The Saguenay, Québec, Earthquake Lights of November 1988–January 1989

A Comparative Study with Reference to the Geoatmospheric Lights Classification Proposed by Montandon in 1948, and a Description Put Forward by Yasui in 1968

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INTRODUCTION

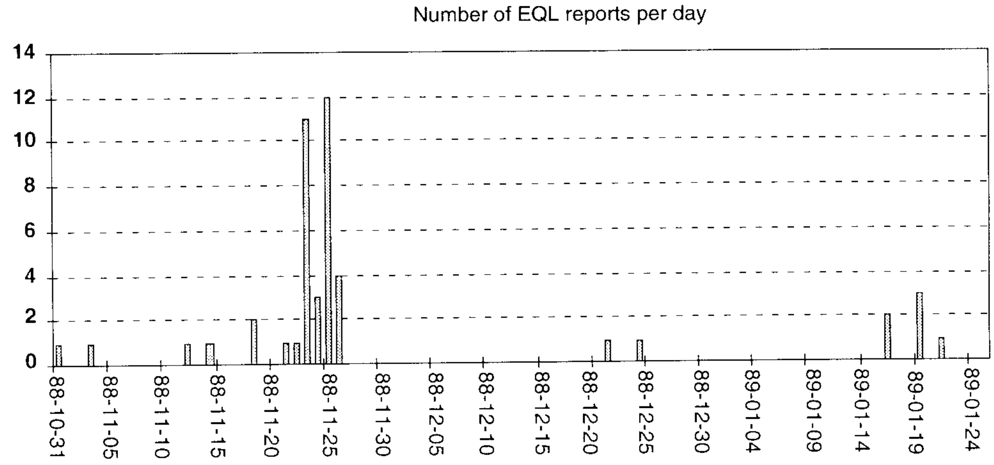
From November 1988 until the end of January 1989 the Saguenay region (Province of Québec, Canada), experienced sixty-seven earthquakes ($M > 0$). A foreshock, magnitude 4.8 m_{bLg}, occurred on 23 November at 4:12 AM (all times in this paper are EST). Two days later at 6:46 PM on 25 November, an unexpected 6.5 m_{bLg} (5.9 m_b) shock was recorded by a network of portable seismometers, distributed near the epicenter by the Geological Survey of Canada after the foreshock. (Both this and the foreshock occurred during the hours of darkness.) The main shock caused strong shaking near the epicenter and was felt over much of northeastern North America. By 11 December, fifty-seven shocks had been registered. Then, after a seismic silence of fourteen days, the activity resumed on 25 December, peaking around 19 January and ending the 23rd of that month with a total of ten more shocks. From that date, another halt lasted until 18 April 1989. The main shock was peculiar due to its 29 km depth in the lower crust of the "stable" pre-Cambrian craton, its low aftershock activity (eighty-four earthquakes over six months), its high L_g-wave energy, and its large aftershock epicentral area (Saguenay = 5.9 m_b, 25 × 40 km; Miramichi = 5.7 m_b, 6 × 6 km). The Saguenay event occurred within the "Jacques Cartier" tectonic block, 17 km south of the southern margin of the Saguenay Graben, which bounds the Jacques-Cartier Bloc on the north side, the southeast border being delimited by the St. Lawrence Rift system (Du Berger *et al.*, 1991).

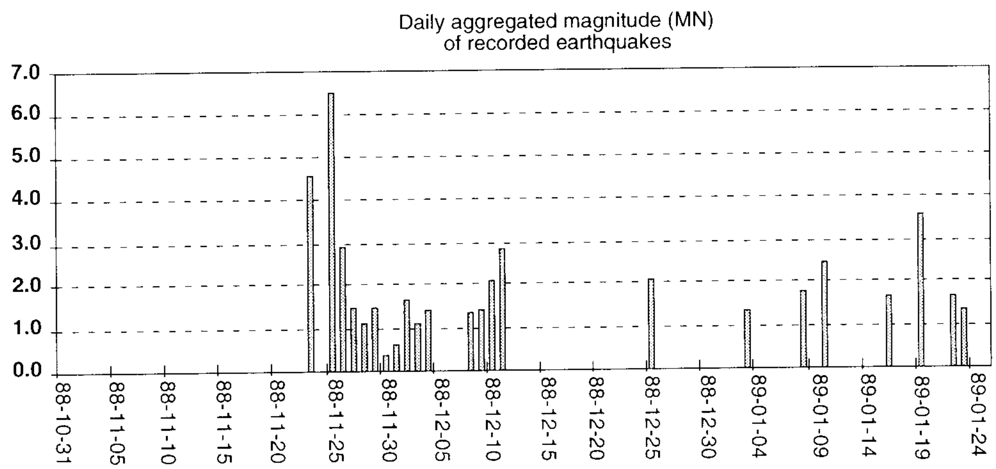
Following the same spatial and temporal pattern of the seismic activity, thirty-eight unusual luminosities were seen by some Saguenay and Lac St-Jean inhabitants, mainly during the foreshock, main shock, and aftershocks of November 1988. It is important to note that eight of those thirty-eight luminous phenomena were observed before 23 November (foreshock), *i.e.*, were possible precursors to the entire sequence. During the December seismic pause of fourteen days, only two new observations were made, but starting 16 January and until 21 January, six more observations were reported following the short resurgence of the January seismic activity (Figure 1).

Some of those luminosity reports were given spontaneously by residents on the local radio station the day after the main shock. Prof. Marcel Ouellet, then at the Institut National de la Recherche Scientifique in St. Foy, heard their testimonies on the radio and through a regional newspaper made an appeal asking the witnesses for written descriptions of their observations. Later, a five-page questionnaire was sent for more details. In addition, some of those witnesses were contacted by phone. After rejecting reports of lunar halo and short evasive reports that were not followed by more detailed written descriptions, forty-six good reports were kept for study and analysis (Ouellet, 1990). Thus, the forty-six reports examined in this paper are probably an underestimate of the total number of luminous phenomena associated with this earthquake (Figure 2).

EARTHQUAKE LIGHTS: EUROPEAN CLASSIFICATIONS

An early classification of earthquake lights (EQL), resulting from observations made by European populations for more than a century, was made by an Italian priest and natural history professor, Ignazio Galli (1910). Those reports, kept in memoirs and catalogs, were studied by a Swiss scholar, Frédéric Montandon. After discarding observations made when stormy or unsettled weather was reported at the time of the earthquakes, Montandon (1948) proposed his 1948 classification based on five types of luminosities frequently described:





▲ **Figure 1.** Graphs of number of EQL reports per day (top), and daily aggregated magnitude ($M_N = m_{bLg}$) of recorded earthquakes (bottom). Prepared by Jean Vézina. Aggregation is done as follows: First the magnitudes of the seismic events are converted to released energy by using the standard formula (Bellair and Pomerol, 1977):

$E = 2.5 \times 10^{11} \times 10^{1.5M}$ where the energy is measured in ergs.

The energy released is summed for each day and the resulting magnitude is computed from the total daily released energy by using the relationship:

$M = \log_{10}(E/E0)/1.5$

1. "Seismic lightning", similar to ordinary lightning and to "sheet" or "heat" lightning but without the thunder.
2. Luminous bands seen in the atmosphere, sometimes horizontally or vertically and sometimes in a bundle, like some polar aurorae.
3. Globular incandescent masses, sometimes seen attached to luminous bands, and sometimes called "meteors."
4. Fire tongues, small "flames" creeping near the ground, or, like *ignis fatuus*, flickering around.
5. Seismic "flames" seen emerging from the ground but very rarely causing damage.

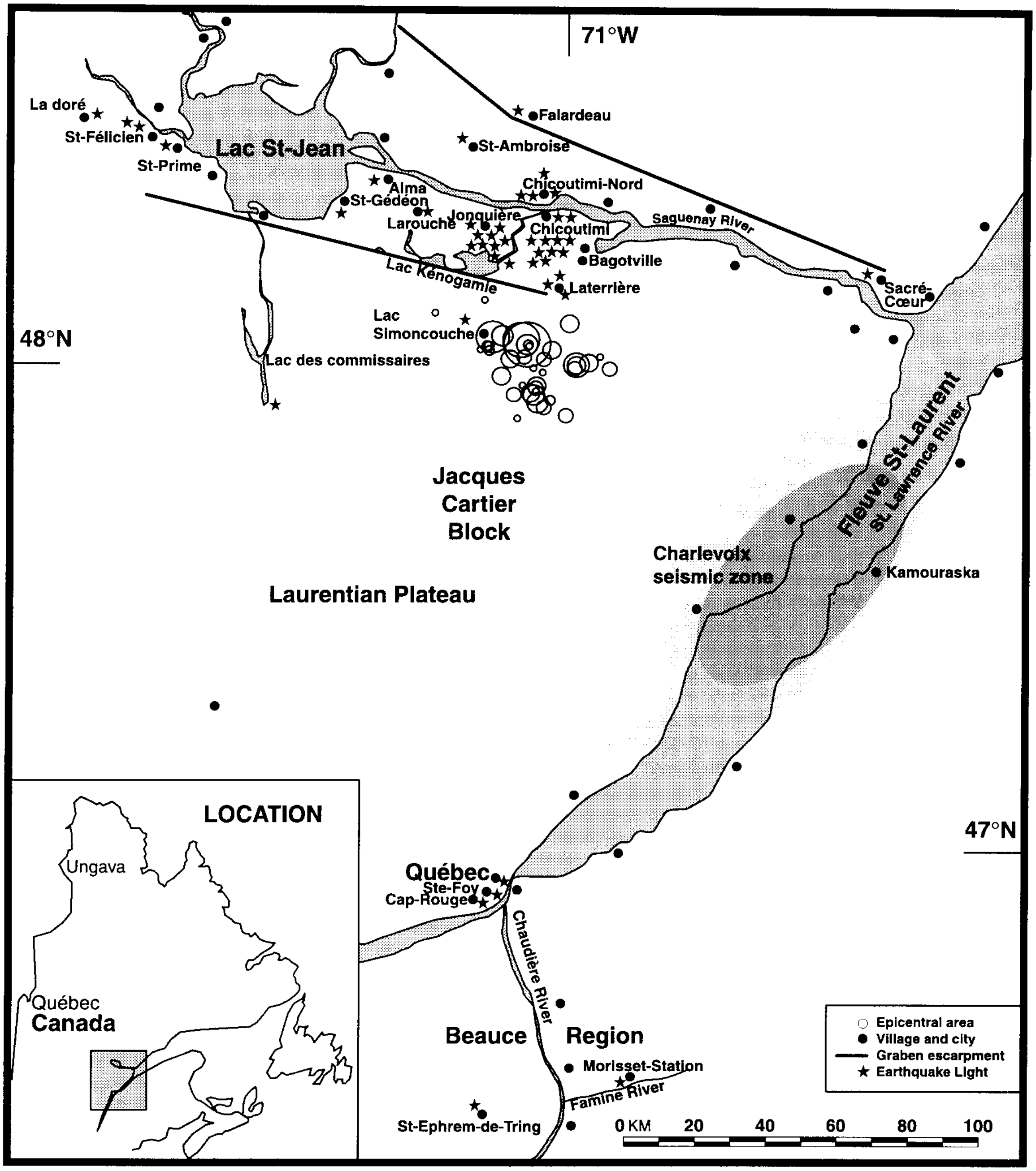
Note the frequent use of the words "similar to", "like", and "sometimes called." Indeed, the causes or mechanisms triggering the luminous phenomena attending earthquakes are not known, so using a name belonging to similar known phenomena must be done with caution.

QUÉBÉCOIS OBSERVATIONS RE-EXAMINED, SORTED, AND COMPARED

The forty-six geoatmospheric luminosity reports, compiled by Professor Ouellet in January 1989, were re-examined, sorted, and compared to the Montandon classification (all the Saguenay descriptions are translated from the original French).

Re-examination

To better appreciate all the representative examples that follow, it must be specified that since thirty-eight of the forty-six EQL reports concerned globular mass or illumination of the atmosphere, the re-examination included verification that no thunderstorms were reported in the monthly reports obtained from Bagotville, the meteorological station only 25 km from most of the luminosity reports for the months of



▲ **Figure 2.** The Saguenay-Lac St-Jean and Québec City regions, showing population spatial distribution and epicentral area of the Saguenay earthquake sequence, as well as the total spatial EQL distribution.

November 1988 and January 1989. It must be specified that the main shock of 25 November occurred under a mainly clear night sky.

The dates of sightings of fast-moving balls of fire seen in the sky were also verified to confirm that they did not coincide with peaks (plus or minus one day) of meteor showers. Indeed, November had two meteor showers, the Taurids on 4 November and the Leonids on 17 November. As noted (Table 1), no incandescent masses had been sighted on 4 November or 17 November. As for the two 18 November observed luminous masses, they were seen performing within one meter of ground level. December and January also had meteor showers, their peaks being around the 14th and the 4th respectively. Again, no incandescent masses were reported around those dates. One could wonder if some other reported incandescent masses could have been sporadic fireballs (isolated meteors). In our twenty-two reports of globular or ovoid masses the possibility seems unlikely. Indeed, the globular masses reported did not show meteor attributes. Many were seen very close to ground level, and those seen in the sky were motionless or presented extremely slow motion. The only possible sporadic meteor candidates

TABLE 1
Date and Types of EQL Observations in Relation to the Saguenay Earthquake Sequence of 23 November 1988 to 23 January 1989 (67 Shocks)

No	Date (yearmody)	Time EST	Location & Distance from Saguenay Epicenter	Type of Earthquake Light	Closest Shock in Time (EST)
1	19881031	1830	Simoncouche Lake, 4 km	3 globular masses popping out of ground	none
2	19881103	1845	Alma, 47 km (Aurora?)	Arced bands rising from the horizon	none
3	19881112	1930	Over St.Lawrence River, in front of Québec City, 160 km	1 globular mass, reddish purple	none
4	19881114	2000	Morisset Station, 200 km (Beauce region)	1 ovoid mass on river shore, orange	none
5	19881118	1650	St-Ephrem-de-Tring, 205 km (Beauce region)	1 ovoid mass (on ground) with two streamer-like appendices	none
6	19881118	1830	Toward the western limit of Laterrière, ~19 km	Luminous discharges rising from the ground	none
7	19881121	1820	Des Commissaires Lake, 75 km	1 globular mass, green, meteorlike	none
8	19881122	2300	Falardeau, 50 km	1 globular pale yellow, falling mass	19881123 0412 M_N: 4.8 m_b: 4.3
9	19881123	~0200	Chicoutimi, 33 km	1 globular mass, yellow, static	19881123 0412 M_N: 4.8
10	19881123	0410	La Doré, 110 km	1 globular mass, orange, 3 m over the ground	19881123 0412 M_N: 4.8
11	19881123	0410	Jonquière, 27 km	Sudden atmospheric illumination	19881123 0412 M_N: 4.8
12	19881123	0412	Chicoutimi North, 35 km	Strong atmospheric illumination	19881123 0412 M_N: 4.8
13	19881123	0412	Larouche, 28 km	Atmospheric illumination	19881123 0412 M_N: 4.8
14	19881123	0412	Jonquière, 27 km	Atmospheric illumination	19881123 0412 M_N: 4.8
15	19881123	0412	Jonquière, 27 km	Atmospheric illumination	19881123 0412 M_N: 4.8
16	19881123	0412	Jonquière, 27 km	Atmospheric illumination	19881123 0412 M_N: 4.8
17	19881123	0412	St-Félicien, 95 km	Unsteady atmospheric illumination	19881123 0412 M_N: 4.8
18	19881123	1745	Chicoutimi, 33 km	1 globular mass, orange, static	19881123 0412 M_N: 4.8
19	19881123	2230	Chicoutimi, 33 km	1 globular greenish mass seen falling	19881123 0412 M_N: 4.8

Shocks $M > 0$ are those from the Saguenay large epicentral area (25×40 km) as found in the Canadian National Earthquake Data Base, the parameters being 47.80° to 48.30° lat. and –73.00° to –70.00° long. It must be specified that the always active Charlevoix seismic zone, ~110 km east-southeast of the Saguenay epicenter and ~150 km north of the Québec City region, was almost completely inactive in November 1988. Note: In an addendum to this table, a graph of aggregated M_N magnitudes of the Charlevoix earthquakes covering 1987–1991 is shown (Addendum to Table 1).

TABLE 1 (CONTINUED)
Date and Types of EQL Observations in Relation to the Saguenay Earthquake Sequence of 23 November 1988 to 23 January 1989 (67 Shocks)

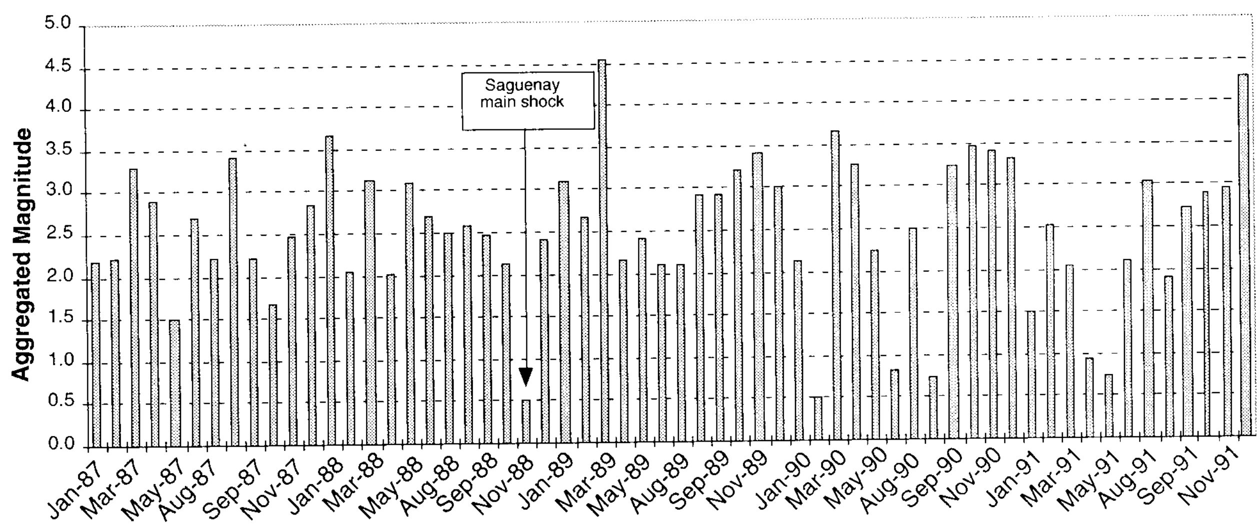
No	Date (yearmody)	Time EST	Location & Distance from Saguenay Epicenter	Type of Earthquake Light	Closest Shock in Time (EST)
20	19881124	1825	Chicoutimi, 33 km	1 globular mass, falling toward Kénogami Lake	19881125 1846 M_N: 6.5 m_b: 5.9
21	19881124	1930	Chicoutimi North, 35 km	1 ovoid mass, white yellow & orange, falling	19881125 1846 M_N: 6.5
22	19881124	2245	Chicoutimi, 33 km	Coronalike effect	19881125 1846 M_N: 6.5
23	19881125	1820	Chicoutimi, 33 km	1 moonlike mass, orange, seen "under" the moon	19881125 1846 M_N: 6.5
24	19881125	1820	Chicoutimi, 33 km	1 moonlike mass, orange	19881125 1846 M_N: 6.5
25	19881125	1845	Chicoutimi North, 35 km	Horizontal ovoid yellow mass, static	19881125 1846 M_N: 6.5
26	19881125	1846	Laterrière, 19 km	Coronalike effect	19881125 1846 M_N: 6.5
27	19881125	1846	St-Gédéon, 50 km	Brief (5 s) atmospheric illumination	19881125 1846 M_N: 6.5
28	19881125	1847	Jonquière, 27 km	Localized atmospheric illumination	19881125 1846 M_N: 6.5
29	19881125	1848	Chicoutimi, 33 km	~6 luminous rays, pastel colors	19881125 1846 M_N: 6.5
30	19881125	1848	Chicoutimi North, 35 km	~7 luminous bands, white	19881125 1846 M_N: 6.5
31	19881125	1850	Chicoutimi, 33 km	Localized atmospheric illumination	19881125 1846 M_N: 6.5
32	19881125	1850	St-Prime, 90 km	Very small globular mass, long tail, near ground	19881125 1846 M_N: 6.5
33	19881125	1855	Laterrière, 19 km	2 coexisting globular masses, 1 red with white smoke, 1 silvery	19881125 1902 M_N: 2.6 (not felt by the witnesses)
34	19881125	1855	Southern limit of Chicoutimi, ~24 km	2 globular masses (same as no. 33)	19881125 1902 M_N: 2.6 (not felt by the witnesses)
35	19881126	0310	Jonquière, 27 km	Flamelike luminosity on ground	19881126 0313 M_N 2.5 (not felt by the witnesses)
36	19881126	1855	Ste-Foy (Québec) 160 km	1 luminous band	19881126 2032 M_N: 1.7
37	19881126	2000	Jonquière, 27 km	Localized atmospheric illumination	19881126 2032 M_N: 1.7
38	19881126	~2215	Sacré-Coeur, 110 km	1 globular mass near ground with long tail	19881126 2154 M_N: 1.7

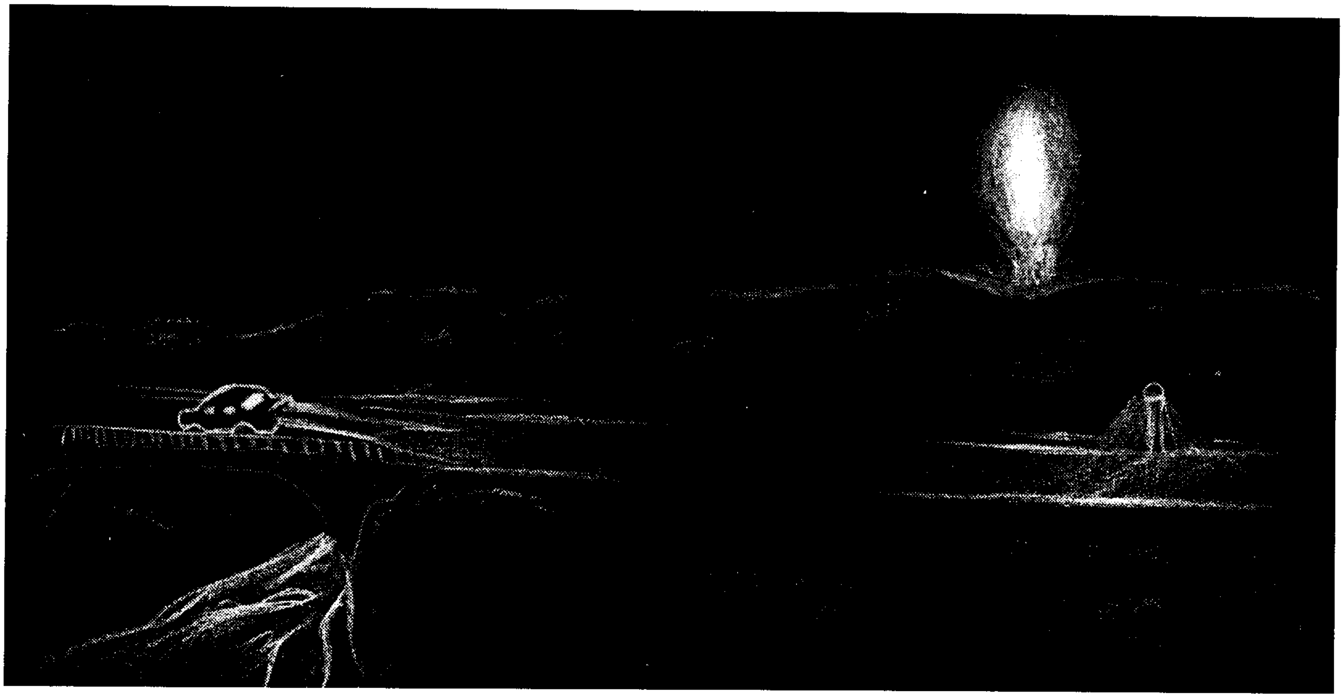
TABLE 1 (CONTINUED)
Date and Types of EQL Observations in Relation to the Saguenay Earthquake Sequence of 23 November 1988 to 23 January 1989 (67 Shocks)

No	Date (yearmody)	Time EST	Location & Distance from Saguenay Epicenter	Type of Earthquake Light	Closest Shock in Time (EST)
39	19881221	0400	St-Félicien, 95 km	1 globular mass, static, sparks	None
40	19881224	1915	Cap-Rouge, 165 km	1 globular static mass, with dripping luminescence & white smoke	19881225 1612 M_N: 2.1
41	19890116	0330	Jonquière, 27 km	Brief (8 s) unsteady atmospheric illumination	19890116 0311 M_N: 1.7
42	19890116	1755	Jonquière, 27 km	1 sudden (1 s) static, large luminous band	19890116 0311 M_N: 1.7
43	19890119	1640	Chicoutimi, 33 km	1 lightning preceded by hissing sound (no tunderstorm)	19890119 1636 M_N: 3.6 (not felt by the witness)
44	19890119	~1700	Chicoutimi, 33 km	1 lightning (no tunderstorm)	19890119 1652 M_N: 1.7
45	19890119	~2100	St-Ambroise, 40 km	Localized atmospheric illumination	19890119 1827 M_N: 1.9
46	19890121	1812	Chicoutimi, 33 km	1 globular white mass, meteorlike	19890122 1224 M_N: 1.6

Addendum to Table 1.

Monthly aggregated magnitudes for the Charlevoix region





▲ **Figure 3.** White light of great dimension within which brighter discharges were observed. Sighted five days before the foreshock of 23 November and in the direction of the future epicenter. Drawn by artist David Leclerc from the witness' description and sketch (not to scale).

would be the 21 November, Lac des Commissaires, green, fast-moving bolide seen falling toward the ground and the 21 January, Chicoutimi, fast-moving white ball.

Sorting and Comparing

Seismic Lightning

There were three reports of the "ordinary" lightning type. The first observation was made on 18 November, the second one on 19 January around 4:40 PM, and a last one around 5:00 PM, near the time of the 4:36 PM magnitude 3.6 m_{bLg} aftershock. Here is the description of the 18 November observation made by two motorists five days before the foreshock, from a road between Chicoutimi and Jonquière, 27 km north of the future epicenter: "... afar, in the open country, I noticed a light of great dimension similar to a camera flash, the only difference was that it sustained its brilliance longer and the intensity of the light varied like a flash coming out of an electric arc welder. The light was white, brighter in the center, and the form somewhat resembled a big electric bulb. ... The duration of the flash was between 3 and 5 seconds. ... This event repeated itself 3 times at intervals of about 5 to 10 seconds. The luminous body, in contact with the ground, had an apparent height of about 20 degrees (from the horizon)." According to the witness, the luminosity seems to have been located between Lac Kenogami and Laterrière, which is very close to the Saguenay Graben south wall (Figure 3). Among some sketches published by Yasui (1973) and depicting some luminous forms observed in Japan at the time of the Matsushiro earthquake swarm of 1965–1967, bulblike luminous forms were also found.

The sheet lightning type (atmospheric illumination) was abundantly observed during the magnitude 4.8 foreshock of 23 November. The great duration and intensity of the luminosity, seen fluctuating in some locations, and its peculiar hue astonished the witnesses. This from Jonquière, 27 km north of the epicenter, 4:12 AM, with the full moon faintly visible behind clouds and no fires in the region: "... my room was all lit up as in a summer thunderstorm. ... The sky had an extraordinary pink hue. ... What astonished us the most is that, although our room is usually dark at night because of our PVC blinds which hide almost all the lights, nevertheless, we saw everything in the room." Similar observations were also reported during the August 1976 Sungpan-Pingwu earthquakes (Wallace, 1980) and the 16 November 1911 Wurtemberg earthquake (Mack, 1912).

Luminous Bands

As in the Montandon classification, I also found occurrences of luminous bands in Ouellet's collection. A display was observed on 3 November (blue-white and violet horizontal arced bands), another one at the end of the main shock (two reports), one on 26 November, and a last one on 16 January. One might have expected more reports of luminous aurora-like bands from the Saguenay region, which is just north of 48° geographic latitude, or 63° geomagnetic latitude, considering that the months of October and November are favorable for their observation and that the year 1988 was very close to the solar maximum of 1990. However, this was not the case. Here is a description of one occurrence. Immediately after the end of the main shock, two independent witnesses made very similar observations of a luminous display. At around 6:48 PM, they both noticed six or seven very long vertical bars or rays in the sky, just over the Saguenay River. The color was a mixture of very pale pastel colors for one and white for the other. They both noticed that there was no perceptible movement from the bands during their five-minute observations. The witness from Chicoutimi North saw the display looking toward the south, and the one from Chicoutimi South toward the north. The Saguenay River (35 km north of the epicenter) is what separates the two towns facing one another. Those cities mark the site where the river becomes a fjord.

Globular Incandescent Masses

This type of phenomenon was the most frequently observed. There were twenty-two reports coming from different places. Often they were seen far from the epicenter or when the seismic activity was low or quiet. Some were stationary (in one case, the yellow and orange mass presented a horizontal elongated form), others were seen emerging from the ground, some were very fast-moving near the ground, one was seen attached to a luminous band—all as described by Montandon. Here is a witness report from St-Prime, 90 km west-northwest of the epicenter: "... two or three minutes after the big quake [main shock, 25 November, 6:46 PM], looking through the window I saw a very small ball of fire [orange] with a very long narrow tail, passing in a straight line and with great speed in the middle of the street and approximately one meter above it ...." (From Kobe, a similar observation was made: A firefighter saw an orange-colored "belt" just above a shaking road that lasted 7 to 10 seconds [Tsukuda, 1997]). This other Saguenay observation was made twenty minutes after a mild aftershock on 26 November, from Sacré-Coeur, a village 110 km east of the epicenter: "... looking through a large window I saw a big ball of fire with a long tail. ... I saw it pass beside my house very low under the telephone pole, crossing the street and going straight down into a ditch behind a house ...."

A very peculiar observation of globular incandescent mass was made by four people while driving on a small road of the city of Cap-Rouge (near Québec City), 165 km southwest of the epicenter, on 24 December at 7:15 PM: "... from the bridge crossing la Rivière Cap-Rouge, we saw another red ball of fire. ... We stopped ... to have a better view. ... It seemed stationary. ... We were seeing little fire droplets falling from the mass and extinguishing themselves within a few meters. ... What looked like white smoke was released from the mass and going upward. After a few seconds the luminous body extinguished itself. What was most surprising was that the luminosity remnant moved in a straight line for a few meters toward the southwest and then suddenly reappeared and behaved itself as described previously. In total we saw the same scenario 3 or 4 times. ... I estimate the ball diameter not greater than 1 meter and its altitude at about 100 meters over the Rivière Cap-Rouge. ... We were located about 300 meters from the mass ...." This report may seem extravagant, but this type of event is not unique in the EQL literature. Chu Chieh Cho from the Szechuan Provincial Seismological Bureau (China), along with three professional seismologists, saw a very similar display the night of 21 July 1976, three weeks before the beginning of the Sungpan-Pingwu seismic sequence (M 7.2, 6.8, 7.2, etc.) and 75 km from the future epicenter. They saw a fireball originating at the ground surface about 100 meters from where they were standing. At first, it was about 1 meter in diameter. It then shot up to a height of 10 to 15 meters, whereupon the volume started shrinking, finally reaching ping-pong-ball size. The ball then curved over in an arcuate trajectory resembling that of a meteor. Before its disappearance, the ball luminosity would dim, then brighten again. Small wisps of white smoke swirled around the ball and a crackling sound was heard (Wallace, 1980).

From the Saguenay earthquake, a last sighting concerning globular mass is worth giving. The luminosity was observed by two witnesses in the middle of the night on 21 December at St-Félicien, 92 km northeast of the epicenter: "... I was awakened by my little boy, who, sitting up in bed, was letting out a little baby cry. ... Through the window we saw a big ball of light that was darting sparks of a color difficult to describe. ... It seems that my little boy had seen it for a few seconds, and then I, ten to fifteen seconds, when it all disappeared." In Montandon's (1948) paper, we find a quite similar observation that was reported to K. Mack, a German astronomer, who had gathered forty-three reports of earthquake lights after the 16 November 1911 Wurtemberg earthquake. The night of the earthquake, a luminous band was seen coming out of the ground. At a certain height, the band transformed itself into a globular incandescent mass for about 2 to 3 seconds, then extinguished itself while *darting sparks*.

Fire Tongue

If one strictly follows the Montandon definition (small "flame" creeping near the ground or flickering around), no fire tongues were observed or reported from the Saguenay, Lac St-Jean population.

Seismic "Flame" (or flamelike ground luminosity)

Only one observation could strictly fit into this category from the forty-six luminosity reports analyzed here. The term "flamelike ground luminosity" would be more appropriate to use than seismic flame. Indeed, the luminosity seen emerging from the ground is very rarely reported to have caused damage. The Saguenay observation occurred at Jonquière, 27 km north of the epicenter, on 26 November at 3:10 AM, during a mild M 2.5 shock that was not felt by the two witnesses who were then in a car. As they were making a U turn in a parking alley, they saw a few meters away a flamelike luminosity issuing from a paved road in a repetitive manner. The road did not exhibit any apparent surface fissures.

These representative examples illustrate the diversity of the luminous phenomena found in the Saguenay reports and demonstrate that this diversity is consistent through time

▲ **Figure 4a.** Photograph taken with fisheye lens by T. Kuribayashi near Mount Kimyo, Japan, on 26 September 1966 at 03:25 (Japan Standard Time). The bluish-white luminosity lasted 96 seconds.

with that described by Galli and Montandon. Equally, each type of phenomenon described by Montandon could still easily be recognized in the Ouellet collection.

THE MATSUSHIRO SEISMIC LIGHTS AND THE LATERRIÈRE (QC) OBSERVATION

A specific description of the Matsushiro earthquake lights, based upon testimonies, sketches, and well documented photographs (Derr, 1973) gathered after the earthquake swarm of 1965–1967, was given by Yasui in 1968. Here is a brief version of his last published summary (Yasui, 1973):

1. The central luminous body is a hemisphere, diameter about 10 to 100 meters, contacting the ground surface. The body is bluish-white, but reflections from clouds, if present, may give part of the luminous body reddish or yellowish colors.
2. The luminescence generally follows the earthquake and may have a duration of a few seconds (longer than common lightning) to several tens of seconds.
3. The luminescence is restricted to several areas, none of them at the exact epicenter. They tend to occur on hill tops or mountain summits in quartz-diorite faulted rock. The luminous body may display a horizontal motion (Figure 4a).
4. Sferics generally accompany the luminescence. (Spheric or sferic is a name frequently used in atmospheric physics. It is a form of electromagnetic wave [radio interference] which accounts for the familiar "static" heard on AM radio receivers. Often it accompanies thunderstorms and is the signature of lightning discharges.)
5. There was no special indication on the magnetometer at the Matsushiro observatory.

Among the detailed reports gathered by Ouellet, one occurrence could easily parallel the Yasui description of the Matsushiro lights. It happened on 25 November in the rural south part of Laterrière, a small village only 20 km from the epicenter. At 6:46 PM, a trapper was just emerging from the woods and was standing at the foot of the northern part of the Jacques-Cartier Bloc, which is delimited at this location by the Saguenay Graben south wall. The sky was clear, the wind very calm (5 km/h), and there was no frost on the trees. He was suddenly surprised by the main shock, but, at the same time, another occurrence captured his attention. For about two seconds he was completely engulfed by a fast-moving bright bluish-white light. A crackling noise emitted by the trees accompanied the movement of the luminous body, which was contacting the surface of the ground. The apparent height of the luminous body was determined to be about 15 m by comparing it to the height of the witness' house 600 m away. As far as the witness could see without being blocked by tall obstacles (forest), the minimum width of the luminous body was about 600 m, but the exact extent could have been greater (Figure 4b). Contrary to the "sheet lightning" which normally illuminates a good part of the sky, it is clear from the witness' testimony that the luminosity

▲ **Figure 4b.** Drawing by artist from witness' description of a bright, fast-moving southeast-to-northwest bluish-white light, accompanied by crackling noise emitted by the trees. Laterrière (P. of Québec), 19 km from the epicenter, observed at the beginning of the 6.5 m_{bLg} mainshock of 25 November 1988. Not to scale. (Artist: Julie Pelchat)

contacted the ground over a fairly large surface but had a limited height (the sky over nearby homes was not all lit). If one takes the Matsushiro lights description put forward by Yasui, common points are noticed: color, form, contact with ground surface, simultaneity with the earthquake, and horizontal movement. On the other hand, the Laterrière luminous body had a shorter duration, seems to have been broader, and no sferics were reported for that precise time. But here one question comes to mind: Was the fast moving light and crackling sound a *moving, large-scale point discharge*? The fact that the sound followed the direction of the light leads to this interpretation. Normally the occurrence of point discharges (or St. Elmo's fire) on bushes or trees, or, for a more classic example, at the tip of a ship's mast, may be observed under or near an approaching thunderstorm. But when no thunderstorm, cumulonimbus cloud, nor power line is present, a point discharge observed exactly at the same time and in the vicinity of the epicenter of a strong earthquake has to be regarded as something that is most likely connected with the catastrophe.

The anomalous point-dischargelike effect is recurrent in accounts found in the EQL literature. One such point-dischargelike account was reported after the 25 January 1946, M 6 Valais Central (Sion) earthquake: "… a detonation was heard and then from the roof of the house, burst out a bright white luminosity accompanied by a strange crackling sound …" (Montandon, 1948).

Another example of crackling sound heard while "flakes of fire" were seen on roofs happened in February 1663 during the numerous great M 7 earthquakes that shook the St. Lawrence valley (Ebel, 1996). Two first-hand written descriptions of this phenomenon were made, one by Mère Marie-de-L'Incarnation in her 1663, CLIX letter (Marshall, 1967), the other by Père Hierosme Lalemant (1663): "The 5th of February, around 5:30 at night, a great 'bruissement' [noise] was heard at the same time in all the extent of New-France [Canada]. … This 'bruissement', always preceding and accompanying the quake, sounded like a house caught on fire, … which made the inhabitants run out only to realize that there was no fire or smoke, but to be surprised by the rocking of the walls. … The houses were moving like trees caught in a storm, and with a sound leading one to believe that a fire was crackling in the attic. … We also saw flakes of fire sliding on roofs without causing any harm other than fear …."

Among the reports coming from the Saguenay region, an observation is worth inserting here. It was witnessed by a whole family on 24 November, the night before the main shock. Around 10:45 PM, looking through the window, three family members noticed a peculiar luminosity filling and covering the neighbor's apical roof. The color was "a luminous blue." A few days before, a similar phenomenon was observed but the luminosity was only partially covering the roof. During the same period, the witness also noticed that her household radio, always tuned to the same frequency (1420 KHz AM), was overcome by "static." Reports of unusual electromagnetic emissions before earthquakes are not rare. Before the Lungling earthquakes (M 7.5 and 7.6, 29 May 1976), rainlike noise was received by an ordinary household radio while earthquake lights were sighted (King, 1983).

Hence, during the Saguenay seismic activity, two reports of point-dischargelike display were reported, a large and strong one over a forested area and another but faint one over an apical roof occurring during a period when radio "static" was heard. As did Yasui in 1973, I propose that all bluish-white anomalous "luminous discharges" seen in contact with an object shortly before or during seismic activity be classified under their own descriptive name: the coronal and point-dischargelike type (St-Laurent, 1991).

DISCUSSION

With regard to all testimonies made by the witnesses, it has been argued that people are naturally alert to all kinds of phenomena observed at the time of a severe earthquake and are apt to regard them as something connected with the catastrophe, while forgetting to consider that the same phenomena are frequently observed on many other occasions. This problem must be considered.

An example is the 3 November observation of arced bands seen from Alma. This report was difficult to evaluate because some of its attributes were those of a true auroral display while others were not. The described blue-violet-white arced bands seen rising from the horizon were typical of the auroral first-phase manifestation when seen near the boreal region. Furthermore, the date was within the autumnal temporal frame (September/October/November) when most aurorae are seen in northern Québec and was close to the 1990 solar activity peak. However, the first phase is normally followed by second and third phases, *i.e.*, the break up of the homogeneous forms giving way to rayed structures later seen as "curtains" near the zenith (second phase), and finally, the aurora becoming quiescent and revealing itself only by the presence of luminous patches before vanishing. Neither of these two last phases was present; it ceased just after the first phase. Moreover, the time when first seen (between 6:30 and 7:00 PM) is very early for auroral manifestations—normally the timeframe being within 9:00 PM to 4:00 AM. Also, the geographic orientation of the occurrence was due *east*, when normally it should have been due *north*, especially during the first phase. Lastly, the witness rejected the possibility of an auroral display because of her familiarity with the phenomenon.

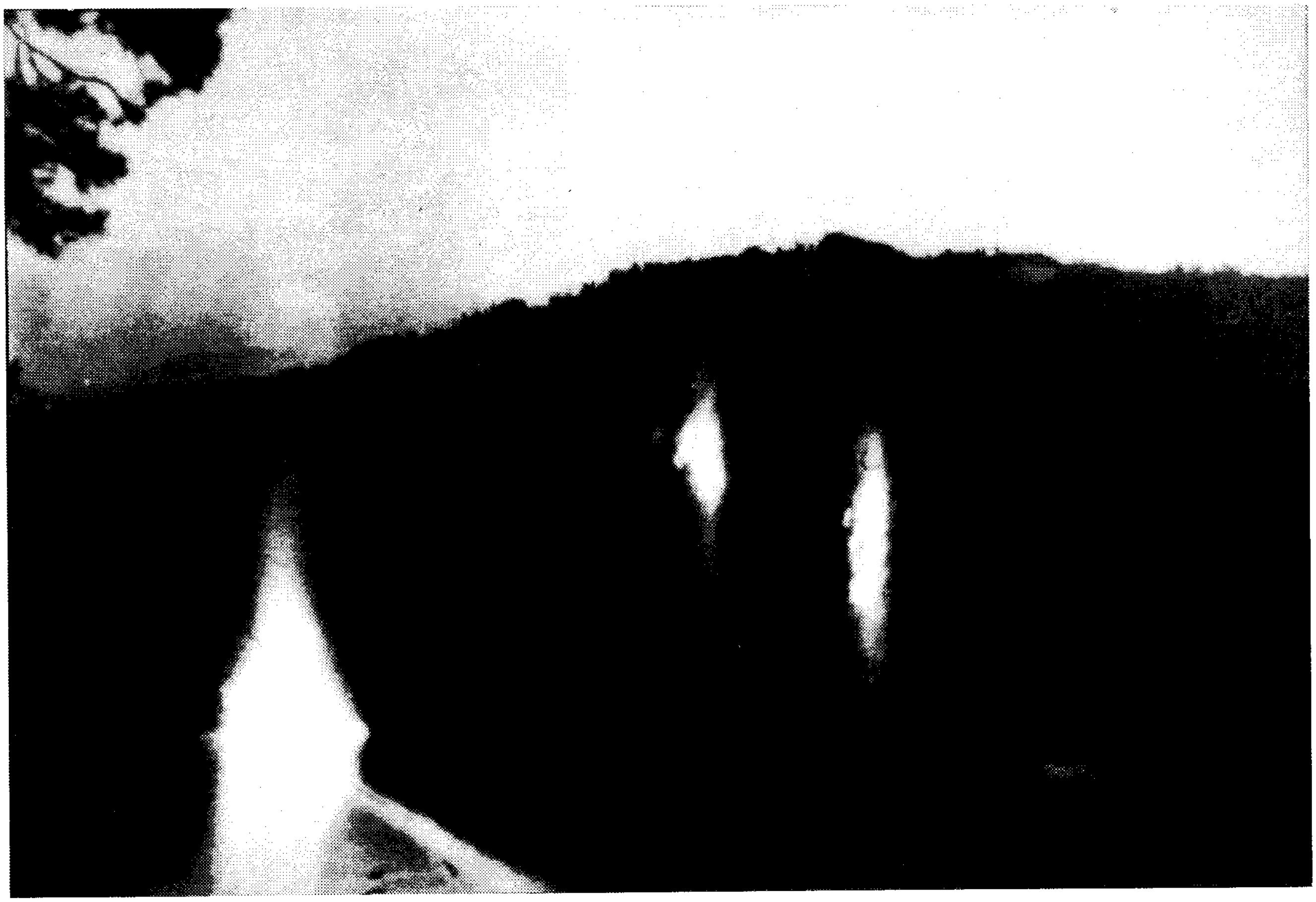
Such reports should not be discarded but rather noted and analyzed so that comparison with further EQL reports involving auroralike displays, especially coming from latitudes where aurorae are extremely rare, could eventually with time and enough observations reveal the true triggering source, *i.e.*, solar activity or seismic activity. Compared to true aurorae, the four other reports of luminous bands or rays were completely atypical (see section on luminous bands). So the interpretation and evaluation of this report as related to the forthcoming foreshock remain open.

Some might consider the eight preseismic observations (31 October to 22 November) to be simply unusual luminosities, or, to use a neutral term that contains no prejudice concerning their nature, "anomalous luminous phenomena" (ALP). "Earth lights" is also another neutral expression, in contrast to another popular pejorative label—unidentified flying object. Others will simply label these eight lights as background noise. But among well advised Canadian ALP researchers, it is well known that in the province of Québec the *average* number of ALP reports per year is around twenty-four, or an average of two reports per month for *the entire populated territory of Québec*. This suggests that perhaps two of the November reports which we have discussed earlier might statistically be expected. However, we would then still be left with six preseismic reports. This investigation has shown that these observations are sufficiently unusual, both individually and in the aggregate, that they demand a better explanation than the simple dismissal implied in the noise label.

As seen earlier, some forms of EQL are nothing new. They are luminous phenomena that are sometimes seen occurring in nature but usually under other circumstances. However, some other forms of ALP are observed solely at the time of earthquakes, for example, (1) flamelike luminosities issuing from the ground in a repetitive manner as in Jonquière on 26 November and at the time of the 16 November 1911, Wurtemberg earthquake (Mack, 1912); (2) balls of fire issuing from the ground as near Simoncouche Lake on 31 October 1988 and as on 21 July 1976, 75 km from the Sungpan-Pingwu epicentral area (both three weeks preseismic events); and (3) columns of light standing over the ground as near Brasov, Romania, during the March 1977 aftershocks of the 4 March, M 7.2 earthquake (Hedervari, 1984) (Figure 5). Those phenomena are never seen occurring in nature on other occasions; they are uniquely reported at times of moderate or great earthquakes.

In previous sections of this paper, the Saguenay reports have been examined by luminosity types, as described by the observers, and compared to the Montandon classification. If the examination is done by considering the location of the sightings in relation to obvious geological features near the epicentral region, an interesting pattern emerges.

Of the forty-six reported sightings of EQL accompanying the Saguenay earthquakes, thirty-eight come from cities located *within* the graben and near the Saguenay River, or from cities bordering the southwest shore of Lac St-Jean, which is also located inside the graben escarpment. This distribution may be significant in spite of the fact that it also reflects the geographical distribution of cities which were naturally built near rivers or lakes, because those thirty-eight inside-graben sightings were also and exclusively the ones which accompanied the earthquake sequence, except for the 18 November occurrence whose exact location (near south graben wall?) is not certain. The eight remaining observations which took place *outside* the graben, and mostly farther from the epicenter, were, interestingly, those which occurred before 23 November, except for the two events in December that took place at the end of the 11–25 December seismic halt. Those eight reports, isolated in both time and space, come from cities and villages that are completely unrelated to the natural geographic distribution of the population near the epicenter: Lac Simoncouche, 31 October, 4 km from the

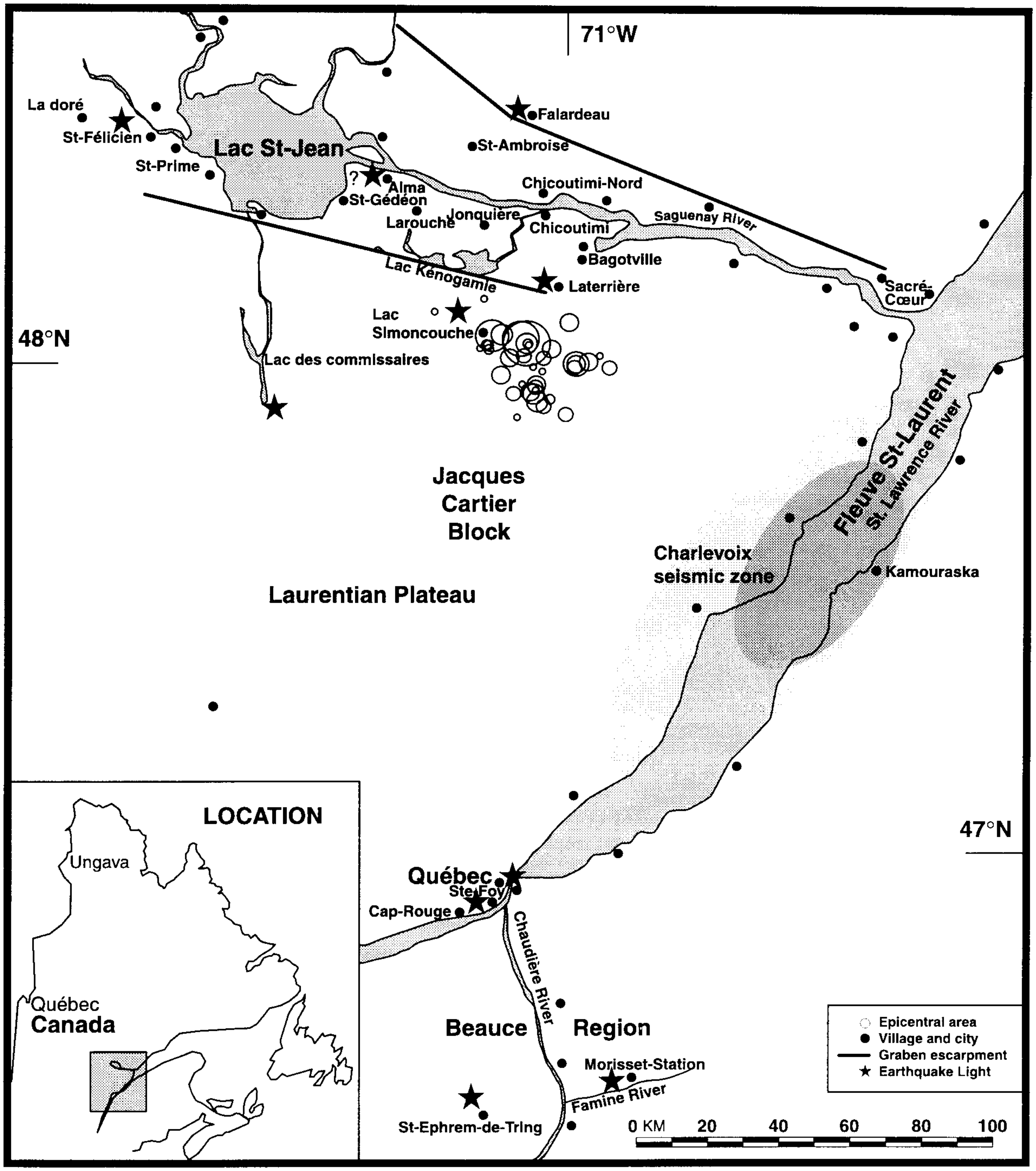


▲ **Figure 5.** One of five pictures taken just before dawn on 23 March 1977, near Brasov, Romania, about 90 km west of the Vrancea seismic zone during the aftershock sequence of the *M* 7.2 main shock that occurred on 4 March. The photographer, Mihai Danciu, characterized the white faintly luminous column as just on the limit of visibility. The film used was ORWO 21 DINs, black and white (ISO 100 ASA equivalent).

epicenter; over the St. Lawrence River in front of Québec City, 12 November, 160 km; Beauce region, 14 and 18 November, 200 km; Lac des Commissaires, 21 November, 75 km; Falardeau, 22 November, 50 km; St-Félicien, 21 December, 95 km; and Cap-Rouge, 24 December, 165 km. All those preseismic and outside-graben reported sightings depicted the luminosities as ovoid or globular luminous masses (Figure 6a). The pattern here is that outside-graben (hence, mostly distant) EQL are exclusively ovoid luminous masses precursory to the foreshock, except for two cases which were precursory to the resumption of seismicity after a period of quiescence. All other observed EQL within the graben accompany the larger events or are contained within the aftershock sequence (Figure 6b).

As previously mentioned, the focus of the Saguenay main shock was at a depth of 29 km and 17 km south of the surface expression of the graben south wall. However, since the configuration of the graben boundary faults is unknown at depth, it is not possible to say whether the focus was on the southern boundary fault, because of the horizontal distance and because "almost any fault or zone of weakness that is both weak enough and suitably oriented to the direction of the principal stress field in the region might have been reactivated. Thus, the reactivated fault is not necessarily related to the most obvious trends or faults even if the proximity of the graben boundaries might have been a factor in the occurrence of the Saguenay earthquake" (Du Berger *et al.*, 1991). It is likewise possible that the presence of the graben boundary faults might have been a factor favoring the occurrence of the luminosity during the earthquake sequence. Indeed, it has been observed that the pattern of ALP observations often shows a close association with faulting and major rivers, suggesting the possibility of an interrelationship among faulting, fluid injection (or natural percolation of ground water), and earthquakes (Derr and Persinger, 1992, 1993).

One does not necessarily notice reports of EQL in every eastern Canada earthquake. However, the absence of reports does not automatically mean absence of EQL. Two reasons for this are possible: Many great earthquakes in eastern Canada have occurred in areas with few inhabitants (*e.g.*, the Ungava Northern Québec earthquake of 25 December 1989, *M* 6.3) or during daylight hours (*e.g.*, the 11:30 AM Charlevoix earthquake of 20 October 1870, intensity IX). When good conditions were present for their observation, *i.e.*, events in populated areas and during hours of darkness, no research was then conducted to verify these possible

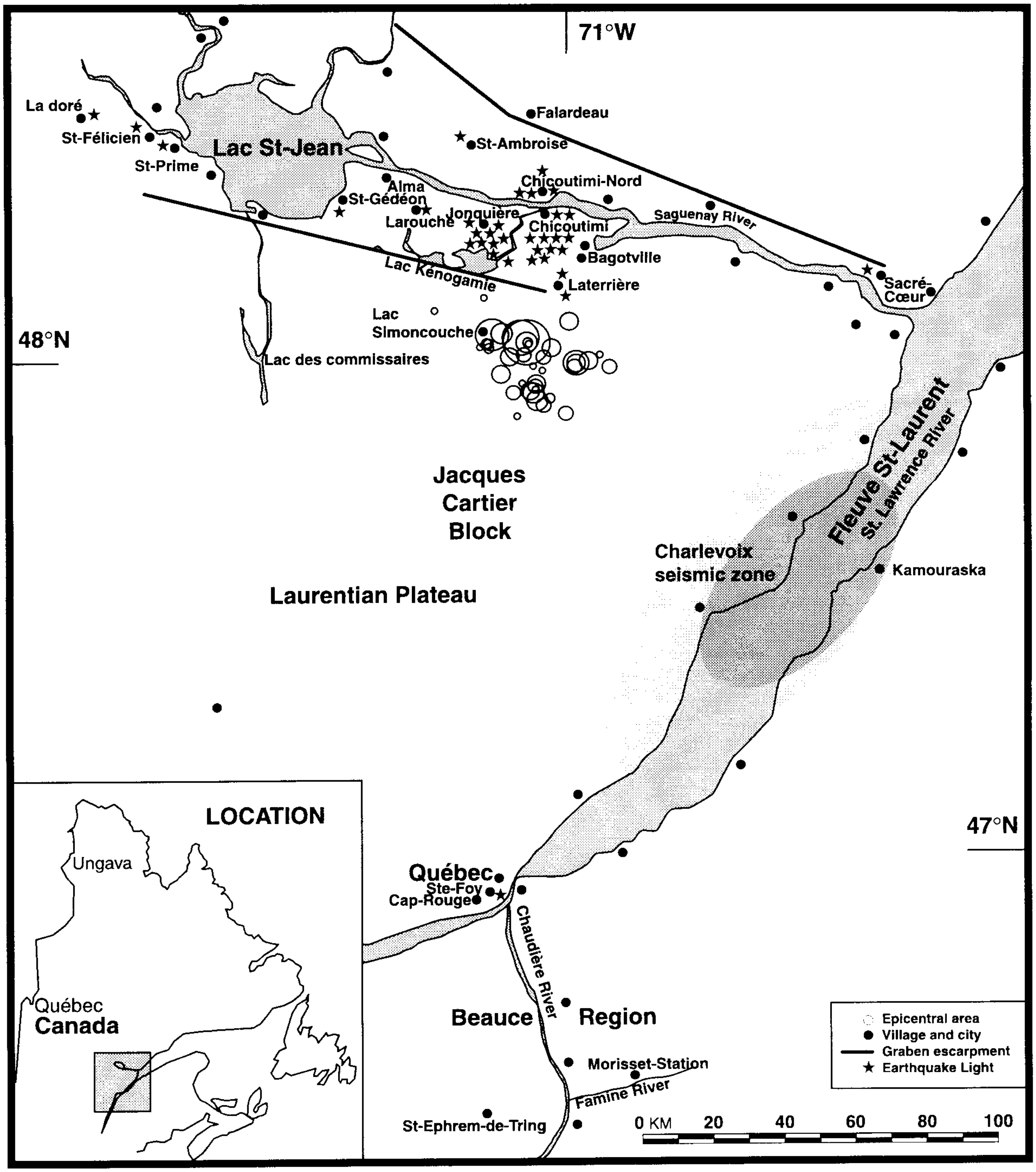


▲ **Figure 6a.** Same as Figure 2 but showing the EQL spatial distribution found only during the Saguenay seismic quiescence, *e.g.*, before 23 November 1988 and during the 11–25 December 1988 seismic halt (mostly outside-graben).

occurrences with the exception of Ouellet (1990) for the Saguenay earthquakes. If research were conducted on an ongoing basis, one could perhaps, with time, find important parallels. For example, do EQL manifest themselves only when a strong earthquake occurs ($M > 5.9$)? Will they be found where the aftershock epicentral distribution is larger than expected for a given main shock magnitude? Do they happen only in regions having similar geological and/or tectonic settings? It should be pointed out that the Saguenay EQL occurred in the same general area of the Laurentian Plateau (Jacques-Cartier Bloc) as the 1663 earthquake, which also produced EQL, and that both earthquakes had a magnitude greater than 5.9.

CONCLUSION

As demonstrated, the diversity of the luminous phenomena found in the Saguenay reports given through representative



▲ **Figure 6b.** Same as Figure 2 but showing the EQL spatial distribution found only during the seismic activity (mostly inside-graben).

examples are consistent through time with the diversity noticed by Galli, Montandon, and Mack at the beginning of the century. Also, each type of phenomenon described by Montandon is still easily recognized in the Ouellet collection. Hence, the Saguenay and Lac St-Jean reported luminous phenomena are largely in accordance with the five types of EQL found in the Montandon classification of 1948. The Yasui description of the Matsushiro earthquake lights is less representative of the Saguenay seismic lights than the Montandon European classification, mainly because of lack of diversity. On the other hand, the Matsushiro lights' specific appearances, because of their similarities with those of the Laterrière (Saguenay) event, should be described and added to the Montandon classification under the name coronal and point-dischargelike type. ■

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