Preface

The Peru-Chile subduction zone, where the Nazca Plate subducts beneath the South American Plate, is one of the most active seismic zones on the Earth. The Great Chilean (Valdivia) Earthquake with the moment magnitude M_W 9.5 occurred in this zone on 22 May 1960. The earthquake was the strongest ever instrumentally recorded; modern estimates demonstrate that almost 25% of the total global seismic energy released between 1906 and 2005 was related to the Great Chilean earthquake. The 1960 Chilean earthquake was a milestone in modern seismological and seismotectonic research. Many hundreds of scientific papers were written on this event, initiating tremendous progress in our understanding of the earth processes responsible for producing large megathrust earthquakes. Even now, 57 years after the earthquake, studies of this event continue bringing new scientific results. Among related effects, the earthquake generated strong global free oscillations of the earth, a phenomenon that had been predicted theoretically at the time. The theory revealed to be correct, and in 1960 the first experimental proof of the earth oscillations was given from observations from strainmeters, tilt meters and long period seismographs.

The great international interest to the 1960 event is related to the trans-Pacific catastrophic tsunami also generated by the earthquake. The great Chilean tsunami of 22 May 1960 struck the nearby coast of Chile about 15–20 min after the main earthquake shock; 1,655 people were killed by the tsunami, approximately 3,000 injured and almost 2,000,000 displaced. Propagating across the Pacific Ocean, approximately 15 hrs later, tsunami waves reached the Hawaiian Islands and killed 61 people. Then around 22–24 hrs after the earthquake, the tsunami waves arrived at the Pacific coasts of the Philippines, Japan, and Russia; 142 people lost their lives in Japan and 32 more in the Philippines. The high degree of destruction and loss of life in a number of the Pacific countries located far away from the source strongly stimulated international cooperation in tsunami research and mitigation, and resulted in the establishment of the International Coordination Group for the Tsunami Warning System in the Pacific (ICG/ITSU, at present ICG/PTWS).

The Chilean subduction zone had been relatively silent since 1960, but recently a sequence of great tsunami generating earthquakes ruptured the megathrust near the 1960 rupture zone. The earthquakes are the 27 February 2010 (M_W 8.8), 1 April 2014 (M_W 8.2) and 16 September 2015 (M_W 8.3) shocks. The tsunamis affected the entire Pacific Ocean and reached large amplitudes for certain coastal populated areas across the Pacific, similar to what occurred during the Chile 1960 event.

During the fifty years that separated the 1960 event with the onset of the recent sequence, the 2004 Sumatra tsunami occurred, which was the most catastrophic tsunami in human history. This event initiated a major upgrade of the existing network of coastal tide gauges and strongly stimulated development of the Deep-ocean Assessment and Reporting of Tsunamis (DART) system and some other systems of tsunami measurements in the open ocean. As a result, the 2010, 2014 and 2015 tsunamis have been recorded by hundreds of high-quality coastal and deep-ocean instruments throughout the entire Pacific Ocean. At the same time, enormous progress in measuring seismicity and strain rate in space and time along subduction zones was achieved, allowing the determination of deformation rates and an understanding of rupture processes on the fault system that makes up the entire South American subduction zone.

Naturally, relatively strong seismic events regularly took place in Chile, but none of these events had a magnitude comparable to the 1960 earthquake. The event of 27 February 2010, a magnitude M_W 8.8 thrust-fault earthquake, occurred near the coast of Central Chile. The epicenter of the earthquake was located offshore from the Maule region and the earthquake became known as the "Maule earthquake". The source area of the 2010 Chilean earthquake was located immediately to the north of the rupture zone of the 1960 Great Chilean Earthquake. The 2010 earthquake was one of the most powerful earthquakes in human history and the largest in the Southern Hemisphere since 1960. In addition to causing major destruction throughout central Chile and killing several hundred people, the 2010 earthquake generated tremors that were felt in many Argentinean cities, and in southern Peru.

Four years later, on 1 April 2014, a new great thrust earthquake with moment magnitude M_W 8.2 occurred off the coast of northern Chile. The epicenter was located 70 km from Iquique and approximately 1,600 km north from the epicenter of the 2010 Chile earthquake. The earthquake generated a major tsunami with the maximum run-up of 4.6 m on the coast closest to the earthquake epicenter. Tsunami waves were observed throughout the entire Pacific Ocean but no noticeable damage was reported except the coast of Chile. Nevertheless, the event attracted considerable scientific interest.

As the final, third event in a tragic symphony of great Chilean earthquakes, a destructive M_W 8.3 (M_W 8.4 by some estimates) earthquake occurred on 16 September 2015. The epicenter of the earthquake was located offshore, 48 km west of Illapel, central Chile, and 480 km north from the epicenter of the 2010 Maule earthquake. The earthquake generated a major trans-Pacific tsunami that strongly affected the coast of Chile with the maximum run-up of 13.6 m and was recorded by numerous coastal tide gauges and open-ocean DART stations. Tsunami waves created severe damage on the near-source coast of central Chile and killed 15 people. The unprecedented mass evacuation of over one million people from the coastal zone prevented a much higher death toll.

In response to this tragic event, Pure and Applied Geophysics (PAGEOPH) announced a Topical Collection of papers “Chile-2015” and opened a “hot-line” for prospective manuscripts. The main focus was on the 2015 event, but the invitation encompassed previous great Chilean earthquakes and tsunamis. The activity of scientists was very high and a great many papers illustrating the earthquake and tsunami studies were submitted.

The twenty-two papers are presented here in a volume that describes the Illapel, Chile 2015 earthquake (M_W 8.3) and tsunami from various aspects including the source rupture and comparison with the observations, using seismologic, geodetic, hydrologic and oceanographic data, giving an excellent documentation of the effects that such a big event generates.

The rupture of the fault is determined with different models and inversion techniques that aim at explaining near field seismograms and teleseismic worldwide observations as well as geodetic GNSS and InSar observations. The geodetic observations allowed scientists to determine the complete permanent surface deformation of the 2015 earthquake. Apart from the seismologic observations, amplitudes of spheroidal mode free oscillations recorded in a network of superconducting gravimeters were also used to estimate the seismic moment.

The tsunami coastal run-up and tide gauge observations provided additional constraints on the rupture models based on seismic records. Near real time modeling of tsunami generation was very effective, and many lives were saved by incorporating real time seismographic records and data from open-ocean instruments into tsunami forecast models, resulting in only 7 minutes of elapsed time between initiation of the earthquake and the tsunami warning.

The earthquake was also observed by water level variations of aquifers as far as the Russian platform, and in a transient anomaly of the magnetic field across Brazil. The GNSS networks addressed the problem of defining the mechanism limiting the extent of rupture during fault break by investigating interseismic coupling. Highly coupled segments correlate with source regions of the Chilean large earthquakes. Furthermore, satellite gravity observations provided evidence that topographic highs on the subducting oceanic plate was a controlling factor in limiting rupture, such that rupture along fault is greatest between areas subducting oceanic relief.

The collection of papers from researchers and worldwide institutions demonstrates the great attention that the South American Chilean subduction margin has garnered. The precise documentation of the broad spectrum of phenomena that are caused or affected by the earthquake rupture is essential to improve risk reduction of populations exposed to earthquake hazards in this region. Great progress has been achieved to be able to issue earthquake communication bulletins with accurate information on the epicenter location and expected damage in real time, and tsunami warnings even ahead of the time the tsunami wave hits populated areas. The next step is to develop methods that allow issuing warnings ahead of the arrival of the seismic wave causing destruction.

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