

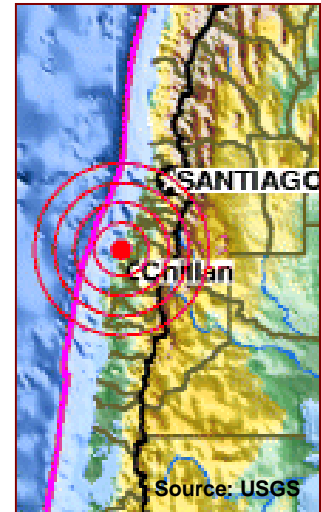


# Event Recap Report: 02/27/10 Chile Earthquake

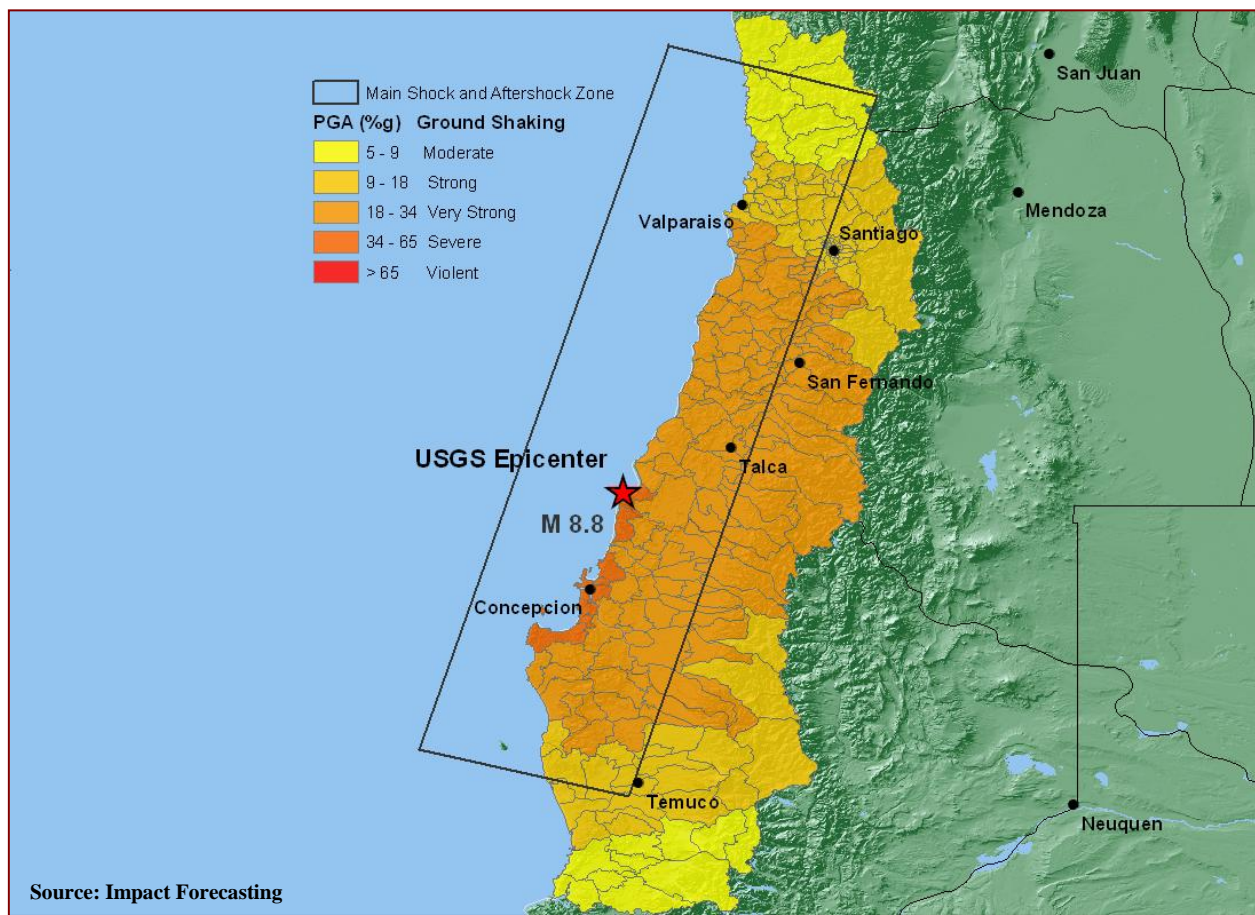
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## Introduction

A powerful magnitude-8.8 earthquake struck central Chile on the morning of February 27<sup>th</sup>, 2010, killing at least 550 people, injuring thousands more and causing devastating damage. The main tremor occurred just off the coast of Chile at 3:34 AM local time (6:34 UTC) with an epicenter 100 kilometers (60 miles) north-northwest of Chillan, Chile or 325 kilometers (200 miles) southwest of Santiago, Chile. The temblor's depth was measured at 35 kilometers (21.7 miles) beneath the earth's surface. Residents close to the epicenter reported shaking for nearly 150 seconds. Following the main earthquake, over 200 aftershocks occurred, of which 150 of these were greater than magnitude-5.0 and 12 were greater than magnitude-6.0. The main earthquake shook buildings and forced evacuations in Buenos Aires, Argentina and was felt 2,900 kilometers (1,800 miles) east from the epicenter in Sao Paulo, Brazil. The enormity of the initial tremor even caused seiches, defined as a standing wave in an enclosed or partially enclosed body of water, to occur in Lake Pontchartrain near New Orleans, Louisiana. Scientists note that the earthquake was so strong that a normal day on earth was shortened by 1.26 microseconds, and violent enough to move the city of Concepcion at least 10 feet (three meters) to the west and the capital, Santiago, about 11 inches (28 centimeters) to the west-southwest. This is the seventh strongest earthquake ever recorded and the fifth strongest since 1900.



The figure below is a simulated spatial distribution of ground shaking from Impact Forecasting's catastrophe model.



# Seismological Recap

## Seismicity and Tectonic Setting of Central Chile

Chile is one of the most seismically-active regions of the world, second only to Japan (Figure 1). On average, a magnitude-8.0 earthquake occurs in Chile once every ten years. Most earthquakes in this part of the world occur along the line where the Nazca Plate (Figures 2 and 3) slides at an angle (known as oblique subduction) under the South American Plate. The subduction zone runs along the entire 5,000-kilometer (3,106-mile) length of the western coastline of South America.

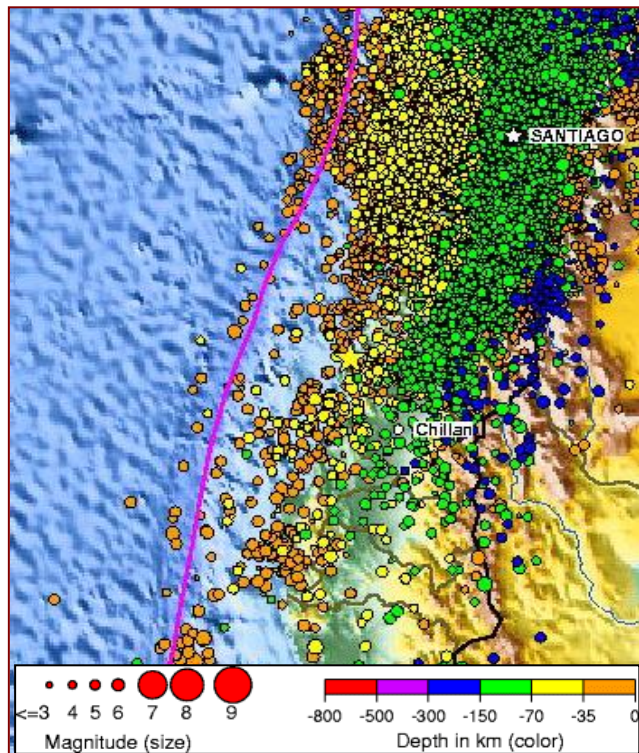


Figure 1: Map showing historic earthquake activity in Chile from 1990 to present. The star is the 2/27/10 earthquake. Magenta line indicates the plate boundary between Nazca and South America (Credit: [www.iris.edu](http://www.iris.edu))

As a result of pushing from the Nazca Plate, the South American Plate has been lifted up, creating the towering Andes Mountains (Figures 3 and 4). Chile is wedged between the Pacific Ocean (Nazca Plate) and the Andes Mountains. Most of the population lives in a narrow longitudinal valley (Lomnitz, SRL, 2004). Most of these valleys are filled with soft soils (Celebi, 1987, BSSA) that can amplify earthquake ground motion by a large factor and result in increased damage to populated areas.

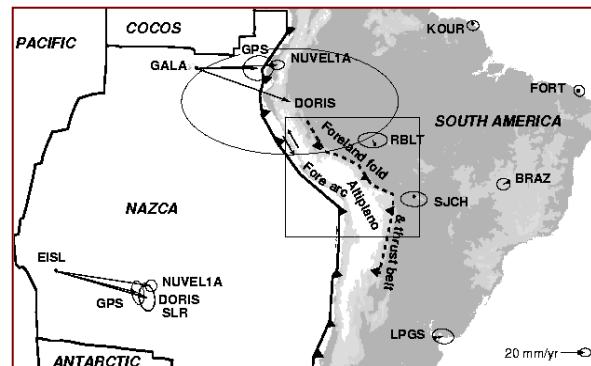


Figure 2: Geometry of the Nazca-South America plate boundary zone at the latitudes of central Chile. The arrows indicate the motion of the Nazca plate towards South America (Credit: [www.igp.gob.pe/geod/andespj.html](http://www.igp.gob.pe/geod/andespj.html))

Climate and terrain conditions of Chile make it difficult to document historical earthquakes of the past (Lomnitz, 2004, BSSA). However, it is known that there were at least 85 destructive earthquakes with magnitudes greater than 7.0 between 1570 and 1960, and 25 earthquakes greater than magnitude-7.0 since 1960. The May 12, 1960, magnitude-9.5 earthquake (Figure 5) in Chile was the largest earthquake ever recorded by seismological instruments. A large area (1,000-kilometer (621-mile) long by 120-kilometer (75-mile) down dip) of the subducting Nazca Plate slipped 20 meters (66 feet) under the South American Plate, producing large ground motions over a large area and also a destructive tsunami. The earthquake shaking itself killed at least 1,655 people (mainly due to collapsed buildings), while the large tsunami waves killed an additional 2,000 people. It should be noted that the worst seismic disaster in Chile's history came in 1939 after a magnitude-8.3 earthquake killed 28,000 people. For reference sake, the great Sumatran earthquake of 2004 in Indonesia was a magnitude-9.1 event that also occurred within a subduction zone area.



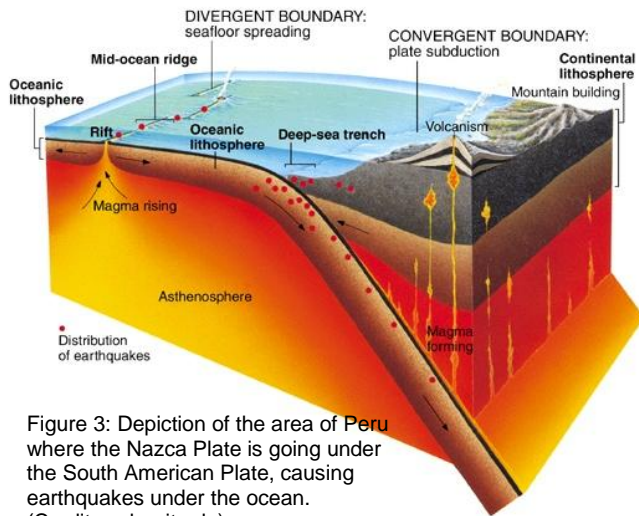


Figure 3: Depiction of the area of Peru where the Nazca Plate is going under the South American Plate, causing earthquakes under the ocean. (Credit: web.mit.edu)



Figure 4: The convergence of the Nazca and South American Plates has deformed and pushed up limestone strata to form towering peaks of the Andes Mountains. (Credit: USGS)

### The February 27, 2010 Magnitude-8.8 Maule, Chile Earthquake

The February 27, 2010 earthquake occurred about 230 kilometers (143 miles) north from the epicenter of the historic May 22, 1960 magnitude-9.5 Chilean earthquake (Figures 5 and 6). The 2010 event occurred at a shallow depth of about 35 kilometers (22 miles) at the locked zone (shallower than 50 kilometers (31 miles)) between the low-angle subducting Nazca Plate and the overriding South American Plate. Based on background seismicity and sense of fault motion studies, the interface between the Nazca and South American plates is seismically coupled between a depth of 20 and 50 kilometers (12 and 31 miles), and because of this large subduction thrust earthquakes occur (magnitude-7.5 and above) at this depth interval (Delouis et al., 1996; 2009). The magnitude-8.8 February 27, 2010 earthquake occurred at the younger portion of the 5,000-kilometer (3,106-mile) subduction zone, where the Nazca Plate dives fast with a stronger coupling (tight sticking that causes strong friction between the two plates) with the overriding plate. In Figures 5 and 6, the rupture areas of the recent earthquake and ensuing aftershocks are shown. The rupture runs nearly 500 kilometers (311 miles) in length and 50 kilometers (31 miles) in width.

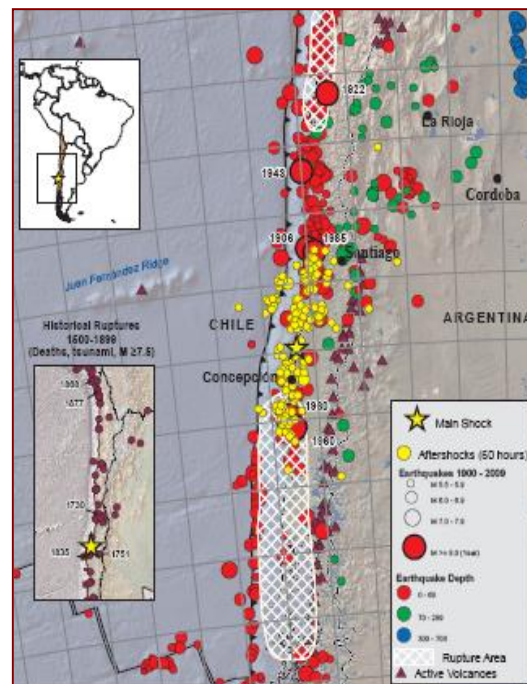


Figure 5: Map showing the spatial relationship between previously located earthquakes (1900 to present) and the 2/27/10 Chile earthquake (yellow star) and its aftershocks (yellow circles). Also shown are the rupture zones of the 1922 1960 earthquakes (white hashed areas). (Credit: USGS)

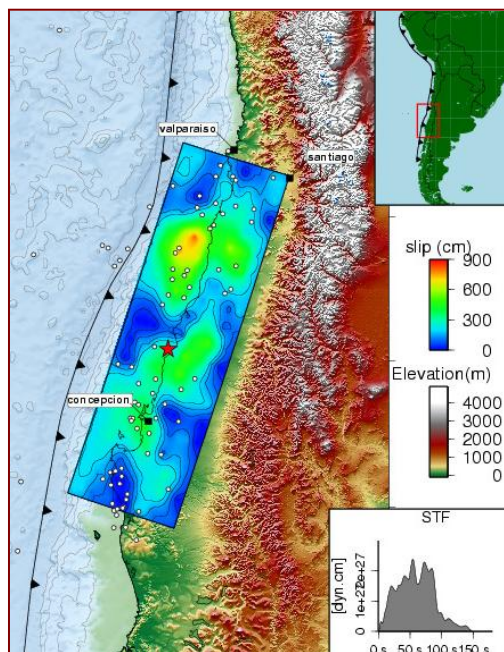


Figure 6: Surface projection of the fault plane slip distribution. The red star represents the epicenter of this event. The white dots are the aftershocks. The lowest inset shows that most of the energy is released during the first 100 seconds (Credit: USGS and [http://tectonics.caltech.edu/slip\\_history/2010\\_chile/index.html](http://tectonics.caltech.edu/slip_history/2010_chile/index.html))

In Figures 6 and 7, a model of the rupture evolution is shown. The colored patches represent the amount of motion (slip), and the contours (Figure 7) represent the amount of elapsed time since the earthquake began. This model estimates a fault motion (rupture) of over 500 kilometers (311 miles) along the length of the fault as well as the distance from the Earth's surface at depths of over 50 kilometers (31 miles). The longest rupture lengths occurred within the first 100 seconds, while smaller displacements continued for the next 150 seconds following the start of the earthquake.

When comparing the recent Chile earthquake with the January 12, 2010 magnitude-7.0 earthquake in Haiti, the maximum amount of slip on the fault during the Chile event is only about two times more (shown in Figure 8). However, the amount of energy released from the magnitude-8.8 earthquake is approximately 512 times more. This is a result of the larger rupture area of the Chilean event.

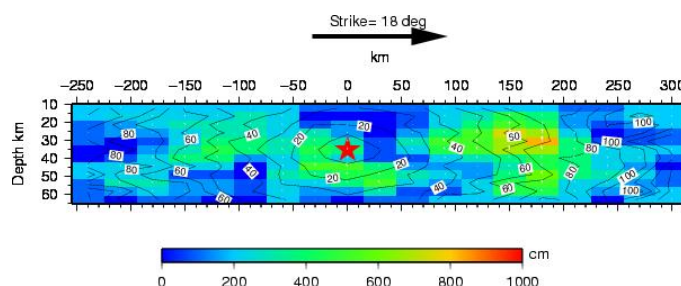


Figure 7: Slip (motion) on the fault plane that produced the magnitude-8.8 earthquake significantly lower than the magnitude-9.5 May, 22 1960 earthquake. (Credit: <http://tectonics.caltech.edu/>)

### Seismic Gaps and Future Seismic Hazard Predictions from Seismicity and GPS Studies

The seismic potential for large and great interplate earthquakes (earthquakes within the boundary between two plates) along the Chilean and southern Peruvian margins of South America has been thoroughly analyzed by scientists in the past (Ruegg et al. 2009; Nishenko, 1985). The majority of the coastal range segments of Chile have been the site of at least one magnitude-8.0 earthquake during the last 130 years with the exception of south central Chile region (red box inset of Figure 6). The last time this area experienced a subduction earthquake was on February 20, 1835 (observed and reported by Charles Darwin) with an estimated magnitude between 8.0 and 8.5 (Lomnitz, SRL, 2004). Segments that have not experienced large earthquakes for many decades, called seismic gaps, are zones of relatively high seismic risk for the near future and will eventually be filled by large-magnitude earthquakes (magnitude-7.7 or larger) (Kelleher, 1972).

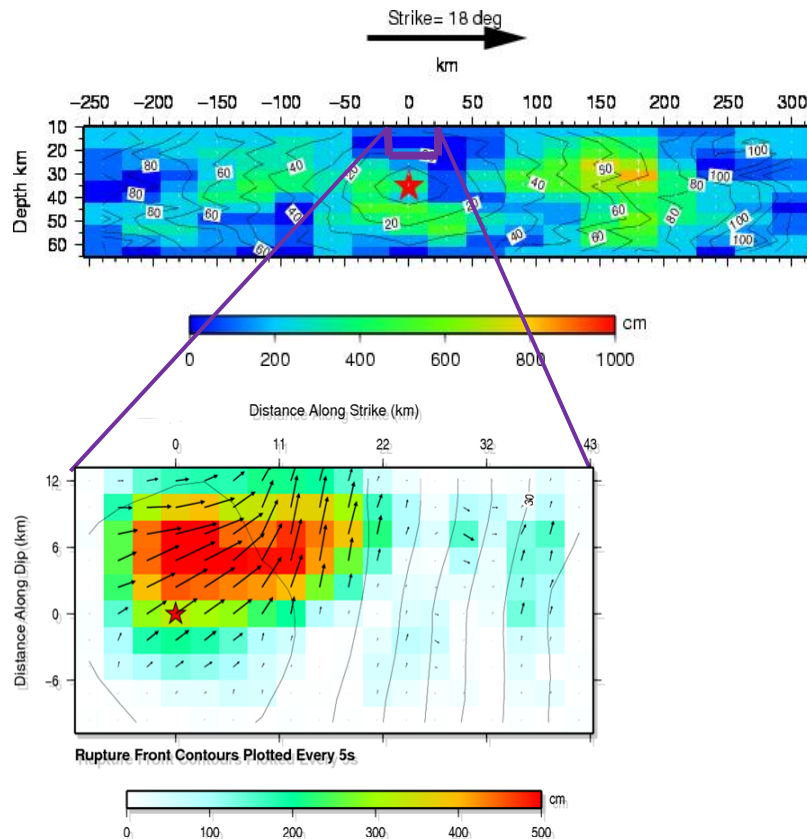


Figure 8: Amount of slip and rupture area comparisons between the February 27, 2010 Chile and the January 12, 2010 Haiti earthquakes (Credit: USGS and Caltech).

Based on a statistical analysis of earthquake repeat times, a scientist predicted a high potential for large earthquakes within a 20-year period (from the date of the study published in 1983) in two regions of central Chile. The first was the Coquimbo-Illapel region, which includes the Valparaíso region (Figure 9a, just south of the 1906 M8.6 in Figure 9b). This first prediction was fulfilled (Lomniz, 2004, GRL) by the 1985 magnitude-8.0 Valparaíso earthquake. The second predicted region of high seismic potential was the Talca-Concepción region, located just north of the rupture zone from the May 22, 1960 earthquake and south of the rupture zones corresponding to the 1928 Talca earthquake and the 1906 and 1985 Valparaíso earthquakes (Figures 9a and 9b). The 1939 magnitude-8.3 earthquake (Figure 9b) that affected the Coquimbo-Illapel region was ruled as a non-typical subduction earthquake (Ruegg et al., 2009; Beck et al., 1998).

GPS observations show that the Nazca Plate is obliquely subducting at variable rates ranging from 80 millimeters (3.15 inches) per year at the location of the February 27, 2010 earthquake to 18.5 millimeters (0.72 inches) per year to the south. Seismologists installed GPS stations to study the motion of the Nazca Plate under the South American Plate in the second seismic gap region. These seismologists' findings indicated that the two plates are seismically locked at a depth of about 55 kilometers (34 miles), and this may be the site of a future major thrust earthquake in the Biobío and Maule region of Chile. However, the most important parameter for hazard is the slip rate, defined as the length of slip that the fault moved divided by the number of years lapsed since the last major earthquake. For example, the May 22, 1960 magnitude-9.5 earthquake occurred after 130 years following the last major event. This provides a slip rate of 18.5 millimeters (0.72 inches) per year, which is less than the convergence rate of the two plates at the location of the 1960 event. Other scientists have concluded that the strains in the second seismic gap have not been relieved since 1835 with a convergence rate of 68 millimeters (2.68 inches) per year. An accumulated slip deficit of more than ten meters (33 feet) is large enough to produce a significant earthquake with a magnitude greater than 8.0. The February 27, 2010 magnitude-8.8 earthquake, by virtue of its location, qualifies as filling the second area of high seismic potential.



The rupture zone of the May 22, 1960 earthquake has the lowest potential along the margin and is not expected to re-rupture within the next 100 years. In northern Chile, a magnitude-8.0 earthquake occurred in 1995 near the city of Antofagasta. This region has been quiet since 1877, and the 1995 earthquake is assumed to have advanced the timing of the next great earthquake in northern Chile (Delouis et al., 1995, BSSA).

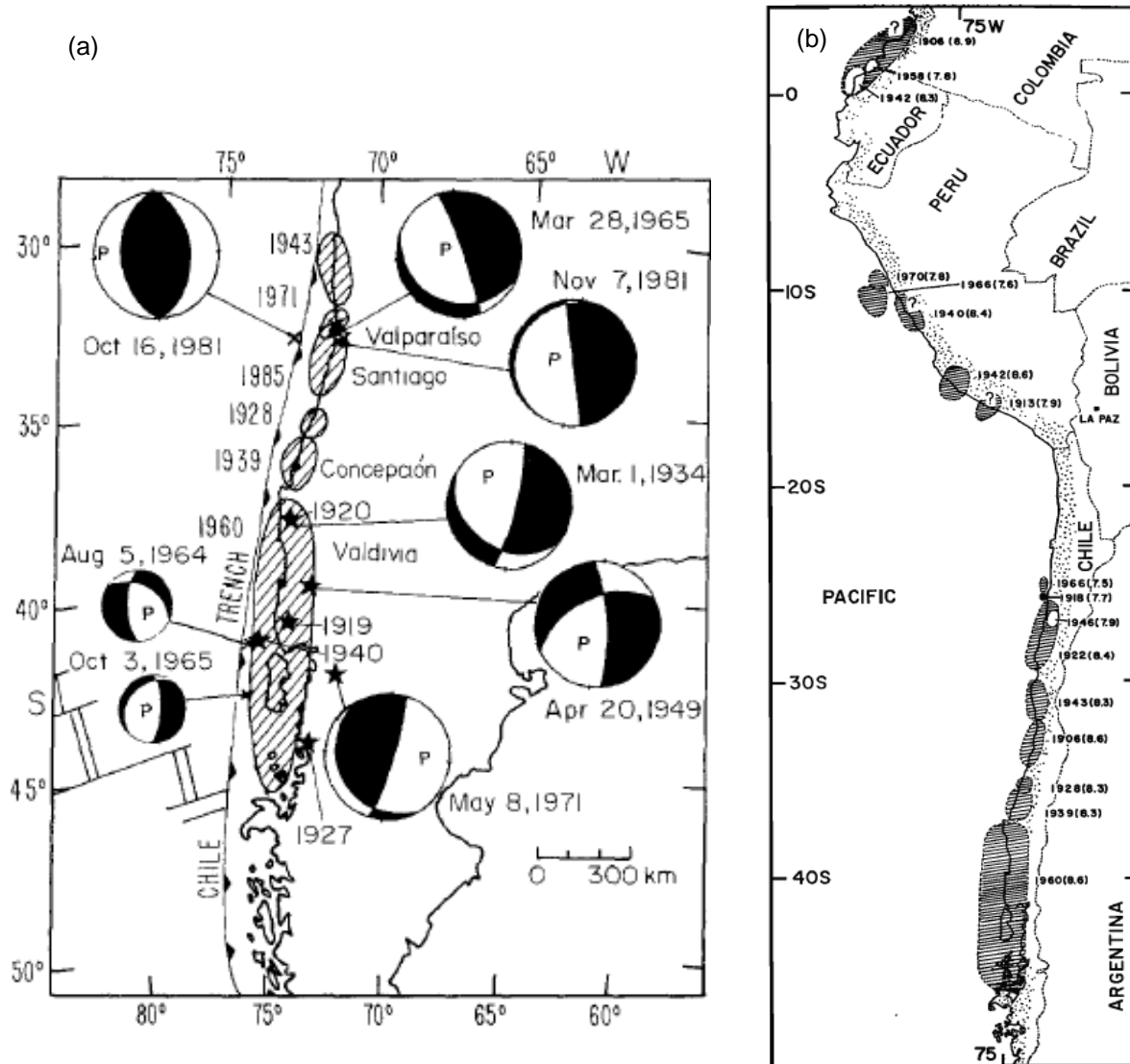


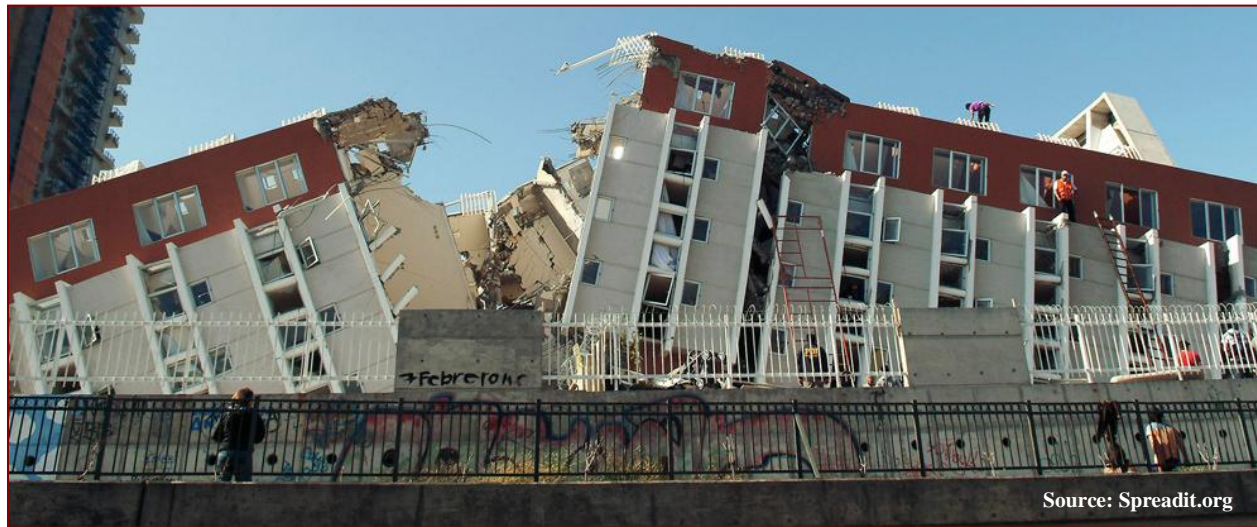
Figure 9: (a) Rupture areas (hatched) of large shallow earthquakes of central and southern Chile until 1985. The black and white balls show the type of fault motions. (b) Hatched areas represent estimated rupture zones of large (magnitudes greater or equal to 7.7) South American earthquakes of most of the 1900s. Numbers in parentheses are magnitudes. The gaps between the hatched zones are future danger zones of earthquakes. (Credit: Astiz and Kanamori, BSSA, 1986)

## Property Effects

The Chilean government indicated that widespread extensive damage occurred and a 'state of catastrophe' was declared. Chile's National Institute of Statistics indicate that there are over 4.5 million households in the country, and at least 1.5 million of these were damaged, over 500,000 of which were destroyed. The quake affected over two million people across six separate regions.

### Concepción

The hardest-hit region was Maule, where the majority of the fatalities occurred. In the city of Concepción, thousands of homes and multi-story structures collapsed, cars were flattened, rubble covered streets and several fires broke out after gas lines ruptured. According to Chilean officials, the majority of the homes that collapsed were older buildings that were constructed with a mixture of sand, clay, straw and water. However, one modern building in Concepción sustained major damage – a 15-story apartment building that cracked in half shown below.



### Santiago

In the capital city of Santiago, officials noted that many of the modern-built homes, buildings and other structures were largely unaffected due to high anti-seismic building codes following years of large earthquakes. Nevertheless, a large number of older homes and other structures were heavily damaged – including three hospitals, the national Fine Arts Museum, the Museum of Contemporary Art and the Divine Providence church. Approximately 3,300 residents in Santiago were left homeless. Wall cracks, chips and damaged façades were also noted on many government buildings and ministry headquarters.

### The rest of Chile

Reports of substantial damage were also indicated in smaller towns and cities closer to the epicenter. In the Maule capital city of Talca, hundreds of buildings crumbled as the main earthquake struck. The city's administrative building and the local hospital were destroyed and almost every home in the city's center was flattened. In Temuco, widespread damage was reported as adobe and façades fell from buildings and crushed cars on the streets below. Additional reports of severe damage came from the towns of Rancagua and Curico.

See Appendix A for Chile's regions and Appendix B for a further breakdown of home and other structure damage per city.



## Fires Following the Main Earthquake

Several building and structure fires were reported after the initial earthquake struck. Local officials noted that many of the fires occurred due to underground gas lines rupturing or at locations where flammable tanks exploded. However, several fires were intentionally set by looters in the cities of Concepción, Santiago and Chillan as well as at the El Manzano prison.

## Post-Earthquake Societal Issues

Within hours following the main earthquake, thousands of looters that included residents of Chile's lower and middle classes took to the streets in the city of Concepción and began ransacking clothing boutiques, grocery stores, electronic stores and ATMs. Several looters set fire to various businesses throughout the city. Many people went to Concepción's port, where products from damaged



storage bins were stolen. Looting was also rampant in parts of Santiago, Chillan and Talcahuano. Once the Chilean government declared a 'state of catastrophe,' a dusk-to-dawn curfew was issued as military soldiers were ordered to enter the uncontrolled cities and restore calm, bringing a quick end to the looting as thousands of troops roamed the streets with assault rifles and dispersed tear gas. According to police officials, door-to-door searches of city residents recovered over 1.03 billion Chilean Pesos (USD 2.0 million) in stolen goods including refrigerators, sofas, mattresses, clothing, crates of liquor and flat screen televisions.

There remains a large disparity in terms of socioeconomics. According to Chile's National Statistics Institute, the top 20 percent of wage earners make an average of 1.66 million Chilean Pesos (USD 3,200) per month, while the bottom 20 percent earn only 176,737 Chilean Pesos (USD 340) per month.

## Building Codes and Types

Since Chile is located in a highly seismic region, the government has a long-established set of strict building codes. A brief look at Chile's building code history indicates that the first seismic codes were established as far back as 1935. The 1972 version of the building code was revised following the magnitude-7.8 earthquake that struck in 1985, though those updates first went into effect in 1993. The 1985 code was later updated in 1996 and 2003. Today, it is estimated that approximately three percent of recently built buildings are not up to the current building code. However, newly built 'essential' facilities do conform to the current code. Overall, about 30 percent of the total buildings in Chile are designed based on older versions of the building code.

The most predominant construction types are masonry (reinforced, confined, or unreinforced), and approximately 60 percent of residential buildings and 40 percent of commercial buildings are of this type. Other residential construction types are based on wood frame, which account for nearly 20 percent of the building stock. For highrise apartments, contractors typically use concrete, while 33 percent of commercial buildings are built using reinforced concrete. Steel construction is used in about 15 percent of commercial structures. Industrial buildings are typically built using steel or light metal.

## Tsunami Effects

The Pacific Tsunami Warning Center (PTWC) immediately issued a Tsunami Warning for nearly every nation bordering the Pacific Ocean (nearly one-quarter of the entire globe) as the magnitude-8.8 earthquake triggered tsunami waves. In Chile, tsunami waves severely impacted a 435-mile (700-kilometer) stretch of the coastline. The highest



unofficial tsunami wave amplitude was recorded offshore Valparaíso, Chile at 8.6 feet (2.6 meters). The tsunami also struck the Juan Fernández Islands (located just off the Chilean coastline), where at least six people were killed and 11 people were reported missing. The coastal town of Talcahuano saw significant losses after a series of large tsunami waves left 80 percent of the town's residents homeless. Ten thousand homes were destroyed and hundreds more were severely damaged. The tsunami also destroyed the town's governing buildings as water rushed inland. In Concepción, tsunami waves flooded coastal neighborhoods and destroyed a large number of homes and cars. Numerous large fishing boats were also washed ashore. In Pelluhue, at least 300 homes were destroyed after an unconfirmed 18-foot (six-meter) tsunami wave overwhelmed the small town. Village officials in Dichato reported 800 homes destroyed after tsunami waves traversed far inland along a river valley. The Chilean Navy was criticized by the government for failing to quickly alert residents along the coast about the impending threat of a tsunami.

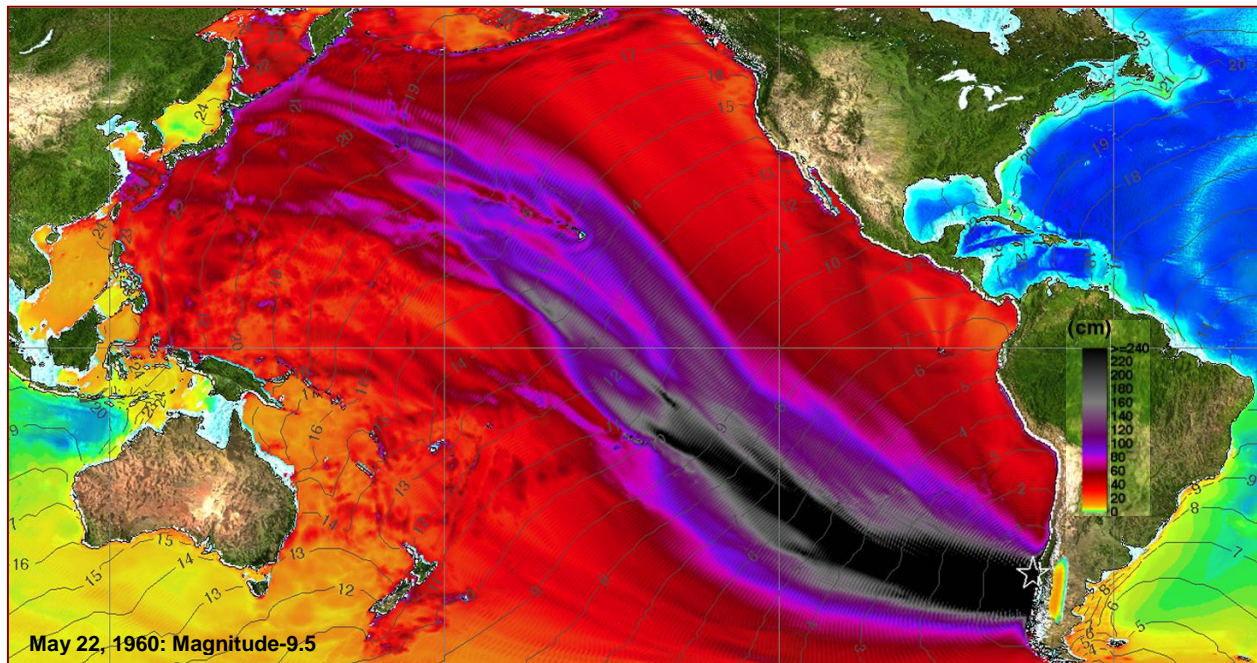
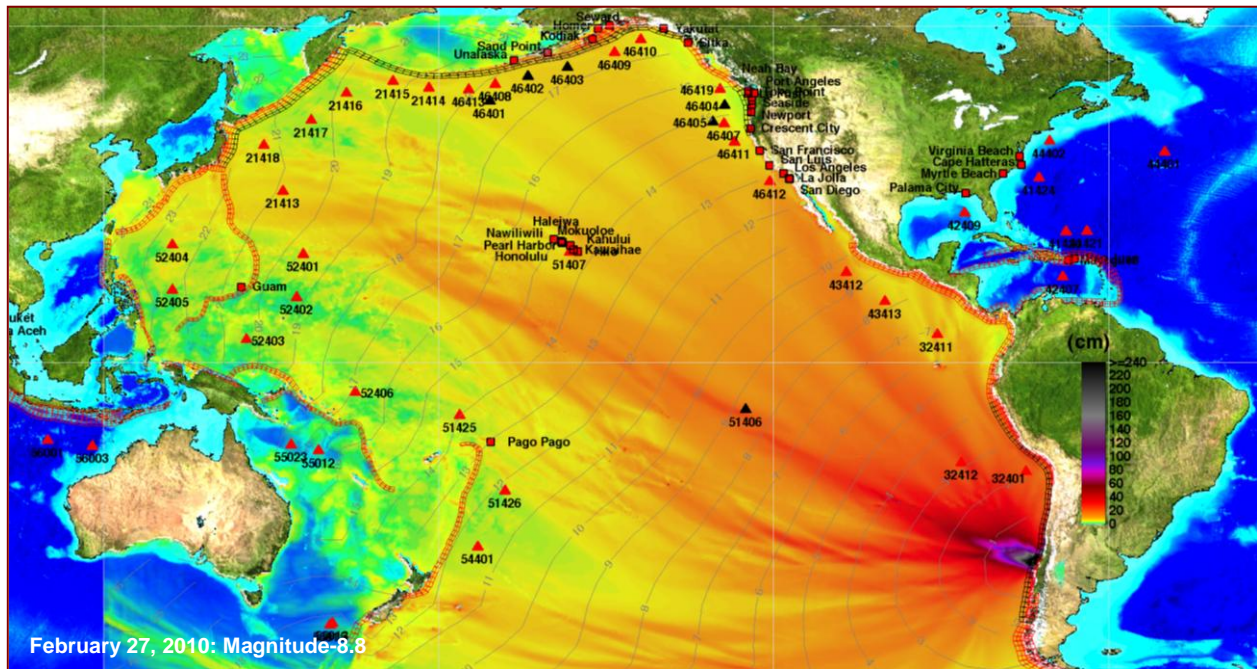
Elsewhere along the Pacific Ocean border, smaller tsunami waves were recorded along coastal sections of the United States, Canada, Russia, Japan, New Zealand, Australia, French Polynesia, American Samoa, the Philippines and Indonesia. The table below shows some notable recorded tsunami measurements reported by the PTWC and the Global Disaster Alert and Coordination System (GDACS).

Notable Tsunami Reports from the PTWC and GDACS			
Station	Country or Territory	Height (m)	Height (ft)
Los Cambuchos	Chile	8.0	26.2
Coronel	Chile	7.9	25.9
Concepción	Chile	7.8	25.6
Dichato	Chile	7.8	25.6
Constitución	Chile	7.7	25.3
Carrizal	Peru	5.8	19.0
Valparaíso	Chile	1.6	5.2
Acapulco	Mexico	0.62	2.9
Kahului, Hawaii	United States	0.98	2.0
Nuku Hiva	French Polynesia	0.95	2.0

See Appendix C for a graphical representation of tsunami damage in Concepción and Talcahuano.



The figures below are two National Oceanic and Atmospheric Administration's (NOAA) computer generated tsunami wave amplitude estimated measurements (in centimeters) in the 24 hours following the February 27, 2010 magnitude-8.8 earthquake (top) and the May 22, 1960 magnitude-9.5 earthquake (bottom).





## Utility Effects

Widespread power outages were reported throughout Chile following the main earthquake. According to the country's three largest electricity companies (Endesa Chile, Chilectra and Transelec), over two million homes lost electricity, including 1.5 million alone in Santiago. However, electricity was restored within five days to the majority of the region due to many of the main power grids not sustaining extensive damage. Electrical production companies such as Empresa Nacional de Electricidad SA and AES Corp. reported that generation units were temporarily shut down due to damage. Overall, approximately 17 percent of total capacity (or 545 megawatts) of power generation was shut down immediately following the earthquake. Landline telecommunications were impacted in the cities of Concepción, Constitución, Talcahuano, Chillan and Curico as large swaths of power poles and power lines were downed. Wireless phone operators (Entel, Claro and Movistar) reported that several antennas had collapsed and minimized available wireless signals. An enormous amount of demand for the limited available signals caused a network overload. Wireless internet access was available in several areas throughout Chile, enabling rescue teams to communicate with international and local aid groups. Other utility issues included the widespread loss of access to clean drinking water, the failing of regional sewage systems and underground gas pipes bursting.



## Industrial Effects

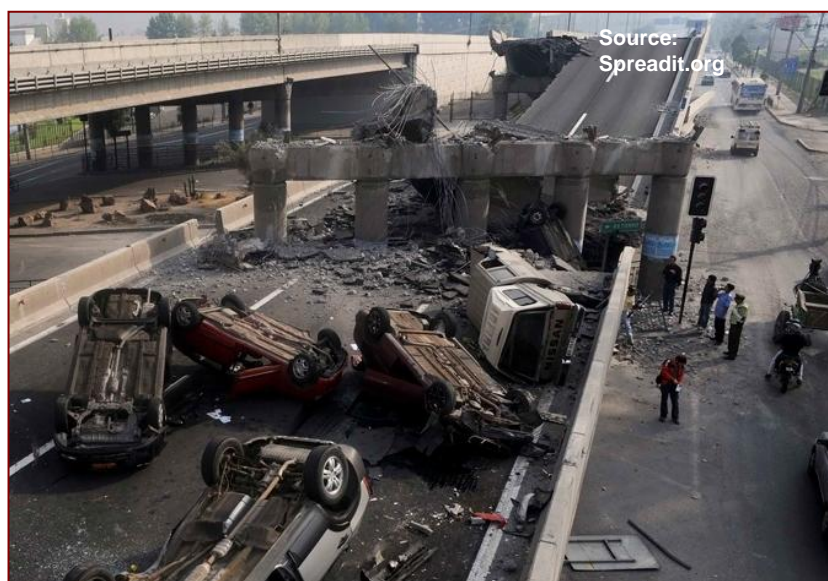
Following the initial tremor, copper production was shut down across central sections of Chile as several mines sustained damage. Some of the companies forced to shut down production were Codelco (El Tiente and Andina), Anglo American (Los Bronces and El Soldado), Scaw Metal (Antofagasta), Amerigo Resources and Freeport McMoRan Copper and Gold Inc. Representatives from each company noted combined shut down of copper cost producers several thousand tons (tonnes), approximately one-fifth of Chile's total copper production. As power was restored, many of the closed mines were able to restart production. Many company officials relayed that further disruptions in copper deliveries were anticipated due to the widespread damage to highways and seaports. Chile produces about 34 percent of the world's copper supply.

Chile's two oil refineries were also affected, with officials saying the 100,000 barrel-per-day Aconcagua refinery near Santiago was forced to shut down for at least five days. However, Chile's state-run oil company ENAP was not certain when the bigger Biobío refinery located near Concepción would again be operational. The Biobío refinery reportedly had no water or electricity supply, but saw no noticeable damages. The Energy Minister noted that Chile was not expected to sustain a fuel shortage, but was prepared to import more fuel if needed.

## Infrastructure Effects

The earthquake severely impacted the transportation infrastructure across Chile. Hundreds of roads buckled along with several key bridges and overpasses collapsed. Many failures were also reported along Chile's only major highway, the north-south Pan American Highway. Significant damage occurred on the highway between Santiago and Temuco, which greatly reduced relief and rescue efforts to the hardest-hit coastal cities. Large amounts of debris on the highway and other roads allowed only small vehicles to travel and not the essential truck traffic to maintain the country's health and economy. A total of eleven pedestrian bridges were damaged along the Santiago-Los Vilos stretch, including a collapse along the Claro River. Chilean officials noted that because the earthquake struck in the overnight hours, the casualty rate was largely minimized due to a lack of traffic on the roads. During the daylight hours, the Pan American Highway is normally bustling with bumper-to-bumper traffic. Going forward, engineers anticipate Chilean governmental officials to analyze the need for another cross-country travel route to minimize future vulnerabilities.

Additional transportation infrastructure damage was reported at Santiago's international airport, where the main passenger terminal sustained significant damage. Airport officials shut down the facility for 24 hours following the main earthquake to inspect the damage. The main runway was largely unaffected, though airlines were limited only to arrivals for the first four days after the earthquake. In Constitución, the town's main airport runway was overwashed by tsunami waves. The Santiago Metro rapid-transit network (consisting of the city's subway



system, bus routes and other public transportation) was temporarily closed and later opened on March 1<sup>st</sup>. At Chile's main ports, widespread damage also reported particularly closest to the earthquake's epicenter. The country's primary seaport located in Valparaíso was ordered closed, while the port in Talcahuano was completely destroyed by the tsunami. In the port city of San Antonio, the port suffered minor damage and was closed for four days before undamaged sections were allowed to reopen. Chilean shipping interests were forced to detour to other ports to the north of the epicenter to minimize the delivery of exports and imports.

Other agricultural infrastructure sectors also were heavily impacted, including crops, wine and fish. According to Chile's chairman of the agricultural chamber, approximately 125 million liters of cellared wine (representing 12.5 percent of the country's inventory estimated at 260 to 312 billion Chilean Pesos (USD 500 to 600 million)) was lost after old storage buildings in the Maule, Cachapoel, Colchagua, Maipo, Casablanca and Biobío regions crumbled. The tsunami and earthquake combined to demolish fishing boats and also kill millions of fish after they were washed ashore. In Talcahuano, the entire fish industry valued at 20.8 billion Chilean Pesos (USD 40 million) was lost. Chile's renowned farm-raised salmon industry was impacted as delivery trucks were unable to transport the fish to seaports due to the main Pan American Highway being impassable. The rest of the agricultural infrastructure (primarily crops) reportedly sustained severe damage.

According to the Chilean Tourism Bureau, the overall tourism infrastructure fared fairly well. The far north and far south tourist sections of Chile which includes popular locations such as Pucon, Puerto Varas and Puerto Montt were generally unaffected. In fact, just days following the main earthquake, the Chile Foreign Office released a statement suggesting that all areas outside of the regions of Maule and Biobío were open for business. Chile's tourism industry brought in 5.2 trillion Chilean Pesos (USD 10 billion) to the country in 2009 and represents nearly 3.5 percent of the GDP.

See Appendix D for a further breakdown of infrastructure damage per city.

## Insurance Market Effects

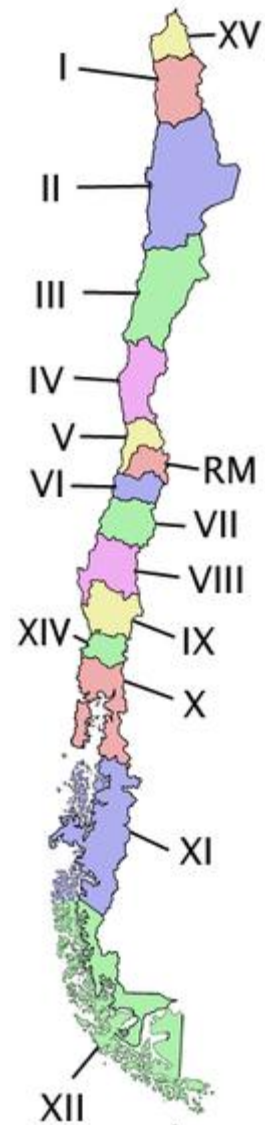
According to the Chilean insurance association AACH, only six percent of the country's homes have earthquake insurance. The low percentage is likely based on the fact that it is sold as an additional policy to fire insurance. Insured losses from the association are estimated at 1.35 trillion Chilean Pesos (USD 2.6 billion), with the majority of the losses coming from commercial policies. Based on various reports from the Chilean government, reconstruction costs were expected to range between 7.8 and 15.6 trillion Chilean Pesos (USD 15 and 30 billion).

# Appendix

## Appendix A

### Regions of Chile

Key	Name	Capital
XV	Arica and Parinacota	Arica
I	Tarapacá	Iquique
II	Antofagasta	Antofagasta
III	Atacama	Copiapó
IV	Coquimbo	La Serena
V	Valparaíso	Valparaíso
VI	O'Higgins	Rancagua
VII	Maule	Talca
VIII	Biobío	Concepción
IX	Araucanía	Temuco
XIV	Los Ríos	Valdivia
X	Los Lagos	Puerto Montt
XI	Aisén	Coihaique
XII	Magallanes and Antártica Chilena	Punta Arenas
RM	Santiago Metropolitan	Santiago



Source: Wikipedia



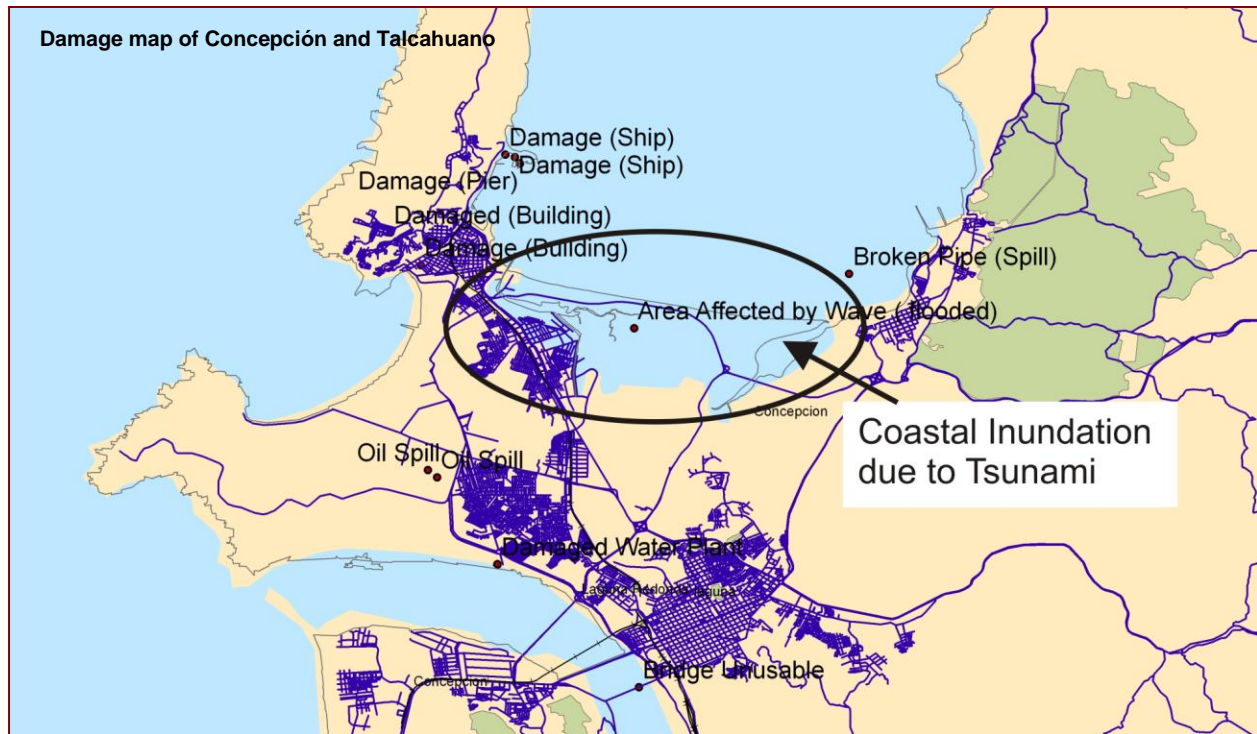
## Appendix B

- Maipu (outside Santiago) – Apartment building severely damaged.
- Santiago – Fine Arts Museum, Museum of Contemporary Art severely damaged.
- Santiago (Nuñoa district) – The Emerald residential project (Paz Corp.) in Santiago's Nuñoa district: there is a possibility that the building will have to be demolished.
- Curico – Over 90 percent of the historical center was destroyed, including a total of 1,000 homes severely damaged, most of which were made of adobe.
- Constitución – Oceanfront industrial region, coastal airstrip, and riverfront community along Rio Maule were inundated by tsunami.
- Lloca – Much of the town was washed away by the tsunami.
- Valpariso (Plan de Vina district) – Several buildings damaged (among them the Festival Building of 9 North, the Tricahue in 8 North, the Achiras in 3 North, Tenerife in 4 Norte and Batuco in Limache Street).
- Curanipe – Severe tsunami damage on the coast.
- Dichato - Water rose steadily (surging above the second floors of homes) and lifted homes off of their foundations; cars were stacked three high in the streets; 800 homes were destroyed.
- Talca –The governmental building of Intendancy (a historical monument) was left uninhabitable; at least two Catholic churches were damaged; a jail wall fell and a fire was intentionally set; numerous houses collapsed, mainly those of adobe.
- Temuco – Building damage, particularly those made of adobe, and façades fell and caused damage to cars; some offices destroyed.
- Talcahuano (near Concepción) – The port was destroyed; streets collapsed; the city building was destroyed; up to 80 percent of Talcahuano's residents are homeless, with 10,000 homes uninhabitable and hundreds more destroyed; coastal regions greatly affected by tsunami.
- Concepción – Damage to historical district where older buildings reside; reports of inhabitants give account of collapses of dozens of homes in the historical center; city hall collapsed; a newly constructed 15-story apartment building in Alto Rio damaged.
- Pelluhue – Three hundred homes were destroyed.
- Cobquecura - Collapsed bridges, crashed buses and sunken pavement.

## HOSPITALS

- Santiago – The Ministry of Health decided to close Félix Bulnes Hospital (a large public hospital in Santiago) due to severe structural damage. The hospital relocated more than 200 patients to other health facilities in Metropolitan Region.
- Talca – All but two of the 13 wings at the Talca Hospital were left in ruins.
- Curicó, Parral and Cauquenes – Each city sustained substantial damage to their hospitals.

## Appendix C



## Appendix D

### AIRPORTS

- Santiago International Airport – Airport terminal suffered severe damage and almost all flights to and from the city were cancelled; national and international flights partially resumed on March 2<sup>nd</sup>.

### MARINE PORTS

- Port of Valpariso (region V) – Terminal Pacífico Sur Valparaíso partially resumed operations at its main terminal on February 28<sup>th</sup> for both passenger and cargo handling; Docks 4, 5, 7 and 8 remain inoperative until further structural inspections are carried out.
- San Antonio – The port suffered extensive damage and left inoperable, with changes in the surface levels of Espigón dock's berths 1, 2, 3 and 5; the port's Puerto Panul bulk handling terminal lost a crane after it fell into the ocean during the quake; San Antonio's fishing port Puertecito was left inoperative by the large waves that hit the coast after the earthquake; the facility's offices were damaged.
- Puerto Coronel (private port) – Extensively damaged.
- Talcahuano (Region VIII) – The main port operated by Empresa Portuaria (a state firm) was extensively damaged by the tsunami.
- San Vicente – Port was left inoperative.
- Naval Base of Talcahuano – The naval base of the Chilean Navy in Talcahuano was greatly affected by the tsunami, seriously damaging the facilities; the Molo 500 dock and ship rehabilitation facility suffered structural damages.
- Ventana (region V) – Port suffered damage; only one of the port's five docks was left operative.
- Isla Mocha – Most of the port infrastructure was completely washed away.
- Caleta Pacheco Altamirano – The administrative offices were flooded; boats were lost; the concrete port area was fractured by the water.

### RAILWAY

- Merval (metropolitan rail system) – Widespread damage caused 17 days of delayed services; the Las Cucharas railway bridge (connecting Viña del Mar to Quilpué district) was damaged.

### ROADS AND HIGHWAYS

- Region V – Damage to Lo Gallardo bridge; landslide damage to Camino Laguna Verde & Ruta E-41.
- Region VI – Ruta de la Fruta highway closed due to damage to the El Durazno and Alhué bridges; no transit along the Graneros overpass on the Ruta H-15 highway due to structural damage; no transit along a stretch of Ruta H-640 due to structural damage; Ruta H-634 road was shut down; Ruta H-10 was shut down due to problems in the El Roble area, while Lolén bridge collapsed; Ruta 1-80-G saw damage on four bridges and was closed.
- Region VII – Road J-60 suffered damage on one of its lanes and many of its bridges; damage noted along Ruta 128 road that connects Parral and Cauquenes; the Curanipe and Duao bridges collapsed; the Escalones overpass over the Mataquito River collapsed.
- Region VIII – Coastal roads suffered major damage; Juan Pablo II Bridge collapsed and need to be rebuilt.
- Region IX – Rodrigo Bastidas Bridge was shut down.
- Region XIV – The road connecting Los Venados to Rupumeica was cut off; transit along the Ruta T-205 road was limited.



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