

SEISMIC HISTORY OF THE SOUTHERN ANDES

BY THE

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(Continued)

1869. November 3.

Arequipa. - Semi-earthquake. (See the first volume).

1870. April 22.

Calama - Earthquake. (See the first volume).

1871. February 23.

Province of Cochabamba. - Earthquake. (See. first vol.)

1871. August 2.

Arequipa - Semi-earthquake. (See the first volume)

1871. October 5.

Province of Tarapacà - Earthquake. (See first vol.)

1876. October 26.

According to Otto Harnecker (Terremotos y temblores. Santiago. 1895) this seismic phenomenon described in the first volume, extended from Arequipa to Cobija and Caracoles, and reached the proportions of an earthquake in Toco, where it almost completely destroyed all the rooms of the saltpeter offices in operation at that time.

EARTHQUAKE AND TSUNAMI OF MAY 9, 1877 IN NORTHERN CHILE AND SOUTHERN PERU

The earthquake of May 9, 1877 and especially the tidal wave that followed have left very bitter memories on the coasts of southern Peru and northern Chile and also in the north of the Atacama Desert. It was felt from the north of Peru to the south of Chile, in Bolivia and in NW Argentina, while it set in motion almost all the liquid mass of the immense Pacific Ocean up to its western coasts and those of California. Its consecutive tremors were numerous and some of them did not fail to keep the people of the affected area in a state of terror.

It is, therefore, a major seismic event.

It gave rise to numerous and extensive reports provided by public officials, especially harbor masters and private individuals, but, unfortunately, few of these reports have a truly scientific character and, for example, it would be totally illusory to discuss the hours to deduce from their critique the exact time of the phenomenon. Moreover, and so it will be seen hereafter, even for the same city, the observations do not cease to differ much from each other.

As for the geological origin of the earthquake, there is no doubt that it was tectonic, due to the considerable extension of its area of destruction, which is exclusively limited to Chile and a small fraction of the Bolivian territory.

But it is impossible to be more precise and the only deduction that can be drawn from the observations with a certain degree of probability, is that this great earthquake occurred along a very extensive line, located in the interior of the continent and somewhat oblique with respect to the Andes mountain range that crossed south of the Tacora. To go further would be to make hypotheses as useless as vain.

The earthquake of August 13, 1868 was born much further north and both earthquakes seem to be related to the angle made by the mountain range at the Tacora junction. It is very probable that this change of direction of the Andes has a deep tectonic cause that worked in very long and very remote geologic times, so that this geographic feature must influence powerfully on the seismic phenomena of the Chilean, Peruvian and Bolivian regions that dominates the Tacora of its enormous mass.

Whatever these general considerations may be, and in spite of the deficiencies and serious discrepancies in the observations, the body of information concerning the earthquake and tsunami of May 9, 1877, does not fail to present a picture of great interest in the history of seismic phenomena in the southern Andes, and for this reason its detailed description is of an importance that cannot be overestimated.

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Observations taken from these documents are indicated by the letters G. (*Geinitz*) H. (*Harnecker*) V. G. (*Vidal Gormaz*) and Z. F. (*Zoilo Flores*).

The comments will be reported and discussed in the following order:

- I. The earthquake.
 1. The pleistosisist area.
 2. Observations made outside the pleistosisist area.
 - a) Observations to the east of the pleistosisist area.
 - b) Observations to the north of the pleistosisist area.
 - c) Observations to the south of the pleistosisist area.
 3. Earthquake aftershocks and accessory phenomena.
 - a) Replicas in the pleistosisist area:
 - b) Aftershocks at points to the north.
 - c) Aftershocks in points south.
 4. Effects of the earthquake on the ground.
- II The tidal wave or tsunami.
 1. Observations made in the pleistosisist area.
 2. Observations made outside the pleistosisist area.
 - a) Observations to the north of the pleistosisist area
 - b) Observations to the south of the pleistosisist area.
 - c). Observations on the western coasts of the Pacific (From New Zealand to Japan).
 - d) Observations made in Oceania

I. THE EARTHQUAKE

1. The pleistosis area.

In order to determine the pleistosis area, we have only vague information about the material damage caused by the earthquake, most of them lacking really concrete details. It will therefore be necessary to be content with vague statements regarding large ruins and with negative data regarding cities in which nothing serious had happened, the latter being by far the most reliable. Thus the limits of the area devastated by the earthquake will be roughly fixed without being able to affirm that it corresponds to the isosis of degree X of the scale of Mercalli; given the very reduced number of victims it is probable on the contrary that the intensity did not pass at any point of degree IX in spite of the supposed disasters that would have suffered such or such populations, whose frightened inhabitants hastened to launch the most exaggerated news.

Chiu-Chiu. According to verbal testimonies that in December 1909 the author was able to collect from some elderly inhabitants, then living in Calama, that village would have been completely ruined. The church tower and several houses were turned upside down to their foundations and if there were no victims, the inhabitants owed it to the long time they had to go outside. Traces of the earthquake are still visible.

This settlement, which was built on a rocky terrain, was completely demolished, leaving its remains as if they had been cut with a chisel. (V. G.)

Despite the fact that Calama is not far from Chiu-Chiu and that it was built on quite shifting and alluvial terrain, it seems to have suffered less if the above-mentioned testimony of the elderly witnesses of the phenomenon is to be believed.

Half of the houses were destroyed, with no personal losses, but the livestock was crushed. The rest of the houses were so badly damaged that only two or three remained habitable.

Almost completely destroyed (G.)

Chacanse (Calama, Chiu-Chiu). Suffered a lot (G.)

On the same meridian as Calama and about 175 kilometers further north, Huatacondo suffered to about the same degree.

The tremor of the night of the 9th lasted two minutes, destroying with its momentum most of the rooms. It was followed by a dreadful darkness caused by the dense dust that rose and the cliffs that with dizzying rushed from the hills to the bottom of the valley... At the hour of the catastrophe two strong detonations were felt on the side of the coast followed, as if produced by the boom of a canon. The oscillation was from NE. to SW. (*La Estrella de Iquique*. VG.)

The information is no more precise for the inland villages located to the north:

Tarapacá and the towns of *Pica*, *Matilla* and *Canchones* were more or less damaged by the earthquake (G.)

Tarapacá. The earthquake caused considerable damage, destroying two thirds of the population. *There were no victims.* (El Porvenir del Callao of 16. V. G.)

La Reforma newspaper estimates the losses caused by the earthquake at 300,000 pesos (V. G.)

From the following text it cannot be deduced whether the disaster in Noria was due to the earthquake or to the ensuing fire.

Noria. This town has been largely destroyed. There was a considerable fire, leaving the machines for making saltpeter, Limeña, Paposo and San Pedro in poor working order. (El Porvenir del Callao of 19. V. G.)

According to the same newspaper Tirana suffered greatly from the earthquake.

San Pedro Saltpeter Office (40 to 50 kilometers SE of Iquique). The catastrophe of May 9 took place at half past eight o'clock and began with two vertical tremors followed by an undulatory movement which, accompanied by strong noise, grew proportionally stronger until the buildings collapsed. It lasted six minutes. Fortunately, there were no victims to lament, but there were some bruises as a result of falling debris and this was due to the slowness with which the phenomenon grew, thus allowing people to flee easily (G.).

This last point cannot therefore be very close to the focus of the seismic phenomenon.

There was no talk of catastrophe in *Chanavaya*.

Tremor at XXII.20. (Civil time). It seems to have come from the coast (G.)

To this news about the effects of the earthquake in the populations located between the mountain range and the sea can be added here those relative to a certain point of the valley of the Loa River, but whose exact position remained unknown to us.

To the east of the mouth of the Loa River there were enormous artificial dams built with large rocks by the ancient Indians to channel the river and use its waters for the irrigation of the valley; but these old and colossal works disappeared completely with the earthquake of May 9, leaving no traces of human labor, forcing the river to change course because of the debris; This leads us to suppose that this region had not experienced a similar cataclysm in the historical epoch of South America, and that the earthquake of May 9 was much greater for the Loa River than any it had experienced for many centuries. (V. G.)

Thus, even if one were to accept the obvious exaggerations in the news reports, the area affected by the seismic disaster, which was not a disaster in the true sense of the word, but one of considerable damage, extended inland from Chiu-Chiu in the south to Tarapacá in the north, that is to say, it covered a meridian length of about 250 kilometers.

As far as its extension along the coastline is concerned, it may have corresponded exactly to the Chiu-Chiu-Tarapacá line, since according to the following news, there would have been great damage in Pisagua, Pabellon de Pica and Cobija. However, nothing serious happened in Iquique and some other ports of the same region, leaving a doubt as to whether the damage in question was not only the result of unfavorable circumstances of the terrain, without the coast itself having been included in the pleistosis area. For these reasons it seems probable that along the coast the pleistosista area did not extend further north than Iquique, where the damages due to the earthquake do not seem to have been very important, but those produced by the tidal wave were.

Iquique. - The strongest tremor ever felt occurred at XX.22, and its duration was the longest ever observed in Peru. It lasted 4'22" without interruption and was so fearful that one could not stand without support. (Dr. Watson G).

The earthquake occurred at about XX,20 (local time), according to unanimous reports. At first the movement seemed to come from the west and then this direction changed during the phenomenon, being the movement already oscillatory, already trepidatory (Report of the Consul of Germany. G).

It was 8 h. 16 m. P. M. The earthquake began with a dull and prolonged noise, which was joined by a strong shaking that increased until it produced a shaking so strong that it was impossible to stand up.

It is estimated that it lasted two minutes, more or less. It was of longer duration than that of August 13, 1868, but not as strong as this one.

At that moment, terror seized everyone's spirits, made more frightening by the cries of "help! fire! the sea is coming out! that women, men and children shouted. It is indescribable what happened at that moment when you could feel the buildings creaking, lamps, glass, bottles and all the glass objects inside the houses swaying from their bases.

They all failed to save themselves, abandoning all they had and leaving their doors open (V. G.).

At 8 h. 18 m. P. M. a dull and formidable subway noise was felt in the direction of S. to N. which was soon followed by a small shaking of the earth in an oscillatory direction. A few seconds later, the earth shook so violently that it was almost impossible to stand upright, declaring a real earthquake whose terrible consequences were not to be expected for a long time.

The movement continued for about 3 minutes, each time with greater force, causing considerable damage to several material buildings, from which some pieces of wall collapsed, as well as immense damage to hotels, grocery stores, china stores, etc., from whose shelves glass bottles and tiles fell, shattering into a thousand pieces.

Falling kerosene lamps caused the fire. (V. G.)

It is very clear that in Iquique the intensity of the earthquake did not exceed grade VII on the Mercalli scale.

From the three pieces of information that follow, it is neither clear nor necessarily clear that the damage produced in Pabellon de Pica, however great it was, was caused solely and exclusively by the earthquake, while, except for the collapse of hills, the latter phenomena undoubtedly played the major role in the work of destruction.

In the night of the 9 of the current, at XX.15, a strong movement of earth was declared in all this coast that lasted consecutively by space of 5 to 6 minutes, increasing gradually of force, and giving by result the almost instantaneous fire of Chanavaya, fire that came to dominate immediately the sea, that invaded by six times the population (Report of the governor of the guaneras of Pabellon de Pica).

The earthquake occurred at about XX.25...33 workers were buried under a landslide of the hills (Report of the governor of the port, G).

Pica Pavilion. - It is completely destroyed. It seems to have been stronger here than at any other point, whence it appears to have been the center. It took place at XX. and lasted 5', during which time more than a dozen fires broke out caused by falling lamps (South Pacific Times G.).

Punta de Lobos. - The tremor was felt at XX.30. (t. medico)

(...id...)

Huanillos. - XX:h. 15' (t. local media) Seemed to come from the interior.

(...id...)

Tocopilla and Cobija. - They said that there were no miners buried in the mines, but possibly three or four victims (V. G-.).

Tocopilla. - A hurried movement of *undulation* and swaying, similar to waves as in the sea; a slow *upward* and *downward* movement, and third a violent shaking. It was as if a great extension of the surface of the sea and its undulations underwent a slow rising and sinking, accompanied by shudders or as if it encountered a resistance to overcome, a resistance similar to that which a thin piece of wood opposes to the friction of the teeth of the saw that cuts it. Applying what has been said to the earth, we assert that it undulated in the general direction of the course of the coast, that moments later it rose and fell, and that in carrying out this vertical movement it shuddered. It seems to us necessary to warn that the perception of these movements was not made at the very moment of the catastrophe, but was suggested to us in great part by observing the effects of the phenomenon... In the works of man the effects are: partial collapse of chimneys of old smelting furnaces; the new ones have remained unharmed.

All the buildings that were saved from the invasion of the sea, because they were built of wood, did not suffer in the earthquake; we only noticed a small detachment between the fixed foundation sill and the rest of the building.

In the interior of the rooms, fragile tools placed in cabinets and boards that were fixed to the east-west walls suffered a great damage. Much less accidents were noticed in the south-north walls...

In our opinion, the duration of the first tremor was two or three minutes... We have not made this assessment with a watch in hand; it is, therefore, only approximate and based on the memories of what we did in that small and terrible lapse of time...

At the time of the catastrophe we felt all the oscillatory movement; it was this that made us sway from one side to the other to maintain the center of gravity... The sifting of sand and dust on the surface of the earth clearly indicate the shuddering movement... (H).

Cobija. - At XX.25 o'clock, on the 9th, a dull noise was felt in the direction of the sea, and instantly an earthquake from the S. O. to the N. E. that deeply moved the whole town of Cobija. The shaking diminished in intensity for about 5", but

increased terribly very soon and with such frightful impetus that many people who were running rolled on the ground, feeling almost all the dizziness precursors of dizziness. The duration of the shaking must have been about two minutes, but there was no one with sufficient serenity of spirit to observe it scrupulously. During this time and in the midst of a complete darkness, produced by a thick dust and the overcast sky.... (Report of a neighbor, communicated to the lieutenant of navy Don Manuel Señoret. V. G.).

The precision of this news proves that the earthquake did not directly produce great damages in Cobija, which the witness would not have failed to describe; therefore, the following must be considered as exaggerated:

Cobija. - More than half of the population was destroyed. The strongest tremor occurred at XX1/2 o'clock and caused great damage (G).

Nothing serious seems to have happened in *Huanillo* either, as can be seen from the following information:

At XX.45, (Callao time) took place in this deposit one of the greatest disasters that are found in the life of the people. A. that hour (of the day 9) shook an earthquake so terrible that it prevented even to be standing. (The governor of the port. *El Porvenir del Callao* of May 16. G.)

From all this it seems that if the earthquake has been destructive in the interior up to the slopes of the mountain range, it did not have the same degree of violence along the coast, or, in other words, the pleistosis area did not reach the shores of the Pacific.

If one is to believe some information that is not very accurate, the western slope of the Cordillera would not have been exempt from considerable damage.

Desaguadero. - (Bolivia. $3216'S$. $69^{\circ}3'W$. Gr.)
The tremor caused the houses to suffer a lot.
Santiago de Anchaca. - ($17^{\circ}2'S$. $69^{\circ}12'W$. Gr.) The earthquake was strong and caused the church to collapse.
Corocoro. - ($17^{\circ}12'S$. $68^{\circ}30'W$. Gr.) The church tower was knocked down by the tremor (V. G.)

The following information must be considered apocryphal:

Tacora. - It was said by information from a muleteer that the tremor caused the colossal mountain of Tacora to collapse (V. G).

Whatever the latter phenomenon, it seems likely that the zone of more or less destruction passed through the Andes and thus the Pleistosis area would have extended obliquely to the Cordillera from Lake Titicaca to Chiu-Chiu, that is, over a longitudinal extension of 650 kilometers.

It has been seen previously that according to all probabilities the pleistosis area was completely included in the mainland, not reaching its limits up to the Pacific coast. However, Milne (The Peruvian earthquake of 9th May 1877, *Trans. seismol. Soc. Japan.* II.11880.50. Tokyo) in calculating by means of four different geometrical methods the geographical coordinates of the center which, in conformity with the ideas of the time, had the seismic phenomenon, found points located in the ocean, the coordinates of the most probable one being: $21^{\circ}22'S$; $71^{\circ}15'W$. Gr., that is, those of a point located about one hundred kilometers west of Pabellon de Pica. If the result thus obtained differs greatly from what seems to be apparent from the observations reported here, even taking into account their deficiency, this discrepancy could well result only from the fact that the famous seismologist could not use but port observations; therefore the longitude is not acceptable, but the latitude is, thanks to this circumstance that the coast of Chile has an almost meridian direction. Thus disappears the apparent disagreement in the calculations of Milne and the pleistosis area, otherwise the earthquake would have had its center to the west of Pabellon de Pica.

Around the pleistosis area, the intensity of the earthquake decreased gradually as the distance from the points where the phenomenon was felt increased, and the observations collected are given below in the order of their increasing distance, dividing them into three series according to whether they are points to the east, north or south of the area in question.

2. Observations made outside the pleistosis area:

a) Observations to the east of the pleistosis area.

Very few observations have been published for points located to the east, i.e. in Bolivia and Argentina.

Regarding the latter country, by means of the still unpublished compilation made by Mr. Davis, Director of the Argentine meteorological office, of the observations made in the meteorological stations of this republic, we only know that the tremor was felt in San Juan and La Rioja. Vidal Gormaz says that it was observed in the northwestern provinces of Argentina.

As for Bolivia and Peru, there are only two pieces of information.

La Paz. - It felt very strong, but did not cause any damage.

Puno. Railroad line and mountain range. - the tremor was felt. (Correspondence addressed to Mr. A. Weiss, Consul in Dresden, Germany).

It is very likely that the phenomenon was felt much farther east of the great Andes Mountains, both in Bolivia and Argentina, but it is not known how far.

b) Observations to the north of the pleistosis area.

In spite of its proximity to the pleistosis area, there does not seem to have been considerable damage in Mejillones to the north by the earthquake itself and since it was not very severe in Iquique, the port of Mejillones and the northernmost points do not belong to the area of greatest violence of the seismic phenomenon. However, it is regrettable that the known observations do not allow to limit with greater precision its limits.

Mejillones del Norte. - XX.15. The earth began to shake and this lasted 5' (Report of Captain F. Medina G.).

XIX (?) 45' Tremor of three tremors, of which the second was the strongest and lasted for one minute (Report of the harbor master. G.)

These reports do not report damages, from which we have the right to deduce that if there were damages in Pisagua, it was due to unfavorable circumstances of the terrain or the corresponding reports have been greatly exaggerated, or, finally, they were caused by the tidal wave.

Pisagua. - The earthquake caused great damage to the railroad and its accessories; but it has not been possible for us to acquire details. It was later learned that the earthquake took place off Pisagua at XX.30, according to the observations of the captain of the steamer "Eten" which was wrecked shortly after on the coast of Aconcagua, and this is the time of greatest credit (V. G.).

XX.20. Undulatory tremor (Report of the harbor master. G.).

There was no damage in Punta Gorda and it may be that the loss of life reported in Cabo Lobos was caused only by the tidal wave.

Punta Gorda. - On board the steamer "Coquimbo", on her voyage from Arica to Pisagua, a sudden and strong shock was felt at XX.31' which lasted 55" (South Pacific Times).

According to the report of the intendant of Atacama, a strong shock of .2'1/2 (G) was felt at the cape itself.

Cape Lobos. - The earthquake and sea movement was terrible, but there was little loss of life (G).

The observations related to Arica do not distinguish between the damage caused by the earthquake or the tidal wave, but from the few details with which they describe the first phenomenon, it must be deduced that only the tidal wave caused considerable losses, and this opinion agrees with verbal

testimonies that the author was able to obtain in 1909 from some former inhabitants of Arica.

Tacna. - The tremor lasted four minutes with a frightful force. The movement was undulatory, from the sea to the land, without any doubt, because, when I was running through the Alameda towards my house (the one occupied today by Mr. Guarachi, in front of the side of the Plaza del Mercado), I saw very clearly the waves from below upwards, that is to say, from the Arica side towards the Tacora.... Two minutes after the first earthquake, the second one took place, although less strong and of less duration than the first one... no house or public building collapsed, except for one or two old walls in the suburbs of the city or in the farms. (Z. F.)

Quake not very strong and without damage (G.)

On the 9th, a little before the sea left Arica, a strong and prolonged tremor was felt in the city of *Tacna*, which fortunately did not cause more damage than a deep alarm in the population, in spite of having the intensity of an earthquake (El Porvenir del Callao, May 19). (V. G.)

Clocks in the NW-SE direction did not stop, but all clocks in other directions did. The hanging lamps oscillated (Report of the German Consul G.).

Ilo. - XX 30 (English Steamship Company time). Undulatory tremor (Report of the harbor master. G.) Strong shaking (G.)

Mollendo. - The tremor was felt at XX.30 and there was an interval of 1'30" between its two tremors (G.).

Mollendo & Islay. - El tremor took place at XX.15 according to the railroad clocks which are regularized every two weeks by means of measurements of the height of the sun (Report of the German Consul G.).

Islay. - Strong shake (G.)

Arequipa. - Beginning of the tremor at XX.19 (chronometer time). It lasted 3'1/2. The movements of the ground were uniform and undulating, without mixing with them strong shocks as in 1868 and for this reason the City did not suffer any damage (Report of the German Consul (G)).

Thus, the city of Arequipa was already far away from the central region, as can be deduced from the nature of the seismic movement.

Tambo de Mora. - El 9, about XXIII.15 (Sic. ?) there was a weak shaking (Report of the port captain G-.).

Quilca. - Strong undulatory tremor at XX.40 (Report of the port captain. G.)

Chala. - XX.40. (Local mean time). A tremor was felt which lasted about 1'1/2 and came from the south. The earth swayed like a hammock (Port Captain G.'s report).

Chinchas Islands. - The tremor was not observed (Report of Captain Port G.).

Pisco. - Very strong shaking because the terrain is alluvial sands. Some damage to houses (G.)

Undoubtedly, this last information must be considered erroneous and exaggerated.

El Callao. - XX.30. Faint tremor. (South Pacific. Times. G.)

El Callao and Lima. - XX.58. The tremor was slightly felt in the form of a slow and prolonged swaying (G.).

Ancon. - At XXI.15, a tremor was felt that lasted 2' and came from the south, while a rumbling sound was heard from the north to the south (Sic.) (G.)

I knew. - The tremor was not felt (G.)

Samanco. - No tremor was noted (G.)

Chimbote. - Earthquake of 20" duration (Port. G. Report).

Santa. - XXI. (Medium weather). Undulatory tremor (Report of the port. G.)

Huanchaco, Pacasmayo, Tumbes. - No tremor was felt. (Report of the ports. G.)

Thus, the northernmost point where the tremor was felt is the port of Santa, whose latitude is 8°58'S.

c. Observations to the south of the pleistosis area.

Mejillones del Sur. - The earthquake happened at XX.15' and lasted 7'. The movement of the earth began with slow undulations that, after 1' were accelerating and changed into a rotating movement. Whoever tried to go to the south, went to the east. After 2' the violence of the movement diminished. The shock was also felt in the sea (G).

Caracoles. - Although the shock lasted 7 to 8', the town suffered little.

According to a report from Mr. C. Baur, the shaking occurred at XX.27' and knocked down all the stoves. The shaking lasted 2'40' and then a gentle, slow movement of the ground was felt for 8'. (G)

It is clear that Caracoles is adjacent to the damaged area, without it having extended as far as Mejillones del Sur.

Antofagasta. - At XX.1/2 o'clock, a very long shock was felt with such strong jolts that people had to find a way to stand up. Its duration was not less than 5'. There was no damage because the houses were made of wood. ("Diario oficial" num. 65. G).

At XX.32', the strongest tremor ever felt on these coasts and of extraordinary violence occurred. The shock lasted 3' with increasing force and 5 according to others. The city suffered little ("El Deber" num. 548).

According to other information the tremor took place at XX.35'. It began gradually and grew in intensity until the houses swayed like trees. No noise preceded the tremor, which may have lasted about 2' 1/2, to 3' at its greatest strength (G).

At XX1/2, the main shock of 3'1/2 duration with a violent oscillating movement. A subterranean noise was noted (Report of the German Consul, Mr. Bischoff).

The earthquake took place at XX o'clock, and lasted about 7' (with a certain discordance in the times that is completely disorienting).

The movement of the earth was at first undulating and slow, accelerating after the first minute, and then acquiring a rotating impulse, to the point of not being able to take a fixed direction; for in trying to go south, it turned to the E. After two minutes of such violent movement, it began to decrease gradually until its termination.

The earthquake itself caused very little damage (the houses are all of wood), throwing all the merchandise, etc., out of the closets; and the kerosene lamps hung or table lamps, went to the floor, immediately causing a voracious fire (V. G).

People who experienced the earthquake on the ground and who were calm enough to notice its effects, have stated afterwards that during the tremor they seemed to be stepping on paper or tin sheets and that the ground was quite hollow. The ground rippled noticeably in a very perceptible manner.

There were people who estimated the duration of the sea tremor at ten minutes, counting the time from its beginning until the end of the ostensible movement (Castillo 2nd commander of the "Blanco Encalada").

At 8 h. 30 m. P. M. of the 9th, the earth began to oscillate, slowly at first and then gradually increasing to the point that the buildings were shaking like a reed; the earth seemed to flee under the plants and the creaking of the timbers; the ringing of the bells and the cries and cries and prayers of those who begged for mercy, terrified and made one lose one's senses.

The earthquake was not preceded by any precursor subway noise, as is usually the case, the oscillation was sudden and apparently from north to south.

In the warehouses and houses there was not a bottle, a jug, nothing left in any cupboard; everything went to the ground shattering to pieces.

According to the calculations of people who kept a bit of cold blood, the earthquake lasted from 2.5 to 3' in full force (Communication from don Ramon Arancibia 2nd V. G).

Thus, in Antofagasta the buildings did not suffer in any way, nor were there any personal losses, but there were material losses resulting from the fall of shelves in the warehouses. The tremor was felt on board ships that were anchored in the port and were sailing at a certain distance.

On board the steamer "Eten", at anchor at Antofagasta, XX.15', a strong tremor was felt which rocked the steamer for 2' (South Pacific Times G.).

On board the steamer "John Elden", 23°43'S, 70°47'W Gr. 23 miles west of Antofagasta, on voyage from Valparaiso to Callao. The sea was calm as a lake when suddenly and without the slightest warning there was a general alarm in consequence of a very strong shaking and vibration felt from stem to stern. Soundings found no bottom at 20 fathoms. Although the steamer was running at full speed, she was stopped for 4 or 5' by the shock.

The latter information must be considered apocryphal.

The impression experienced on board the armored ship "Blanco Encalada", then stationed in Antofagasta, was one of oscillation from stern to bow, with the ship's bow to the north (Captain Castillo, second in command V.G.).

The Paposo. - The tremor was felt at 8 h. 20 m. P. M., estimating its duration in 5 minutes. The direction of the movement was from N E to S O. The tremor began without noise and slightly, increasing little by little until, at last, there was a moment in which the shaking of the earth was so strong that it was almost impossible to stand up. The impression that it caused, in the population was terrible, as it is easy to suppose, thinking all to flee to the hill for fear of the exit of the sea; but fortunately there were no misfortunes to lament.

The buildings are made of wood, so they suffered very little; but not so the enclosures and divisions of the field, which were made of stone, which were torn and demolished almost entirely (Report of the maritime subdelegate V. G.).

The phenomenon was felt in the ocean about 100 miles west of Taltal.

The Chilean ship "Maria Luisa", which was at sea, 100 miles from the coast and on the parallel of Taltal, 25°24' S. latitude, experienced the earthquake at 8:30 P. M. on May 9. P. M. on May 9; calculating its duration in 5 minutes. No current was perceived (V. G.).

Chañaral de las Animas. - The tremor was felt very strong and of long duration (V. G.).

XV h.3/4. Strong tremor that lasted 2'. Caused the lamps placed on the tables to jump and would have fallen if they had not been held. Lasted Well 1'45' (report of Mr. Waltenrath to the *Weserzeitung*. (G)).

Caldera. - According to the lighthouse time the tremor took place at XX. 20 and at XX.26, according to the railroad time (the former is regularized, from time to time by means of observations of sunset and sunrise and the latter by means of observations made with the sextant or by comparison with the marine clock, of some Navy officer). The duration of the phenomenon was 3'20" according to very concordant observations of the port captain, the lighthouse keeper and the German consul. It was undulatory and trepidatory and put in pendular movement the hanging lamps (Report of the German consul. G.).

The earth began to shake at XX.25, at first gradually and then with increasing intensity until the oscillations reached their greatest degree after 1'1/2. They came from the north and were not dangerous. They lasted between 3 and 3'1/2 (*Deutsche Nachrichten* from Valparaiso).

In this port the intensity was therefore of degree IV of the Mercalli scale.

Copiapó. - Strong tremor. No disasters. The first movement took place at XX.20 ("*Diario Oficial*" G.)

Its duration is estimated at 4' (G.)

Chanarcillo and other places in the valley of Copiapó. - A strong shaking was felt (G).

Port of Huasco. - The tremor took place at XX.20; it was strong and lasted for 3'. No misfortune on land or at sea (Report of the maritime subdelegate. V. G.).

Carrizal Alto and Carrizal Bajo. - The tremor was felt at XX.30 and seemed to come from the north (G).

Freirina. - Tremor that lasted 3 or 4' (G).

Vallenar. - Strong undulatory tremor, without precursor noise; it lasted 2' and the movement seemed horizontal ("*Diario Oficial*" G).

La Serena. - The shocks began at XX.31 mean time according to a wall clock whose march is frequently verified. The shock marched from north to south with oscillations OE (*Sic*). No noise preceded the tremor which lasted 1'58". The oscillatory movement was slow, but very strong. The strong shock that usually characterizes earth tremors was not noticed, although the extraordinary slowness of the oscillations made one compare the movement to that felt on board in a calm sea (Report of the German Consul G).

Coquimbo was still in the area of grade IV intensity.

The tremor of the 9th took place at about 8 h. 15 m. P. M. producing a prolonged earth movement that lasted no less than 4', according to the most general version; but without precursor noise, in such a way that for many it passed unnoticed. Most of the people who felt it claim to have experienced a dizziness of which they were not aware, until by the oscillations or movements of the lamps they came to know that the earth trembled (report of the maritime governor V. G.).

Valparaíso. - XX.25. or XX.30. Prolonged, but gentle tremor with slow and regular oscillations for 1' or so (Report of the German Consul. G).

A hanging lamp that constituted an 8-foot-long pendulum, swung about 3 inches from each side of its equilibrium position.....

... The movement was soft and of very slow oscillations. In my house there was no noticeable creaking of doors and windows which is usually felt with ordinary tremors (Report of Mr. Hilliger. G).

According to the statement of the commander of the corvette "Chacabuco" that then sailed from Valparaíso to Juan Fernández, the tremor was not felt on board. It was not observed either in Santiago and, nevertheless, it results from the preceding observations that the phenomenon conserved in Valparaíso the IV degree of intensity and the enormous extension of the area corresponding to this degree was noticed, since it was the same in Caldera.

In Santiago, the tremor clearly presented the characteristics of a seismic phenomenon already far away. No observations were made in other points of the great longitudinal valley of central Chile.

At 8:30 P. M. of May 9, 1877, an oscillatory movement of the ground was felt in Santiago de Chile, soft and prolonged that lasted for the space of 1' or more. Many people did not perceive the movement, but others experienced a certain faintness similar to the first symptoms of dizziness. The direction of the movement was believed to be from north to south, judging by a pendulum that, oriented from E. to O. stopped its movement, and likewise by the oscillation of the gas lamps that conserved for a long time their movement from N. to S. and vice-versa.

The tremor in Santiago was not preceded by a precursor noise, as is often the case, and the same thing happened in most of the Chilean localities where the oscillatory movement of the earth was perceived (V. G.).

Constitution. - The tremor was felt at XX.40, but soft and prolonged, from north to south and only perceptible by a few people (V. G.).

It corresponds to degree II or perhaps degree III of the Mercalli scale. What is certain is that according to the testimony of the maritime sub delegate of Tomé, the tremor was not felt in this locality nor was any subway noise experienced.

In all rigor it would not be impossible that the seismic phenomenon had been felt in Lebu, but provided that an error of one day is admitted in the following observation of the maritime Sub-delegate of this port. It reads as follows:

...The only thing we have felt here on May 10th at XX.40, is a dull noise like a volcanic eruption or a tremor, but no earth tremor...

The extreme limits of the sensitive shaking area of the Chilean earthquake of May 9, 1877 between Santa to the north and Constitución to the south thus cover a distance of more than 3,000 kilometers, without it being known how far it extended to the east, nor to the west.

3. EARTHQUAKE AFTERSHOCKS AND ACCESSORY PHENOMENA.

As is usually the case, the earthquake was followed by numerous aftershocks, but precise information is very scarce. They are given below in the same order as before, that is to say, starting with the localities of the pleistosist area and continuing with those located respectively to the north and south of it.

a. Replicas in the pleistosista area.

San Pedro Saltpeter Office. - (40 to 50 km. S E of Iquique). All night there were less strong tremors that made the machines shake and resonate, without any damage. (G).

Chanavaya. - Throughout the night it continued with intervals of a few seconds and on the 11th the tremors were repeated 5 by 5 minutes (G).

The earth movements after this terrible event have continued, and up to this moment (day 12) they are still felt, but decreasing in intensity (V.G.).

Throughout the rest of the night (of the 9th) there were very strong tremors with intervals of seconds, which increases the fright. Up to this hour, XI.30 of the 10th, the tremors are repeated 5 in 5 minutes. ("El Porvenir del Callao" of 16. G.)

Huanillo. - From the hour of the earthquake until this moment (the 10th) the earth shakes from 30 in 30', in a way that makes one fear a repetition of the catastrophe. (Report of the Maritime Governor, "El Porvenir del Callao" of 16. G.)

Punta de Lobos. - All night it shook, but with less force. (South Pacific Times. G.)

Cobija. - On the 13th at II.50, upon entering the port, such a strong and prolonged shock was felt that the captain of the "Lima" decided not to anchor. It soon passed at XIII.50, being between Cobija and Tocopilla, another very strong tremor was felt at XX.30 (V.G.).

The number of tremors in the night of the 9th until V, of the 10th has been 34, two of them entirely original for coming without noise and with a dry blow from bottom to top. The tremors and subterranean noises continue without interruption since the 9th, noting that the strongest ones began at midnight. (V.G.)

b. Aftershocks at points to the north.

Arica. - All night trembling at intervals. (Report of the Governor of the port. G.)

Shocks were felt as late as VII on the 10th. (Governor G.)

Tacna. - Throughout the night and for many days, the aftershocks were repeated at short intervals, with longer intervals each day. (Z.F.)

Arequipa. - The shaking lasted all night and the following day (Correspondence addressed to Consul A. Weiss in Dresden. G.).

Chala. - There was no other tremor. (G.)

Thus, the area in which the aftershocks occurred did not extend to the port of Chala.

c. Aftershocks at points south.

Caracoles. - All night long it shook with few intervals and 15 days later not a day passed without one or more tremors. (G.)

Antofagasta. - It continued shaking from minute to minute with more or less force. (Communication from Mr. Ramon Segundo Arancibia. V.G.)

The aftershocks still lasted on the 13th, day in which the people fled to the hills as a result of one of them. (G.)

The tremor was repeated with short and long intervals. ("Diario Oficial", 65).

The ground movement lasted until XXII.10 on the 9th, and in the interval of 36 hours more than 80 tremors were observed ("El Deber" number 548).

Paposo. - The tremors followed one after the other on the night of the 9th, 10 minutes at a time, more or less, diminishing immediately but repeating frequently throughout the month of May, until the middle of June. (V.G.)

Chañaral de las Animas. - Light and intermittent shaking continued all night. (Communication of C. Waltenrath to the Weserzeitung. (G.)

Copiapó. - In the following days strong subterranean noises and repeated tremors were experienced, reaching their number to 27 until the 16th, having been very strong 7 of them. (V.G.)

Numerous movements were felt all night and until XI½ o'clock on the 11th from time to time tremors were felt. ("Diario Oficial". G.)

Chañarillo and other places in the valley of Copiapó. - From 8:30 p.m. on the 9th until the afternoon of the 10th the earth remained in continuous motion. No noise accompanied the tremors which differed greatly in intensity and duration, some lasting more than 4'. (G.)

There are very few aftershocks that were noted with day and date; they are found in the first volume of the history and the area where they occurred did not go beyond Copiapó in a southerly direction.

Freirina. - Up to the 10th there were 4 more light tremors. (G.)

4. EFFECTS OF THE EARTHQUAKE ON THE GROUND.

The effects of an earthquake on the ground are of the greatest importance, since from their study can be drawn the demonstration of its tectonic cause. Unfortunately, the disaster of May 9, 1877, provided only some cracking and collapse of hills, i.e., accessory effects from which nothing can be deduced about the origin of the phenomenon.

As for a change of level of the coast that would have been observed in Pisagua and in Iquique, it is known by experience that never happens a great earthquake in Chile without similar effects are affirmed, but they always lack a truly scientific investigation that can allow to believe in their reality. As for the magnetic disturbance that was observed in Antofagasta, it is not a question here, at least plausibly, but of a mechanical movement, the compasses working momentarily as a seismoscope, which usually happens very often.

Calama. - The wet and flabby ground sank somewhat and the Loa River stopped its course for 24 hours. (V.G.)

Chiu-Chiu. - On the ground and near the volcano, according to travelers surprised by the earthquake, the stones were seen jumping from the ground with the tremor, making suspect that this region was near the center of commotion. (V.G.)

Chanavaya. - Several cracks up to 15 meters deep were opened in the ground in some parts. (G.)

This information should be considered greatly exaggerated.

Mejillones del Norte. - As a consequence of the tremor countless stones collapsed from the hills. (Report by Captain F. Medina. G.)

Huatacondo. - There followed a dreadful darkness caused by the dense dust that rose and the cliffs that with dizzying rushed from the hills to the bottom of the valley. A rain of fire fell in the midst of the darkness, which was nothing more than sparks produced by the stones when they violently collided with each other in their swift race. ("La Estrella de Iquique". V.G.)

There are numerous reports of luminous phenomena to which the great earthquakes have given rise, but they have never been verified by observations of a truly scientific character. For this reason many seismologists deny their reality or, at least, reserve their opinion. The explanation of the anonymous observer of Huatacondo does not differ from that of a well-known seismologist, Griesbach.

It is not convenient to discuss the volcanic phenomenon that would have accompanied the earthquake in Pisagua according to the correspondent of the "Comercio de Lima".

Pisagua. - A very knowledgeable practitioner of this port, as he has been there for many years, says that he was surprised, a few days ago, to see that the anchor of a ship was at the bottom in 10 fathoms of water (18.2 meters) when before in the same place it was only at 45.5 meters.

I and another observed here another phenomenon: the-earth has dropped considerably since the earthquake of the 9th; today it bathes in the high tides lands and broken lands that have always been dry and with some buildings. (V.G.)

Antofagasta. - According to data communicated by Lieutenant V. Cueto, officer of the armored ship "Blanco Encalada", the following phenomena were also noted: The compasses experienced until minutes after the earthquake a deviation N E., of a quarter more or less. The barometer dropped about two millimeters with abruptness. The air was more fiery than in the moments before the earthquake. The sky, which had been clear during the day, began to cloud over, and a stratus became noticeable, crossing the sky from NE. to SW. with persistence. (V.G.)

Iquique. - The bottom of the sea seems to have sunk, since several boulders in the bay are no longer visible, even at low water. (Report of the Governor of the port. G.)

No hydrographic survey was made of the ports of Pisagua and Iquique, so that these changes in level are doubtful.

As is often the case, the earthquake was followed by large fires in several cities in the pleistosis area.

Tocopilla. - In the mountains, the collapse produced by the earthquake has been general.

We have in this place a ravine of a road four leagues long that, bordered by steep slopes, crosses the entire coastal mountain range; it has been strewn with debris all along this route, proving that the earthquake has shaken with equal force the entire immense mass of this mountain range.

On the plain, composed of dry sediment soil, small cracks have opened up and the surface soil and dust have been removed in a manner similar to sifting through a sieve.

On the beach, the sand shuddered even after the catastrophe with a movement similar to the one we have just described (H.).

II. *The tidal wave or tsunami.*

The tidal wave or tsunami that followed the earthquake extended to almost the entire periphery of the Pacific, from the southern territories of Chile to California and from New Zealand to Japan. The observations made in several ports are very numerous; they can compete in proximity with those that were made on the occasion of the earthquake of August 13, 1868 and other phenomena of the same class that have provided so many precise data for the study of the tidal waves or tsunamis are not known. The one in question caused great material losses and numerous shipwrecks and also allowed Geinitz to verify the equality between the speed and the propagation of the perturbations of the sea level produced by a seismic shock or by the solar lunar attraction, as von Hochstetter had already done for the tsunami of August 13, 1868.

1. *Observations made in the pleistosista area.*

The numerous reports on the tsunami along the coast of the Pleistosist area agree on the magnitude of the phenomenon and its disastrous effects on the populations and the ships anchored in the ports, but they differ greatly on the time interval that separated the tsunami from the earthquake. Several informants say *immediately after*, while many others estimate the value of this interval at 5, 15 and even 30 minutes. Therefore it is not possible to resolve the question, with which it would have been possible to deduce by another way the approximate distance between the seismic focus and the Pacific coast.

Iquique. - Near XX1/4, a great din was heard, accompanied by a slow movement of the earth, and announced the terrible tremor, whose frightful oscillations originated the catastrophe that followed. These movements lasted more than 3 minutes; the earth rumbled, whirlwinds of dust were raised by the shaking and women and children screamed, when all the people fled to the hills at the sound of the cry: The sea! The sea! An indescribable scene as the bells announced a fire in the south of the city. The prolonged oscillation disturbed the equilibrium of the sea, which then flooded the higher ground, drowning and taking with it a quarter of the workers. The material losses can be valued at more than two and a half million soles (South. Pacific Times. Callao, May 10. G.).

The first wave, or rather the outflow of water took place five minutes after the seismic shock with half flow (Report of the Governor of the port. G.).

After the tremor, very high waves followed, turning the lower town into a heap of rubble. To make matters worse, a fire broke out which was later extinguished, so that material losses and casualties were restricted to those caused by the scourge of the tidal wave. The steamer "Griminosa" and a schooner were left dry on the island. (Dr. Watson. G.)

The first departure from the sea took place at XX.50, that is, about half an hour after the tremor. The movement was smooth, but the retreat was much faster. Some

people claim to have observed that the sea had retreated before the first outflow, but because of the darkness it is difficult to say anything definite about this. The second outflow of the sea, already stronger than the first took place at twenty-first o'clock, and according to observers there were three or five others at longer or shorter intervals; the last occurred about one o'clock, after a new shock, and was the most damaging. It is not known exactly which was the greatest of the oscillations of the sea, but, it is almost certain that it was this last one. The height above the mean level was 16 ft. (G.)

According to another report published by the South Pacific Times, the sea surge took place 20 minutes after the tremor and invaded the city eight times during the night (G.).

There were 30 victims and the waters rose 6 to 10 feet above the walls of the customs house (Diario oficial de la R^a de Chile. 62).

Cistern. - Water carrier and traveling steamer between Arica and Iquique, in charge of providing drinking water to the population. This ship was thrown over Serrano Island, and also a brigantine, which was also destroyed.

Many coastal schooners and an infinite number of smaller boats, such as launches, dinghies, barges, etc., were also wrecked on the coast, leaving the sea and the beach covered with debris.

In the bay of Iquique a German ship loaded with saltpeter sank, and another ship went to the beach, destroying itself. (V. G.)

The sea immediately came out with waves of trees 3 meters high that dragged the buildings with them.

The sea was the neighborhood of the entire stretch of the coast from La Puntilla to El Morro. More than three miles previously covered by magnificent buildings, large warehouses, industrial establishments, powerful centers of commerce, animation and life, presented the terrifying spectacle of piles of ruins mixed with the debris that the sea did not cease to throw on the beach.

The sea concentrated all its fury in the northern part of the town called La Puntilla, where the most valuable establishments in the saltpeter industry in Iquique were located. That part of the population has been completely devastated.

The Morro neighborhood has suffered as much or more, if you will, than La Puntilla. All the docks have disappeared.

On land there were no casualties; but not so in the navy. Many have been the unfortunate ones snatched by the sea.

The havoc in the bay was immense. (V. G.)

The earth was still shaking to the rhythm of a terrifying subterranean noise, when the voices of fire! fire! fire! were heard in the four corners of the city....

We cannot express what we all felt, as we found ourselves under the pressure of two calamities that seemed to dispute the primacy: the fire and the sea. We did not know whether to abandon everything to save ourselves from the sea or from the fire.

The fire started 7 blocks from the sea (875 meters, more or less), and two of the pumps had to be placed on the beach to provide water to the others, but at the beginning of the operation, the cry of "the sea!

The sea swallowed the two pumps and the dedicated firemen had to flee for their lives, as a huge wave invaded the coast and swept away everything in its path.

The picture offered by the city and its inhabitants cannot be painted, nor can our pen.

To see the streets full of men, women, children and old people shouting, crying, invoking Providence and calling out to their wives, their children, their parents, can never be explained by poor human language.

The population camped from the houses called Gibraltar, of Mr. Romero, to the distance of two leagues (9 kilometers) from this port, on the slopes of the hills.

Only terror could have driven so many to cross the cold, sandy pampas and rocky slopes.

The earth tremors continued in 5-minute increments, more or less alarming; meanwhile, the sea was destroying everything in its path.

What a dreadful night, and what eternal hours we spent until the dial came! (V. G.)

Mejillones del Norte. - The sea rose around XXI.10' the same night. The distance to the point where it receded before the flood, reached to 18 or 20 feet, and after the flow the water rose about 10 feet above the shore. In the space of 4 minutes there were four oscillations of the sea, the fourth being the largest. The flows rose 6 feet and twice 13 feet above the ordinary level. (Report of the C. of the port). As at XXIII o'clock, the sea flooded the population with which there were many deaths to lament, originating great damages. The sea rose from 9 to 10 feet. (Report of Cn. Fr. Medina. G.)

Pisagua. - XXIII. The sea went down; there were four oscillations at intervals of 2, 3, and 10 hours. The second was the highest and reached 10 English feet (Report of the Port C. G.).

Chanavaya. - The sea invaded six times the population, dragging in its ebb all the houses and buildings of the administration that are in the elevated part; the sea could not destroy them, but they have disappeared the docks of the shipment, works of loading, hydraulic machine and watering place. All the ships, with few exceptions, have collided with each other, causing notable damages; up to this date, 6 have been wrecked, which were thrown to the beach. We still do not know the nature of the personal misfortunes that have occurred. In Pabellon, 33 workers were buried under the sand as a result of a landslide (V. G.).

The first wave occurred 20 minutes after the first shock and the sea movement started by a retreat. There were 3 waves with an interval of 8 to 10 minutes; the second, that is the highest, reached 35 feet, surpassing by feet 4 the level of the highest tides.

More than 3,500 souls are left homeless.

The sea put out the fires (El Deber num. 550. G.)

According to the South Pacific Times, between XX.25 and XXII.10, there were .5 waves (G.)

...Vessels that did not sink were unable to sail.

The real port of Chanavaya that had four blocks of buildings destroyed, where the commerce was, located in a high plateau at the foot of the hills; at the moment of the earthquake the people ran to the hills, but the detached stones of the high ones rolled vertiginously toward the top causing numerous victims and injuring many.

Moments later, a fire broke out due to the fall of the kerosene lamps, a new enemy that set fire to the destruction caused by the earthquake.

The people, somewhat surprised, descended to attack the voracious fire, and when they managed to suffocate it in part, the sea entered, roaring frightfully, rushing over the population, forcing the workers to run towards the hills to flee from the third enemy, but not without leaving some of them among the debris, drowning in the sea.

By the 13th the sea remained rough; according to the Nacional de Lima of May 15, more than 200 people had perished by drowning.

Molle. - In this cove the sea totally destroyed the hold of Ugarte, Ceballos y Cia. and J. Gilmeister y Cia. with large stocks of saltpeter. There was one victim and heavy casualties in the two ships in the area, due to collisions between them, due to the strong ebb and flow of the sea. (V. G.)

Pica Pavilion. - The sea surge was repeated six times and extinguished the fires. (Official report of the Governor. G.)

The tsunami occurred at XX.25 (25' after the earthquake); 5 ships sank and 27 were so damaged that they could not leave port. There were more than 200 casualties (South Pacific Times. G.)

Punta de Lobos. - The overflowing wave sank the ships "Shamrock" and "María Antoinette". In addition, three ships had to be abandoned due to their poor condition, leaving seven more dismantled (V. G.).

Immediately after the earthquake, the sea began to recede and returned in less than 10 minutes, passing over the town in a wave 35 feet high (South Pacific Times. G.).

The first wave appeared at XX.30, i.e. 10 minutes after the crash. The movement was started by a backwash. Two waves of which the second was the largest, occurred in 30 minutes; the first rose 20 English feet and the second 35 above the ordinary level and dragging houses (Report of the Governor of Port G.).

Huanillos. - About 15' after the earthquake, the sea began to gradually recede and then receded to a negligible height above its ordinary level.

There were three big waves with intervals of half an hour or so rising the first 30 feet; they were less high the other two.

4 ships perished and 13 were damaged. Numerous loss of life (Report of the Maritime Governor. G.).

(The earthquake) produced by consequence that the sea came out of its bosom and dragged with it the greater part of the population, leaving two thousand souls, who will have more or less in the reservoir, without a drop of water (El Porvenir del Callao of the 16th).

Tocopilla. - The tidal wave took place immediately after the earthquake according to Mr. F. Palma and according to the Commander of the "Eten" the sea rose 15' later (G.).

It seems to us that the duration of the first tremor was two or three minutes, and from this moment until that in which the sea made its first exit, about two minutes more passed; total, therefore, four or five minutes?

They (the manifestations of the ocean) began to be noticed by some neighbors who were late in escaping. They saw the sea swell, grow and exceed its natural limit in a calm but continuous way; they heard the buildings behind them creaking and finally we all saw the ravages and the invaded limit.

Some say that the sea came out in a wave, we affirm that it was an overflow with ebb and flow, that there was no such wave that rushes in bursting and invades just with its thrust at a very high level... These waves accompanied the sea in its overflow and cooperated effectively to destroy both the fragile wooden buildings and the solid slag walls.

Our bay is protected to the south by a hill of very low elevation; on this side the sea has invaded the watershed, reaching 10 or 15 feet more than the height it had in the tame part of the port; in this the wave next to the beach has perhaps one or two feet of elevation, while in the other, where it receives its agitation directly from the bosom of the sea, it has six to eight feet and edemas a proportional thrust; adding to the height of the overflow that of these waves and the thrust, the difference in height that the sea bathes in one and the other part is easily explained...

At three to four feet the water rose higher on this outing (the ten o'clock at night) than on the previous ones.

Between one and the other there was an interval of time of one and a half hours... The phenomenon worked in an intermittent manner and increased in strength. Between the absolute calm of the sea until this new agitation, there was an interval of time of three quarters and an hour and a quarter... After this departure the sea remained still...

The height that invaded the sea, measured approximately was from thirty to forty-five feet, between the two extremes designated below. To fix the mathematical altitude, it is necessary to know the level of the tide at those hours. No one in this town had seen the sea recede before or after the first departure; we think it not unwise to admit that it has been a downward event, and if it did not precede this, it at any rate followed it. Among the observations we rely on, we cite the following; the beach was covered in certain parts with a certain species of shellfish vulgarly designated by the name of "loco"; these shellfish live below the water level at its lowest tides and adhere with mocha solidity to the rocks; when the sea retreated, they remained dry and loosened their contact to regain the waters; in this they were surprised by the current of the returning water and thrown on the beach. Heavy iron objects such as plates, wheel rims, etc. have completely disappeared (H.).

The correspondent of "El Deber" who traveled in the steamer of the Republic "Abtao", commissioned by the Government of Chile to give aid to the populations destroyed by the earthquake of the coasts of Bolivia and Peru, asserts that a week after the earthquake some neighbors of *Tocopilla*, found on the coast the flagpole of the captaincy of the port of Mejillones of Bolivia: "likewise some rails of the railroad of this city". If true, this fact would demonstrate the existence of a coastal current, contrary to the one experienced in Antofagasta and in other points of the Chilean coast, noticed by the "Blanco Encalada" and other ships. The shape of Mejillones Bay may cause this strong countercurrent. Tocopilla is 62 miles N of Mejillones from Bolivia.

Cobija. - The sea outflow caused great damage.

According to the report of the Commander of the "Eten", 8 minutes after the collision, the sea rose 30 feet (G.)

Within 5 minutes of the great upheaval, the sea was seen to swell calmly, without a single wave to ripple it: it passed the seawalls and invaded the houses in the midst of a frightful noise; produced by the walls, the walls and wooden partitions that gave way to the weight of the water. All the people exhaled a cry of supreme anguish, seeing, not with their eyes that they had no light, but with their imagination and with a broken heart, since they had no houses or homes. The sea rose to 11.9 meters above its ordinary level, and when it retreated with violent impetus it washed away the ruins it had produced at its coming. Three more waves overflowed, each coming down from its reach first, until the sea again acquired its level.

It is worth noting that the first outflow of the sea was not a boisterous surge but a swelling, as has already been said, and so slowly it rose, that there are people who went into their houses to take out blankets and other objects, getting their feet wet, and have gone out again looking for other objects without the water hurrying them too much. The water has also come from SW. to NE.

It would not be possible to say which houses collapsed with the earthquake and which ones bent to the invasion of the sea; the only thing that has been seen is that minutes¹⁰ after the tremor neither the square nor the street of commerce (which was called Beni) no longer existed; having disappeared therefore 97 houses of which there is no more trace than about 20 walls that remain standing by chance.

Part of the merchandise and other goods have been found 8 and 10 miles N. of Cobija.

Losses in house and merchandise values have been prudently estimated at 627 thousand pesos.

.....
On the 12th the corpses of several people missing in the village began to be found.... The dead have reached 14 (V.G.)

According to data published in "El Nacional de Lima", the sea rose 9.4 meters in *Cobija*; but it is wiser to stick to the data inserted above.

A cove between Cobija and Mejillones del Sur. Twenty minutes after the collision, the flow rose from 60 feet (G.)

Mejillones del Sur. - The invasion of the sea occurred half an hour after the tremor without having been observed before. The height of the wave reached 35 feet. After this first outflow, the sea receded about two blocks; a quarter of an hour after the first outflow the second took place with dizzying speed, the wave rising to 70 feet in height, thus originating great damage. The third outing occurred about three-quarters of an hour later. (G.)

The sea overflowed half an hour after the earthquake, without making itself felt. Only to the noise of the first houses that broke its invasion and that it dragged suspended, responded the general cry of alarm; the sea! the sea!.... Some people in a number greater than 8, were engulfed by the waves and succumbed.

In the first exit of the sea, the vertical height reached by the wave would be more or less 7 meters, sweeping away many houses. Then it retreated, fleshing out the beach for about 250 meters, making its second invasion 15 minutes later, reaching a vertical height of 19.5 ⁽¹⁾meters above the ordinary level, crashing against the houses of the population with dizzying speed, sweeping away seawalls, piers, stone stairs, etc., and the first two rows of blocks of the population that were facing the sea, forming a shapeless heap of everything.

About 45 minutes later, the third exit from the sea took place, causing a loss of 810,000 pesos for the population of *Mejillones de Bolivia*.

The departure of the sea caused the greatest damage to the town, and the ground continued to move incessantly during the 10th and 11th.

The large sac of the *Mejillones* bay allowed the seismic wave to be dammed in greater quantity than in other points, as can be verified by comparing the phenomenon with the one that occurred in *Antofagasta*.

Antofagasta. Hardly had the inhabitants of the town been able to breathe, a terrifying scream escapes from the overwhelmed inhabitants of *Antofagasta*: the sea... the sea is coming... the sea is advancing!

The sea, which in *Antofagasta* is always boisterous and agitated, had remained without movement; but suddenly a monstrous wave rushes over the first buildings facing the beach and sweeps them away.

A house is swept intact (it was, like all wooden houses) up to 125 meters from the shore, carried by the sea as a simple small boat, boats and other smaller vessels were driven to the town's main square.

The damage caused by the sea has been immense, causing a loss of 600 to 700 thousand pesos. (Communicated by Mr. Ramon Segundo Arancibia. V. G.)

The seismic wave was not felt as those produced by the winds, but as a sudden rise of the waters, marked by the scandal in 3.5 meters and with powerful currents in E. direction. -0. and in the opposite direction. These currents were felt about 15 minutes after the great shaking and with a force of 8 to 10 miles. They changed every ten minutes. Apparently, in *Antofagasta*, the wave penetrated the *Punta Tetas*. When the "*Blanco Encalada*" was outside (12 o'clock at night more or less), a current was noticed that forced her to make use of her engines at every moment to prevent her from going down in the direction of *Chimba* creek. The vibration produced on board by the shaking of the waters was similar to that which would be produced by the violent dragging of the ship on a rocky bottom. (Report of Lieutenant Cueto, of the "*Blanco Encalada*". V. G.)

Soon the tidal wave occurred, and the sea invaded the houses three times, destroying some and transporting others and causing great damage to the warehouses. (Official Journal No. 65).

According to one report, the sea was calm until the big wave came.

The first flow occurred about 10' after the first shock and started with a strong backwash of the sea. Up to midnight 4 oscillations of the sea were observed and lasted all night and for two days with intervals of 40 to 80 minutes. The fourth or the largest of these waves reached a height of 2 meters above the high tide marks, i.e. 2m½ meters above the mean sea level. (Report of the German Consul, Bischoff. G.)

¹ Typo (with great consequence) : Vidal-Gormaz, from where the number is taken, indicates 11.5 meters and not 19.5 meters (sic !)

The sea began to withdraw a few minutes after the earthquake, leaving the harbor basin dry and the drowned rocks that serve as a barrier well fleshed out, returning at once to the coast without great noise. From this moment an undertow was produced which caused a current in the sea, from N. to S., with a force of 8 miles per hour. During the phenomenon the vessel tacked lively and kept her bow between E. and O. by N. The sea and wind were SW. The same effect was experienced by the sailing vessels off Antofagasta, which numbered 6 to 7. There were many continuous ebbs and flows which seemed to have their origin in the N.

The sea overflowed onto land reaching a vertical height of 3 meters above the level of the common high tides. (V. G.)

It is not true that abnormal currents on these coasts for several days after the event resulted directly from the tidal wave, as the following information claims. This is a mere hypothesis that lacks evidence.

Finally, the Republic's steamer "Abtao", which traveled the coasts of Bolivia and southern Peru, after the earthquake of the 9th, until the end of the month, repeatedly noticed swathes of currents and marked scouring in the sea, in an unusual manner, which could only be attributed to the upheavals caused by the cataclysm of May 9th.

2.- Observations outside the pleistosista area,

A.-OBSERVATIONS TO THE NORTH OF THE LITIGATION AREA.

As explained above it is likely that in a northward direction the pleistosista area, did not pass over Iquique. It will begin, therefore, per the port of Mejillones.

Mejillones del Norte. The entire lower part of the city swallowed by the sea; several entire families perished (V. G.).

For Cabo Lobos, the damages due to the earthquake, if any, were not distinguished from those produced by the tsunami and the same in Pisagua, those attributed to the earthquake should be understood only from the tsunami (see observations above). (see the observations reproduced above).

As far as the port of Arica is concerned, the following observations do not explicitly relate the damage caused by the earthquake, which is in agreement with verbal testimonies given to the author by former inhabitants; according to them, the losses resulted only from the tidal wave.

Arica. The railway line was destroyed up to the bridge of the Chacalluta river, that is to say, six miles. All this pampa between the said river and the city had been inundated by the sea, and with such force, that the "Wateree," which had been stranded more than a mile away in the year 68, was swept by the undertow, to near the seashore, to where her remains now lie. The entire lower part of the harbor town had been completely swept away, to the extent that neither the location of the buildings nor the houses were known. Neither a boat nor a launch had been saved, and of the wharf only a few iron piles remained, which have been preserved until now to indicate their location. There were hardly any personal disasters to lament because the inhabitants of the port, having learned from that of August 13, 1968, knew the danger and the means to avert it. (Z. F.)

The Custom House was flooded and all the goods deposited there damaged. The wharves were washed away by the waves and the whole part of the town up to the church line, the British consulate, the cable office and the Pacific steamship office completely destroyed. The cable house lost. The wreck of the steamer "Wateree" U. S. war steamer of N. A. lost on August 13, 1868, washed two miles N. along the beach. The position of the cable has changed: it has been left in sight in the bay. S. buoy of the cable dragged about a quarter of a mile to the N.

The railroad station, engines, cars and other accessories completely destroyed and scattered in different directions: only the ruins of the cable office were left standing in that place.

The big wave rose 65 feet (19.75 meters) (El. Nacional de Lima of the 13th).

The sea advanced up to 6 blocks (750 meters); according to "La Reforma", the losses caused by the earthquake and the tidal flush reached a value of 4,000,000 pesos. There were 5 victims (El Comercio de Lima of the 14th).

The sea surged 8 times and rose 39 feet, the greatest flow having occurred at IV on the 10. The ravages produced by the earthquake and tidal wave were described as truly terrible. The hull of the "Waterree" stranded by the tidal wave of 1868 was carried two miles farther north along the coast. The flow must have been the same height as in the year alluded to. (El Deber num. 540 G.)

Arica. - At about XXI o'clock (average local time) the first flow took place and reached the height of the seawall and then the sea retreated. Its first outflow coincided with the full tide. The flows followed one after the other at intervals of about half an hour. The highest wave, that is to say the penultimate one, took place at IV.30 on the 10th and reached a height of 8.6 meters (Report of the Governor of the port. G.).

The tidal wave began at XXI by a retreat of a quarter of a mile or so. The first four waves followed each other until midnight, the fifth at I 1/2, the sixth at III, and the next two at IVh and IVh,5. The one at IVh was the largest and reached a height of 40 to 45 feet above the high tides mark. The currents were circular in the bay and out in a S. to N. direction (Report of the German Consul in Tacna. G.).

It will be noted, the great discrepancy that exists in these three relations with respect to the height reached by the main wave.

Ilo. - Flow from 12 to 15 feet (G.)

A quarter of an hour after the tremor, the sea retreated and a large wave occurred. There were three that followed at half hour intervals. The sea continued to move until V o'clock on the 10th. In its retreats the sea dropped 20 feet below its ordinary level and rose 20 feet on its way out. The third wave was the greatest. These flows produced nothing remarkable. (Report of the Cn. of the port. G.)

According to these observations the tidal wave happened in Ilo a quarter of an hour after the tremor and according to those made in Quilca, the sea withdrew at the instant of the earthquake to leave 10 minutes later. It results from this that the times of XXIII.30 and XXIII.45 reported for the intermediate port of Mollendo are erroneous. In this there is no doubt.

Mollendo. - The sea began to rise for the first time at about XXIII and 1/2 o'clock, passing its level about 7 feet above the highest tides. Its first oscillations were not observed. The waves seemed to come from the SW. and S. On the 10th the sea did not present anything particular and on the contrary it was extremely choppy on the 11,12th and 13th (Report of the German Consul. G.).

At XXIII.45 the tidal wave began with a retreat of the sea. There were three oscillations with intervals of 10 to 15' and the mean term of its height was from 2 1/2 m. to 3 in. The second was the greatest (Report of the. Cn. of the port. G.).

The observations made on Islay do not fix even approximately the time span between the earthquake and the tsunami.

Islay. - After the tremor there were three waves whose height of more than 5 feet above the ordinary full tides damaged the seawalls (Report of the German Consul. G.).

Sea swelling of about 8 feet. The city being located on top of vertical rocks above the sea, the tidal wave could have gone unnoticed. (G.)

Quilca. - Ten minutes after the indicated hour 'the one of the tremor that is to say XX.40) a great wave rose on the shore, leaving the sea of 300 meters out of its limits. At the instant of the tremor the sea withdrew 20 meters and returned as just said. It moved up to 13 (Report of the Captain of the port. G.)

Chala. - There was no invasion of the sea (Port Captain's report. G.).

Pisco. - El movement of the sea lasted until V of the 10 and the flow rose of about 8 ft.

At about XXIII.30 a lot of noise was felt in the anchor chains. Already since XX an extraordinary movement of the sea had been noticed. At 1.45' on the 10th, the strongest wave; the movement began with an ebb. There were two large waves, the second

at III o'clock at the hour of full tide. Minor flows followed at 10 to 15' intervals until the 11th. (Report of the Cn. of the boat Amelia).

Chinchas Islands. - El tidal wave began by a rise of the sea. The highest flow took place at I of 10 and rose ½ foot above the highest tides, which here are 10 feet (Port Report. G.).

On the night of the 9th to the 10th, the sea overflowed at 12 o'clock at night, reaching an unexpected height, without causing any damage. El Comercio de Lima says that a strong full and no less strong currents were experienced, causing the destruction of a boat in the S islands (V. G.).

Tambo de Mora. - The overflowing of the sea occurred on May 9 and swept away a row of houses in the town (V. G.).

The first and highest wave (10 feet above ordinary full tides) was noted at 1.40 on the 10th. There were three oscillations of the sea, the second at II.35 and the third with full tide at III.15. Up to XV.50' on the 10th the ebb and flow of the sea continued at intervals of 10 to 20 minutes (Report of the Port Cn. G.).

El Callao. - The main outgoing of the sea began at V 1/2 o'clock on the 10th, but from an hour before strong upward and downward movements of the waters in the harbor and also violent currents were already noticeable (G.).

The maritime governorship observed the, rising of the sea on the 10th at IV.40 (Accurate observation of the time. Clock fixed daily by a cannon shot at XII o'clock). The tidal wave began with full tide. The greatest height reached 10 English feet. The swirling currents lasted three days with more or less force (G.).

A vessel left on the dock of the dock (V. G.)

Shortly after midnight on the 9th, several people noticed in the *babia* a strange state of movement of the sea, whose noise became more frightening as the morning approached. At about IV o'clock on the 10th, the water had risen and was bursting against the walls of the docks and particularly against the dock quay. The loss of human life was estimated in hundreds and of property in millions (G.).

According to all probabilities this last information is false as far as loss of life is concerned, since the other documents do not mention it.

El Callao. - In the sea an extraordinary movement was already manifested on the 9th at XXIII o'clock and soon after it filled the bay, making the currents and the whirlwinds turn the ships on their anchors. It does not seem sane to call waves to this phenomenon, which would give to suppose an undulatory movement, while this tidal wave consisted of a series of dilated rotating rises of the waters, forming numerous cyclonic currents (Sic) of great speed and intensity that lasted some hours (South Pacific Times. G.).

Ancon. - El tidal wave began to rise and lasted from II to IV o'clock on the 10th in the form of flows that followed one after the other in 5 minutes. The first wave was the biggest and reached 4 or 5 feet in height (G.).

There was little damage from the tidal flushing that occurred on the night of the 9th to the 1st.0.

It is not known whether the landslides in Pasamayo resulted from the earthquake or the tsunami, but more likely from the latter.

Pasamayo. - There were 5 landslides in the port; but no details could be obtained about the sea and the earthquake (V. G.).

Huacho. - The sea came out making great damage to the Salinas railroad. A boat was lost, and the sea was experiencing great ebb and flow.

Supe. - The first wave occurred at IV o'clock with the full tide. For 24 hours the movements followed each other at 10-minute intervals, the second wave being the largest. The sea invaded the beach to an extent of 100 feet and the second wave passed 20 feet farther out, rising three feet higher than the first (G.).

Casma. - At Oh1/2 on the 10th, a 75-foot wave was noted inland with the full tide flow. The second wave was higher, and flooded the shore and the boats. The third, even higher, completely inundated the beach and reached the cottages at a distance of 1,800 Spanish feet. The sea retreated, and then there were flows at two-hour intervals that reached the same distance as the first wave. This movement lasted until the 11th. The houses being situated as they are six feet above the level of the sea, they suffered no damage (G.).

Samanco. - Do not note the exact time of the tsunami whose waves rose 12 feet above the ordinary sea level (G.).

Chimbote. - No waves were observed, but the sea was down from 21 English feet and up from 6 at IX.50 on the 10th, with no other movements noted (Report of Port Cn. G.).

Santa. - At I, III and VII o'clock on the 10th (mean time) the sea rose ten feet above the high tides, the latter movement being the greatest (Port report. G.).

Huanchaco. - From 11.30 to III o'clock on the 10th the tidal wave began with full tide that exceeded its ordinary extent by 30 feet. There were three extraordinary flows of 12 in 12 hours. With the first of them, the sea exceeded 20 feet its usual limit and decreased the height of the following ones. The ships were dry-docked at anchor with a depth of 25 to 30 meters (G.).

Pascamayo. - The phenomenon was also experienced in this port, but no data were received (V. G.).

The tidal wave began with a retreat of the sea at VII.45 on the 10th. There was a single wave and 10 minutes later the sea returned to its ordinary level (Port report. G.).

Tumbes. - El movement took place with the full tide. At XI o'clock on the 10th the biggest wave was produced and 20 minutes later the second one; a third one was not noticed (Report of the port. G.).

Guayaquil. - From this port they report that nothing extraordinary was noticed (G.).

This negative observation was due to the port's remoteness at the bottom of a very narrow inlet. No information was obtained from the ports of Ecuador, Colombia and the Central American republics. The tidal wave was observed in Mexico and California.

Acapulco. - On May 10, a flood inundated the coasts of the state of Guerrero and in Acapulco it rose up to the plaza.

According to news supplied by an officer of the Lackwanna, an extraordinary and rapid rise of the water took place in this port at about 10 o'clock. There followed four such surges at intervals of 15 minutes, and each time the level rose and fell three feet. From noon until XVI, other weak flows followed at 10' intervals. On the 11th between XI.15 and XI.40, a sudden rise and fall of the flow was noted and a second rise at XI.50. From noon to XVI, there were five flows with irregular intervals of 25 to 35 minutes (Star and Herald. Panama. May 21. G.).

The tsunami spread much farther north to the California coast.

Gaviota. -San Luis Obispo County. 35°10' N.) A telegram of the 10th announces that this day at VII.10, the sea rose 12 feet and retreated, the phenomenon being repeated three times at an interval of 10' (G. According to the Weserzeitung.)

According to the Chala port report, there was no tidal wave on May 9, but the port captain adds:

But on the 14th very early in the morning, the sea began to move and at X o'clock came a flood which was terrifying at midday and remained so until the 16th. There were no waves, but the sea was in flux and rose at most 6 English feet above its ordinary height.

Although it is strange that there was no tidal wave on the 9th in Chala, the strictly negative form of the text with respect to the event, and the but with which the relation of the tidal wave of the 14th is accompanied, leave no room for any doubt. On the other hand two observations of Callao and Ancon speak of abnormal movements of the sea in these ports on the 14th. They read as follows:

El Callao. -On the night of the 14th there was a strong tremor; the sea returned (no doubt referring to the 9th) without damage, but it so alarmed the population that half of the inhabitants moved to Lima (V. G.).

Ancon. - There were few damages with the tidal flush occurred in the night of the 9th to the 10th, happening the same thing on the 14th, producing the sea floods and great alarm. (V. G.)

It seems therefore indisputable that there was at least a second tidal wave on the 14th in the ports of Ancon, El Callao and Chala and even two if

we confront the observations of Chala with that of Callao. What is certain is that on the coasts of the region there were two tremors on the 14th, to which the abnormal phenomena of the sea on the same day can be attributed. The following is Polo's text on the subject.

On the 14 at V., (Arequipa) another tremor. On the same 14th at XX o'clock, weak oscillation in Lima, almost without noise. At XXI o'clock, strong tremor felt also in Callao and Mollendo.

To the first tremor, that is to say, to that of Arequipa at V o'clock, could correspond the tidal wave of Chala and to the second one, which between XX and XXI o'clock extended from Arequipa to Callao and Lima, could correspond the tidal wave of Callao and Ancon.

There is no other interpretation that can reconcile these contradictory data.

A.-OBSERVATIONS TO THE NORTH⁽²⁾ OF THE LITIGATION AREA

Tsunami observations south of the Pleistosis area have been very numerous and generally well made.

The Paposo. - The sea remained calm at the moment of the earthquake and in the subsequent moments; but then it began to agitate, moving away and approaching the coast, without experiencing notable variation with respect to the ordinary level; but at the end there was a rise of 2.5 to 3 meters above the highest tides, overflowing the sea through the low places without causing any damage (V. G.).

(Chañaral. - Immediately after (the tremor) the sea overflowed to the point of destroying a large part of the population, whose losses were later estimated at 181,000 pesos, according to official documents (V. G.).

After the earthquake, the sea retreated about two blocks. It was for the people living in the lower part of the city the signal of a general flight to the hills. An hour and three quarters later the sea returned and flooded all the houses from the Magallanes cruises to the railway station. After this first exit the fire broke out in the buildings of the Compañía de Carrizalillo and in less than two hours there was nothing left of them but smoking rubble. Hardly had the flames been subdued and the fire stopped, and no more was feared in the center of business, when a powerful wave came rolling back and completely extinguished the fires as it passed over the five-block buildings. (Deutsche Nachrichten. Valparaiso. G.)

More than two hours after the tremor, large waves occurred and the sea crossed from 50 to 100 meters the marks of the highest tides. They came from the south to the north and the second one was the most devastating (Diario Oficial N.0 58) (G.)

The sea invaded the population at XXIh1/4 and progressively gaining more land flooded it from XXIh1/2 to XXIII (El Mercurio del vapor. 542) (G.)

The tidal wave occurred about two hours after the earthquake, although a strong swell was already noticeable beforehand. There were three outflows from the sea. The first time, the waters entered from 50 meters and returned without having caused any damage. At about XXIII.1/2 o'clock, they returned without the slightest noise, entered from about 200 meters and retreated with a frightful noise. The third and last departure occurred two hours later and was the greatest (Mr. Waltenrath's report to the *Weserzeitung*) (G.)

The sea was so rough that the boats could not hold alongside the steamer Lontué. This agitation did not have the same appearance as on other occasions, as it appeared in different directions and with violent and irregular movements (V. G.).

Note the great discrepancy in the time of the beginning of the Caldera tidal wave between the two following relations.

Caldera. - At about XXIII o'clock, the sea suddenly and noiselessly began to recede to a distance of 200 feet; then and with the same silence it gradually filled the port until it passed 5 feet at the highest point of the high tides. This movement

⁽²⁾ Typo : obviously : TO THE **SOUTH** !

continued in full force until the following day and whirlwinds were produced. (Deutsche Nachrichten of Valparaíso.)

At about XXI o'clock, the sea began to retreat and the first flow took place at about XXI.30, about an hour after the tremor. The tidal wave began to recede, although the sea level was slowly dropping. The ebbs and flows alternated with very irregular intervals whose most ordinary duration was 5, 10, 15 and 20 minutes. They were particularly frequent at the beginning and the following day. The third wave reached the height of 7 feet above mean level at I.5' in the early morning of the 10th, i.e. 4 feet above full tide, or 14 feet above low tide, whereas the difference between full and low tide generally does not exceed 6 feet. The flows of the 11th at VII and at IV reached almost the same height, but were slower and less violent (Report of the German Consul) (G.).

Carrizal Bajo. - At about XXIIh, the sea receded and rose again.

The sub-delegate of the port reports that at about XXI I.1/2 o'clock more or less it was noticed how the sea slowly retreated, returning 10 minutes later to its level which it crossed after 4 feet above the highest tide marks. The rising and falling movement of the sea was repeated for three hours and several vessels were damaged (G.).

Huasco. - At dawn, eddies were noticed in the waters of the bay, and at about 8:00 a.m. the sea lowered about two vertical meters, and a swelling came in immediately that did not cause any harm, remaining very calm afterwards, as in ordinary times (V. G.).

Coquimbo. - At 10:37 P.M. it was noted that the sea was retreating, albeit slowly, fleshing out an extension of 8 to 10 meters, after which it returned to its place, rising little by little more than 1.5 meters above the ordinary level of the full tide.

Throughout the night from the 9th to the 10th a small up and down movement was noticed, which took place regularly between 5 and 15 minutes, with the sea rising and falling to a little more than one meter, producing a strong undertow that lasted until the morning of the 11th, when everything returned to its normal state.

With the exception of the corvette of S.M.B. "Amethyst", which was on the tug, all the ships in the port had 110 meters of chain at the bow to the N. and the same at the stern. Due to the effect of the undertow produced by the ebb and flow, they loosened their moorings a little until the vessels were four quarters of the way out. Only the Guatemalan boat "Palatine", which was anchored close to land in the S. corner of the bay, cut the grating, being the only incident that occurred in the port (V. G.).

At about XXII.1/2 o'clock the cry was heard: the sea is retreating! It retreated far away and when it returned it climbed until it reached the middle of the parade ground. At XXIII o'clock it retreated, with great violence. The movement lasted until 1h of the 10 and the sea was already rising and already lowered of about two meters (Mercury of the vapor N.° 542) (G.)

Valparaíso. - On the following morning a strange movement was noticed in the port which continued until the 11th. (Report of the German Consul) (G.).

In addition, the sea was in continuous up and down movement every 15 minutes, rising and falling 2m.2 between the ebb and flow, which gave an excess over the ordinary full tide of 0.7 meters. This phenomenon continued until the afternoon of the 11th (V. G.).

On the 10th and 11th, advances and retreats of the sea were noted in the harbor waters at intervals of 10 to 15', the ebb and flow rising and falling about 2.20 meters (Report of the German Consul) (G.).

Juan Fernandez Island. - No movement was experienced at sea, as he was able to verify in the port of San Juan Bautista. Only on his return to Valparaíso did he learn of the earthquake (Report of the Captain of the frigate Chacabuco).

In the absence of observations made in the port of San Antonio, which at that time was not yet authorized, we have the following made at sea a short distance away.

The Nicaraguan boat "Aguila", according to its captain, says that on May 11, being off the port Nuevo de San Antonio, 20 miles away, he noticed a strong current in the sea from N. to S., which dragged him 50 miles to the S. The wind was south and the ship was heading to Valparaíso (V. G.).

The same as on the occasion of the tidal wave of August 13, 1868, many good observations were made in the ports of southern Chile.

Consitution. - The sea began to withdraw slowly at about 11h. 15m. P.M., returning the flow 20 minutes later, with great noise. It was, therefore, the first flow at 11h. 35m., and the second a few minutes past midnight, and about 12h. 15m. A.M. of the 10th.

A third flow, quite large, was verified at 5:00 A.M. on the 10th, when the full tide of this day was supposed to take place at 11 in the morning. The ebb and flow were many on the 10th, 11th and 12th. Small ebbs and flows were many on the 10th, 11th and 12th, being already very small on the last one.

When the waters of the Maule descended before the first flow, they produced an extraordinary current, dropping so low that they left the ships in the estuary dry. The flow was also violent, cutting the moorings of several of them, stranding them on the shore or on the island. One of the ships was dragged out to sea, with complete loss of its moorings. All the vessels experienced more or less serious damage (V.G.).

Tomé. - At 12h. 30m. A.M. of the 10th and part of the 11th, ebb and flow were noted in the waters of the sea, repeating the high tides every 30 minutes; the waters rose and fell 1.2 meters more than the tides of Sicily (V.G.).

Talcahuano. - The sea movement occurred at the beginning of May 10, without causing any damage of any kind to the population or the bay.

The first impression of the movement was felt by an ebb of the sea, which broke up an extension of 200 meters, leaving some ships in very little water, others stranded and all the boats dry. At 12h. 30m. A.M. came the flow and rose on the highest tides 1.11 meters and continued in this trepidation every half hour until 3h A.M.; succeeding a slow swell that reached at its maximum height to 1.95 meters, descending accordingly in the same way.

The base of the oscillation added to the Sicilian tide, which reaches 1.78, was 5.68 meters.

The largest flow flooded Rocuant Island (400 meters long), the Talcahuano meadows, and destroyed part of the railroad fence.

The sea remained in a repeated oscillation of less than 1 meter for three days until it returned to its ordinary level (Report of the maritime governor. (V.G.))

The phenomenon was more or less identical in the bay of Concepción (V.G.).

Coronel. - At 8:30 on the night of the 9th, a small earth tremor was felt which, judging by the small number of people who felt it, must have been almost insensible; but at dawn on the 10th, between 2 and 9 a.m., the sea showed a succession of extraordinary ebb and flow. The sea was rising and falling 1.21 meters more than in the high tides and major low tides of the year. Each of these movements of rise and fall of the sea took about 50 minutes, repeating 4 consecutive times and reaching a difference in level of 3.03 meters. In addition, on the following days (11 and 12), the ordinary tides took place with a notable undertow, the sea rising more than usual (Report of the maritime subdelegate).

It should be noted that the bay of Coronel is open from the W. to the S.W., while that of Concepción is open to the N.

Lota. - On the night of the 9th, at about 11h. 30m. P.M. an extraordinary movement was noticed in the waters of this bay that was prolonged until 12⁽³⁾ of the dawn of the 10, hour in which the sea was collected 60 meters more or less with respect to its ordinary descent (desplayó), leaving stranded part of the smaller boats that were anchored 15 meters off the pier, remaining in this state during 20 minutes. After this course of time, it came out with great force, extending the waves up to the front of the office of the tenancy of customs, tide that went out about 30 meters to those that are noticed ordinarily; it is to warn that in the mementos in which this incident happened, a very strong and very strange noise was felt that produced great alarm in the neighborhood of the port.

The phenomenon was noticeable until the 11th, with only the difference that the full and low tides followed each other at intervals of 40 minutes and were not as alarming as those that took place the previous days. (Report of the manager of the Customs. V.G.)

Although the Lebu inlet is open from the north to the southwest, it seems that the tidal wave was not felt, no doubt because it is very far inland.

However, the rough seas experienced on the 11th, 12th and 13th can be attributed to this phenomenon.

In the port of Lebu and in the neighboring coves no extraordinary tides have been noted. The undersigned has his office and house on the margin of the river and port, from where the high and low tides are accurately observed, the house being located

⁽³⁾ Typo: until 2 of the dawn, in accordance with Vidal-Gormaz, 1878.

only five decimeters higher than the level of the highest tides of the living waters. This proves (he refers to the dawn of the 10th) that there has been no rise of the sea in this port, nor has there been any low tide other than the natural one; another proof I can cite, and that is that in the port (Caleta de Balleneros) all the barges and boats are beached on the beach, securing them from the high tide, and none of these vessels have noticed any alteration, so that the sea has not experienced movements that coincide with the phenomenon of the North.

On the 11th, 12th and 13th a very rough sea was experienced along the coast and in the port, so much so that on the 13th it cost me a great deal of work, even exposing my life, to pass the visit to the steamer "Limari", which took the cargo and passengers that were bound for Lebu, because it was totally impossible to carry out any boat traffic operation. (Report of the maritime subdelegate, dated June 4).

Vidal Gormaz attributes the following two shipwrecks to the tidal wave, but does not give explicit evidence of the fact.

A Chilean barquichuelo, of the size of 25 tons of registry, and trip from Carrizal Bajo to *Río Toltén*, ran aground in *Trehuin* beach, suffering total loss. The crew was saved on land, but the information does not advance anything about the evidence of the shipwreck.

Buena Esperanza. Chilean sloop, of the size of 30 tons of register, of the traffic of the coast of Arauco; in trip of the Lebu river for the *Tirua* creek, beaten by a strong wind of the north, ran to the south and went to run aground in the mouth of the Mehuin river, where it suffered total loss. The castaways were saved on land.

In the bay of Queule, a great tidal wave occurred on the 13th, a date insisted upon by the author of a letter to the newspaper "La Republica" of Santiago. This delay of three days seems all the more strange that in Corral, a port further south, the abnormal tides were observed from the 9th.

Being the day (the 13th, and note well) in complete calm, with nothing to indicate what was going to happen, suddenly an immense wave was formed that threw itself with resounding fury on a great part of the coast of Queule, bathing in an instant about four blocks (500 meters) of the shifting sands of that part of the coast (coast E. of the inlet of Queule), that transformed them completely. But as soon as the first wave was unwound, a second wave, more powerful than the first, resembling a very high mountain, poured gently and gradually over the beach and neighboring fields until it covered twice as much land (1,000 meters) as the previous one; so that it narrowly missed entering the Queule River, which flanks the sandy beaches near the Mission.

All this happened with astonishing speed; it took only a few moments, just minutes, for the waves to come out, spread out on the immense beach and return to their natural limits.

After the event, the sea has been in continuous and unusual ebb and flow, with strong currents in different directions every quarter of an hour.

As you will understand, such an attitude of the ocean has produced a deep sensation in all the inhabitants, in the expectation of a probable cataclysm, from which we would have no time or means of salvation.

The Indians, above all, are the most strongly impressed, as they say they have never heard or know that their ancestors witnessed anything similar to this extraordinary phenomenon.

About the tidal flush that could have been felt on the 10th, 11th and 12th, the inhabitants of the port of Queule do not tell us anything, in spite of having inquired with determination; and it should be noted that Lebu experienced a rough sea that began on the 11th.

Corral. - The tides in this port, from the 9th to the 12th inclusive, have had an almost continuous alternating movement of elevation and depression, the difference in level being 1 meter, with the exception of the 10th which was 3 meters. On this day of depression, in the inlet to the S. of the port, whose topography is completely low, the sea came out to a distance of 200 meters outside its ordinary limit. (Report of the maritime governor).

The tidal wave was observed in the Valdivia river up to the city of the same name and also in the Angachilla river.

On May 11, the city of Valdivia witnessed a phenomenon whose cause no one has been able to investigate so far.

The Valdivia River was in continuous and strange movement all day. It looked something like the prelude to a terrible terrestrial oscillation.

The Valdivia would rise at times and then widen to overflow its waters. The same thing was noticed in the Corral and the Angachilla rivers.

According to what was known a few days later, at the mouth of the Rio Bueno, at 40°11' S. latitude and 73°41' W. longitude, such a rough sea developed that it prevented for several days the departure of the steamships from the traffic of that and the port of Corral. ("La Verdad" of the 13th. V.G.)

Ancud. - On the night of the 9th, from 11h. P.M. until 3h. A.M. of the 10th, the ships in the bay noticed a great extraordinary and variable current that caused the ships to drift from N. to S. from hour to hour.

On the 10th it was noted at the pier that from 11 to 12 o'clock the tide rose and fell three times. (Report of the maritime governor).

The sea on the night of the 9th, from 11h. P.M. until 3H. A.M. 10, was in constant boiling; it seemed like a huge cauldron of boiling water: the tides rose and fell every hour, making the ships bale abruptly.

The captain of the national boat "Enriqueta Wilver" observed that during that time the current from the N. was extraordinary, inclining to suppose that perhaps it reached 10 miles per hour. His vessel turned five times from N. to S., in the upwelling, with great speed, fearing that at times the mooring lines would be broken, such was the violence.

The wind at the time was blowing from the N. and at 3H. A.M. on the 10th it hovered to the NW, then calmed down. The barometer showed variable weather.

The agitation of the sea lasted until the 12th at 1h. P.M., at which time the sea acquired its normal calm. (V.G.)

Puerto Montt. - Little movement of the sea was noted (G.)

Chiloé Archipelago. - In the interior of the Archipelago some irregularities were noted in the waters on the 10th. (V.G.)

It is not possible to deduce from the following observations that the tidal wave would have been felt as far as Punta Arenas.

Punta Arenas. - On May 17, the sea rose 75 centimeters higher than during the Sicilian tides and the phenomenon is attributed to the continuity and strength with which the SW winds had blown. In the previous days. (Report of the maritime governor. V.G.).

During the month of May and until the middle of June the captains of the steamers of the race noticed great agitations and currents of the sea along the coasts of Peru and Chile. According to our opinion, Vidal Gormaz lacked evident proofs to have these more or less abnormal phenomena as a direct consequence of the tidal wave of May 9. It says thus:

The South Pacific Times of Callao, after reporting the shipwreck of the English steamship "Eten", adds the following: that it justifies the currents and phenomena that occurred in the sea due to the earthquake of May 9 no less than the duration of those.

Captain Mills of the English steamer "Lima", says that during his last voyage from Valparaiso to Callao he experienced an extraordinary current that dragged the steamer towards land. This forced him to change course several times to get away from the coast. On the previous voyage he left Islai at the usual time and set a course N. 69° W., with which he calculated to pass 5 miles outside Punta Atico, and having sighted said point he noticed that he was going over land on the inside of said point.

He had to change course 21° to the W. in order to avoid the danger.

During his travels after the May 9 earthquake, he observed strong currents that pulled him ashore so violently that it was essential to be constantly vigilant, changing course to avoid the rocks.

It is to be believed that the captain of the "Eten" did not observe this phenomenon in a timely manner, and since the night he left Valparaiso it was raining and there was a heavy fog, he could not see the land towards his ordinary course and the current we have mentioned attracted him towards the rocks of Ventanas Point.

None of these conjectures remain if one looks at the logbook of the steamer "Lima".

Some other commanders have observed the same current, and even if it is still uncertain whether this phenomenon will continue, it would be advisable for those who have had the opportunity to observe it to take note of what has been said in order to proceed with certainty.

In almost all the ports between Callao and Valparaiso, Captain Mills says that the sea has been very rough.

On June 15 the steamer "Lontué" could not communicate with land. The passengers going to the S. had to go to Pisco in Lima, to wait there for the S. steamer.

The sea was so rough at Chañaral that the boats could not hold alongside the steamer. This agitation did not have the same appearance as on other occasions, as it came in different directions and with violent and irregular movements.

In summary, the tidal wave of May 9, 1877 was felt along the western coasts of South America from Gaviotta (California) to the Chiloe archipelago, whose latitudes differ by 78°, i.e. a quarter of the earth's circumference if the inclination of this line with respect to the meridians is taken into account.

C. Observations on the western coasts of the Pacific (From New Zealand to Japan).

Most of these observations are due to Geinitz who collected them as painstakingly as von Hochsteter had done for the tsunami of August 13, 1868.

Chatam Island. - On the night of May 11, Mr. TH. Ritchie noted a tremendous surge of flow that nearly inundated Old Jamies and washed away Waitangi Bridge.

According to other information, the sea did not rise as much as in 1868.

New Zealand. Dunedin. - The difference in sea level between the high and low water reached 18 inches to 5 feet.

Port Chalmers. - The tidal wave at dawn (of the 11th) was noted, bursting the sea a few feet above the beach, a movement that lasted all day.

Oamaru. - The waters rose and retreated noticeably at intervals of about a quarter of an hour. In the early morning (of the 11th) at low tide, the level came out suddenly and within 10 minutes reached 1 foot above high tides. These flows continued throughout the morning. About noon the sea invaded the bay with frightful violence, destroying the piers in spite of their solid construction, retreating in a few minutes with terrible currents and whirlwinds which at XII 1/2 ceased almost completely.

Timaru. - Shortly after VII o'clock on the 11th the first surge was observed and from then until late in the afternoon the sea rose and fell alternately and rapidly, reaching 3 or 4 feet in level change.

Akaroa. - All day (11) the sea was very rough, and at 1 o'clock large swells began to rise several times at five-minute intervals. At III o'clock they had their greatest height, or that of 10 feet above the highest tide marks, with which all the houses on the coast were inundated. These disturbances ceased at XVII.

Le Bon's Bay. - An extraordinary flow occurred at VII o'clock and was interpreted as a sign of a great earthquake at some unknown point. The swell came in the form of large, long waves which then receded so rapidly that from the shore it was possible to descend into the harbor bottom. About midday a wave came with such violence that it knocked down two tramway bridges, carrying away portions of one of them. Throughout the day, numerous waves flooded the land. At midnight, time of the normal full tide, there was another wave that did not fail to cause some damage. The phenomenon continued on the 12th.

Pigeon Bay. - Manowara (Bay of Islands). On the 11th at V o'clock, an extraordinary receding sea was noted. On the night of the 10th P. Me. Alister had moored his boat in an inlet of the shoal and on returning on the 11th at V o'clock, found it dry to a great distance even though it was long past the time of full tide flow. As he waited, he heard a rumble of thunder and saw a huge wave approaching... Then the sea went down again with great rapidity. Some Maoris from the Bay Islands noticed that at V o'clock the sea had risen 8 feet in a few minutes. From then until late in the afternoon the sea rose and fell alternately at intervals of 20 minutes. (Report of Captain Edwin; Proc. of the Wellington Phil. Soc. 21 Jul. 1877).

Lyttelton. - The first surge took place at IX.5 on the 11th (New Zealand mean time), the movement being started by a rise in the flow, reaching a height of 2 feet 9 inches at that time. At X.10 the sea began to subside and its level dropped to 2 feet in 9 minutes. The ebbs and flows were repeated every 10 minutes until XVI or XVII o'clock, at which time the sea returned almost to its normal state of motion. At the time of half tide, i.e. about XI.1/2 o'clock, the sea then had its greatest height, or that of 18 inches above the tides of the highest spring full tide marks, its level having risen 9 feet 6 inches between IX and IX.1/2. (Communication from Mr. Webb to the German Consulate at Christchurch).

The following list presents some discrepancies with the previous one.

At VII o'clock it was noted that the sea, very rough and turbid, invaded the port with extraordinary speed, leaving its level of 18 inches in 7 minutes. At about IX o'clock it was rising and falling by 3 feet at every 3 minute interval and later by the same height at every 9 minutes. At about X o'clock and in the hour of the half tidal flow, it rose in a very short time from 6ft 9 inches to 11 ft 9 inches and at X.40, in 5 minutes it dropped from 14 ft 9 inches to 13 feet. At noon the disturbances decreased on the approach of the full tide which took place at XIV o'clock, the water remaining very muddy. Two hours after the full tide, or about XVI o'clock the level being 16 feet, the sea began to fall rapidly.

Kaiapoi. - On the 11th there were flows that entered the Waimakariri River; they did not attract attention because the waters were very calm. The city is located 3 miles from the mouth of the river and the biggest wave rose with a speed of 6 miles per hour up to the suspension bridge that is located halfway, but without causing any damage. The first wave occurred at about VI o'clock and three others followed until VII o'clock, the movement continuing until midday with longer intervals. The sea remained very rough throughout the morning. At noon on the 12th there were two other consecutive waves that entered the river and whose waters presented strong currents throughout the afternoon of the same day.

Cook Strait. - The flows were very noticeable and the waves traveled from S. SE. Although according to Captain Lloyd's testimony the first one would have come from the W.

Western coasts. - The tidal wave was not felt except in the Buller River (Westport).

Wellington. - Shortly before VII, about three parts of the tidal flow, an extraordinary flow was noticed. Suddenly there burst into the bay an enormous mass of water which caused a great movement under the vessels; in a quarter of an hour the flow had reached the level of the most ordinary high tides; then receded the sea with the same rapidity and 15 minutes later reached the signal of the lowest tides.

From this time on, flows occurred at intervals of 8' before VIII, 10' before X, with the level change being 5' and 2' respectively at VIII and X. At midday the difference in level did not exceed 1 foot with an interval of 7' between flows. All day these disturbances continued and there were between VII and XV about 20 departures and withdrawals from the sea.

Gisborne (Poverty Bay). - During the night of the 11th, a great movement of the sea reigned; at III hours and 3 quarters of the tidal flow, there came in the bay a wave which rose 8 feet above the hull of the Go. Ahead and caused in the river a sudden rise of 3 to 4 feet. About IX.30, a second wave invaded the river and at IX.45 another followed almost immediately afterwards by a fourth. The sea was very choppy in the bay. (G.)

According to the harbormaster's observations, successive large waves followed VII, IX, XI, XII.40 and XIV.30 (Wellington mean time).

Tauranga. - The flow took place at VIII o'clock on the 11th, raising the water 3 feet above spring tides. Then a sudden drop in level happened in a short time and the phenomenon was repeated all day.

Auckland. - The height of the first flow reached 7 to 8 feet with a duration of 7 to 8' or so. Subsequent waves did not exceed 3 ft.

Russel. - The flow rose from 6 feet.

In almost all ports the tidal wave began by an outflow from the sea and only in Wanganui by a backwash (Letter addressed by Mr. E. B. Dickson to the German Consul in Auckland).

Australia. - On the coasts of Australia the tidal wave was noticed only in the ports that did not protect the interposition of other lands or other islands such as New Zealand, and for example if it manifested itself on the southern coasts of Queensland or the Victoria colony, it was to such an insignificant degree that it did not attract attention.

The waves were observed at several points between the 37th and 23rd parallels.

Fort Denyson Sidney. - At V.20 o'clock on May 11, the tide gauge curve was disturbed by a sudden wave which began by a surge, the same as in 1868. Shortly before VI o'clock, it was followed by a second wave of much greater height and a third one formed at VI.35 with a very rapid flow; 15 minutes later there was a third much smaller one with a great backwash which was interrupted by several smaller waves even at VII.30. These waves continued for a long time in the same way with somewhat irregular intervals; for example between XII and XIII.1/2, at XIV more or less with

the flow of the tide and at about XVIII, etc. Their height progressively decreased and they ceased completely on the 13th. On the tide gauge curves, some indentations corresponding to the waves were observed, but they are not enough to hide the ordinary "sinusoidal" shape of the lunisolar attraction tides. The deepest slack below the two-foot line appeared at II.1/2 and XIV of 13 and III.1/2 of 14. Flows greater than 6 feet in height occurred at XX of 11, XIX.1/2 of 12 and XX.1/2 of 13, alternating with those of lunisolar origin in such a way that the latter appeared as accessories relatively to the former.

Newcastle. - According to the tide gauges, the sea movement also began with a surge at V.20 on the 11th. After a very rapid ebb, three waves followed, the first two at an interval of 40' and the fourth 20' or 25' later. It grew in height until the third, the height of the fourth being equal to that of the first. Then an even deeper ebb was followed by a fifth wave. The sixth wave occurred after VIII and three notches in the sea level records corresponded to interference waves. Several of the following flows also present disorderly rises. In this port two waves greater than 6 feet followed the XIX of the 11th and XX.1/2 of the 12th, comprising between them a full tide, whose height did not exceed the ordinary lunisolar tides. The lowest ebb measured only 11 inches above zero of the scale and occurred on the 11th shortly before noon. (Report by astronomer H.C. Russel. Sydney).

No observations were made at ports in the lands between Australia and Japan.

Japan. Yeddo. - On May 11 the full tide was supposed to occur a little after XVI o'clock, but having already lowered the level by about 1 foot, the sea suddenly rose again by two feet.

Then the inhabitants of the shores of the sea and of the river, being amazed by the phenomenon, did not hesitate to think that an earthquake was approaching. The general fear was intense until the water level began to drop (Letter from E. Naumann. G.).

Yokohama. - The flow occurred suddenly and everyone feared it was the prelude to an earthquake.

Kadzusa. - On May 11, the fishermen were full of joy as a result of a very abundant catch, when suddenly, at about 12 o'clock, big waves invaded the beach and carried away the fish and the nets, frightening the people very much. Shortly afterwards the sea calmed down and the fishermen returned to fishing. At about sixteen o'clock the big waves were repeated, and many people drowned, except for those who fled hastily to the neighboring hills. There were numerous victims and wounded, but no one perished in Kitaidzumi. (G.)

Toshu. - From the 11th to the 15th, the ebb and flow of the sea was disturbed and large swells were observed from time to time.

Kamaishi. - Between IX and X on the morning of the 12th, the flow rose so rapidly in the bay that the villages on both sides were flooded and their inhabitants had to flee to the hills. The waters came down with the same speed. At about XII and again at about XIV, the phenomenon was repeated, each time with little pause until between XVII and XVIII the sea was rising and falling 10 feet every 5 minutes. The exact end of the phenomenon was not noted, but the sea was calm at midnight. During the whole time of the tidal wave, the ocean was calm as a mirror. (Letter from E. Knipping. Geogr. Mitth. 1877. 394. G.)

Mori-Oka (Rikiuchiu). - The Kitagamigawa riverbed had risen the previous day when the sea rose 10 feet higher than usual on the 13th.

Hakodate. - On May 14 at about XI.30 or so the sea suddenly went down very deep, rising again 10' later, and throughout the afternoon it continued to rise and fall alternately at intervals of 20'. The waves reached their greatest height between XIV.30 and XIV.35, and inundated the lower part of the town. After XV, the ebbs and surges progressively diminished and by sunset the sea had completely subsided. The greatest difference in level between the ebbs and flows was 8 feet, with each movement occurring in a time of 10'. (Japan gazette and Hiogo News. G.)

D. Observations made in Oceania.

Only negative information is available from the island of Taiti. On the contrary, the tsunami was disastrously felt in the Marquesas Islands archipelago.

A well-characterized tidal surge has hit the shores of Nukahiva. Fortunately it was not very strong in Tahio.ac.

On the 10th, at about 4 a.m., the sea, otherwise calm, left its bed and advanced to the beach path, which it completely covered. It then retreated until it left a space of 20 meters beyond the last piles of the pier dry. At once there was an oscillatory movement. Suddenly the sea was very low, suddenly very high. This back-and-forth motion lasted all day. The average difference in level is estimated at about 4 meters.

The tide has been more violent in Anaho, in the NE part of Nukahiva, where it has caused damage. Of Nukahiva, where it has caused damage. Several European buildings, including a house belonging to M. Hart, were swept away by the sea, which went 200 meters into the land. The employees of M. Hart, awakened with a start, barely had time to run to the mountain.

This extraordinary movement of the sea has been felt, it seems, throughout the archipelago and with different characters.

Thus in Vaithan and Pauman no oscillatory movements have been observed, as the sea has been very low all day (May 10) (Messenger de Taiti. June 1, V.G.).

The phenomenon was of great proportions in the Sandwich Islands.

The great tidal wave of May 10 was felt simultaneously throughout the Sandwich Islands group (The Honolulu advertiser. El Deber de Valparaíso of July 18. V. G.).

Hilo. - On Thursday, May 10, at 4 a.m., the sea was seen to rise in an unusual manner; at 5 a.m. a huge wave formed and flooded almost all the warehouses in front of the city, carrying away a large quantity of lumber and the entire stone wall of the Makai seawall. The vertical height of the wave, as later ascertained, was 3m. 317⁴ above low tide. In Wahakia the damage was terrible. All the houses were thrown 91 meters from the water. The landing stage and the steamboat hut, the upper hut, the bridge and all the dwelling houses form only a mass of ruins extending far inland. One hundred persons died and many others have suffered mutilations and contusions. The body of a woman was found along the Hoolii. The boats of the whaler "N.A. Pacific", Captain Sonthers, anchored in the roadstead, picked up 6 persons at the time of drowning in the bay. The "Pacific" was anchored in 7.28 meters of water; she was found dry when the sea invaded the beach and when she returned it made her turn over several times on herself.

All day the sea has done nothing but rise and fall... The water has completely flooded Coconut Island, whose hospital has disappeared. (A private letter, V.G.)

Kahului (West Maui Island). - On May 10 at about IV.3/4, the fishermen in the bay noticed a receding sea that left the entire harbor bottom dry; then the sea returned with great rapidity and rose 4 to 5 feet above the high tide signals. A second wave not as high as the first, and a third, even lower, preceded the fourth, almost equal to the first. On the 12th the sea was still rising and falling, but more calmly.

Kauai Island. - The tsunami was also felt.

Honolulu. - (Oahu Island) On May 10 about V.20 it was noted at the docks that the flow was moving with great velocity and thanks to measurements taken by pilot Babcock, it was noted that the level dropped 21 inches in 5 minutes. About VI o'clock the sea returned and rose 34 inches in 10 minutes. All day and into the following night these rising and falling movements continued, but with decreasing intensity. The greatest difference in level between ebb and flow reached 58 inches in the morning. According to the harbor master, the greatest low took place at VII.1/2 and the highest rise at VIII.32 with a maximum total drop of 4 ft. 10 in. (G.)

Larger slopes in various harbors: Hilo; 36 feet - Kealakekua; 30 - Kawaihae; 5 - Kahului; 22 - Haena; 12 - Honolulu; 4 to 10 inches - Nawiliwili; 3 feet. (Hawaiian gazette. G.)

It will be noted that there is a large discrepancy between the latter information and the preceding one regarding the amount of maximum slope in Honolulu harbor.

Apia. (Upolu Island, Samoa).

The tidal wave took place at V.1/4 or V.1/2 on May 10 (local time), but it was not noted whether it started by an outflow or a retreat of the sea. The main oscillations occurred at intervals of 10 to 15', the fourth being already minor. The movement of

⁴ This number refers to an indication by Vidal-Gormaz, but with a mistake. The original is 3^m, 713 (not 3m,317), probable conversion from the 13.5 feet measured by Mr. Severance (cf. Geinitz).

the sea lasted all day, but was gradually decreasing. By means of the traces left by the water on a post placed on the sea shore, it was possible to assess the rise of the water level at 49 English inches above the ordinary high tides or 35 above the spring. It was not observed which was the greatest surge.

From IX.1/2 o'clock on the 11th (time of low tide) a tidal wave occurred, the greatest oscillation of which took place at about VI o'clock and with a height of about 12 feet. The phenomenon was repeated every 10' and lasted still at VIII, with an unevenness of 5 to 6 feet, being already the lowest speed of the ebb and flow. These movements continued until about noon with noticeable lessening. There were no casualties. (Report of the German Consulate).

Additional note

The Iquique earthquake is of remarkable interest in the history of general seismology. It produced, in fact, abnormal oscillations in the levels of the meridian foresight of the Pulkowa observatory and then the Russian astronomer Magnus Nyren rightly attributed them to a remote earthquake. For the first time, then, it was experimentally demonstrated that a great seismic phenomenon vibrates the entire land mass and that the waves of a tele-earthquake propagate to the farthest points of the surface of the globe. In this case Pulkowa's telescope functioned as a micro-seismograph.