

The Large Chilean Historical Earthquakes of 1647, 1657, 1730, and 1751 from Contemporary Documents

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Abstract The four largest historical earthquakes of central Chile in the seventeenth and eighteenth centuries, 1647, 1657, 1730, and 1751, are studied using contemporary documents available in the *Archivo General de Indias* of Seville (Spain). These documents provide detailed information about these earthquakes. This is the first time these documents have been used directly for a seismological study. The 1647 earthquake practically destroyed the city of Santiago. Damage to the cathedral and main buildings is given in detail. The 1657 earthquake near the city of Concepción produced a large tsunami that further contributed to the damage. The 1730 earthquake, the largest of these events, caused damage in a large region that extended more than 1000 km from Copiapó in the north to Concepción in the south. This event caused heavy damage in Santiago and was followed by a large tsunami that affected the region between Valparaíso and Concepción. The 1751 Concepción earthquake was the next largest earthquake of this period. It affected a very large region from Santiago to Valdivia, including a large tsunami that destroyed Concepción and made it necessary to relocate the city. We suggest that this event was very similar in size and extent to that of Maule in 27 February 2010.

Online Material: Documents of the Archivo de Indias about the Chilean earthquakes of 1647, 1657, 1730, and 1751.

Introduction

Central Chile is one of the most seismically active regions of the world with earthquakes of magnitude $M_w \sim 8$ occurring approximately every ten years. A few times every century, these earthquakes reach magnitudes of $M_w > 8.5$ and thus are megaequakes. These megaequakes cause significant destruction and major tsunamis. The M_w 8.8 Maule earthquake of 27 February 2010 is the most recent very large earthquake. This event ruptured a zone that extends at least 450 km along the Chilean coast, and its aftershocks covered an area that extends from the coast to the trench for a length of over 600 km. Although there is no consensus yet, this event probably broke the entire contact zone between the Nazca and South American plates (see [Delouis *et al.*, 2010](#); [Madariaga *et al.*, 2010](#); [Moreno *et al.*, 2010](#); [Lorito *et al.*, 2011](#); among others). The central zone of the 2010 event had been identified as a possible seismic gap in the early 1990s because it had been quiet since the last large earthquake of 1835, an event carefully studied by [Darwin \(1845, pp. 321–333\)](#); see [Campos *et al.* \(2002\)](#). Although this gap has been under close scrutiny since the late 1990s ([Moreno *et al.*, 2008](#); [Ruegg *et al.*, 2009](#)), there were no obvious signs of precursory activity before February 2010, except for a concentration of seismic activity in the region that was later identified as the hypocenter of the

earthquake ([Madariaga *et al.*, 2010](#)). The data gathered so far show that the 2010 earthquake produced a tsunami and broke a region that is comparable in extent to that of the megaequakes that occurred on 25 May 1751. The 1751 event destroyed the city of Concepción to such an extent that it was moved from its initial location to a site that was less exposed to large local tsunamis. We feel that information on historical earthquakes is of great importance when comparing modern events with their predecessors. A recent survey of the most important historical earthquakes in Chile was given by [Lomnitz \(2004\)](#).

The most detailed study of historical earthquakes in Chile is that of [Montessus de Ballore \(1912\)](#), who published a history of earthquakes in the Central Andes in 16 volumes. As sources for his study, he used the work of three Chilean historians: Miguel Luis Amunátegui, Diego Barros Arana, and Benjamín Vicuña Mackenna ([Vicuña Mackenna, 1869](#); [Amunátegui, 1882](#); [Barros Arana, 1834](#)). These historians used contemporary documents, some of which were reproduced in their books and also by Montessus de Ballore. Many other documents also exist that are of interest to historical seismologists but have not been considered by historians. The importance of having direct access to as many

original contemporary documents as possible about the large central Chilean earthquakes of 1647, 1657, 1730, and 1751 prompted us to search for them in the *Archivo General de Indias* (AGI) of Seville (Spain). The AGI archive was created in 1785 and preserves most of the documents concerning the Spanish colonial administration from the sixteenth to the nineteenth centuries (see the [Data and Resources](#) section). The AGI documents are a valuable source of information about historical earthquakes in North, Central, and South America that have not been sufficiently analyzed from a seismological point of view. For each of the four Chilean earthquakes studied here, we have found a large number of documents in official reports and letters to the King of Spain from the Viceroy of Peru, the Governors of Chile, the administrative court of Santiago, the Bishops of Santiago and Concepción, and the members of the religious orders and private persons whose convents and houses were affected by the earthquakes in the different towns. This is the first time these documents are used directly for a seismological study. For each earthquake, the documents cited in the paper are listed in chronological order in the [Appendix](#). References in the paper to the individual documents are given by the two last digits of the year followed by the order number of the document for that particular year as they appear in the [Appendix](#) (for example, 47.1 is the first document for the year 1647).
 (E) A complete list of these documents is available as an electronic supplement to this paper (in Spanish).

For a critical assessment of the information contained in the documents, regarding their seismological interest, one must take into account the historical, sociological, and local contexts. Chile was a colonial region that depended administratively on the Viceroy of Peru. Most of the documents, besides providing information about the earthquakes, also were directed at obtaining financial aid from the Viceroy of Peru and the King of Spain. They reflected local interests, and, for this reason, they may have tended to exaggerate the amount of the destruction and the quality and cost of the destroyed buildings. However, they provide useful information to evaluate the extent of the damage, for example, if the buildings were made of cut stone, stone and mortar, brick, or adobe. Detailed information about the damage is only given for the most outstanding buildings such as the cathedrals of Santiago and Concepción, churches, and monasteries, sometimes including their construction costs.

The Santiago Earthquake of 13 May 1647

The city of Santiago de Chile was founded in 1541 by Pedro de Valdivia in the valley of the Mapocho River. The plan of the city, designed by Pedro de Gamboa, had a rectangular grid shape with straight perpendicular streets and a main square (*Plaza Mayor*) at its center where the cathedral and public buildings, such as the house of the Governor, city hall, administration (*court audiencia*), royal houses (*casas reales*), town council (*cabildo*), and prison, were located (Fig. 1). This was the typical plan for cities established in

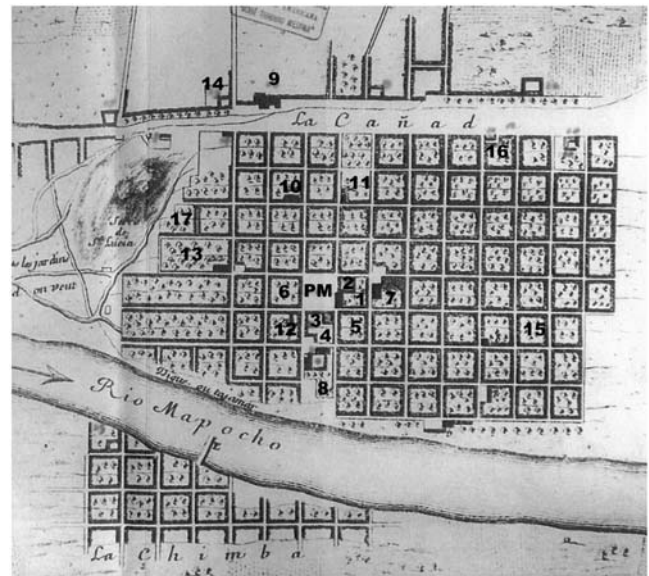


Figure 1. Map of Santiago with the location of buildings damaged in the 1647 earthquake (based on J. Bellin, 1754; up is south and right is west). PM, *Plaza Mayor* (main square); 1, cathedral; 2, Bishop's palace; 3, Governor's palace; 4, royal court; 5, royal houses; 6, city hall; 7, Jesuit college. Convents: 8, Santo Domingo; 9, San Francisco; 10, San Agustín; 11, La Concepción; 12, Santa Clara; 13, La Merced. 14, S. Juan de Dios hospital. Parishes: 15, Santa Ana; 16, San Lázaro; 17, San Saturnino.

America by the Spaniards in the sixteenth and seventeenth centuries. Outside the *Plaza Mayor*, there were several churches and convents: the Jesuit school (*Colegio de la Compañía*); the friar convents of Dominicans (*Santo Domingo*), Franciscans (*San Francisco*), Agustinians (*San Agustín*), Mercedarians (*Merced*), the nun convents of Agustinians (*Concepción*), and Clarisians (*Santa Clara*); the hospital of *San Juan de Dios*; the parish churches of *Santa Ana*, *San Lázaro*, and *San Saturnino*; and a number of small chapels and hermitages. In the seventeenth century, the city had about 300 houses and 5000 inhabitants.

On 13 May 1647, a large earthquake, known as the earthquake of May (*el terremoto de Mayo*), practically destroyed the whole city and killed one-fifth of its inhabitants. Modern references to this earthquake are given by Lomnitz (2004). Studies about this earthquake are based on the detailed analysis made by Montessus de Ballore (1912, pp. 9–63). Montessus de Ballore divided his study of the earthquake into 11 parts: I, time and duration of the earthquake; II, the seismic motion; III, atmospheric circumstances; IV, effects of the earthquake in Santiago; V, ground effects and hydrographic perturbations; VI, extension of shaken area and focus; VII, supposed sea motion; VIII, aftershocks; IX, light phenomena; X, annex with original documents; and XI, bibliography. As sources for his study, he used the work of the Chilean historians Miguel Luis Amunátegui and Diego Barros Arana. Montessus de Ballore reproduced as annexes the texts of three contemporary documents and lists

15 contemporary documents in the bibliography, which were reproduced by Amunátegui (1882).

The documents found in the AGI about the 1647 earthquake, from 21 May 1647 to 14 August 1664, are indexed under the following headings: Chile 11, 12, 13, 21, 22, 27, 29, 66; and Lima 53, 59. They are letters to the King of Spain, Felipe IV, from the Viceroy of Peru, Pedro Álvarez de Toledo, Marquis of Mancera; the Governor of Chile, Martín de Mújica; the Bishop of Santiago, Gaspar de Villarroel; the Royal Court of Santiago (*Real Audiencia*); the City Council of Santiago (*Cabildo*); Royal Officers (*Oficiales Reales*); ecclesiastics; members of religious orders; and private persons. There are also orders by the King, court orders, and official reports. The documents concern the occurrence and characteristics of the earthquake, victims and resulting damage, and particular actions to be taken to help in the reconstruction.

The first documents about the earthquake are letters sent to the King of Spain from members of religious orders of different convents of Santiago, from 21 May to 23 May, eight days after the earthquake (47.1–47.13). The first official documents are letters to the King on 23 May sent by the Royal Officers (47.14) and on 26 May by the Royal Court (*Audiencia*) of Santiago (47.15). An important document is the long letter sent on 9 June from the Bishop of Santiago to the President of the High Council of the Indies (*Consejo Supremo de Indias*), García de Haro (47.18). A very detailed description of the earthquake is found in a letter sent by the Jesuit Gonzalez Chaparro on 13 July (47.20). The state of the buildings and measures to be taken for the reconstruction of the city, especially the tax exemptions, are discussed in the documents from 22 August to 24 November (48.2–48.4). On 14 January 1648, the Viceroy ordered a provisional exemption of four taxes for the citizens of Santiago (48.1, 48.4). On 20 July, a long report was sent by the *Audiencia* to the King with details about the damage caused by the earthquake (48.13). From May to July of 1648, there are a series of letters to the King from the Bishop, the *Audiencia*, and the citizens of Santiago (48.6–48.14).

Information about the Earthquake

The origin time of the earthquake is given by all sources as 22:30 local time (e.g., between ten and eleven [*entre las diez y las once*], 47.2, 47.3; at half past ten [*a las diez y media*], 47.7, 47.10, 47.13, 47.15, 47.17). The duration of shaking in Santiago is given as being between one-half of one-quarter of an hour (450 s; 47.25) to one-quarter of an hour (900 s; 47.3), which seems exaggerated. Most estimations of the duration are given in terms of the time that it takes to recite one *credo* (Christian recitation of faith known as the Apostles Creed, which is also used as a prayer), that is, about 45–50 s. Different reports suggest that the earthquake lasted three *credos* (48.13), less than four *credos* (47.20), and four *credos* (47.17), that is, between 135 and 200 s. This is a reasonable value for an earthquake of this size. Montessus de

Ballore (1912) gave a similar estimate of three minutes (180 s), which corresponds to three *credos*.

The earthquake was considered by some to be the largest ever felt in America (47.2, 47.7). The extent of its shaking was reported to be between 30 *leguas* (167 km; 47.1) and 100 *leguas* (557 km; 47.15, 47.17), where 1 *legua* is equivalent to 5573 m. It extended from the valley of Quillota (modern Aconcagua River) to the Choapa River in the north and to the Maule River in the south (47.13, 47.20) for a distance of about 420 km parallel to the coastline (Fig. 2). Another estimate proposes a length of 100 *leguas* (557 km) from the Cauquenes River in the south to the Limarí River in the north (47.18; Fig. 2). Shaking was accompanied by heavy noise (which sounded like artillery underneath the earth), and the earthquake was said to have been felt as far as the town of Cuzco, Peru, which is about 2500 km away (48.13).

No foreshocks were mentioned, and the mainshock is said to have come suddenly (47.20) without any warning (47.18). The number of aftershocks was large. Earthquakes continued into the night and the three or four following days, but they were not as strong as the first one (47.13). The number of aftershocks reported were 180 (48.1, 48.4) and 300 (48.13, 48.14); unfortunately, the time span of the aftershocks

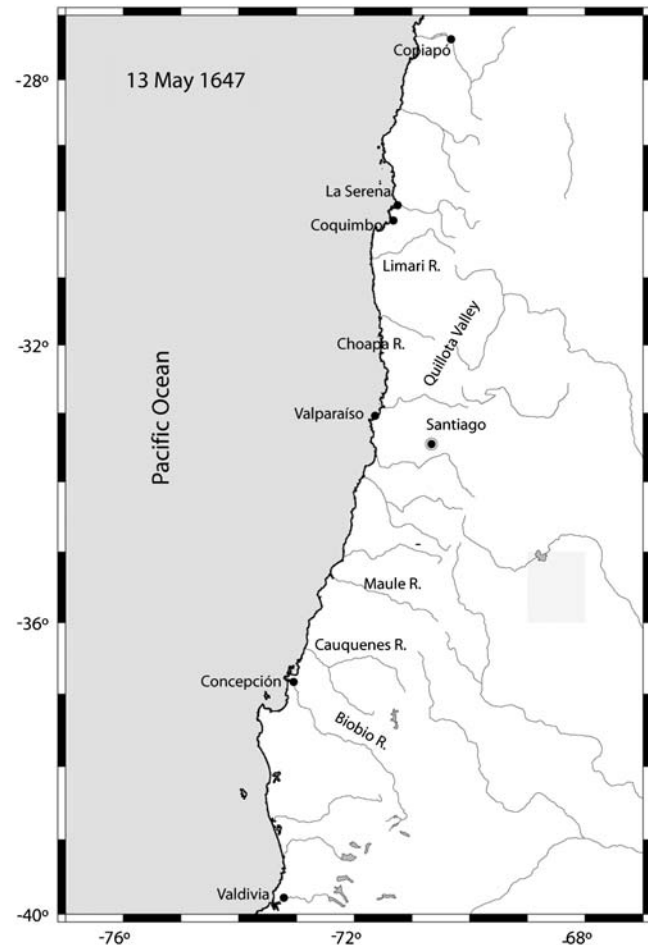


Figure 2. Map of the region surrounding Santiago with the towns and villages affected by the earthquake of 1647.

was not specified. Two aftershocks were singled out as having been especially large, even by one estimate, larger than the mainshock (47.20). No mention was made of the damage caused by the aftershocks.

There are references to the effects on the ground. The ground broke in the hill of Santa Lucia, to the southeast of Santiago, with some landslides. Two large boulders came down from a nearby hill and reached the houses (47.20). Mentions are made of the ground breaking and water welling out (47.7, 47.20), which may refer to cases of liquefaction.

Casualties and Damage

The first estimates reported 670 people buried in the first days after the earthquake (47.1, 47.25). This number soon rose to about 1000 (47.15), which is the number repeated in later documents (47.17, 47.20, 48.6). This number applies only to Spanish citizens and does not count the Indians, negro servants, and victims outside the town (47.25). It is specified that most victims were among the middle and upper classes, and the names of 25 of them are given (*Mil personas muertas, las más gente de buena vida y nombre*, 47.20). Since the population of Santiago was about 5000, this means that one-fifth of the entire population of the town died during the earthquake. After the earthquake, a plague affected the town and resulted in between 2000 and 4000 additional deaths, mainly among the Indian and negro populations (48.13, 48.14, 50.1).

Damage is reported only for the town of Santiago. At that time, Chile was very sparsely populated by Spanish settlers, and damage suffered by Indian villages was not reported. No information is given about damage in the coastal town of Valparaíso, 120 km to the west of Santiago. The other nearest important town was Concepción about 519 km away (Fig. 2), which is said not to have suffered any damage (50.2). Damage in Santiago was very extensive, with all houses, convents, and churches destroyed (*No quedó casa, convento ni iglesia que no se asolase*, 47.1; *sin dejar templos, conventos ni edificios que no asolase y derribase*, 47.13). Destruction is said to have extended to the whole town (47.5, 47.7), and no building was left standing (*No dejó en ella edificio en pie*, 47.10). Even the foundations of the buildings were affected so that one could not build upon them (47.20). The documents emphasize the good quality of the construction of many of the buildings, churches, monasteries, and private houses (*iglesias, templos, monasterios, capillas y casas de costosa fábrica y labor curiosa*, 48.13).

Explicit mention is made of the damage to the cathedral; Jesuit college; convents of *Santo Domingo*, *San Francisco*, *San Agustín*, *la Concepción*, *Santa Clara*, and *la Merced*; hospital and church of *San Juan de Dios*; parish churches of *Santa Ana*, *San Lázaro*, and *San Saturnino*; city hall; court house; royal houses; house of the *cabildo*; and prison (locations shown in Fig. 1). The cathedral was built facing the *Plaza Mayor*. The damage suffered by the cathedral is described in great detail. Its structure is said to have been

excellent so that, from the point of view of its architecture, nothing in America could be compared with it (*Es obra tan prima y de tan excelente fábrica que, aunque hay otras más suntuosas, no hay en las Indias otra que se la pueda igualar en los términos de la arquitectura*, 48.3). It was built between 1566 and 1600. The structure was formed by three naves of cut stone. The columns and arches of the central nave, made of cut stone, withstood the earthquake (*quedaron todos en pie*), except for one which was damaged (48.3), and the wooden roof on the central nave also withstood the shaking. But this was not true of the two lateral naves, which came down (*cayeron las dos naves*) because, owing to a lack of funds, they had been finished with adobe (47.18, 47.20). The left lateral nave suffered more damage than the right nave (48.3). The exterior walls were so severely damaged that they needed to be rebuilt (48.3). All of the ornamentations inside the church, such as the altars and images, were destroyed (*Cayeron los altares, retablos e imágenes haciéndose mil pedazos*, 47.18). The whole building was damaged except for the columns and arches of the central nave.

The Jesuit college and church were built near the cathedral (Fig. 1). The church was of solid construction with walls of cut stone, a wooden roof (*fortísima en murallas cubierta de ciprés*, 47.20), and a dome on the transept. The dome and the arches of the transept withstood the motion (*no cayó la cúpula de media naranja por la fortaleza del crucero*, 47.20). The college, however, collapsed completely (*Cayó todo el colegio*, 47.20). The convent of the Dominican friars (Fig. 1), situated one block south of the *Plaza Mayor*, had a church with brick arches, 15 chapels, and a newly built cloister. The church and the cloister came down (*una ilustre iglesia y un claustro nuevo quedó todo tan asolado*; 47.18, 47.20). The convent of Agustinians was still under construction, and only the central of the church naves was finished. The church collapsed completely (*cayó todo y lo que no ha caído esta mucho peor*; 47.18, 47.20). The convent of Franciscans was of very solid construction (*se llevaba la prima en fortaleza*, 47.20) with a tall tower, two cloisters, and many rooms and offices. Everything was destroyed (*desbaratolo todo la ruina*, 47.12; 47.18). The destruction of the church of the convent of Mercedarians, except for its major chapel, is specified as well as that of the convents of *Santa Clara* and *La Concepción* and the hospital of *San Juan de Dios*; the infirmary of the hospital was not destroyed, and thus bedridden sick people were spared (47.18). The convent of Franciscans and the hospital of *San Juan de Dios* (labeled as numbers 9 and 14, respectively, in Fig. 1) were located at the southern edge of the city at the south side of a ravine (La Cañada), parallel to the Mapocho River, which bordered the city on the north, while the rest of the convents were in the city center.

There are no descriptions of the damage to the administrative buildings and private houses. The destruction is said to have been widespread, affecting all buildings of the city (*Asoló y derribó toda la suntuosa pompa de los edificios de esta triste y afligida ciudad*, 47.20). The destruction also

extended to ranches and farms (*estancias y chacras*) outside the town of which at least 50 or 60 were destroyed (47.1, 47.7). Earthquake intensity at Santiago may be estimated at X–XI (MM, modified Mercalli scale).

Costs and Reconstruction

A large number of the documents are concerned with measures to be taken in the reconstruction and the costs thereof. The costs are given in *pesos* and *ducados*. The *peso* was a silver coin in America equivalent in Spain to *real de ocho* (eight *reales*; *real* was the smallest silver coin). The *ducado* was the monetary unit commonly used in Spain and its colonies for financial transactions. One *ducado* was equal to 1.38 *pesos*. In seventeenth century Spain, an income of 50 *ducados* or less per year was considered the poverty threshold. A modest family could spend as little as one *ducado* per month on food, and a soldier's expenses were set at 72 *ducados* per year. An aristocrat, however, could have rents of more than 20,000 *ducados* per year. The value of the loss of some buildings are given; for example, the church of the convent of *San Francisco* is said to have cost 200,000 *ducados* (47.12) and that of the Jesuit college cost 100,000 *ducados* (47.18). The losses of the convent and church of *San Agustín* were estimated at 100,000 *ducados*. The losses of the cathedral were estimated at 30,000 *ducados* (47.18).

A very detailed document specifies the contributions to the reconstruction to be made by the King, the Governor, the town, members of religious orders, traders, farmers, Indians, etc. (48.4). The first measure proposed to economically help in the reconstruction was the exemption of the citizens of Santiago from four types of taxes: *Alcabala*, *Almojarifazgo*, *Unión de Armas*, and *Papel Sellado* (48.5). The *Alcabala* taxed all sales between 2% and 5%; *Almojarifazgo* taxed all goods coming from Spain or passing from one port to another at 5%–10% of their value; *Unión de Armas* was a tax to finance the Spanish army stationed outside Spain, mainly in Flanders and Italy; the contribution fixed for the viceroyalty of Peru was 350,000 *ducados* per year; and *Papel Sellado* was the tax imposed since 1636 for using official sealed paper (cost up to one *peso*, depending on the type of document) in all public and private documents. The exemption was solicited on 25 October 1647 and approved by the Viceroy on 24 November. However, the order with the approval of the King granting the solicited exemptions did not arrive in Chile until 1 June 1649 (49.1). A year later, a letter from the King to the Viceroy asked if these exemptions were still necessary (50.3).

Other economic measures proposed were taxing some specific products such as wine exported to Buenos Aires, copper from the mine of Coquimbo (Fig. 2), and rentals of stores in Santiago. For the reconstruction of churches and convents, it was proposed that two-ninths of the tithes of the dioceses of Santiago and Concepción and other ecclesiastical funds from the duties corresponding to the vacant bishoprics of Peru be applied. Provisions were also made for the mort-

gage of houses affected by the earthquake and the lowering of prices for reconstruction materials (48.4). Cash contributions were made from several sources, for example, by the Governor, 2000 *pesos*; the Viceroy, 12,267 *pesos*; the Archbishop of Lima, 7000 *pesos*; and the citizens of Lima, 12,000 *pesos*.

To help in the work of reconstruction, it was proposed to employ soldiers, prisoners, slaves, and Indians from the neighboring villages, in addition to hired labor (48.4). The reconstruction of the royal houses is given in detail, and its total cost was 16,970 *pesos* (48.2). For the cathedral, using all of the possible materials from what was left; the cost was estimated at 52,387 *pesos* (48.3). Hastily rebuilt, the cathedral suffered damage again during the earthquake of 15 March 1657, which destroyed the town of Concepción, 519 km south of Santiago. The cathedral was rebuilt again between 1662 and 1687 but was destroyed again in the great Valparaíso earthquake of 8 July 1730. The construction of the present-day cathedral, of a completely new design, was started in 1748 and finished in 1830.

Interpretation

The May earthquake occurred on 13 May 1647 at 22:30 local time, which corresponds to 2:30 UTC on 14 May. From all of the accounts, we conclude that the epicenter was located near the city of Santiago. Heavy shaking extended to a distance of about 500 km in the north–south direction between the Choapa and Maule Rivers. This can be taken as an estimate of the dimension of the source. However, information about the damage is restricted to the city of Santiago. [Lomnitz \(2004\)](#) estimated the magnitude of the May earthquake as $M_s \sim 8$. He also suggested, following other authors, that the May earthquake may not have been of subduction origin but was due to a local source near Santiago. We cannot exclude this possibility, but the reports of damage extending more than 500 km along the coast make us think that this event was similar to other central Chilean earthquakes, most notably the Valparaíso earthquake of 1906. Large earthquakes of magnitude close to 8 have occurred in Chile inside the subducted Nazca plate. The most important and damaging of these events in modern times was the Chillán earthquake of 18 January 1939. This earthquake occurred 70 km inside the Nazca plate slightly north of Concepción, according to [Gutenberg and Richter \(1941, p. 31\)](#). [Beck et al. \(1998\)](#) found a depth of 80–100 km from the modeling of far-field records of this event. Other M_w 8 intraplate earthquakes have occurred in recent times in northern Chile: in 1950 near Antofagasta ([Campos and Kausel, 1990](#)) and under Pica in Tarapaca ([Peyrat et al., 2006](#)). Thus, we cannot exclude the possibility that 1647 was of that origin, but we could find no evidence for or against it in the contemporary documents studied.

The Concepción Earthquake of 15 March 1657

The city of Concepción was founded in 1550 by Pedro de Valdivia at the Concepción Bay (Fig. 2). For almost

300 years, it was a frontier town between the territories occupied by the Spaniards and those under the control of the Mapuche Indians. In the middle of the seventeenth century, Concepción was a small town with about 80 houses, greatly affected by the continuous wars with the Indians. Montessus de Ballore (1912, pp. 63–74) based his study of the 1657 earthquake on the contemporary report by Alonso de Solorzano and later histories of Chile of the middle eighteenth century by Pedro Córdoba y Figueroa and Miguel de Olivares, and a manuscript by José Toro Zambrano, Bishop of Concepción. He notes the total destruction of the town and gives the time of the earthquake as 8 p.m. local time. The documents from the AGI with information on the earthquake of 1657 are under the headings of Chile 13, 22, 27, 29, 62, 66 and Lima 59.

Information about the Earthquake

Information about this earthquake is very limited because, at that time, Concepción was a small town. The first reference to the earthquake is found in the long report to the King of Spain (Felipe IV) from Alonso de Solorzano y Velasco, officer of the Royal Court (*Oidor*) of Santiago, about the state of the nation. Written on 2 April 1657, less than a month after the earthquake (57.1), the report was mainly about the wars with the Indians and contained only a short paragraph about the earthquake. The date of the earthquake (15 March) is given, but the time is not. The town is said to have been completely destroyed; it was left ruined and devastated from its foundations (*Quedó muy arruinada y asolada desde sus cimientos*, 57.1). Shaking was followed by a tsunami where the seawater entered the streets and houses three times. The combined effect of the earthquake and the tsunami caused the complete destruction the town: buildings fell down, supplies were lost, and about 40 people died (*cayeron los edificios y se perdieron los viveres y murieron hasta 40 personas*, 57.1). People abandoned their houses and fled to higher ground. The total destruction of the main church was reported. The church was the only building that had been left standing in the destruction of the town by the Indians two years earlier. The convents of Dominicans, Franciscans, and Augustinians and the Jesuit school were all ruined. In a letter sent by the Viceroy Luis Enríquez de Guzmán, Count of Alba de Aliste to the King (20 April), reference is made to the total destruction of the town by the earthquake and tsunami (57.2).

A year later (10 March 1658), a letter from the Royal Court of Santiago makes reference to the earthquakes that destroyed Santiago in 1647 and Concepción in 1657 and mentions the damage caused by the tsunami in the latter (58.1). In the following year (8 August 1659), another letter from the Royal Court to the King reports the petition of the General Procurator of the Order of *N. S. De La Merced*, Fr. Juan de Castro asking for help because of the damage to the convents caused by various earthquakes that occurred during the previous ten years, especially those of 1647 in Santiago

and of 1657 in Concepción, which left the convents destroyed without buildings and churches (59.2). Outside Concepción, the earthquake was felt in Chillán and Maule (59.3; Figs. 2 and 3). In 1661, reference was made to the earthquake and tsunami in Concepción in a letter to the King from the Governor of Chile, Pedro Porter Cassanate, in which he praised the leadership and governance of the Bishop of Concepción Dionisio Cimbrón (61.1). In 1662, a letter to the King reports of the destruction in Santiago by the earthquake of 1647 and the fact that the little that was reconstructed was later destroyed by the earthquake of 1657 (*destruyó lo poco que nuestras cortas fuerzas pudieron fabricar en lo perdido*, 62.1). This is the first reference to the damage in Santiago by this earthquake (62.1). None of these documents give the time of the earthquake, so the 8 p.m. local time given by Montessus de Ballore may be doubtful.

In conclusion, the contemporary documents confirmed that this earthquake occurred on 15 March 1657, but its origin time has yet to be determined. The generation of a tsunami points to an epicenter offshore. Damage in Concepción indicates that the offshore fault rupture was near this town. The damage caused by the earthquake in Santiago, 519 km north of Concepción, indicates a large shock. The area of

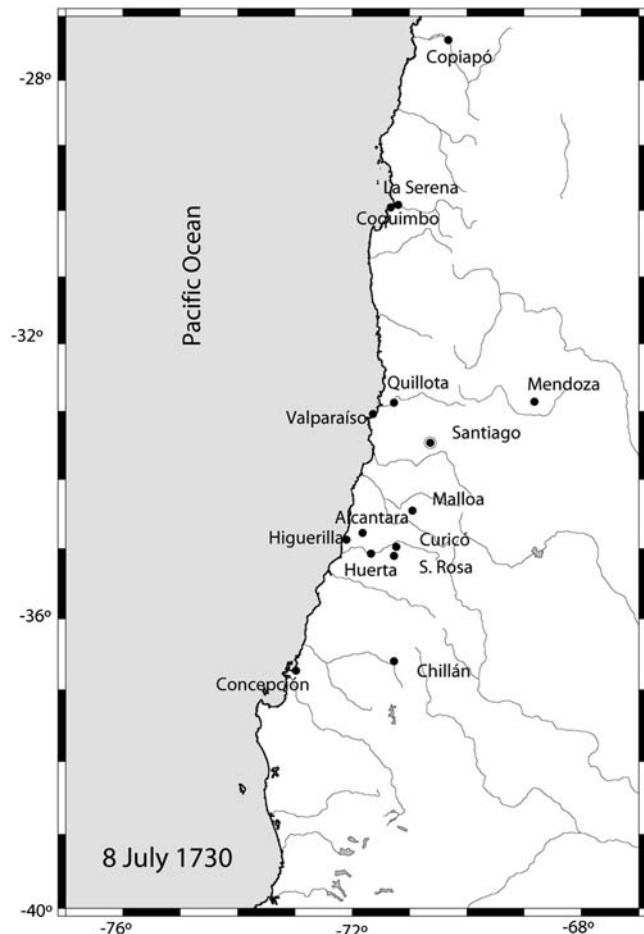


Figure 3. Towns and villages affected by the earthquake of 1730.

destruction of this earthquake extends from Concepción to the Maule River in the north (Fig. 2). This is an area of very similar extent to that of the 1835 Darwin earthquake. We have no information about the southern termination of the rupture zone of this event because this was Mapuche territory where very few Spaniards lived. Although this event generated a large tsunami, we do not think that it was as large as the 2010 earthquake, even though it seems to have ruptured a large part of the area broken in February 2010. Lomnitz (2004) estimated the magnitude of the 1567 earthquake as M_s 8 or slightly less.

The Earthquake of Valparaíso and Santiago of 8 July 1730

The megaequake of 8 July 1730 was considered by Montessus de Ballore (1912, pp. 75–93) to be the largest earthquake to have ever occurred in Chile prior to 1912. He considered the extent of the affected area, the magnitude of the damage, and the tsunami generated, which especially affected Valparaíso and Concepción (Fig. 3). He based his analysis on the information provided by Barros Arana (1834) and Vicuña Mackenna (1869) and the documents provided by them. The earthquake totally destroyed the town of Valparaíso, a natural harbor situated at a bay 120 km west of Santiago; founded in 1544 with its first fortified wall built in 1559, it was defended with the first fortifications in 1594 (Fig. 3). In 1682, it was declared a fortified town and military garrison because of its importance as the natural harbor of Santiago and the dangers of incursions by English corsairs. In 1730, it was still a small town with about 1000 inhabitants. The contemporary documents found in the AGI for this earthquake extend from 20 August 1730 to 22 September 1739 and are indexed under the heading Chile 145. The first document is a letter from the Bishop of Concepción, Francisco Antonio de Escandón, to the King of Spain, Felipe V, almost two months after the earthquake, with a detailed description of the damage in this town (30.1). The most detailed description of the damage in Santiago is in the letter from the Bishop of Santiago, Alonso Pozo y Silva (31.7). A good account of the damage in the whole country is given in the letter from the Governor of Chile, Gabriel Cano Aponte, to the Viceroy of Peru, José de Armendáriz, Marquis of Castelfuerte (31.4). As in the previous cases, the documents are official reports and letters to the King from the Governor of Chile, the Viceroy of Peru, the Bishops of Santiago and Concepción, and the Royal Court of Santiago, and letters from members of the various religious orders of the convents affected by the earthquake and from private persons.

Information about the Earthquake

The origin time of the mainshock of 1730 is poorly defined; it is given as before dawn (31.1), between three and four local time (30.1), at four (31.11, 31.12), and at five (31.4). Another document states that at half past four, a

tremendous and horrifying earthquake occurred (*Vino a las cuatro y media un terremoto tan tremendo y horroroso*, 31.2). The earthquake was preceded by a large foreshock at about half past one local time (30.1, 31.2, 31.4), or between one and two (31.4). The foreshock was strong enough to awaken almost everyone; people abandoned their houses and spent the rest of the night outdoors (31.11). This explains the rather small number of casualties in Santiago compared with the earthquake of 1647. A large number of aftershocks followed the mainshock, especially during the first five days (31.2), and they continued until July 20. At least three of the aftershocks were reported to be large, although not as large as the first (31.4). Almost a year later (8 March 1731), earthquakes were still being felt (31.8, 33.3).

Damage and Casualties

Damage was very extensive: shaking affected the whole kingdom (*Alcanzó la conmoción de la tierra a todo el reino*, 30.1) and was considered to be widespread (31.9), extending from Copiapó in the north to Concepción in the south, a distance of more than 1000 km. From north to south, the towns reported to have suffered damage are as follows: Copiapó, La Serena, Coquimbo, Quillota, Valparaíso, Mendoza (Argentina), Santiago, Malloa, Alcantara, Curicó, Santa Rosa, Chillán, and Concepción (31.11, 35.10; Fig. 3). The north–south extent was double that of the 1647 earthquake. It was considered to be the largest earthquake since the establishment of the Spanish settlements (31.4, 33.1), larger than the one of 1647 which did not cause damage in Concepción. However, the number of people who died was only between four and six (30.1, 31.10). As already mentioned, this was due to the occurrence of a large foreshock that woke people up and allowed them to flee to safety.

Valparaíso

The town was reported to have been completely destroyed by the earthquake, and all of the convents were devastated (31.11, 35.10, 35.11). Besides the effect of the earthquake, the flooding produced by the tsunami added to the devastation (31.4). There were no reports of the damage to individual buildings or details of the effects of the tsunami.

Santiago

Most of the documents for this earthquake refer to damage in the capital, which is said to have been completely ruined: All of the city has been ruined and almost buried by its own buildings (*Toda esta ciudad se ve arruinada y casi del todo sepultada entre sus mismos edificios*, 30.3). In particular, all of its churches and convents are said to have been destroyed (30.4, 30.5). The same applies to the buildings of the city council (*cabildo*) and the city hall (*ayuntamiento*), public buildings, and hospitals (31.3). Also ruined were the palace of the Governor, royal houses, army buildings, and warehouses (30.1, 31.10). All of the churches and private

houses (*todas las casas de la ciudad*) suffered total ruin (*ruina total*), with very few left standing (31.4, 31.5, 31.7, 39.1). A description of the damage is only given for churches and convents, which were the largest and most well-constructed buildings.

The damage to the cathedral is described in great detail (31.4, 31.7, 31.8). The cathedral, rebuilt between 1662 and 1687 after the earthquake of 1647, was a large building with three naves. The walls of cut stone were heavily damaged and fractured, some of the buttresses had completely fallen, and the rest of the building was ruined with the arches fallen. The tower of brick, the highest in town, was totally ruined, and it was said that it must be demolished. Its dome was quartered and opened. Adjacent office and living buildings made of adobe were completely destroyed (31.8). The cost of the damage was estimated at 30,761 pesos (33.3, 33.4, 34.2, 36.3).

Damage in other churches was also reported. The convent of *San Agustín*, described as built of brick and mortar, was left with the walls ruined, with one side collapsed and with damage to part of the ceiling. Parts of the two towers of its church came down. The 36 arches of brick and mortar of the cloister all fell down. The living quarters of the friars were badly damaged (30.4). A detailed description is given of the damage suffered by the convent of *Santo Domingo* (31.9). The large church of three naves is said to have collapsed and needed to be rebuilt completely from its foundations. The bell tower, of considerable height and well built of brick and mortar, collapsed and left the four large bells buried. Only parts of the walls and some arches were left standing. A dome in one of the chapels fell down. For the other buildings of the convent, those of brick and mortar were damaged and those of adobe were completely destroyed (31.9). The convent of *San Francisco* also suffered heavy damage, with its large church of cut stone and mortar ruined and its tower collapsed (31.7, 32.2, 32.5, 33.2, 35.5). The church of the Jesuit school, built of cut stone and mortar, did not collapse, but it suffered serious damage to its arches and vaults (31.7). The school of *San Diego* suffered damage to its church and cloister (33.2, 35.7, 35.10).

There were also reports of damage in other convents and monasteries. The convent of *Santa Clara* suffered heavy damage, and its church collapsed. Its tower came down and killed one person (31.1). Living quarters were left unusable (31.4), and losses were estimated at 32,600 pesos (35.6). All of the buildings of the convent suffered great damage (35.14, 35.16). The monastery of the *Capuchinas*, built of adobe, tile, and wooden beams, came down completely, including its church with its tower and the cloister (32.4, 32.6, 35.1, 35.13); damage was estimated at 20,402 pesos (35.8). The convent of *Nuestra Señora del Socorro* suffered heavy damage in the living quarters and cloister, but the church of stone and mortar remained, though its tower fell down in part (35.5). Repairs were estimated to be more than 10,000 pesos (35.10, 35.11). In the convent of *La Merced*, all of the vaults came down (31.7). The monastery of *Las Agustinas* also

suffered damage (31.4, 39.2). The convent of *La Santa Recolectión* suffered damage, especially in its church, which was estimated at 21,320 pesos (35.10, 35.12). The convent of *El Carmen* suffered damage to the roof of the church and to its tower, which came down, and to its living quarters; the cost of the damage was estimated at 16,413 pesos. Although the damage was so great, only two people are reported to have died.

Concepción

Damage in Concepción was due to the shaking and flooding through the town caused by the tsunami; the sea entered the plazas and streets and took with it all that it found (*el mar entrándose por las plazas y calles, llevándose consigo cuanto encontró*, 30.1). The sea retreated at first and then advanced and inundated the streets and houses throughout the town. Two-thirds of the buildings are said to have been ruined. The cathedral and other churches, though inundated, were left standing (30.1, 35.17). However, the convents of *San Francisco* and *San Agustín* and the church of the *Hospital of San Juan de Dios* are said to have been ruined by the tsunami (31.11, 31.12). There were only two or three people who were reported to have died, as well as a number of cattle, because of the tsunami (31.9). This is attributed to the knowledge that the people, who took to high ground when they saw the sea recede, gained from previous experiences.

Other Towns

Damage at other towns was only given in general terms with very little detail. Damage refers only to the convents, and nothing is said of private houses. In La Serena, it was specified that houses and the parish church were ruined: falling to its violence the houses and the sacred temples (*cayendo a su violencia las casas y los sagrados templos*, 33.1). Without specific details, it is said that the convents of Campaña, Alcantara, Malloa, Monte, Santa Rosa, Quillota, Chillán, Unique, Huerta, Curicó, Iguerilla, Coquimbo, Mendoza (Argentina), and Copiapó were ruined (31.11, 35.10, 35.11, 35.17). Damage affected towns between La Serena to the north and Concepción to the south (Fig. 3).

Interpretation

The earthquake of 8 July 1730 occurred at 4:30 local time (corresponding to 8:30 UTC or between 7:00 and 9:00 UTC). It was preceded by a strong foreshock at 1:30 (5:30 UTC or between 5:00 and 6:00 UTC) and was followed by a long series of aftershocks that were felt for more than a year after the mainshock. It caused a large tsunami that affected Valparaíso and Concepción. Its epicenter can be placed somewhere offshore Valparaíso, which is said to have been totally destroyed. Damage in the capital Santiago was very extensive, and details are given for the cathedral and main churches; the intensity was estimated at X–XI (MM

scale). Damage was reported for towns and villages from Copiapó in the north to Concepción in the south over a distance of more than 1000 km. The total destruction of Valparaíso, significant damage in Santiago, and generation of a tsunami put its fault rupture offshore Valparaíso. Lomnitz (2004) estimated the magnitude of this event at M_s 8.5–9. There is no doubt that this was the largest event that affected central Chile in historical times. The north–south extent, its tsunami, as well as damage reports put this event in the same magnitude range as the 27 February 2010 earthquake. A future earthquake of this size in central Chile is not to be excluded.

The Concepción Earthquake of 25 May 1751

The earthquake of 25 May 1751 and the subsequent tsunami mainly caused the destruction of Concepción, which was afterwards rebuilt in a different location. Montessus de Ballore based his analysis of this earthquake mainly on the accounts of the nineteenth century historian Claudio Gay. A considerable number of documents with information about this earthquake have been found in the AGI; these are under the index headings of Chile 146 and 147. They contain a great variety of documents written between 25 May 1751, the same day of the earthquake, and 14 April 1758. Many of the documents concern the relocation of the town after the earthquake.

Information about the Earthquake

The time of the mainshock is given by most documents as the early dawn of 25 May 1751 between one and two local time. For example, at half past one, this town experienced a terrible earthquake (*a la una y media se experimentó en esta ciudad [Concepción] un tan terrible terremoto*, 51.6, 51.12, 51.13). Other estimates are at 12 local time (51.8, 52.5); between 12 and one (51.10, 51.30), which may refer to the foreshock; at one (51.26); and between one and two (58.6). The mainshock was preceded by a foreshock that occurred one or two hours before the main event on the night of 24 May between 11 and 12. The foreshock was large enough to awaken most people, who then abandoned their houses (51.1, 51.10). The duration of the mainshock is simply described as “horrible” (*cuya fuerza y duración era espantosa*, 51.8, 51.28) and “terrible” (51.10). Only one document gives the duration more precisely as six minutes (51.6). The mainshock was followed by a long series of aftershocks, which were numerous and very frequent (51.5, 51.6). One account reports 155 shocks between the mainshock and the eleven hour of the same day (51.1). Aftershocks were reported as being very frequent during the whole year (51.66). The size and catastrophic effect of the earthquake are expressed by some of the adjectives used to describe the event: horrible (*espantoso*), astonishing (*asombroso*), violent (*furioso*), and terrible (*lastimoso*; 51.8, 51.10, 51.28, 51.52, 51.53, 51.70). Damage extended from Santiago in the north to Valdivia in the south,

but most reports refer to damage in Concepción and in towns and villages around it.

The earthquake generated a large tsunami that was felt mainly in Concepción, Valparaíso, and the Juan Fernández Islands, where it produced significant damage (Fig. 4). In Concepción, waves reached the ruins of the city walls twice and swept away everything in its path (51.1, 51.13, 51.40). Three main waves in Concepción were mentioned, which affected three *leguas* (about 15 km), with the main wave at a height of 12 *varas* (about 10 m; 58.6). This tsunami is said to have been the third in 20 years (*desde el año treinta ha habido tres*, 51.48). This must refer to the tsunamis of 1730, 1737, and 1751. The earthquake of 24 December 1737 with an epicenter near Valdivia also caused damage to the cathedral of Concepción. One document states that experience shows that all earthquakes that take place in the southern coasts result in the outgoing of the sea (tsunami), which causes the greatest damage (51.54). Casualties in Concepción were given as about 20 (52.5), or more precisely 28 (51.26); and in the island Mas-a-Tierra (today Robinson Crusoe) of the Juan Fernández Islands, there were 36 deaths (51.24), most of whom drowned due to the tsunami. Special mention is made of the deaths of the Governor of the Islands of Juan Fernández and his family (51.28, 51.32) and, in Curimón, of the Prelate and the Mayor (51.6). In 1751, as in 1730, the occurrence of a strong foreshock allowed the people to abandon their houses before the occurrence of the mainshock. The population’s experience with previous tsunamis prepared them to flee to higher ground when they felt

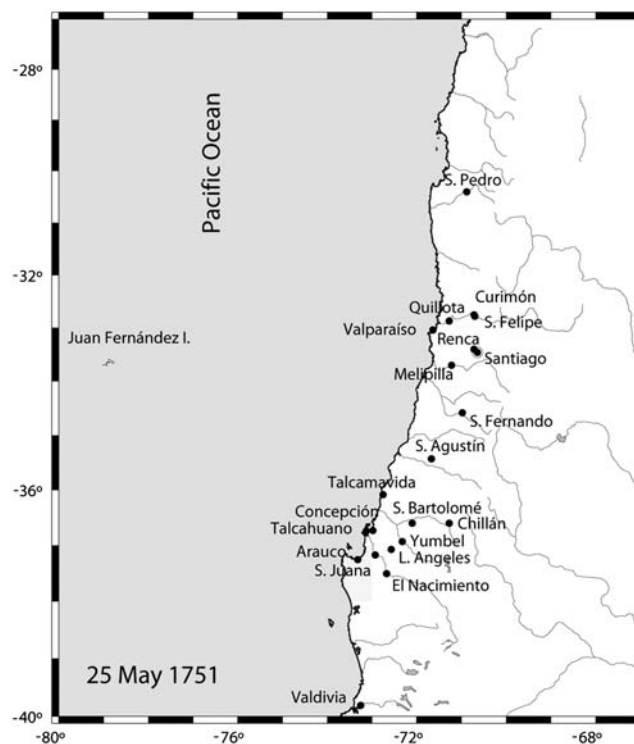


Figure 4. Towns and villages affected by the earthquake of 1751.

the earthquake shaking, which explains the low number of casualties.

Damage

Most of the information contained in the documents about the damage caused by the earthquake and tsunami is limited to the city of Concepción. General descriptions talk of total devastation and ruin, affecting all churches and buildings (*total asolación...total ruina...derribando templos y edificios sin reserva de casa alguna*, 51.28). The city is said to have been left in total ruin by the earthquake (*arruinada enteramente en el terremoto*, 51.17, 51.19, 51.20, 51.23). In addition to the effects of the earthquake, flooding of the greatest part of the city by the tsunami occurred in three main waves (*agregado de la repetida salida del mar*, 51.24). Another document specifies that the city was devastated not only by the horrifying shaking of the earth but also by the flood from the sea (*no solo asolada en el movimiento horroroso de la tierra, sino con la salida de mar que inundó sus aguas la mayor parte de la ciudad*, 52.19). Specific mention is made of the royal houses, military barracks and warehouses, the court building, and other public works (52.6). The churches were reported to have suffered damage but not total collapse, as was the case for the palace of the Governor (51.6). Other documents say that all of the churches fell down including the cathedral, which was of recent good construction (*cayeron todas las iglesias...y la catedral que se hallaba nueva y hermosamente construida*, 52.4). A very detailed description is given of the damage to the cathedral. Although the building did not collapse, it is said that it could not be used, because of the damage to the walls (51.5). The upper part of the tower and its dome came down (51.6). The cathedral is said also to have suffered damage in the earthquake of 1737 (52.14). Specific mention is made of the damage to the monastery of the Trinitarian nuns, the only monastery in the city. The monastery is said to have been totally ruined (*arruinado enteramente*) so that the nuns could not live in it (51.12, 53.8, 58.7, 58.8). The same level of destruction affected the convent of San Francisco, even though it was a large and well-built church (51.71, 55.4).

Reports of damage at other localities are as follows (Fig. 4):

- Santiago: houses and churches were damaged (51.6).
- Valparaíso: several houses, churches, and the walls of the castle were ruined (51.25).
- Renca: buildings, warehouses, and the new church fell down (51.6).
- San Felipe el Real: the roofs and walls of houses and the church came down (51.6, 51.25).
- Curimón: a house collapsed (51.6).
- Quillota: the roofs and walls of houses and churches were damaged (51.6).
- San Fernando: city hall houses collapsed and the roof of the church fell (51.6).

- Melipilla: buildings fell down and all of the roofs suffered damage (51.6).
- San Agustín de Talca: left totally destroyed (51.28).
- San Bartolomé: ruined (52.12).
- Talcahuano: chapel was ruined (52.3, 53.9).
- Chillán: totally destroyed (51.10, 51.13, 56.7).
- Yumbel-Yungay: ruined (51.18).
- Los Ángeles: part of the church and of the town wall fell (51.5, 51.15).
- Talcamavida: the church fell (51.5).
- Valdivia: believed to be ruined (51.28).
- Isla de Juan Fernández: the town and fort were devastated (56.7).

The damage extended from Santiago in the north to Valdivia in the south, with the heaviest damage in Concepción and its surroundings. Damage was also reported in San Pedro, Santa Juana, San Felipe el Real, Logroño de S. José, Arauco, and El Nacimiento (51.9, 51.10, 51.25, 56.7; Fig. 4); however, no details were provided.

The damage caused by the tsunami was very intense in Concepción, as we have seen, and on the island Mas-a-Tierra (Robinson Crusoe) of the Juan Fernández Islands about 670 km from the coast of Chile where the fort of Santa Barbara, founded in 1749, houses, warehouses, the church, and the Governor's house were destroyed (51.24, 51.28, 51.31, 51.32, 51.33, 56.7).

Relocation of the City of Concepción

The damage caused by the tsunami in Concepción showed the necessity of changing the location of the city, because it had experienced three floods by the sea in the last 20 years (reference to those of 1730, 1737, and 1751) and many other earlier floods (51.53, 51.49, 51.70). In view of this situation, the citizens arrived at an agreement about the need to search for a location on sufficiently high ground where there would be no danger of being affected by future tsunamis. A large number of documents are dedicated to this topic (some representative documents include 51.34, 51.35, 51.43, 51.58, 51.63, 51.67). The old location is now the town of Penco. Four possible new locations were proposed: Valle de la Mocha, Loma de Parra, Loma de Landa, and La Rinconada (Fig. 5). The characteristics of each location, including the distance from the old location and to the sea coast, height above sea level, soil conditions, as well as the costs of relocation, were considered and discussed. Neighbors seemed to have favored Loma de Parra because of better ground conditions, but the decision made by Governor Domingo Ortiz de Rozas on 25 December 1751 finally put the new town at Valle de la Mocha (also called Valle de Rozas), the present location of Concepción, next to the Biobío River (Fig. 5). Those who argued against the selection of Valle de la Mocha insisted that it had bad ground conditions of sand and a mixture of sand and soil called *tumao* by the local Indians. Damage by later earthquakes, especially on 21 May 1960 and 27 February 2010, showed that this was not a

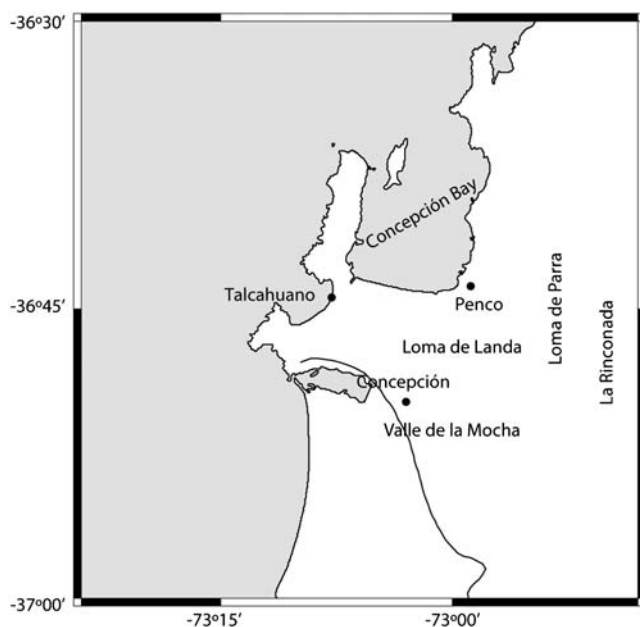


Figure 5. Sites proposed for the relocation of Concepción (ancient and present-day Concepción are shown as Penco and Concepción, respectively).

good decision. The discussions about the advantages and inconveniences of the relocation and the best way to carry it out continued for several years from 1752 to 1754 (52.5, 54.1, 54.6, 54.8). A total estimate of the costs of the relocation including construction of a bridge over the Andalien River, water conduction, royal houses, Governor's palace, administrative buildings, and a new cathedral was given as 1,190,579 pesos.

Interpretation

In conclusion, the 1730 and 1751 earthquakes are the largest events that are known to have occurred historically in central Chile. The 1751 earthquake was reported to have caused damage from Santiago in the north to Valdivia in the south. The main destruction was concentrated around the ancient city of Concepción (present-day Penco) and the surrounding towns. The tsunami mainly affected Concepción, the Islands of Juan Fernández, and Valparaíso. In Concepción, the tsunami completed the destruction caused by the earthquake. The number of victims was relatively low, a total of about 70, most of whom drowned in Concepción and the Island of Juan Fernández. The small number of casualties was due to the large foreshock that came a few hours before the mainshock. The population that had suffered two recent tsunamis fled to higher ground as soon as the earthquake occurred.

The description of the damage, the tsunami, and the areal extent of this event is very similar to that of the 2010 Maule earthquake. The 1751 earthquake seems to have affected a region to about 100 km south of the end of the region affected by the 2010 earthquake. The latter caused great

damage as far south as the town of El Nacimiento, and it was not strong in Valdivia. Lomnitz (2004) estimated the magnitude of the 1751 earthquake as M_s 8.5. In view of the magnitude of M_w 8.8 for the 2010 earthquake, we think that Lomnitz' magnitude is a conservative estimate for the 1751 earthquake.

Conclusion

A large number of contemporary documents concerning the characteristics of and damage caused by the large Chilean earthquakes of 1647, 1657, 1730, and 1751 has been found in the AGI. This is an example of the information that can be found in this archive about earthquakes in Central and South America for the sixteenth to eighteenth centuries. The documents found for the Chilean earthquakes, although used by historians, had not been analyzed previously from a seismological point of view. They provide details and important information pertinent to the seismic risk evaluation of the region. The two earthquakes of the seventeenth century, 1647 and 1647, are not as well documented as those of the eighteenth century (1730 and 1751) because the population was more widely dispersed in central Chile during that time. In spite of this problem, it seems to us that the 1647 and 1657 earthquakes were smaller than those in 1730 and 1751. They seem to be much closer in size to the earthquakes of 1822 in Valparaíso and 1835 in Concepción.

Although new information has been found about the damage caused by the 1647 earthquake in Santiago, the exact nature of its source still has not been fully explained. If it was not a subduction zone earthquake, as suggested by Lomnitz (2004), it may have happened inside the downgoing slab similar to many other slab-pull or slab-push events of magnitude close to 8, such as the Chillán earthquake of 1939 (Beck *et al.*, 1998).

The earthquakes in 1657 and 1751 with an offshore epicenter near Concepción produced large tsunamis which severely affected this town. The last one led to the relocation of the city to a place protected from tsunamis, although this site has poor soil conditions as evidenced by the large damage suffered by Concepción after the 21 May 1960 (M_w 8.2) and the 2010 earthquakes. The 1751 earthquake shook a large region from Santiago to the north to Valdivia in the south. From the data we found in the AGI archive, the 1751 earthquake seems to be very similar to the recent 27 February 2010 event.

The 1730 earthquake with an epicenter offshore near Valparaíso was the largest of the four events that we studied. It affected a zone stretching for more than 1000 km along the coast from Copiapó to Concepción and caused great damage in Santiago and Valparaíso. It produced a large tsunami that especially affected Valparaíso and Concepción. A repeat of this event in the future is not excluded, and thus this region should be carefully surveyed.

In Figure 6, we show a schematic view of the results of our investigation. The thick gray and black lines along the

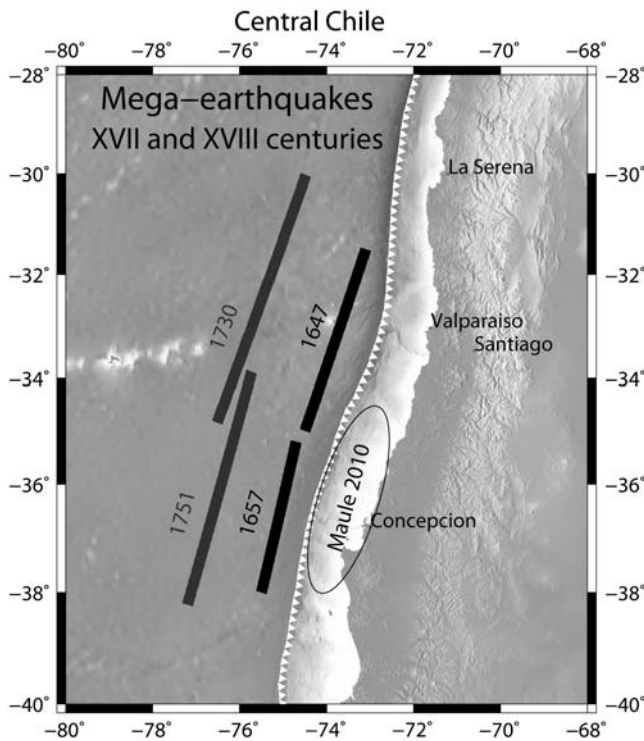


Figure 6. Proposed rupture extents for the Chilean earthquakes of 1647, 1657, 1730, and 1751.

coast show the rupture extent of the 1647, 1657, 1730, and 1751 earthquakes inferred from the reports we found in the AGI. These rupture zone estimates are, of course, subject to a high level of uncertainty because a report of the damage from an earthquake does not necessarily mean that the rupture zone passed near this point. In spite of this caveat, we estimate that the four megaearthquakes of the seventeenth and eighteenth centuries in central Chile broke the entire plate boundary from 30° S to 38° S, which is almost 900 km. The largest of these events, the Valparaíso earthquake of 1730, had a magnitude of at least 9 and should be carefully considered in studies of seismic risk in central Chile.

Data and Resources

The Spanish documents used are available at the *Archivo General de Indias*, Seville, Spain (www.mcu.es/archivos/MC/AGI, last accessed on 22 April 2012).

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Appendix

A list of the cited documents is shown below in chronological order (letters are addressed to the King of Spain unless otherwise specified). The indexed reference headings used by the *Archivo General de Indias* are shown in parentheses. References in the text to each individual document

are given by the two last digits of the year followed by the order number of the document for that particular year (for example, 47.1 is the first document of the year 1647) according to the complete list given in ⑤ the electronic supplement.

Earthquake of 13 May 1647

- 21 May 1647 47.1, Letter from the friars of San Juan de Dios (Chile 27)
47.2, Letter from the friars of San Agustín (Chile 27)
- 22 May 1647 47.3, Letter from the friars of Santo Domingo (Chile 27)
47.4, Second letter from the friars of Santo Domingo (Chile 27)
47.5, Letter from Magdalena del Rosario, nun of the Convent of the Concepción (Chile 27)
47.6, Second letter from Magdalena del Rosario (Chile 27)
47.7, Letter from Pedro Gómez Pardo (Chile 27)
47.8, Letter from the nuns of the Convent of Concepción, (Chile 27)
47.9, Letter from Clemencia de Escobar, nun of the Convent of Santa Clara (Chile 27)
47.10, Letter from Juan de Cuevas, Rector of the College of the Society of Jesus (Chile 27)
- 23 May 1647 47.12, Letter from the friars of San Francisco (Chile 27)
47.13, Letter from the Public Accountant of Santiago (Chile 29)
47.14, Letter from the Royal Officers of Santiago (Chile 29)
- 26 May 1647 47.15, Letter from the Royal Court of Chile, with three reports (*oficios*) signed by Martín Suárez (Chile 11,R8,N54)
- 7 Jun 1647 47.17, Letter from Nicolás Polanco de Santillana, Member of the Royal Court (*Audiencia*; Chile 11,R8,N55)
- 9 Jun 1647 47.18, Letter from Gaspar de Villarroel, Bishop of Santiago to García de Haro, President of the Higher Council of the Indies ([Montessus de Ballore, 1912](#), pp. 27–40)
- 13 Jul 1647 47.20, Letter from González Chaparro to Alonso de Ovalle ([Montessus de Ballore, 1912](#), pp. 50–59)
- 10 ? 1647 47.25, Letter from the Town Council of Santiago (Chile 27)
- 18 Feb 1648 48.1, Report by Martín Suárez, Royal Attorney, with copies of four documents (Chile 21, R2,N30,3)
48.2, Report by Martín Suárez, with copies of eight documents (25 pages; Chile 21,R2, N30,4)
48.3, Report by Martín Suárez, with copies of 11 documents (26 pages; Chile 21,R2,N30,5)
- 13 Mar 1648 48.4, Report by Martín Suárez on the reconstruction with copies of 9 documents (50 pages; Chile 21,R2,N30,5)
48.5, Minutes of the Royal Court sent to the Viceroy of Peru, Marquis of Mancera (Chile 12,R1,N15,2,1–9)
- 30 May 1648 48.6, Letter to the King from the Bishop of Santiago, Gaspar de Villarroel (Chile 61)
- 6 Jun 1648 48.7, Letter from the Royal Court of Santiago (Chile 12,R8,N90)
- 26 Jun 1648 48.8, Letter of Nicolás Polanco, Member of the Royal Court (Chile 12,R8,N92)
- 29 Jun 1648 48.9, Letter from the Town Council (Chile 27)
- 6 Jul 1648 48.10, Letter from the Royal Court Attorney, Juan de Huerta Gutiérrez (Chile 12,R8,N91)
- 7 Jul 1648 48.11, Letter from Antonio Fernández de Heredia, Member of the Royal Court (Chile 12,R,N.15,1,1)
- 8 Jul 1648 48.12, Letter from the Royal Court of Santiago (Chile 21,R2,N30)
- 12 Jul 1648 48.13, Letter from Royal Court of Santiago ([Montessus de Ballore, 1912](#), pp. 41–50)
- 20 Jul 1648 48.14, Letter from 14 citizens of Santiago (Chile 27)
- 1 Jun 1649 49.1, Order of the King (Chile 12,R8,N93,5,1)
- 26 Jan 1650 50.1, Letter from the Town Council (Chile 27)
- 10 Feb 1650 50.2, Letter from the Town Council (Chile 27)
- 4 May 1650 50.3, Letter from the King to the Viceroy of Peru Count of Salvatierra (Chile 12,R1,N15,3,1)

Earthquake of 15 March 1657

- 2 Apr 1657 57.1, Report to the King from Alonso de Solórzano y Velasco; mentions the earthquakes of 1647 and 1657 (Chile 13,R3,N7,1,15)
- 20 Apr 1657 57.2- Letter from the Viceroy of Peru (Lima 59, N39)
- 5 Jun 1657 57.3, Letter from Joan de Huerta (Chile 13, R3,N8,1)
- 10 Mar 1658 58.1, Letter from the Royal Court of Santiago (Chile 13,R3,N22)
- 8 Aug 1659 59.2, Letter from the Royal Court with information about the solicitor of La Merced (Chile 66)
- 10 Aug 1659 59.3, Letter of the attorney of the Royal Court of Santiago (Chile 13,R5,N62)
- 25 Jun 1661 61.1, Letter from Pedro Porter Cassamate, Governor of Chile (Chile 22,R5,N23)
- 14 Aug 1662 62.1, Letter with four signatures (Chile 27)

Earthquake of 8 July 1730

- 20 Aug 1730 30.1, Letter to the King from the Bishop of Concepción (Chile 145.1)

- 27 Oct 1730 30.3, Report on the ruin of the monastery of La Pura y Limpia Concepción (Chile 145.16)
- 6 Nov 1730 30.4, Report on the ruin of the convent of Santiago de la Orden de San Agustín (Chile 145.2)
- 19 Nov 1730 30.5, Letter from the Viceroy of Peru (Chile 145.3)
- 1 Jan 1731 31.1, Report by José Fernández Montero on the damage of the convent of Santa Clara (Chile 145.4)
- 3 Jan 1731 31.2, Letter by Sor María, nun of the convent of Santa Clara to his brother (Chile 145.4)
- 3 Jan 1731 31.3, Letter by the citizens of Concepción of Chile (Chile 145.5)
- 31.4, Letter to the Viceroy of Peru from the Governor of Chile (Chile 145.6)
- 31.5, Letter to the Governor of Chile from the Viceroy of Peru (Chile 145.6)
- 20 Feb 1731 31.7, Letter from the Bishop of Santiago de Chile (Chile 145.7)
- 8 Mar 1731 31.8, Report by Luis Ramírez de Salas, majordomo of the cathedral of Santiago (Chile 145.13)
- 29 Mar 1731 31.9, Report of General Procurator of the Dominican Order of Santiago (Chile 145.8)
- 11 Jul 1731 31.10, Memorandum with a letter from the Viceroy of Peru to José Patiño (Chile 145.3)
- 12 Aug 1731 31.1, Report of Fray Francisco Seco, General Procurator of the Franciscan Order (Chile 145.9)
- 31.12, Royal order and memorandum (Chile 145.9)
- 13 Nov 1732 32.2, Report of the ruin of the Chapel of the Dominican Order (Chile 145.10)
- 17 Nov 1732 32.4, Letter from the Royal Court of Chile (Chile 145.11)
- 19 Nov 1732 32.5, Letter from the Governor of Chile (Chile 145.10)
- 28 Nov 1732 32.6, Report on the ruin of the monastery of the Capuchin nuns of Santiago (Chile 145.11)
- 14 Apr 1733 33.1, Letter from Melchor de Jauregui y Carrera, Vicar of the town of La Serena (Chile 145.12)
- 24 Nov 1733 33.2, Report (Chile 145.15)
- 19 Dec 1733 33.3, Report on the ruin of the cathedral of Santiago (Chile 145.14)
- 22 Dec 1733 33.4, Letter from the Royal Court of Chile (Chile 145.13)
- 20 Apr 1734 34.2, Letter from the Bishop of Santiago (Chile 145.14)
- 3 Mar 1735 35.1, Letter from the Viceroy of Peru (Chile 145.15)
- 23 Apr 1735 35.5, Report on the ruins of the convents of the Order (Chile 145.17)
- 35.6, Report on the ruins of the convents (Chile 145.17)
- 35.7, Report on the ruin of the convents of the Franciscan Order in Chile (Chile 145.18)
- 35.8, Report on the repairs of the convent of the Capuchin nuns (Chile 145.19)
- 27 Apr 1735 35.10, Letter from Fray Francisco Beltrán, provincial minister of the Franciscan Order (Chile 145.17)
- 28 Apr 1735 35.11, Letter from Manuel de Salamanca, president of the Royal Court of Chile (Chile 145.18)
- 35.12, Report on the ruin of the convents of the Franciscan Order in Chile (Chile 145.18)
- 30 Apr 1735 35.13, Letter from the Royal Court of Chile (Chile 145.19)
- 1 May 1735 35.14, Letter from the Royal Court of Chile (Chile 145.20)
- 5 May 1735 35.16, Letter from the Royal Court of Chile (Chile 145.22)
- 6 May 1735 35.17, Report by Fray Francisco Seco, General Procurator of the Franciscan Order (Chile 145.24)
- 11 Dec 1736 36.3, Report on the repair of the convents of the Franciscan Order (Chile 145.28)
- 4 May 1739 39.1, Letter from the president of the Royal Court of Chile (Chile 145.26)
- 22 Sep 1739 39.2, Letter from the Bishop of Santiago (Chile 145.27)
- Earthquake 25 March 1751
- 25 May 1751 51.1, Report by Tomás Carminar (Chile 146.3.2)
- 26 May 1751 51.5, Letter to the Governor of Chile from Francisco de Rivera on the ruin of Concepción (Chile 146.3.2)
- 28 May 1751 51.6, Letter from the Governor of Chile (Chile 146.1.2)
- 28 May 1751 51.8, Report on the ruin of Concepción (Chile 146.3.2)
- 28 May 1751 51.9, Report on the damage of the earthquake (Chile 146.3.2)
- 29 May 1751 51.10, Report on the ruin of Concepción (Chile 146.3.2)
- ? May 1751 51.12, Report on the ruin of Concepción (Chile 146.3.2)
- 4 Jun 1751 51.13, Report of the Royal Court on the actions to take after the earthquake (146.3.2)
- 4 Jun 1751 51.15, Damage in Los Angeles reported by Pablo de la Cruz y Contreras (146.3.2)
- 5 Jun 1751 51.17, Copy of a letter of the *Corregidor* of Concepción (Chile 146.3.2)
- 5 Jun 1751 51.18, Letter from the Royal Court on the aid to Concepción (Chile 146.3.2)

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| <p>5 Jun 1751 51.19, Letter from the Governor of Chile Domingo Ortiz de Rozas on the defense of Concepción (Chile 146.3.2)</p> <p>5 Jun 1751 51.20, Letter to the Town Council on the defense of the forts (Chile 146.3.2)</p> <p>16 Jun 1751 51.23, Agreement on payments (Chile 146.3.2)</p> <p>27 Jun 1751 51.24, Letter from the Viceroy of Peru on the ruin of the Islands of Juan Fernández (Chile 146.3.2)</p> <p>15 Jul 1751 51.25, Letter from the Viceroy of Peru with a copy of the letter of the Governor of Chile on the damage of the earthquake (Chile 146.1.1)</p> <p>20 Jul 1751 51.26, Letter of the City Council of Concepción on the earthquake and tsunami (Chile 146.4.3)</p> <p>9 Aug 1751 51.28, Report on the ruin of the Islands of Juan Fernández (Chile 146.2.2)</p> <p>9 Aug 1751 51.30, Inventory of the arms after the earthquake (Chile 146.3.2)</p> <p>10 Aug 1751 51.31, Report on the ruin of the Islands of Juan Fernández (Chile 146.2.3)</p> <p>11 Aug 1751 51.32- Letter from the Viceroy of Peru on the help sent to the Islands of Juan Fernández (Chile 146.2.1)</p> <p>13 Aug 1751 51.33, Letter from the Royal Court of Peru on the help sent to Chile after the earthquake (Chile 146.3.2)</p> <p>1 Sep 1751 51.34, Letter from the Governor of Chile on the convenience of the relocation of Concepción (Chile 146.3.3)</p> <p>25 Sep 1751 51.35, Report on the agreement of the relocation of the city of Concepción (Chile 146.3.3)</p> <p>9 Oct 1751 51.43, Report on the election of the new location for the city of Concepción (Chile 146.3.3)</p> <p>14 Oct 1751 51.48, Letter on the convenience of the relocation of Concepción to Loma de la Parra (Chile 146.3.5)</p> <p>16 Oct 1751 51.52, Letter from Lucas de Mesa Suelo, Court Official of Concepción, in favor of the relocation to Loma de la Parra (146.3.3)</p> <p>16 Oct 1751 51.53, Letter from José de Saralegui, priest of Concepción, in favor of the relocation to Loma de la Parra (146.3.5)</p> <p>16 Oct 1751 51.54, Letter in favor of the relocation to Loma de la Parra (146.3.5)</p> <p>18 Oct 1751 51.58, Letter from 24 citizens of Concepción on the reasons for the relocation of the city to La Mocha (Chile 146.3.5)</p> <p>5 Nov 1751 51.63, Letter from the Court Officials on the voting about the relocation of Concepción and the diversity of opinions (Chile 146.3.5)</p> <p>3 Dec 1751 51.66, Report by the Governor of Chile about the relocation of Concepción (146.3.4)</p> | <p>20 Dec 1751 51.67, Report by the Governor of Chile about the relocation of Concepción (Chile 146.3.4)</p> <p>No date 51.70, Letter from Manuel de San Cristobal y Riba, Member of the City Council of Concepción, about the selection of Loma de la Parra (Chile 146.3.3)</p> <p>No date 51.71, Letter from Tomás de Rozas, Franciscan Superior, about the selection of La Landa (146.3.3)</p> <p>25 Jan 1752 52.3, Provisions for the new city of Concepción (Chile 146.3.2)</p> <p>31 Jan 1752 52.4, Letter from the Dean and Chapter of the Cathedral of Concepción on the damage of the cathedral and seminary (Chile 146.4.2)</p> <p>2 Feb 1752 52.5, Letter from the Bishop of Concepción de Chile on the damage to the city and its relocation (Chile 146.4.1)</p> <p>3 Feb 1752 52.6, Report on the expenses from the new city of Concepción (Chile 146.3.2)</p> <p>15 Mar 1752 52.12, Report by Juan Baptista de Borda, Royal Notary, on the relocation of Concepción (146.3.4)</p> <p>9 Mar 1753 53.8, Report by the Royal Notary about the documents from Sola y Agüero (Chile 146.5)</p> <p>22 Oct 1753 53.9, Report by Gerónimo Sola and Juan Vázquez Agüero to the Governor of Chile (Chile 146.6.3)</p> <p>24 Sep 1754 54.1, Letter from the Bishop of Concepción, José del Toro, on the inconveniences of the relocation to La Mocha (Chile 146.7.2)</p> <p>16 Oct 1754 54.6, Letter from the Bishop of Concepción to the Governor of Chile on the relocation to La Mocha (Chile 146.7.2)</p> <p>30 Nov 1754 54.8, Letter from the Bishop of Concepción, José del Toro (Chile 146.7.2)</p> <p>14 Dec 1756 56.7, Letter from Dr. Salas, Royal Court Officer (Chile 147.2.3)</p> <p>1 Apr 1758 58.6, Letter from Francisco Javier Barriga (Chile 147.7.4)</p> <p>14 Apr 1758 58.7, Summary of a report by the City Council (Chile 146.10.2)</p> <p>14 Apr 1758 58.8, Royal warrant to the Governor of Chile (Chile 146.10.3)</p> |
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