CHAPTER 5

SEISMICITY OF THE COUNTRY

In any seismic country it is possible to determine differences in the type and frequency of the seismic events occurring in different areas. There areas where there are a lot of earthquakes of small size, and other areas where there are few earthquakes, but they are large.

This chapter describes the variation of seismicity through the country (in this case Chile), providing the main characteristics of the seismic activity in each seismic zone.

CHAPTER OBJECTIVES

1 . Describe the characteristic of the earthquake's occurrence in the country (Chile).
2. Define the different ways of earthquake's occurrence in different regions of the country (Chile).
3. Describe the historical seismic activity of the country (Chile).

NOTICE

THIS CHAPTER MUST BE DEVELOPED SEPARATELY BY EVERY COUNTRY, HOWEVER CHILE'S SEISMICITY IS SHOWN AS AN EXAMPLE.

5.1 GENERAL CHARACTERISTICS OF THE SEISMICITY IN CHILE

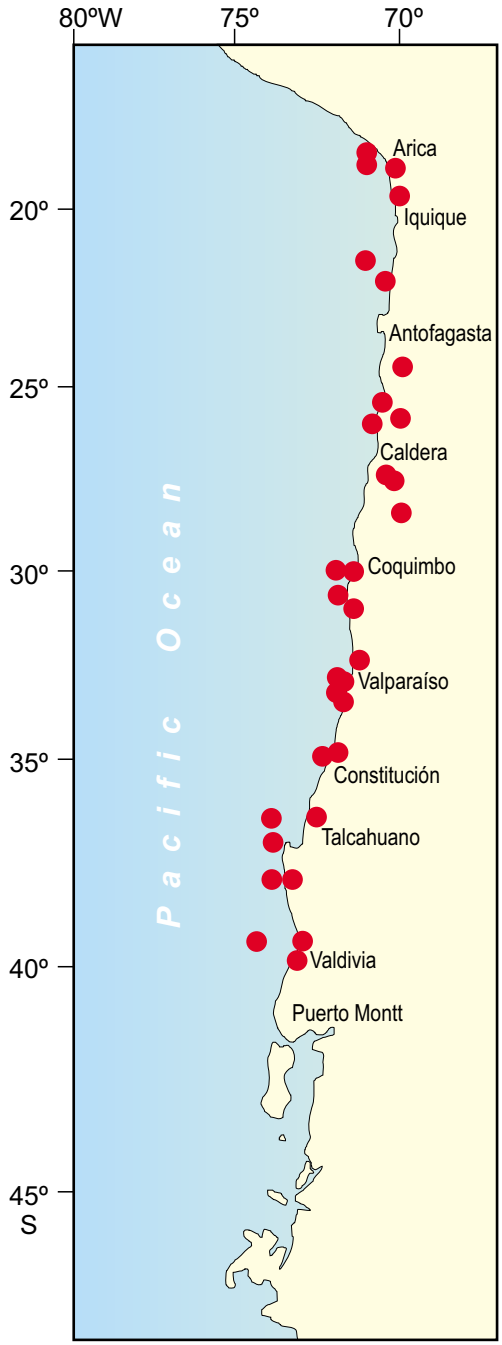
The West coast of South America is outlined by the eastern border of the Nazca tectonic plate and is characterized by its extreme seismicity. There is a very narrow seismic band (100-150 km wide) between the Andes mountain range and the Peru-Chile Trench.

Major differences is seismicity, in morphology of the coast, and in potential for generation of large tsunamis exist along the coastline of Chile.

An outstanding and well-known feature of the spatial distribution of hypocenters along South America is the gap in seismic activity between depths of 320 and 525 kilometers.

The deep earthquakes (deeper than 525 km) define two relatively narrow belts of activity, and the number of small-magnitude events relative to the number of large-magnitude events is very low.

The intermediate-depth activity tends to cluster in space. There is a peak in activity between depths of about 100 and 130 km; most of these events occur between about latitudes 17ºS. and 24ºS. (near the bend in the coastline between Peru and Chile). This is also the region that has lacked large shallow earthquakes for about the past 120 years. The gap in seismic activity at intermediate depths between about latitudes 25.5ºS. and 27ºS. is evident; however, this region has experienced many large shaflow events.

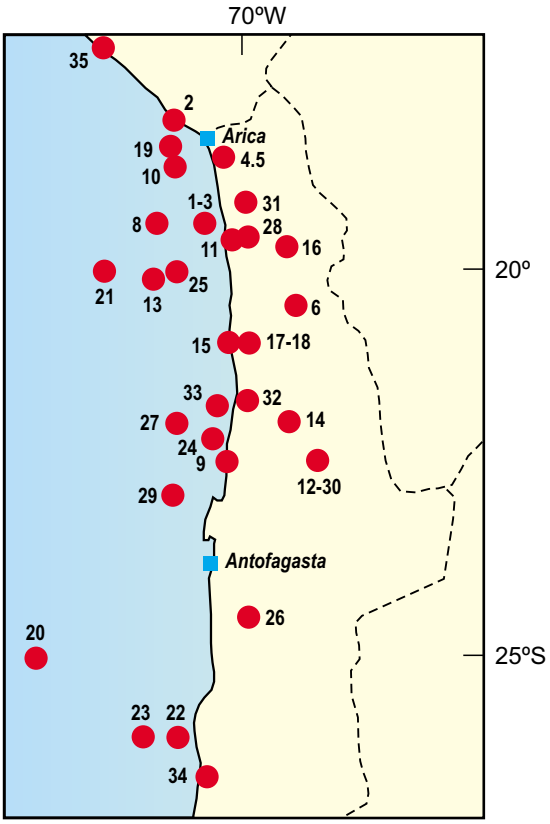


Large earthquakes in Chile.

5.2 SEISMIC ZONING

5.2.1 NORTH CHILE

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



Earthquake's location in northern Chile.

a) The northernmost region (18ºS-20ºS.), sometimes called the "big bend" area in the South American coastline, has a history of destructive earthquakes and tsunamis. Great earthquakes in 1604, 1705, 1868, and 1877 destroyed Arica (located at 18.5ºS. latitude) as well as other coastal towns, and generated Pacific-wide tsunamis that were destructive.

b) The second region in North Chile lies between 20ºS. and 22ºS. latitude. Here, earthquakes have occurred both offshore and inland. The offshore earthquakes have produced several tsunamis, but none has been destructive.

c) The Province of Antofagasta (22º - 27ºS. latitude) includes much intermediate-depth activity, but lacks major shallow shocks 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 generated a damaging tsunami.

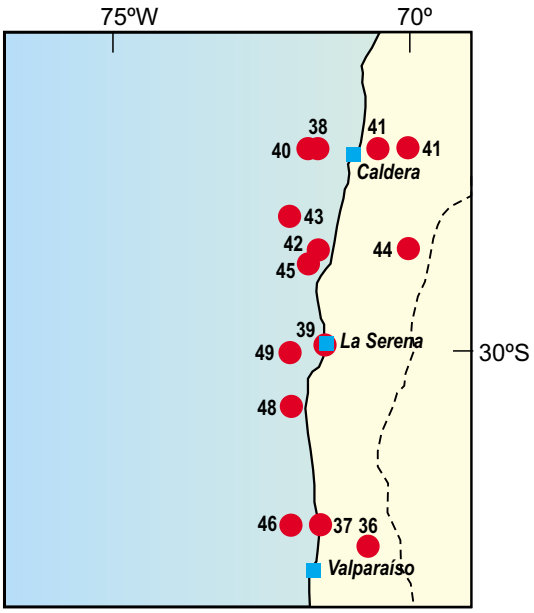
SEIAMIC HISTORY OF NORTH CHILE (18ºS - 27ºS)

Event Nr.	Year	Date Mo.	Day	Lat. ºS	Long. ºW	Mag.	Effects
1	1543			19,0	70,5	7,7	Max. Mercalli Intensity= X
2	1604	11	24	17,9	70,9	8,4	Great tsunami
3	1615	09	16	19,5	70,5	7,5	Max. Mercalli Intensity= X
4	1681	03	10	18,5	70,3	7,5	Doubtful tsunami
5	1715	08	23	18,5	70,3	7,5	Doubtful tsunami
6	<1 768			20,5	69,4	7,7	Max. Mercalli Intensity= VII
7	1831	10	09	18,5	71,0	7,0	Max. Mercalli Intensity= VII
8	1833	09	18	19,0	71,0	7,4	Max. Mercalli Intensity= VII
9	1836	06	03	22,6	70,3	7,5	Local Tsunami
10	1868	08	13	18,6	71,0	8,5	Great Tunami
11	1869	08	24	19,6	70,2	7,4	Local Tsunami
12	1870	04	22	22,7	68,9,	7,5	Max. Mercalli Intensity= X
13	1871	10	05	20,1	71,3	7,5	
14	1876	10	26	22,1	69,6	7,2	Max. Mercalli Intensity= VII
15	1877	05	10	21,0	70,3	8,8	Great sunami
16	1878	01	23	19,9	69,5	7,3	
17	1905	04	26	21,0	70,0	7,0	
18	1906	08	30	21,0	70,0	7,2	
19	1906	12	26	18,0	71,0	7,0	
20	1909	06	08	25,0	73,0	7,6	
21	1911	09	15	20,0	72,0	7,3	
22	1918	12	04	26,0	71,0	7,8	Tsunami
23	1925	05	15	26,0	71,5	7,1	
24	1928	11	20	22,5	70,5	7,1	
25	1933	02	23	20,0	71,0	7,6	Small Tsunami
26	1936	07	13	24,5	70,0	7,3	Small Tsunami
27	1940	10	04	22,0	71,0	7,3	Small Tsunami
28	1945	04	19	19,5	70,0	7,2	
29	1947	07	29,	23,5	71,0	7,0	
30	1948	12	26	22,5	69,0	7,0	Small Tsunami
31	1956	01	08	19,0	70,0	7,1	
32	1967	12	21	21,9	70,1	7,3	Small Tsunami
33	1970	06	19	22,2	70,5	7,0	
34	1983	10	04	26,5	70,6	7,4	Small Tsunami
35	1988	04	12	17,3	72,4	7,0	

5.2.2 NORTH CENTRAL CHILE (27ºS - 33ºS)

This region is characterized by a shallow dipping seismic zone and by a lack of volcanism. Destructive tsunamis this century have occurred in this area at a 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.



Earthquake's location in north-central Chile

SEISMIC HISTORY OF NORTH-CENTRAL CHILE (27ºS - 33ºS)

Event Nr.	Year	Date Mo	Day	Lat. ºS	Long. ºW	Magnitud	Effects
36	1687	07	12	32,8	70,7	7,3	
37	1730	07	08	32,5	71,5	8,7	Great Tsunami
38	1819	04	11	27,0	71,5	8,5	Big Tsunami
39	1849	12	17	29,9	71,4	7,5	Big Tsunami
40	1851	05	26	27,0	71,6	7,2	Tsunami
41	1859	10	05	27,0	70,0	7,7	Big Tsunami
42	1918	05	20	28,5	71,5	7,9	
43	1922	11	07	28,0	72,0	7,0	
44	1922	11	11	28,5	70,0	8,3	Great Tsunami
45	1923	05	04	28,7	71,7	7,0	
46	1931	03	18	32,5	72,0	7,1	
47	1939	04	18	27,0	70,5	7,4	
48	1943	04	06	30,8	72,0	8,3	Small Tsunami
49	1955	04	19	30,0	72,0	7,1	Small Tsunami

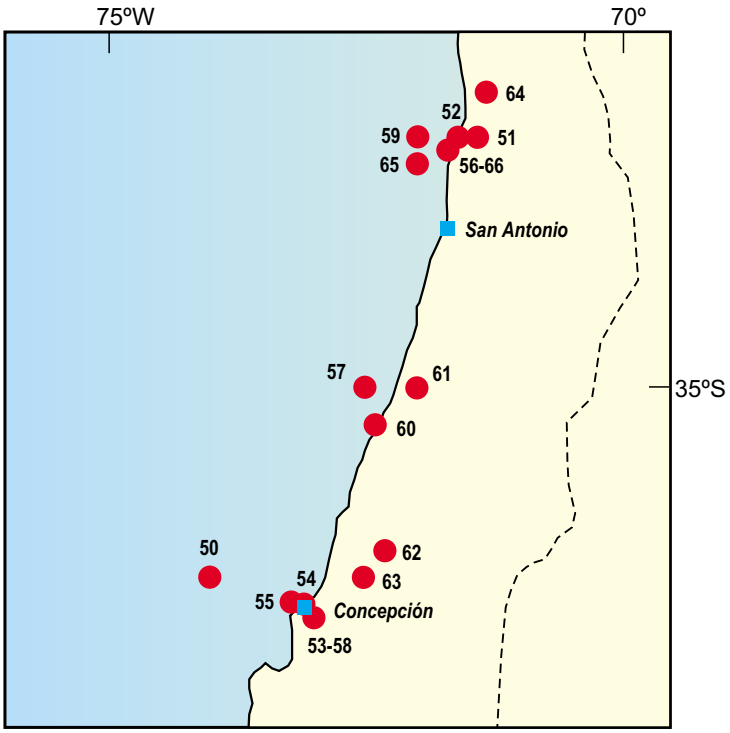
5.2.3 CENTRAL CHILE (33ºS - 37ºS)

Central Chile can be divided in three regions, as shown in the diagram.

a) The region near Valparaiso (33º-34ºS) is marked by the intersection of the Juan Fernandez Ridge with the Peru-Chile Trench, and the abrupt appearance of volcanism to the south. Five tsunamigenic earthquakes have occurred in this area: November 19, 1811; November 19, 1822; October 16, 1868; August 17, 1906 and March 3, 1985. The Nov. 19, 1822, and Aug. 17, 1906, earthquakes were centered almost at the same location. Both had magnitudes of 8.5 or larger and both caused damage.

b) South of Valparaiso (34ºS-36ºS), a moderate-size seismic gap exists, where the potential for future earthquakes is good. Four events having magnitudes of 7.5 or larger have occurred in this area, but none of these generated a destructive tsunami.

c) Concepcion Region (36ºS-37ºS). In the southern part of Central Chile there were two events in 1835 and 1939 with magnitudes higher than 8.0; the first one generated a destructive tsunami. Lower magnitude events occurred in 1751, 1868, 1878, 1953, and 1971.



Earthquake's location in central Chile.

SEISMIC HISTORY OF CENTRAL CHILE (33ºS -37ºS)

Event Nr.	Year	Date Mo	Day	Lat. ºS	Long. ºW	Magnitud	Effects
50	1751	05	25	36,5	74,0	8,0	Tsunami
51	1811	11	19	33,0	71,4		Small Tsunami
52	1822	11	19	33,0	71,6	8,5	Great Tsunami
53	1835	02	20	36,8	73,0	8,2	Great Tsunami
54	1838	05	07	36,7	73,3		Small Tsunami
55	1868	09	14	36,7	73,2		Small Tsunami
56	1868	10	16	33,1	71,7		Small Tsunami
57	1871	03	25	35,0	72,5	7,5	Small Tsunami
58	1878	02	14	36,8	73,0		Small Tsunami
59	1906	08	17	33,0	72,0	8,6	Great Tsunami
60	1923	02	17	35,3	72,4		Small Tsunami
61	1928	12	01	35,0	72,0	8,4	Tsunami
62	1939	01	25	36,3	72,3	8,3	
63	1953	05	06	36,5	72,5	7,6	
64	1971	07	07	32,5	71,2	7,5	
65	1975	05	10	35,7	74,6	7,8	
66	1985	03	03	33,2	72,0	7,8	Small Tsunami

DO YOU KNOW ... ?

The May 22, 1960, earthquake in Southern Chile generated a tsunami that spread out through the entire Pacific Ocean, producing damage in places so far away as Japan, Hawaii and Colombia. There were also deaths in Japan and Hawaii. In this last place the damages were estimated to be $ 75 million (US).

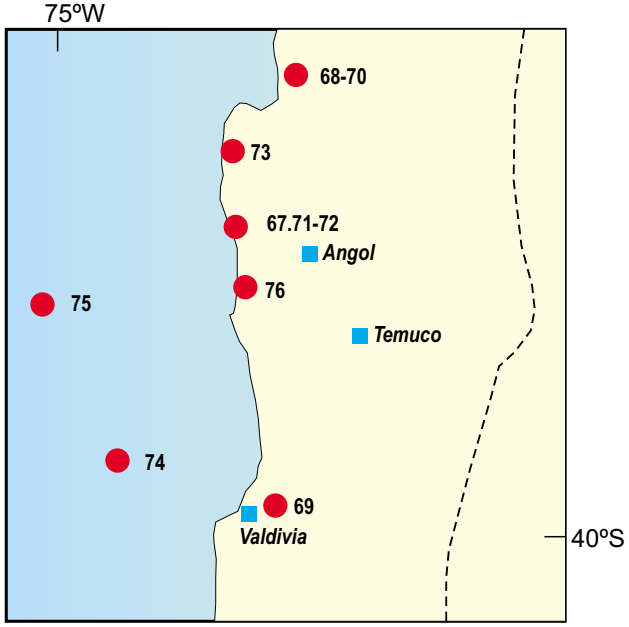
5.2.4 SOUTH CENTRAL CHILE (37ºS. -41ºS.)

This zone is characterized by a shift of major seismic activity to an offshore structure near the northern boundary of this region, as seen in the diagram.

Large earthquakes occurred in this region on October 28, 1562; February 8, 1570; December 16, 1575, March 15, 1657, and May 22, 1960. The 1562, 1570, 1575, and 1960 earthquakes produced destructive tsunamis.

Intervals between the destructive earthquakes of 1575, 1737 (South Chile), 1837 (South Chile), and 1960 (Valdivia area, 40º S. latitude) appear to be larger than those of both the Concepcion and the Valparaiso areas (that is, more than 100 years).

The May 22, 1960, earthquake was the largest seismic event in this region since 1570.



Earthquake's location in South-Central Chile.

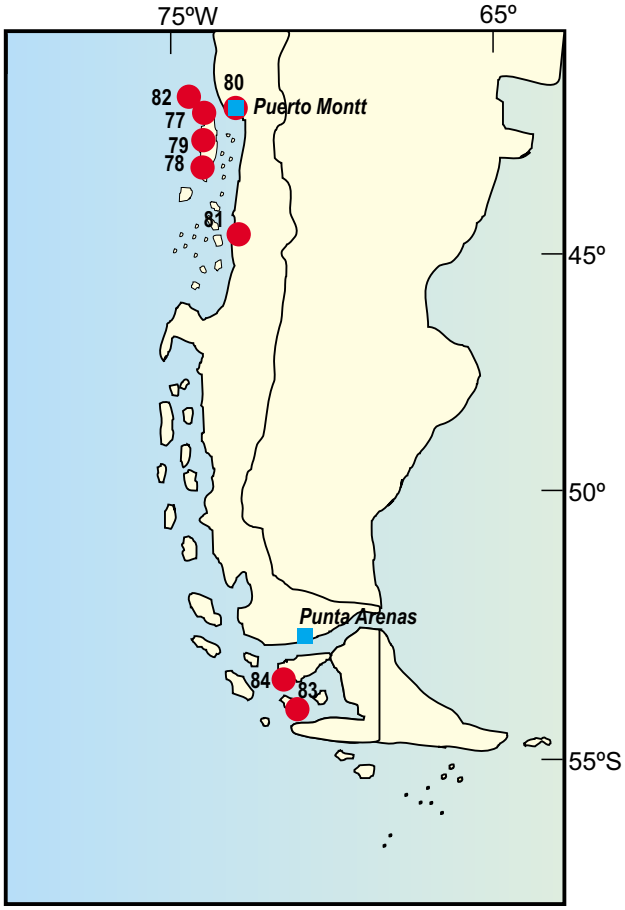
SEISMIC HISTORY OF SOUTH-CENTRAL CHILE (37ºS - 41ºS)

Event Nr.	Date Year	Mo	Day	Lat. ºS	Long. ºW	Magnitud	Effects
67	1562	10	28	38,0	73,5	8,0	Great Tsunami
68	1570	02	08	37,0	73,0	8,5	Great Tsunami
69	1575	12	16	39,8	73,2	8,5	Great Tsunami
70	1657	03	15	37,0	73,0	8,0	Great Tsunami
71	1920	08	20	38,0	73,5	7,0	Small Tsunami
72	1949	04	20	38,0	73,5	7,3	
73	1960	05	21	37,5	73,5	7,3	Small Tsunami
74	1960	05	22	39,5	74,5	8,9	Great Tsunami
75	1960	11	01	38,5	75,1	7,4	
76	1974	08	20	38,4	73,4	7,0	

5.2.5 SOUTH CHILE (41ºS - 60ºS)

This zone can be divided in three different seismic regions as seen in the next diagram.

a) Region from 41ºS - 45ºS: The coastline of South America changes dramatically at 41ºS 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 41ºS latitude), earthquakes generated damaging tsunamis in 1633 and 1837. A damaging tsunami occurred at 44.6º S latitude in 1929.



Earthquake's location in South Chile.

b) Region from 45ºS-53ºS: South of the triple junction between the Peru-Chile trench and the Chile Ridge at 46ºS 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.

c) Region from 53º S-60º S: Seismic records are incomplete because of the recent settlements of the South American Continent near 53º S latitude. Records that do exist, however, indicate that the seismicity is low. The earliest record of earthquake activity is the Magellan Strait earthquake of 1878. Two large earthquakes occurred within a 10-hour period in 1949.

SEISMIC HISTORY OF SOUTH CHILE (41ºS - 60ºS)

Event Nr.	Date Year	Mo	Day	Lat. ºS	Long. ºW	Magnitud	Effects
77	1633	05	14	41,8	74,0		Small Tsunami
78	1737	12	24	43,0	74,0	7,5 - 8	
79	1837	11	07	42,5	74,0	8,5	Large Tsunami
80	1871	12	28	41,5	73,0		
81	1927	11	21	44,6	73,0	7,1	Tsunami
82	1940	10	11	41,5	74,5	7,0	
83	1949	12	17	54,0	71,0	7,7	Local Tsunami
84	1950	01	30	53,5	71,5	7,0	

A) REPORT

REPORT FROM THE PAST

On December 16, 1575 there was a severe earthquake in the South of the country whose characteristics were very similar to the one which occurred several centuries later in the same region (May 22, 1960). Due to this similarity is important to keep a record of the effects of that particular event.

The Indian territories south of the Bio-Bio River contained five frontier outpost: Imperial, Valdivia, Villarrica, Osorno and Castro. All five were destroyed by the areas earthquake of 1575. According to reports by the Commander of Valdivia and the Governor of Chile there were more than twenty deaths in Valdivia, a large number considering the nature and size of the settlement. Cracks and fissures opened in the ground during the main shock and during some of the larger aftershocks. The tsunami reached Valdivia, located on a river of the same name about 25 km upstream from its mouth, shortly after the earthquake, " while the earth still shook", i.e. during the initial aftershocks. The water came rushing upstream, reversing the natural flow of the river. The rising water knocked over houses, poles and uprooted trees. Two galleons, riding at anchor in this port were sunk. After the ebb, the inhabitants had time to flee to higher ground.

The tremors continued for a period of forty days. Sizable cracks appeared in the ground and landslides were also recorded, a river flowing from lake Riñihue became blocked in its upper reaches. The dam lasted until April of the following year, when after prolonged rains the water level in the lake rose considerably, causing the dam to burst and resulting in much devastation farther downstream; more than 1200 indians perished and many cattle were lost as well; but the population of Valdivia was saved due to the foresight of its Commander, who had all low-lying houses evacuated well in advance.

The tsunami was highly destructive along the entire coast of southern Chile, up to Concepción where the amplitudes were too low to cause damage. Nearly 100 Indians were drowned along the coast of La Imperial, north of Valdivia, where Indian settlements exist to this day.

The description and extent of damage due to earthquake and the tsunami match closely the effects of May 22, 1960.

B) CHAPTER SUMMARY

- Spatial distribution of hypocenters is characterized by the lack of intermediate depth seismic activity between depths of 320 and 525 kilometers.

- Shallow earthquakes are distributed along or close to the coastline everywhere in the country.

- Most intermediate depth earthquakes (between 100 and 130 kilometers deep) occur in Chile from latitude 17ºS to latitude 24ºS near the bend in the coastline between Chile and Peru.

- Major differences in seismicity exist along the coastline of Chile.

- In the Transverse Valleys Region (27ºS-33ºS latitude) there is a lack of Neogene volcanism.

- Several seismic events have occurred in different regions of the country which have produced destructive tsunamis.

- No seismicity is recorded presently in South Chile between latitude 45ºS and latitude 53ºS.

C) QUESTIONS/PROBLEMS

1. What is the characteristic of intermediate depth earthquakes in Chile?

2. List three characteristics of the seismicity of South Chile.

3. What are the largest magnitude events occurred in Chile?

4. In which region have most of the important seismic events occurred?

5. Using books in the library, draw the location of volcanoes over the maps of seismicity for the different regions of the country.

D) CHAPTER TEST

A. Multiple Choice. Choose the letter that best completes the statement or answers the question.

1 . Between the Andes and the Peru-Chile trench there is a very active

a) fault
b) volcano
c) seismic belt
d) tsunami

2. The northern part of North Chile is characterized by

a) the lack of volcanism
b) big tsunamis
c) deep earthquakes
d) shallow earthquakes

3. The region where the potential for future earthquakes is highest is

a) South Chile
b) Central Chile
c) North Central Chile
d) North Chile

4. The largest magnitude earthquake ever recorded occurred in

a) South Chile
b) North Central Chile
c) Central Chile
d) South Central Chile

5. The earthquake that occurred in 1575 was very similar to the earthquake of

a) 1868
b) 1922
c) 1960
d) 1985