# STUDIES IN COMPARATIVE SEISMOLOGY

# EARTHQUAKE CONDITIONS IN CHILE

BY

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## TERREMOTO[2] OF NOVEMBER 10, 1922

### IMMEDIATE ANTECEDENTS

While Chile rightly has the reputation as a whole of being an earthquake region, it is nevertheless true that it may be divided into several different earthquake provinces, each of which is distinguished geographically from the others by the occurrence of shocks that are peculiar to it, both as to extent and intensity. The southern portion of the inhabited region, south of latitude 36°, of which Concepcion is the central point, is comparatively free from shocks. Valparaiso and Santiago, in latitude 34°, are central in an area of extreme activity, which extends northward up the coast to about latitude 32°. Copiapo, in latitude 27°, lies in a third province of somewhat more moderate activity; and northern Chile, comprising the district from Antofagasta to Arica, is again relatively inactive. Still further north, in southern Peru, in the vicinity of Arequipa, is the most active earthquake province in all South America.

The terremoto which gave rise to this report occurred in the province of Atacama, in which Copiapo is situated, but its vibrations extended sensibly beyond Concepcion on the south and northward beyond Iquique. It was, therefore, an extremely widespread phenomenon. It is possible that the conditions that led up to it may have been connected with the seismic activity of the entire coast. It is therefore desirable to note the temblors which occurred during the preceding month of October[3].

*October 4* —Temblor in the south. According to advices received yesterday by the State telegraph, a strong earth tremor was felt shortly after noon in the south. It occurred at 12h 12m p.m., with the center in the vicinity of Constitucion, where the quivering of the earth was most intense. The tremor was also felt with force at Parral, Ouirihue, and Empedrado.

*October 11* —Washington, D. C. The seismographs in this capital registered this morning one of the most violent earthquakes of which there is record. The center is estimated to be 3,800 miles south of this city (3,800 miles corresponds to 55 degrees of latitude, and, measuring from Washington, this places the earthquake in latitude 16 south, in southern Peru). The estimate thus agrees with the advices from Peru, which follow.

*October 12* —Lima, Peru. An intense earthquake yesterday shook an extensive zone in the southern part of Peru, occasioning considerable damage in Arequipa and elsewhere. The railroad line between Arequipa and the coast suffered appreciably. Telegraphic communication with the south was interrupted.

October 16 —Lima, Peru. Notices continue to be received regarding the earthquake in the south. The movement was confined to the department of Arequipa; Camana, Caraveli and Arequipa suffering most. In Arequipa certain buildings fell and others were seriously damaged. There were no deaths, but the number of wounded is very large. The material losses are great.

*October 17* —Santiago. In Constitucion, according to telegraphic advices, a strong earth tremor was felt a little after 5h 3m p.m. It extended throughout the department. This shock was not registered by the seismographs in this capital.

*October 22* —Santiago. A strong temblor. In the midst of the play at the theater last evening, at 11h 3m p.m., there was felt a formidable temblor which alarmed the entire population. A panic was produced in the theater, which was fortunately only momentary. When the tremor had passed the play was resumed. Six ladies were assisted from the theater in a swooning condition. At midnight a strong subterranean noise was heard, not accompanied by a sensible movement.

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[2]Terremoto, in the usage prevailing in Chile, signifies a destructive earthquake and contrasts with temblor which is used to designate an earthquake of less severity. Thus the earthquake of November 10, 1922, is called a terremoto in Copiapo, Vallenar, and other places where its effects were disastrous; but it is more appropriately described as a temblor in Valparaiso and Santiago, where the public was startled but no damage was done. We unfortunately have no similarly convenient terms in English; but the words terremoto, earth movement, and temblor, earth quiver, may well be adopted and used with their Chilean signification. That usage is to be understood wherever they appear in this report.

[3]The data here cited are taken from the daily paper, El Mercurio, Santiago.

*October 28* —Concepcion. In the early hours of dawn today people were violently awakened by a terrible temblor which alarmed the entire neighborhood. The movement was of little duration, but of such intensity that if it had been but a few seconds more prolonged Concepcion would probably have been reduced to ruins. The entire population ran into the streets in panic, many without clothing and others half dressed. The outcries of the people and the desperate flight of many, with the noise of falling shelves in stores and of breaking doors and windows, increased the general confusion. Fortunately, when the first moments were passed it was seen that the temblor had not caused the damage which at first was feared, the destruction being confined to the window panes of various galleries and doors, and so forth, and the show cases in the shops.

A short time after the first shock others of much less violence were felt, even though they were accompanied by subterranean noises. A large part of the people passed the night in the streets or in the patios of the houses. It is the general opinion that it is many years since there has been so violent a temblor at Concepcion.

The greatest damage done consists in the cracking of walls of various houses, especially those of stucco and those which were adorned with heavy ornaments. In the jail of the Comissaria, an old building of poor construction, part of the roof of one of the interior wings fell with a wall. There were no personal injuries.

Notices from Tome, Coronel, Lota, Talcahuano, describe a sharp shock but no damage. From Chillian it is reported that at 3h 15m a.m. there was felt an extremely violent temblor which greatly alarmed the people. The oscillations were determined as being from southeast to west, and it is stated as a fact that a long time has elapsed since an earth-shock of equal intensity with that which occurred to-day has been experienced.

*October 31*—Temuco. At 3h 8m on Saturday morning three temblors were felt, which caused no little alarm.

Coigüe. At 3h 15m on Saturday morning there was a severe temblor, which lasted about 15 seconds and alarmed all the neighborhood.

*November 8* —Copiapo. In the late hours of the afternoon, at 6h 30m p.m. today, this city experienced a prolonged temblor, that caused great alarm in the entire population. The movement was relatively gentle but of very great amplitude, so that people rushed into the streets in panic, fearing with good reason that the shock was a recurrence of one of those great earthquakes which have repeatedly devastated this region. Advices from neighboring places indicate the temblor was felt generally, but did no damage.

The preceding notices suffice to demonstrate that there was general activity in the earthquake zone of Chile and southern Peru throughout its entire length, in the autumn of 1922. The terremoto of October 11 at Arequipa, although not very destructive, was apparently severe enough to relieve the strain in that region, for there are no reports of particularly heavy after-shocks. The north-central district of Chile, comprising Copiapo, had no part in the movements until November 8, and appears to have been a locus of gradually increasing strain. In Santiago, in the south-central province, there was a strong temblor on October 22, and the southern province, comprising the area around Concepcion and Constitucion, was the scene of repeated though moderate activity throughout the month of October.

In each of these districts the shocks experienced during these weeks were of unusual severity; that is to say, they exceeded in violence anything within very recent experience; and they may be regarded as representing the culmination of a strain of moderate severity, in all the districts except that of Copiapo. In the latter the strain had attained proportions which could be relieved only by movements of disastrous effect.

In thus considering the terremoto of November 10 as an incident in the general activity of a zone 1,500 miles (2,500 km.) in length, we are linking together local phenomena, each of which no doubt is related to geologic conditions peculiar to the province in which each separate temblor occurred. Because of the disjointed condition of the materials, the rocks, it is impossible that there should be continuity of effect throughout so extended a mass. This is obviously true when we consider the numerous faults and volcanic intrusions by which it is divided into blocks of irregular shape. In the vicinity of Arequipa the mountain trends are northwest and southeast, departing at an angle of 45° or more from the north-south ranges of Chile. Throughout the latter there are many points of division indicated by short

mountain ranges and basins that have the aspect of Basin Range structure. Volcanoes stand aligned along great fractures, several hundred miles in extent. Intrusions of various kinds of igneous rocks, ranging from granite to basalt, form a complex that is extremely heterogeneous in its capacity to transmit pressure or elastic waves; and these rocks are, superficially at least, so crushed that there are but few masses that would yield a respectable building stone.

From these facts it follows that unity or continuity of activity cannot be regarded as a result of continuity of structure throughout this long earthquake region. The superficial facts would, on the contrary, lead us to expect local manifestations of the relief of strain; and yet it is evident from the wide distribution of the shock of November 10 that it was a general, not a local, phenomenon. To be sure, it did not extend to Arequipa; but throughout the north-south range of the Chilean coast, from Iquique to Concepcion, a distance of 1,250 miles (2,000 km.), it was distinctly felt, with intensities represented by V or more of the Rossi-Forel scale. From southeast to northwest the diameter of the isoseismal of intensity IV or more appears to have attained 1,625 miles (2,600 km.), for Buenos Aires reported a strong temblor, and the island of San Felix, situated in the Pacific Ocean, 500 miles (800 km.) west of the Chilean coast, was notably shaken.

The vast extent suggested by these superficial linear dimensions indicates great depth of origin. It will appear in the discussion of the geologic structure of the region of maximum intensity that the pressure to which the earthquake is attributable originated beneath the Pacific Ocean, and that the shock was propagated eastward in the direction of thrust-planes lying at a low angle beneath the Pacific and the Cordillera of the Andes. With this concept in mind, we are in a position to understand how it is that the great terremoto affected the entire earthquake zone, in contrast to the many local temblors which have been recorded as distinct occurrences in separate parts of it. The great earthquake appears to correspond to movement on a very deep-seated, widespreading thrust-fault, while each of the minor occurrences may be regarded as representing the relatively superficial displacement of a segment of the general structure. This view of the relation of the parts to the whole and of the controlling structure was reached only after prolonged study on the ground.

## EXPERIENCES IN THE TERREMOTO

### At Copiapo

On arriving in Copiapo the writer received from Dr. Luis Sierra Vera a very accurate account of the earthquake of November 10, 1922. Dr. Sierra had experienced many earthquakes and some severe ones. He was accustomed to observe them and had formed the habit of promptly noting the times of beginning and passing of the different phases which might occur. His residence was situated in the upper part of Copiapo on the alluvial fan which descends from the high mountains on the east and which is composed chiefly of loose cobbles and sand, but is thoroughly drained. It was compact enough to constitute a fairly good foundation, and houses in that section were not materially damaged when well built, as was Dr. Sierra's. He was reading when the thunder of the approaching earthquake announced it. He rose to his feet, placed his watch on the table, took out his notebook, and wrote "Maximum grade." It was my privilege to see the notes which followed and, lacking the transcript which I had hoped to receive from Dr. Sierra, I quote the record from memory, as follows, in translation:

> Preliminary tremors 1' 30"; violent phase 3' 30" ; diminishing 2'; two very strong shocks 30"; coda 4'. Total duration 11' 30".

Dr. Sierra described the terremoto as one not only of long duration but also of great violence, and this latter impression was confirmed in conversation with other residents of Copiapo who had experienced the earthquake of 1918. Nevertheless, it appears from the studies of tapiales, that is of the walls which were partly overthrown, that the actual acceleration did not exceed four-tenths of the acceleration of gravity and was in general considerably less. That is to say, the shock did not attain the extreme violence reached by some of the most severe earthquakes on record, and was probably comparable with the earthquake of September 1, 1923, in Tokyo. The great damage sustained by the cities in its path was due to its prolonged duration and to the very bad condition of many of the buildings exposed to it.

*Questionnaires*—It being impossible to interview personally any considerable number of individuals in the different towns or throughout the province, a questionnaire was prepared, with the aid of Dr. Sierra, and was officially distributed by the Governor of the Province of Atacama, Dr. Luis Romero. About a thousand were sent out and some three hundred were returned. The information which they contain varies greatly in character, and the labor of digesting the answers to the questions was considerable. We are again indebted to Dr. Sierra for the summary of results given in Appendix II. In the following notes, the data contained in a number of the questionnaires are arranged for the convenience of the reader, somewhat in narrative form, but with strict adherence to the facts as stated by the individual contributors.

### Residents of La Serena

(1) Professor Gustavo Lagos, residing on Calle Infanta, was standing in his house facing north. He heard no premonitory sound. He perceived no other indication of the beginning of the shock than the movement. It came from the north. The hour was 23h 50m by city time. The duration was 3 minutes, more or less. He went out into the patio and observed that the sky was clear, the stars shining; but afterward it clouded over and there was lightning. The movements varied in intensity. They appeared to be in a vertical direction, from below upward. They were all sharp from the very beginning and all of the same kind. There were about three strong following shocks between 12h 30m and 3h a.m. The walls of the house were not cracked, except slightly at the corners. It was built of adobe brick with wood ties and stood on a compact

gravel formation. The roof was of corrugated iron on wood rafters. The furniture was not thrown down, but one vase fell from a table.

(2) Señor Eulijio Robles Rodriguez, Ministro of the Court of Appeals, was in his library and had just risen to his feet, facing east. He afterward did not remember what might have been the first indication of the earthquake, but thought there was a noise. The time was 11h 50m p.m. He did not note the duration. He joined his family and remained a long time in the street with his sons. During the earthquake he observed that the movements diminished toward the middle of the shock, but only to be renewed with the same or even greater rapidity. Following the termination of the principal shock there were two very strong ones and innumerable slighter ones up to 5h a.m., when he went to sleep. He observed very frequent flashes of lightning. It was said by some that they proceeded from contacts of electric wires, but they continued after the light had been cut off. The furniture of his house did not fall over. The house was built of a wood frame with adobe bricks and corrugated iron roof. It stood on compact gravel formation. Vertical and horizontal cracks appeared in some of the walls.

(3) Senor Alfredo Clausen, Defensor Publico de la Serena, was in the street walking westward. He perceived a sound, simultaneous with the first shock. The movements came from every direction. The earthquake was from northwest to southeast. It began more or less exactly at 11h 52m p.m. by the city time and lasted about 4 minutes. He estimated that there were four vibrations per second. The movements varied in character, being rather more brusque than gentle, more rapid than slow. Senor Clausen states that between the dates of November 17, 1922, and March 25, 1923, he published a number of articles on the phenomena of earthquakes and their relations to astronomical conjunctions, sunspots and so forth, combating the popular superstitions. Unfortunately, none of these articles, which appeared in *El Chilena* of La Serena, has been available for examination.

(4) Senor Luis F. Alfaro Varleta, empleado, residing at Calle Domeyko, No. 1, was seated in his house drinking mate (tea). According to his observation the first indication of the earthquake was the sudden shock itself. It came from below, upward, as proved to his satisfaction by the fact that all the water was thrown out of his wash-basin, without the latter being upset. The time was 11h 55m p.m. by his watch and by a clock which stopped at that time. The duration is estimated by some at 6 minutes. During the earthquake he four times went down from the second story, in which he and his family lived, and returned upstairs, to carry them out, and when this was done the earthquake was still continuing. Three shocks at intervals of about a minute were experienced. All of the glassware on the sideboard was thrown down, as well as vases, etc. The movements were long and brusque. The movements appeared the same in each impulse and seemed to last a minute. No damage beyond small cracks was occasioned in his house of adobe brick and wood frame.

(5) Senorita Maria Lidia Pinto P., a teacher, living at Calle Vicuna 114, had retired, but was still awake. She perceived no indication of the earthquake before the occurrence of the shock, which began violently. It appeared to come from the north. The beginning was at 11h 56m by her watch, official time, and the duration approximately 10 minutes, followed at intervals by after-shocks. She ran into the patio and thence to the street, where she stayed to observe the heavens. They were lighted by electric flashes, which crossed each other at every repetition of the shocks. She had observed that the sky was clear at 9h p.m. when she entered her house, but during the earthquake it was covered with clouds. Dishes and glasses fell from the tables, but no furniture was overturned, nor was the house damaged. The character of the shocks, especially at first, was very brusque and prolonged. The succeeding ones were shorter and less violent, but always very sharp. None which occurred that night was gentle. At first they came every 5 or 10 minutes and later every 20 or 30 minutes. The last occurred at 5h a.m. and those which followed during the day were more gentle and farther apart.

(6) A telegrapher, Señor Bernardo Cortes, D., was in the telegraph office in communication with Valparaiso. He was seated facing south. The first shock came from behind him, from the north, at 23h 50m exactly by the office clock. The impulses were violent from the beginning. The first were long, rapid and brusque, while the repetitions were of minor intensity and duration. The successive shocks appeared quite distinct, separated by intervals of a minute. There were two of great violence about 2 minutes apart. The shocks were not preceded by any noise, but accompanying them were sounds such as would be made by a heavy truck. They came from the north and were the same throughout. His house (or office) was built of thick walls of adobe with roof of corrugated iron. It was cracked in straight vertical fissures. Some articles of furniture remained standing, others (mirrors, pictures, lamps and table) were overturned. Senor Costa adds the following observations: During the earthquake he observed a sudden change in the sky, which, having been clear and starlit, became overcast, clouded and lighted by lightning flashes from the north. The clouds drove rapidly toward the northeast. For some days prior to the catastrophe the sea had been very tranquil and at a slightly lower level than usual, so that the subsequent change was even more notable. There was a decided change of temperature during the same day (November 10). During several days previous he noted an uneasiness among animals (steers and cows) in the pastures near his house, particularly at night, a condition which made him cautious.

### Residents of Coquimbo

(1) Senor Eduardo Olivares Quadra, an employee of the post-office, residing in the port of Coquimbo, was standing and at the moment of the shock was reading. He faced north. The first indication of the earthquake was an immense subterranean noise. (Coquimbo is built on a peninsula of solid granite.) The oscillations appeared to be from right to left, as if the shock came from the Cordillera of the Andes. His watch gave the hour as 11h 57m p.m. by telegraph time. The duration was approximately 3 minutes. He aroused and dressed his children. There were two principal shocks at an interval of a minute apart. The first was slow (lento), strong (ipero) and longer; the second was short and sharp. The former he estimated to have lasted 90 seconds and the latter 30 seconds. The sounds accompanying the earthquake had the character of those produced by great rockfalls in a mine. Their direction could not be determined with precision. The house, No. 1411 Calle Aldunate, was built of light materials and stood on rock. It suffered no damage of any consequence. But tables, wardrobe and other articles of furniture were thrown down and overturned from east to west.

Señor Casandra supplies the following notes:

The night of the earthquake was one of great calm. There was only a slight breeze from southwest, with a suffocating heat. The sky was completely covered with clouds. It was about 11h 52m that a terrifying subterranean noise was heard and was followed in a few seconds by the earthquake, which comprised two strong shocks, proceeding from east to west, while the sky was lighted by lightning flashes. About two hours after the earthquake came the maremoto with its three successive waves. The last was the one which did the most damage. It rose to an altitude of 5 meters and attained a distance of 2 km. in the lowest part of the coast. Elsewhere parts of the shore suffered not at all from the wave, indicating that the waters were impelled by strong currents from northwest to southeast. (Coquimbo Bay is a cul-de-sac opening toward the northwest. The wave, passing the wide entrance, was low and did not rise high along the eastern or western shores, but the waters were constricted at the southern end and attained an extreme height of 7 meters above mean level at the railroad wharf—B. W.)

(1) Senor Ivan Franulic, residing at Calle Pratt No. 1274, was standing in his bedroom, awake. He experienced no warning. The shock struck suddenly. He did not observe the direction or the time, but seized his son to escape. He could not open the door. A wall fell, suffocating them with dust. The door opened and he ran out to the street, where it seemed that the earth would open. "The earthquake was strong enough." There were at least 3 shocks in 4 minutes. They were rapid and sharp. In the house pictures fell and furniture slid, but the mirrors did not fall and windows were not broken. Drawers opened or closed according to position. Those facing south remained closed; those facing north flew open.

(2) Senor Lacarias Rojas Veregara, a tailor, was in the Grand Hotel Vallenar. He was lying down but awake, facing north. He first perceived a noise, which appeared to come from the east. On hearing it he jumped for the key of the door and the shock struck. Grabbing his watch from the bureau, he observed the time to be 11h55m p.m. He estimated the duration at 3 minutes. Seeking to escape, he fell in jumping from the veranda and landing on all fours remained in that position till the earthquake was over. There were three shocks, the first from the east, the second from the south, while in the third it appeared that the earth would fly to the sky. The respective durations of the several shocks was 1.5 minutes, 30 seconds, and 1.5 minutes. He could take account of these details, since he had no family in Vallenar. The sound which was like subterranean thunder came from the Cordillera de los Andes, and had lasted 5 seconds when the shock struck. The subterranean sounds continued after the earthquake and resembled waves passing toward the ocean.

(3) Senor Arsenio Tapia Opuso Molina lived at Calle Pratt No. 1728. He was a merchant and agriculturist and was in his house writing. Although lying down he was awake and somewhat nervous. He faced north. He did not observe any preliminary indications, but experienced three shocks which seemed to come from the east. He remained in a doorway until the shocks ceased. It seemed as though the house must fall, to judge by the movements (somajeras?) which shook the timbers. The movements were long, rapid and brusque; each one lasted a minute and followed one upon another. There was a sound like thunder, which seemed to come from the coast. His house of adobe with wood frame was rendered uninhabitable, the walls being cracked and thrown out of plumb.

(4) Senor Guillermo Gray Lopez, of Calle Serrano No. 1357, and engaged in business as insurance and commercial agent, was in his room about to retire. He first heard an exceedingly strong noise, which seemed to come from below. The hour was almost 12. As he ran through the first passageway of his house, which was very narrow, carrying a two-year-old daughter, the eastern wall fell upon him and threw him against the western wall, where he remained buried to the waist. The child was unhurt and was cared for by its mother, who then freed her husband and supported him to the patio. He states that although he was so injured as to be unable to move, he did not lose his sense of direction, in spite of the darkness of the night and the confusion of falling walls. The movements were long, rapid and brusque; they came from every direction, some horizontal, some vertical, and each was of prolonged duration, a minute or more. They were preceded by a very brief interval by a subterranean noise resembling that made by a heavy cart rolling over a pavement. His house stood on loose ground. It was built of adobe and wood frame, with some walls of tabique. Two out of three rooms in the western part remained standing, but ruined. The rest of the house was all thrown down except the party walls of adjoining houses.

(5) Senor Leonio Bardian Ovalle, cashier of the National Bank of Savings, and residing at Calle Pratt No. 1067, was standing at work in his office. He was facing north. He first observed a most powerful noise, followed immediately by the shock. The movement came from left to right, from the ocean toward the Cordillera. The time was 11h 46m by the office clock, which was then stopped. The duration he estimated at 3 or 4 minutes. He ran at all speed to his room, where he remained in the protection of the door of his

room during the entire earthquake. He observed two principal shocks, without any cessation of the vibrations. The movements were all long and brusque. In the stronger ones the ground seemed to jump from above downward, but the dominant movement was from the sea toward the Cordillera. So violent were the oscillations that he was obliged to cling to the door with arms and legs in order not to fall on his face. The building had a front and left lateral wall of tabique (wood frame); while the back and right lateral were of tapiales. The light walls of tabique remained upright, but the tapiales were thrown down and the roof with them.

(6) Senor Agustin Banaza was lying down but awake, when he heard a noise like the tearing of cloth. It appeared to come from above. The shock came from west to east, since the walls of the house fell in that direction. The hour was 11h 55m p.m. He was unable to remain upright and dragged himself out into the hallway. There were three shocks, of which the second appeared the strongest. The movements were prolonged, rapid, and brusque. Each appeared to last a minute. The house consisted of six rooms, of which four were of tabique with adobes, the rest being of adobe walls. The latter fell, but the frame house remained habitable.

(7) Senor Guillermo Gallo, living at Calle Serrano, corner of Talca, an agriculturist, was lying down in his house, awake, reading and facing east to west. He first perceived a great noise and shock, more or less at 11h 50m p.m. The duration he estimates at about 4 minutes. He at once ran to save his sons, and since he was moving about constantly during the earthquake he does not trust himself to give details. But he is sure the shock came from the sea, moving toward the Cordillera. The furniture was thrown down, including sideboard and wardrobes measuring 1 to 1.20 meters by 2 to 2.50 meters. They fell forward from north to south. The house consisted of a wood frame of 4 by 4 inch timbers braced diagonally and filled with small adobe brick. It had no rafters and was not wired. Some of the adobe brick fell out, and the plaster fell. Two rooms were crushed by the fall of the adjoining house, built of tapiales and adobe brick, which was a complete ruin.

(8) Senor Victor Arochas, a traveling salesman, who resided at the Hotel Pardo, was walking in the street. The first shock struck as a single blow from below upward. The time was 11h 53½m and he observed with his watch in hand that it lasted 7 minutes. He struck a light and sought to avoid being knocked down, as the street was very narrow. The shocks were brusque, rapid and distinct, each one lasting 3 seconds, according to his observation. He compares the noise of the earthquake to the breaking of great quantities of glass.

(9) Senor Rector Miranda Alvarez, of Calle Pratt No. 1490, was asleep in his house adjoining his store, it being his habit to retire early, as he is at pains to state. He lay with his head to the sea and feet toward the Cordillera. He is of the opinion that he woke before the earthquake actually began. He observed a brief noise and immediately after it a great movement of the earth, which appeared to come from the sea toward the Cordillera. The furniture was thrown in that direction. He sprang from bed and ran to place himself in the large doorway which opened into the store. After the first shock he sought his brothers and brought them to the same place. But he observed three distinct shocks, with the following details : After the first sound came a sharp movement which was followed by a calm, as if it were finished, but the movement then recommenced with almost greater force than before. The movements were distinct one from another, their direction being unlike. It did not seem possible to estimate the lengths of the shocks, but he would judge that they lasted several seconds.

(10) Senor Eduardo Wolf, a builder, living at Serrano, corner of Colchagua, was asleep in a "chalet" on Calle Serrano, lying with his face toward the east. He first perceived a violent shock. The oscillations appeared to come from all directions. He could not say in what direction the earthquake advanced, other than that it moved from east to west. By his watch it began at 11h 45m p.m., and lasted 5 minutes, more or less. He dressed himself, it being impossible for him to get out in the darkness. His cot having been

overturned, he could not find the door. He repeats that the first shock was long and very violent, the others, which he could not count, were shorter and less violent. Senor Wolf adds the following information regarding the ground under Vallenar, basing his statements on his experience as a builder. Between the plaza and the upper part of the city, as well as between Calle Merced and the river, the formation is gravel, which is on the average 2 meters deep. It rests on clean sand. North of Calle Merced and up to the north embankment (of the terrace) the gravel is but 1 meter deep and rests upon hardpan (or mud?) ("fango"). From the plaza to the station, the hardpan? (fango) is met at shallow depth and consequently there is water at a depth of a meter. All the houses of Vallenar tremble when an automobile or cart passes. He is therefore of the opinion that the subsoil is quicksand or fango throughout.

### Residents of Freirina

(1) The curé of Freirina, Padre Felix Morey Amengual, was in his house, lying down but awake. He faced south. The first indication was a sharp blow like that of a bomb exploded beneath the earth. It came from below upward. Following the first blow there came oscillations of great rapidity, at first from the sea toward the Cordillera (west to east) and afterward from north to south. The hour was 2 minutes before 12 by his watch. The destructive shock lasted half a minute. He was unable to go out by any of the doors and finally escaped by a hole between the roof and the fallen walls. He did not clearly recall the number of shocks, but would say that there were three or four destructive ones and afterward many strong ones which followed each other very rapidly, during the night and following day. The first movements were extremely rapid and brusque. The others were not equally so, but nevertheless were rapid and sharp. He states: "I do not feel able to define the duration of the individual shocks, but in my judgment during the 24 hours following, the earth did not cease to oscillate, although imperceptibly, the heavier shocks succeeding each other at irregular intervals." No sound of any kind accompanied the first shock, which felt like an explosion. The following shocks produced a noise, which was amazing and terrifying. They all came like explosions. His house of tapiales, surmounted by adobe bricks, standing on gravel and boulders, consisted of two wings. The north-south one fell, whereas the east-west one did not. But all the walls were cracked or thrown out of plumb.

### Residents of Huasco

(1) Francisco Quinones Gorman was asleep in his house in Huasco with his face toward the coast. He perceived no preliminary indication of the terremoto, which struck suddenly. It appeared to him to come from northwest, and lasted several minutes. The hour was 11h 55m. He remained in bed, hoping it would pass, but on learning of the rise of the sea he fled. The first shock was long and strong. The succeeding ones were short, but still strong and rapid. They lasted 10 seconds more or less. The sound began simultaneously with the temblor. It sounded like thunder. His house was built on solid rock of wood frame and roof of galvanized iron. A part of the plaster fell. A jar, full of "loza", fell to the floor and rolled about.

(2) Señor Pedro 2d Ruiz was in his house, sleeping with his face to the west. He experienced a strong shock which appeared to come from in front. The terremoto advanced from south and west, to judge by the falling of objects, which was in the opposite direction. The duration was 10 minutes. The hour was 23h 50m, official telegraph time of Vallenar. He gathered his family in the passage of his house, preventing their running out, while he looked for matches, lighted a candle, and they dressed themselves. There appeared to be three principal shocks, at very short intervals, but it shook

continuously. The shocks were long, rapid and brusque, each lasting approximately 3 minutes. Having been asleep, he recognized only the terrible noise that accompanied the terremoto. The articles of furniture overthrown were a center table, wardrobe and "veladores". They fell in part to the north and in part toward the west. This statement applied also to the walls of the enclosure.

### Residents of Caldera

(1) Senor Enrique E. Ramirez, an official, was asleep in his house, facing north. He first perceived a great noise, which appeared to come from in front of him, whereas he states that the earthquake came from the south. The hour was 11h 45m p.m. and the duration was 7 minutes. He ran into the street with his little children. He did not distinguish separate shocks, but observed an equality in noise and vibration throughout. He adds the following information regarding the maremoto: The first rise of the sea occurred about 12h 30m. The greatest wave advanced between 2h and 3m a.m. of November 11. At Ramadas Point the advance amounted to 600 meters and to 125 meters along the harbor front. The customs house, railway station and other buildings were destroyed or moved.

(2) Senor Jorge L. Becerra, Alcaide de Aduana, was asleep in his house facing north. He was awakened by a strong noise, which came from the north, from the right, from below upward in front. The terremoto also appears to him to have come from the north. The hour was 11h 50m according to his watch, which kept good time. The duration he estimates at three-quarters of an hour of constant trembling. He got up and ran to the playa to see the maremoto, which destroyed the customs house and other buildings. (It is difficult to reconcile this apparently immediate action with the times given in the preceding account).

(3) Senor Bernado Tornini, a merchant, was on board the steamer Flora, anchored in the bay. He was sitting in the cabin with friends, looking toward the north. He first heard the sound, which began about 11h 50m. The duration was about 5 minutes. Of the group, which included the captain of the vessel and the harbor master, together with several others, Señor Tornini was the first to give the alarm. They went on to the deck and walked from stern to prow. They observed many lightning flashes, some of which seemed to fall on the poop of the steamer in a terrifying manner. On going ashore they encountered a warm rain, which began to fall about half an hour after the beginning of the terremoto. The sea rose several times, but without surf, and at its greatest advance attained a height of 6 meters above the highest tide.

(4) Senor Guillermo W. Lavan Rives was on board the steamer Flora, anchored in the bay. He was standing facing east. There was a noise which he took to be that of the winches of the steamer. He went ashore, and 15 minutes after the beginning of the terremoto he observed close at hand the initial rise of the maremoto, being at the time in the boat in which they came from the ship. While we were still at a short distance from the passenger pier the sea had begun its first slow rise. When the landing-steps were reached they could not use them, because the boat was on a level with the flooring of the dock. This first rise attained a height of 5 meters, more or less, above high tide. The several advances of the sea which followed were greater than the first, but always gradual. The maximum attained 7 meters above the normal stage and advanced 35 meters more or less, doing much damage. It occurred about 3h 30m a.m.

(5) Senora Ana S. de Baez, Administrador de Correos Telegrafos, was walking in the street and did not perceive any indication before the earthquake, which began at 11h 48m by the official time of the state telegraphs. After the earthquake the sea remained completely tranquil, that is, without waves, but after 30 minutes began to advance. It rose without noise and without surf. Between 12h 30m a.m. of November 11 and 9h a.m. of the same day the sea advanced many times, each advance lasting 20 minutes,

more or less. According to approximate estimates, the greatest advance was 50 meters in the higher parts of the port and 100 meters in the lower part. The level reached by water is estimated at 5 meters above the level of the sea. The greatest occurred between 2h and 4m a.m. These data la Senora Baez submits as in accord with the facts, while admitting that there may be some errors, since it was impossible to observe and estimate in all its magnitude a phenomenon so unfamiliar to the experience of those living on the spot.

### Residents of Chanaral

(1) Senor Guillermo Zepeda was in his house on Calle San Martin, Chañaral, sitting, looking toward the northwest. He observed a subterranean sound accompanied by a sudden, brusque shock. It came from behind him. The oscillations were from the sea toward the Cordillera. The shock began at 11h 50m. It lasted 3 minutes with maximum intensity, and continued during half an hour of minor oscillations. He rose to his feet and would have run, but the movements of the ground made it difficult even to stand. There were about three principal shocks at intervals of 2 minutes. The movements were long, rapid, gentle (suaves) and regular. During and after the terremoto, when the sea rose, people observed a kind of roar in the bay, which led them to think a volcano might be in eruption. The noise of the terremoto began with the first shock and resembled the noise that accompanied the maremoto. Although very much louder, it resembled that of heavy surf. The day following the earthquake it was observed that the sea had withdrawn, leaving a great extent of the playa uncovered.

(2) Senora Maria Isable T. Zeballos, Director of Primary Instruction, was asleep facing the south. The shock itself was the first indication she perceived. It appeared to come from the east, from her left, because on rising to her feet she leaned to that side. The earthquake was not alarming. She partly dressed and went into another room. The maremoto began an hour after the shock and continued about 4 hours. The sea advanced three times. It rose 9 meters, destroyed 14 blocks of houses, and swept 4 blocks inland. The movements were gentle, but prolonged. The sound preceded the shock and resembled that of a heavy cart. She did not notice any variations of the movements.

(3) Senor Oswald Fernie, engineer, though lying down was awake. The first indication was the sound, which came from the south. The terremoto began, more or less, at 12 o'clock and continued 3 minutes. He remained a minute in bed and the rest of the time in his room. He observed the movements to be almost continuous and slow and gentle.

### Residents of Copiapo

(1) Professor Carlos A. Gonzales H., residing at Chañarcillo 1010, was sitting in his house facing northwest. He first perceived a loud noise like thunder from the northwest. He judged, by the direction in which the walls fell, that the earthquake came from the northwest. The hour was 11h 55m by his watch, which he had set that same day with the railroad time. He was unable to estimate the duration. He went out into the street with his family, not running, but pausing long enough to sense the oscillations and seek a safe place. There were three shocks at brief intervals. The first was prolonged, rapid, but gentle; the second was sharp. They were distinct and lasted during minutes.

(2) Señor Luis A. Romo Ch., Intendente of Atacama, was in his bedroom, lying down, but awake. The first indication of the earthquake was a subterranean noise of great intensity. It came from the south and very soon from underneath. The earthquake came from the south, as was demonstrated by telegraphic advices. It occurred at 23h 55m, by a good watch compared with the telegraph time. The duration was about 4 minutes by his watch. He remained

in bed during part of the movement and then went out into the patio and remained standing, holding on to a tree to avoid falling. He observed two shocks, a first and afterward a second, which was more violent and caused him to leave his bed. The movements he describes as prolonged, almost continuous, rapid and brusque. The movement was indeed almost equal. It was an earthquake of great intensity throughout. The sound was heard first. It suggested the rolling of a cart or of many carts of enormous weight, coming from the south; subsequently the shaking and groaning of the structure, as well as of the door and windows did not permit the earthquake sound to be heard. The furniture fell and danced. It comprised wardrobes, stands (estantes), and an iron safe, which measured 70 cm. Most of them fell toward the west. The house was a wood frame with cana de Guayaquil, the roof of wood and galvanized iron. Some of the timbers were broken, the frames were partly wrenched apart, and most of the plaster and ceilings fell. Nearly all of the adobe wall surrounding the inclosure fell.

(3) Señor Federico Melendez M., of Calle Infante 551, was at Calle Rodriquez 440; had just gone to bed and was reading. He faced northwest. The first indications were a noise and small shock which lasted a second. He thought it came from in front; that is, from the northwest. In his haste to save his children he took no note of the direction of the movement or of the time. He put on his trousers and succeeded in finding his shoes, but dropped them to pick up a child asleep near him. Having opened the door, he remained standing in it and did not run out because the child was naked. His wife did not stop for clothes, but gathered up the baby and little boy and ran toward the inner patio. As he sought to follow her the door on the northeast (No. 1) side of the room slammed in his face, while that on the northwest (No. 2) opened. By it he ran into the hallway and so to the street. Señor Melendez gives details of the displacements of furniture as shown here: He thinks that after the first swinging shock there was a single one, whose vibrations were intense and were maintained possibly for 5 minutes. It appeared to him that the movements began from northwest to southeast and afterward developed in all directions, with dominant brusqueness in the initial direction. He observed that the waves were long and well defined, momentarily interrupted or cut off, producing very notable horizontal shocks due to inertia in a northwest to southeast direction. His house stood on comparatively firm ground (compact gravel and cobbles of a coarse alluvial fan) near the base of the mountain (east of the city). It was built of wood frame with cane (cana de Guayaquil). It suffered no other damage than that of cracks above the doors and windows.

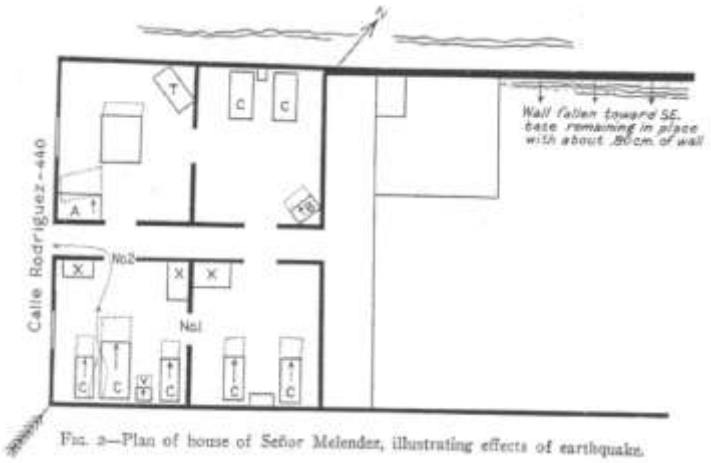


FIG. 2.—Plan of house of Señor Melendez, illustrating effects of earthquake.

Fig. 2 – Plan of house of señor Melendez, illustrating effects of earthquake

(4) Señor Manuel Corona, F., agent of the Sociedad de Minas i Fundacion de Carrizal, was sitting in his house at Calle Infante 1060, facing north,

under an electric light. The earthquake was initiated by a great noise and shock almost simultaneously. He could not state the direction. The hour was 11h 50m, at exactly which time there stopped a large pendulum clock that was kept on railroad time. He did not note the duration, but could estimate that the strong movement lasted 4 minutes. He left his room to go out on to a porch, turning on the electric light, but it was quickly cut off. As the movement continued to increase he ran out toward a tree and held on to it, since he had difficulty in remaining erect. The motion began to decline, but as it still continued he ran into the open toward the hill, but did not go on, as the shocks had greatly diminished. He is unable to describe separate shocks. The movements appeared long and not very brusque. A stand (estante) and bureau were thrown down and nearly all articles were moved out of their places. His house stood on cultivated ground and was of wood frame with cane (cana de Guayaquil). It suffered no damage except loss of plaster and stucco and the breaking of some beams, which were in poor condition.

(5) Señor Luis G. Brand, C., Professor del Liceo de Hombres, was in the Liceo lying down but awake, and facing southeast. He first noticed a strong noise, but did not observe its direction. He judged that the earthquake came from southwest toward northeast by the movement and the noise of the windows. The hour was 23h 46m , by Santiago time. He estimates the duration at 4 minutes. He went out into the patio and there awaited the termination of the shocks. In addition to that which he designates the terremoto itself, he noted a second and a third temblor with intervals of 4 and 2 minutes. The movements were long, rapid, and brusque. The shocks were distinctly separated. He observed the sound which preceded the shock. It resembled that made by a heavy cart. The building stands on firm ground (compact gravel and boulders) and consists of wood frame with cana de Guayaquil. The ceiling was cracked and part of it fell.

(6) Señor Jose Escanriaza, chief of the third telegraph district, was walking in the street facing northwest. He first perceived a loud subterranean noise, followed by a temblor of moderate intensity ("regular intensidad"). It came from the south, according to telegraphic reports from Vallenar. He had no watch at hand. He ran to avoid being crushed by falling walls. There were two shocks, the first of moderate intensity, but increasing in violence almost immediately. The sound resembled that of a heavy cart.

(7) Señor Ladislav A. Arestizabal, an apothecary residing at Calle Carrevas 708, was in his house, asleep. He was awakened by a great movement accompanied by much noise. He is unable to say from what direction it came. The hour was 23h 50m, more or less, and the duration 6 minutes, by his estimate. He started to dress, but to save his child he was obliged to desist. Naked he ran to the balcony and jumped into the street. He received the child from his wife, whom he assisted to descend, and they ran to the plaza for safety. After the first shock, he felt many others, at intervals which he could not estimate. There was a great deal of noise, in part like thunder with detonations. Immediately on going into the street he observed a light in the north, the heavens being rosy. The stars appeared to tremble. The movements which followed the principal shock were of long duration, at least some of them, but of almost uniform intensity, like the swinging of a hammock. The barking of dogs increased the sense of tragedy in the situation. There were times when one sensed only the great noise, without movements that could be perceived without instruments.

(8) Señor Felix P. Olea, an attorney and notary public, living at Atacama No. 545, was seated in his bedroom looking toward the south. He first perceived a noise which appeared to come from in front to the right and from below. The hour was 11h 50m by his watch. The duration he estimates at 6 minutes. Pie jumped to his feet to prevent his wife and child from running out, as he had great confidence in the construction of the house. The movements were many and very continuous. They were long, especially the first, and repeated many times; some were rapid and sharp; some of those which succeeded the first occupied more than half a minute. The sound preceded the first shock by about 10 seconds. It resembled that of an automobile and

appeared to come from the southwest. All of the furniture was overturned in the house, which stood on cemented gravel. It was of wood without plaster, except two interior rooms which had mud roofs; they fell in.

(9) Señor Aristides G. G. Zoraguin, professor in the School of Mines, was sleeping lightly in his house at Avenida Juan Martinez No. 128. The first indication was a noise like distant carts, followed in a few seconds by the movement. It appeared to come from the west, judging by the displacement of the furniture. The piano, wardrobes and other heavy furniture marched from east to west and reached the middle of the rooms. The hour was 11h 47m by railroad time. The duration was perhaps 4 minutes. He remained standing in the middle of the street watching the oscillations of the building from south to north and the wave-like movement of the earth. There were three principal shocks, the last being the most violent. They were rapid and brusque. The house was of wood frame, filled in with small adobe brick. The section which consisted of these materials, with wire inside and out, suffered no damage whatever. The same was true of a part which consisted of a wood frame filled in with brea (brush); but in another part where the walls were filled with adobes, the frames separated at the corners. The suburb in which his house is situated is near the mountain and it is noteworthy that not a single house in it was thrown down, although some of them were of poor construction. Yet they were not damaged in the least.

(10) Señor Oscar Letchier, La., apothecary, living at Calle Atacuna 477, was lying awake in his house, when he perceived a strong shock. It appeared to come from all directions. The hour was 11h 55m more or less. The duration was about 10 minutes, as he would estimate. He carried his youngest son down stairs and returned for his wife and other children, who had remained, as it were, paralyzed. He recognized three shocks, almost without intervals of quiet. The movements were long and rapid, very brusque, unlike any he had previously experienced, and lasted three minutes more or less. The sound began at the same time as the shocks and resembled the discharge of heavy artillery. The noise was so great that his voice, which he describes as somewhat powerful, could not be heard 3 meters away.

(11) Professor Pedro Villagran Arrayo, living at Rodriquez, corner of Vallejo, was standing in his house facing southeast. He first perceived a loud subterranean noise, which came from the southwest. The time was 11h 50m by his watch. The duration was 10 minutes by his estimate. While his wife opened the doors to allow the children to escape to the street, he ran to one who was still sleeping. They then fled to a crossing of two streets, where they remained during the rest of the earthquake. He did not observe the number of shocks. The terremoto began with a rapid movement, which demonstrated the great danger. After about 3 minutes it became very violent and irregular. The earth rocked in every direction. After about 5 minutes it returned to its initial period with regard to the intensity. Very soon after the earthquake began the city lights failed, leaving everything in complete darkness. On entering the street one observed great lightning flashes in the southeast, which illuminated the tragic obscurity. That lasted a few moments. Shortly after the terremoto had ceased the atmosphere began to undergo a complete change. From having been clear it became humid and cold and 2 or 3 hours afterward began to drizzle.

(12) Senor Samuel Jenkins, an agriculturist and miner living at Calle Colipe 475, was lying asleep in his house, when he was roused by a loud and very violent noise. He faced south and it appeared to come from the right, that is from the coast. The hour was 11h 50m p.m. The terremoto lasted during 2 minutes of great violence and 5 minutes of less intensity. He remained in his room. There were two shocks at intervals of a minute, more or less. He noted both horizontal and vertical shocks, in alternation, the same being very hard. The noise at first resembled thunder and then became confused with that of shattering windows and falling roofs.

### Residents of Tierra Amarilla

(1) The Secretario Municipal of Tierra Amarilla, Senor Juan 2d Echeverria, was sitting in his house facing the west and first perceived a great noise, together with a very brusque movement, which came from in front of him. The hour was 11h 55m and the strong movement lasted 2 or 3 minutes. He ran out into the street and went ahead to avoid falling. He and a friend helped each other to stand by holding hands. He estimates the number of shocks at five or six of high intensity at intervals of quarter of an hour apart. They were long, rapid and brusque. The shocks which followed the great temblor were quite distinct from it. The noise at first resembled that of a train. During the succeeding shocks it suggested a heavy cart rolling over hollow ground. Some articles of furniture were thrown down and fell toward the east. The house of wood frame filled in with brush and mud plaster was not cracked. Some cracks appeared in the roof of mud and rushes. Senor Echeverria further observed that the railroad was damaged by the caving of fills. Pendulum clocks were stopped. Pictures and other hanging objects banged against the wall. Windows were broken. There were electric discharges, and in the mines some timbered stopes caved in.

### Residents of Puquios

(1) At Puquios, the most eastern point from which the questionnaire was returned, Señor Arthur C. Cahera, a mining engineer, was sitting in the house of a friend when the terremoto began. It came from the south according to the way it felt. The hour was 11h 55m , official time. The duration was 3 minutes. He took the time. During the movements he went out into the street and took a "pimiento". He felt four shocks separated by distinct intervals, the length of which he did not observe. The movements were long and rapid, not to say brusque. They were distinct and the last was from below upward. Each one lasted 45 seconds by his estimate. A noise began simultaneously with the shock. It resembled surf. It seemed to come from the east. Furniture did not fall over, but was moved out to the middle of the room. The house stood on compact gravel and sand. The house, consisting of wood frame with walls of cana de Guayaquil and adobe, was wrenched at the corners. The wall of adobes surrounding the inclosure was damaged throughout its extent.

### Residents of Salado

(1) At the railroad station Estacion de Salado, situated 35 km. inland from the coast, the station master, Señor Carlos J. Duarte, was in his room lying south to north and awake. He heard a sound like a locomotive approaching rapidly from the west; that is, from the coast. At the same time he seemed to hear the sea breaking close at hand. The hour was 11h 55m by railroad time, and the duration was more than 5 minutes. He observed that the sky was lighted as by the moon for the space of 5 minutes, after which darkness set in again. There were many shocks, which continued until 7h a.m. next day. A sideboard and shelves were overturned toward the west. No damage was done to the station, which was built of wood and roofed with galvanized iron.

### Residents of Potrerillos

(1) Señor Hernando Osandon D., a chemist, was in the mining camp of the Andes Copper Company. He was about to fall asleep, when he experienced a severe earthquake shock. It was 6 minutes before 12 by his watch, which was set by the mining time and presumably by that of the railroad. The terremoto lasted about 5 minutes. Awakened, he lighted a candle, looked at his watch, got up, and opening the window looked out. He then went to bed and followed

the movements of the ground. There were possibly three shocks at equal intervals, but the movement appeared continuous, except that a fresh impulse was given three different times. He states that he did not suppose there was any sound except the earthquake, but what there was resembled the rolling of a heavy cart a long way off. It appeared to come from the east.

(2) Señor Hermogenes Pizarro A., was at Agua Helada, a camp northeast of the mining camp of Potrerillos, about 4,000 meters above sea. This is the highest point and the farthest northeast from which any information has been received. He was asleep facing east and was awakened by the movement of the ground. The shock came from southwest and moved northeast, at 11h 50m p.m. Potrerillos time. He did not observe the duration. He went out and stood on a point of rock nearby. There were two shocks about 20 seconds apart. The second one was much the more intense. Cups fell from the shelves toward the northwest, the shelves themselves extending southeast to northwest. The movements were horizontal from southwest to northeast. They were slow and gentle. The intensity was almost constant during the first 30 seconds and then increased. Each movement lasted about 30 seconds. He did not perceive any sound.

## EFFECTS ON MONUMENTS

In the city of Copiapo there were three monuments which were notably damaged by the terremoto. They all stood on the Alameda, a street running from firm granite down an alluvial cone of coarse cobbles and sand to the river, and consequently differing in the character of the foundation material. The first of the monuments, dedicated to O'Higgins, stood nearest the hill on the firmest ground. It was a marble shaft standing on a pedestal and it remained intact, but was rotated at the joint of the pedestal and shaft through an angle of 3°. The bottom moved from left to right, anti-clockwise with reference to the top section.

The Matti monument, erected in honor of a local citizen, consisted of a bronze statue on a lofty stone pedestal. The statue fell toward the river, because the actual base on which it stood consisted of two stone slabs, and the one on that side gave way when the shock threw the weight of the bronze upon it. The violence of the vibration that enabled the shock to tilt the bronze may be attributed to the character of the soil, which was soft, this statue being nearer the river than either of the other two.

Between the O'Higgins and Matti monuments stood a more pretentious structure dedicated to Atacama. The pedestal was 12.6 feet (3.85 meters) high and was surmounted by a bronze figure 9.5 feet (2.9 meters) tall. The pedestal consisted of several sections. At the base was a wide concrete block representing four steps; it was followed by a segment built up of four tiers of brick, laid in weak mortar; and upon this came a concrete structure, said to be hollow and modeled with appropriate offsets. Between the pedestal proper and the bronze there was interposed a thin concrete slab, which was not seen from below, but which, as it was not fastened in place, formed a loose segment between the pedestal and the statue.

The most obvious effect of the earthquake was to throw the statue in such a way that it came to lie with its foot about 21 feet (6.5 meters) from the center of the monument and its head toward the latter (*e* in Fig. 5). It was evidently thrown with violence and its path was apparently such as would be communicated to it by rotation of the pedestal in a clockwise direction.

The pedestal of the Atacama monument showed abundant effects of rotation. The bricks between the two masses of concrete were crushed, rounded and displaced as if the base had twisted about under the superincumbent weight and the shearing had been concentrated at the weak joint. Upon ascending to the top it was found that the thin slab upon which the statue had stood was twisted about on the next lower section and yet was nearly parallel with the steps of the base. It seemed as though the inertia of the statue had held the thin slab steady while the entire pedestal turned clockwise under it. This movement threw the statue. The slab appears thereafter to have remained fixed on the pedestal which stood still, while the base turned under the brickwork in an anti-clockwise movement. This may have been the case, but it cannot be demonstrated, for the sides of the different sections were not originally parallel and it is impossible to reconstruct their positions before the rotation occurred.

This conclusion follows from the observations of compass courses on the several sections on all four sides, which are given below.

| Section | North side | East side | South side | West side |
|---|---|---|---|---|
| Loose slab . . . . . | N. 26° E. | N.64° W. | N. 25° E. | N.65° W. |
| Top of concrete . . . . | N. 40° E. | N.56° W. | N. 56° E. | N.58° W. |
| Brick section . . . . . | Crushed | | | |
| Top step . . . . . | N. 33° E. | N.64° W. | N. 64° E. | N.58° W. |
| Lowest step . . . . . | N. 38° E. | N.60° W. | N. 60° E. | N.55° W. |

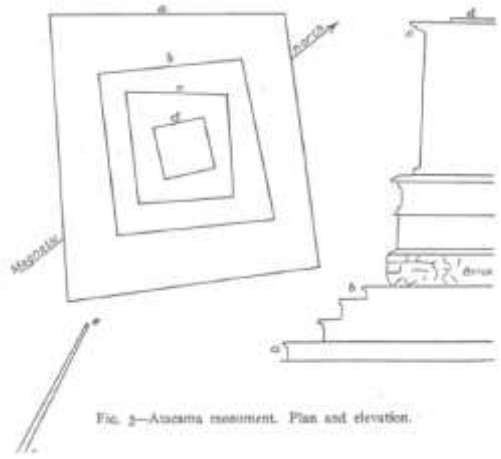


Fig. 3—Atacama monument. Plan and elevation.

Fig. 3 Atacama monument. Plan and elevation.

The above courses are plotted in figure 3 and suffice to show that the Atacama monument when originally constructed had no two sides parallel, nor any right angle. What the original positions were or how much the parts may have rotated with reference to each other is therefore indeterminable. It follows none the less from the throwing of the statue and the crushing of the brick that a rotary movement was communicated to the structure.

## SURFACE EVIDENCES OF FAULTING

Experience in California in tracing active faults leads to the expectation that similar faults in other countries may be identified by fissures, landslides, ponds, and valleys, which range along the outcrop in a line. As has already been stated, the search for such evidences in Atacama was practically vain and the failure to find them led to the conclusion that the mechanism of faulting differed in some important particulars from that which has been recognized in California.

The inquiry for fissures was included in the questionnaire that was widely distributed, and many of the responses cite instances of their occurrence. But in every case it is demonstrated by the evidence of the location or was found on examination that the cracks which were described were produced by superficial landslides and were controlled by the slope of the basement-rock surface beneath the alluvium. The fissures of this type were not connected with earthquake faults.

Two occurrences were found, however, which appear to have had more deep-seated relations. Both occurred near Vallenar, in the region of highest intensity, one being at the mouth of the Quebrada Jilguero, the other in the bluffs of the Arroyo Valparaiso.

### QUEBRADA JILGUERO

The Quebrada Jilguero enters the Rio Huasco about 3 miles (5 km.) east of Vallenar from the northeast. It is characterized by the peculiar feature of a narrow canyon in hard rock, through which the Jilguero runs in the last few hundred yards before joining the main stream. Its valley above the canyon is wider and lies between high banks of gravel. The facts are, perhaps, best explained by considering the Huasco and the lower section of the Jilguero as superimposed on the firm rock by the gravels that formerly filled the entire valley. The streams meandering over the aggraded surface assumed their present courses and were hung up on a spur of hard rock, in which they have cut their actual channels.

The rock on the western side of the Jilguero canyon, which is about 150 feet (45 meters) high, was riven from bottom to top by a movement which is reasonably attributable to the earthquake. It was broken and spalls, which showed fresh fractures, fell from the cliff. The crack itself, however, did not show any displacement. The two sides appeared to fit, practically as before. It was traceable only by freshly broken surfaces and by the opening of old joints, which it traversed. Its strike was north 45° east, magnetic, and the dip was 60° northwest. (See photograph, Plate XXII B.)

### VALPARAISO SLIDE

The Arroyo Valparaiso enters the Huasco about 2 miles (3 km.) east of Vallenar by a valley cut in the gravel formation. The latter is somewhat firmly cemented and stands at a steep angle of rest, but the valley is none the less wider than others like it, and there is a narrow bottom-land along the stream. The bluff on the east rises 165 feet (50 meters) above the brook and in its upper part exhibits a distinct fault scarp, below which there are masses of the gravel that have slid down. (Plates XXII-XXVI.)

The scarp is 42 feet (13 meters) high. It is straight in a north 35° east magnetic direction and dips 75° west toward the valley. In these respects it conforms to what would be expected in an ordinary landslide. But the surface is hard, when scratched with a knife, and exhibits striations that dip 55° from the horizontal, downward toward the north. These details appear to distinguish it as a shearing plane on which there has been compression. If so, it is older than the erosion of the valley, since the shear could not have developed except in a continuous mass of gravels.

The slide below the scarp is a large body of the gravel formation, which shows transverse fractures and displacements in a gravitative direction, downstream. Their positions can best be appreciated by inspection of the photographs. They were fresh fractures and demonstrated notable movements in the recent shock, but the slide as a whole is much older. It originated in some much earlier earthquake and has been repeatedly shaken, as is evident in the contrast of weather slopes and fresh fractures.

The scarp may reasonably be regarded as a fault scarp, the outcrop of a deep-seated compression fault which here traverses the gravel deposits. Definite proof of the extension of the fault plane into the rocks is, however, lacking, as they are not uncovered.

## DISTRIBUTION OF INTENSITIES

It is generally assumed that a study of the apparent intensities of an earthquake shock, as indicated by the degree of damage suffered at various points within the area of vigorous activity, will define a central tract of maximum effect, surrounded by zones of less and less vigorous action, diminishing outward. The central tract is assumed to contain the epicenter. These conditions have not been realized in the investigation of the Atacama shock under discussion. The field observations show that the apparent intensity of the movements was similarly violent at widely separated points and depended in large measure upon local conditions.

Apparent intensity is here distinguished from the actual force with which the earthquake vibrations are transmitted through the outer crust of the earth. The latter passes through the dense and highly elastic rocks where the pressure due to superincumbent load is high. Where the vibrations emerge at the surface of the earth they produce effects which vary greatly, the amplitudes and periods changing according to the resistance offered by the relatively inelastic materials at the very surface. The destructive action on buildings also varies with the nature of the superficial materials that support the foundations. Inasmuch as the observed effects are thus independent to a notable degree of the original force, the apparent intensity deduced from them is not a satisfactory indication of the real intensity. This subject was discussed at length in the report on the earthquake in northern California in 1906[4].

Four facts stand out as controlling conditions which make it impracticable to draw lines of equal intensity, isoseisms, according to the surface evidence: (*a*) The earthquake produced almost no visible effects upon the landscape of the plains and mountains. There is, therefore, no evidence of intensity, not even that there was a shock, except where structures had been built by man. (*b*) The region is so inhospitable that habitations are very sparsely and irregularly scattered over it. The evidence that may be found in their damage or destruction is consequently exceedingly meager, (*c*) Where buildings exist or existed the nature of the foundation was in most cases the controlling factor. Structures built on rock suffered little or no damage. Those on gravel terraces were severely shaken, but often not with destructive violence. Those which stood on river alluvium or other soft material, especially when it was filled with water, were generally wrecked. (*d*) The geologic condition of faulting also determined lines of high intensity, which fixed centers of destructive violence at the points where they crossed the alluvial fills that occupy the valleys. From these considerations it follows that what we may observe on the surface in this and similar cases is the apparent local intensity, a result of several strictly local, unsystematic conditions.

In the course of a journey that covered the area of material damage to structures, the writer observed evidences of very high relative intensity at Vallenar and vicinity, at El Transito on the Huasco, at San Antonio on the upper Copiapo, at Copiapo itself, and at Potrerillos. These places are scattered over a distance from south-by-west to north-by-east of 175 miles (280 km.). The east-west diameter of the area is about 47 miles (75 km.). Within an oval of these dimensions lie the severest effects. But within that same area are villages, built essentially like the others, which suffered little or no damage. Investigation shows that they owe their immunity to the character of the material on which they are built or to the distance that separates them from a fault or to good construction, whereas the examination of the damaged buildings led to the conclusion that the causes of failure were to be found in the weakness of the foundation material or in the proximity of a fault or in the construction of the building or in a combination of all of these conditions.

[4] State Earthquake Investigation commission, Report, vol. I, part I, pp.160-162 and 200, 1908.

A valuable group of data bearing on the local effects of the shock is contained in the answers received from those who experienced it and who courteously sent in answers to the questionnaires which had been distributed. The answers were studied by Dr. Luis Sierra Vera, of Copiapo, an assistant to Count Montessus de Ballore and a seismologist familiar with earthquakes in this region. His digest of the questionnaires will be found in Appendix II. From it we extract the following estimates of intensity at various places. To complete the list some places that are not included among the questionnaires, but which were visited by the writer, are included. They are marked by an asterisk. The data are arranged from south to north by latitude and for each latitude they are stated in the order from east to west.

*Intensities deduced from questionnaires*

| Latitude | Longitude | Place | Intensity, R.F. | Local conditions |
|---|---|---|---|---|
| | ° ′ | | | |
| 27° to 27°50′ . . . | 70 50 | Caldera | VII-VIII | Rocky coast |
| | 71 20 | Copiapo | IX-X | Marshy fil |
| | 70 17 | Tierra Amarilla | | Near fault; river gravels |
| | 70 08 | Tres Puentes | | |
| | 70 05 | Loros | | |
| | 70 03 | San Antonio | X | On fault and marshy fill |
| 28°30′ to 29°00′ . . | 71 15 | Huasco | VII-VIII | Rocky coast |
| | 71 14 | Huasco bajo | IX-X | Marshy fill |
| | 71 07 | Frerina | VIII-IX | On fault; gravel terrace |
| | 70 46 | Vallenar | IX-X | Near faults; marshy fill |
| | 70 16 | El Transito | IX-X | On fault; gravel cone |
| | 70 12 | La Pampa | VIII | Gravel terrace |
| 30° . . . . . | 71 20 | Coquimbo | VII | On fault; rocky coast |
| | 71 14 | La Serena | VII-VIII | Gravel terrace |
| | 70 42 | Vicuña | VIII | Do. |
| | 70 32 | Rivadavia | IX | On fault; gravel terrace |

Examination of the preceding table shows that the maximum apparent intensities were observed in the vicinity of Vallenar (at Vallenar itself, at El Transito east of the city, and at Huasco Bajo west of it). Similar effects were noted at Copiapo, 140 km. north-by-east from Vallenar. The surface materials beneath the two towns are much the same and the apparent intensities may fairly be compared. No material difference can be distinguished. We may conclude that the destructive force was equally violent at these two cities and they were similarly situated with reference to the fault or faults on which it originated.

We may next inquire whether the initial release of elastic strain occurred nearer one or the other place; in other words, where was the focus of the earthquake?

The direction of movement of the longitudinal wave being outward from the focus it affords a means of locating the latter when determinable. In the absence of more exact data we have to fall back on the human testimony, which, unreliable though it is, is significant when a number of observers agree.

From the answers to questionnaires we find that at La Serena four persons recognized the approach of the earthquake from the north, while two observed east-west oscillations. The latter were, presumably, the lateral vibrations that succeed the longitudinal. At Vallenar two persons noted the first shock as coming from the east and two from the west. Another put it down as from the south. Two others perceived it to be from below upward. These last observations suggest that the city was not far from the epicenter and the violence of the movements in the neighborhood would confirm the inference. It happened that on the day following the great earthquake the direction of movement of the after-shocks was noted by telegraphy. Telegraph operators at Vallenar communicating with those at Copiapo wired: “It shakes.” And those

at Copiapo perceived the shock a few seconds later[5]. Thus the testimony adduced indicates that the origin of the shock lay to the north of La Serena, presumably at some considerable distance since the shock was weak at that place, and somewhere on the further side of Vallenar from Copiapo; that is, to the south or southwest of Vallenar. Observations of rock falls in the mountains southwest of the city and the statements of goatherds, whose stone huts were utterly leveled (plate VIII), would suggest that there was a locus of high intensity perhaps 12 miles (20 km.) from the town in that direction.

These deductions from the field evidence do not accord closely with the determinations of origin which have been calculated from seismograms. As is stated in Appendix I, Messrs. Macelwane and Byerly locate it about 85 miles (140 km.) southeast of Vallenar. This is near El Transito, where the shocks were extremely violent. They also cite the calculations of Sieberg and Gutenberg who place it 37 miles (60 km.) northeast of the city in an uninhabited region. It is evident that the approximate assumptions from which the results are determined do not permit of accurate conclusions. The movements of the elastic rockmasses, slipping and snapping back on the fault plane or planes, were exceedingly complex. The assumption that there was some initial point of rupture, which could be taken as the instantaneous focus, appears doubtful in the light of the above cited evidence.

[5]Oral statement of the chief telegrapher at Vallenar

## STUDIES OF TAPIALES

Among the earliest efforts of the writer on arriving in the area shaken by the earthquake was to discover effects from which the intensity of the shock at any particular point might be deduced. The conditions in the towns were most unsatisfactory. The wrecked buildings were of so many different types and conditions, the foundation materials were so unequal in character, the evidences were so confused, that no definite estimates were possible. Nevertheless, the general impression was that the weak structures had failed because they were weak and not because they had been subjected to very violent forces.

In the course of the field work attention was soon riveted by the mud walls, which occur everywhere. They are built by tamping mud into a frame so as to produce a large block, which is called a tapiale, from the Spanish tapar, to tamp or pound down. They are of uniform size, being 1 meter wide, 2 meters long in the direction of the wall, and 0.5 meter thick. They thus offer blocks which have approximately the same resistances to oppose to any force that tends to overthrow them, a condition which, on the average, gives an indication of the relative intensity in different areas. By the application of West's well-known formula one might also arrive at some indication of the acceleration of the force; that is, of the intensity. (Plates XXVII-XXX).

A little study soon showed the necessity of considering some qualifying conditions. A perfect tapiale, being half as thick as it was wide, would be overthrown by a force having an acceleration of 4.8 meters per second per second. But perfect tapiales are rare. Moisture rising from the ground causes the corners to slough off and reduces the width of the base. Similar effects are produced by hand, since it is often convenient to take dirt from a tapiale in cultivating the fields or mending the roads. The value of the tapiale as a seismometer is thus grievously and inconsiderately diminished.

Furthermore, it became evident that an impulse which had not been strong enough to overthrow a tapiale in its first effect had sufficed to break off the corner on which the weight was to a greater or less extent concentrated. The subsequent overthrow might then be the effect of forces distinctly inferior to that which would have been required if the tapiale had been strong enough to bear its own thrust upon the corner.

In addition to these considerations, it was necessary to take account of the long continued action of the earthquake, which could not have failed to produce coincidences between the earthquake vibrations and the oscillations of the walls, and must thus have had excessive effects.

Somewhat careful studies in the area of maximum effects, that is, from Vallenar to Copiapo, resulted in certain general conclusions that remain uncontradicted by other evidence of equal validity and are probably sound, namely:

(1) Some tapiales out of any wall remained standing wherever they were observed. Hence we conclude that nowhere did the acceleration attain the maximum of 4.8 meters per second per second, which must have overthrown them all.

(2) Measurements of a large number of tapiales which had been overthrown showed that their bases varied from 40 to no more than 25 cm. in thickness. The force required to overturn them, therefore, did not surpass 4 meters per second per second, and in the case of the narrower bases need not have exceeded 2.5 meters.

(3) The large proportion of tapiales which had bases near 30 cm. thick and which had been overthrown indicated that an acceleration of 3 meters per second square had generally been attained.

(4) These observations were made, as a rule, upon walls standing upon the widespread gravel fill of the broad valleys or river terraces. The deduction is therefore to be applied only with due consideration of the foundation coefficient characteristic of dry, partly consolidated gravel masses.

To elucidate these general statements, the specific observations are given in the instances described below, and the reader is referred to the photographs of tapiales which illustrate typical conditions.

A field situated about 1 km. southwest of Copiapo was surrounded by walls of tapiales running south 63° west and south 27° east. Large sections of the former were thrown, whereas in the latter only occasional blocks had been overturned. A road ran parallel with the south 63° west course, along the northwest side of the wall, and the tapiales had been undermined on that side by the removal of dirt, as was shown by the hoe-marks on the lower corners of the blocks. They had generally fallen in that direction, i.e., toward the northwest. Some had broken off at the foundations, which consisted of stones placed in two rows, with the outer edge slightly raised, but no wider apart than the width of the wall. Others had broken at the first joint above the base. The wall running at right angles to this one remained standing, almost intact. Its stability may have been due to the proximity of solid rock under the gravel plain, since that side of the field was close to the hills. On the other hand, the directions of the two walls may have been a factor in the difference of effects. The course of the standing wall, south 27° east, made an angle of about 35° with the longitudinal waves of the shock. The course of the overthrown wall, south 63° west, made an angle of about 55° with the same waves. The difference of angle may have been sufficient to give the impulses an effective component in the one case and not in the other. If so, it was the longitudinal, rather than the transverse, waves that overthrew the one wall. The initial impulse advanced from south to north and should have thrown the blocks toward the south. They fell toward the northwest, toward the side on which they were undermined. Hence, the initial impulse did not throw them, but the elastic return did. The destructive component of the force had an acceleration between 3 meters and 4 meters per second per second, according to measurements of the bases of the blocks. The impulse in the direct course may then have approached 5 meters as a maximum, but probably did not exceed 4 meters.

In the vicinity of Vallenar observations were made on many walls of tapiales, and always with the same general results as to the probable intensity of the forces. It is probable that the acceleration reached 4 meters per second per second, and may have exceeded it, but it often was less, the foundation coefficient being a very important factor. Walls of tapiales two blocks high had been built around the railroad yards and also around some inclosures on the larger estancias. They had generally stood fairly well and furnished a check on the lower walls. A good example was photographed at the estancia de Buena Esperanza. (Plate XIV A).

The following is the analysis of the reactions in this case (see figs. 4 and 5):

The dimensions were as given in the figures. Taking the two blocks as a whole, the center of gravity falls at *C* (fig. 4), and the force required to start a turning movement around one corner of the base would have an acceleration of 2.3 meters per second per second. If the two blocks were one, that force would suffice to overthrow them. They were, however, not attached, and the impulse acting upon the lower would cause it to turn, while the upper remained still, in an upright position. The weight of the upper would thus be thrown upon its corner and the center of gravity would be transferred to *C* (fig. 5). The effect is to stabilize the system and to raise the acceleration to 4 meters per second per second, in the case examined, if both blocks are to be overthrown. This rarely happened, and is attributable to special weaknesses where it did occur. When the upper block was thrown, it was obviously due to the to-and-fro oscillations of the lower block, as a result of repeated impulses.

Hence it would appear that the force in this case, as in others similarly studied, probably did not attain an acceleration of 4 meters per second per second, but very probably exceeded 2.3 meters.

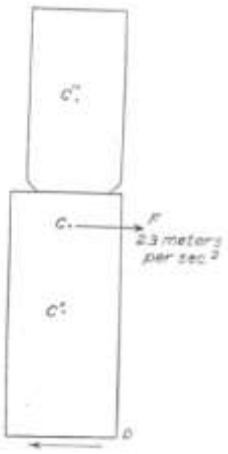



Fig. 4 —Effect of earthquake force on wall consisting of two tapiales. If the two acted as a single body, a force acting at *C* with an acceleration of 2.3 meters per second per second would overthrow the wall.

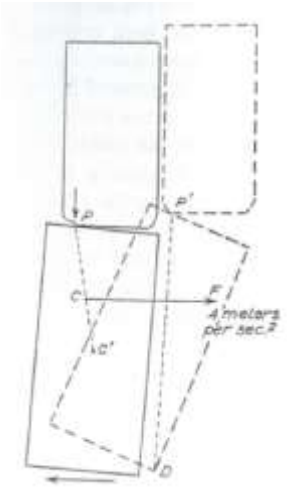



Fig. 5 —If the two tapiales separated, then the initial tilt of the lower would throw the upper on to its corner *P* and a force of 4 meters per second per second applied at *C* would be required to overthrow the wall. The lower block could not be overturned until the line *DP'* passed the vertical.

PLATE LEGENDS

I. Plate I
   A. Copiapo. General view of Copiapo basin and city. Area of greatest destruction lies in distant middle ground to right of church in center of picture. This is the area of marshy formations. There was less destruction in left (eastern) half of city, which is on slope of alluvial cone. Hills in right (western) half of panorama are Paleozoic rocks and belong to Coast range. Those on left (east) are of Mesozoic rock and constitute foothills of the Andes. Paipote at mouth of the Quebrada Paipote, where it joins the Copiapo valley, lies in extreme middle distance.
   B. Coast range between Pueblo Hundido and Chanaral. The dark rocks which form heights of distant hill are Paleozoic slates and schists; light-colored masses are intrusive granite. High ridge in middle foreground shows outcrop of a large dike of black diabase, probably also of Paleozoic age. The view illustrates the characteristic structure of Coast range of Atacama.

II. Plate II
   A. Coquimbo. Looking north across district swept by earthquake wave.
   B. Coquimbo. Looking south to low district, swept by earthquake wave.

III. Plate III
   A. Coquimbo. Effects of earthquake wave in railroad yard; height of wave 26 feet (8 meters), above mean tide.
   B. Coquimbo. View from hill south of bay, looking northwest across flat swept by earthquake wave.

IV. Plate IV
   A. Near Coquimbo. Hut, on coast 16 miles (25 km.) south of city, not damaged by earthquake, showing weakness of shock at this point.
   B. Coquimbo. Jointed Paleozoic granite near northern end of promontory.

V. Plate V
   A. Vallenar. Water forced out of river bed by shaking down of alluvium.
   B. Vallenar. Two-story frame and adobe house standing among ruins of one-story massive adobe houses.

VI. Plate VI
   A. Copiapo. Typical adobe ruin.
   B. Copiapo. Good adobe ruined by heavy mud roof.

VII. Plate VII
   A. Copiapo. Adobe wall of large building intact, tied with timbers; tapiales thrown down. temporary shelter of rushes.
   B. Tatara. Estancia west of Vallenar. near fault line; adobe buildings wrecked.

VIII. Plate VIII

IX. A and B. Vallenar (12.5 miles (20 km.) southwest of). Examples of effect of the earthquake upon massive structures of dry stone walls ; located on gravel plain above fault.

X. Plate IX
   A. Vallenar. Church tower intact.
   B. Vallenar. Walls of church, showing columns and walls of cana de Guayaquil on frame construction.

XI. Plate X
   A. Copiapo Church in Plaza Godoy. Frame structure, interior walls and plaster crushed.
   B. Smelter chimneys at Huasco. Note twisting effect at node of vibration.

XII. Plate XI
   A. Copiapo. Destruction of tombs of massive masonry.

B. Vallenar. Ruins after the removal of the dead and wounded, victims of ignorance and carelessness, who numbered 1,300, nearly one-third of the population.

XIII. Plate XII
A. First class construction of frame and "brea" or brush; to be plastered with mud.
B. Average construction of frame, cana de Guayaquil, and adobe; to be plastered with mud.

XIV. Plate XIII
A. Upper Copiapo valley, San Antonio. Rebuilding a wall of tapiales.
B. Upper Huasco valley, La Pampa. Very old adobe house with mud roof.

XV. Plate XIV
A. Vallenar. Wall of tapiales; two high, partly thrown.
B. Vallenar. Typical ruin of adobe house with heavy mud-covered roof; front wall pushed out by rafters.

XVI. Plate XV
A. Upper Copiapo valley, San Antonio. Looking northwest, showing general destruction of adobe houses.
B. Upper Copiapo valley, San Antonio. Looking southwest, showing general ruin and a new wall of tapiales.

XVII. Plate XVI
A. Upper Copiapo valley, San Antonio. Cemetery walls standing on east, west, and south, on gravel cone inside canyon; white rhyolite dike in Jurassic sandstone.
B. Upper Copiapo valley, San Antonio. View up valley, showing broad, marshy fill on which village stands.

XVIII. Plate XVII
A. Upper Copiapo valley, Potrero Seco. Walls of tapiales thrown down, gate columns standing: typical view of wide canyon.
B. Upper Copiapo valley, at La Sureta. A primitive plough consisting of a tree-trunk and roots.

XIX. Plate XVIII
A. La Pampa on Rio Elqui. Wall thrown and column standing.
B. La Pampa on Rio Elqui. Columns and roof free to sway but not overthrown.

XX. Plate XIX
A. Copiapo. Atacama monument, showing statue thrown 16 feet (5 meters) from its pedestal.
B. Copiapo. Base of Atacama monument, showing detail of brick layer sheared by rotation of upper structure.

XXI. Plate XX
A. Copiapo. Overthrow of Matti monument by failure of pedestal
B. Vicuña. Monument in park, not disturbed

XXII. Plate XXI
A. Vallenar. Rock fall on track up Huasco valley, near Quebrada Jilguero and fault line.
B. Vallenar. Railroad up Huasco valley, showing displacement of track.

XXIII. Plate XXII
A. Vallenar. Quebrada Jilguero, 3 miles (5km.) east; view of cliff at outlet of the quebrada into valley of the rio Huasco, showing earthquake cracks opened in last shock.
B. Vallenar. Quebrada Jilguero, looking through canyon by wich it enters Huasco. On left is cliff which was fractured by earthquake, and in foreground is reinforced concrete bridge that was not injured.

XXIV. Plate XXIII
A. Vallenar. 2 miles (3 kilometers) west of quebrada Valparaiso, general view of big slide.

B. Vallenar. Quebrada Valparaiso, view of quebrada showing position of big slide with reference to terrace level as seen across Huasco valley.

XXV. Plate XXIV

A. Vallenar (2 miles (3 kilometers) west of). Slide in Quebrada Valparaiso, in Pleistocene terrace gravels, looking north.

B. Vallenar. Slide in Quebrada Valparaiso, looking north from near middle of slide.

XXVI. Plate XXV

A. Vallenar. Quebrada Valparaiso, details of big slide showing old mass shaken down in previous earthquakes and view across terraces of Huasco valley.

B. Vallenar. Quebrada Valparaiso, view of old slide, showing breaking down of mass in last earthquake.

XXVII. Plate XXVI

A. Vallenar. Slide in Quebrada Valparaiso; near view of striated surface in Pleistocene gravels.

B. Vallenar. Looking south across Rio Huasco from Quebrada Valparaiso, along fault line.

XXVIII. Plate XXVII

A. Copiapo. Detailed view of tapiale wall, which runs NW.-SE.

B. Copiapo. General view of tapiale wall running NW.-SE. and of distant wall at right angles to it. showing effect of earthquake.

XXIX. Plate XXVIII

A. Copiapo. Field in valley, southwest of city; wall of tapiales extending southwest.

B. Copiapo. Same field as in upper view; wall of tapiales extending southeast.

XXX. Plate XXIX

A. Copiapo valley, above Copiapo near Tierra Amarilla. Showing standing and fallen tapiales; looking south parallel to longitudinal earthquake waves.

B. Copiapo valley, below Copiapo at Ramadillas. Showing wall of tapiales running N.-S. parallel to longitudinal earthquake waves.

XXXI. Plate XXX

A. Vallenar. Wall of tapiales near the city, extending east across the line of longitudinal vibrations.

B. Vallenar. Narrows in the valley of the Rio Huasco caused by a fault-ridge of Paleozoic rocks; looking west, down stream toward the city.

XXXII. Plate XXXI

A. Copiapo. Fruit dish, showing the two hind legs, indicated by white points, on which it danced on sideboard as shown in B.

B. Copiapo. Matta sideboard and fruit dish which made record of gyrations shown in plate XXXII B.

XXXIII. Plate XXXII

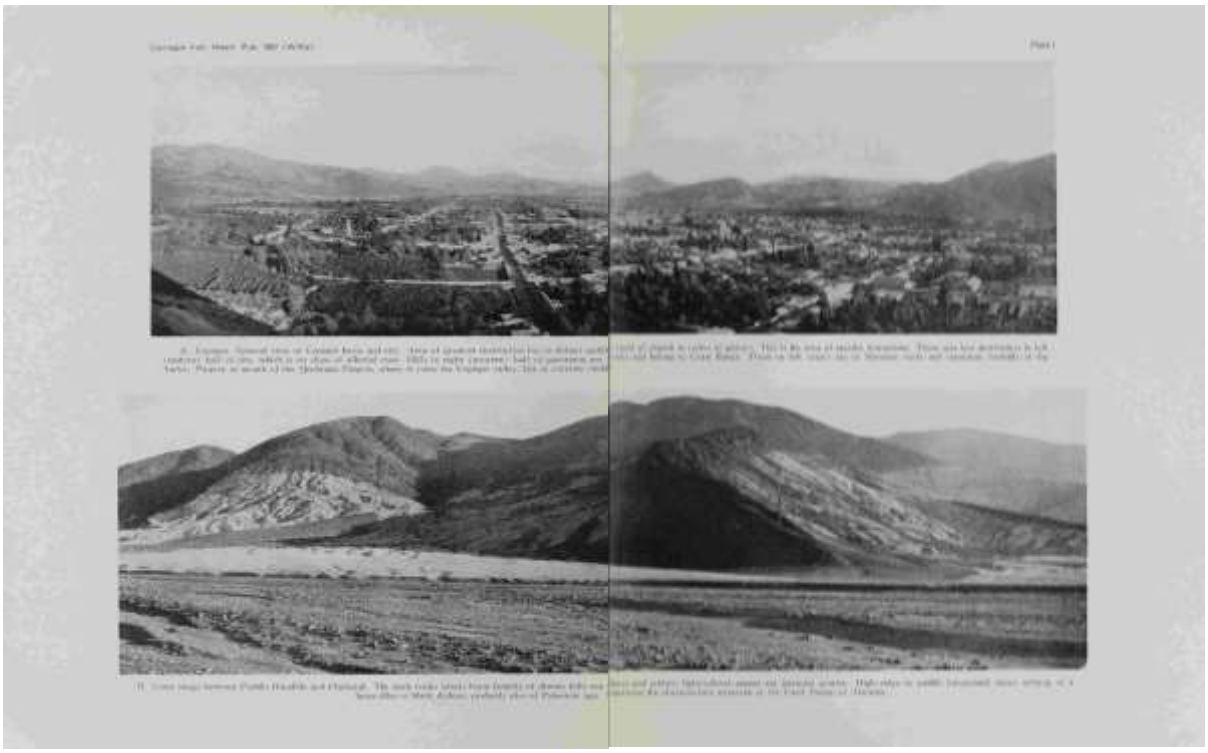
A. Copiapo. Matta sideboard, the fruit dish that danced.

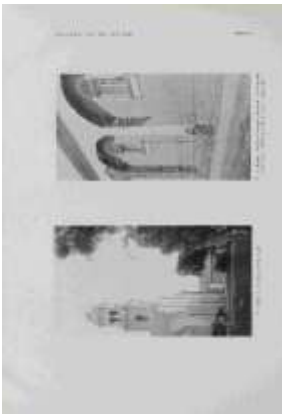
B. Copiapo. Matta sideboard; the record it wrote in zig-zagging on the polished surface and in sliding straight down and off.

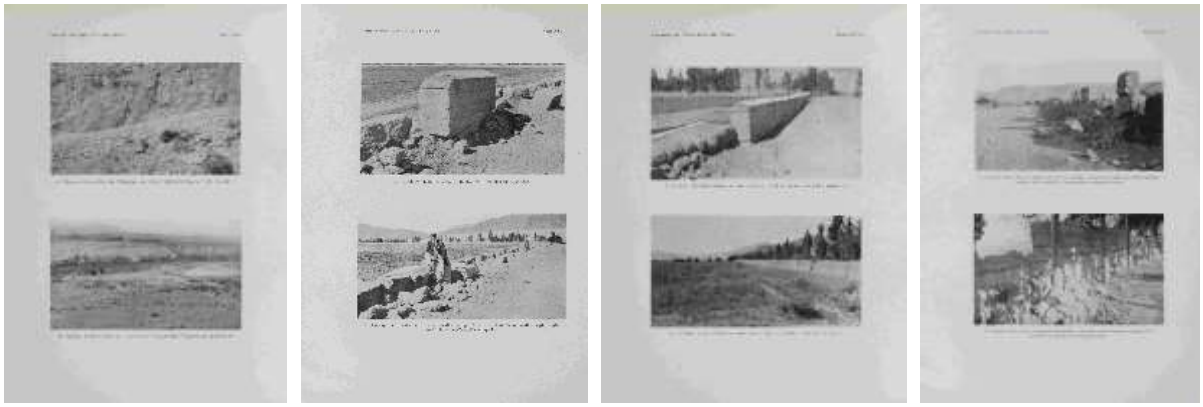
XXXIV. Plate XXXIII

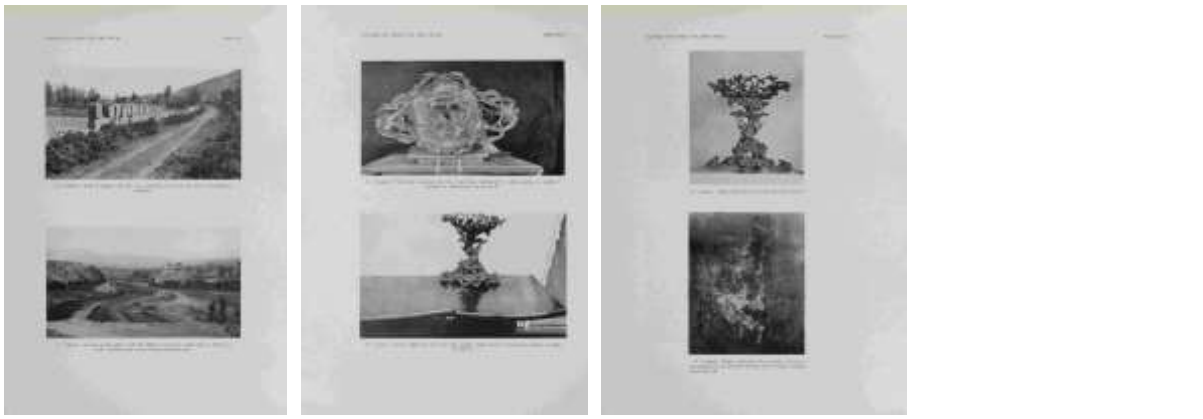
A. Copiapo. Adobe house 70 years old, wrecked by collapse of roof: outer walls suffered but little, being held together by beams of ceiling which may have be seen projecting through. Foundation material is river gravel, but bed-rock lies not far below surface.

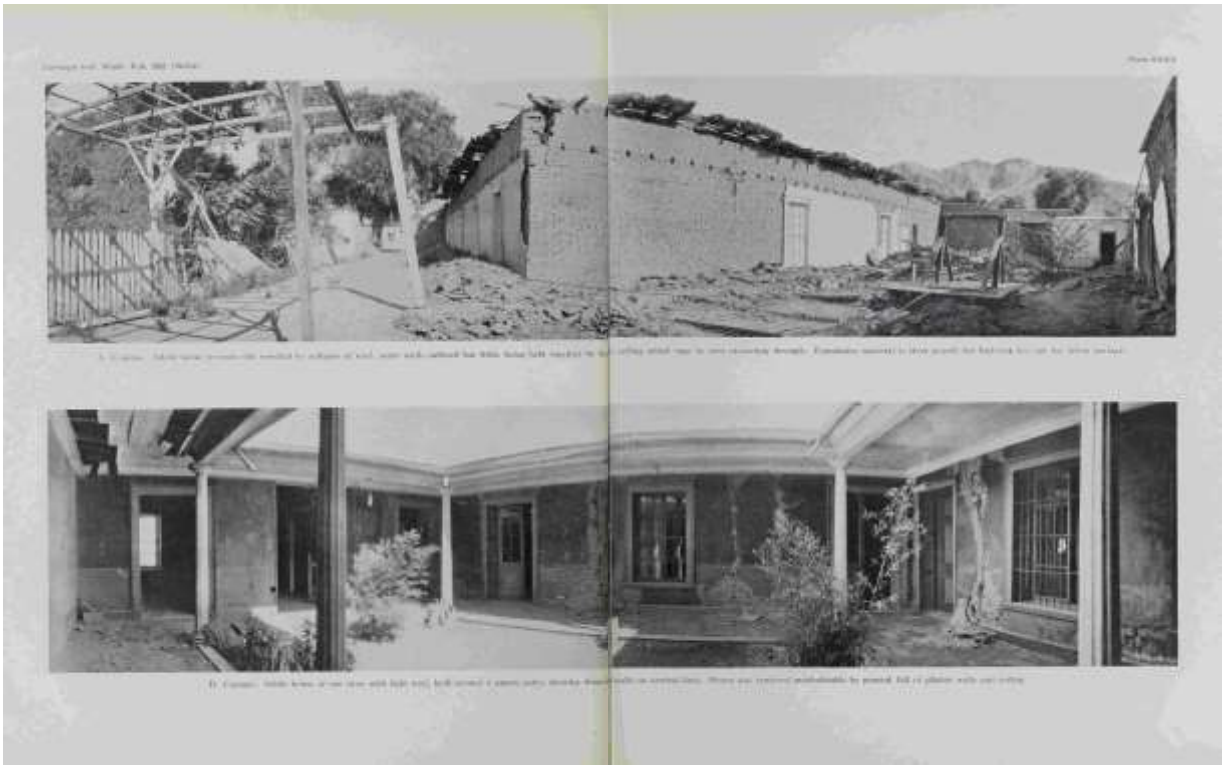
B. Copiapo. Adobe house of one story with light roof, built around a square patio, showing shearings of walls on vertical lines. House was rendered uninhabitable by general fall of plaster walls and ceiling.











APPENDIX I

# REPORT ON SEISMOGRAMS OF THE EARTHQUAKE OF NOVEMBER 10, 1922

BY J. B. MACELWANE, S. J., AND PERRY BYERLY

## THE EPICENTER OF THE EARTHQUAKE AS DETERMINED BY SEISMOGRAPHIC DATA

It may seem superfluous to discuss the seismographic records of the Chilean earthquake of November 10, 1922, in view of the two studies already published by Sieberg and Gutenberg and by the latter alone[6]. However, the authors feel that the more extensive material available to them and their entirely independent analysis of the records and calculation of the epicenter are a sufficient contribution to require publication in this volume if the study of the earthquake is to be complete.

This instrumental part of the report was undertaken at the request of Professor Willis after he had completed his study of the phenomena in the field but before any of his conclusions were available. Most of the labor of preparing it has devolved upon the junior author. The senior author has been able to do little more than suggest and criticise throughout the progress of the work.

For the purpose of the location of the epicenter of the earthquake of November 10, 1922, Professor Bailey Willis has collected from a great number of seismographic stations throughout the world original seismograms of this earthquake, or copies of them. In addition to these there were available reports from certain other stations. These stations are listed in tables on page 139, and in the last column of each table the nature of the data is given: O representing original seismogram; C, copy; and R, report only. A considerable number of additional records were loaned but these were not suitable for the exact determination of times.

When the study was first undertaken it was suggested by Professor Willis that, since the field observations pointed to more than one center of violent intensity, the analysis of the seismograms might also point to this same multiplicity of epicenters. Gutenberg[7] has concluded from the study of the records that perhaps three shocks were registered, of which the second originated at a point west of the first. But impulses which arrive after the beginning of the earthquake and which may be due to later shocks at the source are difficult to identify exactly as to time of arrival since they are confused by the motion due to the earlier shock.

However, the possibility was considered that two shocks from separate foci might have occurred at times so close together that waves from one source would be the first to arrive at stations in one direction while waves from the other source would arrive first at stations in another direction.

In this study there was a lack of seismograms from stations close to the center of disturbance and the location of the epicenter was thus dependent on observations at distant stations. In such a case, the imperfections of the travel time curves for these distances together with the possibility that at some stations one of the early first preliminary waves of Mohorovicic[8] may have been registered, or perhaps the beginning of $P_n$ may have failed to register, cause a considerable discrepancy to enter into the computed

[6] A. Sieberg und B. Gutenberg, Das Erdbeben in der chilenischen Provins Atacama am io November 1922, Ver. der Reichsanstalt fur Erdbebenforschung in Jena, Heft 3, 1924; also B. Gutenberg, Bearbeitung der instrumentellen Aufzeichnungen des Atacamabebens am 10 November, 1922, Nachtrag zu Heft 3.

[7] Gutenberg, loc. cit.

[8] A. Mohorovicic, Rad Jugoslavenske Akademije, 1922.

epicentral distances of the stations. Thus for this earthquake the epicentral distances as computed from the S-P intervals at the various stations fail to reach to a common intersection. The tables given by Gutenburg in Sieberg's " Erdbebenkunde " were used in the investigation.

In the first trials an effort was made to reduce these discrepancies by assuming two epicenters, one near Iquique with a time of occurrence of o = 4 — 32 — 42, and the other near Coquimbo and a time of occurrence about 20 seconds earlier. But this did not offer a satisfactory solution. Nor were other efforts to explain discrepancies of computed distances by multiple epicenters successful.

Finally a group of 26 stations at epicentral distances of less than 100° were chosen since for such distances our travel time tables are less in error. Where possible these stations were selected for the sharpness of the first arrival and the excellence of the time service, but in certain regions all the stations available were used.

The times of the arrival of P at these stations were taken and the probability method of Geiger[9] was applied to compute a most probable position of the epicenter. After two adjustments this resulted in placing the epicenter at $\phi_0$ = 29°00' ± 14' $\lambda_0$ = 69°59' ± 19'; and the time of occurrence at $t_0$ = 4h 32m 33s ± 2s U. T. November 11, 1922.

From the co-ordinates of the various stations and those of the epicenter, the epicentral distance of each station was computed. This distance was then used with Gutenberg's tables and the expected arrival times of P and S were computed.

In table 2 are given for the 26 stations used in locating the epicenter the observed arrival times of P and S together with the differences of the observed and computed values. In table 3 the same data are given for other stations.

It must be remembered that the epicenter of an earthquake as indicated by the records of seismographs points to the region of the beginning of disturbance and does not at all define the extent of the source[10].

[9] L. Geiger, Herdbestimmung bei Erdbeben aus den Ankunftszeiten, Göttingen, 1910.

[10] H. F. Reid, Starting Points of Earthquake Vibrations, Bull. Seis. Soc. America, vol. 8, pp. 79-82, 1918.

*Arrival Times of P and S*

| Station | Δ° | P | O-C | S | O-C | Data |
|---|---|---|---|---|---|---|
| | | *m s* | *s* | *m s* | *s* | |
| Santiago | 4.5 | 33 35 | -8 | 34 24 | | O |
| Villa Ortuzar | 11.3 | 35 21 | +3 | 36 36 | +10 | R |
| La Paz | 12.6 | 35 40 | +5 | | | R |
| Rio de Janeiro | 24.8 | 38 00 | -5 | 42 27 | +4 | O |
| Washington | 68.2 | 43 33 | +1 | 52 30 | -4 | C |
| Georgetown | 68.2 | 43 37 | +5 | | | R |
| St. Louis | 70.2 | 43 45 | +2 | 52 55 | -3 | O |
| Ithaca | 71.7 | 43 53 | -1 | | | C |
| Ann Arbor | 72.4 | 44 04 | +8 | 53 16 | -8 | O |
| Chicago | 72.6 | 44 01 | +3 | 53 09 | -19 | C |
| Good Hope | 73.1 | 44 20 | +19 | 53 42 | +8 | C |
| Northfield | 73.2 | 44 07 | +6 | 53 31 | -3 | O |
| Ottawa | 74.6 | 44 11 | +1 | 53 43 | -8 | C |
| Lick | 82.1 | 44 57 | +5 | 53 03 | -11 | O |
| Berkeley | 82.8 | 44 54 | -2 | 55 21 | 0 | O |
| Lisbon | 88.3 | 45 24 | -4 | 56 32 | +13 | O |
| San Fernando | 88.7 | 45 28 | -2 | 56 36 | +13 | C |
| Malaga | 90.0 | 45 31 | -6 | | | O |
| Victoria | 90.9 | 45 40 | -2 | 56 21? | -22 | O |
| Toledo | 92.1 | 45 49 | 0 | 56 41 | -13 | C |
| Apia | 93.3 | 45 57 | +2 | 57 02 | -3 | O |
| Algiers | 94.9 | 46 03 | 0 | 57 07 | -10 | O |
| Cartuja | 95.5 | 45 46 | -20 | | | C |
| Tortosa | 95.5 | 45 58 | -7 | (57 17) | (-3) | C |
| Barcelona | 96.8 | 46 09 | -3 | | | C |
| Honolulu | 98.6 | 46 39 | +18 | 57 23 | -24 | C |
| Balboa | 39.1 | 40 27 | +11 | | | O |
| Vieques | 47.4 | 41 02? | -16 | | | C |
| Vera Cruz | 54.4 | 42 02 | -4 | 49 39 | -01 | R & C |
| Tacubaya | 56.0 | 42 16 | -03 | 49 50? | -13 | R & C |
| Cambridge | 71.0 | 43 42 | -08 | 52 46 | -26 | O |
| Johannesburg | 84.0 | 45 00 | -3? | 55 33? | -1 | O |
| Spokane | 87.7 | 44 47 | -37 | 55 12 | -61 | O |
| Coimbra | 89.7 | 45 14 | -21 | 56 25 | -7 | O |
| Marseilles | 99.9 | 46 30 | +3 | 57 27 | ?-31 | R & O |
| Oxford | 100.6 | 46 25 | -6 | | | C |
| West Bromwich | 100.7 | 46 23 | -08 | | | C |
| Paris | 101.0 | 46 34 | +01 | | | C |
| Edinburgh | 102.0 | 46 33 | -04 | | | O |
| Uccle | 103.1 | 46 34 | -08 | | | C |
| Zurich | 103.8 | 46 48? | +03 | | | O |
| Rocca di Papa | 103.9 | 46 45 | -01 | | | O |
| Strasbourg | 103.9 | 46 48 | +02 | | | C |
| DeBilt | 104.2 | 46 41 | -06 | | | C |
| Pompeii | 104.6 | 46 19? | -30 | | | O |
| Frankfurt | 105.1 | 46 49 | -02 | | | O |
| Nordlinger | 105.7 | 46 53 | -02 | | | O |
| Munich | 106.0 | 46 50 | -05 | | | O |
| Hamburg | 107.4 | 46 54? | +20 | | | C |
| Vienna | 108.9 | 47 08 | 0 | | | O |
| Batavia | 144.7 | 52 10? | (P′)-12 | | | C |
| Bombay | 144.7 | 49?47 | -5 | | | O |
| Tokyo | 154.1 | 52 33? | (P′)-08 | | | C |
| Osaka | 157.7 | 52 52 | (P′)4 | | | R & C |
| Manila | 162.4 | 52 49 | (P′)-4 | | | C |
| Hong Kong | 172.3 | 52 50 | (P′)-7 | | | C |

# APPENDIX II

## DISTRIBUTION OF INTENSITIES

By DR. LUIS SIERRA VERA

Note. Dr. Luis Sierra of Copiapo, a devoted student inspired by Comte Montessus de Ballore, undertook the labor of analyzing the responses to the questionnaires, which were sent out to secure information regarding the personal experiences and observations of the inhabitants in the shaken region. The three hundred answers have been summarized in an earlier part of this volume (pages 42 to 45), but no attempt was there made to evaluate the intensities at different points. To this task Dr. Sierra brought special experience and knowledge of his countrymen. His digest of the data and his estimates of intensity, expressed in terms of the Rossi-Forel scale, are given in the following tables. The localities are arranged in order of latitudes, from north to south. B. W.

| place | name | hour | Furniture overturned | ground | house | damage | Intensity (Rossi-Forel) |
|---|---|---|---|---|---|---|---|
| El Salado | Carlos Jorquera D. | 11 55 | Sideboard, cabinets, etc. | alluvion | wood with corrugated iron roof | | |
| Chañaral | Raphael Basaure C. | | Nothing fell | slag heap | wood with galvanized iron | none | |
| | Guillermo Zepeda | 11 30 | None | solid | wood with roof of corrugated iron | none | |
| | Maria Toro de Zevallos | | None | beach sand | wood with corrugated iron | none | |
| | Oswald Fernie | | Nothing fell | sand | wood frame with zinc | none | |
| Potrerillos | Luis S. Rojas A. | | Nothing fell | solid | Adobe, wood and zinc | insignificant | 8 |
| | Hermojenes Pizzaro | 11 50 | do. | limey beds | corrugated iron | none | 7 |
| | Enrique Vicuna | 11 55 | pictures, etc | solid | Adobe and wood frame | slight | 8 |
| | Manuel Ossandon | 11 50 | nothing | alluvion | Adobe | only cracks | 8 |
| | Jose Figueroa | 11 55 | Nothing fell | solid | Canvas | none | 7 |
| | Valentin Pena | 11 50 | nothing | wash | Adobe | slight | 8 |
| | Jorje Vallejos Gallo | 11 50 | do. | solid | Adobe and wood | slight | 8 |
| Caldera | Francisco Linandarija | 11 50 | Nothing fell | solid | wood | none | 7 |
| | Enrique Escobar | 11 45 | do. | do | with cane and roof of zinc | none | 7 |
| | Jorge Lado Bercera | 11 50 | none | | cane with mud and zinc | none | 7 |
| | Bernardo Tornini | 11 50 | Nothing fell | rocky | do. | none | 7 |
| | Guillermo W. Lara | 11 55 | none | silt | wood cane and mud | none | 7 |
| | Ana S. de Baez | 11 48 | Nothing fell | solid rock | wood with roof of zinc | none | 7 |
| | Jose Rubio | 11 53 | do. | clayey | tapiales and adobes | Appreciable | 8 |
| | Santiago H. Faull | 11 45 | do. | solid | Adobes cane and wood | slight | 8 |
| Puquios | Arturo A. Cabrera | 11 55 | Nothing fell | Alluvion | wood frame adobe and wood | Appreciable | 8 |
| | Jacinto Herrera A. | 11 55 | tables, wardrobes, etc. | do. | wood frame | do. | 8 |
| | A. Mahuecin Robledo | 11 55 | tables, cabinets, etc. | do. | adobe and wood | Considerable | 9 |
| Copiapo | Carlos A. Gonzales | 11 55 | Sideboards and small table | alluvion | framework with Guayaquil cane | uninhabitable | 10 |
| | Francisco E Yuraszeck G. | | nothing | do. | pine wood | partial destruction | 9 |
| | Ramon Albornoz | 11 48 | everything | do. | Tapiales, adobes, wood, and guayaquil cane | destroyed | 10 |
| | Luis A. Romo Ch. | 11 55 | various furniture | firm | wood with guayaquil cane | heavy damage | 9 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Federico Melendez M | | nothing | do | wood frame | small | 9 |
| | Juan de D. Picon | 11 | 50 | a bureau | alluvion | tapials and adobes | moderate damage | 9 |
| | Alfredo R. Ansieta | 11 | 50 | various furniture | do | walls and wood frame | heavy damage | 9 |
| | Manuel F. Munizaga | 11 | 50 | cabinets and statuary | do | adobes and adobes with wood | do. | 9 |
| | Manuel Corona F. | 11 | 50 | some | do | wood with guayaquil cane | moderate damage | 9 |
| | Ernesto Berg. Floto | 11 | 50 | wardrobe and iron safe | | Tapiales, adobes and wood frame | heavy damage | 9 |
| | Ernesto Pareda L. | 11 | 55 | one table | very alluvial | Tapiales, adobes and wood frame | do. | 9 |
| | Manuel Castillo Z. | 11 | 50 | wardrobes and cabinets | | Frame with brush | uninhabitable | 10 |
| | Jorje Laferriere | 11 | 50 | some | alluvial | Adobes and Tapiales | do. | 10 |
| | Crisologo Cispedes | 11 | 45 | much | sedimentary | wood frame with guayaquil cane | heavy damage | 9 |
| | Jorje Barquin V. | 11 | 45 | some | Alluvion | walls and wood frame | roofs destroyedand base of walls | 9 |
| | Domingo Riveros T. | | | destroyed | do | tapiales and adobes | total destruction | 10 |
| | Ramon Rosas A. | | | nothing | | tapiales | heavy damage | 9 |
| | Luis Gmo. Brand | 11 | 46 | | firm | wood frame | appreciable | 8 |
| | Jose Escauriaza | | | cabinets and shelves | alluvion | wood frame | do. | 8 |
| | Ladislas Agullo | 11 | 50 | part of clothes press. | do | do. | heavy damage | 9 |
| | Margarita, V. De pellegrini | | | all the furniture | do | do. | Appreciable | 8 |
| | Alberto Vallejos C. | 11 | 50 | wardrobes | firm ground | do. | moderate | 8 |
| | Roberto Meeks V. | | | many fell, others not. | soft | do. | Considerable | 9 |
| | Felix Piuciro O. | 11 | 50 | everything fell | wash | Wood frame boards and some adobe | do. | 9 |
| | Horacio Arce B | 11 | 55 | a cabinet | alluvion | wood frame with zinc roof | Appreciable | 8 |
| | Julio A. Bravo | 11 | 50 | | do | wood frame, boards and mud | do. | 8 |
| | Vincente Rogers C. | 11 | 48 | some, such as bookcases | do | wood frame | do. | 8 |
| | Aristides G. Garcia | 11 | 47 | did not fall, but moved toward west | near hill | adobes, wood, and corrugated iron | moderate | 8 |
| | Fabriciano Morales | 11 | 55 | a cabinet | | wood frame | insignificant | 8 |
| | Oscar Letelier | 11 | 55 | wardrobes and shelves | sediment | Adobes, cane, and wood | moderate | 8 |
| | Lidia Richards | 11 | 55 | nothing fell | | Mud | insignificant | 8 |
| | Pedro Villagran | 11 | 50 | cabinets, small tables, wardrobes, etc. | alluvion | Adobes and corrugated iron | Appreciable | 8 |
| | Samuel Jenkins | 11 | 50 | wardrobes | do | Wood and cane | slight | 8 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Francisco Finus | 11 55 | cupboards and tables | | Adobes and wood frame | Appreciable | 8 |
| | Anjel E. Guerra O | 11 53 | wardrobes and cabinets | wash | Tapiales and cane | considerable | 9 |
| | Guillermo Barth C | 11 45 | wardrobes and cabinets | alluvion | Adobes and wood frame | Appreciable | 8 |
| | Ricardo A. Vallejos | 11 55 | bureaus and wardrobes | do | wood frame | do. | 8 |
| | J. Amadio Beluzan | 11 55 | heavy wardrobes | | cane and mud | moderate | 8 |
| | Amalia Julio Vda. De Amor | | many articles of furniture | on solid hill | Adobes and cane | Considerable | 9 |
| | Manuel meneses R | 11 50 | one round table with three legs | alluvion | Adobes wih wood | moderate | 8 |
| Tierra Amarilla | Lorenzo Jofre Flore | 11 55 | wardrobes and ohers | alluvion | Cane with wood and mud | considerable | 9 |
| | Jose Felix Zamorano | 11 54 | shelves etc | do. | wood, brush and roof of zinc | Appreciable | 8 |
| | Juan 2nd Echeverria | 11 55 | a wardrobe | firm | wood frame | moderate | 8 |
| | Pedro Cerda | 11 45 | some fell | alluvion | wood frame with cane | do. | 8 |
| | Carmelo Destefani | 11 45 | buffets, tables, etc. | firm | wood with cane | do. | 8 |
| | Eduardo Thaden | 11 55 | wardrobes, cabinets, etc. | alluvion | cane and mud | Appreciable | 8 |
| | Martin Vitali | 11 45 | tables, chairs, etc. | rock and alluvion | cane, mud and wood | Considerable | 9 |
| Carrizal Bajo | Pedro Cuello | 11 50 | tables, wardrobe, etc. | firm rock | wood, mud and corrugated iron | slight | 8 |
| | Vincente Arredondo | | bookcases with books. | firm | wood | none | 7 |
| | Fernando A. Zadivich | 11 56 | | solid rock | wood and corrugated iron | | |
| | Carlos A. 2nd Echegaray | 11 56 | nothing fell | rocky | wood | none | 7 |
| | Juan A. Contreras | | | solid rock | wood | none | 7 |
| | Tomas C. Tello | 11 55 | none | solid | wood with mud | none in buiding | 7 |
| Huasco | Luis Hurtado V. | 11 55 | all the furniture | | adobes with wood and zinc | Considerable | 9 |
| | J. Manuel Villanueva | 11 50 | nothing fell | alluvion | tiles and adobes with zinc roof | uninhabitable | 10 |
| | Clodomiro Marticorona | 11 55 | nothing | solid | wood frame and zinc | slight | 8 |
| | Pedro Cruz | 11 50 | some boxes | solid | wood and zinc | none | 7 |
| | Antonio Montero | 11 55 | wardrobes, cabinets, tables, etc | solid | wood frame and zinc | Considerable | 9 |
| | Francisco Quinones | 11 55 | | solid | do. | sight | 8 |
| | Pedro 2nd Ruiz | 11 50 | wardrobes, sideboards, tables, etc | alluvion | wood frame with adobes and mud | uninhabitable | 10 |
| Freirina | L. Vega A. | | nothing fell | solid | brush and mud | insignificant | 8 |
| | Braulio Blanco Torres | | cabinets, etc. | gravel | wood frame and corugated iron | moderate | 8 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Felix M. Amengual | 11 58 | nothing fell | solid | tapiales and adobes | Considerable | 9 |
| | Luis A. Roman | 11 54 | cabinets, tables, etc. | do. | adobes wood and zinc | moderate | 8 |
| Vallenar | Silvano Vargas M. | 11 40 | wardrobe, sideboard and shelves | Alluvion | Adobe with woven brush | uninhabitable | 10 |
| | Eduardo Wolf | 11 45 | contents of shelves | of gravel | wood frame with small adobes | moderate | 8 |
| | Ivan Franulie | 11 50 | mostly pictures | Alluvion | Adobe with boards and corrugated iron | heavy damage | 9 |
| | Alejandro Flores | 11 55 | tables, boxes, stands, etc. | do. | Tapiales , adobe and zinc roof | very great | 9 |
| | Zacarias Rocas, G. | 11 55 | various articles of furniture | do. | Adobe, wood and corrugated iron | Considerable | 9 |
| | Custodio Cruz | | everything fell | Coarse stream wash | tapiales and adobes | uninhabitable | 10 |
| | Arsenio Tapia, O. | | pictures and racks | Alluvion | Adob and wood | do. | 10 |
| | Manuel Varela, D. | 11 50 | wardrobe | do. | Tapiales wood and mud | uninhabitable | 10 |
| | Ceferino Tornero | | all furniture | firm | Adobe, wood and zinc | moderate | 8 |
| | Francisco Cantuarias | 11 57 | | Alluvion | tapiales, adobe and wood | Considerable | 9 |
| | Pascual Soler | 11 50 | everything buried | do. | tapiales and adobes | heavy damage | 9 |
| | Ricardo Adriazola | 11 54 | wardrobes and washstands | Coarse stream wash | Walls adobe and wood frame | Considerable | 9 |
| | Hernando Osandon | 11 54 | the furniture did not fall | Made ground | wood frame with galvanised iron | small | 8 |
| | Guillermo Gray, L. | 12 0 | wardrobes, stands, etc. | Alluvion | Tapiales, adobe and wood | very appreciable | 9 |
| | Luis de Block | 11 55 | almost everything | Bed of old river | Adobe walls and zinc roof | walls shook much; roof did not | 9 |
| | Leoncio Bardian | 11 46 | furniture was crushed | Alluvion | Adobe wall, wood frame and wood | uninhabitable | 10 |
| | Delfina P. v. de Femenias | 11 55 | much was demolished | | Adobes and wood frame, roof of boards and zinc | do. | 10 |
| | Erminia C. de Diaz | | all the furniture | Alluvion | wood, zinc, corrugated iron and tapiales | do. | 10 |
| | Elba J. Pinto | | do. | | Tapiales with thatched roof | do. | 10 |
| | Augustin Barraza | 11 55 | sideboard | | wood frame, adobe | only in walls | 8 |
| | Ester Flores de Mery | | nothing fell over | Alluvion | tapiales and adobes with zinc roof | uninhabitable | 10 |
| | Pantaleon Barraza | | do. | Sandy | Adobe and wood | Considerable | 9 |
| | Francisco Diaz | 11 55 | everything fell | Alluvion | Tapiales and wood | uninhabitable | 10 |
| | Hector Mieres, A. | 11 49 | tables, chairs, etc. | Firm | Adobe, wood frame and zinc | do. | 10 |
| | Jose M. Caballero | | wardrobes, pictures, etc. | | Adobe walls, Adobes and wood | moderate | 10 |
| | Rosa, Juleta, J. | | furniture did not fall | | Adobes, wood frame and wood | appreciable | 10 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Transito v. de Ordenes | 11 50 | everything fell | | Mud walls and adobes | uninhabitable | 10 |
| | Abdon Naini | 11 55 | do. | Sandy | Adobes and mud walls | do. | 10 |
| | Abraham Q. Rodriguez | | do. | Alluvion | Adobes | Considerable | 9 |
| | Hernando Mancilla | | | Alluvion | Tapiales and adobes | uninhabitable | 10 |
| | Carlos Aguilar | 11 50 | bookshelves, bureaus, etc. | Earth | Tapiales, adobes and zinc | do. | 10 |
| | Luis A. Hidalgo | 11 55 | everything fell | Alluvion | Tapiales and thatch | do. | 10 |
| | Max Nolff | 11 50 | | do. | Tapiales with zinc roof | do. | 10 |
| | Juan A. Pereira | 11 50 | much fell | | Adobes and wood frame | moderate | 8 |
| | Guillermo Gallo | 11 50 | wardrobes, bookshelves, etc. | Sedimentary | Adobes and wood | Considerable | 9 |
| | Victor Arochas | 11 40 | all the furniture | Alluvion | Wood frame and adobes | do. | 9 |
| | Hector Miranda | | nothing fell from movement | | Tapiales and adobes | do. | 9 |
| | Pablo A. Morales | 11 55 | everything fell | | Adobes, wood frame and zinc | uninhabitable | 10 |
| | Maximo Reygadas | 12 0 | nothing fell | Alluvion | Adobes, tapiales and corrugated iron | Considerable | 9 |
| | Ventura Galan | 11 45 | everything fell | | Tapiales, adobes, wood and corrugated iron | uninhabitable | 10 |
| La Serena | Gustavo Lagos | 11 50 | nothing fell | solid, rocky | Adobe and wood | insignificant | 8 |
| | Jose M Zarate | 11 47 | a mirror | rocky | Adobes and zinc roof | moderate | 8 |
| | Blanc D. de Lazo | 11 50 | nothing | firm | adobes and wooden roof | nothing | 7 |
| | Josias Richards C. | 11 50 | a goblet from the table | firm | Adobes and wood frame | moderate | 8 |
| | Pedro Godoi L. | 12 15 | some pictures | firm | wood frame, adobes and zinc roof | Appreciable | 8 |
| | Maria E. Araya | 12 10 | some small tables | solid | adobes and wood | do. | 8 |
| | Oscar Miranda G. | 11 55 | mostly tables | solid | tapiales, wood and corrugated iron | none | 7 |
| | Antolin Anguita B. | 12 0 | objects from shelves | firm | Adobes and zinc roof | moderate | 8 |
| | Federico Kuhlmann | 11 55 | pedestal with vase | firm | Tapiales, wood frame and galvanized iron | Appreciable | 8 |
| | Eulojio Robles R. | 11 50 | nothing fell | solid | wood and zinc | insignificant | 8 |
| | Alfredo Claussens | 11 52 | do. | | | | |
| | Luis F. Alfaro V. | 11 55 | some furniture | | Tapiales, adobes and wood frame | insignificant | 8 |
| | Maria L. Pinto | 11 56 | no furniture fell | solid | Adobes with zinc | none | 7 |
| | Luis R. Barraza | 11 47 | | rocky | Adobes, wood and zinc | slight | 8 |
| | Oscar Cabezas B. | 11 55 | nothing fell | solid | Adobes | insignificant | 8 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Emilio de la Torre | 11 50 | do. | solid | Adobes and wood | moderate | 8 |
| | Hugo Bravo R. | 11 55 | all the furniture | alluvion | Adobes and wood | heavy damage | 9 |
| | Julio Mantero | 11 55 | nothing fell | firm | Adobes, wood frame and zinc | insignificant | 8 |
| | Rosa Cortez A. | 11 55 | do. | solid | Wood frame and adobes | none | 7 |
| | Bernardo Cortiz D. | 11 50 | tables, pictures, etc | firm | Adobes, wood, and zinc | slight | 8 |
| | Eduardo Olivares C. | 11 57 | wardrobes, sideboards, tables, etc. | solid | light material | do. | 8 |