1.0	X
	CHILE	COQUIMBO	29.95	71.42	1.0	
	CHILE	TONGOY	30.27	71.52	1.0	X
1971 07 09	CHILE	VALPARAISO	33.08	71.67	1.2	X
1973 10 05	CHILE	VALPARAISO	33.08	71.67	0.4	

TABLE 14. EFFECTS OUTSIDE PERU-CHILE OF TSUNAMIS GENERATED IN NORTH CENTRAL CHILE

EVENT DATE YEAR MO DA	COUNTRY OR STATE	REPORTING CITY OR REGION	LAT. °	LONG. °	RUNUP (M)	DAMAGE	PACIFIC QUADRANT
1730 07 08	JAPAN	NE. HONSHU				X	NW. PACIFIC
1819 04 11	HAWAII	W. HAWAII ISLAND					NE. PACIFIC
	HAWAII	HONOLULU	21.32	-157.83			NE. PACIFIC
	PACIFIC	MANGAREVA	23.12	134.95			NW. PACIFIC
1922 11 11	COLUMBIA	APIA	5.08	- 75.97	1.8		NE. PACIFIC
	HAWAII	HILO	19.70	-155.07	2.1	X	NE. PACIFIC
	HAWAII	HONOLULU	21.32	-157.83	0.3		NE. PACIFIC
	CALIFORNIA	SAN DIEGO	32.70	-117.17	0.20		NE. PACIFIC
	CALIFORNIA	SAN FRANCISCO	37.80	-122.47	0.20		NE. PACIFIC
	PHILIPPINES	ZAMBOANGO	6.90	122.08	0.10		NW. PACIFIC
	TAIWAN	TANSHUI	25.17	121.43		X	NW. PACIFIC
	JAPAN	NAGASAKI	32.68	135.18		X	NW. PACIFIC
	JAPAN	CHOSHI	35.72	140.83			NW. PACIFIC
	JAPAN	OSAKA	35.95	137.27		X	NW. PACIFIC
	JAPAN	KOBE	35.97	123.67			NW. PACIFIC
	JAPAN	OFUNATO (IWATE)	39.07	141.72		X	NW. PACIFIC
	W. SAMOA	APIA	-13.80	-171.75	1.8		SE. PACIFIC
	W. SAMOA	PAGO PAGO	-14.27	-171.72	1.8	X	SE. PACIFIC
	AUSTRALIA	SYDNEY	-33.92	151.17	0.15		SW. PACIFIC
	NEW ZEALAND	TIMARU	-44.38	171.23			SW. PACIFIC
	NEW ZEALAND	PORT CHALMERS	-45.82	170.65	0.18		SW. PACIFIC

TABLE 15. SUMMARY OF DAMAGE AND NUMBER OF DEATHS CAUSED BY NORTH CENTRAL CHILE TSUNAMIS

EVENT DATE YEAR MO DA	REPORTING CITY OR REGION	EFFECTS	DEATHS
1730 07 08	CONCEPCION, CHILE	TOWN INUNDATED	
	VALDIVIA, CHILE	SOME DESTRUCTION	
	COQUIMBO, CHILE	RANCHES DESTROYED	
	OJIKA PENINSULA, SANRIKU, JAPAN	RICE FIELDS FLOODED	
1819 04 11	COPIAPO, CHILE	SEA OVERFLOWED LAND 300 M	
	CONCEPCION, CHILE	SCHOONER GROUNDED	
1859 10 05	CALDERA, CHILE	BOATS, PORT INSTALLATIONS DAMAGED	
1922 11 11	COQUIMBO, CHILE	GREAT DESTRUCTION, 2-KM INUNDATION	HUNDREDS
	CHANARAL, CHILE	DESTRUCTION 4 BLOCKS INLAND	
	CALDERA, CHILE	HOUSES DESTROYED, 100-M INUNDATION	
	HILO, HAWAII ISLAND	MINOR DAMAGE	
	PAGO PAGO, AMERICAN SAMOA	MINOR DAMAGE	
	JAPAN, TAIWAN	MINOR DAMAGE	
1943 04 06	LOS VILOS, CHILE	FISHING VESSELS DAMAGED	
1955 04 19	LA SERENA AND TONGOY, CHILE	EXTENSIVE DAMAGE	
1971 07 09	VALPARAISO, CHILE	SOME DAMAGE	

TABLE 16. CITIES AND AREAS ALONG THE COAST OF NORTH CENTRAL CHILE THAT REPORTED TSUNAMIS FROM ALL SOURCE REGIONS

EVENT DATE YEAR MO DA	SOURCE	REPORTING CITY OR REGION IN NORTH CENTRAL CHILE	S. LAT. °	W. LONG. °	RUNUP (M)	DAMAGE
1868 08 13	N. CHILE	CHANARAL	26.38	70.67	5.0	X
1877 05 10	N. CHILE	CHANARAL	26.38	70.67	5.0	X
1877 10 09	N. CHILE	CHANARAL	26.38	70.67		
1922 11 11	NC. CHILE	CHANARAL	26.38	70.67	9.0	X
1926 12 09	NC. CHILE	CHANARAL	26.38	70.67		
1922 11 11	NC. CHILE	SAN AMBROSIO ISLANDS	26.47	79.88		
1851 05 26	NC. CHILE	CALDERA	27.07	70.83	1.5	
1859 10 05	NC. CHILE	CALDERA	27.07	70.83	5.5	X
1868 08 13	N. CHILE	CALDERA	27.07	70.83		X
1877 05 10	N. CHILE	CALDERA	27.07	70.83	2.0	
1918 12 04	N. CHILE	CALDERA	27.07	70.83	5.0	X
1922 11 11	NC. CHILE	CALDERA	27.07	70.83	7.0	X
1926 12 09	NC. CHILE	CALDERA	27.07	70.83		
1966 12 28	N. CHILE	CALDERA	27.07	70.88	0.4	
1906 08 16	C. CHILE	CALDERA	27.07	70.83		
1952 11 05	KAMCHATKA	CALDERA	27.08	70.68	2.8	
1957 03 09	ALEUTIANS	CALDERA	27.08	70.68	1.3	
1960 05 22	SC. CHILE	CALDERA	27.08	70.68	2.9	
1975 11 20	HAWAII	CALDERA	27.08	70.68	0.5	
1923 05 04	NC. CHILE	ATACAMA	27.50	70.00		
1882 02 23	NC. CHILE	SAN ANTONIO	27.88	70.05		
1877 05 10	N. CHILE	CARRIZAL BAJO	28.07	70.58	1.5	
1868 08 13	N. CHILE	CARRIZAL BAJO	28.13	71.25		X
1851 05 26	NC. CHILE	HUASCO	28.50	71.25	3.0	
1903 12 07	NC. CHILE	HUASCO	28.50	71.25		
1926 12 09	NC. CHILE	HUASCO	28.50	71.25		
1964 03 27	ALASKA	HUASCO	28.50	71.25		X
1922 11 11	NC. CHILE	SAN FELIX ISLANDS	28.97	70.50		X
1955 04 19	NC. CHILE	LA SERENA	29.90	71.30	1.0	X
1730 07 08	NC. CHILE	COQUIMBO	29.95	71.42		X
1849 12 17	NC. CHILE	COQUIMBO	29.95	71.42	5.0	
1858 04 24	NC. CHILE	COQUIMBO	29.95	71.42		
1868 08 13	N. CHILE	COQUIMBO	29.95	71.42	7.5	X
1869 08 09	N. CHILE	COQUIMBO	29.95	71.42	3.0	
1877 05 10	N. CHILE	COQUIMBO	29.95	71.42	2.0	
1880 08 15	NC. CHILE	COQUIMBO	29.95	71.42		
1906 08 16	C. CHILE	COQUIMBO	29.95	71.42		
1922 11 11	NC. CHILE	COQUIMBO	29.95	71.42	7.0	X
1930 12 29	NC. CHILE	COQUIMBO	29.95	71.42		
1952 11 05	KAMCHATKA	COQUIMBO	29.95	71.42		X
1955 04 19	NC. CHILE	COQUIMBO	29.95	71.42	1.0	
1964 03 27	ALASKA	COQUIMBO	29.95	71.42	4.0	X
1960 05 22	SC. CHILE	COQUIMBO	29.95	71.42	2.1	
1955 04 19	NC. CHILE	TONGOY	30.27	71.52	1.0	X
1943 04 06	NC. CHILE	LOS VILOS	31.93	76.58		X

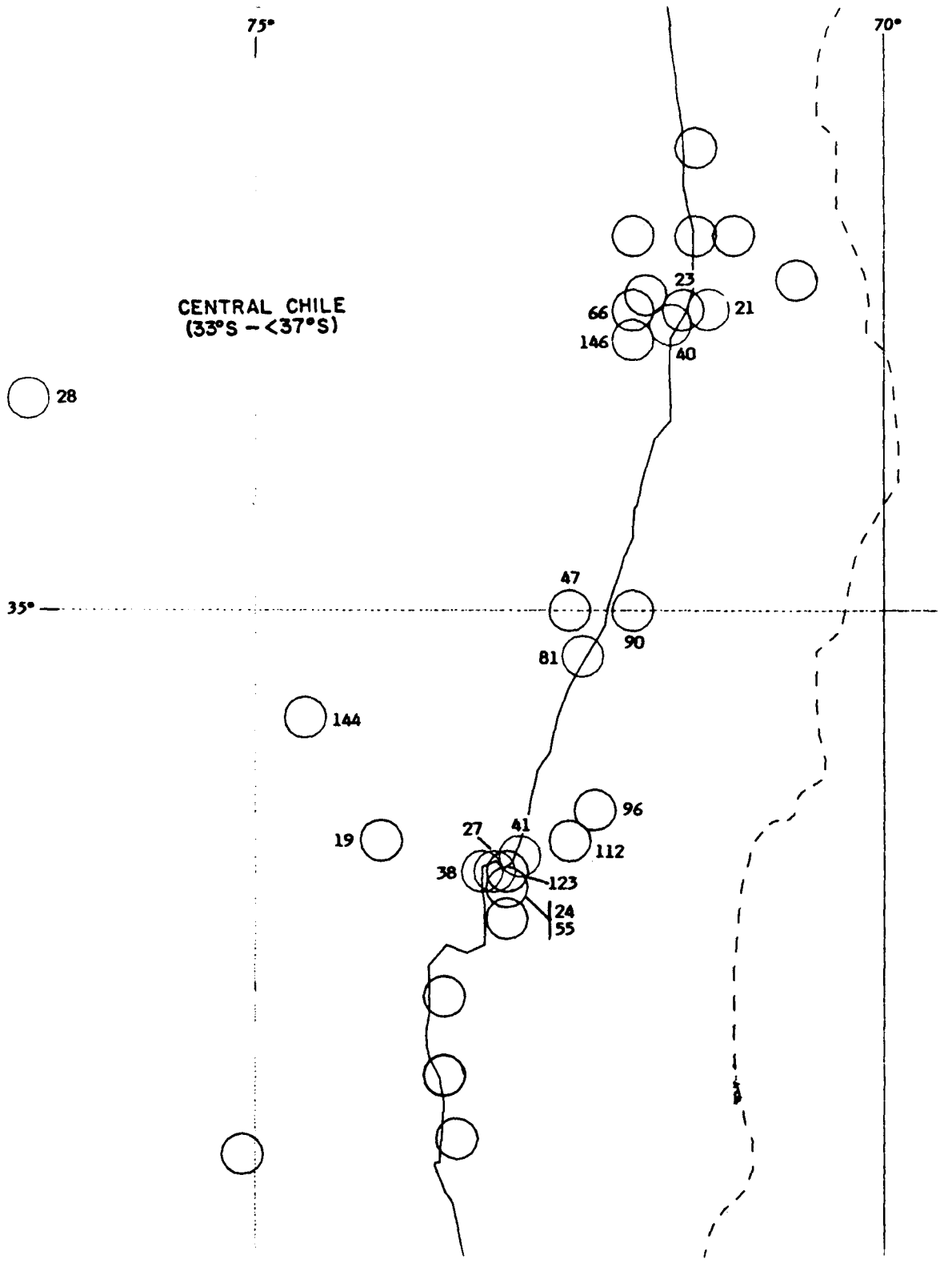


FIGURE 27. EPICENTERS OF TSUNAMIGENIC EARTHQUAKES OF CENTRAL CHILE
[NUMBERS REFER TO EVENT NO. IN TABLE 17.]

CENTRAL CHILE

[33° S. - <37° S.]

Near Valparaiso, 33° S. - <34° S.

The region near Valparaiso in Central Chile is marked by the intersection of the Juan Fernandez Ridge with the Peru-Chile trench, an increase in the dip of the Chilean seismic (Benioff) zone, and the abrupt appearance of Neogene volcanism to the south (McCann, 1979). Six tsunamigenic earthquakes have occurred in this area. The Nov. 11, 1822, and Aug. 17, 1906, earthquakes centered almost at the same location; both had magnitudes of 8.5 or larger and both caused damage. A magnitude 7.8 earthquake, which occurred in this area on Mar. 3, 1985, generated a small tsunami. Large-magnitude events tend to migrate south along this section of the seismic zone. That in 1985 was slightly south of the 1906 event and may have partially relieved the strain in this area.

South of Valparaiso, 34° S. - <36° S.

A moderate-size seismic gap exists south of Valparaiso, where the potential for future earthquakes is good (McCann, 1979). Near the end of this century a new series of earthquakes could start south of Valparaiso, and the epicenters could progress as far south as 46° S. latitude, including the entire Central Valley Province of Central and Southern Chile (Garcia, 1976). Four events having magnitudes of 7.5 or larger have occurred in this area, but none of these generated a destructive tsunami.

Concepcion Region, 36° S. - <37° S.

In the southern part of Central Chile, the interval between the large tsunamigenic earthquakes of 1570 (South Central Chile), 1657 (South Central Chile), 1835 and 1928 (Concepcion area, 36.8° S.) is about 90 years. All these earthquakes have a magnitude of 8+, and their accompanying tsunamis have similar characteristics. At the southern boundary of this region a shift occurs in major seismicity from the Range Fault to an offshore structure occurs. The Transverse Ranges intrude the Central Valley at this point, and appear to mark the boundary of another tectonic unit along the Peru-Chile coast (Lomitz, 1970).

Table 17 lists the tsunamigenic earthquakes that have occurred in Central Chile, and gives information about the tsunamis they produced. (See table 1 for alternate data, erroneous dates, and events that appeared in the literature but are not believed to have been tsunamis). The data included in table 17 are believed to be the most accurate available. Of the 19 events listed, four were damaging locally and three were reported in areas of the Pacific outside the west coast of South America. One-half the events (9) are given a validity rating of "3" or "4."

The literature gives some information about the size of the tsunami for more than two-thirds (14) of the events in table 17. The size may have been indicated by a tsunami magnitude, a tsunami intensity, or a measured or estimated runup height. Of the 14 events that had such information, only three had reported runup heights of less than 1 meter. The event on Feb. 12, 1839, is

unusual in that it was reportedly caused by an underwater eruption located between Valparaiso and Juan Fernandez Islands, Chile. The events listed in table 17 are plotted on a map of Central Chile in figure 27. Figure 28 shows the frequency of occurrence of the tsunamigenic earthquakes for each degree of the coastline of Central Chile. Shaded areas indicate the number of tsunamigenic earthquakes that caused damage.

Table 18 lists the dates of 10 tsunamis that were generated in Central Chile and gives names of cities that reported each event. If a value is not given for the runup height and an "X" does not appear in the damage column, then the area was reported in the literature but descriptive effect information was not given. Tsunamis in Central Chile have been observed as far north as Central Peru and as far south as Chiloe Island (42° S. latitude).

The Aug. 17, 1906, event caused the most damage and affected the largest extent of coastline in this area. Figure 29 shows the extent of the coastline affected by the 1906 event (hatched area) and the areas where damage occurred (dark area).

Table 19 gives dates of four tsunamis generated in Central Chile and the names of cities outside the area that reported the events. The 1906 event caused slight damage at three sites in Hawaii, and the 1751 event inundated areas of southeast Honshu, Japan. The most recent tsunami described in the present report occurred in this region on March 3, 1985. It was recorded at Hawaii, Alaska, Japan, and Tahiti, in addition to other areas. Figures 30 and 31 show the extent of the area outside Peru-Chile reporting the tsunamis of 1906 and 1985, and figure 40 depicts similar information for the tsunamis of 1751 and 1835.

Table 20 is a summary of property damage and number of deaths caused by tsunamis in Central Chile. Although most tsunamis generated in this area have caused only minor effects, those in 1751 and 1835 caused fatalities. Table 21 lists the names of cities in Central Chile that have reported tsunamis, the dates of the tsunamis, the runup heights, and whether damage occurred. Figure 32, a bar graph of the data shown in table 21, shows the number of tsunamis per degree of coastline.

TABLE 17. TSUNAMIGENIC EARTHQUAKES OF CENTRAL CHILE

EVENT NO.	EVENT DATE YEAR MO DA	TIME	EARTHQUAKE DATA S. LAT. °	W. LONG. °	MAGNITUDE	DEPTH (KM)	TSUNAMI DATA RUNUP (M)	MAGNITUDE	INTENSITY	VALIDITY	REFERENCES
19 *<	1751 05 25	0500	36.5	74.0	6.0		3.5	1.8	3.5	4	1,9,10,31,38,49,51
21	1811 11 19		(33.0	71.4)			4.0	2.0	2.0		9,38
23 *	1822 11 19	0230	33.0	71.6	8.5		3.5	2.0	2.0	4	52
24 *<	1835 02 20	1530	36.8	73.0	8.2		24.0	4.0	3.0	4	52
27	1838 05 07		(36.7	73.1)			0.7		0.0		9,38
28	1839 02 12		33.6	76.8							9,38
38	1868 09 14		(36.7	73.2)			1.0		0.5		9,38
40	1868 10 16		(33.1	71.7)			1.0		0.5	3	9,38
41	1869 01 27		(36.6	72.9)			0.7		0.0	3	9,38
47	1871 03 25	1454	35.0	72.5	7.5		1.0		0.5	3	9,38,52
55 *	1878 02 14		(36.8	73.0)			0.7		0.0		9,38
66 *<	1906 08 17	0040	33.0	72.0	8.6	25	3.6	1.8	2.0	4	9,10,18,20,31,38,51
81	1923 02 17		(35.3	72.4)			1.5	0.6	1.5		9,38
90	1928 12 01	0406	35.0	72.0	8.4	25	1.5	0.6	0.5	3	1,9,31,38,51
96	1939 01 25	0332	36.3	72.3	8.3	60					51
112	1953 05 06	1717	36.5	72.5	7.6	60					51
123	1961 10 18	1652	36.7	73.0	6.5	15					51
144	1985 03 03	2247	33.2	72.0	7.8	SH	2.5	0.1		4	35
146	1975 05 10	1429	35.7	74.6	7.8						51

NOTE: * Indicates that the earthquake caused a destructive tsunami.
< Indicates that the tsunami was reported outside the South American coast.
() Parentheses around the latitude and longitude indicate that the epicenter was derived from the coordinates of a city name given in the reference.
SH in depth column = shallow.
See footnotes at end of table 1 for explanation of column headings.

TABLE 18. EFFECTS IN PERU-CHILE OF TSUNAMIS GENERATED IN CENTRAL CHILE

EVENT DATE YEAR MO DA	COUNTRY	REPORTING CITY OR REGION	S. LAT. °	W. LONG. °	RUNUP (M)	DAMAGE
1751 05 25	PERU	CALLAO	12.08	77.13		
	CHILE	JUAN FERNANDEZ IS.	33.00	80.00		X
	CHILE	VALPARAISO	33.08	71.67		
	CHILE	CONCEPCION	36.83	73.05	3.5	X
1811 11 19	CHILE	VALPARAISO	33.08	71.67	4.0	
1822 11 19	CHILE	VALPARAISO	33.08	71.67	3.5	X
1835 02 20	PERU	SAN VINCENTE DE CANETE	13.10	76.38		X
	CHILE	JUAN FERNANDEZ IS.	33.00	80.00	4.5	
	CHILE	VALPARAISO	33.08	71.67	0.5	
	CHILE	CONSTITUCION	35.33	72.42	3.5	
	CHILE	COLIUMO BAY	35.52	72.95	4.0	
	CHILE	COELEMA	36.48	72.70	24.0	
	CHILE	TOME	36.63	72.95	4.0	X
	CHILE	TALCAHUANO	36.67	73.17	9.0	X
	CHILE	PENCO	36.75	73.00		X
	CHILE	CONCEPCION	36.83	73.05	18.0	
	CHILE	ISLA MOCHA	37.50	73.18		
	CHILE	VALDIVIA	39.77	73.25		X
	CHILE	CHILOE ISLAND	42.50	73.92		
1868 10 16	CHILE	VALPARAISO	33.08	71.67		

TABLE 18. EFFECTS IN PERU-CHILE OF TSUNAMIS GENERATED IN CENTRAL CHILE (CONT.)

EVENT DATE YEAR MO DA	COUNTRY	REPORTING CITY OR REGION	S. LAT. °	W. LONG. °	RUNUP (M)	DAMAGE
1869 01 27	CHILE	TOME	36.63	72.95		
1878 02 14	CHILE	CONCEPCION	36.83	73.05		X
1906 08 17	CHILE	IQUIQUE	20.25	70.13		
	CHILE	TALTAL	25.43	70.55		
	CHILE	CALDERA	27.07	70.83		
	CHILE	COQUIMBO	29.95	71.42		
	CHILE	VALPARAISO	33.08	71.67		X
	CHILE	CURAUMILLA CAPE	33.12	71.83		
	CHILE	CURICO PROVINCE	34.98	71.23		
	CHILE	CONSTITUCION	35.33	72.42		
	CHILE	TALCA PROVINCE	35.47	71.67		
	CHILE	MAULE PROVINCE	35.53	71.72		
	CHILE	SAN ANTONIO	35.58	71.63		
	CHILE	TOME	36.63	72.95	1.5	
	CHILE	PENCO	36.75	73.00	1.5	
	CHILE	CORONEL	36.98	73.17		
1923 02 17	CHILE	CONSTITUCION (MAULE R.)	35.33	72.42	1.5	
1928 12 01	CHILE	CONSTITUCION	35.33	72.42	1.5	
1985 03 03	CHILE	QUINTAY			2.0	
	CHILE	ALGARRABO	27.08	70.58	1.5	
	CHILE	VALPARAISO	33.08	71.67	1.1	
	CHILE	CARTAGENA	33.53	71.65	2.5	
	CHILE	SAN ANTONTO	35.58	71.63	3.5	

TABLE 19. EFFECTS OUTSIDE PERU-CHILE OF TSUNAMIS GENERATED IN CENTRAL CHILE

EVENT DATE YEAR MO DA	COUNTRY OR STATE	REPORTING CITY OR REGION	LAT. °	LONG. °	RUNUP (M)	DAMAGE	PACIFIC QUADRANT
1751 05 25	JAPAN	SE. HONSHU				X	NW. PACIFIC
1835 02 20	HAWAII	KAUAI ISLAND	22.00	-159.50			NE. PACIFIC
1906 08 17	HAWAII	HILO	19.70	-155.07		X	NE. PACIFIC
	HAWAII	S. MAUI ISLAND	20.00	-156.50	3.5	X	NE. PACIFIC
	HAWAII	KAHULUI	20.93	-156.48		X	NE. PACIFIC
	HAWAII	HONOLULU	21.32	-157.83			NE. PACIFIC
	CALIFORNIA	SAN DIEGO	32.70	-117.17	0.15		NE. PACIFIC
	CALIFORNIA	SAN FRANCISCO	37.80	-122.47	0.09		NE. PACIFIC
	JAPAN	KUSHIMOTO	33.47	135.78	0.44		NW. PACIFIC
	JAPAN	ABURATSUBO	35.15	135.63	0.08		NW. PACIFIC
	JAPAN	MIYAGI KANAGAWA	(38.25	141.00)	0.20		NW. PACIFIC
	JAPAN	HAKODATE	41.77	140.72	0.30		NW. PACIFIC
	MARQUESAS	NUKU HIVA IS. HAETAEAO	- 9.00	-140.00		X	SW. PACIFIC
1985 03 03	HAWAII	HILO	19.70	-155.67	0.24		NE. PACIFIC
	HAWAII	HONOLULU	21.32	-157.83	0.15		NE. PACIFIC
	ALASKA	ADAK	51.87	-176.67	0.12		NE. PACIFIC
	ALASKA	SAND POINT	55.31	-160.53	0.07		NE. PACIFIC
	ALASKA	SEWARD	60.08	-149.57	0.25		NE. PACIFIC
	JAPAN	MIYAKO	39.63	141.98	0.05		NW. PACIFIC
	JAPAN	KUSHIRO	42.97	144.40	0.05		NW. PACIFIC
	JAPAN	NEMURO	43.37	145.60	0.05		NW. PACIFIC
	ECUADOR	GUAYAQUIL	- 2.13	- 79.54	0.15		SW. PACIFIC
	TAHITI	PAPEETE	-17.53	-149.57	0.05		SW. PACIFIC
	GAMBIER IS.	RIKITEA	-23.12	-134.95	0.06		SW. PACIFIC

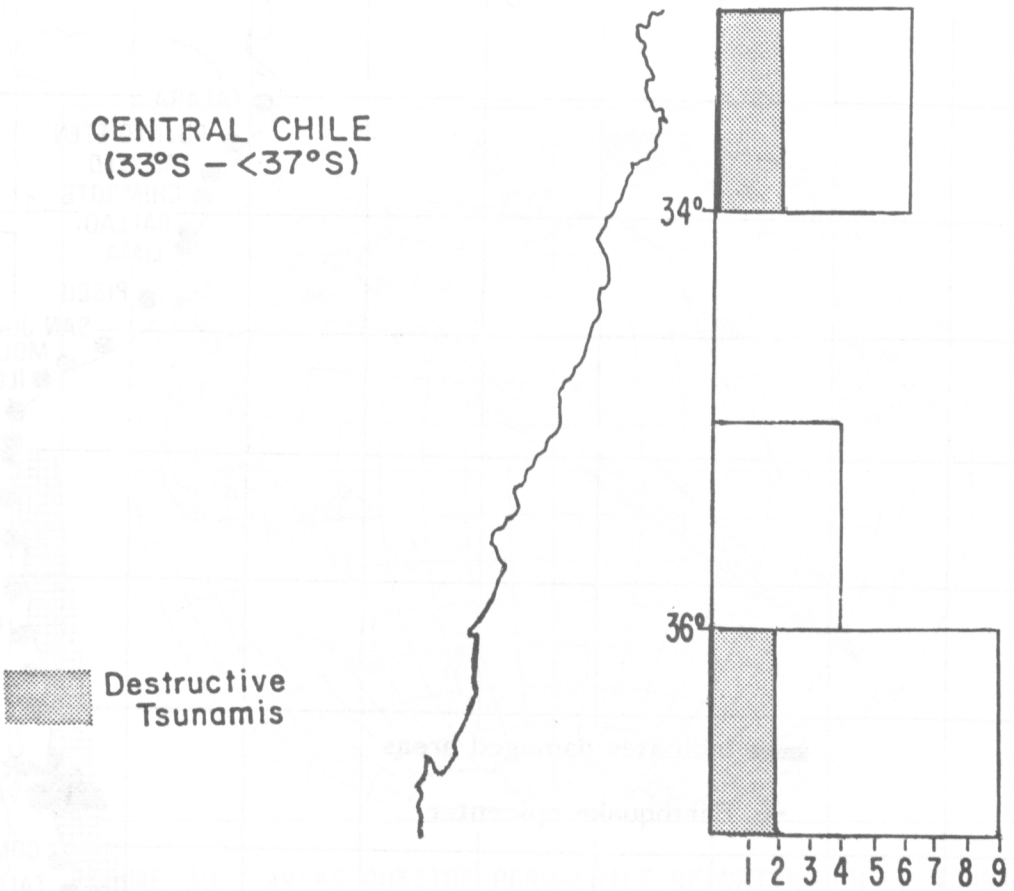
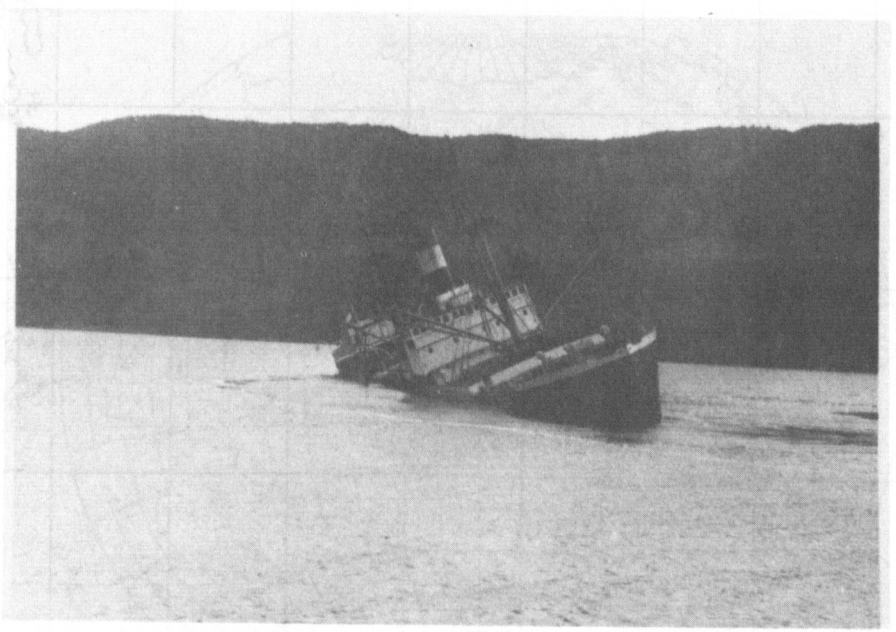


FIGURE 28. NUMBER OF TSUNAMIGENIC EARTHQUAKES PER DEGREE OF CENTRAL CHILE COASTLINE



THE "CANELOS" AGROUND IN VALDIVIA RIVER AFTER TSUNAMI OF MAY 22, 1960

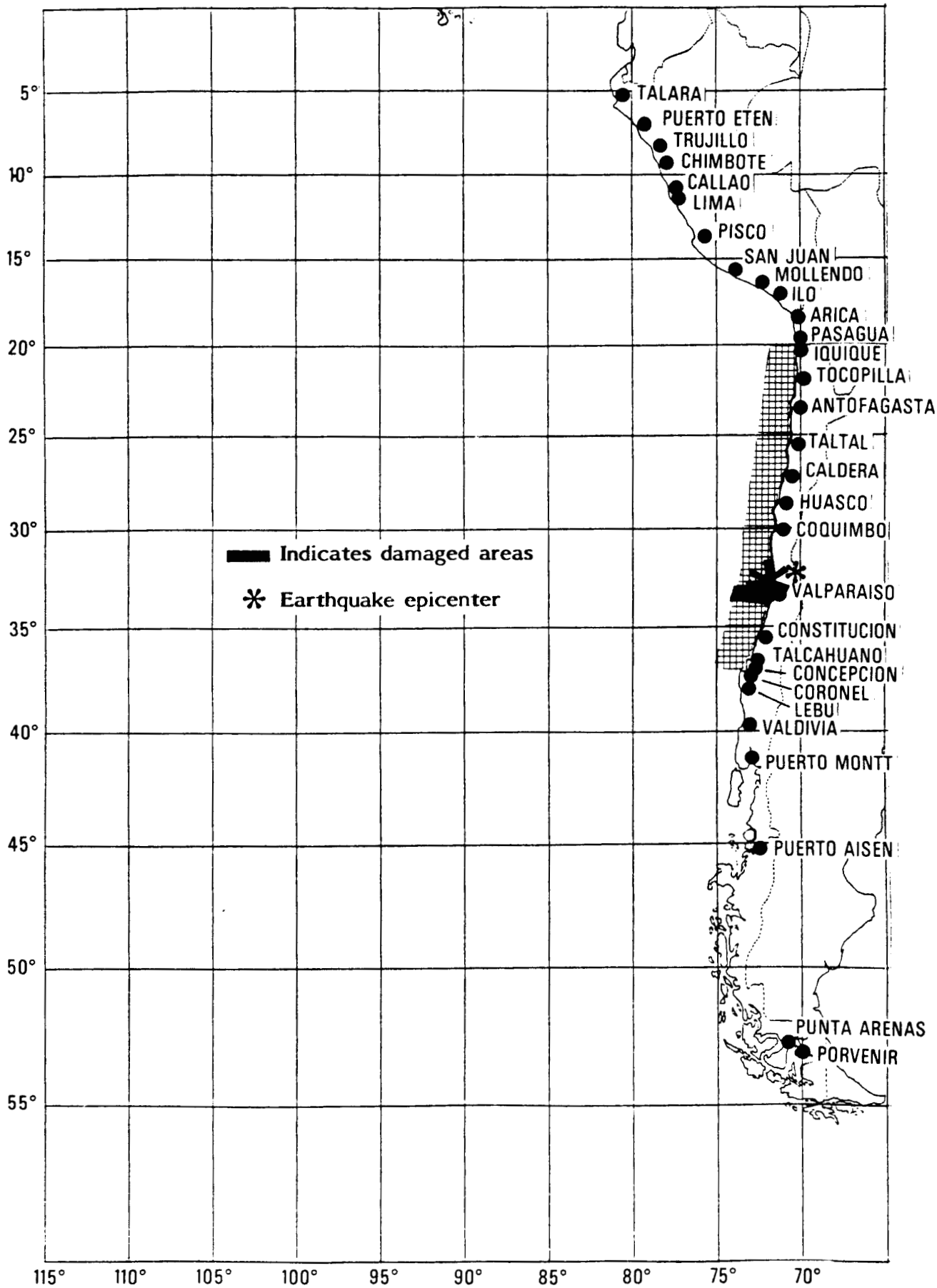


FIGURE 29. AREA OF PERU-CHILE COASTLINE AFFECTED BY CHILE TSUNAMI OF AUG. 16,1906

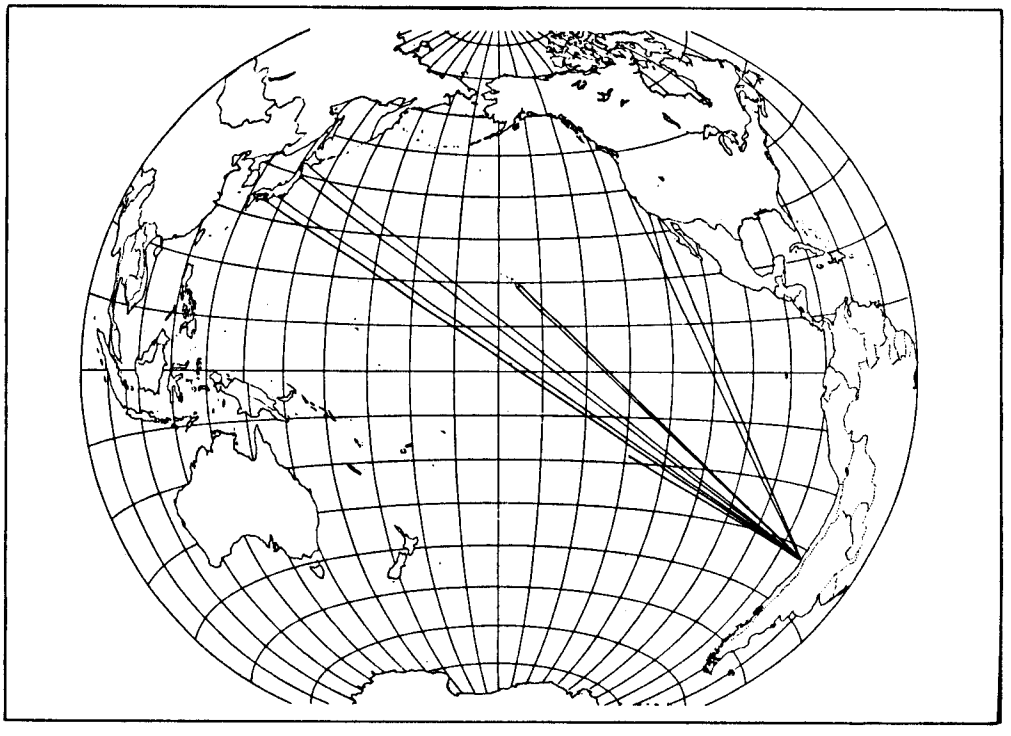


FIGURE 30. AREAS OUTSIDE PERU-CHILE REPORTING CHILE TSUNAMI OF AUG. 16, 1906

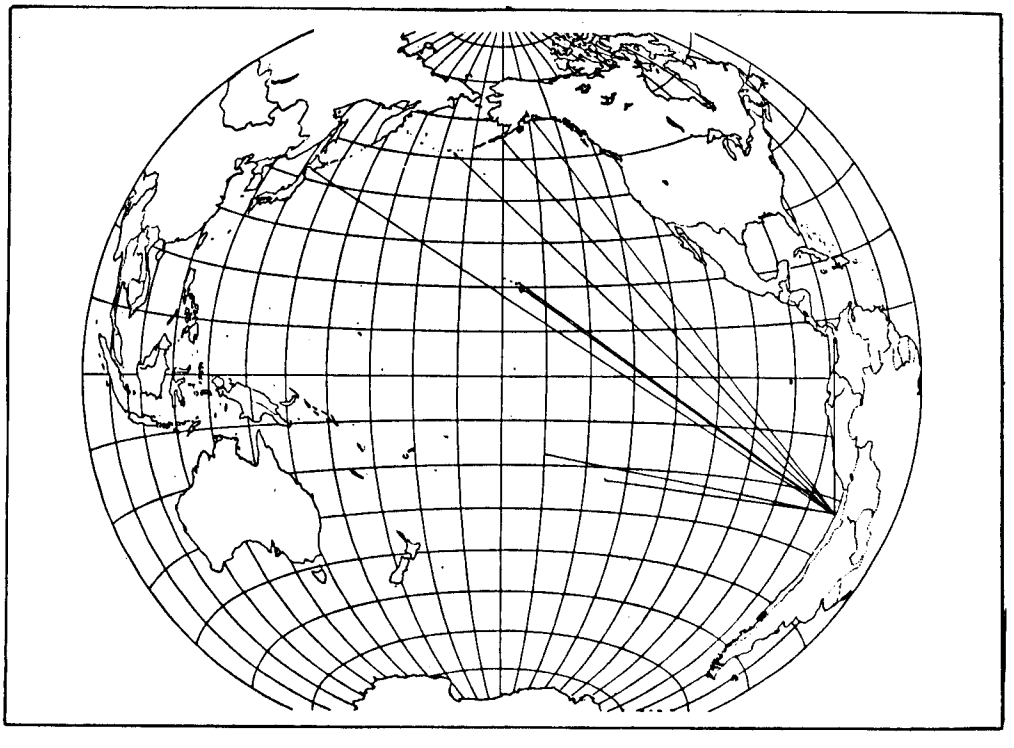


FIGURE 31. AREAS OUTSIDE PERU-CHILE REPORTING CHILE TSUNAMI OF MAR. 3, 1985

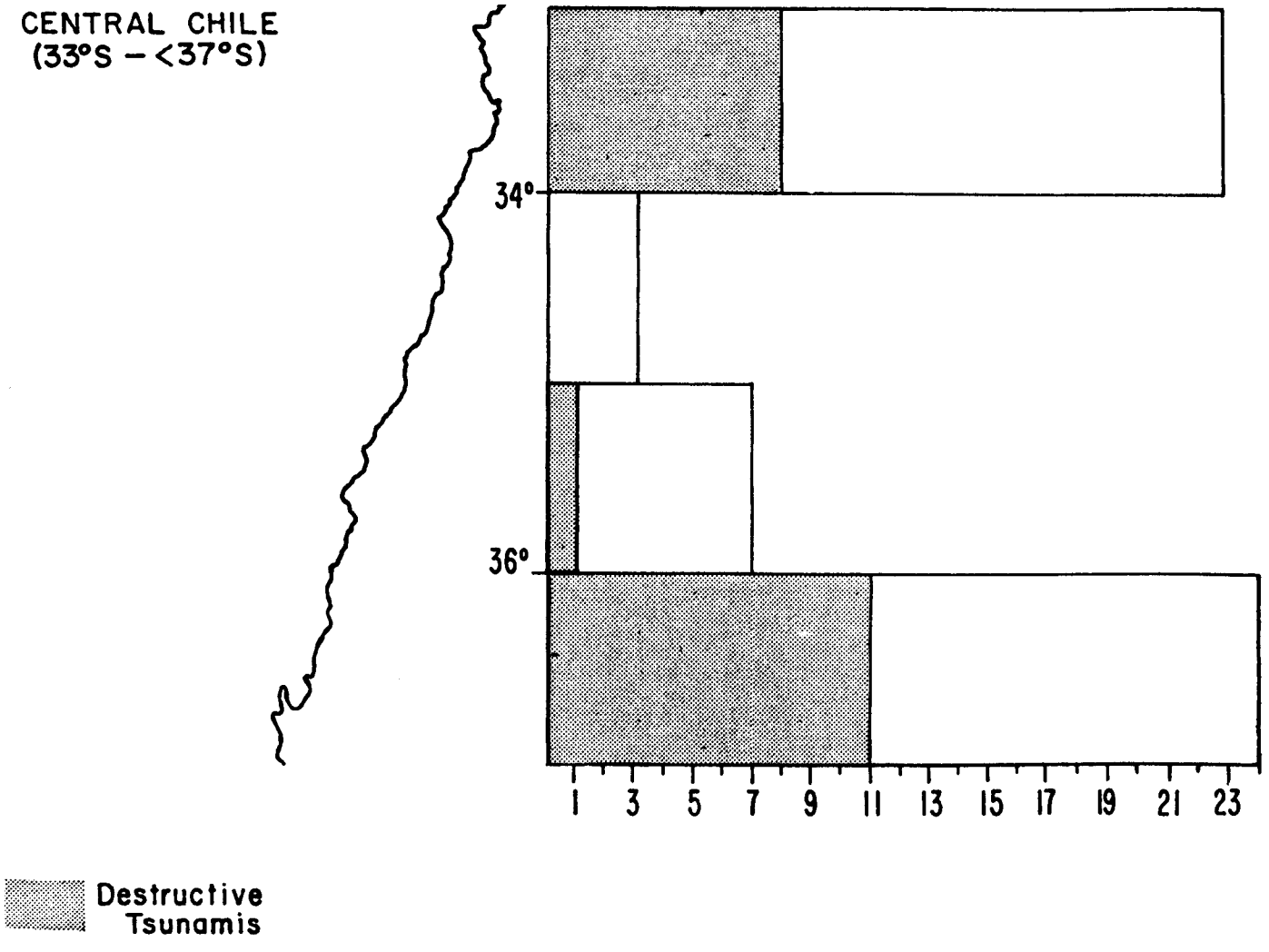


FIGURE 32. NUMBER OF REPORTED OBSERVATIONS OF TSUNAMI EFFECTS PER DEGREE OF CENTRAL CHILE COASTLINE

TABLE 20. SUMMARY OF DAMAGE AND NUMBER OF DEATHS CAUSED BY CENTRAL CHILE TSUNAMIS

EVENT DATE YEAR MO DA	REPORTING CITY OR REGION	EFFECTS	NO. OF DEATHS
1751 05 25	CALLAO, PERU	SOME DAMAGE	
	CONCEPCION, CHILE	TOWN FLOODED	25
	JUAN FERNANDEZ ISLANDS	SETTLEMENT WASHED AWAY	35
	SE. HONSHU, JAPAN	HOUSES FLOODED	
1822 11 19	VALPARAISO, CHILE	SHIPS THROWN ON SHORE	
1835 02 20	TALCAHUANO, CHILE	80-TON SCHOONER CARRIED 300-M INLAND, TOWN INUNDATED	
	TOME AND PENCO, CHILE	TOWNS INUNDATED	
	VALDIVIA, CHILE	MINOR DAMAGE	2
	JUAN FERNANDEZ ISLANDS	AREA FLOODED	
1878 02 14	CONCEPCION, CHILE	SHIP NEARLY SUNK	
1906 08 17	VALPARAISO, CHILE	FLOODING	
	KAHULUI, MAUI ISLAND	MINOR DAMAGE	
	MARQUESAS ISLANDS	CHURCH DAMAGED	

TABLE 21. CITIES AND AREAS ALONG COAST OF CENTRAL CHILE THAT REPORTED TSUNAMIS FROM ALL SOURCE REGIONS

EVENT DATE YEAR MO DA	SOURCE	REPORTING CITY OR REGION IN CENTRAL CHILE	S. LAT. °	W. LONG. °	RUNUP (M)	DAMAGE
1751 05 25	C. CHILE	JUAN FERNANDEZ ISLAND	33.00	80.00		X
1835 02 20	C. CHILE	JUAN FERNANDEZ ISLAND	33.00	80.00	4.5	
1868 08 13	N. CHILE	JUAN FERNANDEZ ISLAND	33.00	80.00	2.0	X
1877 05 10	N. CHILE	JUAN FERNANDEZ IS.	33.00	80.00		
1657 07 09	C. CHILE	VALPARAISO	33.08	71.67		
1730 07 08	NC. CHILE	VALPARAISO	33.08	71.67		X
1751 05 25	C. CHILE	VALPARAISO	33.08	71.67		
1765	NC. CHILE	VALPARAISO	33.08	71.67		X
1811 11 19	C. CHILE	VALPARAISO	33.08	71.67	4.0	
1822 11 19	C. CHILE	VALPARAISO	33.08	71.67	3.5	X
1835 02 20	C. CHILE	VALPARAISO	33.08	71.67	0.5	
1868 08 13	N. CHILE	VALPARAISO	33.08	71.67		
1868 10 16	C. CHILE	VALPARAISO	33.08	71.67		
1877 05 10	N. CHILE	VALPARAISO	33.08	71.67	1.1	
1906 08 17	C. CHILE	VALPARAISO	33.08	71.67		X
1943 04 06	NC. CHILE	VALPARAISO	33.08	71.67	0.8	
1946 04 01	ALEUTIANS	VALPARAISO	33.08	71.67	0.8	
1952 11 05	KAMCHATKA	VALPARAISO	33.08	71.67	0.9	X
1957 03 09	ALEUTIANS	VALPARAISO	33.08	71.67	2.0	
1960 05 21	SC. CHILE	VALPARAISO	33.08	71.67	0.3	
1960 05 22	SC. CHILE	VALPARAISO	33.08	71.67	1.7	
1964 03 28	ALASKA	VALPARAISO	33.08	71.67	2.2	
1966 10 17	PERU	VALPARAISO	33.08	71.67	0.4	
1971 07 09	NC. CHILE	VALPARAISO	33.08	71.67	0.6	X
1973 10 05	NC. CHILE	VALPARAISO	33.08	71.67	0.4	
1983 10 04	N. CHILE	VALPARAISO	33.08	71.67	0.4	
1985 03 03	C. CHILE	VALPARAISO	33.08	71.67	1.1	
1906 08 17	C. CHILE	CURAUMILLA CAPE	33.12	71.83		
1877 05 10	N. CHILE	LLICO	34.76	72.17		
1906 08 16	C. CHILE	CURICO PROVINCE	34.98	71.23		

TABLE 21. CITIES AND AREAS ALONG THE COAST OF CENTRAL CHILE THAT REPORTED TSUNAMIS FROM ALL SOURCE REGIONS (CONT.)

EVENT DATE YEAR MO DA	SOURCE	REPORTING CITY OR REGION IN CENTRAL CHILE	S. LAT. °	W. LONG. °	RUNUP (M)	DAMAGE
1835 02 20	C. CHILE	CONSTITUCION	35.33	72.42	3.5	
1868 08 13	N. CHILE	CONSTITUCION	35.33	72.42	3.5	X
1877 05 10	N. CHILE	CONSTITUCION	35.33	72.42	5.0	
1906 08 17	C. CHILE	CONSTITUCION	35.33	72.42		
1923 02 17	C. CHILE	CONSTITUCION (MAULE R.)	35.33	72.42	1.5	
1928 12 01	C. CHILE	CONSTITUCION	35.33	72.42	1.5	
1960 05 22	SC. CHILE	PTO. CONSTITUCION	35.33	72.42	2.5	
1906 08 17	C. CHILE	TALCA PROVINCE	35.47	71.67		
1835 02 20	C. CHILE	COLIUMO BAY	35.52	72.95	4.0	
1906 08 17	C. CHILE	MAULE PROVINCE	35.53	71.72		
1906 08 17	C. CHILE	SAN ANTONIO	35.58	71.63		
1878 04 12	N. CHILE	BUCHUPUREO	36.08	72.77		
1835 02 20	C. CHILE	COELEMA	36.48	72.70	24.0	
1835 02 20	C. CHILE	TOME	36.63	72.95	4.0	X
1868 08 13	N. CHILE	TOME	36.63	72.95	4.5	X
1869 01 27	C. CHILE	TOME	36.63	72.95		
1877 05 10	N. CHILE	TOME	36.63	72.95	0.8	
1906 08 17	C. CHILE	TOME	36.63	72.95	1.5	
1960 05 22	SC. CHILE	TOME	36.63	72.95	2.5	
1835 02 20	C. CHILE	TALCAHUANO	36.67	73.17	9.0	X
1868 08 13	N. CHILE	TALCAHUANO	36.67	73.17	4.0	X
1868 10 02	PERU	TALCAHUANO	36.67	73.17		
1877 05 10	N. CHILE	TALCAHUANO	36.67	73.17	15.0	X
1920 08 20	SC. CHILE	TALCAHUANO	36.67	73.17		X
1936 07 13	N. CHILE	TALCAHUANO	36.67	73.17	1.0	
1952 11 05	KAMCHATKA	TALCAHUANO	36.69	73.10	1.8	
1957 03 09	ALEUTIANS	TALCAHUANO	36.69	73.10	1.4	
1960 05 22	SC. CHILE	TALCAHUANO	36.69	73.10	5.0	
1964 03 27	ALASKA	TALCAHUANO	36.69	73.10	2.5	
1966 10 17	PERU	TALCAHUANO	36.67	73.17	0.3	
1835 02 20	C. CHILE	PENCO	36.75	73.00		X
1877 05 10	N. CHILE	PENCO	36.75	73.00		X
1906 08 17	C. CHILE	PENCO	36.75	73.00	1.5	
1562 10 28	SC. CHILE	CONCEPCION	36.83	73.05		X
1570 02 08	SC. CHILE	CONCEPCION	36.83	73.05		X
1604 11 24	PERU	CONCEPCION	36.83	73.05		X
1657 03 15	SC. CHILE	CONCEPCION	36.83	73.05		
1730 07 08	NC. CHILE	CONCEPCION	36.83	73.05		X
1742 03 23	C. CHILE	CONCEPCION	36.83	73.05		
1746 10 28	PERU	CONCEPCION	36.83	73.05		
1751 05 25	C. CHILE	CONCEPCION	36.83	73.05	3.5	X
1819 04 11	N. CHILE	CONCEPCION	36.83	73.05		X
1835 02 20	C. CHILE	CONCEPCION	36.83	73.05	18.0	
1878 02 14	C. CHILE	CONCEPCION	36.83	73.05		X
1960 05 22	SC. CHILE	CONCEPCION	36.83	73.05		
1868 08 13	N. CHILE	CORONEL	36.98	73.17		
1906 08 17	C. CHILE	CORONEL	36.98	73.17		
1960 05 22	SC. CHILE	CORONEL	36.98	73.17	2.0	

SOUTH CENTRAL CHILE

[37° S. - <41° S.]

A shift of major seismic activity from the Range Fault to an offshore structure occurs near the northern boundary of this region (37° S. latitude). This shift is marked by the appearance of the Transverse Ranges, which intrude the Central Valley (Lomitz, 1970). The May 22, 1960, earthquake (mag. = 8.6) was the largest seismic event in this region since 1570. The rupture length of the 1960 tsunami was as much as 1000 km, one of the longest lengths of rupture recorded anywhere in the world. Consequently, this region is believed to have a low potential for large-magnitude earthquakes and resulting tsunamis in the near future.

Intervals between the destructive earthquakes of 1575, 1737 (South Chile), 1837 (South Chile), and 1960 (Valdivia area, 40° S. latitude) appear to be larger than those of both the Concepcion and the Valparaiso areas (that is, more than 100 years). If the epicenters are migrating southward as is occurring in the Central Chile area, the possibility exists for great tsunamigenic earthquakes in the next century (Iida, 1983).

Table 22 lists the tsunamigenic earthquakes that have occurred in South Central Peru. (See table 1 for alternate data, erroneous dates, and events that appeared in the literature but are not believed to have been tsunamis). The data included in table 22 are believed to be the most accurate available. Of the 11 events listed, four were damaging locally. Interestingly, three of the damaging events occurred in the 16th century, and only the May 22, 1960, tsunami has caused damage in the last 400 years. About one-half the events (5) are given a "4" validity rating, indicating these events are believed to be true tsunamis.

The literature gives some information about the size of the tsunami for seven events in table 22. Of these, only one had a reported runup height of less than 1 meter. The May 22, 1960, event recorded the highest runup (25 m) of any event on the Peru-Chile coast. Figure 34 shows the frequency of occurrence of the tsunamigenic earthquakes for each degree of coastline of South Central Chile. Shaded areas indicate the number of tsunamigenic earthquakes that caused damage.

Table 23 gives dates of eight tsunamis generated in South Central Chile and the names of cities that reported each event. If a value is not given for the runup height and an "X" does not appear in the damage column, then the area was reported in the literature but descriptive effect information was not given. Modern methods of reporting and measuring runup heights have expanded significantly the amount of data available for the May 22, 1960, tsunami, which was observed throughout the length of the coast of Peru-Chile. This tsunami is comparable to the great tsunamis that occurred in Northern Chile 100 years ago (1868, 1877). Figure 35 shows the extent of the coastline of South Central Chile affected by the May 22, 1960, tsunami (hatched area) and the areas where damage occurred (dark area).

Table 24 lists the names of cities outside the Peru-Chile coast that reported the May 22, 1960, tsunami. This tsunami damaged cities in Hawaii, Japan, and the West Coast of the United States and was recorded throughout the Pacific

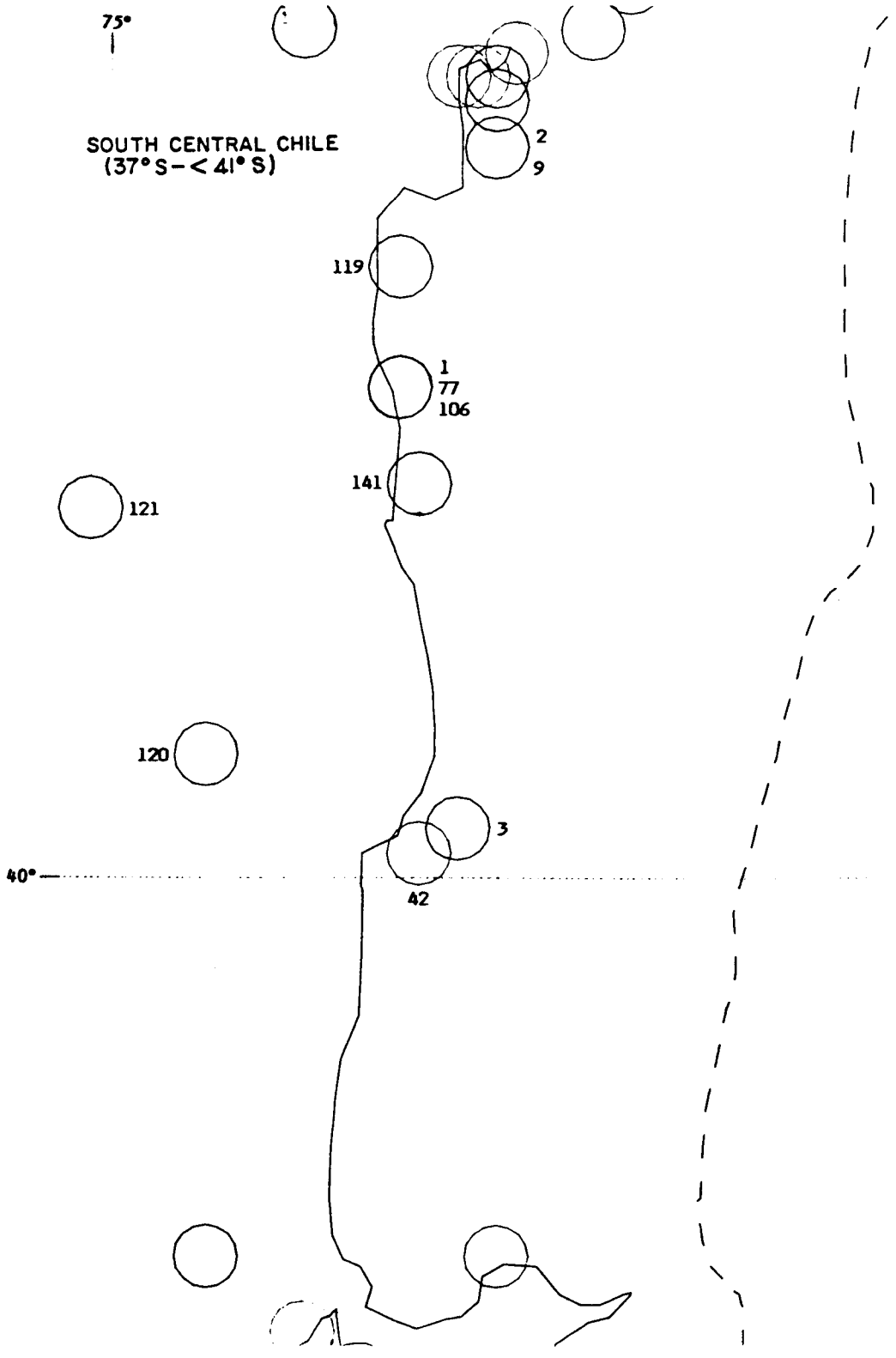


FIGURE 33. EPICENTERS OF TSUNAMIGENIC EARTHQUAKES OF SOUTH CENTRAL CHILE
[NUMBERS REFER TO EVENT NO. IN TABLE 22.]

TABLE 22. TSUNAMIGENIC EARTHQUAKES OF SOUTH CENTRAL CHILE

EVENT NO.	EVENT DATE YEAR MO DA	TIME	EARTHQUAKE DATA S. LAT. °	W. LONG. °	MAGNI-TUDE	DEPTH (KM)	TSUNAMI DATA RUNUP (M)	MAGNI-TUDE	INTENSITY	VALIDITY	REFERENCES
1 *	1562 10 28	1000	38.0	73.5	8.0		16.0	4.0	3.5	4	1,9,10,31,38,52
2 *	1570 02 08	1300	37.0	73.0	8.8		4.0	2.0	3.0	4	1,9,10,31,38,51
3 *	1575 12 16	1830	39.8	73.2	8.5					4	52
9	1657 03 15	2330	37.0	73.0	8.0		8.0	3.0	2.5	3	1,31,38,51
42	1869 02 06		(39.9	73.4)			0.7		0.0		9,38
77	1920 08 20	1615	38.0	73.5	7.0	15	1.4		1.0		1,9,10,38,51
106	1949 04 20	0329	38.0	73.5	7.3	70					51
119	1960 05 21	1002	37.5	73.5	7.3	33	1.0	0.0	-1.0	4	5,9,10,38,47,51
120 *<	1960 05 22	1911	39.5	74.5	8.6	33	25.0	4.7		4	51
121	1960 11 01	0846	38.5	75.1	7.4	55					51
141	1974 08 20	1044	38.4	73.4	7.0	36					51

NOTE: * Indicates that the earthquake caused a destructive tsunami.
< Indicates that the tsunami was reported outside the South American coast.
() Parentheses around the latitude and longitude indicate that the epicenter was derived from the coordinates of a city name given in the reference.
See footnotes at end of table 1 for explanation of column headings.

TABLE 23. EFFECTS IN PERU-CHILE OF THE TSUNAMIS GENERATED IN SOUTH CENTRAL CHILE

EVENT DATE YEAR MO DA	COUNTRY	REPORTING CITY OR REGION	S. LAT. °	W. LONG. °	RUNUP (M)	DAMAGE
1562 10 28	CHILE	CONCEPCION	36.83	73.05		X
1570 02 08	CHILE	CONCEPCION	36.83	73.05		X
1575 12 16	CHILE	VALDIVIA	39.77	73.25		X
1657 03 15	CHILE	CONCEPCION	36.83	73.05		
1920 08 20	CHILE	TALCAHUANO	36.67	73.17		X
1960 05 21	CHILE	VALPARAISO	33.08	71.67	0.3	
1960 05 22	PERU	TALARA	4.58	81.28	3.9	
	PERU	CHIMBOTE	9.08	78.62	1.9	
	PERU	CALLAO (LA PUNTA)	12.08	77.17	1.8	
	PERU	SAN JUAN	15.35	75.15	1.0	
	PERU	MATARANI	17.00	72.12	1.5	
	CHILE	ARICA	18.47	70.32	2.0	
	CHILE	ANTOFAGASTA	23.65	70.42	1.4	
	CHILE	CALDERA	27.08	70.68	2.9	
	CHILE	COQUIMBO	29.95	71.42	2.1	
	CHILE	VALPARAISO	33.08	71.67	1.7	
	CHILE	PTO. CONSTITUCION	35.33	72.42	2.5	
	CHILE	TOME	36.63	72.95	2.5	
	CHILE	TALCAHUANO	36.69	73.10	5.0	
	CHILE	CONCEPCION	36.83	73.05		
	CHILE	CORONEL	36.98	73.17	2.0	
	CHILE	ARAUCO	37.25	73.32		
	CHILE	LEBU	37.63	73.72	5.0	
	CHILE	PTO. TIRNA	38.33	73.52	5.0	

TABLE 23. EFFECTS IN PERU-CHILE OF THE TSUNAMIS GENERATED IN SOUTH CENTRAL CHILE (CONT.)

EVENT DATE YEAR MO DA	COUNTRY	REPORTING CITY OR REGION	S. LAT. °	W. LONG. °	RUNUP (M)	DAMAGE
	CHILE	ISLA MOCHA	38.33	73.90	25.0	X
	CHILE	PTO. SAAVEDRA	38.78	73.40	9.0	
	CHILE	MEHUIN	39.43	73.22	15.0	X
	CHILE	VALDIVIA	39.80	73.24	10.0	X
1960 05 22	CHILE	CORRAL	39.86	73.42	10.0	
	CHILE	MANSA RIVER	40.55	73.76	8.5	
	CHILE	ANCUD	41.87	73.83	12.0	
	CHILE	CHILOE ISLAND	42.50	73.92	10.0	X
	CHILE	GUAFO	43.58	74.83	10.0	
	CHILE	AYSEN	45.40	72.70	3.0	
	CHILE	PUNTA ARENAS	53.17	70.93	0.4	

TABLE 24. EFFECTS OUTSIDE PERU-CHILE OF MAY 22, 1960 TSUNAMI GENERATED IN SOUTH CENTRAL CHILE

COUNTRY	REPORTING CITY OR REGION	LAT. °	LONG. °	RUNUP	DAMAGE	PACIFIC QUADRANT
COLOMBIA	TUMACO	1.85	- 78.73		X	NE. PACIFIC
PACIFIC	CHRISTMAS ISLAND	1.98	-157.48	0.45		NE. PACIFIC
COLOMBIA	BUENAVENTURA	3.90	- 77.10			NE. PACIFIC
CANAL ZONE	NAOS ISLAND	8.92	- 79.53	0.42		NE. PACIFIC
COSTA RICA	QUEPOS	9.40	- 84.17	0.15		NE. PACIFIC
COSTA RICA	PUNTARENAS	9.97	- 84.83	0.33		NE. PACIFIC
GUATEMALA	SAN JOSE	13.92	- 90.83	0.42		NE. PACIFIC
MEXICO	SALINA CRUS	16.17	- 95.20	0.63		NE. PACIFIC
HAWAII	ANEOWEONUI			3.3	X	NE. PACIFIC
PACIFIC	JOHNSTON ALOLL	16.75	-169.52	0.69		NE. PACIFIC
MEXICO	ACAPULCO	16.85	- 99.92	0.33		NE. PACIFIC
HAWAII	SOUTH POINT	18.92	-155.68	4.0		NE. PACIFIC
HAWAII	KAALUALU	18.97	-155.62	5.2		NE. PACIFIC
HAWAII	HONUAPO	19.10	-155.55	5.2		NE. PACIFIC
HAWAII	PUNALUU	19.13	-155.50	3.4		NE. PACIFIC
HAWAII	HALAPE	19.27	-155.25	1.5		NE. PACIFIC
HAWAII	KALAPANA	19.35	-154.98	2.1		NE. PACIFIC
HAWAII	KAIMU	19.37	-154.97	4.0		NE. PACIFIC
HAWAII	HOOKENA	19.38	-155.90	2.1		NE. PACIFIC
HAWAII	HONAUNAU	19.42	-155.92	1.5		NE. PACIFIC
HAWAII	OPHIKAO	19.43	-154.90	1.8		NE. PACIFIC
HAWAII	POHOIKI	19.45	-154.85	1.8		NE. PACIFIC
HAWAII	NAPOOPOO	19.48	-155.92	4.9		NE. PACIFIC
HAWAII	KEAAU	19.60	-155.03	3.7		NE. PACIFIC
HAWAII	HILO	19.70	-155.07	10.5	X	NE. PACIFIC
HAWAII	KAILUA	19.72	-155.98	2.4		NE. PACIFIC
HAWAII	PAPAIKOU	19.75	-155.10	2.7		NE. PACIFIC
HAWAII	ONOMEA	19.80	-155.13	3.4		NE. PACIFIC
HAWAII	PEPEEKEO	19.83	-155.10	1.5		NE. PACIFIC
HAWAII	HONOMU	19.85	-155.10	3.7		NE. PACIFIC
HAWAII	HAKALAU	19.90	-155.13	2.7		NE. PACIFIC
HAWAII	LAUPAHOEHOE	20.00	-155.25	2.1		NE. PACIFIC
HAWAII	KAWAIHAE	20.03	-155.83	2.7		NE. PACIFIC
HAWAII	HONOKAA	20.07	-155.45	1.8		NE. PACIFIC
HAWAII	WAIPIO V.	20.13	-155.60	2.4		NE. PACIFIC

Basin. Figure 36 shows the extent of the reports (in table 24) and the areas where property damage occurred.

Table 25 is a summary of property damage and number of deaths caused by four damaging tsunamis in South Central Chile. More than 3,000 people have been killed by tsunamis spawned on this narrow band of coastline. Although damaging, the May 22, 1960, tsunami did not caused as many deaths in this area as did the 1570 tsunami. Concepcion has been damaged repeatedly by tsunamis in this area. The 1960 event was especially devastating to Hawaii, where it caused $75 million in property damage and 61 deaths.

Table 26 lists the names of cities in South Central Chile that have reported tsunamis, dates of the tsunamis, runup heights, and whether damage occurred. According to table 26, the area has been affected extensively by tsunamis generated in North Chile as well as by those generated locally. Figure 37, a bar graph of the data in table 26, shows the number of tsunamis per degree of coastline.

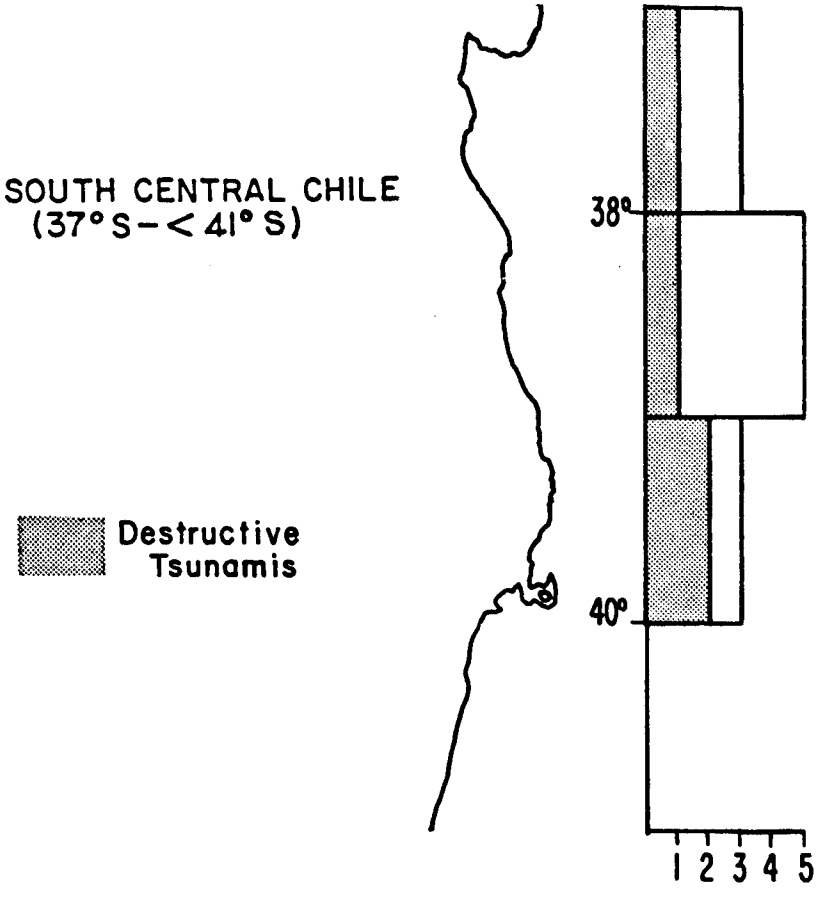


FIGURE 34. NUMBER OF TSUNAMIGENIC EARTHQUAKES PER DEGREE OF SOUTH CENTRAL CHILE COASTLINE

TABLE 24. EFFECTS OUTSIDE PERU-CHILE OF MAY 22, 1960 TSUNAMI GENERATED IN SOUTH CENTRAL CHILE (CONT.)

COUNTRY	REPORTING CITY OR REGION	LAT. °	LONG. °	RUNUP (M)	DAMAGE	PACIFIC QUADRANT
HAWAII	N. WAILUA	20.17	-156.82	2.7		NE. PACIFIC
HAWAII	POLOLU V.	20.22	-155.73	3.7		NE. PACIFIC
HAWAII	UPOLU PT.	20.27	-155.87	2.7		NE. PACIFIC
HAWAII	MAUI ISLAND	20.88	-156.50	4.5		NE. PACIFIC
HAWAII	KAHULUI (MAUI I.)	20.93	-156.48	2.8+		NE. PACIFIC
HAWAII	HONOLULU LANDING	21.32	-157.83	4.3		NE. PACIFIC
HAWAII	MOKUOLOE (OAHU I.)	21.43	-157.80	0.24	X	NE. PACIFIC
HAWAII	KAHALUU	21.45	-157.83	2.4		NE. PACIFIC
HAWAII	OAHU ISLAND	21.50	-158.00	4.0		NE. PACIFIC
HAWAII	KAUMAKANI	21.93	-159.63	1.6		NE. PACIFIC
EL SALVADOR	LA UNION	13.33	- 87.82	0.36		NE. PACIFIC
HAWAII	NAWILIWILI (KAUAI)	21.97	-159.33	1.7		NE. PACIFIC
HAWAII	KEKAHA	21.97	-159.72	3.0		NE. PACIFIC
HAWAII	KAUAI ISLAND	22.00	-159.50	4.5		NE. PACIFIC
HAWAII	PAKALA	22.05	-159.35	3.2		NE. PACIFIC
HAWAII	WAHIAWA BAY	22.05	-159.55	4.2		NE. PACIFIC
HAWAII	HAENA	22.22	-159.55	2.8		NE. PACIFIC
MEXICO	MAZATLAN	23.18	-106.43	1.08		NE. PACIFIC
MEXICO	LA PAZ	24.16	-110.32	1.44		NE. PACIFIC
MEXICO	TOPOLOBAMPO	25.62	-109.05	0.24		NE. PACIFIC
MEXICO	GUAYMAS	27.92	-110.90	0.36		NE. PACIFIC
HAWAII	MIDWAY ISLANDS	28.22	-177.37	0.60		NE. PACIFIC
MEXICO	ENSENADA	31.88	-116.60	2.5		NE. PACIFIC
CALIFORNIA	SAN DIEGO	32.70	-117.17	1.38		NE. PACIFIC
CALIFORNIA	LA JOLLA	32.87	-117.25	0.42		NE. PACIFIC
CALIFORNIA	WILSON COVE	33.00	-118.55	1.23		NE. PACIFIC
CALIFORNIA	SAN PEDRO	33.70	-118.25	0.90		NE. PACIFIC
CALIFORNIA	LOS ANGELES	33.71	-118.27	1.50		NE. PACIFIC
CALIFORNIA	ALAMITOS BAY	33.75	-118.12	0.93		NE. PACIFIC
CALIFORNIA	TERMINAL ISLAND	33.75	-118.23	1.83		NE. PACIFIC
CALIFORNIA	LONG BEACH	33.75	-118.23	1.71		NE. PACIFIC
CALIFORNIA	SANTA MONICA	34.00	-118.50	1.05		NE. PACIFIC
CALIFORNIA	PORT HUENEME	34.15	-119.20	2.64		NE. PACIFIC
CALIFORNIA	ALAMEDA	37.77	-122.30	0.18		NE. PACIFIC
CALIFORNIA	SAN FRANCISCO	37.80	-122.47	0.87		NE. PACIFIC
CALIFORNIA	CRESCENT CITY	41.76	-124.22	3.7	X	NE. PACIFIC
OREGON	ASTORIA	46.20	-123.77	0.30		NE. PACIFIC
WASHINGTON	NEAH BAY	48.37	-124.62	0.27		NE. PACIFIC
WASHINGTON	FRIDAY HARBOR	48.55	-123.00	0.18		NE. PACIFIC
WASHINGTON	ECHO BAY	48.75	-122.90			NE. PACIFIC
CANADA	TOFINO	49.15	-125.90	0.36		NE. PACIFIC
ALASKA	SWEEPER COVE	51.87	-176.63	1.5		NE. PACIFIC
CANADA	CAPE ST. JAMES	51.93	-131.02	0.36		NE. PACIFIC
CANADA	MCKENNY ISLAND	52.65	-129.48	0.42		NE. PACIFIC
ALASKA	MASSACRE BAY	52.82	-186.83	3.30		NE. PACIFIC
ALASKA	UNALASKA	53.88	-166.53	1.38		NE. PACIFIC
CANADA	PRINCE RUPERT	54.32	-130.33			NE. PACIFIC
ALASKA	KETCHIKAN	55.33	-131.63			NE. PACIFIC
ALASKA	KAKE	56.97	-133.92			NE. PACIFIC
ALASKA	SITKA	57.05	-135.35	0.9		NE. PACIFIC
ALASKA	WOMENS BAY	57.72	-152.52	1.29		NE. PACIFIC
ALASKA	KODIAK	57.82	-152.50	0.7		NE. PACIFIC
ALASKA	JUNEAU	58.30	-134.42			NE. PACIFIC
ALASKA	SKAGWAY	59.45	-135.32	0.36		NE. PACIFIC
ALASKA	YAKUTAT	59.55	-139.73	0.9		NE. PACIFIC
ALASKA	SEWARD	60.10	-149.43	1.38		NE. PACIFIC
PACIFIC	MOEN ISLAND	7.45	151.85	0.06		NW. PACIFIC
PACIFIC	KWAJALEIN ATOLL	8.73	167.73	0.75		NW. PACIFIC

TABLE 24. EFFECTS OUTSIDE PERU-CHILE OF MAY 22, 1960, TSUNAMI GENERATED IN SOUTH CENTRAL CHILE (CONT.)

COUNTRY	REPORTING CITY OR REGION	LAT. °	LONG. °	RUNUP (M)	DAMAGE	PACIFIC QUADRANT
TAIWAN	KEE-LUNG	25.15	121.75	1.14		NW. PACIFIC
JAPAN	NASE	28.38	129.50	0.48		NW. PACIFIC
JAPAN	SASEBO	33.17	129.72	1.29		NW. PACIFIC
JAPAN	KUSHIMOTO	33.47	135.78	2.2		NW. PACIFIC
JAPAN	MOZI	33.95	130.97	0.87		NW. PACIFIC
JAPAN	DANNOURA	33.97	130.95	0.42		NW. PACIFIC
JAPAN	IZUHARA	34.20	129.30	0.18		NW. PACIFIC
JAPAN	SHIMIZU	35.02	138.48	1.5		NW. PACIFIC
JAPAN	MAIZURU	35.48	135.40	0.54		NW. PACIFIC
JAPAN	TUKIZI	35.67	139.77	0.12		NW. PACIFIC
JAPAN	CHOSHI	35.72	140.83	2.1		NW. PACIFIC
JAPAN	RIKUZEN	38.00	140.92	6.4		NW. PACIFIC
JAPAN	SHIOGAMA	38.32	141.00	2.8	X	NW. PACIFIC
JAPAN	ONAGAWA	38.45	141.47	4.2	X	NW. PACIFIC
JAPAN	OFUNATO	39.07	141.72	4.9		NW. PACIFIC
JAPAN	KAMAISI	39.27	141.90	0.69		NW. PACIFIC
JAPAN	S. RIKUCHU	39.30	141.88	5.6		NW. PACIFIC
JAPAN	N. RIKUCHU	39.83	141.52	6.3	X	NW. PACIFIC
JAPAN	HACHINOHE	40.50	141.50	3.3	X	NW. PACIFIC
JAPAN	OMINATO	41.25	141.15	0.21		NW. PACIFIC
JAPAN	MUTSU	41.28	141.17	6.3	X	NW. PACIFIC
JAPAN	HAKODATE	41.77	140.72	2.2		NW. PACIFIC
JAPAN	HOKKAIDO	42.00	143.00	5.0		NW. PACIFIC
JAPAN	URAKAWA	42.17	142.78	3.15		NW. PACIFIC
JAPAN	KUSHIRO	42.97	144.40	1.8		NW. PACIFIC
JAPAN	MONBETU	44.35	143.37	0.36		NW. PACIFIC
KURIL IS.		47.00	155.00	4.7		NW. PACIFIC
FIJI IS.	SUVA HARBOR	-18.15	178.43	0.99		SW. PACIFIC
GALAPAGOS	SAN CRISTOBAL	-0.90	- 89.62	0.6		SE. PACIFIC
ECUADOR	LA LIBERTAD	-2.20	- 80.92	1.89		SE. PACIFIC
PHOENIX IS.	CANTON ISLAND	-2.82	-171.72	0.12		SE. PACIFIC
W. SAMOA	APIA	-13.80	-171.75	4.9	X	SE. PACIFIC
AM. SAMOA	UPOLU	-13.92	-171.75	4.9		SE. PACIFIC
AM. SAMOA	PAGO PAGO	-14.27	-171.72	4.9		SE. PACIFIC
AM. SAMOA	TUTUILA	-14.30	-170.70	4.9	X	SE. PACIFIC
PITCAIRN I.		-25.07	-130.10	12.2		SE. PACIFIC
EASTER I.		-27.08	-109.33	6.0		SE. PACIFIC
AUSTRALIA	CAIRNS	-16.92	145.78	0.03		SW. PACIFIC
AUSTRALIA	TOWNSVILLE	-19.27	146.83	0.30		SW. PACIFIC
AUSTRALIA	URANGAN JETTY	-25.28	152.97	0.18		SW. PACIFIC
AUSTRALIA	BRISBANE	-27.45	153.07	0.21		SW. PACIFIC
AUSTRALIA	BALLINA	-28.87	153.58	0.06		SW. PACIFIC
AUSTRALIA	NORFOLK I.	-29.07	167.95	0.21		SW. PACIFIC
AUSTRALIA	ILUKA	-29.42	153.37	0.63		SW. PACIFIC
AUSTRALIA	COFFS HARBOR	-30.30	153.15			SW. PACIFIC
AUSTRALIA	LORD HOWE I.	-31.53	159.07	0.66		SW. PACIFIC
AUSTRALIA	FREMANTLE	-32.11	115.75	0.30		SW. PACIFIC
AUSTRALIA	NEWCASTLE	-32.93	151.78	0.15		SW. PACIFIC
AUSTRALIA	SYDNEY HARBOR	-33.80	151.27			SW. PACIFIC
AUSTRALIA	FT. DENISON	-33.85	151.23			SW. PACIFIC
AUSTRALIA	EDEN	-37.05	149.97	1.68		SW. PACIFIC
NEW ZEALAND	TAURANGA	-37.70	176.18	0.90		SW. PACIFIC
AUSTRALIA	PT. MACDONNELL	-38.07	140.70	0.24		SW. PACIFIC
NEW ZEALAND	WELLINGTON	-41.28	174.78	0.93		SW. PACIFIC
AUSTRALIA	HOBART	-42.88	147.33	0.33		SW. PACIFIC
NEW ZEALAND	LYTTELTON	-43.62	172.72	0.42		SW. PACIFIC
NEW ZEALAND	TAYLORS POINT	-45.78	170.67	0.57		SW. PACIFIC
NEW ZEALAND	PORT CHALMERS	-45.82	170.65	0.42		SW. PACIFIC
NEW ZEALAND	DUNEDIN	-45.88	170.55	0.36		SW. PACIFIC

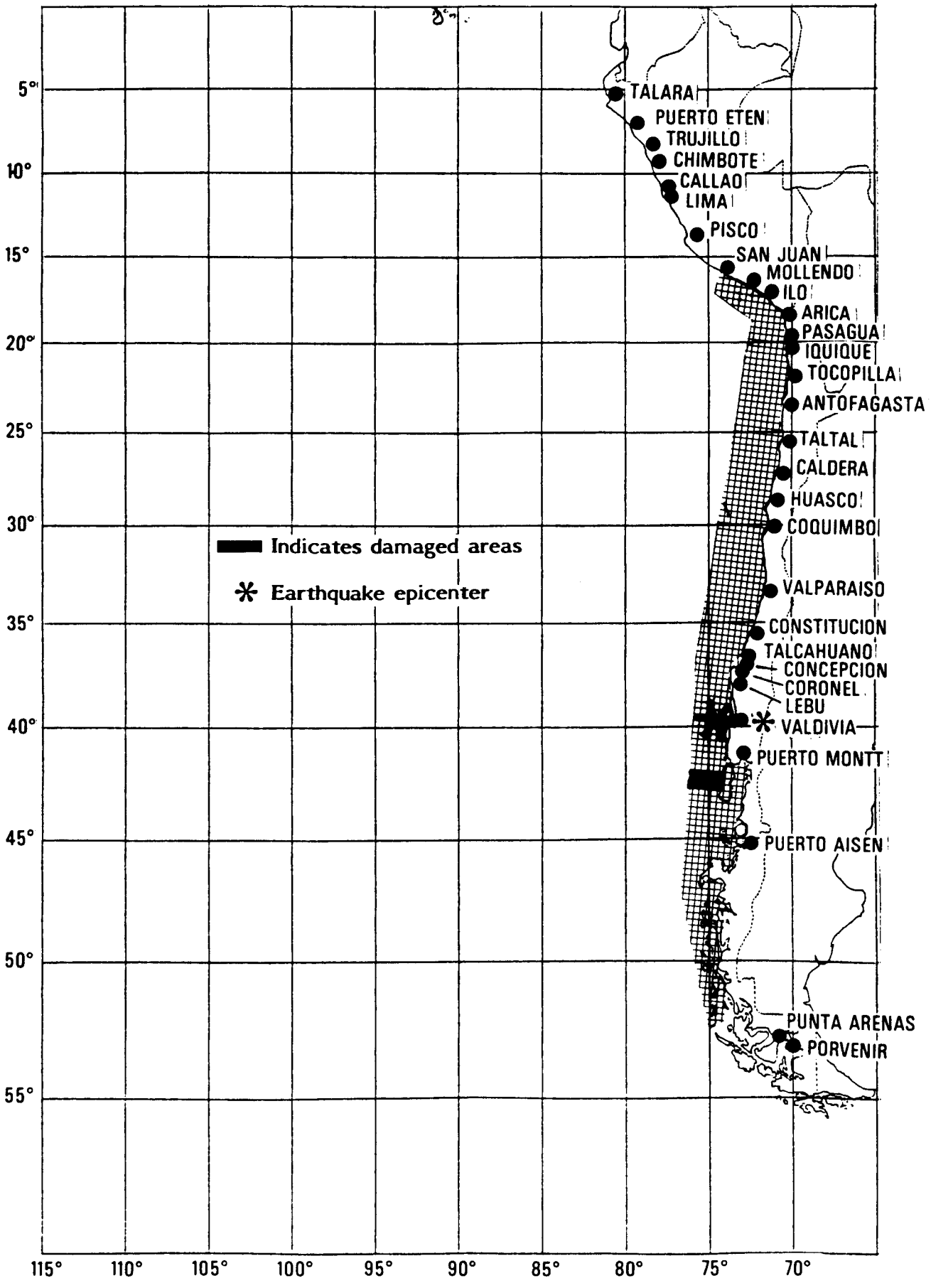


FIGURE 35. AREA OF PERU-CHILE COASTLINE AFFECTED BY CHILE TSUNAMI OF MAY 22, 1960

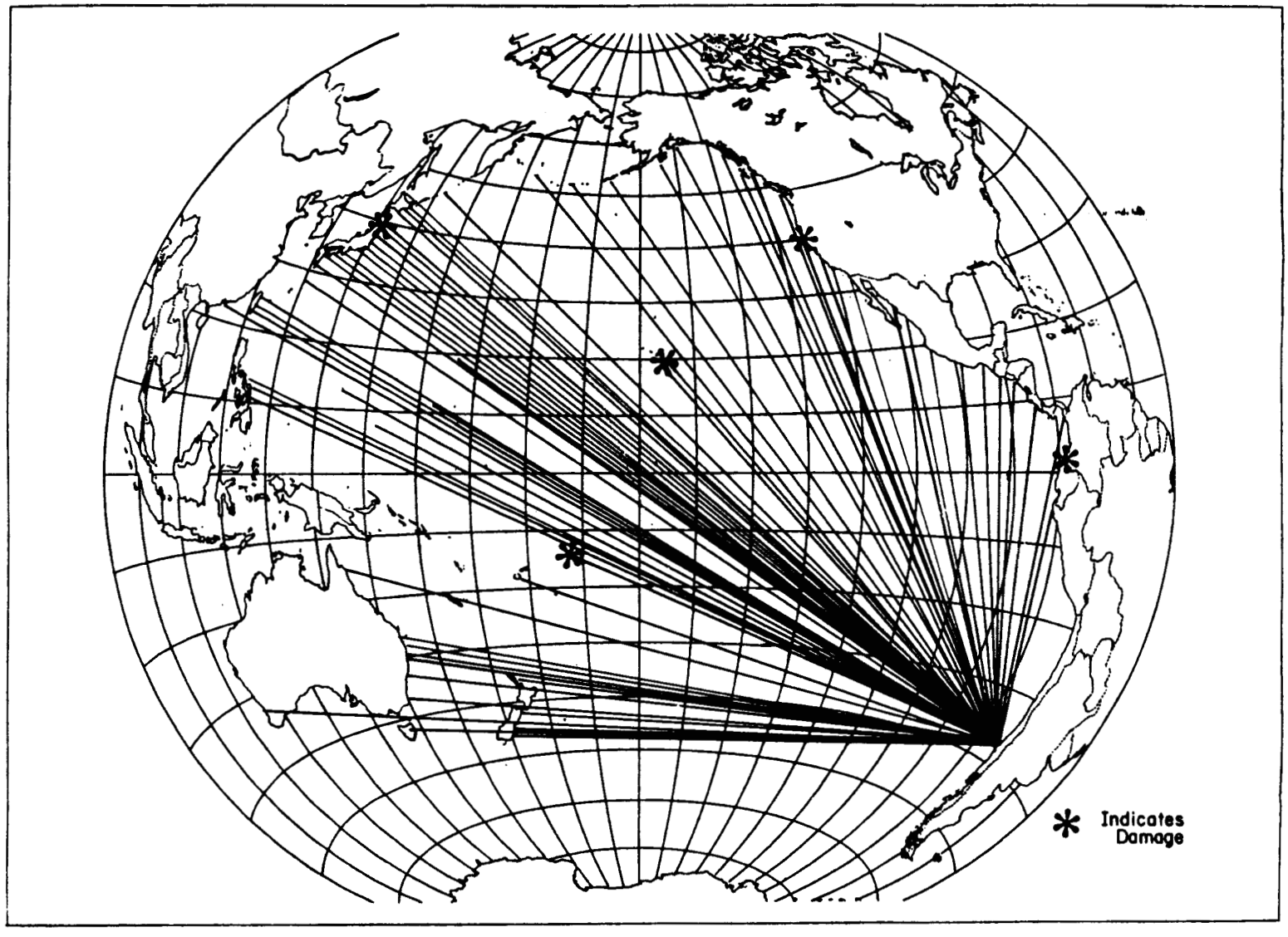


FIGURE 36. AREAS OUTSIDE PERU-CHILE REPORTING CHILE TSUNAMI OF MAY 22, 1960

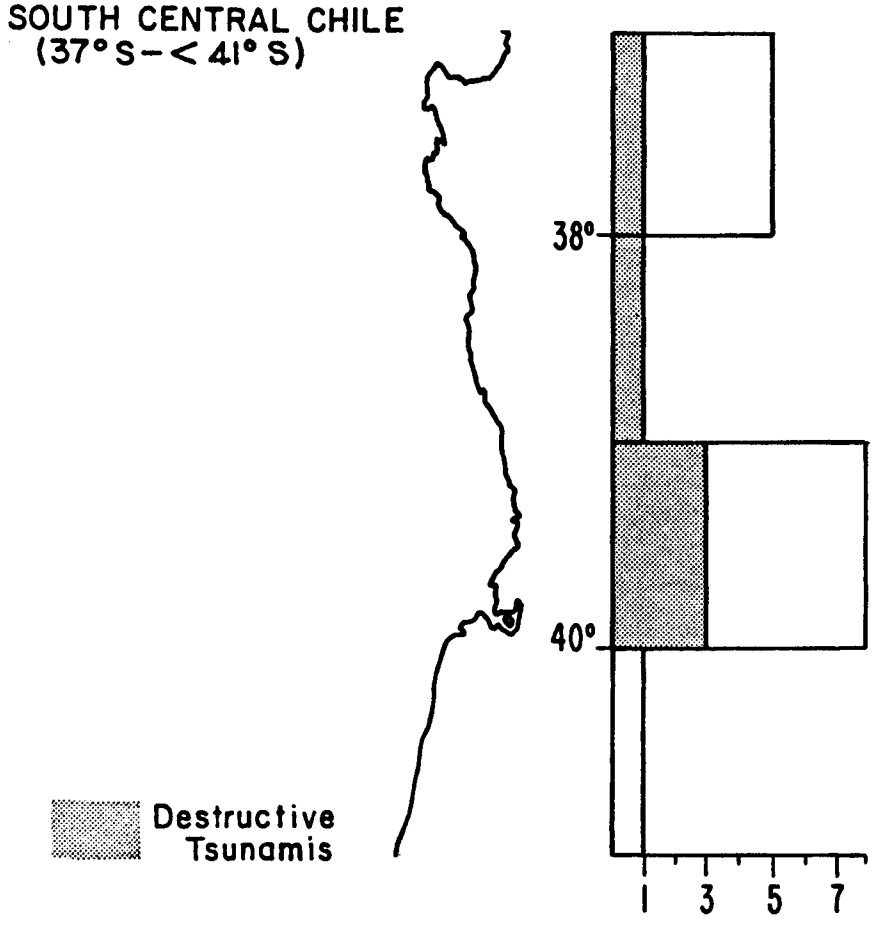


FIGURE 37. NUMBER OF REPORTED OBSERVATIONS OF TSUNAMI EFFECTS PER DEGREE OF SOUTH CENTRAL CHILE COASTLINE

TABLE 25. SUMMARY OF DAMAGE AND NUMBER OF DEATHS CAUSED BY SOUTH CENTRAL CHILE TSUNAMIS

EVENT DATE YEAR MO DA	REPORTING CITY OR REGION	EFFECTS	DEATHS
1562 10 28	CONCEPCION, CHILE	1,500 KM OF COAST INUNDATED	MANY
1570 02 08	CONCEPCION, CHILE	TOWN SUBMERGED	2,000
1575 12 16	BAHIA CORRAL, CHILE	TWO GALLEONS WRECKED	
	VALDIVIA, CHILE	HOUSES, POLES, TREES WASHED AWAY	100
1960 05 22	CHILOE IS., CHILE	MINOR DAMAGE	200
	VALDIVIA, CHILE	TOWN DEVASTATED	130
	MEHUIN, CHILE	2 SHIPS LOST, AREA DEVASTATED	
	ISLA MOCHA, CHILE	ALMOST COMPLETE DESTRUCTION	
	ALL OF CHILE	$550 MILLION DAMAGE	1,000
	CRESCENT CITY, CALIFORNIA	$30,000 DAMAGE, 2 SHIPS LOST	
	WEST COAST	$500,000 DAMAGE	
	SAMOA ISLAND	$50,000 DAMAGE	
	OAHU ISLAND, HAWAII	$250,000 DAMAGE	
	ALL OF HAWAII	$75 MILLION DAMAGE	61
	JAPAN	$50 MILLION DAMAGE, 4,885 STRUCTURES DAMAGED	199
	RABAUL, NEW BRITAIN	BULK STORES FLOODED	

TABLE 26. CITIES AND AREAS ALONG COAST OF SOUTH CENTRAL CHILE THAT REPORTED TSUNAMIS FROM ALL SOURCE REGIONS

EVENT DATE YEAR MO DA	SOURCE	REPORTING CITY OR REGION SOUTH CENTRAL CHILE	S. LAT. °	W. LONG. °	RUNUP (M)	DAMAGE
1877 05 10	N. CHILE	CORONEL	37.02	73.15	3.0	
1877 05 10	N. CHILE	LOTA	37.08	73.17	1.5	
1868 08 13	N. CHILE	LOTA	37.12	73.17		
1868 08 13	N. CHILE	ARAUCO	37.25	73.32		
1877 05 10	N. CHILE	ARAUCO	37.25	73.32		
1960 05 22	SC. CHILE	ARAUCO	37.25	73.32		
1835 02 20	C. CHILE	ISLA MOCHA	37.50	73.18		
1966 10 17	PERU	LEBU	37.62	73.72	0.3	
1868 08 13	N. CHILE	LEBU	37.63	73.72		
1960 05 22	SC. CHILE	LEBU	37.63	73.72	5.0	
1868 08 13	N. CHILE	SAN VINCENTE DE CANETE				X
1960 05 22	SC. CHILE	PTO. TIRNA	38.33	73.52	5.0	
1960 05 22	SC. CHILE	ISLA MOCHA	38.33	73.90	25.0	X
1960 05 22	SC. CHILE	PTO. SAAVEDRA	38.78	73.40	9.0	
1960 05 22	SC. CHILE	MEHUIN	39.43	73.22	15.0	X
1575 12 16	SC. CHILE	VALDIVIA	39.77	73.25		X
1730 07 08	NC. CHILE	VALDIVIA	39.77	73.25		X
1835 02 20	C. CHILE	VALDIVIA	39.77	73.25		
1837 11 07	S. CHILE	VALDIVIA	39.77	73.25		
1877 05 10	N. CHILE	VALDIVIA	39.77	73.25		
1960 05 22	SC. CHILE	VALDIVIA	39.80	73.24	10.0	X
1868 08 13	N. CHILE	CORRAL	39.86	73.42	4.0	
1960 05 22	SC. CHILE	CORRAL	39.86	73.42	10.0	
1975 11 29	HAWAII	CORRAL	39.86	73.42	1.7	
1837 11 07	S. CHILE	MANCERA ISLAND	39.87	73.40	2.0	
1877 05 10	N. CHILE	CORRAL BAY (ENSENADA)	39.96	73.42	0.6	
1960 05 22	SC. CHILE	MANSA RIVER	40.55	73.76	8.5	
1877 05 10	N. CHILE	PUERTO MONTT	41.47	73.00		

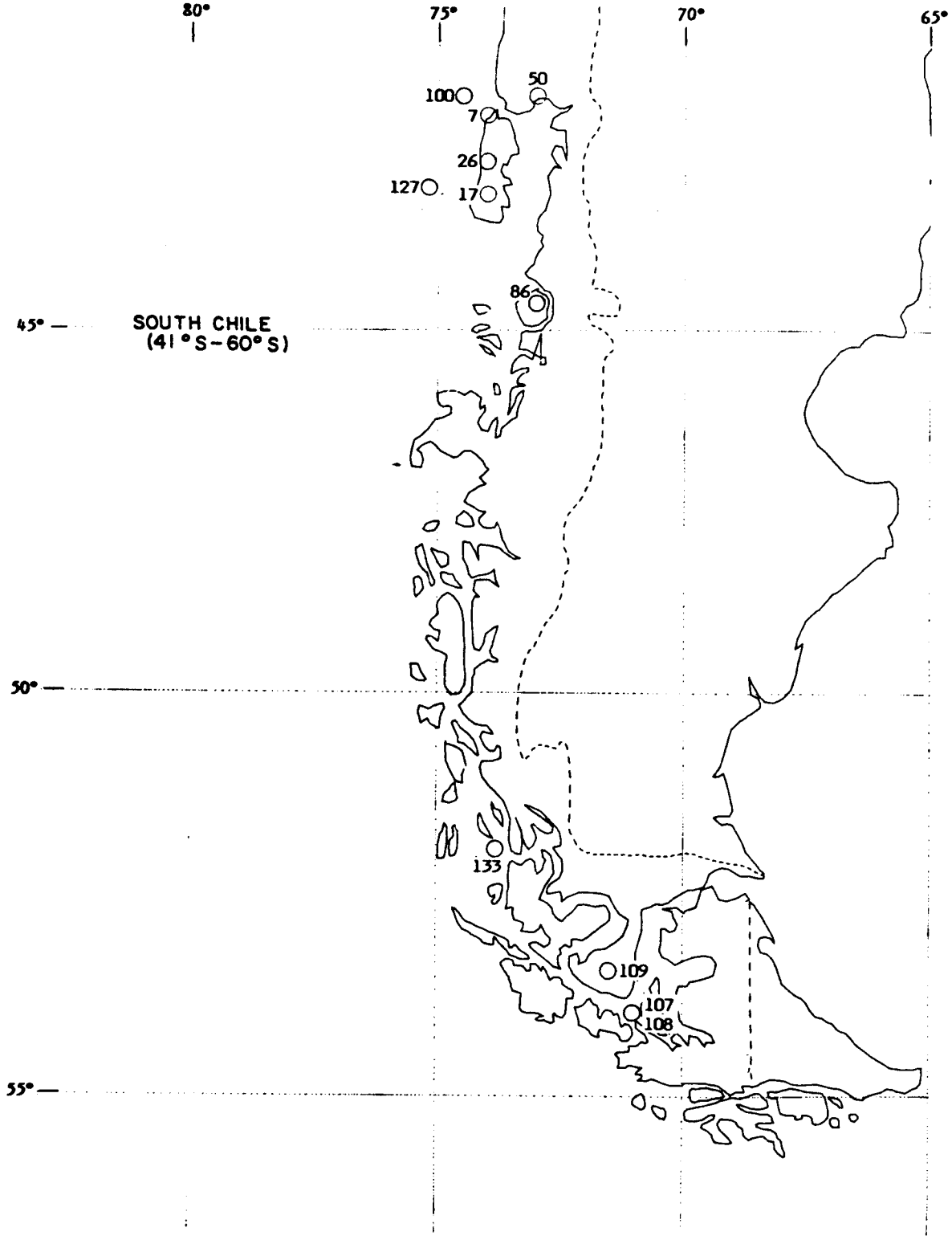


FIGURE 38. EPICENTERS OF TSUNAMIGENIC EARTHQUAKES OF SOUTH CHILE
[NUMBERS REFER TO EVENT NO. IN TABLE 27.]

SOUTH CHILE

[41° S. - 60° S.]

Region from 41° S. - 45° S.

The coastline of South America changes dramatically at 41° S. latitude. From this point south, the coastline becomes irregular and has numerous islands, bays, and inlets. This indicates that the collision between the Pacific and South American Plates is not as pronounced in this area, and perhaps that the two plates are not being forced past one another as is occurring along the coast to the north. In the northern part of this region (near 41° S. latitude), earthquakes generated damaging tsunamis in 1633 and 1837. A damaging tsunami occurred at 44.6° S. latitude in 1929.

Region from 45° S. - 53° S.

South of the triple junction between the Peru-Chile trench and the Chile Ridge at 46° S. latitude, the oceanic part of the Antarctic Plate is being subducted beneath the South American Plate at a rate of about 2 cm/year. Magnetic anomalies in the Southeast Pacific indicate that segments of the Chile Ridge collided with the southern part of the South American Continent 26 million years ago. Since that time, there has been a great decrease of volcanic activity on the Continent and a cessation of folding in the sedimentary basins (McCann, 1979).

Region from 53° S. - 60° S.

Seismic records are incomplete because of the recent settlement of the South American Continent near 53° S. latitude (McCann, 1979). Records that do exist, however, indicate that the seismicity is low. The earliest record of earthquake activity is the Magellan Strait earthquake of 1878 (mag. = 7-8?) (McCann, 1979). Two large earthquakes occurred within a 10-hour period in 1949 (mag. = 7.5), producing a rupture length of about 300 km. This region may not rupture in the near future, because the last rupture was in 1949.

Table 27 lists the tsunamigenic earthquakes that have occurred in the South Chile region, together with information about the tsunamis they produced. (See table 1 for alternate data, erroneous dates, and events that appeared in the literature but are not believed to have been tsunamis.) The data included in table 27 are believed to be the most accurate available. Of the 11 events listed, three were damaging locally and one was reported in areas of the Pacific outside the west coast of South America. Two of the events have a validity rating of "4," indicating that the compilers of the data considered them to be true tsunamis.

The literature gives some information about the size of the tsunami for six of the events in table 27. The size may have been indicated by a tsunami magnitude, a tsunami intensity, or a measured or estimated runup height. Of the six events that had such information, only two had reported runup heights of less than 1 meter. Figure 38 is a map of the earthquakes listed in table 27. Figure 39 shows the frequency of occurrence of the tsunamigenic earthquakes for each degree of the South Chile coastline. Shaded areas indicate the number of tsunamigenic earthquakes that caused damage.

Table 28 lists the dates of four tsunamis in South Chile and the cities outside the area that reported each event. An "X" in the damage column indicates that damage occurred at that city. If a value is not given for the runup height and an "X" does not appear in the damage column, then the event was reported in the literature but descriptive effect information was not given.

Table 29 gives the names of cities outside the Peru-Chile area that were affected by the earthquake of Nov. 7, 1837. Primary effects occurred in Hawaii. Figure 40 shows the entent of the effects of this and other tsunamis. Table 30 is a summary of property damage and number of deaths caused by three tsunamis in South Chile.

Table 31 lists the areas along the coast of South Chile that reported tsunamis from all source regions. Chiloe Island reported two tsunamis generated in South Chile and three generated outside the area; three of the five tsunamis caused damage in the area. Chiloe Island, however, has not sustained devastating effects from tsunamis generated in South Chile, even though its location makes that island particularly vulnerable to tsunamis.

Ancud, Chiloe Island, and Guafo have reported runup heights of 10 meters from past tsunamis. The fact that only a few sites have sustained damage throughout the long coastline in this region is remarkable, considering the number of devastating tsunamis generated in Peru and Chile and the degree of damage they have caused thousands of miles from Chile. This phenomena may be explained partially by the existence of few populated cities along this section of coastline and by the fact that the system of islands and inlets acts as an effective shield. Figure 41, a bar graph of the data shown in table 31, gives the number of tsunamis per degree of coastline.

ACKNOWLEDGMENTS

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TABLE 27. TSUNAMIGENIC EARTHQUAKES OF SOUTH CHILE

EVENT NO.	EVENT DATE YEAR MO DA	TIME	EARTHQUAKE DATA S. LAT. °	W. LONG. °	MAGNITUDE	DEPTH (KM)	TSUNAMI DATA RUNUP (M)	MAGNITUDE	INTENSITY	VALIDITY	REFERENCES
7 *	1633 05 14		(41.8	74.0)			2.0		1.5		9,38
17	1737 12 24		43.0	74.0							9,31,38
26 *<	1837 11 07	1130	42.5	74.0	8.5		6.0	3.0	3.0	4	1,5,9,10,31,38,52
50	1871 12 28		(41.5	73.0)			1.0		0.5		9,38
86 *	1927 11 21	2312	44.6	73.0	7.1	33	2.8	1.0	2.0	4	1,9,10,18,20,38,51
100	1940 10 11	1841	41.5	74.5	7.0	33					51
107	1949 12 17	0653	54.0	71.0	7.7	33	0.7		0.0		51
108	1949 12 17	1508	54.0	71.0	7.7	33	0.7		0.0		51,38
109	1950 01 30	0057	53.5	71.5	7.0	33					51
127	1965 10 03	1615	42.9	75.2	6.5	31					51
133	1970 06 14	0000	52.0	73.8	6.6	10					51

NOTE: * Indicates that the earthquake caused a destructive tsunami.
< Indicates that the tsunami was reported outside the South American coast.
( ) Parentheses around the latitude and longitude indicate that the epicenter was derived from the coordinates of a city name given in the reference.
See footnotes at end of table 1 for explanation of column headings.

TABLE 28. EFFECTS IN PERU-CHILE OF TSUNAMIS GENERATED IN SOUTH CHILE

EVENT DATE YEAR MO DA	COUNTRY	REPORTING CITY OR REGION	S. LAT. °	W. LONG. °	RUNUP (M)	DAMAGE
1633 05 14	CHILE	CHILOE ISLAND	42.50	73.92		X
1837 11 07	CHILE	MANCERA ISLAND	39.87	73.40	2.0	
		CHILOE ISLAND	42.50	73.92		
		VALDIVIA	39.77	73.25		
1927 11 21	CHILE	PUERTO AISEN	45.45	72.97		X
1949 12 17	CHILE	PORVENIR (ADMIRALTY BAY)	53.25	70.27		
		GABRIEL STRAIT	61.76	65.50		

TABLE 29. EFFECTS OUTSIDE PERU-CHILE OF TSUNAMIS GENERATED IN SOUTH CHILE

EVENT DATE YEAR MO DA	COUNTRY	REPORTING CITY OR REGION	S. LAT. °	W. LONG. °	RUNUP (M)	DAMAGE	PACIFIC QUADRANT
1837 11 07	HAWAII	KAU					NE. PACIFIC
	HAWAII	KAAHELU					NE. PACIFIC
	HAWAII	KANOKAPA					NE. PACIFIC
	HAWAII	HILO	19.70	-155.07	6.0	X	NE. PACIFIC
	HAWAII	KAHULUI (MAUI I.)	20.93	-156.48		X	NE. PACIFIC
	HAWAII	LAHAINA	20.95	-155.68	2.5		NE. PACIFIC
	HAWAII	HONOLULU	21.32	-157.83			NE. PACIFIC
	JAPAN	NE. HONSHU					NW. PACIFIC
	W. SAMOA	APIA	-13.80	-171.75			SE. PACIFIC
	AM. SAMOA	PAGO PAGO	-14.27	-171.72			SE. PACIFIC
	TONGA IS.	VAVAU	-18.36	-174.00			SE. PACIFIC

TABLE 30. SUMMARY OF DAMAGE AND NUMBER OF DEATHS CAUSED BY SOUTH CHILE TSUNAMIS

EVENT DATE YEAR MO DA	REPORTING CITY OR REGION	EFFECTS	NO. OF DEATHS
1633 05 14	CHILOE ISLAND	HOUSES WASHED AWAY	SOME
1837 11 07	HILO (HAWAII I.) KAHULUI (MAUI I.)	66 HOUSES DESTROYED	14 2
1927 11 21	PUERTO AISEN, CHILE	BOAT TRANSPORTED TO TREE TOP	

TABLE 31. CITIES AND AREAS ALONG THE COAST OF SOUTH CHILE THAT REPORTED TSUNAMIS FROM ALL SOURCE REGIONS

EVENT DATE YEAR MO DA	SOURCE REGION	REPORTING CITY IN SOUTH CHILE	S. LAT. °	W. LONG. °	RUNUP (M)	DAMAGE
1868 08 13	N. CHILE	ANCUD	41.87	73.83		
1877 05 10	N. CHILE	ANCUD	41.87	73.83		
1960 05 22	SC. CHILE	ANCUD	41.87	73.83	12.0	
1633 05 14	S. CHILE	CHILOE ISLAND	42.50	73.92		X
1835 02 20	C. CHILE	CHILOE ISLAND	42.50	73.92		
1837 11 07	S. CHILE	CHILOE ISLAND	42.50	73.92		
1868 08 13	N. CHILE	CHILOE ISLAND	42.50	73.92		X
1960 05 22	SC. CHILE	CHILOE ISLAND	42.50	73.92	10.0	X
1960 05 22	SC. CHILE	GUAFO	43.58	74.83	10.0	
1960 05 22	SC. CHILE	PUERTO AISEN	45.45	72.97	3.0	
1927 11 21	S. CHILE	PUERTO AISEN	45.45	72.97		X
1960 05 22	SC. CHILE	PUNTA ARENAS	53.17	70.93	0.4	
1949 12 17	S. CHILE	PORVENIR (ADMIRALTY BAY)	53.25	70.27		
1949 12 17	S. CHILE	GABRIEL STRAIT	61.76	65.50		

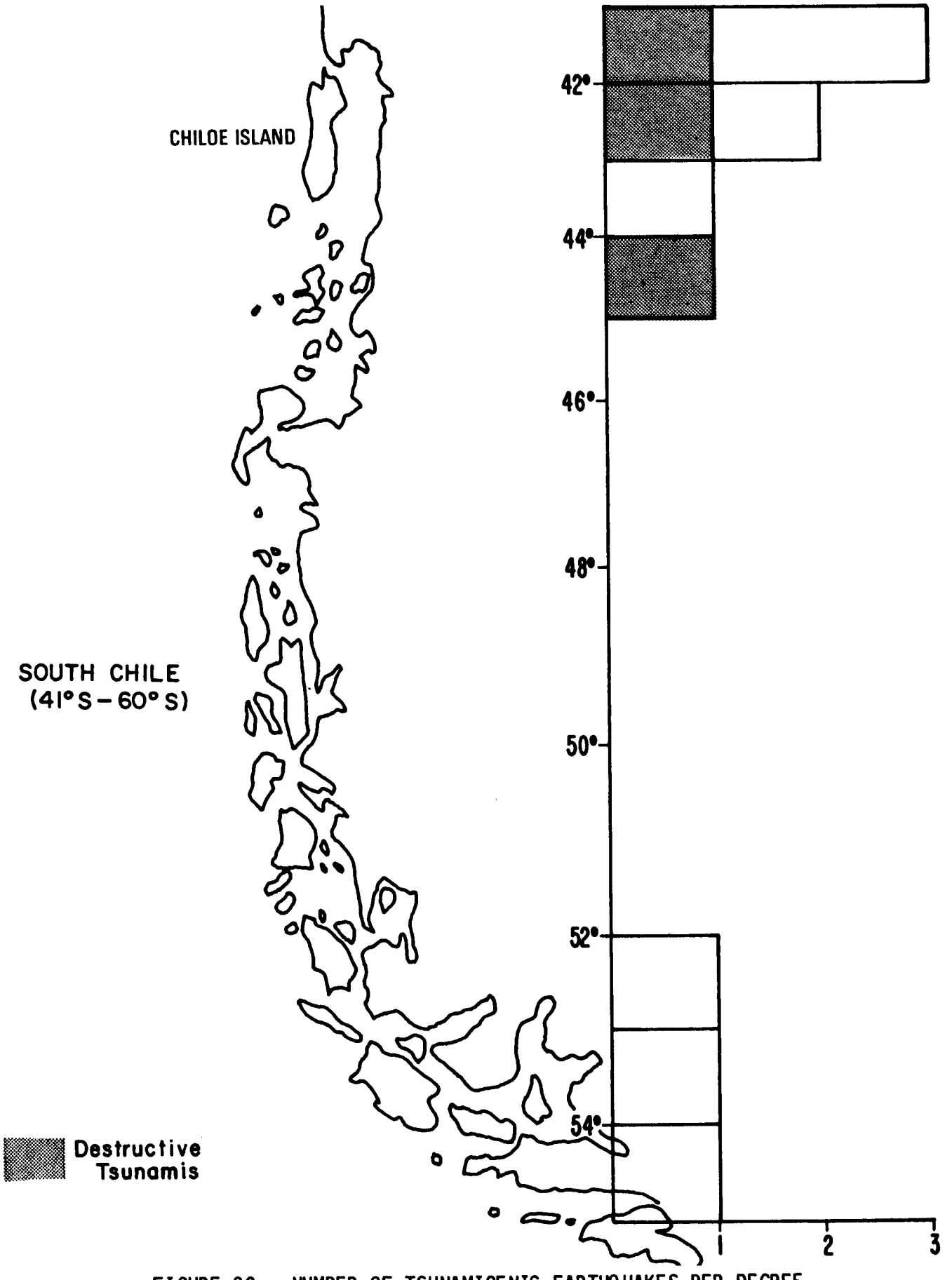

FIGURE 39. NUMBER OF TSUNAMIGENIC EARTHQUAKES PER DEGREE OF SOUTH CHILE COASTLINE

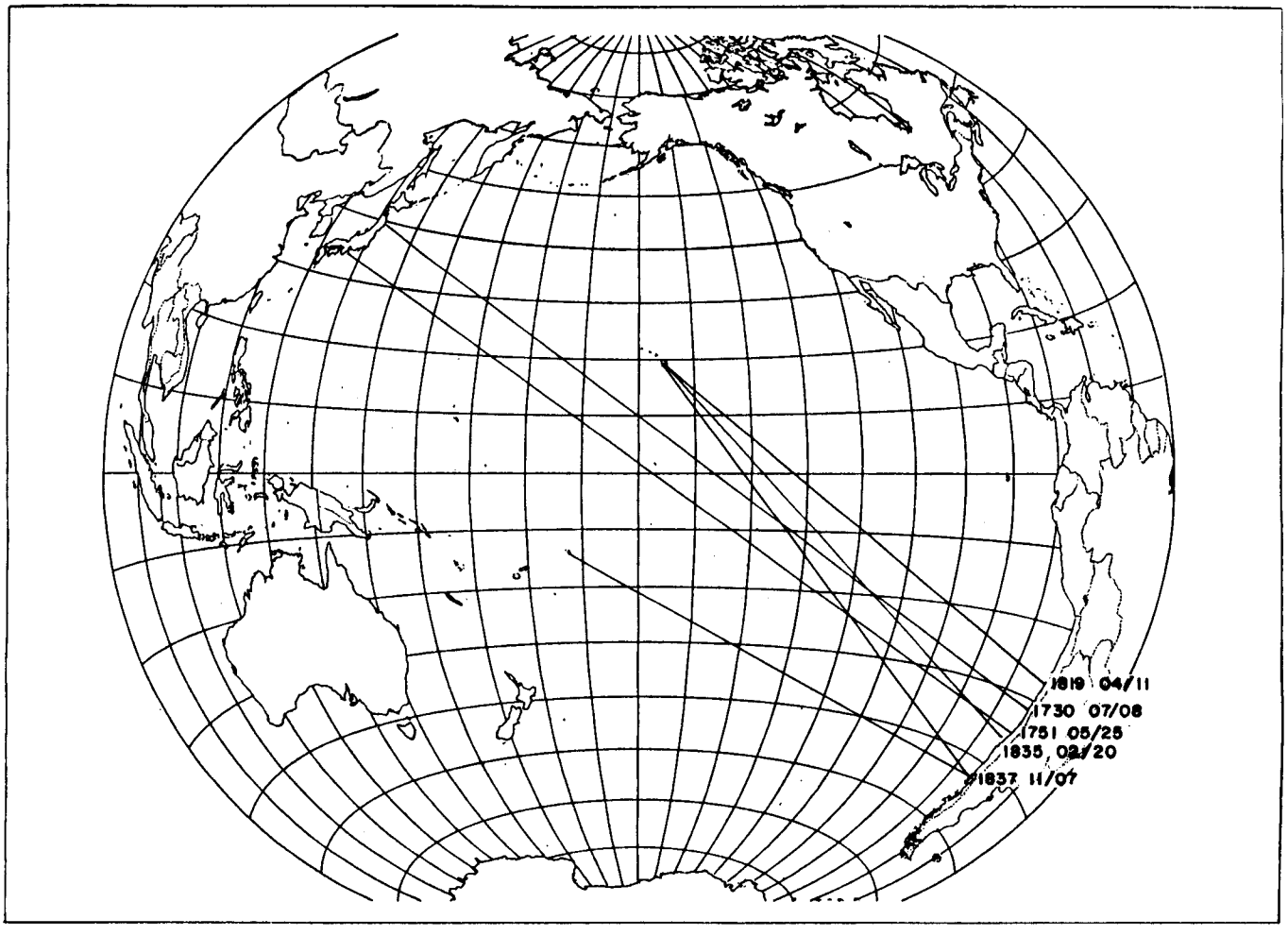

FIGURE 40. AREAS OUTSIDE PERU-CHILE REPORTING THE TSUNAMIS OF JULY 8, 1730; MAY 25, 1751; APRIL 11, 1819; FEB. 20, 1835; AND NOV. 7, 1837

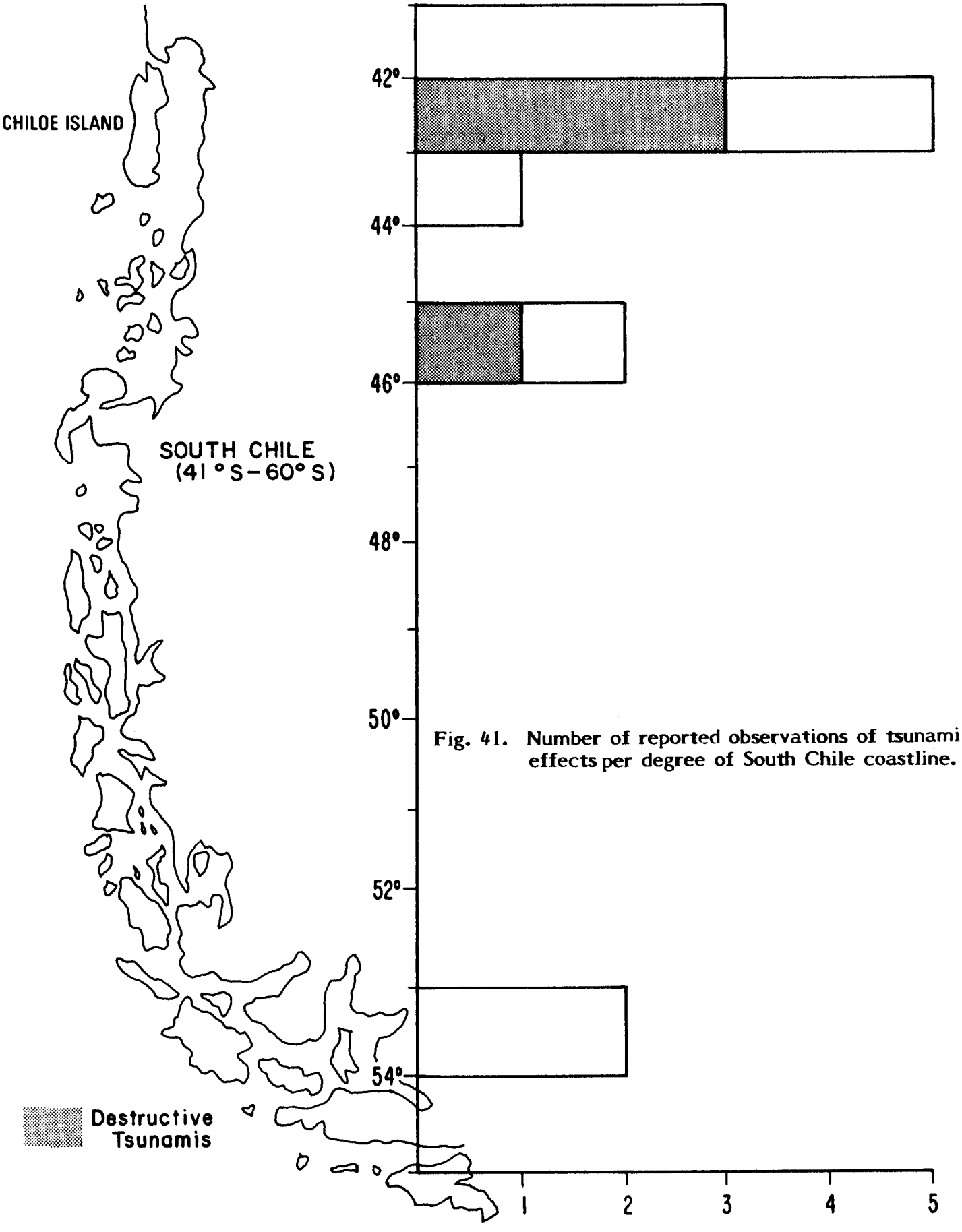

Fig. 41. Number of reported observations of tsunami effects per degree of South Chile coastline.

FIGURE 41. NUMBER OF REPORTED OBSERVATIONS OF TSUNAMI EFFECTS PER DEGREE OF SOUTH CHILE COASTLINE

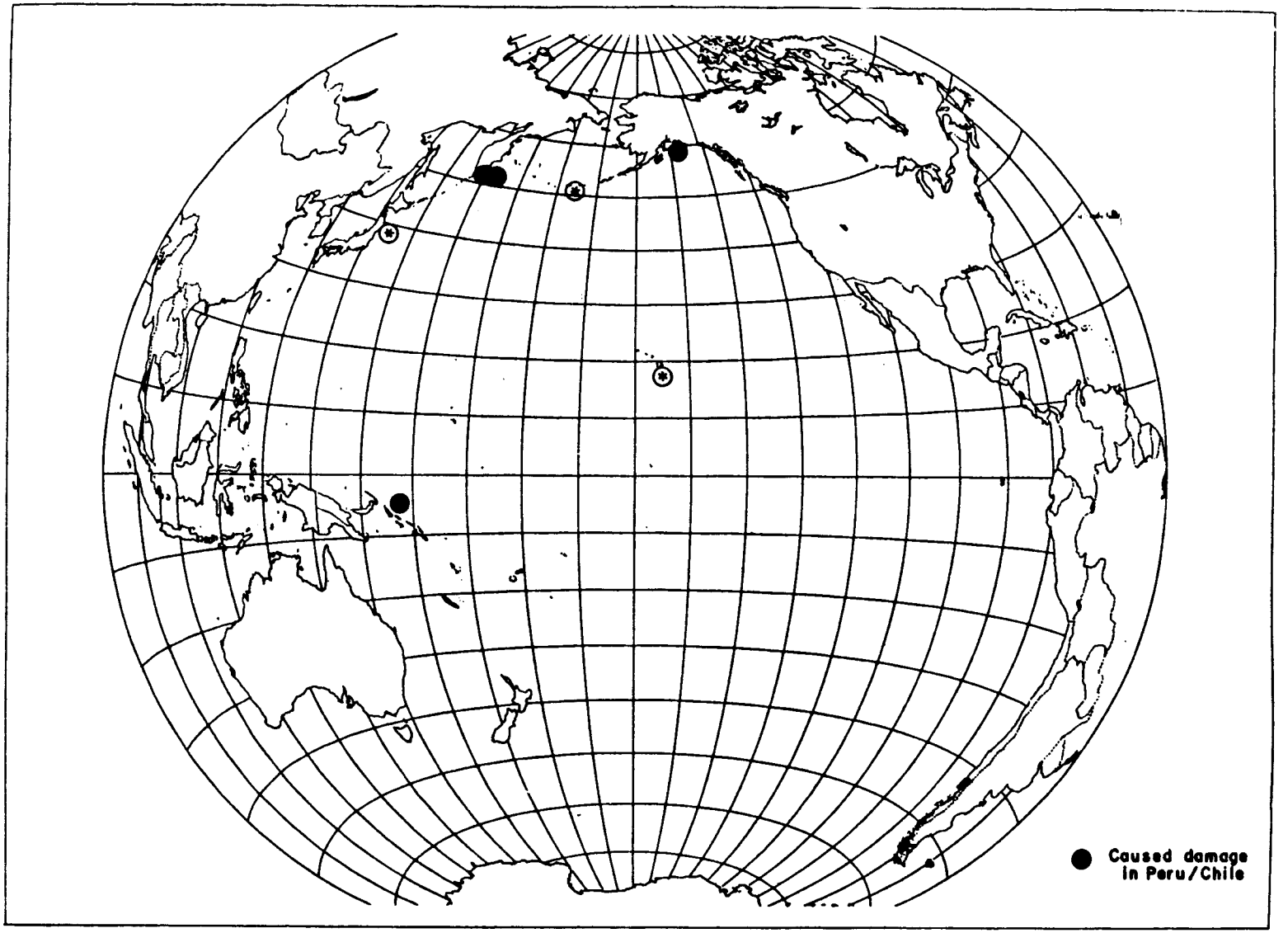

FIGURE 42. REMOTE-SOURCE TSUNAMIS REPORTED IN PERU-CHILE

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APPENDIX

SUMMARY TABLES AND RELATED DATA

Table I summarizes available earthquake and tsunami-related data for six source regions along the Peru-Chile coast. Because the length of coastline for each region varies, the size of each region should be considered before comparing data presented in the table.

Table II summarizes the effects of Pacific-wide tsunamis caused by Peru-Chile earthquakes. Hawaii and Japan have been affected or damaged by these events more frequently than any other country. Mexico, Central America, Colombia, and Ecuador reported only by the May 22, 1960, event. The occurrence of the 1868 and 1877 earthquakes in North Chile; the 1906 earthquake in Central Chile; the 1922 earthquake in North Central Chile; and the May 22, 1960, earthquake in South Central Chile is supporting evidence for the hypothesis that major tsunamigenic events migrate south along the western coast of South America and then return to the north to begin the sequence again. An event in November 1960 in Peru may mark the beginning of another north-south sequence of events.

Seven earthquakes in the North and West Pacific have generated tsunamis that were reported in Peru and Chile (see fig. 42). Table III gives information about these tsunamis, four of which caused damage in Chile. Tsunamis that affect Chile most often occur in the North Pacific--in the Kamchatka Peninsula/Aleutian Islands/ Gulf of Alaska areas. Although these areas frequently spawn Pacific-wide tsunamis, the remoteness of that part of the Pacific from the Chile-Peru coast ensures adequate warning time for low-lying communities.

Data in table IV show that some ports in Peru and Chile are more vulnerable to Pacific-wide tsunamis than are others. Arica, located in the "big bend" area of the Peru-Chile coast, has reported the largest number of tsunamis, but Valparaiso and Antofagasta also have reported several. Table V describes the damage caused by four of the seven events listed in table IV.

Most tsunamis that have been generated in this area by nonlocal earthquakes originate in the north and northwest regions of the circum-Pacific seismic belt. Tsunamis in the Northwest Pacific are more likely to cause damage in the coastal section adjacent to the Peru-Chile trench (from 3° S. to 41° S. latitude). Tsunamis of both local and nonlocal orgin may strike the coastal area south of the Peru-Chile trench. Only local tsunamis, however, historically have caused destruction in this area.

TABLE I. SUMMARY OF EARTHQUAKE AND TSUNAMI-RELATED DATA FOR PERU-CHILE COAST

SOURCE REGION	PERU	N. CHILE	NC. CHILE	C. CHILE	SC. CHILE	S. CHILE
TOTAL COASTLINE REPRESENTED (°)	14	9	6	4	4	14
TOTAL NO. OF TSUNAMIGENIC EARTHQUAKES	34	44	27	19	11	11
MAG. >7.0 EARTHQUAKES THAT GENERATED TSUNAMIS (%)	64	52	90	43	42	33
NO. OF EARTHQUAKES GENERATING DESTRUCTIVE TSUNAMIS PER DEGREE OF COASTLINE	0.6	0.6	1.2	1.2	1.0	0.2
MAGNITUDE RANGE OF TSUNAMIGENIC EARTHQUAKES	6.6-8.6	6.0-8.5	6.0-8.7	6.0-8.6	7.0-8.8	7.0-8.5
NUMBER OF TSUNAMIS GENERATED WITH RUNUP HEIGHT OF ≥5.0 M.	5	4	4	1	3	1
MAXIMUM REPORTED RUNUP HEIGHT (M)	24	24	16	24	25	4
NO. OF TSUNAMIS THAT WERE DAMAGING OUTSIDE SOUTH AMERICA	0	2	2	2	1	1

TABLE II. PACIFIC-WIDE TSUNAMIS GENERATED BY PERU-CHILE EARTHQUAKES
[TABULATION OF RUNUP AND DAMAGE]

	HAWAII	SOUTH PACIFIC	NEW ZEALAND	AUSTRALIA	PHILIPPINES	TAIWAN	JAPAN	ALASKA	CANADA	USA
EVENT DATE YEAR MO DA	RUNUP (M)	RUNUP (M)	RUNUP (M)	RUNUP (M)	RUNUP (M)	RUNUP (M)	RUNUP (M)	RUNUP (M)	RUNUP (M)	RUNUP (M)
1868 08 13	4.5X	3.0X	5.4X	1.2	R		1.5X	R		0.6
1877 05 10	9.0X	1.8X	6.0X	R			3.0X			0.5
1906 08 17	3.5X	X					0.4			0.2
1922 11 10	2.1	1.8X	0.2	0.2	0.1	X	X			0.2
1960 05 22	10.5X	4.9	0.9	1.7	12.2	1.1	6.3	1.3	R	2.6

X = damage.

R = tsunami reported in area, but runup information not available.

TABLE III. REMOTE-SOURCE TSUNAMIS AFFECTING PERU-CHILE

EVENT DATE YEAR MO DA	RUNUP (M)	SOURCE REGION	EPICENTER CAUSE	LAT. °	LONG. °	MAG.
1888 03 13	4.0	BISMARCK SEA	V	5.6S	148.0E	
1933 03 03	28.0	SANRIKU, JAPAN	T	39.2N	143.0E	8.3
1946 04 01	32.0	E. ALEUTIAN ISLANDS	T	52.8N	163.5W	7.4
1952 11 05	16.0	KAMCHATKA PENINSULA, USSR	T	52.8N	159.6E	8.3
1957 03 09	16.0	CENTRAL ALEUTIAN ISLANDS	T	51.3N	175.8W	8.3
1964 03 27	32.0	GULF OF ALASKA-ALASKA PEN.	T	61.0N	147.7W	8.4
1975 11 29	8.0	HAWAII	T	19.4N	155.1W	7.2

V = volcanic
T = tsunami

TABLE IV. RUNUP (IN METERS) IN PERU-CHILI FROM REMOTE-SOURCE TSUNAMIS

CITY	1888	1933	1946	1952	1957	1964	1975	TOTAL
TALARA, PERU			0.5		0.8	1.0		3
CALLAO, PERU			0.6	0.3	0.3	2.0		4
MATARANI, PERU			0.6		1.3	1.0		3
ARICA, CHILE	X			1.2	1.3	2.1	0.4	5
IQUIQUE, CHILE		0.4				X		2
ANTOFAGASTA, CHILE			0.9		1.0	1.0	0.3	4
CALDERA, CHILE				2.8	1.3		0.5	3
HUASCO, CHILE						X		1
COQUIMBO, CHILE				X		4.0X		2
VALPARAISO, CHILE			0.8	X	2.0	2.2		4
TALCAHUANO, CHILE				1.8	1.4	2.5		3
CORRAL, CHILE						1.7		1

X = damage.

TABLE V. SUMMARY OF DAMAGE IN PERU-CHILE FROM REMOTE-SOURCE TSUNAMIS

EVENT DATE YEAR MO DA	SOURCE REGION	REPORTING LOCATION	DAMAGE
1888 03 13	BISMARCK SEA	ARICA, CHILE	SHIPS SMASHED.
1946 04 01	E. ALEUTIAN IS.	IQUIQUE, CHILE	BOATS DAMAGED.
		JUAN FERNANDEZ IS., CHILE	SOME DAMAGE.
1952 11 05	KAMCHATKA PEN., USSR	VALPARAISO, CHILE	HOUSES INUNDATED.
		COQUIMBO, CHILE	PIER, MARKET, RAIL LINE INUNDATED.
		CALLAO, PERU	SOME DAMAGE.
1964 03 28	SOUTHERN ALASKA	IQUIQUE, COQUIMBO, HUASCO, & SAN VINCENTE, CHILE	SLIGHT DAMAGE, MAINLY TO SHIPPING.

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