

ABSTRACT  
OF A  
MEMOIR  
ON THE  
EARTHQUAKES IN THE ISLAND OF LUZON  
IN 1880.

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## SECTION I.

## GENERAL OBSERVATIONS AND EFFECTS.

## I

*Description of the Earthquake in Manila.*

Since the remarkable catastrophe of 1863, which destroyed its principal buildings, burying under them many victims, this capital has enjoyed a relative rest which has been improved to develop the wealth of the country. The shocks of 1869 and 1872, not being accompanied by disastrous effects, did not retard this prosperity, and all who had lived here since that time saw with the utmost satisfaction the rapid progress which during the last ten years had been made in commerce, navigation, industry and even in the arts; but this lively satisfaction was embittered from time to time by the recollection, the sad tradition, the quasi geological law, that from the conquest down to our days these phenomena at intervals of ten or twenty years neutralized by their fearful consequences the progress made in the mean time.

On the fourteenth of July 1880, at 12.53 at night, the first shock happened, and this, although short, was the most severe which had been experienced in Manila for several years. The motion was found to be in two directions, nearly at right-angles with each other, the first from South-east to North-west and the second from South-west to North-east, which seems to indicate the existence of two distinct foci of equal intensity of action, one in the second quadrant and the other in the third, since the amplitude of the oscillations recorded on the horizontal seismometer at the meteorological observatory of this capital were respectively  $5^{\circ} 25'$  for the first, and  $4^{\circ} 58'$  for the second. Figure 1, which together with the four following are taken from the publications of Father Federico

Faura, S. J., Director of the Meteorological Observatory, shows clearly the directions and relative intensities of the horizontal motions.

There was also in this earthquake some movement in the vertical direction, as the vertical seismometer moved through four millimetres of its scale.

Within an hour and a half after the first shock two new shocks were felt; these in Manila were unimportant, but in other places, as we shall see further on, they were more considerable, as in the provinces of Laguna, Morong and La Infanta, where during that night and the following day the recurrences were more frequent and the effect on buildings greater.

After this first shock, which, without producing great alarm in the vicinity, doubtless served as a salutary warning to take precautions which avoided greater misfortunes in the following shocks, the ground remained undisturbed during the 15th and 16th. On the 17th two slight shocks were again felt, which, although feebler than those of the 14th, indicated that the ground was not yet at rest; and indeed at 12.40 P. M. on the 18th, the fearful phenomenon was repeated in all its intensity, and in 70 seconds, which seemed however interminable, tumbled down a large portion of city and terrified the inhabitants, who, losing the innate confidence in the soil on which they stood, felt under their feet a force invisible, immense, mysterious, which in sepulchral silence with terrible might destroyed in a few seconds the work of many years, and threatened them with an instant and strange death. The inundation which rolls forward and engulfs thousands of people; the lightning which causes such terror and destruction with its thundering explosions and phosphoric light; the grand volcanic paroxysms with their flames and their showers of burning ashes which bury great tracts of country, and with their rivers of lava which overwhelm and destroy everything in their paths; all these phenomena have a character of grandeur which, while it overpowers the mind, invites it to contemplate them and charms it with their colossal splendor. All these phenomena offer to the imagination an imminent

danger, a death more or less probable, against which however there is always the hope of defending one's self. But the earthquake with its sombre silence, its unknown origin, its sudden and boundless effects, which may be a few cracks in the walls of buildings, or the disappearance of one or a hundred villages with all their inhabitants, this phenomenon so treacherous and at the same time omnipotent overwhelms the mind and leaves an impression never to be eradicated.

The pendulum of the seismograph at the "Ateneo Municipal" traced a line which indicated the motions of the ground, giving a figure so complicated that it is not possible to follow the line in its full extent, and even less to describe the complicated series of motions which caused it. We reproduce the figure (Fig. 2) from which may be seen the principal oscillations with their directions and relative intensities; and we copy entire the observations made and published by the observatory of the Ateneo Municipal on the 19th of July.

"July 18.—Sky covered with cirrus clouds all day; winds constant from the third quadrant; barometer rising; temperature moderate; evaporation 6.1 millimetres.

"*Note*:—At 12.40 in the night there was an earthquake which showed oscillation, trembling and what is commonly called rotation. It is not possible to record here all the movements of the pendulum, owing to their number and variety. To satisfy the desire expressed by many people we reproduce the figure described by the pendulum of the horizontal seismograph, which we think worthy of extended study. Today we limit ourselves however to the indication of the principal directions and amplitudes of the motions, leaving the remainder until the figure giving all the motions has been lithographed:—

"First maximum oscillation=from E.  $5^{\circ}$  S. to W.  $5^{\circ}$  N. Amplitude of the greatest oscillation in this direction is  $22^{\circ}$  in the slope of the seismic wave,  $11^{\circ}$  to the East, and  $11^{\circ}$  to the West.

"Second Maximum Oscillation=from South-west to North-east; amplitude  $19^{\circ}$ , but with the difference that the greater part of the motion  $10^{\circ} 10'$  was towards the South-west, and

the remainder  $8^{\circ} 50'$  towards the North-east.

“Third Maximum Oscillation=from N.  $4^{\circ}$  W. to S.  $4^{\circ}$  E., amplitude  $16^{\circ}$ , of which  $9^{\circ}$  was towards the South and  $7^{\circ}$  towards the North; consequently the impulse appears to have been from the North, towards the South.

“The index of the vertical seismometer was moved 34 millimetres from its position.”

From the time of the heavy shock of the 18th until nine o'clock on the morning of the 19th according to the observations, there were felt many weak oscillations and shocks, all in directions from the South of East to the North of West.

Not only did the oscillations and shocks of little intensity continue until nine o'clock in the morning, the hour at which the observations cited ended, but they continued from that time almost without interruption, some easily perceptible, and others only recorded by the seismograph, until 3.40 o'clock on the afternoon of the 20th, when a new catastrophe came again to try our hearts, already disturbed, not only by the deep impression made by the former earthquake, but because the persistency of the motions and the continued vibration of the soil indicated clearly that under our feet that terrible motor, that mysterious force which in an instant might annihilate us, was still acting.

The violence and intensity of this second shock were greater even than of that of the 18th. And although the amplitude of the oscillation, as given by the record of the seismograph (Fig. 3), did not show as great an angle as the maximum of the 18th, the greater intensity ought to be attributed to this fact, that on the 20th the pendulum after starting was not allowed to finish its oscillation, but was forced to move in other directions without completing its curve on the plate, thus, as is clearly shown in the figure, the lines *aa*, *bb*, *rr* do not mark complete oscillations, but semioscillations. The pendulum, descending to the center of the plate with a velocity which would have raised it to a point almost as high as that reached on the other side, was moved by a force which not only destroyed the motion already possessed by the pendulum, but constrained it to ascend again to a height almost equal to

the first, which in reality represented an amplitude much greater than the  $22^\circ$  that had been recorded on the 18th.

The observations made at the meteorological observatory of the Ateneo describe the earthquake thus:—

“At 3.40 on the afternoon of the 20th strong shock felt; duration 45 seconds. First maximum oscillation; direction from S. E.  $15^\circ$  N., to N. W.  $15^\circ$  S.; amplitude  $17^\circ$ , of which  $8^\circ$  to the N. W. and  $9^\circ$  towards the S. E. Second maximum oscillation from S. E.  $5^\circ$  N., to N. W.  $5^\circ$  S.; amplitude  $12^\circ$ , of which  $5^\circ$  towards the E., and  $7^\circ$  towards the W. The index of the vertical seismograph was moved 22.5 millimetres from its position.”

Some days after the earthquakes, the director of the observatory, Father Federico Faura, published a résumé of the observations in which this description was somewhat modified, as it was pointed out that the amplitude of the second maximum oscillation ought not to be  $12^\circ$ , but that this  $12^\circ$  was the amplitude of a semi-oscillation.

The pendulum continued during the remainder of the afternoon to oscillate in a way which was most disheartening to those of us who know that the instrument showed motions in the earth, although we could not perceive them. At 8 o'clock in the evening one of the vibrations was felt very perceptibly, and at 10.40 occurred the third earthquake with shocks more violent and irregular even, according to the feelings of many people among whom was the writer, than the former ones. Its duration was also greater than that of the earthquake in the afternoon, amounting to 55 seconds, and the vertical shocks moved the index of the vertical seismograph 28 millimetres instead of 24 as in the former case.

The situation could not be more trying; the shocks occurred more frequently; the intensity and violence of the motions increased; and many persons fearing any one of the thousand catastrophes which might happen, sought safety in boats on the river or bay. Considering the topographical situation of Manila, with the bay on one side and the lake *Bay* on the other, menaced thus by these two bodies of water which might in a few minutes inundate the whole low plain

which separates them, in which are placed the most considerable villages of the province, these precautions were very proper.

We give here the observations made with the seismograph of the Ateneo Municipal relating to the last earthquake, and published in the papers of the 22d.

“At 10.40 p. m. on the 20th a very heavy shock. Direction of the first oscillation S. W. to N. E. exactly; amplitude  $17^{\circ}$ ,  $9^{\circ}$  to the S. W. and  $8^{\circ}$  to the N. E. Amplitude of the second oscillation  $10^{\circ}$  from E. to W. exactly,  $5^{\circ}$  to the E. and  $5^{\circ}$  to the W. Duration 55 seconds. The index of the vertical seismometer was moved 28 m. m.”

In Fig. 4 may be seen the record left by the pendulum on the plate; and it is to be observed that, as in the two great earthquakes which preceded this one, the directions from the second toward the fourth quadrant are greatly in excess; so much so in the shock at 3.40 p. m. on the 20th, that this direction alone is observed, and in the last shock the two directions again appear as in the first of the series; with only this difference, that in the former the energy of the motions from the second to the fourth quadrants was greater than that of the motions from the first to the third, and in the latter the contrary was the case.

After this last great earthquake the vibrations of the earth gradually diminished until the pendulum stayed at rest for long intervals of time, a thing which had not been observed from the 18th until 3 p. m. on the 21st. These feeble shocks which were felt at irregular intervals, far from alarming us, rather reassured us, as their intensity became less and less and the intervals between them became greater and greater. Only at daybreak on the 25th a single shock was felt somewhat heavier than these others since the 20th, but this was without notable importance and left on the seismometer the curve represented in Fig. 5, in which only a single direction, that from the first towards the third quadrant, is seen; the direction from the second towards the fourth quadrant, which had been in former earthquakes the source of the most persistent and greatest motions, having consequently disappeared. The

amplitude of the oscillation in this last shock was only  $4^{\circ}$ , and the index of the vertical seismograph was only moved one millimetre.

In the latter part of July there was published, as we have before said, by the Director of the Meteorological Observatory a résumé of the observations made on the earthquakes between the 14th and the 25th of the month, in which after describing in detail the apparatus which had served to make the horizontal and vertical measurements, he proceeds to give an account of the earthquakes which had happened in the provinces in the Northern part of Luzon in the months of April and May, and deduces from the accounts which he had received concerning the direction of the motions, *that the center of seismic oscillation coincides with a volcano which has been for a long time extinct, situated between Lepanto and Abra in the central mountain chain of Luzon, in latitude  $16^{\circ} 22'$  and longitude  $127^{\circ}$  East of the observatory of San Fernando* <sup>(1)</sup> <sup>(2)</sup>.

One would be led to suppose, from the fact that the Director begins his observations in this way, that the earthquakes of April and May, as the Director clearly indicates, continued until the beginning of July, and had a connection with those of July 14—25 which we have just been describing. It will be of interest for us to test in some way the existence of this center of seismic oscillation, of this long extinct volcano situated in the central mountain chain, and marked with such certainty by the illustrious director. We have travelled over the districts of Lepanto and Benguet for some days; we have tried to reach the point which he has indicated by its latitude and longitude; we have taken on the spot notes which we will further along set down on the intensity of the phenomena in the neighborhood of the supposed focus; and we expected logically that there it would have been felt with greater intensity than elsewhere in Luzon. Nowhere have we met any-

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(1) This geographical position does not correspond to any point of Abra or Lepanto, but rather to a point to the South of the latter, and in the center of the district of Benguet.

(2) *Longitude  $121^{\circ}$  East of Greenwich.*

thing to confirm this hypothesis, neither extinct volcano, nor indications of an ancient or modern volcanic formation. There are only found plutonic formations constituting the great mountain chain, metamorphic formations (schists and slates of various kinds), sedimentary, lower tertiary, or perhaps cretaceous formations, and modern alluviums. We learned that the effects of the earthquakes had not been by far as great as in the provinces in the center of Luzon; and finally upon visiting the point which appears to agree, by its situation between the two districts, with the supposed focus of seismic irradiation, which was the high mountain called Dalá cited in various works, and in some of them as volcanic, we met at 1600 metres above the sea-level with magnificent tertiary limestones, which by their presence protest against the theory of a volcanic origin of this mountain, which by a printer's error Father Faura has placed between Lepanto and Abra while it really is between Lepanto and Benguet. In spite of this negative testimony let us not venture to form an opinion on Father Faura's hypothesis before hearing his statements; let us see whether the data which he has used will not clear up our doubts on the subject. We have conferred with him and he has frankly shown us that in proposing this hypothesis he only considered the reports, more or less exact, which he had received from the provinces of the North, and that with them and a map before him he thought he had found the focus of seismic irradiation, which according to our view does not exist.

We have insisted at some length on this point, because the hypothesis is already laid before the public, and by it an important and still obscure problem of geology is solved or professed to be solved, and the author of this hypothesis is such a respectable gentleman as Father Federico Faura. Our silence would have been construed either as blameworthy forgetfulness or as assent to his opinion.

He proceeds in the résumé to analyze the different figures which were drawn on the seismograph by the pendulum; he then gives some reflections on the various foci of seismic irradiation, on their positions and on the changes which these

foci have undergone from one earthquake to another; and he concludes with the following paragraph, which we transcribe because it condenses the important part of the observations:—

“We will now review, and fix what the figures tell us. In that of the 14th, which is the one which is numbered 1 in the first plate, we note two centers of seismic irradiation, one in the second quadrant where the earthquake began, and the other in the first quadrant where it ended. On the 18th we again find the two foci just mentioned, but other new ones appear, which drive the pendulum in all imaginable directions, as may be seen in Figure 2, plate 1. The record of the earthquake of the afternoon of the 20th, in which it may be observed that the focus of the second quadrant is working with wonderful violence while the others have disappeared, is given in Fig. 3, plate 2. Now we will examine Figure 4 plate 2 which shows the fearful shock of the night of the 20th; we notice a very great change with regard to the foci of seismic irradiation; the oscillations from East to West, which correspond to the focus which was working before with so much violence, are gradual and of much less intensity; on the contrary, those from N. E. to S. W. show a great force of undulation from these points. Finally let us observe Fig. 5, plate 2, which shows the last important oscillation at daybreak on the 25th; it will be seen that only the focus in the first quadrant now appears working with very slight intensity, the other foci disappearing completely. We will not now try to deduce any consequence of the results thus far pointed out; we have only wished to point them out in order that they may be studied by others for themselves without being influenced by our opinions.”

It is much to be regretted that the learned Jesuit, who at the time of the earthquake was always beside his instruments in an observatory perfectly supplied with scientific instruments of all kinds, to whom were immediately sent all the official telegraphic and postal notices on earthquakes from the provinces, in order that with them, with his instruments and with his science he might obtain some result from their study; it is lamentable, we say, that that scientific gentleman left some

days without seeking to deduce the consequences from his observations, only indicating the facts observed in order that investigators who had no instruments, no observatory, no time at those sad moments to devote to scientific speculations, might consider them without being influenced by the opinions of Father Faura.

If, as we believe, and as appears from his own words, he had formed an opinion concerning the phenomenon, although not exact yet with some foundation, he ought to have published it, even though it might have been with the reserve which in this kind of studies, so new and complicated, ought always to be claimed; and in so doing he would have rendered a service to science, which today uses all kinds of observations, however insignificant they may be, to deduce from them some valuable result. The Scientific Commission recently created in Zurich under the direction of the learned Prof. Albert Heim to study earthquakes, begins by recognizing its ignorance on this class of phenomena, and invites all persons interested in science, not only in that nation but in the whole world, to collect and send to the commission facts and opinions, however unimportant they may seem; and it carries its kindness and good intention even to the point of printing and circulating most detailed interrogatories, so that those who wish to contribute to this grand work may do so with greater facility and certainty. If that commission asks aid from the whole world, with what gratitude would they have received the deductions, the result of the studies on the Luzon earthquakes of July, made by Father Faura. For our own part, we must declare freely that we should have had much greater satisfaction in following the opinion of Father Faura if it had convinced us, than in sending out, alone and unguided by Father Faura's theories, our own opinions full as they are of doubts, reserves, and vacillations.

## II

### *General Remarks on the Effects produced.*

It is truly wonderful that with such violent shocks in all directions, with such great movements as were experienced

during the three great earthquakes, there remained standing in Manila a single building of rubble masonry. We freely confess that after the earthquake of the 18th we expected to find the town in ruins; and we could not explain the good condition of all or almost all these masonry buildings. They were without apparent injuries; although in very bad repair, their walls falling to pieces, their frames rotten, the partitions broken or tumbled down, yet they were standing and without being notably or even very perceptibly out of line.

We were equally surprised after the shocks of the 20th, especially as the buildings had already been shaken; but the effects were not as great as we all expected they would be, bearing in mind that some of the oscillations had amplitudes greater than  $22^{\circ}$ , and that the index of the vertical seismograph was moved 34 millimetres, and considering the energy which these motions indicated.

It would be too long a task to describe all the effects of the earthquakes on buildings; and further, as the only object of such a description would be to determine the direction and nature of the motions, which we already know with great certainty from the records of the seismometer in the observatory, we have thought best to omit this description. Those who wish to investigate this subject, can find it given with minute details in the reports made under the Inspectorate General of Public Works.

We shall then limit ourselves to a few general considerations, which may, if we are successful in presenting them, be found useful in reference to future constructions in Manila, with regard to the methods of erecting buildings, as well as to the sites chosen.

In the first place, and as a general rule, it is worthy of notice, that the greater part, if not all, the cracks which have opened in the ground, the upheavals of the surface, and even the depressions which have been observed in some places, have always taken place in the vicinity of rivers, or estuaries (marshes) or the sea. We have confirmed this, not only in Manila, but in various other places in Luzon, and we have always found that this class of phenomena present themselves

in the neighborhood of old watercourses or of those formed by recent inundations, where the sudden shocks produce in the superficial and, so to speak, spongy formations unequal motions, according to the form and nature of the older formation on which they repose; and consequently cause upheavals, fissures, depressions and perhaps submersion of portions of the soil. On the banks of the river Pasig and the shores of the marshes in the neighborhood of Manila these effects were to be clearly seen; and it may be set down as a general rule that the buildings situated in the immediate vicinity of these bodies of water suffered much more than those further away. A good example is the suburb San Miguel on the right bank of the Pasig, which is composed mainly of well-built structures, and which suffered much more than other suburbs further from the river, whose buildings were badly built and out of repair. In the Palace of Malacañang, the residence of the governor, situated close to the same river, besides great damages caused by the three great shocks in the old part of the edifice, a fissure two centimetres wide and approximately parallel to the watercourse was formed, causing the fall of a great part of the masonry wall which ran along the boundary-line of this enclosure. That fissure some 40 metres long, although narrow and probably partly filled by the falling in of its sides, could be sounded to a depth of four metres, which indicates that its depth was much greater when it was first formed; it may be safely assumed that it traversed the whole modern fluvial alluvium, and reached the volcanic deposit which forms the basis of almost all the province of Manila and part of Bulacan.

This recent alluvium may be supposed to be more yielding, more impregnated with water, in short, more spongy in the localities now passed through by streams of water than in dry regions, and that in the former places the sudden shocks of the earthquakes produce irregular motions which give rise to fissures. Through these fissures the compressed water which fills the soil seeks to escape, carrying with it decomposing vegetable materials which give to the water a dark color, a nauseous odor, or sometimes a sulphurous one, producing great

alarm on the part of some persons, who imagine that every fissure is the opening of a volcano.

The same effects which we have just described on the Pasig, took place, but on a much greater scale, in the region of the Grande river in the province of Pampanga (Rio Grande de la Pampanga) which extends from Cabanatuan in Nueva Ecija to mount Arayat. In this region, concerning which we shall speak more in detail further on, in certain places there were formed fissures some kilometres long and some metres wide, which converted that locality into a real net through which three months afterwards, though continuous rains had undoubtedly contributed to fill these cracks up, we had great difficulty in travelling, as at every instant we were in danger of falling into the fissures.

Analogous, though less violent, effects were observed in the region of the river Agno, in the province of Pangasinan, in the villages of Bayambang and Alcala, on the river Grande of Tarlac (Rio Grande de Tarlac), in the district of Aguso, and in general on all the rivers of wide beds which traverse alluvial plains; so also on the coast near the mouths of great rivers, as in the villages of Mamban and Atimonan in the province of Tayabas, situated on alluvial formations, where there were fissures near the sea of the same form and identical origin with those above mentioned.

Besides these effects on the ground, against which there is no means of protecting buildings except by removing them as far as possible from the water and building them of light and elastic materials, we ought to consider the effects observed in the buildings themselves, in order to deduce from them if possible the modifications which ought to be introduced in future structures.

The author now enters into a practical consideration of the best forms of constructions followed in this country.

## SECTION 2.

### LOCAL OBSERVATIONS AND EFFECTS.

This section will include the local observations and effects in a great part of the island of Luzon; and for the purpose of

establishing some order in the description, we have divided the island into three zones, that of the North, that of the center, and that of the South, which will correspond to as many chapters; and in a fourth chapter will be given a résumé of all the observations, in order to deduce the extent of the zones of disturbance.

## I

*Effects observed in the provinces of the North of Luzon.*

## PANGASINAN.

As has already been mentioned, we began our examination of the island of Luzon in the province of Pangasinan, landing at Sual and passing through the villages of L<sup>u</sup>igayen, Bimale<sup>y</sup>, Dagupan, Mangaldan, San Jacinto, Man<sup>a</sup>gag, Binalonan, San Manuel, Urdaneta, San Carlos, Malasiqui, Bayambang, and Alcalá.

The effects produced generally by the earthquakes of July were not nearly as great or as disastrous in this province as in Manila; not so much because the vibrations were less intense or less numerous, but because the principal masonry buildings, the churches, the parochial houses, the court-houses, and a very few private buildings in the more important villages, are covered with galvanized iron or with *nipa*, very few buildings being covered with tiles. Besides, the scarcity of building stone in this flat province where almost all the soil is alluvial has rendered the use of brick obligatory, so that the masonry is much superior to that seen in the central provinces, where generally volcanic stone is used.

From all the reports which we received from the rectors of the parishes and the principal persons in the villages which we passed through, as well as from the official records which were placed at our disposal by the governor of the province, it is evident that of the three great earthquakes only that of the 18th was felt with great intensity, the two of the 20th having been of little importance, and the feeble shocks which before and after those days were felt so frequently in Manila passing unnoticed. Further it is to be remarked, from the effects

noticed in the ground and on buildings, as well as from the reports given by the persons above named, that the intensity of the earthquake of the 18th was less and less from the South-eastern portion of the province towards the North-western portion, so that in the villages situated around the gulf of Lingayen (Sual, Lingayen, Bimaleý, Dagupan, etc.) there were only the very slightest injuries to masonry buildings, even those covered with tiles; while in other villages in the interior (San Jacinto, Malasiqui, Bayambang, etc.) the earthquake left very evident marks of its influence, not only in the buildings which were left in ruins, as the churches of San Jacinto and Malasiqui, but also in the ground, where fissures were produced which can be seen today, as in the villages of Mayambang, Alcalá and Asingan.

From this observation it may apparently be deduced that the general direction of the motion was from the second to the fourth quadrant.

#### PROVINCE OF LA UNION.

In this province situated to the North of Pangasinan the earthquakes of July were felt even less than in the latter province; and the same law of decrement of intensity from the South toward the North, or more exactly from S. E. to N. W., was observed. In none of the buildings, which are of a weak sandstone and not of the best workmanship, have there been great injuries. However some of the earthquakes were felt with the same violence as in Manila; in some of the villages, as in Namagpacan in the northern part of the province and near the seashore, the shock of the 18th was felt with some intensity, but did not however cause any damage; the others according to the statement of the curate were imperceptible. On the contrary in Balasang, a village further inland, but situated toward the East and near the first foot-hills of the mountain chain, the earthquake of the 18th was felt with great force, and caused more damage to the church and convent than happened to any other buildings on the coast. And the two earthquakes of the 20th were felt here, although but feebly.

This remarkable difference between two villages distant

but a league from each other can not, as we think, be attributed solely to the gradual diminution of the seismic current, for although this is very evident in an extent as great as that of the whole island, it is not natural to suppose so sudden a change in a phenomenon which has such wide extent. The notable circumstance that subterranean noises were heard at the instant of the earthquake in Balasang and not in Namagpacan brings up the question whether in the general commotion there were not produced in the mountains near to Balasang subterranean disturbances which increased the vibrations in that limited district.

We think it useless to detail the effects produced in all the villages of the province, and we confine ourselves to a few of the effects, which can show how the violence of the phenomenon diminished, leaving aside the others which are of no interest in our present investigation.

<sup>Vill+</sup> Balasang. It may be remarked that this village situated, as we have said, a short distance from Namagpacan towards the interior, was the point of all the province where the earthquake of the 18th and some later shocks were felt with the greatest intensity. The convent and church were left in a bad condition with cracks in all the arches over the doors and windows, and some in the walls. The ground on which the convent stood was cracked transversely to the edifice, doubtless on account of the pressure which the vertical motions produced, or perhaps on account of bad foundation.

A house built of boards and stucco which stood near the convent lost its walls, leaving in the front only the cane gutters hanging from the eaves.

Finally, the curate of the village, Father Juan Perez, pointed out to us a remarkable effect, which showed the intensity of the shocks. A small tree, called in the country Bag-bag, five metres high, with quite a stout trunk and very few branches, fell during the earthquake tearing out its roots; a remarkable effect, knowing which we can not explain how a single building in the village remained standing. Really we should not have believed such a thing possible, if we had not the statement of such a respectable person.

## DISTRICT OF BENGUET.

The diminution of intensity from the interior towards the coast, which we had just observed, led us to visit this district, situated on the East of La Union. We went from Aringay, and passing through Galiano by a road which at some points reaches a height of 1550 metres above the sea, we arrived at La Trinidad, the capital and only Christian village of this district. We were further induced to make this excursion by a story which we had heard, and which was founded on an old chronicle of the order of the Augustines, as, according to this story, at the beginning of the last century quite a large number of cottages, situated to the East of Aringay and occupied by the natives, had disappeared in a great earthquake which produced the submersion of an extensive tract of land.

According to the reports which we received from the commandant of this district, Señor Oraa, and a few which we were able to collect, we were able to conclude that on the 18th of July there were felt not only the earthquake at mid-day, but also two others a short time afterwards; the third which occurred two hours after the first being accompanied by a great subterranean noise. The shocks of the two following days were of little intensity, including those of the 20th, which could not be distinguished by their force from the others. We did not obtain any information from the officers of the Civil Guard, the only Europeans living there, concerning accidents caused by earthquakes; and attempting to verify the story which we have mentioned above, we were unable to gain any facts. Doubtless the topography of the beautiful plain in which La Trinidad is situated might give some reason for conjectures on the subject. A level circular plain about four kilometres in diameter is surrounded on all sides by hills whose height does not exceed 130 metres. In the interior of this plain is a lake whose only outlet is through a fissure toward the north-east, and this outlet perhaps gives rise to the river which empties at Bauang (Union). Looking down on this circular depression from the last heights (1550 metres altitude) which are passed in reaching La Trinidad, the valley

presents all the appearance of an old crater and it was our first impression that it was one. We, on the following day, examined some of the hills which surround the valley, thinking to find in them the rocks which would confirm or modify our suspicions. Not a single volcanic rock did we find; on the contrary we were surprised to see calcareous rocks with a great abundance of fossils (madrepores and some bivalves) which could not be older than the tertiary period. How shall we explain then this great depression, so regular and flat, whose soil is composed of alluvium washed down from the surrounding hills, and is consequently posterior to them. We are far from suggesting that this is the origin of the story cited, because the time passed is not sufficient for the tradition to die out even among savage races, and because much less is the time sufficient in a geological point of view for all vestiges of such a phenomenon to have disappeared, or for so thick a deposit of alluvium as now covers and converts the plain into a fertile prairie to have formed.

But it occurs to us that perhaps the chronicle is not without foundation, but that an analogous phenomenon independently of any volcanic action may have happened in some other locality in the district, which unfortunately is very little known, if not in La Trinidad; and that by subterranean commotions, produced perhaps by the earthquakes whose action reaches the surface of the ground, a circular valley was formed, the first effect being to inundate the country until the water by its pressure and chemical action made an outlet for itself, leaving dry at the end of some centuries beautiful prairies like the one we are now considering.

We did not think the foregoing observations out of place because they are somewhat connected with our work, and because this district of Benguet by its situation, its delightful climate with a temperature which varies annually between 8 and 20 degrees centigrade, and from many other circumstances, is a very interesting locality in the interior of Luzon, which at no distant day will attract the attention of the government.

## NORTH AND SOUTH YLOCOS

As these two provinces are topographically the same and form a continuous zone from South to North, and as the phenomena observed in both of them are very few and of little interest, we shall consider them together. The provinces are bounded on the West by the China Sea, and on the East by the central cordillera, which separates them from Lepanto and Abra. Throughout the whole territory considered, the earthquakes of July were but feebly felt, and did not produce any considerable effect either in the buildings or the ground. Here, as in the other provinces which we have studied, the diminution in intensity from South to North is to be noticed; and this is confirmed not only on the coast, but also in the interior of the island, since, according to all the reports received concerning the provinces of Cagayan and Ysabela at the time of the earthquake from various residents, only the earthquake of the 18th was felt, and this, although it lasted quite a time, did not cause any injury to the very few masonry buildings which exist in these provinces. As there were no effects to examine in the last named provinces, we did not visit them, saving thus the time which we required in the provinces to the South.

From Tagudin, the first village in the Southern part of South Ylocos, up to Pasuquin near Cape Bojeador in North Ylocos, we could not observe in any of the intermediate villages that there had been any seismic action which merited attention; and in all these places we were assured by the curates that the shock of the 18th was felt, followed for some days by very slight shocks which in many cases were not perceived. From the village of Cabugao towards the north we began to notice injuries to the buildings, which attracted our attention the more because it in a certain measure destroyed the law of decrement which we had before observed; but we discovered that these injuries were not due to the earthquakes of July, but to one which happened in December 1879, which was stronger here than the July ones, and which must have acted over a very small area, as it was felt only in the villages of

North Ylocos. It should be noted that the effects which we observed in buildings indicated clearly that the law of decrement in the earthquake of 1879 was the reverse of that in the July earthquakes, that is from North to South.

#### DISTRICTS OF LEPANTO.

Although our journey to Benguet had shown us that no notable phenomenon had occurred in central Luzon, if it were not a slight increase of intensity in the earthquakes compared with the Western coast, we resolved nevertheless to make a new excursion to Lepanto; not so much to widen our field of observation, as to test a theory published by Father Faura concerning the existence of an extinct volcano in this district, which was said to be the probable center of seismic irradiation. We have published our opinion and our observations on the supposed focus elsewhere, and we have nothing to add now; but we have promised to describe the principal seismic effects in this district and we will fulfil our promise.

Our itinerary was as follows:—We left Candon and going through Salcedo passed over the mountain Tila to Angqui situated on the left bank of the Abra in its high part. Then we passed over to Cervantes, Mancayan, Tubuc, and Mount Datá, returning to Cervantes to go to Cagayan, the principal place of the district. Thence we descended again to the coast, passing the mountains at a place called Tabalina; and went through Tiagan to Santa Maria a town on the coast to the north of Candon.

In none of the places named, which were composed principally of small huts built of wood, cane, or cogon, could we see any effects of the earthquakes, and the reports which we could collect from the natives agree in saying that the earthquake of the 18th alone was of any importance; the remainder, which were felt until the 20th, were very small and scarcely perceptible. We are able to estimate the relative intensities of the shocks from the high dry stone walls which the natives erect to support their little tracts of cultivated land in the mountains; and the perfect state in which we found these walls indicated that the motions of the earthquakes had

not been violent enough even to tumble down these weak constructions.

At the metallurgical works at Mancayan there is, besides other structures, a furnace for refining copper with quite a high chimney, which was not injured at all by the earthquakes. The mines at this place have been worked for a long time and in a most economical manner so far as the supporting walls are concerned, and in not a single case did the walls fall down.

Only on the Southern side of Mount Datá were we able to find any considerable marks of seismic action on the ground ; and these were due not only to the intensity of the shock, but also to the special configuration of the ground. On the banks of the deep stream, which from its direction appears to be an affluent of the river Suyuc, there were places where the earth had fallen in, where there appeared to be numerous cracks on both banks, though they had but little length.

An analogous phenomenon, but of less extent, happened on the North-east slope of the mountain in the neighborhood of Cayan ; we will not describe it, as it offers nothing new.

#### ZAMBALES.

On the return from the provinces of the North, our assistant Don Enrique d'Almonte (the writer having been taken sick) passed from Sual to the province of Zambales, and in some of the villages gathered information, from which it appears that the earthquakes, except perhaps that of the 18th, were but little felt, and caused neither damage to buildings nor cracks in the ground. We will not give the details of the very slight effects which were observed ; we will only add that the mail steamer "Elus" was sailing along this coast during the afternoon and night of the 20th, and that on board of her none of the fearful shocks felt at Manila were noticed.

## II

### *Effects observed in the Central Provinces of Luzon.*

#### TARLAC, PAMPANGA AND BATAAN.

The tract of country which extends Southward parallel to the mountain chain of Zambales from the limits Pangasinan,

including the three provinces which we are about to study, was but little influenced by the earthquakes of July; however it may be observed that their energy was greater in the more distant points, those just to the East of the mountains of Zambales, than in points nearer to Manila, as should be the case according to the law observed in the provinces in the North. In the province of Bataan, which is the most Western one and includes both slopes of Mount Mariveles, the Southern end of the Zambales chain, the earthquake of the 18th had but little intensity, and the others were just perceptible, in no case causing damage to buildings in this province; while in Pampanga and Tarlac the effects were much greater in the villages distant from the Zambales mountains.

In Camiling, Capas, Mabalacat, Angeles, Bacolor, and Guagua, all situated on a North and South line near the mountains, we did not observe any great marks of the earthquakes, either in the buildings or the ground; in other places like Tarlac, Arayat, Santa Ana, Mexico and Macabebe situated further to the East, the effects in the ground and buildings were much greater; for example the church at Mexico was left in such a condition that it was necessary to pull it down, and in Macabebe one of the towers of the church was tumbled into ruins.

#### NUEVA ECIJA.

The effects of the earthquake of the 18th of July, the only one which was very heavy in this province, were truly imposing in all the region included between Cabiao and Cabanatuan on one side, and on the other side the river which rising in the mountains on the East of the province and passing through Bongabong, Cabanatuan and San Ysidro finally joins near Mount Arayat with the Rio Chico de la Pampanga forming the Rio Grande de la Pampanga. To the violence of the shocks, there was here joined the circumstance that the soil is of very recent formation consisting of the modern alluvial deposits of the Rio Grande; and these two circumstances together caused great and unequal depressions and numerous fissures, from which water and sand in great quanti-

ties were discharged, inundating extensive tracts of land and rendering many fields valueless.

The general direction of the great fissures was from East-north-east to West-south-west; and the spaces between these fissures were divided in every direction by others which were narrower (from 10 to 50 centimeters wide) but very deep. Three months after they were formed, although there had been heavy rain storms meanwhile, the fissures were not filled up; and when we visited them many still were of very great depth. Some of the great fissures run in the direction already given from the district of Sapan to Buliran, passing through the village of San Antonio, and having a breadth which reaches in some places 10 metres.

Between the river and village of San Antonio there were two fissures which were so wide as to appear like sections of the earth; the one nearest the river had a breadth of 6 metres, and the other, 200 metres away from the first, a breadth of 10 metres, and the ground between the two sank two and a half metres.

At some points near the bank of the river so numerous were the cracks that the ground presented the appearance of a pavement, the stones of which had been thrown out of position and level. At other places, besides the fissures, there were notable changes of level, so that the surface of the ground was broken into steps as in the case of a farm in the district called Delincuente near the village of San Antonio, where in a sugar-cane field which was originally flat, the surface was so disturbed that in some cases the top of one row of plants fully grown was on a level with the roots of the next, and of the 10 hectares of the field 8 remained valueless.

The width of some of the fissures was so great that in one of them a carabao (boat) disappeared; and we could see full grown trees (*magnifera indica*) hanging by their branches on the edges of the fissures. We might give great numbers of this kind of accidents, but it would only uselessly enlarge our too diffuse account, without adding any facts which can not easily be imagined; such as the partial destruction of a few houses of cane and "nipa," when two or more of the supporting posts happened to fall into a fissure.

Happily for the unfortunate people, the earthquake happened at an hour (noon) when they were necessarily in their houses, thus avoiding the many accidents and injuries, which would have occurred had they been working in the fields. A single accident of this kind was recorded, which happened on the farm of a man named Juan Fernandez. Three children were playing together when the earthquake began; they were frightened and ran towards the house, which two of them reached; but the third fell into a fissure which opened under his feet and immediately closed again. After the first instants of anguish, excavations were commenced on the spot pointed out by his little companions, and after several attempts his body was found at a little depth, completely crushed.

The vertical shocks were so sudden and so violent that the effects were much greater than in any other part of Luzon which we have visited. We will only mention the damages which masonry buildings suffered: the church of San Ysidro, which although without a roof fell so quickly as to bury in its ruins a child who was passing near it; the church of San Antonio, the front of which fell down, and the tower of which, built of small rounded stones laid in cement, the best kind of masonry perhaps, was thrown down even to the base; and many other masonry buildings which were more or less damaged. We think it will be of interest to describe two cases more in detail; the first is that of a deep well, having a lining built of the best masonry with a foundation of concrete, in the suburb of Sampang near a distillery which was supplied from it. The violence of the shocks lowered the ground on which the distillery stood about one metre, without greatly disturbing the machinery in it; while the well, which was full of water, was left dry and partly filled with sand, and the masonry curbing, either on account of its different density with reference to the soil, or for some other cause which it is difficult to discover, was left projecting some distance above the surface of the ground. The second case, which seems to us the most notable of any observed in the whole extent of territory affected by the earthquake, was that of the church in the little village of Jaen, this edifice had been recently constructed, and con-

sisted of great upright timbers 14 varas high, 2 varas of this length being sunk into the ground, united at the tops by joists; and on this framework a light roof of wood, cane and "nipa". The building was 60 varas long and 18 wide, and the lateral partitions were of nipa. This structure which would be considered extremely strong against earthquakes, fell to the ground in a most unexpected way. It was thrown vertically to such a height that the upright posts were drawn out of their beds in the ground with scarcely any injury, and then the whole building fell together. A single one of the uprights, which was more strongly attached to the foundation than the others, was not drawn out of the ground, and although it had a diameter of 40 centimetres, it was broken off like a cane at its base, a few fragments of the building remaining attached to the fibres which were not torn away.

In 1871 we inspected for the same purpose some houses in Cottabato, and in 1879 others in a village near to Surigao; these houses were built of wood and nipa and had been thrown down by earthquakes, but they had fallen because the posts by rocking in all directions had opened the framework at the top until the inclination of the timbers was so great that the building fell by its own weight. It is impossible to invent a method of building which will be proof against shocks which throw structures two varas high, and draw the posts out of their resting-places in the ground without greatly disturbing the soil. From facts procured on the spot, we have succeeded in restoring the building as it was at the instant of its fall, in order that a clearer idea may be formed of the wonderful power of the earthquake.

In the mountains East of the province, in the jurisdiction of Bongabon, there were cases in which rocks on the sides of chasms were thrown down, but we were unable to examine them because during our stay the roads were impassible. We will say however on the word of the Curate of San Ysidro, that in the chasm of Lupingan, the banks formed of hanging rocks were thrown down in to the bed of a stream, stopping the water for two days, at the end of which time the water, having risen and its pressure being greatly increased, forced its way through

and caused a sudden inundation to the agreeable surprise of the people of the region who were sorrow-stricken at the sight of the dry river-bed.

#### BULACAN.

This province like that of Nueva Ecija is traversed by a great river, which rising in the mountains which separate Bulacan and the district of La Infanta passes from East to West and runs into the Rio Grande de la Pampanga, which empties by numerous mouths into the bay of Manila. In spite of the similarity of topography of these two provinces, and although the intensity of the earthquakes was about the same in both, yet the region of the Bulacan river did not present the disastrous effects which were described in speaking of the region of the river of Nueva Ecija. The difference arose, we believe, from the difference of the geological characters of the soil; in the latter the soil is composed, as we have said, of thick layers of modern alluvium, which are without consistency, and hence subject to disturbances of the surface, and consequently to the fissures which we have described; on the contrary in Bulacan the soil is composed of very deep strata of a volcanic stone which is strong and elastic, in which changes of level, fissures, and land-slides are impossible.

This great volcanic formation, of whose origin and wide extent we shall at some future time speak more fully than is here possible, when it was formed, raised the level of this province, leaving the streams running in deep channels as may to-day be observed, and crowding in the banks of the river, which are very steep throughout the volcanic formation. To this last fact it is to be attributed that this province is so free from inundations, and that the recent alluvium posterior to the volcanic formation is only of a very insignificant thickness and very uniform, as it has been for long periods of time free from the action of the water which is usually at a level below the alluvium. As a confirmation of this hypothesis we can cite the low and littoral region of this province, whose surface is almost down to the sea level, and which is composed of recent alluvia in which there have been observed phenomena

analogous to those of Nueva Ecija, that is, fissures and elevations and depressions of the surface. In the low region just mentioned is the town of Hagonoy, where the earthquakes were felt with extreme violence, and gave rise to depressions and inundations which caused the destruction of houses built of wood and "nipa," and to the opening of fissures two metres wide from which poured forth water and sand in abundance.

We have then in this province two distinct regions in which to study the action of earthquakes; the region of the volcanic formation, which includes the central portion of the province, and the low and littoral portion. In both regions the damages to masonry buildings have been great, perhaps somewhat greater in the low towns than in the high ones; thus, for example, the church and the elegant modern tower of the capital town were destroyed completely, while in Balinag, San Rafael, Angat, and other places on the high land, all the buildings remained standing, although somewhat injured.

In the high region structures in cities suffered, while the ground and structures in the country remained intact; while in the low region structures both in the city and country have been considerably damaged. Neither in this province nor in the others which we have studied were the earthquakes of the afternoon and night of the 20th felt with great violence, although in Manila which is very near they were extremely violent. It is to be noted that the intensity in the different towns of Bulacan was inversely proportioned to the distance from Manila.

After these general remarks on the effects observed in this province, we do not consider it necessary to give details on the different towns which we have travelled through, as they teach nothing new, only confirming the general law which we have given as to intensities and directions of movements, to which there is not a single exception in this province. We will cite a single geological phenomenon which may almost always be seen at time of great earthquakes. There is in a suburb of the village of San Miguel de Mayumo, called Sibul, a large spring; the water is charged with sulphur and iron; and this spring has of late years acquired importance, not only on account of

its medicinal properties, but on account of the beauty of its situation. The spring pours out from under a layer of limestone, and has formed around the orifice a little basin about a metre deep with a corresponding outlet. At the time of the earthquake, this spring completely dried up and it was only after some hours, which had been probably necessary to overcome the obstacles which were thrown down by subterranean disturbances, that the water, which was much more turbid than usual, returned.

#### PROVINCE OF MANILA.

Although this province is of very small area, it presents points of observation where the intensity of the earthquakes was very different. The earthquakes of the 18th and 20th of July were everywhere very strongly felt; but, comparing carefully the effects experienced in the different towns of the province, it can be divided into two zones which were differently affected; one from the Pasig river toward the North, in which the shock of the 18th produced all or the greater part of the damages, which were but very little increased by the shock of the 20th; the other from the river Pasig toward the South, in which the first earthquake having produced the same effects as in the remainder of the province, the two shocks of the 20th considerably added to the damage, and caused others besides, throwing down structures which had resisted the first shock. We do not seek to carry our theory so far as to consider the Pasig as the mathematical dividing line of the two zones; for this would be thought by many to be a scientific refinement, a mathematical nicety, which we ought to avoid when treating of nature, which in its grand march is not accustomed to submit itself to the petty and too frequently unvaried rigor of science. But it is really worthy of observation, even though it be accidental, that the villages situated on the left bank of the Pasig were damaged much more in the earthquakes of the 20th than those on the right bank. In Manila even, with numerous buildings on both banks of the river, it was noticed that the large structures (churches and towers) suffered more on the left bank than on the right; thus the towers of the

cathedral and of San Agustin, and the cupolas of San Francisco and Recoletos were thrown down almost completely on the 20th; while in the suburbs on the right bank all remained standing without any important damage, the towers of Santa Cruz, Quiapo, Binondo and San Sebastian, all high and of no better construction than those in Manila.

With regard to the other villages in the province, it was observed that in those to the North of the Pasig river, such as Malabon, Navotas, Caloocan, Mariquina, Cainta, and even Pasig on the bank of the river, the destruction was not complete except in the case of masonry buildings in a more or less ruinous condition; while in those to the South of that river, as Paco, Santa Ana, Guadalupe, Pateros, Parañaque, Las Pinas, etc., the damages were more important, in some cases amounting to complete destruction, as in the solid sanctuary of Guadalupe, an ancient structure which had withstood the shocks of the last three centuries without injury, and which, having remained standing through the earthquake of the 18th, was completely destroyed by the falling of its arched roof of masonry on the 20th.

#### PROVINCE OF LA LAGUNA AND

#### DISTRICT OF MORONG.

Let us group these two provinces together, as they include the whole perimeter of the great lake Bay, in which the earthquakes of July present such variations that their study is very complicated, and it is very difficult to deduce general consequences which give a more or less exact idea of the phenomena during the three days, the 14th, 18th, and 20th of July, in which they manifested themselves.

We observe, in the first place, that while the first earthquake of the series, that of the night of the 14th, left no traces of its action in the localities which we have so far studied, and would have had no importance had it not been followed by other greater ones, in the region which we are about to investigate at some points it had a much greater intensity and a much longer duration, and caused considerable damage.

Passing around the lake from Taguig towards the South following the West coast, all the reports which we obtained and the effects which we observed demonstrated that the first earthquake had had no importance in Muntinlupa, Tunasan, Biñan and other places as far as Santa Cruz. In the last place it could be seen that the effects produced by it were much greater than had been observed up to that point; for example, the fall of brick partition walls, and numerous cracks in stone walls of coursed masonry.

In the other towns on the East coast as Longos, Paete, Panguil, Siniloan, etc. and in the corresponding ones in the district of Morong as far as Pililla, we obtained reports of that earthquake, and we were shown marks of seismic action which revealed a greater intensity even than in Santa Cruz; in the village of Pililla the force was so great as to open wide cracks in the church and tower, and throw down one of the few masonry houses which exist in this place. Leaving this village toward the West, the intensity of that earthquake seems to have been constantly less and less until we reach the province of Manila, in which we have already described the phenomena.

The earthquake of the 18th was felt very heavily in both provinces; it is to be noted however that on the Western coast from Taguig to Bay the intensity was somewhat less than on the opposite side of the lake. Thus, the towns Biñan, with many masonry structures, Santa Rosa, Calamba and Los Baños felt the earthquake without any damage; while in the towns on the Eastern coast from Santa Cruz to Santa Maria the masonry structures were mostly laid in ruins.

The earthquake of the 20th, on the contrary, acted with greater violence on the Western coast than in the other parts of the two provinces, and had in some villages greater intensity but less duration than that of the 18th. In confirmation of this statement we will give the following well-known fact. As soon as the people of Biñan knew that Santa Cruz, the capital of the province, had been destroyed by the earthquake of the 18th, while the buildings in their town had escaped injury, they loaded a number of boats with materials and men and went to aid the people of the capital. When they were

returning on the 20th and were about to run into their own port, the earthquake of 3 P. M. took place, and was felt in the boats with extraordinary violence; and when they landed they found their principal buildings demolished. The earthquake which occurred that night finished the work of destruction. We had occasion to make another noteworthy observation in travelling along the Southern coast of the lake, in the villages of Calamba, Los Baños and Bay, situated almost on the slope of the great volcanic mountain called Maquiling. In these three villages so near to the volcano whose influence in the earthquake had been so much exaggerated in Manila, we were agreeably surprised to see only the slightest damages compared with the localities visited before and after this small volcanic region.

The observation of this reduction of intensity led us to believe that the great volcanic mass of Maquiling, the first of the chain of mountains which separate this province from Batangas and Tayabas, served as a barrier to the seismic vibrations, and reduced their intensity, which according to what was observed later was very much less in the Southern provinces.

#### DISTRICT OF LA INFANTA.

Three days journey from the village of Siniluan in the province of La Laguna through high and wild mountains, brought us to Binangonan de Lampon, the only village in this province on the island of Luzon. The island of Polillo, containing a village of the same name, is a part of this district.

From the reports which we were able to obtain and the effects observed, we conclude that the earthquakes were extremely severe in this locality, although not so severe as was represented by the public press of Manila, which derived its information from some natives from the Pacific coast through intelligent and well-meaning persons in the province of Laguna.

A certain journal went so far as to suppose that a volcano had appeared on the Pacific coast, and spoke of the formation of new mountains and the disappearance of old ones, of great gaseous and liquid discharges, of a great number of boats cast

up on the shores to a great height above the sea, and even of the disappearance of hundreds of human beings. The greater part of these statements were false and the remainder exaggerated as we shall see.

At about the same time as in Manila in the night of July 14th occurred the first earthquake, which was much more intense here than in Manila. In fact the people of Binangonan assert that this earthquake was the most severe one felt since 1863. Before 9 o'clock on the morning of the 15th the shock was repeated nine times. During the 15th, 16th, 17th, and 18th of the month so frequent were the repetitions that, as many people have assured us, not an hour passed without a shock, and the greater part of them were preceded by subterranean noises.

A little after midday on the 18th the great earthquake happened, which caused all the injury to buildings and all the disturbances to the ground, of which we shall speak hereafter.

From this time the ground was still until the 20th, when four more shocks were felt during the afternoon and night; it was impossible for us to ascertain the exact times of the earthquakes, but it is reasonable to suppose that they were the same as in Manila. The intensity of the shocks of the 20th was by common report very much less than that of the shock of the 18th.

On the following days slight shocks were frequently felt, but they grew weaker and finally ceased. The governor of the district informed us that in the island of Polillo only the earthquake of the 18th was felt, and that it only caused a very little damage to the church. We were not able to visit the island because at the season of our arrival at La Infanta (22d of December) it is impossible to make the passage from any point without great danger of shipwreck.

The effects produced in the buildings of Binangonan by the earthquake of the 18th were the following:—The church, the tower and the convent, the only masonry buildings in the village, which we were informed were not in good condition, fell to the ground. The church had walls of plaster and a roof of nipa. The tower was all built of plaster, and the convent was built of plaster with a tile roof. The destruction

was complete, especially of the tower, whose foundations were so moved as to disturb the ground which surrounded them.

The government house, the court-house, the barracks, all built of wood and nipa, were so badly injured as to be uninhabitable, and they were so much inclined that the latter finally fell down. More than two hundred houses built of wood and nipa were ruined by the great disturbances of the surface of the ground; some fell down leaving the vertical posts standing loosely in their beds, which had been enlarged by the oscillations.

The disturbances of the ground were, so far as we could see, small in the neighborhood of the village; but they were very considerable at two points on the shore of Puerto Real de Lampon, and in the mountains which separate this district from that of Morong and the province of Bulacan. Close by the village there were only a few fissures of little length near to a stream called Sapa, which runs in a deep bed through a meadow on the North-eastern side of the town, and a little more than a kilometre distant from it. The hanging clay banks of this stream fell down in several places dragging with them the vegetation; and in one place where the bed was very narrow (scarcely two metres wide) the caving-in obstructed the current so that the meadow was partly inundated for a few hours, until the obstruction was washed away.

The other place was about half-an-hour's journey in a South-westerly direction from the town; here fissures were formed of a greater length than those just mentioned, but of very small width, which poured out water and mud. The same thing happened on the shore of Santa Monica and in some other places around the town, but in all these cases the phenomena were on so small a scale as to be hardly worth mention.

In the mountains of the dividing chain of the island, on the West and North-west of Binangonan the effects were very important, producing numerous and great land slides on the steep Eastern slope, which were formerly covered by thick vegetation, and leaving great tracts completely bare. Five months afterwards although the vegetation is very vigorous,

we could count more than sixty of these bare places in the single mountain called Binnan at about six leagues to the North-west of Binangonan. The few inhabitants in the mountains (for the most part natives, negritos,) hurried down to the plains in all haste, terrified at phenomena which made such frightful noises and made the earth vibrate so continuously.

On the coast of the Puerto Real de Lampon, four miles (Spanish) from Binangonan, there are important depressions, one at Point Tacligan and another at a place called Quinanliman. The sketch given herewith shows exactly the situation of these two places.

At Point Tacligan the depression of the land increased from A and C towards B; at the last point, where formerly the land was some decimetres above the surface of the water, the water was six metres deep; while at A and C, the ground was lowered only so much that the vegetation, which was very thick at this place, was killed by the action of the salt water on its roots. At B the dead tops of the submerged trees were visible. It appears as if the whole tongue of land had revolved about an axis approximately parallel to the line AC.

At Quinanliman the depression had a wide extent, but was very irregular in depth: the greatest depth was four metres at the centre line DE of the submerged surface; and from this line in both directions the depth gradually diminished.

A suburb called San Rafael had been formed in this locality a short time before the earthquakes, to take advantage of the good forming land. This suburb was submerged the 18th of July, and was abandoned without loss of life. It is probably this incident which gave rise to the story in Manila that hundreds of human beings had disappeared.

With regard to the story of the boats which had been cast up on the shore to a great height above the sea, we could not find any confirmation of it; even the fishermen in Puerto Real were astonished when we told them of it. The only accident which offers any explanation of such exaggeration is that some small boats which had been out in the estuary which opens into this port, were thrown by the inundating waters up

Binangonan  
*de Lampon*

*Embarcadero de Polo*

*Castillo*

*Puerto Real de Lampon*

*Visita de S. Rafael*  
*(S. Emergida)*

*5 varas*

*Punta Tacloyan*

*7 varas de hund<sup>to</sup>*

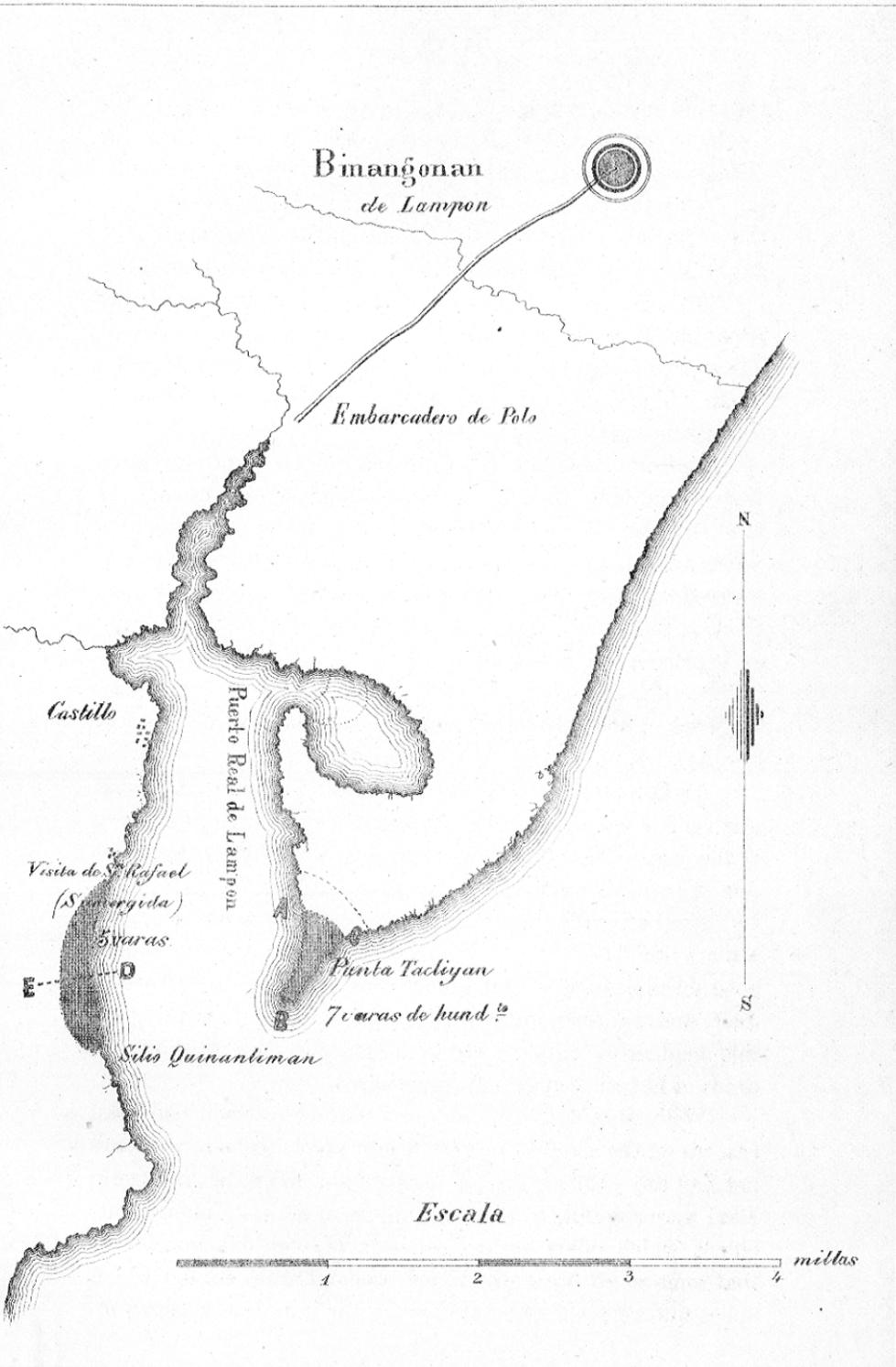
*Silos Quinantiman*

*Escala*

1 2 3 4 *millas*

N

S



into the mangrove thickets which line the shores of the estuary, and were left dry when the water returned to its level.

#### PROVINCE OF CAVITE.

The effects produced in this province were almost as great as those in the contiguous parts of the province of Manila. The shocks were felt with equal violence and in equal number, although it was observed that the intensity was gradually less from North-east to North-west.

We will not enter into details concerning the action of the earthquakes; it will be sufficient to say that some buildings were more or less injured, while the ground showed no marks of violence except some small cracks at points near the shore, as at Cañacao, where several were opened which poured out water and sand.

### III

#### *Effects observed in the Southern Provinces.*

##### BATANGAS.

It was with great anticipations that we went to examine this typical volcanic province, thinking to find more notable marks of the earthquakes of July in its soil than in any of the provinces already travelled over. The reports, sometimes terrifying and sometimes reassuring, which were received in Manila concerning the volcano of Taal and mount Maquiling, which were then considered the arbiters of our fate; the telegrams, as laconic as alarming, which represented these mountains to be first in full eruption and then perfectly quiet; those urgent warnings, advising the precautions to be observed on account of the suspicious state of the volcano; all these reports, these prophetic warnings, which were in no way confirmed, excited our desire to visit this province, which we expected to find completely disorganized by the earthquakes of July. What was our surprise to find that if those volcanoes had had any influence on the effects of the earthquakes, it was a markedly beneficial one.

Neither the crater of Taal nor the boiling springs on the South-western side of Maquiling, which we examined carefully,

showed any marks of recent change, much less of such cataclysms as young and enthusiastic imaginations had thought they saw. According to the reports which we obtained in the locality, when people had become somewhat reassured, it seems that not only did no new volcano appear, (a supposition which might have arisen from one of the beautiful tropical sunsets or from mistaking some other peak) but that the old ones showed no abnormal activity, indeed not as much as they often do when unaccompanied with earthquakes.

We entered this province from the town of Calamba in La Laguna, and passed successively through the towns of Santo Tomas, Tananang, and Talisay, Taal, <sup>A</sup>Batang, Batangas, San Jose, and Lipa; returning to Santo Tomas, we took the road to San Pablo and afterwards proceeded to Tayabas. We stopped in Santo Tomas especially to investigate the hot springs of Mount Maquiling, and again in Talisay as the nearest point from which to visit the little island which was formed by the volcano of Taal in the middle of lake Bombong.

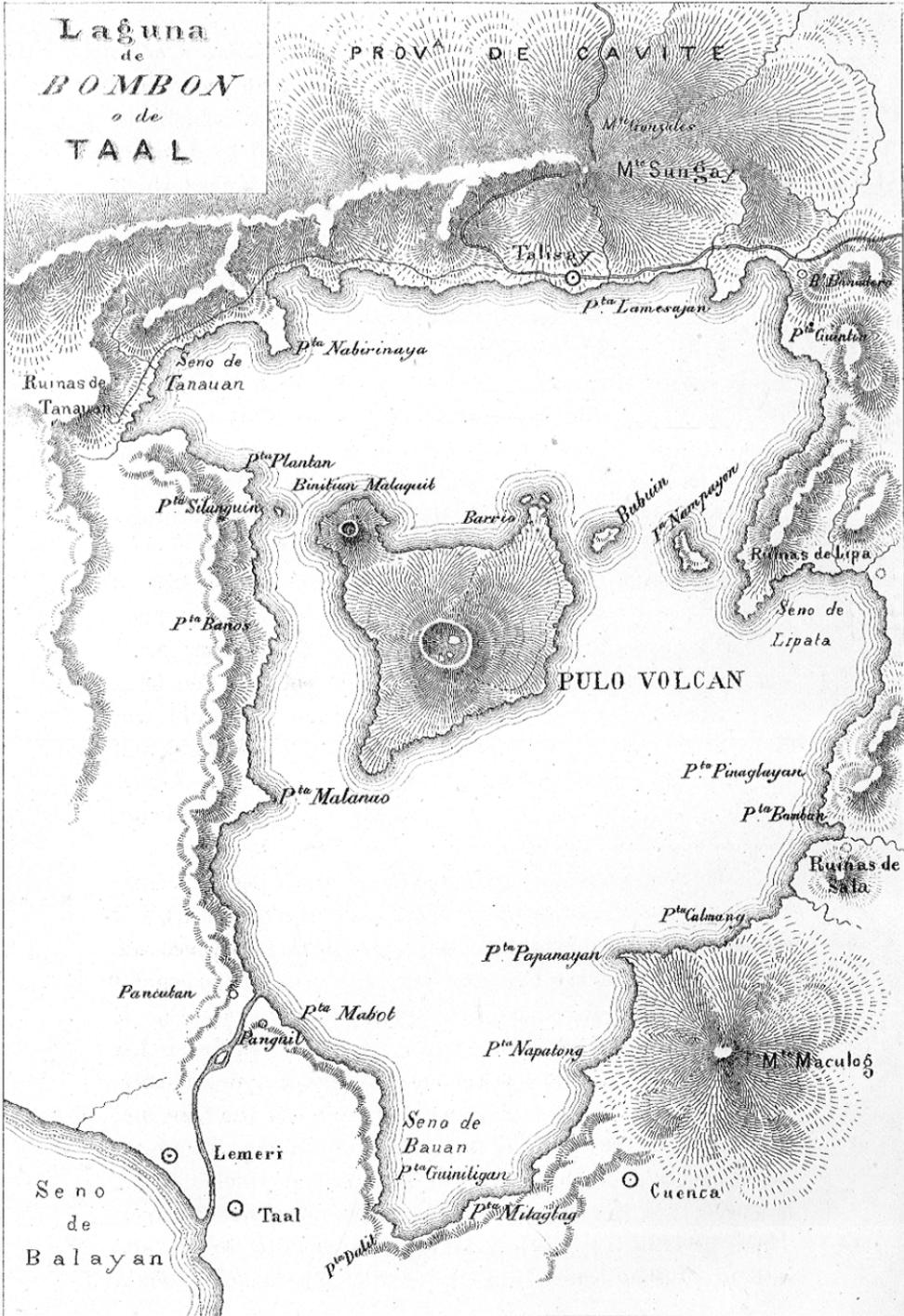
In none of the villages passed through did we observe any effects of the earthquakes, either in the ground or the buildings. In Santo Tomas, the village nearest to the province of La Laguna, the church was considerably damaged, but this was due to faulty construction rather than to the action of the earthquake; as the convent next to the church, which was built of masonry and covered with tiles was so little injured that it was, without repairs, continually occupied. In the town of Lipa, where there were numerous edifices of masonry covered with tiles, and higher than we have seen elsewhere in the Philippines\*, there was not the slightest injury; even in the five-story tower of the church there was not a visible crack.

The same earthquakes were felt as in Manila; but the greater part of the reports received agree in assigning the greatest importance to the shock of the 18th, and placing the anterior and posterior ones much lower in the scale of intensity.

The statements which we could make concerning the effects in this locality would be mainly negative; it will suffice

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\*There are some buildings having a ground floor and three other stories, all covered with a tile roof.



to say that, with the exception of the village of Santo Tomas, none of the churches of this province, including the very high one of Taal, nor of the great masonry structures which are numerous in many of the villages, suffered noteworthy damage, the small damage experienced amounting to a few cracks which did not affect the stability.

Here we ought to terminate what we have to say concerning the earthquakes of July in this province; but considering that, among the theories which have been advanced by eminent men in all times relating to such phenomena, there is one theory which attributes them to volcanic action, we can not let such an inviting opportunity pass by to study an active volcano in the midst of a zone lately disturbed by heavy earthquakes, as well as to say a few words on that igneous center and the scientific paper which was intended to show a connection between this volcano and past seismic events.

The sketch herewith shows the situation in the lake of Bombong of the island called Puló Volcan in whose top there is now a crater, as well as the situation of the other small islands in the same lake, all of which are volcanic and have been active in historic times. The islands of Bubuín and Nampayon appeared in 1716, forming then a single island, and the principal crater was then in an island known as Subugnapul which disappeared in the eruption of that year, although its base may still be seen near the island Puló Volcan.

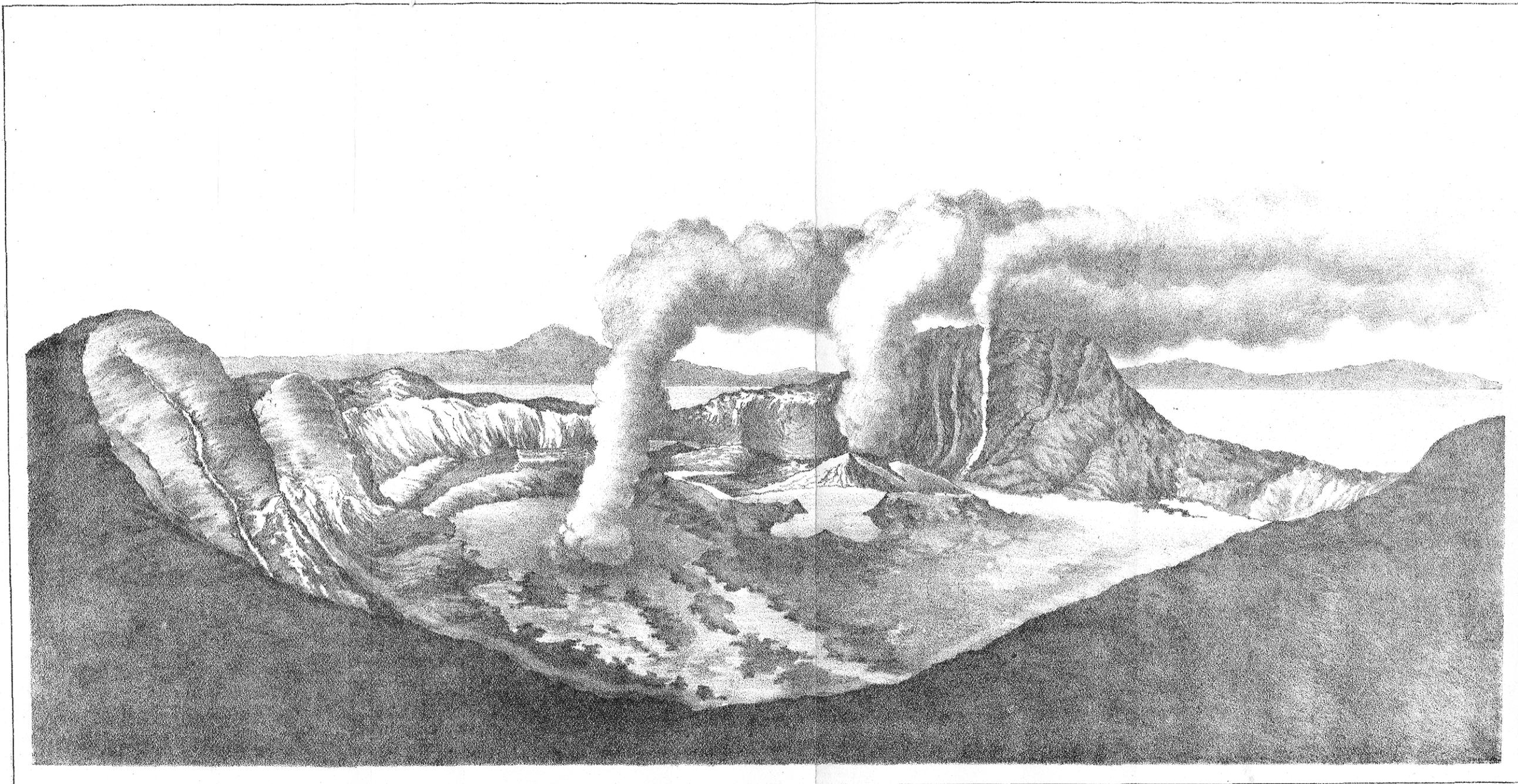
The greatest length of the island of the volcano is from North-east to South-west and is about five miles (Spanish), and the height of the edge of the crater is on the South-eastern side 190 metres, and on the Northern side 275 metres. The general form of the edge of the crater is approximately oval, (Fig. 3) with its major axis 2600 metres long. The interior surface is that of an inverted truncated cone, whose height is approximately that of the edge of the crater above the water of the lake, and whose smaller base is the bottom of the crater. There are several small cones on the floor of the crater of which only one is active, and this one throws out great quantities of vapor. There are also two boiling lakes, with metallic oxides and salts in solution, which color the smaller one a pure emerald

green, and the larger one a reddish yellow.

In the larger lake every few hours the center is blown up like an immense bubble, which rises one, two, or three metres above the surface and finally bursts, revealing a black orifice and making the boiling water appear all imaginable colors.

It is impossible for us to describe the beauties of the crater, whose bottom and interior walls, accessible at various points, present such varied structures and colors, from the black and compact basalts to the fragile, spongy, and almost transparent modern scoriae. The most finished description would not give even an approximate idea of that grand amphitheater, where every stone has its history, having been thrown thousands of times up to great heights, and having been dissolved and deposited until there are multitudes of transparent and colored crystals. In the sketch which has been given, the relative situation of the various parts of the crater may be seen.

The changes which this volcano has undergone and the disasters which it has caused since historical times are very remarkable. According to the chronicles of the time of the conquest, the crater was then on the South-western point of the island of Puló Volcan, having a cone which exists today and is called Binintian-Malaquit. A few years after the conquest that crater ceased acting, and another appeared on the Eastern side of the island, which in 1716 was submerged, leaving above the surface the two islands Bubuin and Nampayon. Then a new crater appeared on the Eastern side of Puló Volcan, which was gradually enlarged toward the West until the present crater was formed, which has not varied much since 1754. Among the various eruptions since the conquest, the most notable are that of 1749 where the village of Salá disappeared, and that of 1754, the greatest of all, when the villages of Taal, Lipa, and Tananang which were then on the shores of lake Bombong all disappeared. All the eruptions have consisted of showers of burning ashes and scoriae, between which showers great blocks of basalt were thrown out, covering the whole region to a depth varying from a few centimetres to two or three metres, and causing the different strata of volcanic material which can be seen throughout the province. We know of no observations



VISTA DEL CRATER DEL VOLCAN DE TAAL DESDE EL BORDE NORTE DEL MISMO

which would show the relation of earthquakes to the eruptions up to 1874; but since that date we are able to give a few, which, as well as some of the facts already stated, we owe to the kindness of the curate of Talisay, Father Celestino Redondo.

On the 17th of May 1874 there was an eruption of black smoke and ashes unaccompanied by an earthquake.

On the 19th of July in the same year there was an eruption of gases, which were so sulphurous that the characteristic odor was perceptible as far as the town of Talisay. A great herd of cattle died on the island of Puló Volcan, on whose Western shore there was abundant vegetation which was mostly burned up. There was however no earthquake.

On the 24th of June 1877 from one until half past six in the morning, seven heavy earthquakes were felt, which were violent enough to cause cracks in the wall of a convent. These earthquakes were felt in Silan in the province of Cavite, but in many villages of Batangas they were not observed. They were not followed by any eruption.

From the last of October 1878 until the 12th of November, subterranean noises were heard frequently in the direction of the volcano. On the day mentioned an eruption began which lasted until the 15th and covered the whole island of Puló with a shallow layer of volcanic ash; there was however no earthquake.

Finally from the 8th of June 1880 the volcano was observed to be more active than usual, and some nights the crater was covered with a glare; and on the 17th, 18th, 19th, 20th, and 21st of July subterranean noises were heard and from time to time a small ball of fire (about half a metre in diameter) appeared above the crater; these balls burst at quite a height into small fragments a part of which fell back into the crater and the remainder upon the exterior slopes.

We might say much more of this volcano whose sphere of action in geological times must have been much greater than in historical times; perhaps then the lake of Bombong was the crater. But this would carry us too far from our present purpose, so we repress our desire until a more opportune occasion.

## PROVINCE OF TAYABAS.

We travelled through this province setting out from Santo Tomas in Batangas and going in the direction of San Pablo ; and we then passed through the villages Dolores, Tiaon, Sariaya, Candelaria, Tayabas, and Lueban all situated on the slopes of the two great volcanic promontories called Majajai and Banajao.

From Lueban we passed over to the Pacific coast, which is a continuation toward the South-east of the coast of La Infanta, and inspected the towns of Mauban and Atimonan ; crossing lastly the narrow isthmus which separates the Pacific Ocean from the sea of Mindoro, we arrived at Laguimanoc, whence we set out for Camarines.

During this journey we observed that the intensity of the July earthquakes decreased from the Pacific coast towards the West. In the towns named, with the exception of Mauban and Atimonan, we did not observe any important effects either in the buildings or ground, the only damages being slight cracks which did not render the buildings uninhabitable. In a single convent, that of Tiaon, which for some time past had not been occupied on account of its dilapidated condition, a part of the roof fell in ; the church which was near the convent was also in a bad condition, but it resisted the action of the earthquake and continued to be used. Neither in Tayabas, nor in Lueban, nor in Sariaya where, besides the church and convent, there are many other masonry buildings with tile roofs, were left any marks of seismic action from the earthquakes of July, which were however felt in as great numbers as in Manila, although with much less intensity.

We will only give a few effects which were observed in Mauban and Atimonan on the Pacific coast, where the phenomenon assumed some importance.

## PROVINCES OF CAMARINES AND ALBAY.

Although this description may appear long, we have thought it necessary to go into details, so that the reader could form his own opinions on the course of the phenomena, independently of our ideas. To bring the account to an end,

we will add a few words about the two provinces named above, in which there was a great diminution in intensity in proportion as the earthquakes had travelled toward the South-east; so that at the extremity of Luzon, near the straits of San Bernardino, there are places where the earthquakes of July passed unobserved.

In North and South Camarines the shocks had considerable intensity in all the villages in the North-eastern parts, but did not however injure any buildings or cause any marked disturbances of the ground. In Nueva Caceres, the capital of South Camarines, where there are many masonry buildings some of which are of great size, as the government house, the bishop's palace, churches with high towers, &c., we were shown as the greatest damage which was caused in that place a small crack in one of the walls of the government house. This crack was even smaller before the local earthquakes of the volcanic region of Mayon, which were felt here in last November, and which opened the crack somewhat. In the other places to the South-east of Nueva Caceres as far as Albay, the intensity was even less. The earthquakes seem to have been entirely extinguished in the line of volcanoes which begins with one called Ysaró and ends with Bulusan, and includes those called Yriga, Masaraga, Bulic and Mayon, the last of which has a height of 8000 ft., and has concentrated in itself all the volcanic activity of the whole region. All this locality is frequently disturbed by local earthquakes which do not generally pass out of South Camarines, and ordinarily are preceded by some eruption, or at least some notable variation in the activity of the volcano.

#### IV

##### *General Deductions.*

If, in some of the places examined in the different latitudes of Luzon, the earthquakes had been registered with accuracy, as they were in Manila, by seismometers, nothing would have been easier than to have traced on the maps the lines which mark the zones of relative intensity; but, lacking these observations, and obliged to estimate the direction and force of the motions by the effects which they produced in each locality,

we have great difficulty in presenting the deductions which indicate generally the character of the phenomena. We shall do it however because, besides fulfilling our obligations, our opinions will leave the reader completely free to form his own ideas; and from the minute and trustworthy observations which we have here recorded he can test or modify the deductions which we make.

We first call attention to this fact, that all the earthquakes from the 14th to the 25th of July can be divided into three classes corresponding respectively to the 14th, 18th and 20th days; and that each of these classes has its own special zone of maximum intensity. The first, which includes all the earthquakes which occurred between the 14th and the 18th, had its greatest intensity on that part of the Pacific coast which corresponds to the district of La Infanta and the province of Tayabas, and on that part of the shore of lake Bay between Santa Cruz and Morong. Leaving this region of maximum intensity, which we have marked on the map with a red line, the intensity became less and less until in Pangasinan in the North, and Camarines in the South, the earthquakes in many towns were not noticed.

The second class, which on account of its great intensity and extent is the most important of all, had its maximum intensity in the territory included between the Western coast of Tayabas and La Infanta and the most Western spurs of the mountain-chain which beginning at Baler runs towards the South and ends in the volcanic mountains of Tayabas near the narrow isthums of Atimonan. The seismic waves in this great shock had much greater extent and intensity toward the North-west than toward the South-east; in the first direction including all the island of Luzon and probably part of the China Sea between Luzon and Formosa, while in a South-easterly direction the seismic action was entirely extinguished before reaching the Straits of San Bernardino, so that the loss of intensity must have been much more rapid. It can be calculated that the surface more or less violently disturbed by the earthquake of July 18th, deducting the part on the ocean as we have no exact observations as to its boundaries, was

Longitud Oriental del meridiano de Madrid



SIGNOS

- ..... Ondas que indican el terremoto del 18 de Junio
- ..... id id id del 20 de id
- ..... id id id del 14 de id

about 357 square leagues.\* On the map we have drawn black lines to show the different places at which the intensity was the same. According to observations made in our journey the region of maximum intensity was in Nueva Ecija, the mountains of Bulacan and Morong, the district of La Infanta and a part of the province of La Laguna, all of which territory is included in the inside curve.

In the determination of the curves which limit the successive zones, we have endeavored to draw them so that they include all the points at which the effects observed, by careful estimate, were about the same, rather than to make them represent the course of the seismic waves; it would have been impossible for us to do the latter, as we had no more exact observations than could be obtained from ruined buildings and disturbances of the ground.

Finally the third group, which includes all the earthquakes which happened on and after the 20th, presents a very small zone of maximum intensity, in spreading from which the motion decreased so rapidly that while the greatest action was on the Western shore of Lake Bay, or perhaps in Manila, in the adjoining provinces toward the North and the South, that is in Pampanga, Nueva Ecija, Batangas and Tayabas, that shock was hardly distinguished from the other slight shocks which were felt from the 18th to the 25th of July. On the map we have drawn a yellow line including a small part of Lake Bay and a short stretch of its Western coast, the peninsula of Jalajala and the island of Talim; and this line incloses the region of maximum intensity, where the action of these earthquakes was much greater than in the other parts of the province of Manila, and where they were especially violent at points South of the Pasig river. In speaking in detail of this province we have called attention to the singular fact that this Pasig river seems to be a dividing line between two districts in which the intensity of the earthquake of the 20th was very different; this fact is our reason for drawing one of the curves to coincide with this river.

April 1881.

JOSÉ CENTENO.

\*56000 square miles.

[See note on next page.]

NOTE. The figures referred to in the first section of chapter 1, are already known to the Seismological Society of Japan, and for that reason have not been given.

