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Seismic Forces and State Power: The Creation of the Chilean Seismological Service at the Beginning of the Twentieth Century

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Abstract: *»Seismische Kräfte und staatliche Macht: Die Schaffung des Chilenischen Seismologischen Dienstes am Beginn des 20. Jahrhunderts«*. In 1906, the Valparaíso earthquake marked a breakthrough in earthquake observation in Chile. During the nineteenth century, seismic observation was mostly a matter of concern to foreign travelers and scientists. Meanwhile, after the 1906 earthquake, seismic knowledge began to have greater importance for the state. The study of all tremors in the country responded to the demand to mitigate the vulnerability of the country facing the threat of earthquakes. For this task, the government of Chile created the Seismological Service, a national network of observatories and seismic stations, but also of observers. These observers helped to produce local seismic knowledge, tracing which places in the country were most frequently exposed to earthquakes.

Keywords: Valparaiso earthquake 1906, political history, Fernand Montessus de Ballore, hazard mitigation.

1. Introduction[1]

After the 1755 Lisbon earthquake, the ideas of the Enlightenment strongly marked the study of earthquakes. During the nineteenth century, earthquakes began to lose their apocalyptic association, with people starting to think about and describe earthquakes as natural phenomena "with which people had to learn to live" (Coen 2013, 2). Many people helped by observing earthquakes around the world. For instance, through several manuals travelers were encouraged to record the earthquakes they observed. Furthermore, observational net-

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works were created in Imperial Austria, Scotland and Switzerland (Coen 2012b, 2013).

Historical studies about the development of seismology have been focused mainly on the nations and empires of the northern hemisphere or their colonies. That is the case of the development of seismology in Japan (Clancey 2006a, 2006b; Orihara and Clancey 2012), the United States (Rodda and Levinton 1983; Goodstein 1984; Geschwind 1998, 2001), Imperial Austria (Kozák and Plešinger 2003; Coen 2012b, 2013), Switzerland (Gisler, Kozák and Vaněk 2008; Westermann 2011; Coen 2012a, 2013), Germany (Pyenson 1985; Westermann 2011), and Spain (Anduaga 2004). However, we know little about the observation of earthquakes and the development of seismology in the ex-European colonies such as Chile, a southern country with big and regular earthquakes.

Likewise, several authors, such as Carl-Henry Geschwind (2001), Gregory Clancey (2006a), Andrea Westermann (2011) and famously Deborah Coen (2013), show that the observation and study of earthquakes respond to different interests. During the second half of the nineteenth century and the first decades of the twentieth century, scientists by personal initiative or by governmental appointment started to create several structures for earthquake observation. Observing shocks was a way to try to understand the internal structure of the earth, to know and understand the geography of the country or to design earthquake-resistant constructions. The way in which they observed was not the same in all places. For instance, while in Japan the observational system relied mainly on instrument-based observations, rejecting the eyewitness testimony of lay observers (Clancey 2006a), in Switzerland and Imperial Austria the lay observers were highly valued by scientists (Coen 2012a, 2012b, 2013).

In the case of Chile, the development of seismology at the beginning of the twentieth century was related to a governmental interest in designing earthquake-resistant constructions. Earthquakes were common across the country's landscape, and represented a permanent threat.

In the eighteenth century, the Jesuit Juan Ignacio Molina stated that earthquakes were a threat to the Spanish colony known as "Reyno de Chile." In his *Saggio sulla storia naturale del Chili* (Molina 1810 [1792]), and in his second edition of 1810, Molina noted how big and destructive earthquakes were part of the geography of the southern territory. After Chilean independence, in the first decades of the nineteenth century, large earthquakes were felt. They brought death, fear and destruction in several places across the 1800 miles that comprise the country. For instance, Maria Graham (later Lady Mary Calcott) observed the 1822 earthquake and reported it in her *Journal of a Residence in Chile during the Year 1822, and a Voyage from Chile to Brazil in 1823* (Graham 1824). Charles Darwin and Robert Fitzroy observed the 1835 earthquake, and reported it in some letters, transactions and books (Fitzroy 1839; Darwin 1840, 1876). The observations and descriptions made by these European travelers served to demonstrate geological ideas that were already being debated in Britain.

In the second half of the nineteenth century, the earliest seismoscopes arrived in the country. In 1849, the astronomer at the US Naval Observatory and lieutenant in the US Navy James Melville Gilliss (1811-1865) arrived in Chile leading an astronomical expedition to the southern hemisphere. While traveling, Gilliss and his assistants perceived that they were not just in an "earthquake country," but also in a country with daily earthquakes (Gilliss 1856). Over three years, Gilliss's expedition registered more than 120 earthquakes in the capital city (Santiago) alone. This number increased to 140 earthquakes observed with a home-made pendulum in the northern city of La Serena (Domeyko 1858). At the end of the astronomical expedition, the Chilean government bought the instruments installed by Gilliss in order to create a National Astronomical Observatory (Moesta 1859). Although the main goal of the National Observatory was astronomical observations, its foundation included a small weather station, equipped with the seismoscopes acquired by Gilliss. However, earthquake observation was far from being a governmental issue.

Similarly to Switzerland in the late nineteenth century (Coen 2012a, 2013), earthquake observation in Chile was linked to weather observations. In several cities in the country, observations of rain, temperature, winds and earthquakes were part of the construction of knowledge about the geography of the country (Domeyko 1861). However, the meteorological observations (and therefore those of earthquakes) worked in an isolated way, without being part of any observational network.

In 1868, the only university in the country (Universidad de Chile) created the Meteorological Central Bureau. The Bureau was in charge of the systematization of the data delivered by a network of 13 observatories that were already functioning in different cities in the country. This network was devoted to recording atmospheric pressure, temperature, rain, winds and earthquakes (Vergara, 1870). As in the Swiss Earthquake Commission (Coen 2012a, 2013), the earthquake observation of the Meteorological Central Bureau in Chile relied mainly on eyewitnesses testimonies. This was not due to a lack of confidence in instrumental observations, as in the case of the Swiss scientists (Coen 2013), but to a lack of instruments. The meteorological network was poorly equipped with only a few thermometers, barometers and pluviometers. Therefore, the Bureau asked the observatories to indicate the time of the first shocks and the end of them, the direction and sort of movement, and the impact on buildings, distinguishing the parts of the structures affected and the building materials of each one (Domeyko 1870). Even when many British, Italian and Japanese contributors to seismology disregarded human observers (Coen 2012a), in Chile, eyewitnesses testimonies were a constant in the Chilean seismic research until the twentieth century.

The Chief of the Meteorological Central Bureau, José Ignacio Vergara (1837-1889), a geographer and engineer, argued that instruments could give more accurate data, but he and other scientists believed that with a good set of instructions for earthquake observation, "acceptable" scientific data could be produced. He demonstrated this in his study of the 1873 earthquake, in which, without any instrumental data, and based only on eyewitness testimonies, he was able to measure the velocity of the propagation of seismic waves with relative accuracy (Vergara 1873; Greve 1964). However, the seismic observation in Chile was mainly focused on the earthquakes that the observers could feel. It was a different case in Germany, where the scarcity of big earthquakes and the development of instruments allowed scientists to study micro seismicity as a source of geophysical and geological information (Westermann 2011).

On the one hand, the development of seismology in Chile seems to have important similarities with its development in the USA. First, both were young American countries "looking" to the Pacific Ocean. In both countries, the need for seismic knowledge was the result of disasters: the great earthquake of San Francisco (USA) and the earthquake of Valparaíso (Chile), both in 1906. Also, both cases had, as their objective, to mitigate seismic risk without an academic or scientific tradition, as in Europe.

The destruction of a big part of San Francisco during the 1906 earthquake worried Californian scientists (Geschwind 2001). A State Earthquake Scientists Commission was quickly established and a few months later some Californian scientists founded the Seismological Society of America (SSA). The main goal of the SSA was to alert the general public and the building trades about seismic hazards. However, they did not have funding from any local or federal agencies. It was only in the 1930s that the work of these scientists and entrepreneurs was able to impact enough on building planning to mitigate seismic risk (Geschwind 2001).

On the other hand, it seems that the devastation caused by the 1906 Valparaíso earthquake had a greater impact on the Chilean national government than the 1906 San Francisco earthquake had on the US government. The case of the institutionalization of earthquake observation in Chile during the first decade of the twentieth century points to a particular case of state building. Valparaíso was not just a prosperous and important city, but it was also the main port of the country, on which almost the entire economy of the country relied. The crisis was not less important, but a crisis can also be a great opportunity. As Samuel Martland's research demonstrates, it was after the earthquake that the authority of the national government overtook the local government of the city, taking the lead in matters that they had previously ignored, such as the planning, zoning and building regulations of the city (Martland 2007). These actions by the national government were far from being isolated actions. On the contrary, they may be seen as the origins of the national state interventionism during the twentieth century in Chile. Something similar happened after the big fire of Valdivia (1909) and the 1928 Talca earthquake, disasters in which the national government saw the opportunity to extend its power (Martland 2007).

My approach is complementary to Martland's research and it arises from a question. Why, after the Valparaíso disaster, in the middle of an economic crisis, did the Chilean national government decide to create a complex institution with huge investment on imported instruments and involve the hiring of a foreign expert? I think that following Martland's suggestion this question can be answered. Maybe, beyond this central government administrative intervention over the urban spaces of the cities, there was a long-term interest in building a country with national public policies. In this scenario, determining the vulnerability of all the cities exposed to earthquakes, the earthquake-resistance design of buildings and the training of national engineers could begin to be an important issue for the power of the state.

Because in fact, unlike the San Francisco case where the concern about seismic risk started from the interest of a few scientists, in Chile this subject arose from the national government's interest. After the Valparaíso earthquake, the national government established national policies to study the impact of the shocks and created institutional structures to mitigate the seismic risk.

As a country repeatedly devastated by earthquakes, work on determining which places are more exposed to seismic activity, and which are the best materials and better techniques for building, would allow mitigation of the seismic risk throughout the country. The production of this kind of knowledge was not designed to help in the urgent reconstruction works in Valparaíso, but could be a source for the national government in order to develop long-term national policies and reforms in the construction sphere. The creation of the Chilean Seismological Service in 1908 responded to these requirements from the national government to mitigate the vulnerability of a country facing the threat of earthquakes. In this way, the national government set out not only to control the territory and geography of the country, but also to control the "way of living" in that territory and that geography.

2. The Earthquake of 1906

The port of Valparaíso began to be a place of strategic importance for international trade in the mid nineteenth century. When British merchants began to have exchanges with the former Spanish colonies in the early nineteenth century, the main port was Buenos Aires. These traders also wanted to reach the Pacific coast, but this was very difficult to do by land. This meant an increasing interest in promoting a South Pacific port. In fact, the government of Chile provided facilities for this project, and after the war against the Peru-Bolivian Confederacy (1836-1839), Valparaíso became the second most important port on the Pacific west coast, after the port of San Francisco in the United States (Sánchez and Jiménez 2011).

Many English, German and American companies settled in Valparaíso (Edwards Bello 1963). Valparaíso became the center of commercial investments and played a strategic role in Britain's communications with South America. To help with this, the Chilean Merchant Navy and the Pacific Steam Navigation Company were founded. The latter was responsible for the communication between various ports in America and Europe and in charge of the British Royal Mail from 1852 (Bunster 1970).

In the late nineteenth century, the buildings in Valparaíso had an average of three stories and during that century no destructive earthquake hit them. At the beginning of the twentieth century, the city grew more rapidly and the port became the economic center of the country (Sánchez and Jiménez 2011).

On 16th August 1906, a violent earthquake struck and wrapped the city in total darkness. Women behaved hysterically, children screamed in panic and men cried to heaven for mercy. After the panic came terror. After the shock came the fires and they lasted four days (Rodríguez Rozas and Gajardo Cruzat 1906). Many people died and nearly 20,000 were injured (Urrutia de Hazbún and Lanza 1993). Two thousand dead was the official number provided by the Bureau of Statistics. However, the chroniclers Alfredo Rodríguez Rozas and Carlos Gajardo Cruzat reported the whole event and calculated a total of 3802 deaths during the night of the earthquake alone. One hundred miles to the east, in the capital, the earthquake was also felt with intensity. "Everywhere the buildings swayed in a different direction, threatening to collapse loudly"[2] (El Terremoto de Anoche 1906). Such was the description of the earthquake on the morning of 17 August by the newspaper *El Mercurio* (Santiago Edition), reporting how the capital city felt it. That morning nothing was known yet of the disaster in Valparaíso, but soon the rumors of the catastrophe began to circulate.

Germán Riesco, the Chilean president, was in his final days of government. That afternoon he received the following telegram: "Almendral burning: rest of city destroyed. Many families buried"[3] (El Terremoto de Anteanoche 1906, 1). Final confirmation came with the telegram sent by Enrique Larraín Alcalde, the "Intendente" of Valparaíso (representative of the national government in Valparaíso): "August 17, 1906. – Interior Minister. – Earthquake here. – Twenty fires out of control. It is not yet possible to calculate life and property damage. I am taking assistance and surveillance action. The catastrophe seems huge. – Larraín Alcalde"[4] (El Terremoto de Anteanoche 1906, 1).

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2 "Por todas partes edificios que bamboleaban en distinta dirección, amenazando derrumbarse estruendosamente."

3 "Almendral ardiendo: resto ciudad destruida. Muchas familias sepultadas."

4 "Agosto 17 de 1906. – Ministro Interior. – Terremoto en ésta. Veinte incendios sin poderlos dominar. No es posible todavia calcular perjuicios vida y propiedades. Tomo medidas ausilios y vigilancia. La catástrofe parece mui grande. – Larraín Alcalde."

The government did not need many words to understand the real scale of the catastrophe for Valparaíso (and also for the whole country): earthquake, fires, destruction and deaths were enough to show that the main port of the country was in ruins. The last big earthquake had been felt in the country in 1880, 26 years before. In contrast to the earthquakes of the nineteenth century, the 1906 catastrophe affected the commercial and financial center of the country, by now a major exporter of raw materials (Cariola Sutter and Sunkel 1982). This was a major political and economic challenge.

Nevertheless, the earthquake resulted in a huge opportunity for the administration of the national government to take control over local decisions about public spaces, such as street lighting or the concessions of public services (Martland 2007). Damage evaluation, land expropriations, taxes and loans became part of the reconstruction of Valparaíso, which took several years. However, other actions were more limited and specific. Taking control over the emergency in the middle of chaos, fear and uncertainty was also part of the national government role.

2.1 The Commission for the Scientific Study of the Earthquake

After the earthquake, Larraín Alcalde ordered the setting up of a military headquarters in the main square and patrols across the entire city. He also established an emergency medical service, the restoration of fresh water and the creation of a commission of food supplies. The removal of debris from the city began on 18 August 1906. Meanwhile, to keep public order, martial law was declared and the order given that anyone who was caught stealing or raping should be shot (Figari 2003, 47).

However, besides the immediate reaction of taking control of the emergency in practical issues of social life, other matters arose. What exactly happened on the night of 16 August 1906? The national government in Santiago knew that a big earthquake had occurred. In fact, the President and his ministers felt it in their own bodies, like all the citizens in the capital city. Actually, the earthquake was so powerful that it broke the pendulum of the only seismograph belonging to the National Astronomical Observatory, located in Santiago (El Terremoto de Anteanoche 1906; Informaciones del Observatorio Astronómico 1906, 5).

Telegrams and newspapers stated that Valparaíso was the center of the catastrophe, but the earthquake was also felt in many other cities in the country. Earthquakes and their destructive power were already known to Chileans, who were used to feeling them. However, what were the characteristics of this particular earthquake? How did it affect the ground, the mountains, rivers, lakes, coasts and sea?

To answer these questions, six days after the catastrophe, the national government created the Commission for the Scientific Study of the 1906 Valparaíso Earthquake (Estudio Sobre el Terremoto 1906; Decree 1906). The government needed answers to these questions to understand the phenomenon and to know how to respond. For this reason, the Commission was assigned the task of studying the earthquake, its characteristics and consequences in all areas of the country. The final report presented by this Commission responded to the following general questions: What happened, where did it happen, how did it happen and what impact did it have?

The Commission comprised civil servants, such as professors and scientists, from public scientific and educational institutions: the National Astronomical Observatory, the University of Chile and the Pedagogical Institute of Santiago. That is the case of Albert Obrecht, director of the National Astronomical Observatory, and the first astronomer from the same observatory, Ernesto Greve. Distinguished geologists and professors from the University of Chile, such as Julio Schneider, Lorenzo Sundt and Ricardo Poenish, also participated in this Commission. They were joined by Hans Steffen (professor of geography) and Jerman Ziegler (professor of physics) from the Pedagogical Institute of Santiago (Decree 1906). A captain in the Chilean Navy, Francisco Vidal Gormaz, who would be the first Director of the Hydrographical Bureau of the Chilean Navy, a military institution that had reached scientific status in the fields of hydrography, cartography and meteorology (Saldivia 2011), also took part in this committee.

Since the seismograph of the National Astronomical Observatory had been destroyed during the earthquake, the instrumental records available came from some "home-made devices" that helped to clarify "some points about the indications of the main direction of the movement" (Steffen 1907, 3).[5] Nonetheless, the study was mainly based on eyewitness testimony, in the same way as in Switzerland and Imperial Austria (Coen 2012a, 2012b, 2013).

To manage and standardize the eyewitnesses' testimony, the Commission distributed a questionnaire to 2500 people across the country, such as mayors, governors and principals of schools, colleges, seminaries and institutes. The list also included engineers, marine governors, port captains, chiefs of the railway and telegraph offices, police commanders, lighthouse keepers, steamship companies, Chilean consuls in other countries, foreign consuls in Chile, gentlemen and citizens with a formal education. Nevertheless, only 6 percent of the 2500 questionnaires distributed were answered.

The Commission faced the challenge of examining the earthquake of the night of 16 August, after it affected the normal lives of the people. How could they complete this task from a scientific point of view? As Daston (2001) argues, ideal scientific objectivity in the middle of the nineteenth century was presented in two different ways, according to different epistemological questions: communitarian objectivity and mechanical objectivity. Meanwhile the

5 "para precisar en algunos puntos las indicaciones de la dirección principal del movimiento."

proponents of mechanical objectivity "worried about how human intervention might distort the phenomena; proponents of communitarian objectivity fretted about how anthropocentric scales of time and space might altogether fail to register certain phenomena" (Daston 2001, 262).

Although the report of the Commission did not mention the word "objectivity," it makes reference to other concepts viewed as problematic in a "scientific study": inaccuracy, divergence, contradiction or preconceived ideas in the observation and recording of the data, mainly in the time or the length of the earthquake, the number of shocks felt or the nature and direction of the movement. For example, with respect to the number of shocks and their duration, José Vergara said that the earthquake comprised three shocks, with a total duration of four and a half minutes, while another informant (Julio Escudero) said that there were ten shocks and only the biggest was the earthquake, with a total duration of at least five minutes (Steffen 1907, 18). According to the composer of the Commission report, Hans Steffen (1865-1936), a German doctor in Geographical Studies and professor at the Pedagogical Institute of Santiago (Sanhueza 2012), this issue appears precisely because the data was not obtained from mechanical instruments, but from human testimonies affected by the earthquake, observations that necessarily need "cold blood and calm in critical moments" (Steffen, 1907, 7). However, even in his critique of the lack of instruments, Steffen clearly highlighted the human testimony about the effects produced by the earthquake and its associated phenomena. To him, the eyewitnesses' testimony gave valuable data to the study of the quake (Steffen 1907).

While the Commission was working on his study, a proposal came from Valentín Letelier, President of the University of Chile, the country's oldest and most important university. Letelier proposed to the Council of Public Instruction the creation of an institution dedicated exclusively to studying and providing training in seismology in the country (Montessus de Ballore 1909a, 2; Greve 1964, 13). Echoing the proposal, the government of Chile decided to hire the French military officer Fernand Jean Baptiste Marie Montessus de Ballore, who was at that time Director of Studies at the École Polytechnique in Paris (Cisternas, 2009).

2.2 Fernand Montessus de Ballore: State Seismologist

Fernand Montessus de Ballore (1851-1923) was trained in mathematics and physics at the École Polytechnique in Paris, a traditional engineering school (Cisternas 2009, 3). In addition, he received military training (Hobbs 1924). Specifically he studied at the École d'Artillerie at Fontainebleau and the École de Cavalerie at Saumur (Hammond 1912), becoming Major of the 28th Artillery Regiment of the French Army. As Cisternas (2007) pointed out, in 1881, Montessus de Ballore was made chief of a military mission and sent to Central America to establish cooperation with the army of El Salvador. There he had his first contacts with seismically active areas (Simon 1923; Gajardo 1923). His observations of seismic and volcanic activity in Central America were published in the *Comptes Rendus Hebdomadaires des Séances de l'Académie des Sciences* and the *Revue Scientifique* in Paris (Montessus de Ballore 1884, 1885a, 1885b, 1885c). In this regard, he also published the book *Temblores y erupciones volcánicas en Centro-América* (first published in Spanish in 1884 and later in French in 1888). The French version earned him a prize from the Paris Academy of Sciences for the best thesis in seismology (Montessus de Ballore 1888).

When he returned to France in 1885, he started a meticulous task, studying and comparing the different seismic zones of the world. In fact, he dedicated the rest of his life to it. He published several papers in English, French, Italian, German, Russian and Spanish in European and American papers (i.e. Montessus de Ballore 1892, 1896, 1897, 1898, 1899, 1900a, 1900b, 1901, 1904, 1906a, 1911a, 1912a, 1914).

According to Julien Fréchet (2008), Montessus de Ballore catalogued, up to 1906, more than 170,000 earthquakes worldwide. His worldwide historical catalogue became larger than Robert Mallet's global catalogue, which reached 6831 seismic movements (Davison 1927). He combined this recording activity with analysis of frequencies and geographical distribution of earthquakes. Also, he analyzed the relationship between earthquakes and atmospheric or astronomical phenomena, using statistical analysis. In fact, Davison (1927) described him as one of the founders of modern seismology, highlighting the fact that his contributions focused mainly on the definition of a spatial distribution of seismicity. Seismicity was very important to Montessus de Ballore, because its study allowed him to know about the geographical distribution of earthquakes and areas of seismic concentration. For his contributions in the field of seismology, Montessus de Ballore received acknowledgments from the international scientific community (Nature 1916, 1921; Hobbs 1924).

A review of his studies shows that his interest in earthquakes was not only descriptive or comparative, but also covered the understanding of the physical nature of the process of earthquake generation. For example, in *Les tremblements de terre: Géographie séismologique* (1906), he described the geographical distribution of 171,000 earthquakes and how they were linked with the instability of the earth's crust. In his work, he suggested that earthquakes have a direct relationship with areas of geological folding. This conclusion was reached through the study of the distribution of earthquakes and their statistical analysis. To conduct his studies, Montessus de Ballore required many data from different places in the world. Many of the most important "seismologists" at that time helped him in this task. For example, François-Alphonse Forel (1841-1912), Georg Gerland (1833-1919), Giuseppe Mercalli (1850-1914), John Milne (1850-1913) and Fusakichi Omori (1868-1923) provided him with information about earthquakes around the world. This frequent communication worked as an informal network and, in his opinion, “created strong bonds of friendship” (Montessus de Ballore 1906b, 28). But his work was not only restricted to statistical studies. In *La science séismologique* (1907), Montessus de Ballore described some physical principles of earthquakes, criticized the notion of the epicenter, classified seismic events into micro-earthquakes, macro-earthquakes and mega-earthquakes, established a relationship between earthquakes and submarine tsunamis, performed a synthesis of seismological instruments and addressed some geological effects (Montessus de Ballore 1907a). In 1907, when Montessus de Ballore arrived in Chile, the academic journal of the American Association for the Advancement of Science described him as “one of the leading authorities on earthquakes” (*Science* 1907, 677).

Also, he was interested in the damage to buildings produced by earthquakes. Montessus de Ballore had begun to investigate construction that was resistant to earthquakes and tremors. In 1906, he published a short book entitled *L’art de bâtir dans les pays a tremblements de terre*. This little 31-page book corresponded to his lecture at the Congress of French Architects held in June 1906. This conference was originally published in volume 19 of *L’Architecture, Journal de la Société Centrale des Architectes Français* (Montessus de Ballore 1906c). In this text, Montessus de Ballore explained the effects of earthquakes on buildings and on building elements, the choice of a building’s location, methods and materials that should not be used and some rules of construction. In late 1906 and during 1907, Montessus de Ballore published a translated and enlarged version of his work presented in Paris. This was published in three parts in the journal of the University of Chile and was entitled *El Arte de Construir en Países Espuestos a Temblores de Tierra*. In addition to the topics covered in the French version, in the Spanish version Montessus de Ballore added a detailed review of different building materials (wood, iron and brick). It also included a comparative description of the effects of earthquakes in different countries such as the Philippines, Portugal, Spain, Italy, Mexico, Japan, India and Burma. Also, he addressed the topic of seismology applied to railways, as well as the building regulations of cities like Lisbon, Algiers, Norcia, Manila and Ischia (Montessus de Ballore 1906d, 1907b, 1907c).

Probably this was the main reason why the Chilean government was interested in hiring Montessus de Ballore. His contract prohibited him from providing services to any company or institution without the permission of the government of Chile. This could have been to avoid a common practice in the nineteenth century. As pointed out by Millán Urzua (2004), during the nineteenth century foreign experts hired by the country as professors finished acting as private consultants to mining companies. With this exclusive contract, Montessus de Ballore became a “state seismologist,” paid by the government of Chile. A decree by the Ministry of Public Instruction of the Republic of Chile (Decree 1907) established an annual wage of 18,000 francs, plus a monthly maintenance of 600 Chilean pesos, plus the payment of his travel from France (with a brief stay in the United States) for 13,575 francs. The government entrusted him with three tasks related to seismic risk (Decree 1907).

The first one was related to producing seismic knowledge. To Montessus de Ballore, in order to know which places were more exposed to earthquakes it was necessary to know the geographical distribution, frequency and intensity of all the earthquakes felt in the country. To obtain this kind of data, daily information from different places across the country was needed. In order to get this, one of the tasks of Montessus de Ballore was the creation of seismological observatories in the country. The details of this institution will be discussed in the next section of this paper.

The second task was related to his role as a consultant expert in the service of the national government: to investigate particular earthquakes and to advise the government about the actions to take in a future possible earthquake. Unlike the case of the 1906 San Francisco earthquake, where newspapers, local opinion-makers and engineers blamed the fires for the city's destruction and not the earthquake (Geschwind 2001), in Chile, newspapers, government and experts exhibited some degree of consensus: the disaster was caused by the earthquake. Earthquakes themselves, and living in a territory exposed to them, were threats. Moreover, the experience had demonstrated that the threat of an earthquake could turn into a real catastrophe. For this reason, many of Montessus de Ballore's reports were related to evaluating earthquake impact on buildings, responding to specific problems of the Public Works Ministry (Montessus de Ballore 1912b, 1912c, 1912f; Montessus de Ballore to the Ministry of Education, 28/11/1908).

But detecting the places that are most exposed to earthquakes and providing consultancy to the national government do not solve the long-term issue of building an earthquake-resistant country. Construction involves engineering and architects. For this reason, the third task was related to the training of future professionals in earthquake-resistant building techniques. To do this, the government required Montessus de Ballore to teach about seismology and seismic architecture in public institutions. In 1909, he was incorporated as a professor at the University of Chile, specifically at the Engineering School. On 15 April 1909, he started teaching the course of Applied Seismology to students of engineering and of architecture. His objective was to establish the foundations of modern training of Chilean engineers in the construction of earthquake-resistant buildings (Cisternas 2009). The first promotion had 17 students (Montessus de Ballore 1911c).

This modernizing view of Montessus de Ballore about seismic-resistant construction, however, was completely opposite to an analogous situation in Japan, when foreign teachers arrived in Japan shortly after the Meiji Restoration (ca. 1868). As Gregory Clancey (2006a) presents in his research, the modern European techniques of construction implemented in Japan disregard the Japanese environment. In 1891, the Nōbi earthquake destroyed the constructions made with these modern European techniques (Clancey 2006a). To Montessus de Ballore, his modern view of construction was directly related to the earthquake resistance of buildings. In his view, the local geology and the particularities of the seismic activity had enormous importance since there are no "universal rules of seismic safety" (Coen 2013, 165).

Although Montessus de Ballore recognized the value and the importance of the local conditions, he also had the possibility of proposing some general rules that considered the different movements produced during an earthquake (Montessus de Ballore 1908, 1912d). To do this, the observation and statistical evaluation of damages after an earthquake was crucial. To him, the scientists had to know the kind of soil, which kind of buildings stood unharmed and which ones collapsed, the materials and the techniques utilized in the construction, but most important, how well these materials and techniques were utilized (Montessus de Ballore 1912g). To Montessus de Ballore, this knowledge about construction techniques also needed to be combined with a detailed knowledge of the local seismicity. In this point, Montessus de Ballore also differed with the idea of global seismology supported by Georg Gerland, leader of the International Seismological Association based in Strasbourg (Coen 2013).

As Coen suggested, within the International Seismological Association (ISA) differences of opinions and tensions were expressed about the modernizing view of a global seismology and "the local realities of communities at risk" (Coen 2013, 163). Meanwhile, to Gerland, seismology had to be a pure science, and not a practical knowledge; to Montessus de Ballore, like Edward Suess in Austria, seismology had to "serve human welfare" (Coen 2013, 171). With regard to this, he wondered:

> Who would dare to say that its practical solution does not deserve our attention? It is in this area that a seismologist can widely exercise his wisdom, in the hope of rendering the greatest service to the country (Montessus de Ballore 1913, 31).[6]

In 1912 and 1913, he criticized the latest meeting of the International Association of Seismology, which was held in Manchester in July 1911. His critique was that the scientists of central and northern Europe gave more priority to the theoretical aspects of seismology than to the practical aspects, such as earthquake-resistant construction (Montessus de Ballore 1912e, 1913). In his view, these European seismologists were worried about "vibrations," and not about "earthquakes," because they did not live in a land where earthquakes were a "reality always threatening" (Montessus de Ballore 1912e, 850).[7]

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6 "¿Quién se atrevería a decir que su solución práctica no merece nuestra atención? Es este un terreno en el que puede ejercerse ampliamente la sagacidad de un sismólogo con la esperanza de rendir los mayores servicios al país."

7 "una realidad siempre amenzante."

3. The Chilean Seismological Service: Drawing the Danger, Knowing the Country

The Chilean Seismological Service was an attempt to pursue human welfare. To Montessus de Ballore, just the accumulation of seismic observations could allow the determination of the places that were most exposed to seismic activity. As he himself pointed out about the role of studying seismicity in Chile:

> If we do not gather specific observations to define how dangerous the different regions of the country are, how can you later solve the fundamental problem that should be a priority for the Seismological Service? (Montessus de Ballore 1912e, 850).[8]

To accomplish this task, the Service had to have a structure and organization that allowed observations across the whole country to be gathered, in which earthquakes were felt daily, as was demonstrated by the observations collected during the second half of the nineteenth century. To achieve this goal, a network was indispensable.

Whereas in Europe, Gerland was pursuing the rise of seismology as an observational science, with the seismograph as the key instrument of this goal, in Chile, Montessus de Ballore prioritized coordinating a network based on a mixture of instrumental records and observers' testimonies. This kind of organization could be defined, in the words of Jeremy Vetter, as a "field network," a modern scientific system of knowledge production where the scientific collaboration of geographically dispersed lay observers is directed and coordinated from a central location (Vetter 2011).

Therefore, in 1908, the Seismological Observatory (of Santiago) was founded, which served as the country's Central Observatory, and the Chilean Seismological Service was established. The Seismological Service consisted of 34 local observatories spread across the country and Montessus de Ballore was its director. Montessus de Ballore distinguished three kinds of observatories in the Service based on the instruments, staff and task of each one. For example, the Central Observatory was a first-class observatory. It was supplied with the necessary equipment for recording local, medium and long-range earthquakes, trained staff to fix and improve the instruments and had the task of centralizing and systematizing all the network information (Decree 1908).

In 1908 and 1909, four second-class observatories were created, two in the north of the country (Tacna and Copiapó) and two in the south (Osorno and Punta Arenas). Each of them was supplied with seismographs. For this kind of observatory, Montessus de Ballore selected science teachers or scientists, prob-

8 "¿Cómo entonces se resolvería más tarde el problema fundamental de que debe preocuparse el servicio sismológico, si no se acumulan observaciones concretas para deslindar con exactitud las regiones más o menos peligrosas del país?"

ably because they had to be familiar with the use of technical instruments. However, it was not mandatory for the observers to be trained in physics, geology or geography; their status as “science men” was enough. This was the case for the chief of the Punta Arenas observatory, Domingo Larraín, analytical chemist, director of the Scientific Library of the Municipal Chemical Laboratory and director of the newspaper *El Magallanes* (Larraín, Domingo to Montessus de Ballore, Fernand, 20/11/1908). Three years later, the Punta Arenas Seismological Observatory was moved to St. Joseph Salesian School in the same city, in the charge of Monsignor José Fagnano, founder of Punta Arenas Meteorological Observatory (Fagnano, José to Montessus de Ballore, Fernand, 11/07/1911).

All the other 29 third-class observatories were founded in 1909. These were scattered around the main cities and islands of the country, each of them with seismoscopes to describe local minor events. For this task – apparently – the reliability of the “observer” was more important than the previous scientific or technical training. For example, José Toribio Medina was a historian, bibliophile and ex-professor at the University of Chile, but his home became a third-class observatory (Toribio Medina José to Montessus de Ballore, Fernand, 08/01/1910).

Not only did observers’ houses become observatories, but also observers’ workplaces. Such was the case of Aníbal Cobo, a secondary school teacher of natural sciences at the Liceo de Copiapó (high school), a place where, in 1908, a second-class observatory was installed (Cobo, Aníbal to Montessus de Ballore, Fernand, 06/05/1908).

But these civil servants were not the only people who worked for the Chilean Seismological Service. In its first institutional report published in 1909, Montessus de Ballore mentioned that 530 “informants” had joined the service, coming from 425 towns across the country (Montessus de Ballore 1909c). Most of them were civil servants such as teachers, chiefs of State Railway stations, telegraph operators of the post and telegraph service of Chile, nitrate miners in the provinces of Tacna and Antofagasta, lighthouse keepers of the navy and chiefs of the international railway of Antofagasta-La Paz (Montessus de Ballore 1911b, 1911c). However, “benevolent observers,” usually gentlemen, also voluntarily sent their reports and observations as “earthquake eyewitnesses” to Montessus de Ballore.

However, most of these observers had poor training in seismic observation or – in the case of the observatories’ managers – did not know how to handle seismic instruments. Like the Swiss Earthquake Commission, the Chilean Seismological Service was also an opportunity to train lay observers in scientific observation methods. For this reason, Montessus de Ballore sent them a “tutorial” or “handbook” on earthquake observation and on instrument handling. In other cases, he sent them brief treatises, instructions, brochures and documents about the study of earthquakes and seismic observation. Such is the case of Adrián Soto of the Anglo-Chilean Nitrate and Railway Company (Santa Isabel Office), who indicated that on 23 February 1908 Montessus de Ballore had sent him a "questionnaire to trace a chart to record their observations," which he had to send back to Montessus de Ballore each month (Soto, Adrián to Montessus de Ballore, Fernand, 21/03/1908). Also, Aníbal Cobo wrote in a letter that he was grateful for the "brief treatise" that Montessus de Ballore sent to him (Cobo, Aníbal to Montessus de Ballore, Fernand, 06/05/1908). In another letter, Cobo reported to Montessus de Ballore that he had found more observers in the north and mentioned that he had sent the instructions about tremors written by Montessus de Ballore (Cobo, Aníbal to Montessus de Ballore, Fernand, 04/11/1908).

The Central Observatory received all the information that it was sent by these observers. Montessus de Ballore – with his assistant, Ismael Gajardo – systematized and separated by town all these reports. All these data were published in the *Bulletin of the Seismological Service*, an annual report created in 1909. In some way, the Seismological Service could be seen as an institutionalization of the collecting data system used by the Commission for the Scientific Study of the 1906 Earthquake. However the Seismological Service resolved the problem that Steffen warned about: the ambiguity of the eyewitnesses' testimonies about the length and time of the earthquake, about the number of shocks and about the nature and direction of the movements. The Seismological Service compensated this problem in some way by combining accurate instrumental measurement with the eyewitnesses' testimonies. Furthermore, the experience of the Commission for the Scientific Study of the 1906 Earthquake was taken to the next level: to produce seismic knowledge on a large scale. In the *Bulletin* all the earthquakes and tremors felt daily in the country and the exact time of each event were recorded by the observatories and the eyewitnesses. Most of those seismographic data were translated into technical language, determining the phase and timing of movements, their directions, and the duration of the movements. However, the observers' testimonies were transcribed entirely, including personal feelings and observations such as the barking of dogs or the shaking of doors (Montessus de Ballore 1909a).

This information was mainly used to make statistical analyses: where and when it shook more in the country. The structure of the bulletins until 1914 was more or less the same: in the first section, the codes used in the *Bulletin*[9] were explained and the names of the volunteer observers mentioned, usually those

[9] Usually, in the *Bulletin* each report was accompanied by a final code. These codes were used to designate each type of "observer." Thus an *E* was used if the observation was from a seismic station; an *F* if the observation was from a lighthouse keeper; *FC* if the report was from a chief of a State Railway station; and a *T* if the information was provided by a telegraph operator of the Post and Telegraph Service of Chile. A *P* was used for the reports from newspapers and a *B* was used for "benevolent observers."

belonging to the elite. Then, the report was divided monthly, reporting the number of all the observations made and tremors felt. Also, the reports indicated in which places most earthquakes were observed and the most important features of these: for example, how strong they had been and how many towns had felt them. Finally, all the daily observations were catalogued.

Doubtless, this huge catalogue of observations – "where the words 'trembling,' 'shaking' and 'tremor' are repeated ad nauseum" (Montessus de Ballore 1912e, 849)[10] – could be exhausted. Maybe for this reason, in 1914 the *Bulletin* excluded these daily observations, but kept the monthly seismic report.

Besides the seismic report, the *Bulletin* also published articles and essays about earthquake-resistant engineering and earthquake theories and reports of big earthquakes or volcanic eruptions. But mainly this report can be seen as an "information tool." All the observations made by this network, centralized and systematized by the Central Observatory and later published in the *Bulletin*, contributed to the production of local seismic knowledge. The data provided by this network allowed the frequency and geographical distribution of all the earthquakes felt in each village in the country to be defined. By "drawing" the places more exposed to earthquakes, the state became more conscious of the "risk" across the whole country. Beyond the disasters, which only served to hasten urgent actions (or rather "reactions"), understanding risk could be seen as an opportunity to master – with a long-term vision – the threatening reality of earthquakes.

4. Conclusion

Based on the study presented in this paper, the sources of information analyzed and the different views and actions developed over the years of earthquake studies, the following main conclusions can be drawn:

Earthquakes have been part of the Chilean landscape since colonial times. During the nineteenth century, seismic observation in Chile was mostly a matter of concern to foreign travelers and scientists. In the second half of the nineteenth century, earthquakes started to be observed as a daily phenomenon, part of the geography that should be registered. But this only became a national matter after the 1906 Valparaíso earthquake.

In 1906, seismic knowledge began to have greater importance for the state. The questionnaire of the Commission for the Scientific Study of the 1906 Valparaíso Earthquake created in 1906 reflects the national government's intention to fully understand earthquakes as a first step toward managing earthquakes and mitigating their effects.

[10] "en que se repiten hasta la saciedad las palabras: temblor, sacudida y remezón."

This vision was materialized through an unprecedented investment in creating the Chilean Seismological Service and hiring Montessus de Ballore as state seismologist.

The network of observatories and observers in the country (with and without instruments), supervised by Montessus de Ballore, helped in discovering the particularities of seismic geography.

Observing earthquakes became a national task to determine the places most exposed to seismic activity and the vulnerability of buildings across the whole country. This enabled the training of engineers and architects in earthquake-resistant construction but mostly demonstrated that earthquakes were more than catastrophes that happened once in a while. Earthquakes were a threatening reality and mitigating the seismic risk was seen as the only way of guaranteeing the nation's welfare.

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