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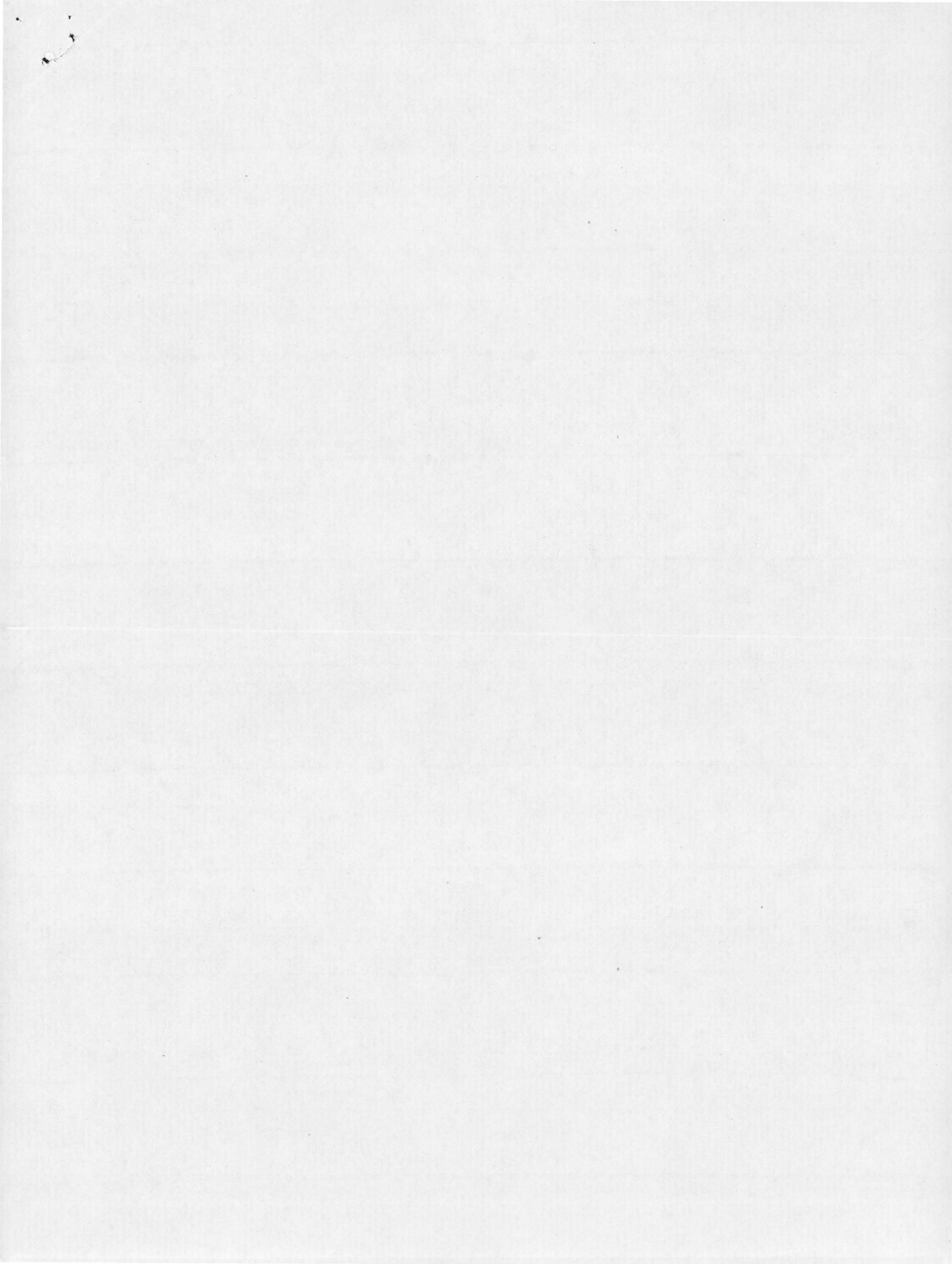
THE ST. LAWRENCE EARTHQUAKE
FEBRUARY 28, 1925
(A FINAL ANALYSIS OF THE DATA COLLECTED)

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ABSTRACT

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The St. Lawrence earthquake occurred at 9h 19m 20s p.m., E.S.T., Saturday, February 28, 1925. The observational data obtained have been thoroughly studied at the Dominion Observatory.

The paper presents a brief résumé of the various lines of investigation which have been followed during the past two years. The reasons are outlined which seem to warrant the conclusion that the earthquake occurred on a fault crossing the St. Lawrence near the mouth of Rivière Ouelle, of which fault the seaward side snapped upward at the time of the shock, the landward side suffering a simultaneous, sudden, horizontal displacement toward the northeast.

DOMINION OBSERVATORY
OTTAWA - CANADA

March 29, 1927.

THE ST. LAWRENCE EARTHQUAKE
 FEBRUARY 28, 1925
 (A FINAL ANALYSIS OF THE DATA COLLECTED)

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The St. Lawrence earthquake occurred at 9^h 19^m 20^s, p.m., E.S.T., Saturday, February 28, 1925. It was felt strongly over eastern Canada and the New England states. Replies to questionnaires reveal the fact that the tremors were felt as far south as Virginia and as far west as the Mississippi. Seismograph records were obtained at practically all the stations in the world; very complete and well-marked ones being registered as far west as Victoria, B.C., as far east as central Europe, and as far south as La Plata. The damage was confined to a narrow belt, approximately twenty miles long, covering both sides of the St. Lawrence somewhat less than a hundred miles below the city of Quebec. Besides this damage indicating the position of greatest disturbance, there was some, due to the soft soil beneath heavy buildings, in less disturbed regions, notably at Quebec and in the valley of the St. Maurice river.

The earthquake was thoroughly investigated by the seismological division of the Dominion Observatory. After a careful examination of many data, a conclusion was deduced, correlating all the observations. The epicentre may be considered as having occurred on a fault line crossing the St. Lawrence near Rivière Ouelle, (about 90 miles below Quebec city), entering the south shore to near St. Pacome, and extending into the north shore, up (perhaps) one or both the rivers Malbaie and Gouffre. The earthquake probably consisted of a sharp upward thrust on the northeast side of the fault, coupled with a strong horizontal movement toward the northeast in the case of the southwest side.

The causes advanced for this earthquake are a major, underlying one, due to an accumulation of stress caused by a slow rising of the Atlantic coast, and several "trigger" causes. Among the latter may be mentioned the Sayles theory of the effect of long periods of drought on a rising section of the coast, and the estuary tide effect, virtually warping up the outer (east) side of the fault, due to a high tide, well inside the fault line zone, and a low tide outside that zone, the conditions obtaining at the time of the earthquake.

In order to discover the strength of the support given to the above generalization by the various observational data, we may review the lines of investigation followed under seven general headings, arranged in the following order:-

1. Field Work
2. Questionnaires, Newspapers, Interviews, etc.
3. Instrumental Data
4. After Shocks
5. Seismic History
6. Surveying
7. Geology

FIELD WORK

The following visits have been made into the disturbed areas:

1. March 5 to March 21, 1925: To Murray Bay, Pointe-au-Pic, Baie St. Paul, St. Urbain, Quebec, Lake St. John region, Chicoutimi, Bay Ha! Ha!, Levis, Rivière Ouelle, St. Pacome, Ste. Anne de la Pocatière, Rivière du Loup, Trois Pistoles, and Shawinigan Falls.
2. April 2 to April 17, 1925: To Ste. Anne de la Pocatière, Ste. Louise, Rivière de Loup, Notre Dame du Lac, Edmundston, St. Pascal, Kamouraska, St. Philippe de Neri, St. Denis, Mt. Carmel, Rivière Ouelle, and St. Pacome.
3. July 31 to August 7, 1925: To Ste. Anne de la Pocatière and vicinity, including Rivière Ouelle and St. Pacome.
4. May 27 to June 7, 1926: To Shawinigan Falls, and St. Joachim.
5. June 21 to June 24, 1926: To St. Joachim region on north shore.
6. July 14 to July 24, 1926: A trip in company with Dr. J. W. Goldthwait, to Shawinigan Falls, thence along the north shore of the St. Lawrence to Quebec and St. Joachim, up the Ste. Anne river to Seven Falls, and around the Isle of Orleans, followed by a visit of several days duration to the south shore, most of the time being spent between Ste. Anne de la Pocatière and Kamouraska.

All the above trips, except the first two, were taken in connection with other work, but on each of them every opportunity was taken to clear up various points with regard to the earthquake.

QUESTIONNAIRES, NEWSPAPERS, INTERVIEWS, ETC.

The following questionnaire series were distributed and examined:

1. A Canadian series (222) sent to well-distributed points in Canada, to be filled in by postmasters and others.
2. An American series (over 250) collected by the United States Coast and Geodetic Survey and very kindly supplied, together with an analysis and map of isoseismals, for points in the United States.
3. A Newspaper series for Canada, consisting of special requests addressed to the editors of newspapers in eastern Canada, asking for clippings.
4. A Telegram series in connection with the after shocks. Mention may be made of the shock of April 10, 1925, immediately investigated by telegrams sent to points on the north shore and by telephone conversations with people at points on the south shore. It was not felt at Ste. Anne de la Pocatière, Chicoutimi, or St. Bruno. It was strongly felt at Kamouraska, Murray Bay and St. Pascal. Also the shock of April 25, 1925, which was investigated at once. It was felt at Chicoutimi and at Ste. Anne de la Pocatière (being a somewhat stronger shock) but was not felt at a series of stations on the transcontinental railway, running parallel to the St. Lawrence about twenty miles south of that river. The general testimony of the telegram investigations was that the after shocks originated in the general vicinity of Kamouraska, Murray Bay, and Rivière Ouelle.

The results of all the questionnaire work indicate that the earthquake was felt as far west as Duluth, as far south as Virginia, as far east as the coast, the tremors being noted nearly to the southern point of Labrador.

The results of some special interviews require individual mention. At the time of the earthquake stories were told of long distance conversations by telephone during which one of the parties felt the shock before the other. These were examined carefully in each case. No such long distance conversation was going on at the

time of the earthquake so far as could be learned. All cases reported were investigated. With regard to the story that radio announcements were made of the quake before the listeners-in could feel it, the following carefully observed fact may be told:- At Rivière du Loup, the manager of the local telephone company was listening to WGY broadcasting a dinner concert from Albany. His house was, according to his description, careening like a ship at sea, while the musicians played, still undisturbed.

The first report given out as to the probable epicentre read as follows:- "At present it may be said that the disturbed fault is either in the bed of the St. Lawrence near Rivière Ouelle, or north of the river about thirty miles, near the eastern boundary of the Laurentides Park". One point which lent weight to the latter choice was the story of the lake ice which "exploded" at the time of the quake. Many attempts were made to have an interview with responsible persons who were near Lake Cartier at the time of the quake. It was not until July 21, 1926, that such an opportunity was secured. An interview was arranged with Mr. Michael Fragasso, an engineer, in charge of construction work on that lake at the time of the earthquake. He gave a very good account of the shock. The ice on the lake cracked at the time but no damage was done at the dam or in the camp. His description of the experiences of himself and his men would tend to give little weight to the earlier reports from Lake Cartier.

One other special report must be given space at this point. The late Dr. John M. Clarke, whose geological investigations in Gaspé are so well known, received word from his friends in that peninsula that the ice-encrusted snow was cracked throughout the whole region by the passing earthquake waves. Investigation in the vicinity of the epicentre showed that such cracks were everywhere as far west as Ste. Louise, (on the south shore), but no farther. This is possibly to be attributed to a vertical vibration near the epicentre and to the east of it. This, combined with the horizontal motion shown by seismographs to the west and south of it, lends strength to the generalization of the last sentence of the second paragraph of this paper.

INSTRUMENTAL DATA

An examination of the reports from the following 26 stations shows how closely the instrumental records support the location in the St. Lawrence. It may be said, in explanation, that O indicates the time at the origin, as determined from the record of the station reporting, and that it is subject to the errors of the clock of the station as well as to the errors of reading, etc. A indicates the distance from the epicentre to the station reporting, as determined from the record of that station.

STATIONS	O.	A
Ottawa.....	9-19-20	480 km.
Algiers.....	9-19-07	5900 "
Barcelona.....	9-18-40	5750 "
Berkeley.....	9-19-06	4250 "
Cartuja.....	9-19-10	5440 "
Cheltenham....	9-19-31	1050 "
Chicago.....	9-19-44	1300 "
Coimbra.....	9-19-08	4820 "
Ekaterinburg..	9-19-18	7610 "
Eskdalemuir...	9-19-27	4140 "
Fordham.....	9-19-27	710 "
Georgetown....	9-19-29	1040 "
Hamburg.....	9-19-18	5240 "

STATIONS	O.	Δ
Helwan.....	9-19-19	8420 km.
Königsberg....	9-19-09	5990 "
La Paz.....	9-19-21	7000 "
Paris.....	9-19-10	5120 "
Pulkovo.....	9-19-11	6110 "
Rio de Janeiro	9-19-20	8280 "
Strasbourg....	9-19-11	5500 "
Toronto.....	9-19-25	760 "
Uccle.....	9-19-13	5070 "
Victoria.....	9-19-00	3870 "
Wien (Vienna).	9-19-11	6050 "
Zürich.....	9-19-08	5650 "
Spring Hill...	9-19-24	2410 "

The adopted value for the time at the origin is $9^{\text{h}} 19^{\text{m}} 20^{\text{s}}$, the geographic coordinates of the epicentre being $\varphi = 47.6 \text{ N.}$, $\lambda = 70.1 \text{ W.}$, a point in the St. Lawrence between the mouth of the Malbaie river on the north and the mouth of Rivière Ouelle on the south: it being understood that the epicentre is not to be considered as a point but rather as a zone the major axis of which lies approximately north and south (mag.) and having a mid-point at the position indicated by the above coordinates.

(The above tabulation is the result of an analysis by W. W. Doxsee, M.A., Assistant Seismologist of the Dominion Observatory. His valued assistance in other parts of the work on this earthquake is gratefully acknowledged at this time.)

The seismograph records at Ottawa quite definitely indicate that the first motion there was toward the epicentre, further confirming the last sentence of paragraph two of this paper.

AFTER SHOCKS

The after shocks of the earthquake were carefully studied. A close observer, living near the epicentral region, tabulated 11 strong shocks during the day following the earthquake. These were all after nine o'clock the next morning. During the night of February 28 - March 1 the shocks were "almost continuous"; certainly very frequent (four besides the main shock being recorded at Ottawa). During the waking hours of March 2 the same observer tabulated 8 strong shocks. His record, continued for a week, and including only well-marked shocks occurring during waking hours, lists, in all, 37 earthquakes.

Special mention may be made of the after shock of 9-30 p.m., Friday, March 6. The shock at Point-au-Pic was quite marked, lasting for from five to ten seconds and causing one to wonder if the house would really stand the strain.

A much more severe shock occurred on March 21, at about 10-20 a.m., E.S.T. It was felt over a wide area and caused alarm as far away as Quebec city.

Mention has already been made of two of the after shocks experienced by known observers and investigated by telegraph, namely the earthquakes of April 10, and April 25, 1925.

The study of the after shocks indicates that these were always felt in the region near the assigned epicentre. If rather weak, they were felt on the south shore of the St. Lawrence, only within a belt five or six miles wide along the river. They were felt farther north, however, which lends weight to the statement

that the epicentre may be an elongated one, lying along a fault extending into the north shore of the St. Lawrence.

SEISMIC HISTORY

Persistent investigation of every indicated source of information as to historical references to the seismic conditions in Quebec has yielded, to date, a list of some 325 earthquakes which have taken place during the past 300 years in eastern Canada and New England. Special mention may be made here of the fact that the following earthquakes, all centering in eastern Canada, are comparable with the shock of February 28, 1925. They are as follows:- February 5, 1663; September 5, 1732; December 6, 1791; October 17, 1860; October 20, 1870; adding the quake of 1925 we have a list of six earthquakes arranged roughly at five (taking account of the 1860 and 1870 shocks coming so close together) intervals of about 60 years. The quake of 1663 may have been worse than any of the others, or it may be that the accounts are exaggerated because of the difficulties involved in investigating reports received at the scattered posts. None of the others, unless perhaps it may be that of 1860, seems to have been less severe than that of two years ago. The investigations will be carried on indefinitely with a view to compiling a complete history of the seismic conditions in the east.

SURVEYING

Immediately after the earthquake, steps were taken to find any controls which might yield quantitative measurements as to any permanent displacements. The only level line run in the area was that from Levis to Rivière du Loup. This had been run in 1915. A request to the Director of the Geodetic Survey resulted in arrangements being made by which that organization re-ran the line of levels between these two towns. The result of that work may be said to have revealed no differences greater than the order of the errors of observation. However, all the differences east of St. Pacome, and Rivière Ouelle, were all in the same sense, the 1925 elevations being above those of 1915, and all the differences west of that point were in the opposite sense, the 1925 elevations being below those for 1915 or the same, THE LEVIS END OF THE LINE BEING CONSIDERED UNCHANGED IN THE INTERVAL OF TEN YEARS, FOR THE PURPOSES OF THE COMPARISON. Although this did not mean very much in itself, as the differences were so small, it was significant in that the differences so arranged themselves. These results suggested the hypothesis of a vertical snapping up of the seaward side of the fault and a horizontal translation of the landward side, an hypothesis which is in accord with all the observational data.

In an effort to check the hypothesis an appeal was made to the Chief Hydrographer. It was discovered that a tide gauge had been in operation near the mouth of Rivière Ouelle, but somewhat below it, at Pointe Origneux, in 1900, but not since. Arrangements were made to have the gauge again operated for the summer season of 1926. This was done. The results, again of the order of the errors of observation and therefore of little weight, indicate, nevertheless, an uprising of the land at the position of the gauge. Further work is to be done on the tidal records to secure a more definite check.

Realizing the value of having as many controls as possible in this region a request was made that the Geodetic Survey establish a line of precise levels on the north shore as far as Murray Bay. This was done during the season of 1926 and other branch lines into

areas where special investigations are being carried on were also put through. These will be of the greatest value in the case of another earthquake in that part of the country.

GEOLOGY

A study of the geology of this region, with particular reference to earthquakes, has not, it seems, been made. Arrangements were made, through the cooperation of the Director of the Geological Survey, for a joint visit to the epicentral area and other affected sections, by Dr. J. W. Goldthwait and the seismologist of the Dominion Observatory. No indications of a recently disturbed fault were found, though it must be stated that the rock surface is not exposed except in isolated peaks or hills, at any other place than the very margin of the river. The joints planes, as revealed at the river, are in two sets, one north-south (mag.), the other north 70° east to south 70° west. The former direction joins the mouth of Rivière Ouelle and the mouth of the Malbaie river, and is in the general direction of the fault indicated by the seismological investigations.

The deep deposits of marine clays in the St. Lawrence valley, coupled with the rather frequent, if relatively mild, earthquake shocks, present a real hazard. An attempt has been made to collect data on as many landslides as possible with a view to studying the varied features presented. At least nine slides of serious magnitude are known to have occurred within the past hundred years. Most of these have been described in publications of the Geological Survey. So far as is known none of them (with possibly one exception now being investigated) were caused by earthquakes. The hazard is a real one, however, and calls for consideration from the engineering profession.

DOMINION OBSERVATORY
OTTAWA, CANADA
May 25, 1927.

Hodgson, E.A.

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St. Lawrence Earthquake

Feb. 28, 1925.
