CIHM
Microfiche
Series
(Monographs)

ICMH
Collection de
microfiches
(monographies)

Canadian Institute for Historical Microreproductions / Institut cenadien de microreproductions historiques

Technical and Bibliographic Notes / Notes technique et bibliographiques

The Institute has attempted to obtain the best original copy available for filming. Features of this copy which may be bibliographically unique, which may alter any of the images in the reproduction, or which may significantly change the usual method of filming are checked below.

- [x] Coloured covers / Couvertura de couleur
- [ ] Covers damaged / Couverture endommagée
- [ ] Covers restored end/or laminated / Couverture restaurée et/ou pelliculée
- [ ] Cover title missing / Le titre de couverture manque
- [ ] Coloured maps / Cartes géographiques en couleur
- [ ] Coloured ink (i.e. other than blue or black) / Encre de couleur (i.e. eutre que bleue ou noire)
- [ ] Coloured plates and/or illustrations / Planches et/ou illustrations en couleur
- [ ] Bound with other material / Relié avac d'autres documents
- [ ] Only edition aveilable / Seule édition disponible
- [ ] Tight binding may cause shedows or distortion elong interior margin / Le rellure serrée peut causer de l'ombre ou de la distorsion le long de la marge intérieure.
- [ ] Blank leaves added during restorations may appear within the text. Whenever possible, these have been omitted from filming / Il se peut que certaines pages blanches ejoutées lors d'une restauration apparaissent dans le texte, mais, lorsque cela était possible, ces pages n'ont pas été filmées.

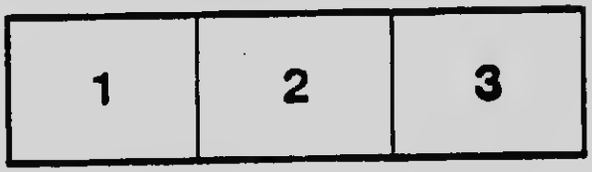
L'Institut a microfilmé le meilleur examplaire qu'il lui a été possible de se procurer. Les détails de cet exemplaire qui sont peut-être uniques du point de vue bibliographique, qui peuvent modifier una image reproduite, ou qui peuvent exiger une modifications dans la méthode normale de filmaga sont indiqués ci-dessous.

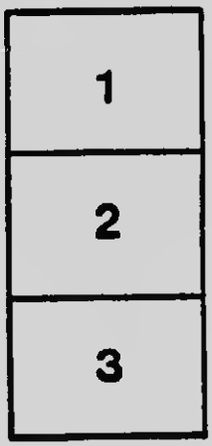
- [ ] Coloured pages / Pages de couleur
- [ ] Pages damaged / Pages endommegées
- [ ] Pages restored and/or laminated / Pages restaurées et/ou pelliculées
- [x] Pages discoloured, stained or foxed / Pages décolorées, tachetées ou piquées
- [ ] Pages detached / Pages détachées
- [x] Showthrough / Transparence
- [ ] Quality of print varies / Qualité inégale de l'impression
- [ ] Includes supplementary material / Comprend du matériel supplémentaire
- [ ] Pages wholly or pertially obscured by errata slips, tissues, etc., heve been refilmed to ensure the best possible image / Les peges totalement ou partiellement obscurcies par un feuillet d'errata, une pelure, etc., ont été filmées à nouveau de façon à obtenir le meilleure image possible.
- [ ] Qpposing pages with verying colouration or discolourations are filmed twice to ensure the best possible imege / Les pages s'opposant ayant des colorations veriebles ou des décolorations sont filmées deux fois afin d'obtenir la meilleur imege possible.

- [x] Additional comments / Commentaires supplémentaires: **Pagination is as follows : p. 130-144.**

This item is filmed at the reduction ratio checked below/
Ce document est filmé au taux de réduction indiqué ci-dessous.

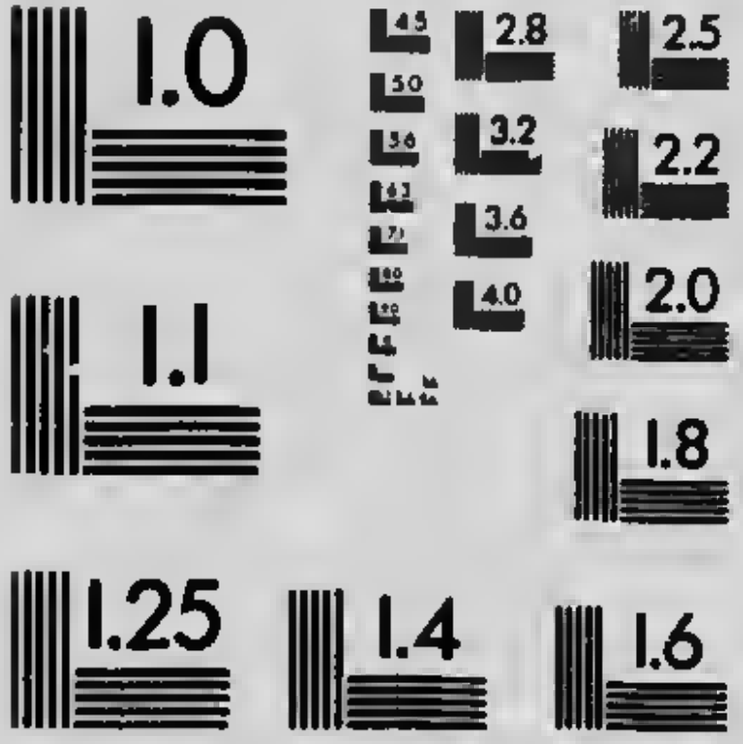
10X	12X	14X	16X	18X	20X	22X	24X	26X	28X	30X	32X
						✓					





MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



APPLIED IMAGE Inc

1653 East Main Street
Rochester, New York 14609 USA
(716) 482 - 0300 - Phone
(716) 288 - 5989 - Fax

With the Compliments of the Author

EARTHQUAKES.

By OTTO KLOTZ, LL.D., F.R.A.S.

EARTHQUAKES.

By Otto Klotz, LL.D., F.R.A.S.

[*Read March* 1, 1907.]

Destructive and calamitous as has been the San Francisco earthquake, yet from the scientific standpoint it has given a decided impetus to the study of seismology, and it has hastened the day when our knowledge of the interior of the earth will be of a definite character, which it is not now, if we except the comparatively few feet that we have penetrated into the earth.

Nature is an aggregation of facts, and it is the sphere of the investigator to correlate these facts and to explain their existence. In the effort to solve the latter advancement is generally gained by the method of elimination.

As facts do not generally admit of mathematical analysis, theories and hypotheses are advanced for their explanation. These temporary fortresses must then be able to resist the relentless cannon of observations and of criticism, for the enemy gives absolutely no quarter. Error succumbs to the first broadside; plausibility turns away many a shot and can stand a long siege. It serves a good purpose in permitting the enemy to reinforce its resources to keep up the attack until either the fortress is razed or a new one has been built within, built with the impregnable nickel-steel armor of truth.

Perhaps a brief review of some of the reasons assigned as the cause of earthquakes, leaving out those of supernatural origin, may not be unprofitable.

We know that there are many sedimentary deposits or formations constituting part of the crust of the earth. We know that they are more or less soluble. We know that the immediate crust of the earth is interseeted and traversed by subterranean water-courses. We know that these waters when brought to the surface are more or less charged with salts—such as lime or sodium—dissolved from the formations through which the water passed. Now let us put two and two together. If a subterranean stream discharges so many cubic feet of water per day, and each cubic foot contains so many grains of lime, how long will it take

to carry away so many tons or cubic miles of limestone rock? The result of our investigation is a hole in the ground, or rather a hole in the earth, and if we make that hole big enough, something is going to happen—the roof is going to collapse—and we have an earthquake. This in brief is the Einsturz or downthrow theory. Now some earthquakes have happened which might be explained by the above, but, for, by far the larger number, other reasons must be sought. Before dismissing the above, it may be suggested, that, although subterranean waters must and do hollow out the earth's crust, the formations slowly adjust themselves to the minute changes continuously wrought by the action of water, so that excessively large cavities are improbable if not impossible.

One of the oldest beliefs about earthquakes is their intimate associations with volcanoes. This opinion died a hard death, in fact, I am not sure that it is quite dead yet, however Professor Milne has shown, especially for Japan—the principal earthquake country—"that the many quakes of that archipelago seemed to show an avoidance of the volcanic centres which are numerous in the interior, and to indicate that volcanic energy was seldom concerned in generating them."

Volcanoes are as a rule shallow-seated, while the movements of earthquakes are tectonic, that is, affecting large areas of the earth's crust and miles in depth.

Another theory that was advanced some forty years ago was the tidal theory. Assuming the earth to be a molten mass covered by only a thin shell, it seemed plausible to have tidal effects by the attraction of the moon and of the sun. Spring and neap tides in the ocean would be manifested by earthquakes of greater and less intensity; similarly for perigee and apogee. However, facts don't fit in right, and the fortress has been abandoned.

When we say that earthquakes are the result of the adjustment of strains and stresses within the earth, the statement is one practically accepted by all seismologists, at the same time, it is far from explaining the cause. What sets up these strains and stresses, and if there are various agencies at work, what is their relative effect?

It is almost axiomatic to assume the earth as a cooling body. Now on this assumption a very pretty scientific theory was advanced some thirty years ago by Lowthian Green, it was the tetrahedral theory of the figure of the earth. Let us follow it for

a moment. Starting with the earth as a molten mass, we have a sphere as the result of the action of gravity. If we revolve the [illegible] we obtain an oblate spheroid, with flattened poles—orange-shaped, the shorter axis being the one of revolution.

The angular velocity of rotation being uniform and constant the whole body would be in stable equilibrium. If now any force or forces are brought into play to disturb this equilibrium strains and stresses are set up, and a counter tendency to relieve these strains is called forth to restore equilibrium. It is at this juncture that the property of the tetrahedron comes into play. Taking as our principal disturbing force of our supposed liquid or molten spheroid of revolution, that of dissipation of heat or cooling process, we find that the crust or shell of the earth tries to adjust itself to the stresses set up by the contracting body, and does so by the line of least resistance, that is, by spreading the stresses over the greatest surface, with the result, that the tendency of the surface of the earth is to assume the tetrahedral form, *i.e.*, of an equilateral pyramid. Or one may say that the contracting earth changes into that form whereby the original superficial area is maintained. For equal surfaces the volumes of the sphere and tetrahedron are to each other as 1:.55; and for equal volumes the surfaces are as 1:.1.45.

Neither the theory nor its advocates gives us a four-cornered earth, its original condition and axial rotation would prevent that. The theory does claim that the tendency however slight or great in effect, must be towards shaping the surface into that of a tetrahedron, or tetrahedroid, the latter having curved surfaces or edges. If a complete transformation from the sphere to the tetrahedron took place, which is of course impossible, we would have, taking the axis of the earth co-incident with an axis of the tetrahedron through one of its apices, a north polar sea, which is the case; three great equatorial oceans; a south polar land cap, which too is the case; and there would be six grand mountain ranges, three diverging from the south pole, corresponding to three edges of the tetrahedron, and the other three encircling the northern hemisphere, being along the remaining three edges of the pyramid.

In the tetrahedron every corner has a surface opposite to it, so that for the earth this would mean that land and water are antipodal, which is fairly well represented in the actual conditions. Another result would be that land masses would be broad in the

northern hemisphere and taper towards the south, which too agrees with our geography. Inversely, the oceans should contract towards the north, a condition fairly well borne out.

Furthermore, the north polar area being represented by a surface and the south polar one by a corner, it would follow that the flattening of the earth in the southern hemisphere would be less than in the northern; and again, gravity would increase less rapidly towards the south pole than towards the north pole. Both these considerations have been confirmed by geodetic and pendulum observations.

If the tetrahedral theory was effective at the early stage of the earth's existence, in giving us many of our mountain systems and our polar physical conditions, to-day with a pretty rigid crust its effect must be vanishingly small and unrecognizable as due to that theory.

We may refer to another theory of the figure of the earth, contained in a paper presented by J. H. Jeans to the Royal Society in 1902. This theory shows, under certain assumptions, that the earth was pear-shaped at a certain stage of its existence, and contracting assumed the spherical form. I cannot in this place pursue this subject of the figure of the earth any further; it was only alluded to to show one of the factors—the contracting forces, ever active, whereby strains and stresses are set-up, and without which no earthquakes are possible.

Fisher in his "Physics of the Earth's Crust" 1889, combats the theory of mountain building as being due to the secular cooling of the earth and the accompanying contractions, but this would not preclude smaller motions to which earthquakes may be relegated. Arrhenius considers the crust of the earth comparatively thin; at a depth of about 40 miles to merge into a hot fluid mass, the magma, due to the increasing temperature. From the deepest boring on the earth the increase of temperature is about 1°F. for 51 feet, or say 100°F. per mile. Beyond a depth of about 200 miles the magma assumes the gaseous form. He writes "the earth as well as the sun contracts, whereby heat is envolved and the contraction partly arrested or decreased. Nevertheless the earth slowly shrinks. This pertains especially to the interior of the earth, for the temperature of the surface is almost wholly due to radiation from the sun, and in a small degree upon the character of the atmosphere. It may be assumed that, broadly speaking, the radiation of the sun and the nature of the atmos-

phere are constant. It follows therefore that the crust of the earth will not follow the shrinking of the interior. Foldings and wrinkles will be produced, and it is the general conclusion, that this is the principal reason for the uplifts of the surface into mountain chains."

That earthquakes are due to an adjustment of stresses in the earth's crust is admitted by all investigators, but on the cause of the stresses, there is far from unanimity of opinion.

Although some earthquakes are due to downfalls, and local ones to volcanic eruptions, yet for the great majority another reason or reasons must be found. Of the latter, the contracting force, already alluded to, is the one first to suggest itself, and has for its support at least great plausibility. It has been combated by able investigators, without however being able wholly or satisfactorily to dispose of it completely.

Leaving out of consideration the earth as a cooling or contracting body, let us picture to ourselves the earth at any time in a state of perfect equilibrium, there being no stresses on its surface nor in the crust. Let us note the physical features, the heights of the mountains, the faulting and folding of the rock formations, the depths of the ocean and the distribution of land and water. Now let the atmospheric influences come into play—rain and snow, heat and cold—together with the varying atmospheric pressure. The pre-existing equilibrium will be immediately disturbed; the water, as ripples, creeks, rivers and streams will begin its work of erosion and denudation; heat and frost will assist in the disintegration of mountain masses, and the ocean beds adjoining the continents will be loaded by enormous amounts of detritus carried from the land. Unless there is a continuous and simultaneous adjustment of the change of pressure, the stresses set up will be cumulative and continue so until they exceed the limit of elasticity, when rupture must take place to restore equilibrium for the time being. Rupture would necessarily be accompanied by earthquakes.

It is obvious therefore that meteoric or atmospheric influences are capable of setting up stresses on the earth's surface. It is safe to say that the whole surface of the earth is in a constant tremor due to stresses. But besides the general condition, there are other factors that come into play, and localize in a measure the seismic disturbance. These are mountain masses and ocean depths, especially if they are contiguous.

Speaking generally, mountains are not masses resting upon the surface of the earth, but must be considered as masses immersed in the earth, just as an iceberg is immersed in the water. The greater the part that projects above the water, the greater must be the part beneath the surface, for the amount of water displaced must be equal to the floating mass, otherwise there would not be equilibrium. Somewhat similar it is with the mountains. Were they resting on the surface, the stresses set up by the superimposed mass would not only be enormous, but would be greater than the crust could support. Furthermore as a superimposed mass it would materially affect the force of gravity in the adjoining region. The most noted investigations of this question was with reference to the attraction of the Himalayas in connection with the Great Trigonometrical Survey of India. Pendulum observations have shown conclusively both in India and in America that this is not the case. However complete equilibrium or isostasy does not obtain, and hence the residual strains and stresses.

It is obvious how through meteoric agencies cycles of changes are produced. The mountains by decrements are wandering seaward, the continents are lightening, and the ocean bed is being loaded, producing a deep-seated inflow from the sea towards the land. These changes are continually taking place, the earth's crust and surface are undergoing constant transformation, however minute; the strains and stresses are continually responding to one another; vast rock formations that seem rigid are by the slow process of time bent and contorted as if made of wire. But when these responses are not synchronous, when there is a lag, equilibrium can only be restored by rupture. This rupture will be along the line of least resistance, and this is generally found in a geological fault, an old rent in the crust, so well illustrated in the California earthquake of last April.

If the earth were a homogeneous body or if at least it were composed of concentric shells each of homogeneous matter, then the geodetic surveyor when carrying on large trigonometric surveys would not be troubled with closing errors, other than those arising from observations. There would be no error due to deflection of the plumb line. As complete isostasy does not however exist, these observed discordances, due to the unsymmetrical distribution of matter, are a measure of isostasy.

Dr. J. F. Hayford has examined the data furnished by the

triangulation of the United States, and has found 71 miles as the most probable value for the depth of compensation, that is, the depth at which the compensation of the excess of matter at the surface (continents) by defect of density below, and of surface defect of matter (oceans) by excess of matter below is complete. At and below this depth the condition as to stress of any element of mass is isostatic, that is, any element of mass is subject to equal pressure from all directions as if it were a portion of a perfect fluid. From this it appears that the behaviour of the magma, situate beyond 71 miles, is that of a liquid.

As earthquakes are so intimately bound up with stresses, we quote Hayford: "In terms of stresses it is safe to say that these geodetic observations prove that the actual stresses in and about the United States have been so reduced by isostatic adjustment that they are less than one-tenth as great as they would be if the continent were maintained in its elevated position, and the ocean floor maintained in its depressed position, by the rigidity of the earth. It is certain that for the United States and adjacent regions, including oceans, the isostatic compensation is more than two-thirds complete, perhaps much more." Hayford's result is one of the most brilliant mathematical deductions in geodesy and geophysics in recent years.

Several causes have been adduced which contribute or may contribute to the production of earthquakes. In investigations one is sometimes led to the discovery of widely different phenomena, which, however, synchronize with each other, thereby raising the question whether one is dependent upon the other, or whether both phenomena depend upon a common cause. Such a case is the possibility of a connection between latitude variations and earthquakes. On this point Professor Omori, one of the foremost of seismologists, says: "From an examination of the mean monthly values of the latitude of Tokio, I have found that all the destructive earthquakes of recent years in Japan occurred exactly or very nearly when the latitude was at a maximum or minimum."

Verily our solid earth is only so in a Pickwickian sense. The surface slides bodily over the figure of revolution, our excursions in latitude being about 26 feet. On solid rock we make marks as reference points, unalterable as we think, for levels and other measures,—the earth heaves but a sigh and our basal points lose their value. In despair almost we exclaim "Is their nothing stable on this earth?"

I shall now refer to three notable earthquake—the one in Canada in 1663, the one of Jamaica in 1692 and the one of Lima in 1746, and shall give a few extracts from original sources. The extracts are perhaps more adapted for a study in ethics than of science.

In the Jesuit relations the great earthquake of 1663 is frequently referred too, but unfortunately the descriptions are so wild and exaggerated that very little scientific value attaches thereto, outside of the statement of its extent, and inferentially, I think, one can locate the fault or rift where the main displacement or adjustment took place.

Lalemant writes under date Sept. 4, 1663: "An earthquake extending over a region more than 200 leagues in length and 100 leagues in width, making 20,000 leagues in all, has shaken this whole country, and caused us to witness some prodigious transformations. Mountains were swallowed up; forests were changed into great lakes; rivers disappeared, rocks were split and their fragments hurled to the very tops of the tallest trees; thunders rumbled beneath our feet in the womb of the earth, which belched forth flames; doleful and terror-inspiring voices were heard; while whales and porpoises bellowed in the waters; in short, all the elements seemed aroused against us, and threatened us with the direst disaster.....It made itself felt from Isle Percée and Gaspée, which are at the mouth of our river, up to Montreal and beyond, as also in New England, Acadia and other far-distant regions." The earthquake happening on the Monday eve, Feb. 5, preceding Shrove Tuesday, had a salutary effect in preventing debauches commonly occurring on that day, "thus Shrove Tuesday was fortunately changed into a Good Friday and also into an Easter."

"They saw very lofty hills striking together with brows opposed, like headstrong rams, then suddenly and instantaneously swallowed up in the yawning of the earth."

Father Charles Simon relates "that a man so shuddered at the sudden earthquake, although at other times he was brave, that his hair, bristling up with horror and standing upright, shook off his fur cap."

The following extract appears to furnish some proof that the adjustment and principal movement took place along the bed of the St. Lawrence where our geologists of to-day have placed "The Great St. Lawrence and Champlain Fault," extending from

beyond Anticosti along the channel of the St. Lawrence to the vicinity of Quebec and thence by a gentle curve to Lake Champlain: "It may be very easily inferred how great was the upheaval of the earth, from the fact that such and so great a river changed its color, not for a brief space of time, but for eight entire days, put on a sulphurous one, and kept it constantly; for, from the bowels of the earth, agitated in their nethermost depth and poured into it, and from sulphurous mines, its waters were diluted with an abundance of liquid sulphur." The earthquake lasted with ever increasing intervals until the following September.

Coming to the earthquake at Port Royal, near the present Kingston, Jamaica, on June 7, 1692, the Anglican minister there writes the following week (15 June): "Captain Ruden's house upon the first concussion sunk into the earth, and then into the sea, with his wife and family, and some who were come to dine with him.....I saw the earth open and swallow up a multitude of people, and the sea mounting in upon us over the fortifications .....the earth working all the while with new motions and tremblings, like the rowlings of the sea... ...I found the sea had entirely swallowed up the wharf, with all the goodly brick houses upon it, most of them as fine as those in Cheapside, and two entire streets beyond that.....In the space of three minutes, about half an hour after eleven in the morning, Port Royal..... was shaken and shattered to pieces, sunk into and covered, for the greater part by the sea, and will in a short time be wholly eaten up by it.....We guess that by the falling of the houses, opening of the earth and inundations of the waters, there are lost 1,500 persons.....Our great and famous burial place was destroyed by the earthquake, which dashing to pieces the tombs, whereof there were hundreds in that place, the sea washed the carcasses of those, who had been buried, out of their graves. .....From St. Ann's we hear of about 1,000 acres of woodland changed into the sea, and carrying with it whole plantations. .....Whole streets (with inhabitants) were swallowed up by the opening earth, which then shutting upon them, squeezed the people to death. And in that manner several are left buried with their heads above ground; only some heads the dogs have eaten, others are covered with dust and earth by the people who yet remain in the place, to avoid the stench.....The two great mountains at the entrance into 16-mile walk fell and, meeting, stopt the river.....At Yellows, a great mountain

split and, falling into the level land, covered several settlements, ...One person had his plantation removed half a mile from the place where it formerly stood, and now good provisions grow upon it." Of the same earthquake Dr. Morley "takes notice that he had felt several lesser shakes, and heard the noise often, which is very loud, and by those not used to hear it, may be easily taken for a rustling wind, or hollow rumbling thunder, but he says it hath some puffing blasts peculiar to itself, most like those of a brimstone match, when lighted, but in a much greater degree, and such as a large magazine of brimstone may be supposed to make when on fire. He adds, that in Port Royal, and many places all over the island, much sulphurous combustible matter had been found, supposed to have been thrown out, upon the opening of the earth, which upon the first touch of fire would flame and burn like a candle." In this earthquake at Port Royal the shore line subsided 26 to 48 feet beneath the sea.

In the same year, 1692, possibly synchronizing with the preceding Jamaican quake was the severe one at Riobamba in the province of Quito, South America.—"It shook the earth in such a manner that it bore off great pieces which were seen to run entire three or four leagues from the place where they had been before, and thus to remove whole fields, with the trees and houses standing. This event occasioned the most extraordinary law-suits that were ever heard of, brought to Lima, to decide to whom these estates belonged: the party on the one side alleging that they were within his jurisdiction or lordship, and the other pleading that he was upon his own land."

This is the most pointed reference to law-suits resulting from earthquakes that I have come across. I think we must take the sliding about of the country nine to twelve miles with a grain of salt.

Imagine Ottawa waking up some fine morning to find itself up at Aylmer or Chelsea!

Coming now to the great earthquake of Oct. 28, 1746, in Lima, I shall quote a few sentences from the volume of the following year describing the catastrophe: "But it is most certain that the two main principles of these dreadful mischiefs are heat and moisture.....However, supposing such to be the case, it does not at all hinder but, that the Almighty-Power may employ these natural accidents as the instruments of punishment to a wicked people. .....There was not before the late great

calamity a more licentious spot upon the earth. The charming serenity of the climate and fruitfulness of the country, the plenty of all things, and the sedate tranquility which the Spaniards perpetually enjoyed, these, together with the extreme beauty of the women, did not a little contribute to an amorous disposition, which was the prevailing passion of the inhabitants."...."Lima, being subject with very little intermissions, to such dreadful calamities, one would imagine it was the habitation only of criminals sent thither for punishment, or of the people who were weary of life, and not of such who made it their choice to live there. But so powerful are the allurements of riches, so bewitching the hope of gain, as to make danger preferable to safety, and the continual fear of death reconcilable with the desire of living long and out of harm's way.....Of all judgments, proceeding from natural causes, which the Deity often inflicts on offenders, in order to satisfy divine justice and manifest his almighty power, the unexpected stroke of sudden earthquake hath ever been the most tremendous, for as much as in one and the same moment they became both the warnings and executioners of its wrath.... ....This fatal catastrophe befel the place thirty minutes after ten at night, when the sun was in five degrees ten minutes of Scorpio, and the moon in not much less of Taurus, so that these planets wanted very little of being in opposition, as they actually were in five hours and twenty-two minutes afterwards, an aspect which by constant observation hath proved unfortunate in this climate; for under its influence these convulsive kinds of agitation in the earth do most usually happen.....On this occasion the destruction did not so much as give time for fright, for at one and the same instant almost, the noise, the shock, and the ruin were perceived together, so that in the space of only four minutes, during which the greatest force of the earthquake lasted, some found themselves buried under the ruins of the falling houses, and others crushed to death in the streets by the tumbling of the walls, which, as they ran here and there, fell upon them.....The earth struck against the edifices with such violent percussions, that every shock beat down the greater part of them."

"Of a total of about 3,000 houses within the city walls, scarce twenty were left standing, and of the estimated population of 60,000 only 1,141 were killed. The small loss of life is due largely to the one-story buildings." The seaport of Lima, Callao, with a population of 5,000 was wholly destroyed by a tidal wave accom-

panying the earthquake; only about 200 escaped. Ships were thrown high and dry over Callao.

In reading the descriptions of these old earthquakes one cannot but perceive a certain mental attitude of the people towards the phenomenon, and that attitude may best perhaps be expressed by saying with Shakespeare "Conscience does make cowards of us all."

The San Francisco earthquake so fresh in your minds, and which has been so much described and illustrated, will be dealt with briefly. The great mountain masses in California running parallel to the coast, and the adjoining ocean depths of the Pacific are conducive, as already indicated, to earthquakes. The break would naturally occur about midway between these depths and the mountains, and furthermore along the weakest line thereabouts, that is, along an old geological fault, as was actually found to be the case. The displacement of the surface adjoined this old fault or rift, which runs northwest-southeast in an almost mathematical straight line for several hundred miles. The nearer to this line, the greater was the displacement or earth movement. Along the rift the greatest horizontal shifting was 16½ feet, the western side moving northward, while the eastern side moved southward. The maximum vertical motion was about 4 feet.

It may be mentioned that our Ottawa Observatory seismograph registered the arrival of the first tremor or shock seven and a third minutes after its occurrence, which is equivalent to a speed of transmission of 340 miles per minute.

The disturbing force varies probably inversely as the square of the distance from the rift, but as far as destruction to buildings is concerned it depends very materially too on the nature of the ground upon which the building stands. This was well illustrated at San Francisco, where the earthquake damage was almost exclusively confined to made or alluvial ground, that part of the city that had been reclaimed from the tide flats. This is an important point and one that will not be forgotten in future construction in earthquake areas.

The Kingston earthquake of last January, although more destructive of life than the San Francisco one, yet as a world-shaking phenomenon was very much smaller than the California one of last April, for the minimum amplitude or swing of the recording instrument at Ottawa was nearly twenty times greater for the latter than for the former. Earthquakes are generally

judged by their destructiveness to man and his works. This depends on how near or close a city or habitations are to the rift, where the greatest shaking takes place. Earthquake instruments are, however, oblivious to man or his toy works, they record simply the working of mother earth; so that the great earthquakes of the seismologist are not necessarily co-incident with the great earthquakes of man.

In the calamitous earthquake of Valparaiso last 16th August, it is reported that the harbor is now ten feet shallower than before that event, and that the motion was mostly vertical.

The most noted vertical movement of recent years was the Alaska quake of Sept. 10 and 15, 1899, when the uplift along the Yakutat coast for upwards of a 100 miles was many feet, reaching its maximum in Disenchantment Bay where the land rose 47 feet.

The last quarter of a century stands out pre-eminently as the most marked in seismic disturbances of which we have any historic record. It began with that cataclysmic explosion of Krakatao in 1883, noted for the red sunsets that followed for the next two years, due to the suspended dust in the upper regions of the atmosphere. Of the important disturbances we may mention those of Ischia near Naples; Tarawera, New Zealand; Charleston, South Carolina; Mino-Owari, the climax of the many thousands of shocks in Japan; Alaskan coast already referred to; Saint Pierre in the West Indies; Formosa; Vesuvius; and the recent quakes at San Francisco, Valparaiso and Kingston. It is estimated that the loss of life resulting from these disturbances is at least 150,000.

The question naturally occurs, whether we in Canada have much to fear, or even anything to fear from destructive earthquakes. Speaking generally, I say no, and this especially for eastern Canada bordering the Atlantic; for we have there not that marked contrast of mountain masses and ocean depths, and our St. Lawrence with its long chain of settling basins in the great lakes carries comparatively little suspended matter to load the ocean bed to produce stresses. When, however, the question is asked, should a severe earthquake happen, where will it most likely occur? Then we are pretty safe in predicting that it will occur along our weakest part of the crust of the earth, and that is, along the Great St. Lawrence and Champlain fault, following the lower part of our ocean stream, already described as the line of the great quake in 1663. As a matter of fact we have more

trembling down there now, especially in the vicinity of Eboulement, near Murray Bay, than elsewhere. As an earthquake risk for any of our large cities, Quebec would have to pay the highest premium.

Should an earthquake visit Ottawa, the chance is remote, the Observatory would be more affected than the Parliament Buildings, for the former is within stone's throw of a line of weakness in the earth—the so-called Gloucester fault.

Time does not permit me to speak of earthquake instruments. I will simply say that one can not but marvel at their sensitiveness. They tell us what is going on in the earth when our senses are wholly unable to detect the slightest disturbance or movement. Whether the old earth heaves a sigh in its long struggle against the inevitable when *rigor mortis* will set in, be it in Japan or Italy, in Chile or Alaska, these silent observers, that literally have their ear to the ground, note the pulsations as they pass in their journey round the world. How gladly would the seismologist launch his little canoe on the seismic wave at the hypocentre or starting place, and just see whither and how fast the wave would carry him. There would be no harbor, no resting place, the course followed would be the one prescribed by nature,—following the line of least resistance. The log of such a journey has yet to be written, and when it is written we will know more about the crust of the earth, and of the interior than we do now.

P.S.—Since the above was written Professor T. J. J. See has sent me a copy of his paper "The Causes of Earthquakes, Mountain Formation and kindred Phenomena, connected with the Physics of the Earth," read Oct. 19, 1906.

Professor See is an able investigator. He devotes 140 pages in the Proceedings American Philosophical Society to expounding his theory. He dismisses all other theories and hypotheses as inadequate for the explanation of the phenomena indicated by the title of his paper. His own theory is that we have to turn to the explosive force of steam for satisfactorily answering the questions suggested above. On the last page he writes: "The great layer of water covering the earth which gives life to animals and plants, and in the form of steam is the greatest mechanical agent of man, when sunk into the crust becomes also one of his worst destroyers, on account of the explosive vapor generated beneath by the internal heat of the globe."

On p. 324 we read: "We thus seem compelled to abandon

the construction theory entirely, and to explain both peaks and ranges with their striking parallelism to the coast by upheavals occurring near the sea, due to the explosive power of steam, which has heaved up the mountains from beneath.... .....And lastly it shows that all mountains are alike inside, whether they burst open and become volcanoes or remain intact."

The same agency he advances for producing earthquakes and volcanoes.

This post-script is not the place to present and discuss the paper at length.

However, one is safe in saying that geophysicists and seismologists will not tacitly say amen, when Professor See exclaims "Eureka."