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The Earthquake in Montmorency County, Quebec, on January 1, 1948

BY

W. G. MILNE

ABSTRACT

This earthquake is, to date, the most severe of a series of small shocks which have occurred in the Province of Quebec over the past few months. Seismograms from six Canadian stations and from Boston are analysed and the epicentre of the earthquake is computed from the readings. The epicentre so found is about fifteen kilometres north and west of the Seven Falls station in Montmorency County. The position of this epicentre in relation to the location of previous earthquakes is discussed and the possibility of a more accurate determination of the origin of future shocks is proposed.

Introduction

There has been a marked increase in seismic activity in the Province of Quebec over the past few months. This increase has been both in the number and the intensity of earthquakes recorded on the seismographs operated by the Dominion Observatory. Although it cannot be said that this activity is limited to any one region, the majority of the tremors fall within specific areas. The strongest earthquakes appear to come from the St. Lawrence River district below Quebec City, such as the one to be studied in this report.

Seismic Areas of Quebec

The Province of Quebec has been the origin of several severe earthquakes. The most familiar of these earthquakes is that of March 1, 1925. Dr. E. A. Hodgson has placed the epicentre of this shock in the St. Lawrence River near Baie St. Paul. Before this there were several severe earthquakes in that particular area, and since that time there have been fourteen small tremors, both recorded and felt, which have originated near there. In order that all such epicentres might be located seismographs were installed at Seven Falls and Shawinigan Falls. This paper is an attempt to determine the exact position of such a quake which had its origin near the Seven Falls station on January 1, 1948.

In addition to this seismic area, there appears to be quite an active region between the Shawinigan Falls station and Ottawa. This other area, although its tremors are very slight, has much more activity. At present there is a study being made to locate this area, but from the evidence at hand it would appear to be north of Ottawa about one hundred miles. The area north of Ottawa has been shaken on the average of four times a month for the last year. It has been active now for about ten years.

There are, from time to time, very small tremors recorded from places in Quebec not in these two main earthquake belts. However such quakes do not appear to repeat themselves so they can be considered as minor local adjustments of the crustal layers.

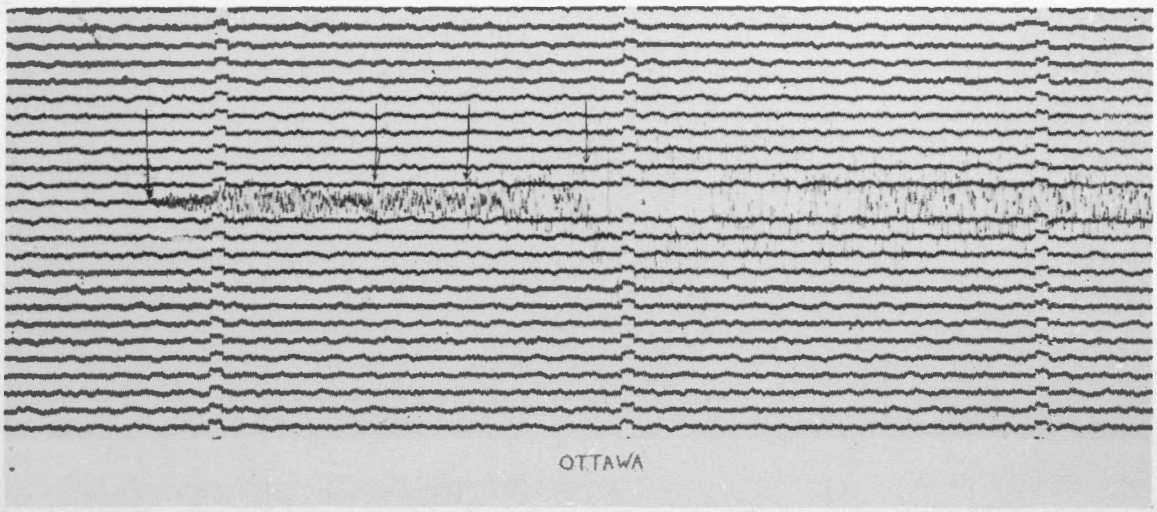
Seismograms Studied

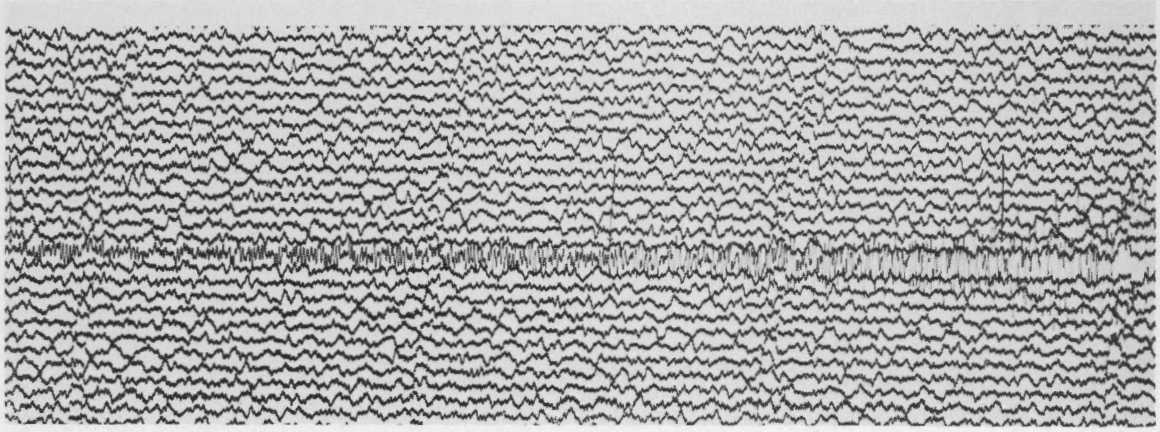
In recent years the most severe earthquake was the one at approximately 1:34 p.m., E.S.T. on January 1, 1948. This earthquake had its origin slightly north and west of the Seven Falls seismograph station, about 30 miles down the St. Lawrence River from Quebec City. It was reported as felt in the immediate area. It was well recorded on the seismographs at Seven Falls, Shawinigan Falls, Ottawa, Temiskaming, Ville Marie, and Kirkland Lake. Father Linehan of the Seismological Observatory at Weston College reported his readings to Ottawa, and has since very kindly loaned his records of this quake to the Division for further study.

The Seven Falls Wood-Anderson seismogram showed no phases after the initial P-phase because of its proximity to the epicentre. It did, however, give a very sharp P_1-phase and the corresponding S_1-phase was obtained from the east-west component Milne-Shaw seismogram of the same station. This component showed a sharp S_1-phase; which would indicate an origin in a northerly or southerly direction. In fact the S-phase was so strong that it displaced the zero position of the Milne-Shaw instrument by as much as two millimetres. At Shawinigan Falls, on the north-south Wood-Anderson seismograph, the initial P-phase was not strong, but there was a strong S_1-phase indicating an origin in an easterly or westerly direction. The Ottawa vertical component short-period Benioff seismogram, and the Weston vertical and horizontal Benioffs showed quite definite phases. The Weston three-component Galitzen seismograms were used as well for S-phase confirmations. The stations at Ville Marie and Temiskaming each use three-component Sprengnether seismographs. Unfortunately, at Ville Marie there was no time control for this day. There is a single vertical component Sprengnether seismometer at Kirkland Lake. From all Sprengnether instruments well defined S-phases were obtained, but the P-phase readings are doubtful. All seismograms used in this study have the sixty millimetre paper speed with automatically recorded radio time signals from CHU at Ottawa, so that the time control is excellent. Copies of the seismograms used are shown in figures 1 and 2.

Interpretation of Readings

The following table gives the final readings of the phases from all records. The values of Δ and H are obtained from an S-P computation using Joliat's Tables for Near Earthquakes (Saint Louis, 1931). All times are 18 hours G.C.T. plus the minutes as shown below.





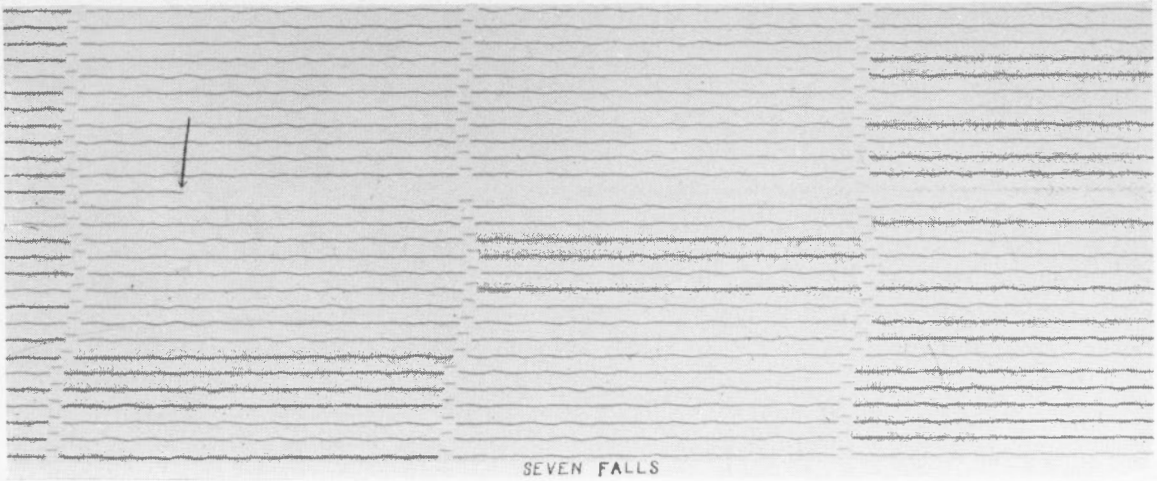
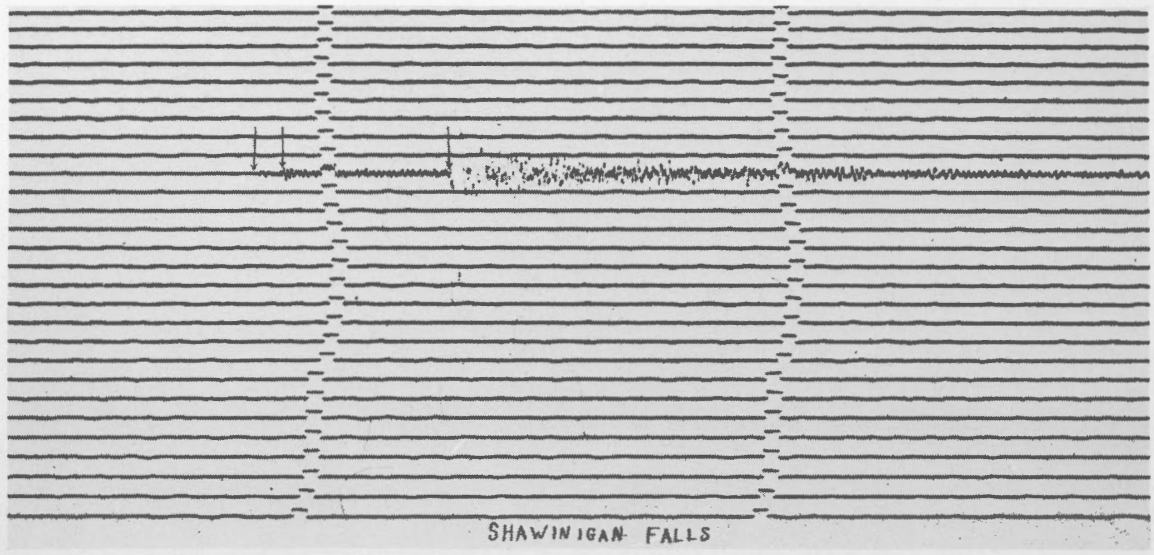
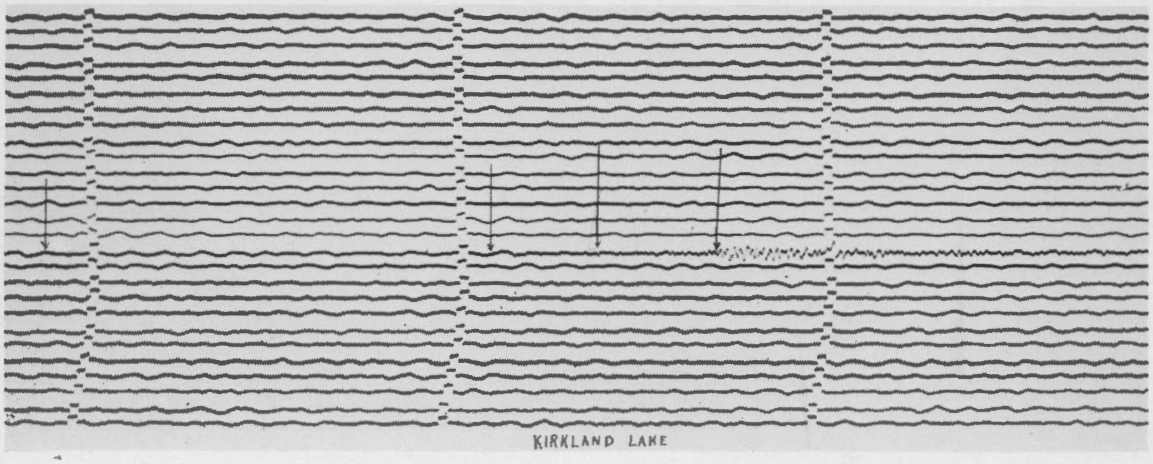


Fig. 1





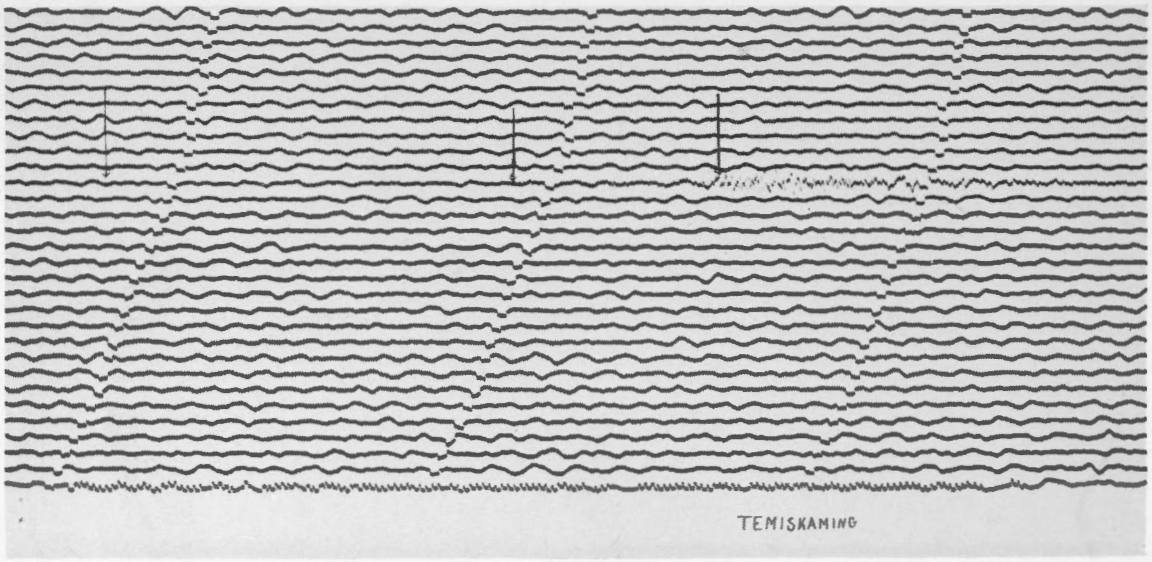


Fig. 2

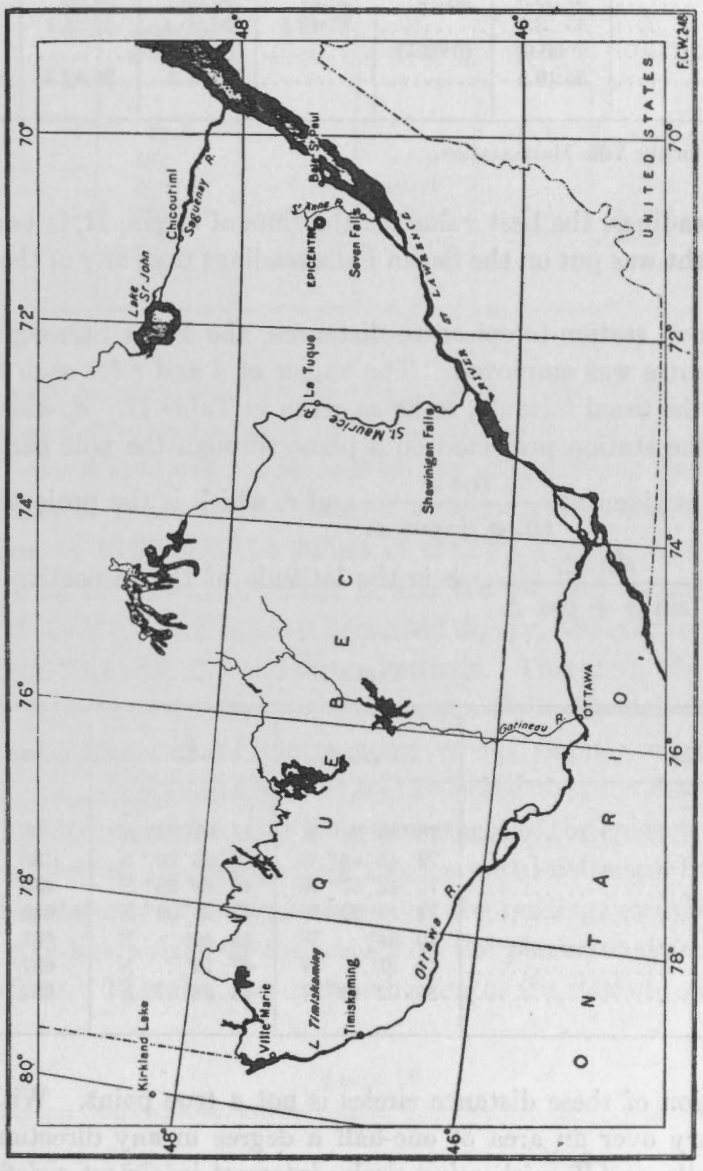

48°
46°
70°
72°
74°
76°
78°
80°
UNITED STATES
Chicoutimi
Saguenay R.
Lake St-John
Ste Anne R.
EPICENTRE
Baie St. Paul
Seven Falls
St. Lawrence R.
St. Maurice R.
La Tuque
Shawinigan Falls
Gatineau R.
OTTAWA
QUEBEC
ONTARIO
Timiskaming
Ville Marie
Kirkland Lake
Ottawa R.

Fig. 3

TABLE I

Station	P_n	P_2	P_1	S_n	S_2	S_1	Δ(km.)
Seven Falls	.....	.....	33:52.9	.....	.....	33:57.9	25
Shawinigan Falls	.....	34:17.3	34:20.6	34:36.8	.....	34:42.8	188
Ottawa	34:48.5	34:56	.....	35:35	.....	35:52.5	430
Weston	34:58.8	35:10	35:21	35:53.8	36:08	36:24	515
Temiskaming	35:13.4	.....	35:43.4	36:20.4	36:38.1	36:51.4	631
Ville Marie*	(0:00.0)	(0:03.5)	.....	(1:07.5)	.....	(1:40.5)	637
Kirkland Lake	35:19.5	.....	.....	36:30.3	36:32.3	37:08.5	669

*No absolute time for the Ville Marie station.

Using these readings, the best value for the time of origin, H, is taken as 18:33:48.0 G.C.T. More weight was put on the Seven Falls readings than any of the others to obtain this value.

From the above station-to-epicentre distances, the Klotz Stereographic method of obtaining an epicentre was employed. The values of d and r for each station and delta were found, from the usual formula, to be as given in Table II. d, which is the distance from the pole to the station projected on a plane through the pole perpendicular to the axis of the earth, is given as $\frac{\cos \varphi}{\sin \varphi + \cos \Delta}$ and r, which is the projected station to epicentre distance, as $\frac{\sin \Delta}{\sin \varphi + \cos \Delta}$. φ is the latitude of the respective station.

TABLE II

Station	Longitude	Latitude	Δ(kms.)	d	r
Seven Falls	70 49′ 36″ W	47 07′ 24″ N	25	392·7	2·26
Shawinigan Falls	72 45′ 48″ W	46 33′ 06″ N	188	398·6	17·1
Ottawa	75 42′ 57″ W	45 23′ 38″ N	430	411·5	39·6
Weston	71 19′ 20″ W	42 23′ 00″ N	515	442·5	52.3
Temiskaming	70 04′ W	46 40′ N	631	398·4	57·4
Ville Marie	79 27′ W	47 19′ N	637	391·8	57·7
Kirkland Lake	80 02′ 43″ W	48 08′ 57′ N	669	383.6	59.6

The intersection of these distance circles is not a true point. With the large scale used, it would vary over an area of one-half a degree in any direction. The Ottawa, Weston, Seven Falls, and Temiskaming circles intersect in almost a definite point. The Shawinigan Falls and Kirkland Lake circles are too large and that of Ville Marie is too small, so that if the best intersection is taken it will be found to be at approximately $\lambda = 70°45'0$ W. and $\varphi = 47° 30'0$ N. This we shall assume to be a provisional epicentre and from further study of each seismogram it will be improved upon.

The distance from each station to the provisional epicentre was computed from spherican trigonometric formulas. At this point in the study the data from the Ville Marie station were dropped. Using these distances and the travel times from Joliat's Tables,

the arrival time of each expected phase was computed. The value of H used for this was 18:33:48.0, as found above. The difference (O-C) between observed and computed arrival times of all phases was then found as shown in Table III. A positive value indicates a later observed arrival time.

TABLE III

Station	Computed Δ(kms.)	P_n O−C	P_2 O−C	P_1 O−C	S_n O−C	S_2 O−C	S_1 O−C (sec)
Seven Falls	42·6	.....	.....	−3·1	.....	.....	−2·1
Shawinigan Falls	187	.....	−1·5	−2·5	−2·8	.....	−2·1
Ottawa	446	−1·3	−0·9	.....	−3·4	.....	−7
Weston	570	−6·4	−8·5	−11.5	−12·2	−14	−24
Temiskaming	637	−1·5	.....	−2·7	−3·3	−3·6	−2·1
Kirkland Lake	701	−3·5	.....	.....	−6·6	.....	−11·3

These values are all negative, Weston and Kirkland Lake being very much so. This would indicate that the value assumed for H is too late or that the computed distances are too great. From a study of the records of the nearby Seven Falls station it will be seen that this value of H cannot be changed enough to account for all the difference. If H now is taken as 18:33:47.0 the values of O-C for Ottawa, Shawinigan Falls, and Temiskaming will all be corrected. That is, the Weston and Seven Falls distances are still too great. If the Weston distance is decreased to, say, 530 kilometres, the O-C values will be brought into line with the rest of the stations. This shift, if made directly south towards Weston, will leave the Ottawa, Shawinigan Falls, Temiskaming, and Kirkland Lake distances all unchanged. Perhaps a movement slightly westward would make all the O-C values approximately zero. It will be noted that the Seven Falls station has been neglected in this discussion. But if the movement of the epicentre is south and west from the assumed position the change from the computed delta will be of the order of 30 kilometres for this station. That does correct all the readings except Kirkland Lake, to which we must give less weight on the basis that the phases recorded here are not particularly outstanding. That now leaves the following as the station-to-epicentre distances.

TABLE IV

Station	Revised Δ(kms.)	
Seven Falls	15	
Shawinigan Falls	185	
Ottawa	437	H = 18:33:47.0 G.M.T.
Weston	530	
Temiskaming	633	
Kirkland Lake	680	

This would move the coordinates in the southwest direction to 70°55′ W. and 47°20′ N. This, as may be seen, is an assumed position, but on the basis of the above argument it must be taken as the epicentre. The shift is on the strength of Joliat's travel-time tables. If, as found by J. H. Hodgson (Bulletin of the Seismological Society, Vol. 36, No. 1, 1947; Contributions of the Dominion Observatory, Vol. 1, No. 1), the P_1-phase has a 10 per cent higher velocity than that given by Joliat, and the other phases a corresponding changed velocity, this epicentre will be shifted in a northeast direction. Since there was no field investigation of the earthquake, the epicentre may be considered to be at 70°55′ W. and 47°20′ N., or on a line northeast from there but no farther than 3 to 5 kilometres along this line.

Geographical Location

This location is on the eastern boundary of Montmorency County on the edge of Laurentides Park. The epicentre may be on the upper St. Anne River only a few miles from Seven Falls. To be specific it is due west of Baie St. Paul on a line running from Lake Jacques Cartier to the St. Lawrence River.

In relation to the St. Lawrence earthquake of March 1, 1925, the epicentre appears to have moved almost straight west about 60 kilometres. It is possible that these disturbances originated on the same fault plane. There seems to be no indication of any abnormal depth of focus from the seismograms of either of these earthquakes. There was one aftershock of the present earthquake on the same day about fifteen minutes later.

Conclusions

The Province of Quebec, as can be seen from the recent earthquakes recorded, is becoming an area with considerable seismic activity. From the stations used to determine the centre of this disturbance, it appears that the areas most likely to require further seismological studies are surrounded on three sides by seismograph stations. It would not be difficult to completely circle any active area with instruments by installing a station at La Tuque or Chicoutimi. Thus with the data on travel-times now being accumulated by the observatory, and the location of the areas fairly well known, a great deal can be learned of the structures underlying certain parts of the province. It is proposed to locate each future earthquake as closely as has been done in this report and thereby increase the present knowledge of the seismicity of the Province of Quebec.