PRELIMINARY REPORT OF THE MIRAMICHI, NEW BRUNSWICK, CANADA EARTHQUAKE SEQUENCE OF 1982.

Anne E. Stevens (editor)

Earth Physics Branch

Energy, Mines and Resources Canada

Ottawa K1A OY3

Earth Physics Branch Open File Report 82-24

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ABSTRACT

In early January 1982 an important series of earthquakes began in the Miramichi region of New Brunswick. This Open-File Report presents an outline of most of the special studies conducted in New Brunswick following the principal earthquake of January 9. Participants were invited to describe their field work and indicate preliminary results, with the understanding that later more intensive analyses might alter initial conclusions. This Report comprises 23 chapters, which include reports on seismological, geologic and other surveys conducted from January to July 1982 and also abstracts of all Miramichi papers presented at the annual meeting of the Seismological Society of America in April 1982.

RESUME

Vers le début de janvier 1982 une importante série de tremblements de terre commençait dans la région de Miramichi au Nouveau-Brunswick. Ce dossier publique donne un aperçu de la plupart des études spéciales effectuées au Nouveau-Brunswick après le tremblement de terre principal du 9 janvier. Les participants ont été invités premièrement à décrire leurs travaux sur le terrain et ensuite à présenter des résultats provisoires. Il est d'ailleurs sous-entendu qu'après des analyses plus élaborées, les conclusions initiales peuvent être modifiées. Ce dossier de 23 chapitres comprend des rapports de relevés séismologiques, géologiques et autres, qui ont été effectués entre janvier et juillet 1982. Les résumés de toutes les communications sur Miramichi présentées au congrès annuel de la Seismological Society of America en avril 1982 sont également joints.

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1. INTRODUCTION

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1982 MIRAMICHI EARTHQUAKES

On Saturday, January 9, 1982, at 08:53 Atlantic Standard Time an earthquake of magnitude slightly greater than 5-1/2 occurred in the unpopulated Miramichi Highlands of northcentral New Brunswick in eastern Canada, followed by an aftershock of magnitude 4 and another of magnitude 5 within the next 3-1/2 hours. Within 32 hours of the main shock, three portable seismograph stations had been installed about 15 km south of the epicentre by three seismologists sent from the Earth Physics Branch of Energy, Mines and Resources Canada, which is based in Ottawa, 700 km to the west. The temperatures at the time were near -20°C and a heavy snowfall had occurred one week earlier. Thus only a small field party was sent initially until it could be determined how long detectable aftershock activity might continue and whether it would be possible to get close enough to the active area to get useful seismograms.

On Monday afternoon, January 11, two and one-half days after the main shock, a second earthquake of magnitude near 5-1/2 occurred. The field programme then rapidly expanded, with significant participation also by American colleagues. Hundreds of small aftershocks were recorded in the next few weeks on both permanent and temporary field stations. In the following eight months, six earthquakes of magnitude 4 or greater have occurred, leading to two additional aftershock field surveys in April and June. At present, nine months after the principal shock, at least one event per day on the average, with magnitude near 1, is still being detected, with several events per month with magnitude near 3.

Although the main shock was widely felt in the Maritime Provinces and the New England States and thus generated considerable public and media interest, it was clear from the beginning that little, if any, serious property damage had occurred. The earthquakes were centred in an unpopulated area with the closest towns lying 50 km away. Fredericton, the provincial capital and largest city (population 45,000) is 100 km to the south. The New Brunswick - Maine border is 80 km to the west. No strong-motion instruments had been installed previously in New Brunswick, so no direct measurements of peak ground motion are available for the larger Miramichi earthquakes. However, effective peak motions were clearly rather small. When various furnished but unoccupied ranger and private cabins in the epicentral area were subsequently examined, almost nothing was found overturned nor dislodged within these buildings. This is a bit puzzling in the view of the shallow focal depths (less than 10 km).

The 1982 Miramichi earthquake activity is important to geoscientists for at least three reasons. First, the main shock and principal aftershock on January 9 and 11 were the largest earthquakes on land in eastern North America since the Cornwall-Massena earthquake of September 1944. Secondly, for the first time in eastern North America, both analogue and digital seismic data have been recorded for earthquakes from a relatively small source volume spanning a magnitude range from 5-1/2 to less than 1, and digital data are available for epicentral distances up to nearly 1000 km. Thirdly, a strong-motion network installed in the epicentral area in early February has produced useable accelerograms from seven aftershocks with magnitudes between 3-1/2 and 5, the first such set of strong-motions records produced in eastern Canada.

SEISMICITY OF NEW BRUNSWICK

Most of New Brunswick lies in Zone 2 of the seismic zoning map in the current edition of the National Building Code of Canada (Figure 1.1). The areas with the larger black dots denotes Zone 2, where there is a risk of moderate damage in earthquakes. To have earthquakes of magnitude 5-1/2 in northcentral New Brunswick was thus no surprise to seismologists familiar with Canadian seismicity.

Figure 1.2 shows earthquakes in New Brunswick and adjacent areas in the 10-year period from 1970 to 1979. The 1982 Miramichi earthquake occurred at 47.0°N, 66.6°W, in an area of previous minor activity. In this 10-year period all earthquakes in New Brunswick had magnitude less than 4, and most less than 3. Until the late autumn of 1981 New Brunswick was not well monitored for earthquakes smaller than magnitude 2-1/2, so more low-level activity may have occurred than that indicated in Figure 1.2. However, the figure does show that earthquakes in New Brunswick do not form any obvious patterns nor outline any single active structure.

Figure 1.3 shows earthquakes of magnitude 3-1/2 and greater in New Brunswick and adjacent areas to the end of 1979. The letter "X" marks the location of the 1982 Miramichi earthquakes. The apparently greater activity in the southern half of the province may reflect its greater population density rather than a significant long-term difference in the actual earthquake activity, since many of the plotted epicentres were determined from non-instrumental data.

The following chapters outline many of the special studies undertaken in New Brunswick in 1982. Some authors have chosen to describe their work in abstract form only; others have contributed a more detailed report. All chapters have been edited to some degree for both style and content, and an attempt has been made to update some of the reports by references to summer field results and papers in preparation.

This Earth Physics Branch Open-File Report will be reprinted by the Earthquake Engineering Research Institute, with headquarters in Berkeley, California and an international membership, for distribution to its members and others interested in the 1982 Miramichi, New Brunswick, earthquake sequence.

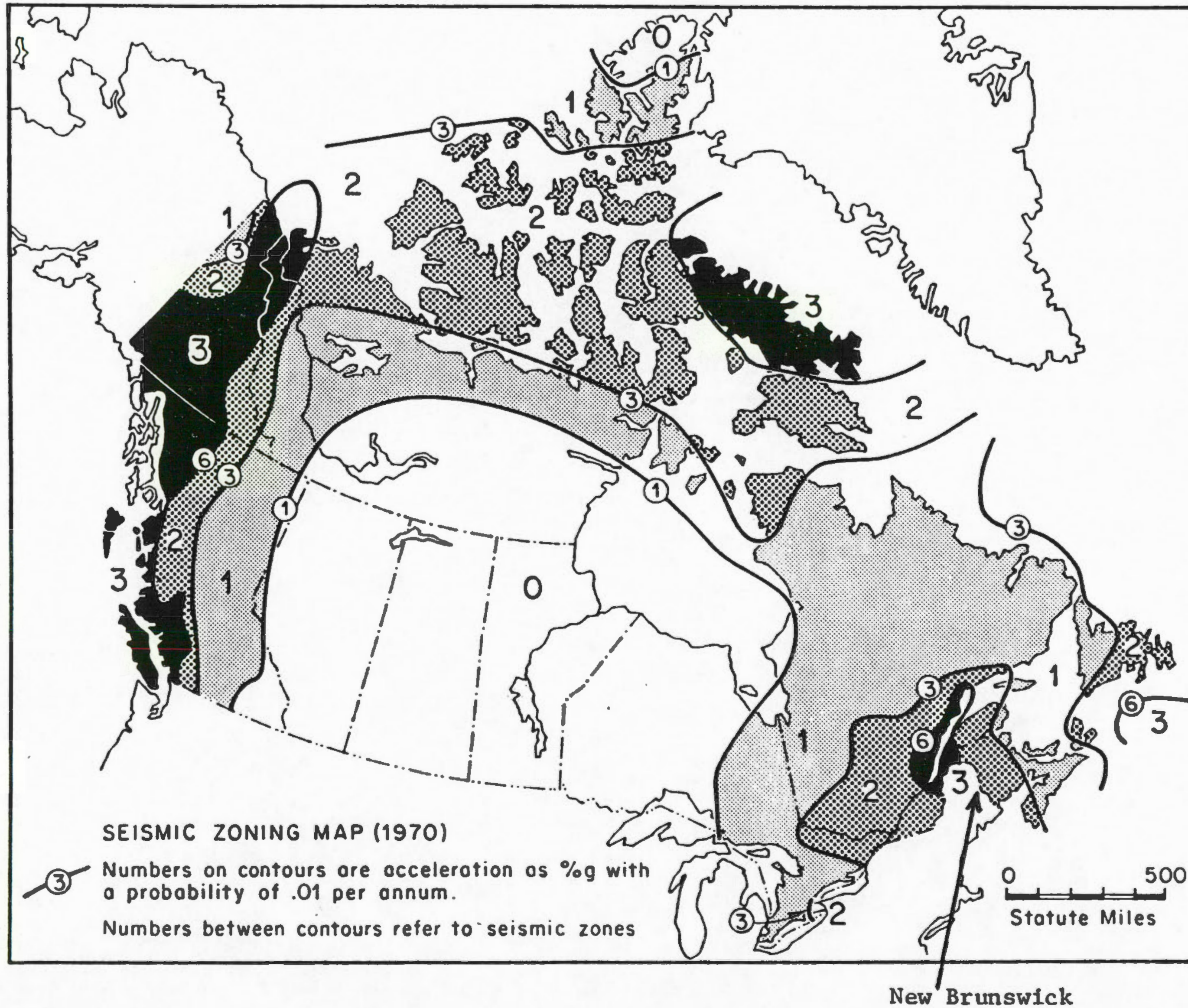


Figure 1.1 Current Seismic Zoning Map for Canada

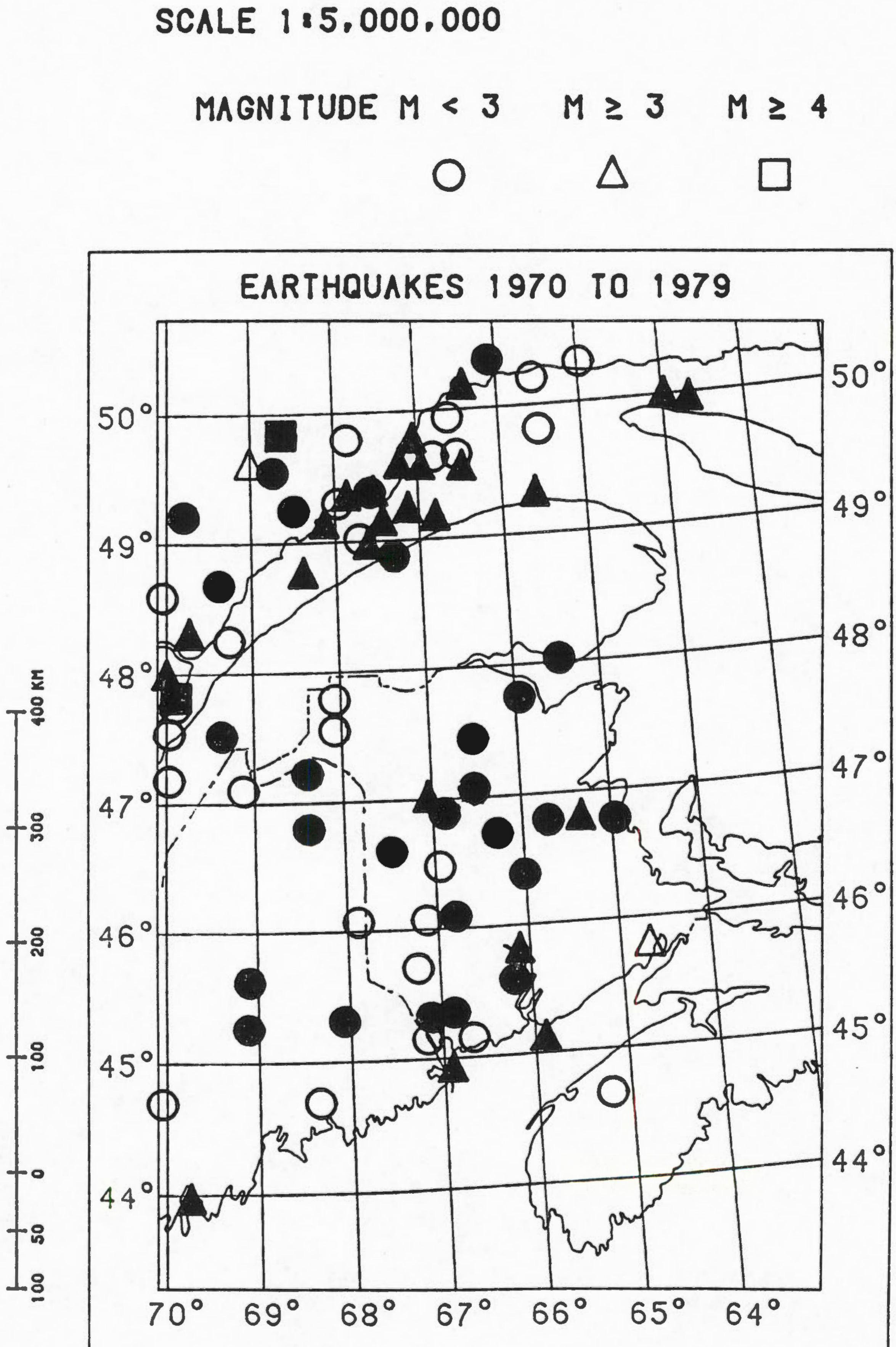
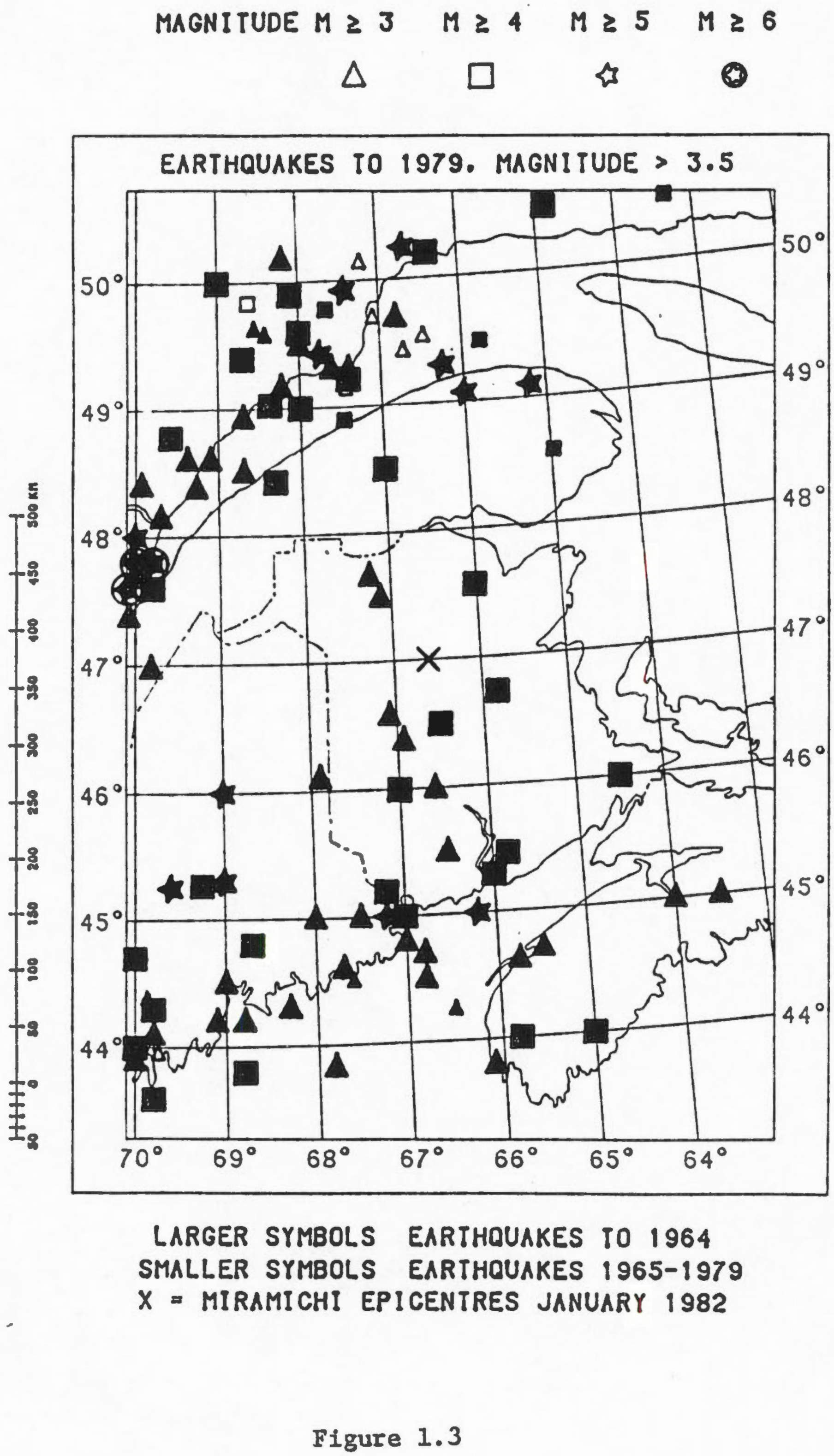

SCALE 1:5,000,000
MAGNITUDE M < 3   M ≥ 3   M ≥ 4
EARTHQUAKES 1970 TO 1979
50°
49°
48°
47°
46°
45°
44°
70°
69°
68°
67°
66°
65°
64°
400 KM
300
200
100
0
50
100

Figure 1.2



LARGER SYMBOLS EARTHQUAKES TO 1964
SMALLER SYMBOLS EARTHQUAKES 1965-1979
X = MIRAMICHI EPICENTRES JANUARY 1982

Figure 1.3

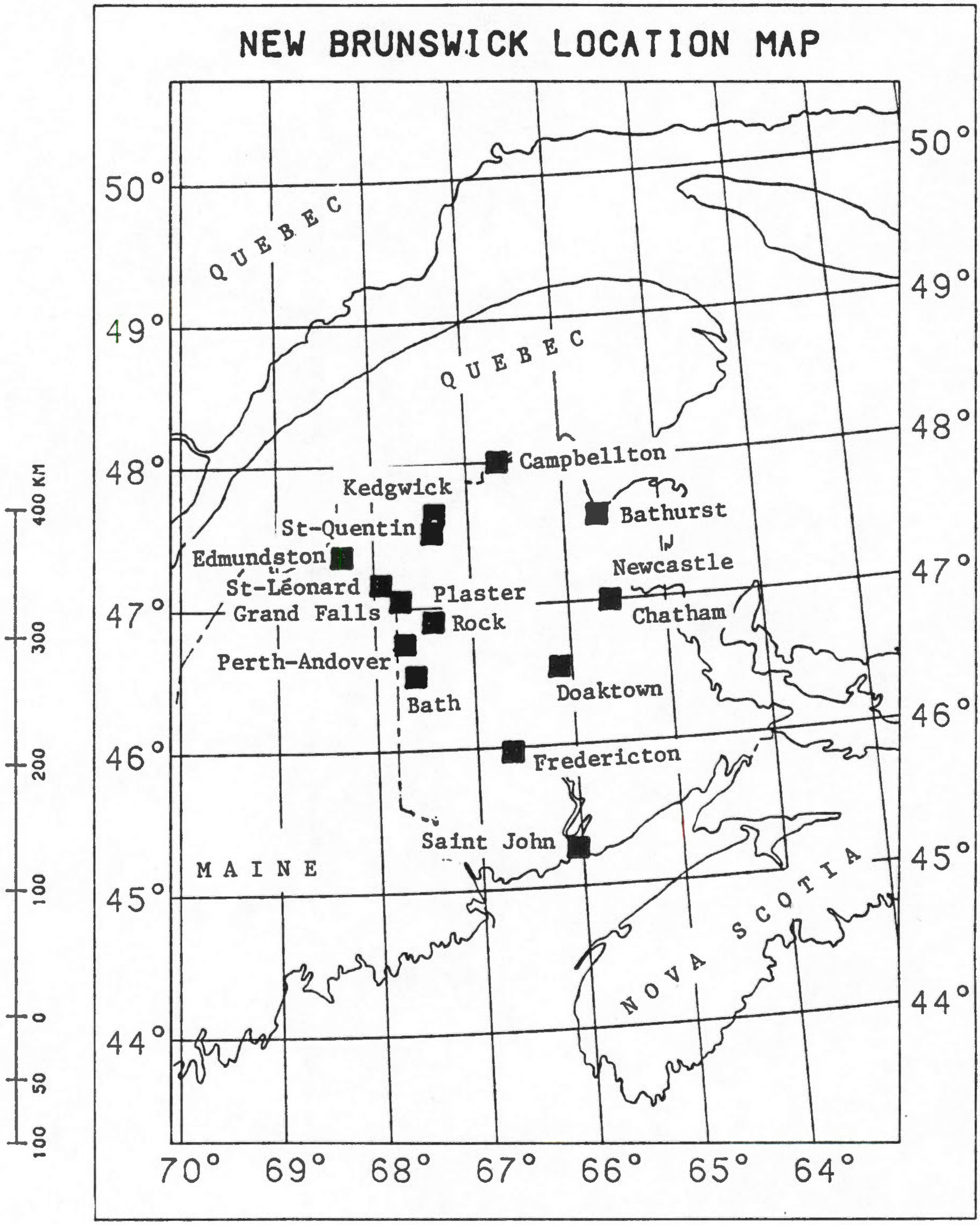

NEW BRUNSWICK LOCATION MAP
QUEBEC
QUEBEC
Campbellton
Kedgwick
Bathurst
St-Quentin
Edmundston
Newcastle
St-Léonard
Plaster
Grand Falls
Rock
Chatham
Perth-Andover
Doaktown
Bath
Fredericton
Saint John
MAINE
NOVA SCOTIA
50°
49°
48°
47°
46°
45°
44°
70°
69°
68°
67°
66°
65°
64°
400 KM
300
200
100
0
50
100

Figure 1.4

2. THE NEW BRUNSWICK EARTHQUAKE OF JANUARY 1982

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"and there shall be earthquakes in diverse places."
Matthew 24:7

There is a certain fascination with earthquakes that is woven through our history and religion; it has been said that the collapse of the walls of Jericho about 1100 B.C. and the destruction of Sodom and Gomorrah were caused by seismic events. It was, therefore, not surprising that the earthquakes in New Brunswick captured headlines throughout the country and for a brief moment pushed interest rates, unemployment, Poland and El Salvador to the back pages.

Surprise! I think that is the best word to describe the reaction of New Brunswickers to the first and even the second shock. The first shock occurred at 8:55 a.m. Saturday, January 9, 1982, breakfast time for most. The almost universal reaction was that the furnace was blowing up. The resulting action of the occupants was then divided between those that rushed to their furnace (there were reports of some with electrical strip heating rushing to find their furnace!) to turn them off and those that rushed to the nearest exit. One quick thinker grabbed a bucket of water, ran to the furnace, stood back and let fly--whereupon the furnace stopped. Time and the realization that little damage had been done soon took away fear and by the time the second aftershock occurred Monday evening, the locals were now "pros" and life went on as normal.

What is it like to experience an earthquake? Imagine yourself to be at morning prayer in Newcastle (110 km east of the epicentre) and read the following account: Father Peter Bagley watched and felt the pillars of St. Michael's Catholic Church move from Saturday's first earthquake. "The whole end of the church bulged like the cover on a boiling pot."

"All of a sudden the floor under me moved." The pillars holding up the great roof of the stone structure swayed. The time was about 8:45 a.m. A number of worshippers had gathered for morning prayer.

He shouted to them to get out of the church and rushed to an entrance.

Referring to the "bubbling sensation" caused by the quake, Father Bagley says there were three such shocks. It was during the second wave when he shouted.

Some, stunned by the event, stood where they were. Others made for the doors.

The earthquake epicentre was at Jack's Lake in the upper reaches of the Little South West Miramichi River. This is wilderness country. The nearest permanent habitations are Plaster Rock, 80 km to the west; Red Bank, 80 km to the east; Boiestown, 80 km to the south; and Bathurst, 120 km to the north. The main shock was given a Richter magnitude of 5.5 to 5.9, the first aftershock just after lunch magnitude 4.9, and the second large aftershock Monday, a magnitude of 5.5.

In terms of the historic seismic record, these magnitudes are not unusual and come as no surprise to seismologists and earthquake engineers, but to have such a large event occurring in one's working lifetime and relatively close to home--that is unique. (The last earthquake of this magnitude to occur in Eastern Canada was at Cornwall, September 5, 1944). The seismological community responded in force and within a few days had the epicentre surrounded with seismographs. The provincial EMO provided coordinators and other governmental agencies, in particular the New Brunswick Department of Natural Resources, provided guides and transportation. About one hundred aftershocks were recorded in the first few days. These records will form an invaluable data set for explaining the mechanism of fault rupture and will most likely give clues to the state of stress and causes of intraplate earthquakes. I, myself, was searching for structural indicators, such as physical movement or damage, which would provide a measure of ground motion from points distant and near to the epicentre. Such information can be compared to our ground motion models used for setting seismic design requirements for our nuclear power plants.

Most seismological instruments are too sensitive and become saturated when they are too close to an earthquake. To record near-field motion, engineers use strong-motion accelerometers that trigger on demand and record directly the ground acceleration. These instruments are set out like bait waiting for the big event. While there are thousands of these instruments in California, the nearest Canadian instrument was at Baie-Comeau on the north shore of the St. Lawrence River.

My first effort was to get near the source. The seismologists had established a base camp at Holmes Lake, about 5 km from the epicentre. They reported no damage to the log cabin camp at which they were staying, or to its contents. I joined the seismologists at their base camp and with the assistance of a forest ranger checked various structures (i.e. several log cabins and one Bailey Bridge) in an easterly arc from 8 km north of the epicentre to the east and then the south. The ranger knew of an isolated cabin to the west and closer to the epicentre. We drove there on snowmobiles. The cabin was well appointed but again, and fortunate to the owner, no damage to structure or contents. The next few days were spent checking out damage reports and recording local impressions of ground motion in the nearest communities and industrial facilities. I visited the chief engineers at Brunswick Mining and Heath Steele, (both underground lead, zinc, silver mines, 100 km and 75 km, respectively, from the epicentre), the Boise Cascade Pulp and Paper Mill in Newcastle, and the shift supervisor at the New Brunswick Electric Power Commission (NBEPC) generating station at Chatham. In all these plants, physical damage was almost non-existent but the main shock was severely felt and caused work interruption while the operators were trying to find out what "blew up". At Brunswick Mining, most underground workers decided that the wisest move was to go home; at Heath Steele, work continued as soon as the miners realised that no premature blasting had occurred. The mining engineer on duty in the hoist frame described the earthquake as a "locomotive moving through at 1000 miles/hour". At Boise Cascade only the control room operators became concerned. The digester controllers thought the boiler had blown up and the boiler controllers thought the digester had gone. At the NBEPC station, two alarms registered.

What should we look for as the data of this earthquake are unravelled? First, the seismic event fits well the mold of a "typical" large eastern Canadian earthquake at distances greater than 80 km from the epicentre, in terms of damage and the description of witnesses. The total lack of damage or of any evidence of physical motion in the epicentral region is to me somewhat of a mystery, and I will be following the seismological investigation closely to see if a rupture sequence can be worked out and which will explain these observations. Second, many of the aftershocks indicated a shallow depth. Could there be a surface break? If so, and if the break or breaks can be found, this will be a geological first.

(The author spent five days in New Brunswick from January 21 to 25. His field notes in the form of a Reconnaissance Report entitled "The New Brunswick Earthquakes of January 9 and 11, 1982" are a "Note to File, 34-2-4-16" at AECB. The mimeographed report, dated March 22, 1982, consists of 8 typed pages, 25 photographs plus photocopies of a large selection of newspaper clippings.)

3. MIRAMICHI, NEW BRUNSWICK, EARTHQUAKES - JANUARY 1982 AFTERSHOCK SURVEY

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INTRODUCTION

The Miramichi earthquake sequence began on January 9, 1982, at 08:53 AST (Atlantic Standard Time) with a moderate magnitude 5.7 earthquake located in a remote uninhabited part of central New Brunswick, but felt throughout populated areas of New Brunswick, Nova Scotia, Prince Edward Island, parts of Québec and much of New England. Figure 3.1 (F. Anglin, private communication) shows the time distribution of events in January both in terms of daily rate of occurrence and distribution of events larger than magnitude 3. Aftershock monitoring with portable stations installed in the field was initiated by the Earth Physics Branch, EMR on January 10 at 13:51 AST and continued until January 22 when most of the portable stations were removed from the field. Following that, a special network of strong-motion accelerographs (SMA) was installed in the epicentral area of the sequence and has run from the beginning of February 1982 to the present date. (See Chapter 8 by Munro and Pomeroy.)

The seismological agencies that took part in the field work included the Earth Physics Branch of the Canadian Department of Energy, Mines and Resources (EMR), who acted as overall coordinator of the field work and deployed 11 seismographs, the Massachusetts Institute of Technology who deployed 10 seismographs, the U.S. Geological Survey with five seismographs and three accelerographs, the Lamont-Doherty Geological Observatory with three seismographs and one strong-motion accelerograph, the State University of New York with three accelerographs, the Bedford Institute of Oceanography with three (ocean-bottom) seismographs and Weston Geophysical Ltd. who loaned five of the seismographs deployed by other agencies. The field work was greatly assisted by the New Brunswick Emergency Measures Organization who coordinated local logistic support throughout the province of New Brunswick, the New Brunswick Department of Highways who ploughed open many roads in the epicentral area and the New Brunswick Forest Service and their forest rangers who assisted in many aspects of the field work in the epicentral area.

FIELD NETWORKS

The field work took place during the coldest part of the Canadian winter in a remote uninhabited area of the New Brunswick central highlands (temperatures -20° to -40°C). Site selection was severely restricted by the lack of roads through the area. Deployment of recording equipment proceeded slowly because of the severe weather and treacherous road conditions that were frequently encountered. A total of 29 sites were used for monitoring the aftershock sequence (See Table 4.1 of Pulli and Table 8.1 of Munro and Pomeroy for site coordinates.) These included nine sites in the epicentral area (Figure 3.2) and 20 temporary sites outside the epicentral area (Figure 3.3). Omitted from Figure 3.2 was station B1 with coordinates 46.855°N, 66.620°W and elevation 466 m, and from Table 4.1 were stations B1, B2 (46.876°N, 66.930°W, 396 m) and B3 (46.803°N, 66.573°W, 432 m).

The main limitation to the recording network was the lack of stations immediately to the west of the aftershock zone (Figure 3.2). Access to this area was impossible during the field survey. This lack of coverage was partially offset by the more distant stations LL and BB shown on Figure 3.3

The equipment deployed included both seismographs and accelerographs. The two types of recorders were often operated side-by-side because few suitable recording sites were available. The digital recorders had to be housed in heated shelters. These were generally summer cottages in which a portable kerosene heater was installed. The analogue equipment was often deployed out of doors without any shelter other than a covering of snow. All the equipment suffered from the low temperatures experienced, and many good data sets were lost because of cold-related equipment malfunctions.

In spite of these difficulties a wealth of good data was obtained including continuous monitoring of the aftershock sequence by at least three stations within 25 km for 15 days from January 10 to 24 and continuous more detailed monitoring by three stations within 10 km for the four days from January 19 to 22. The larger aftershocks in the 7-day period from January 16 to 22 included 14 events of magnitude up to 3.5 recorded on at least three digital stations and many other events recorded on one or two digital stations. The SMA network has recorded a magnitude 4.8 aftershock on March 31, 1982, at 17:02 AST and several smaller events (see Munro and Pomeroy).

PRELIMINARY SEISMICITY RESULTS

The deployment of seismographs in the epicentral area from January 19 to 22 (Figure 3.2) allowed the aftershocks to be located with the most accuracy, probably better than ± 1 km in position and ± 2 km in depth. A partial analysis of these data shows that the activity is concentrated in a volume of approximately 4 km NS by 6 km EW by 7 km deep (Figure 3.4) with some indication of a southwardly steeply-dipping trend in the focal depths. (See also Figure 4.3 of Pulli). These results must be considered provisional at this time (May 1982) however, and may be changed by a more thorough analysis of the data for this period.

The composite focal mechanism (local focal sphere) shown in Figure 3.4 is in particular very uncertain. It shows a tendency for a composite strike-slip mechanism for the aftershocks in this period, but the solution is not well defined by the data and there are many readings inconsistent with this solution.

(See also the SSA abstract by R.J. Wetmiller in Chapter 23.)

FIGURE CAPTIONS

Figure 3.1 (lower)

The number of earthquakes per hour from January 09 to 31, 1982, as recorded at the Edmundston (EBN) seismograph station, epicentral distance 140 km, detection threshold about magnitude 0. Many smaller aftershocks, partially recorded on EBN or detected by field stations, are not shown.

Figure 3.1 (upper)

Time history of aftershocks with magnitude 3 or greater. Magnitudes are provisional and may be revised.

Figure 3.2

Field stations deployed in the epicentral area. The two-letter station codes are defined in Chapter 4 (Table 4.1) and Chapter 8 (Table 8.1). Some sites had both a seismograph (S) and an accelerograph (A). The operating dates of each station are shown, with a triangle denoting records available for only part of a given day due to a malfunctioning analogue instrument or to a digital instrument that records only when triggered.

Figure 3.3

Field stations deployed in New Brunswick outside the epicentral area. (See also caption of Figure 3.2) Four stations (UNB, EBN, GGN, LMN) were operating before the sequence began. KLN, EBN, GGN and LMN are telemetered digital stations.

Figures 3.4

Preliminary analysis of 45 aftershocks from January 19 to 22, 1982, located with analogue records from stations HL, LC, MR and occasionally from more distant stations. (See also caption of Figure 3.2) Two insets show a north-south cross-section and the distribution of P first motions on the lower focal sphere. Both are preliminary and may be re-interpreted.

MIRAMICHI EARTHQUAKES AS OBSERVED ON ECTN STATION EBN

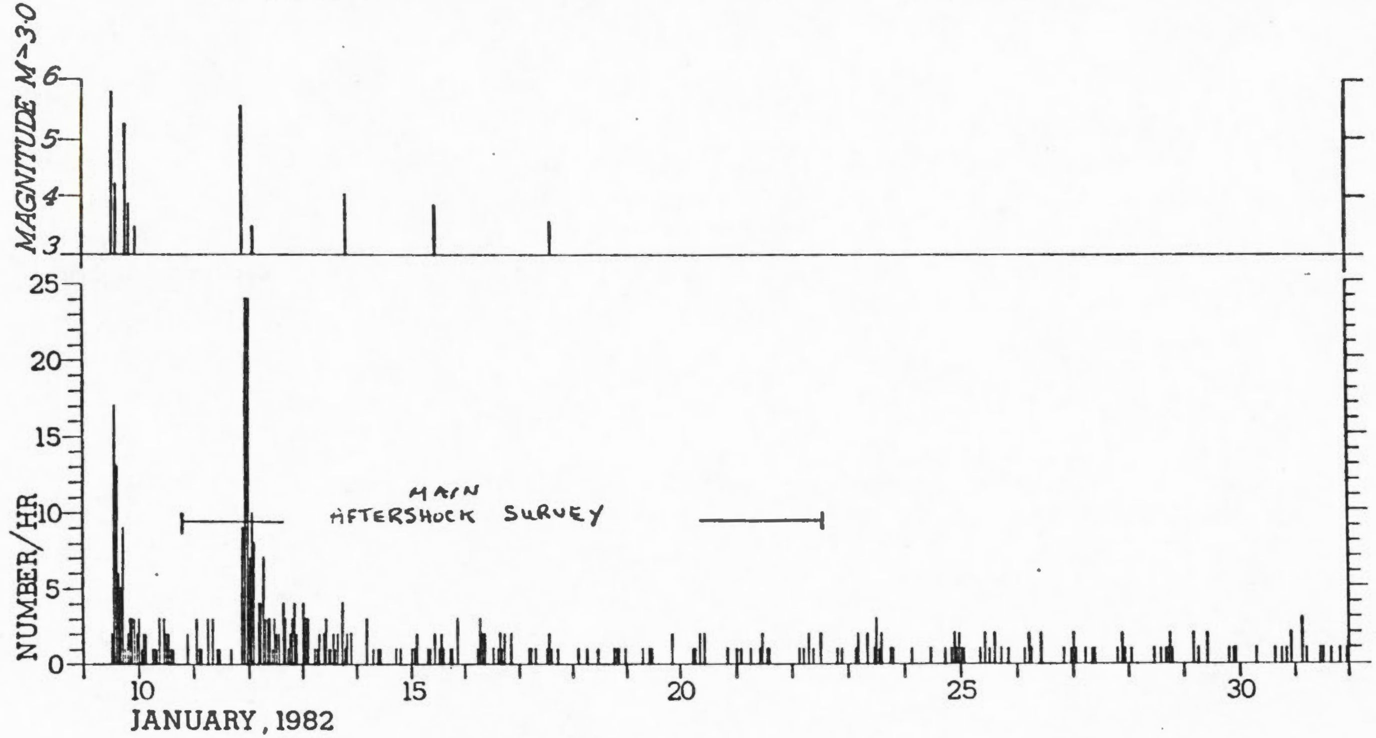


Figure 3.1

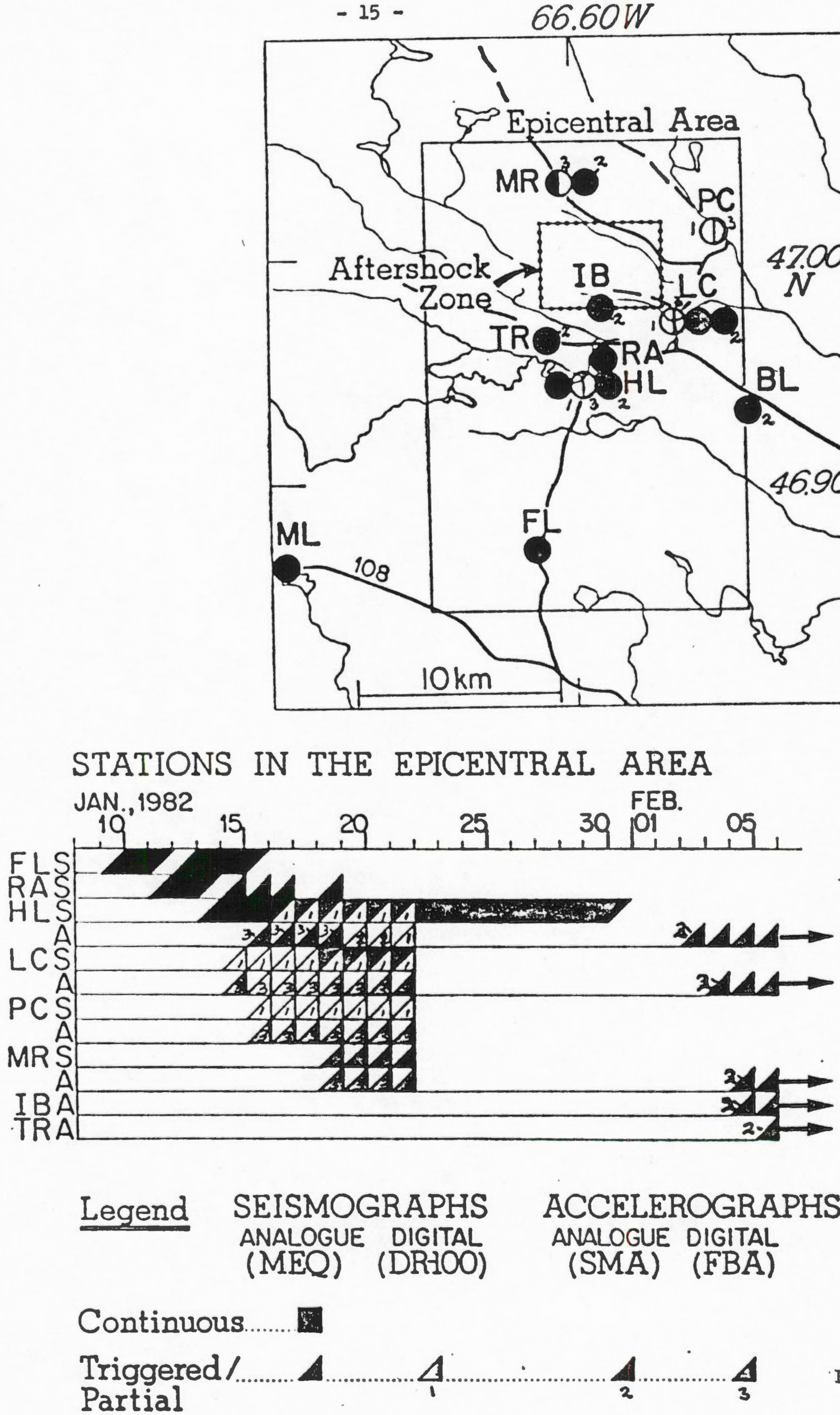
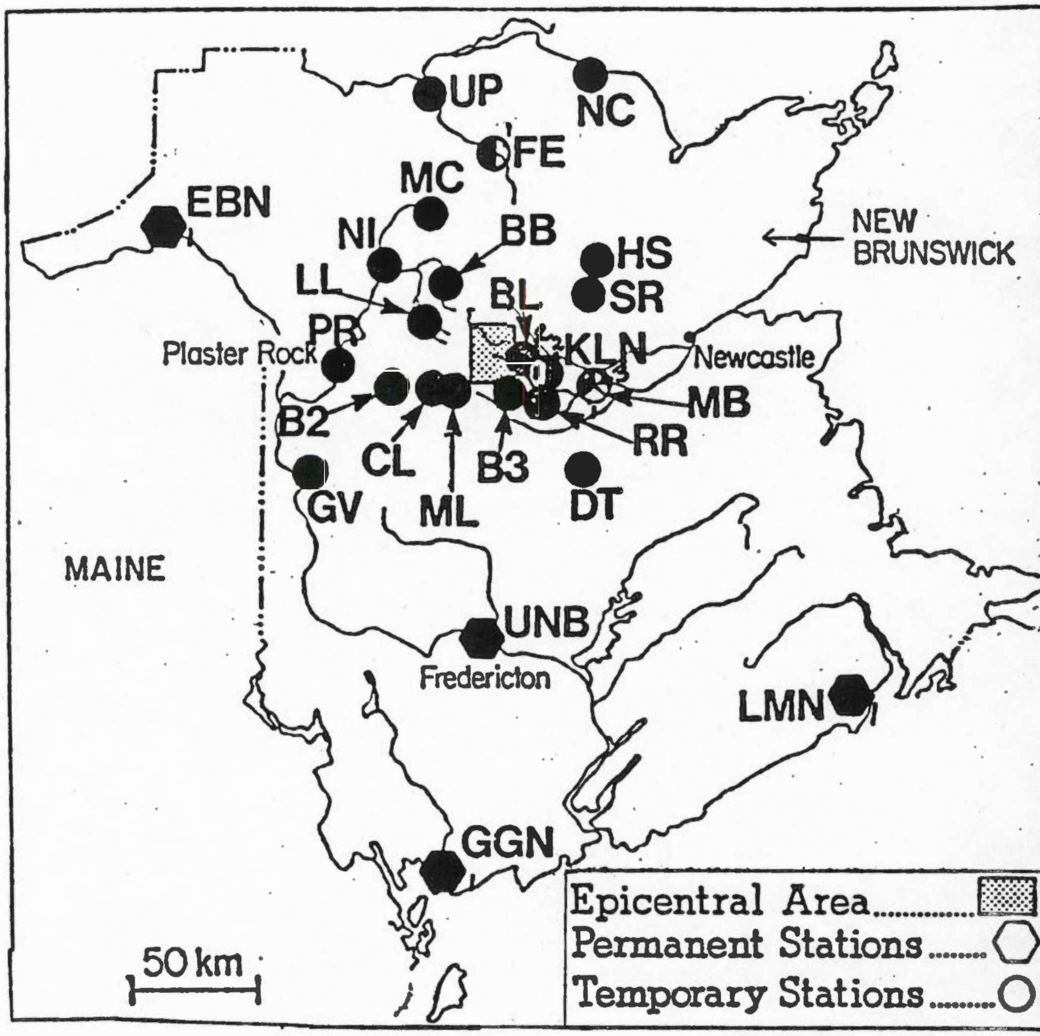

66.60W
Epicentral Area
MR
PC
Aftershock Zone
IB
LC
47.00 N
TR
RA
HL
BL
46.90
FL
ML
108
10km
STATIONS IN THE EPICENTRAL AREA
JAN.,1982
FEB.
10
15
20
25
30
01
05
FLS
RAS
HLS
A
LCS
A
PCS
A
MRS
A
IBA
TRA
Legend
SEISMOGRAPHS
ANALOGUE (MEQ)
DIGITAL (DR100)
ACCELEROGRAPHS
ANALOGUE (SMA)
DIGITAL (FBA)
Continuous
Triggered/Partial

Figure 3.2


UP
NC
FE
MC
EBN
NI
BB
HS
SR
NEW BRUNSWICK
LL
BL
PR
Plaster Rock
KLN
Newcastle
MB
B2
RR
CL
B3
DT
GV
ML
MAINE
UNB
Fredericton
LMN
GGN
Epicentral Area
Permanent Stations
Temporary Stations
50 km

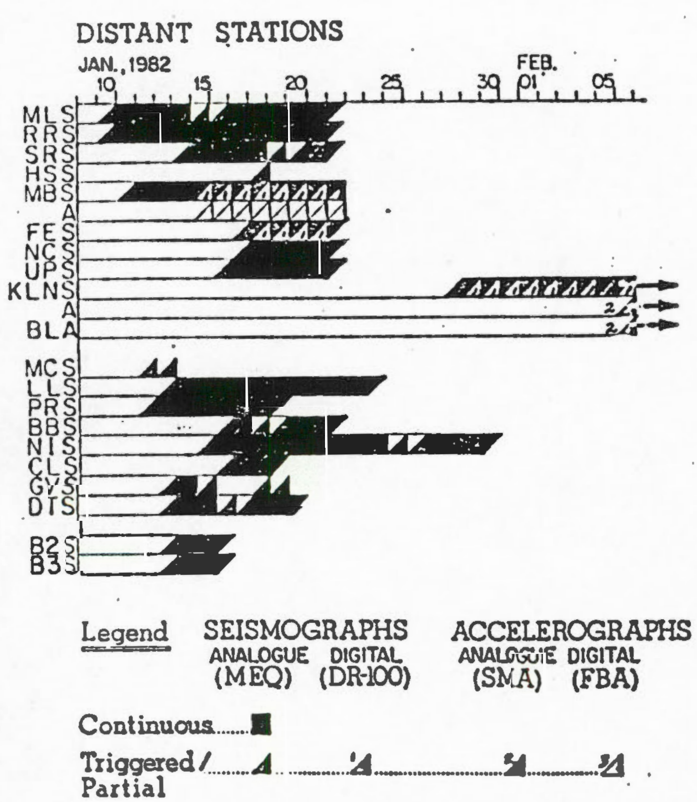
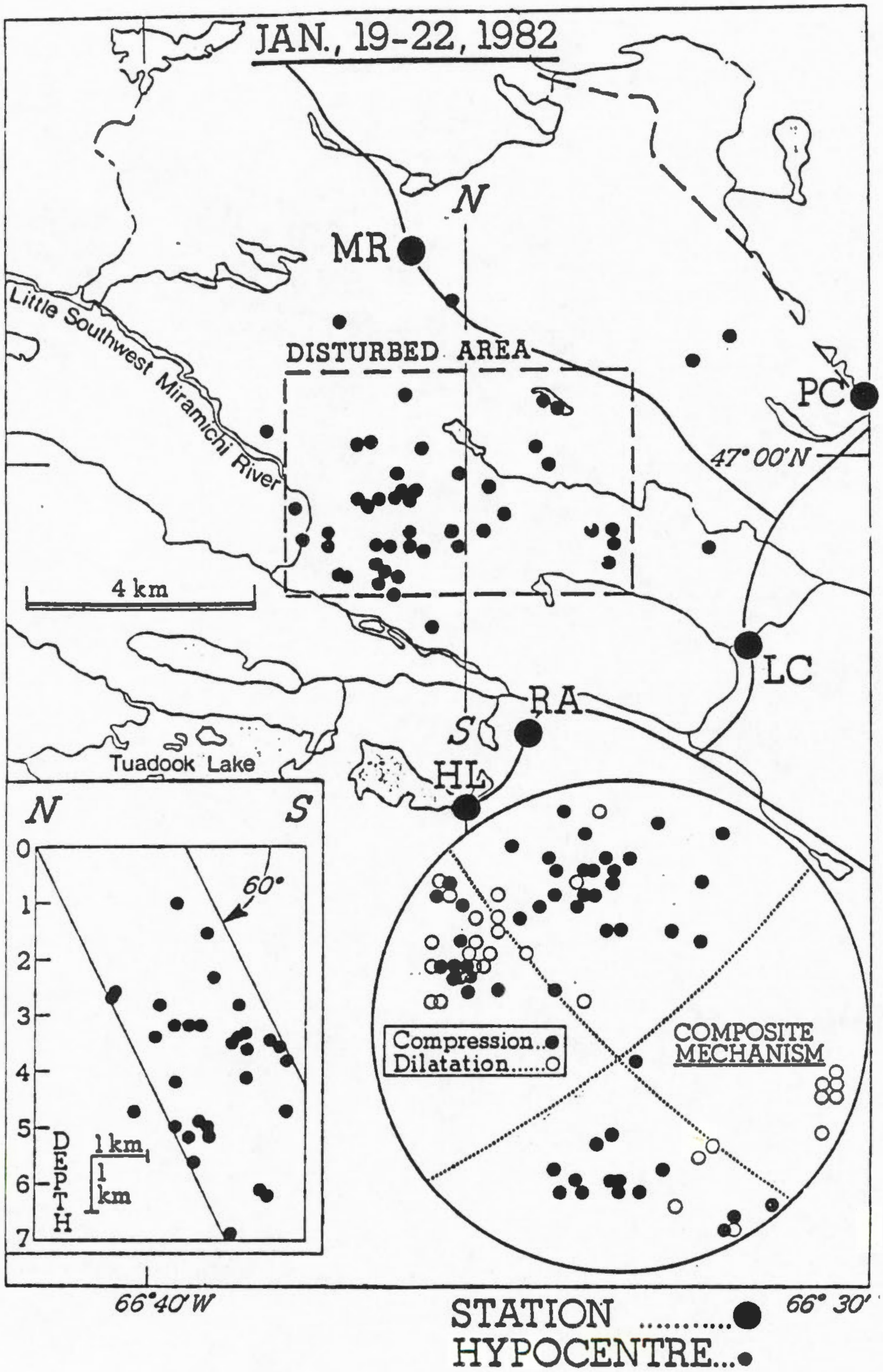

DISTANT STATIONS
JAN., 1982
FEB.
10
15
20
25
30
01
05
ML S
RR S
SR S
HS S
MB S
A
FE S
NC S
UP S
KLN S
A
BL A
MC S
LL S
PR S
BB S
NI S
CL S
GV S
DT S
B2 S
B3 S
Legend
SEISMOGRAPHS
ANALOGUE (MEQ)
DIGITAL (DR-100)
ACCELEROGRAPHS
ANALOGUE (SMA)
DIGITAL (FBA)
Continuous
Triggered / Partial

Figure 3.3



JAN., 19-22, 1982
N
MR
Little Southwest Miramichi River
DISTURBED AREA
PC
47° 00'N
4 km
LC
RA
S
Tuadook Lake
HL
N
S
0
1
2
3
4
5
6
7
60°
DEPTH
1 km
1 km
Compression
Dilatation
COMPOSITE MECHANISM
66°40'W
STATION
66° 30'
HYPOCENTRE

Figure 3.4

4. REGIONAL AND FIELD SEISMIC STUDIES OF THE NEW BRUNSWICK EARTHQUAKES OF JANUARY 1982

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The New Brunswick earthquakes of January 1982 have generated a vast quantity and variety of data, which should have a significant impact on the estimation of the earthquake hazard in this area.

The effort in data acquisition by the Massachusetts Institute of Technology (MIT) has been two-fold. First, our permanent network, at a mean epicentral distance of about 600 km, has provided digital recordings of the main shock and most of the aftershocks of magnitude greater than 3. Secondly, our group operated a ten-element temporary seismograph network in the epicentral area for nearly three weeks.

An example of the regional short-period data is shown in Figure 4.1. Although a portion of the signal is clipped, the early phases and coda waves provide important information about the source and the path. This seismogram has been filtered at four frequency bands and the attenuation of the coda waves has been determined. Q values range from 1250 at 0.7 Hz to 3000 at 6.0 Hz.

The MIT field crew arrived in New Brunswick on the evening of January 10 with three portable instruments. The base of operations was in Plaster Rock. These instruments, installed on January 11, were in operation during the magnitude 5.5 aftershock that evening (21:41 UT). On January 13, seven additional instruments were brought into the area and installed during the next two days. The final network configuration is shown in Figure 4.2, which also includes the stations operated by the Canadian team (EPB) and two other American Groups (USGS, SUNY). (See also Figures 3.2 and 3.3 of Wetmiller.) Station coordinates and operators are listed in Table 4.1. The station distribution was controlled in part by the limited road access and the extreme weather conditions. With limited interruptions, the temporary network operated until January 30. On January 19, three stations (CL-County Line, PR-Plaster Rock and GV-Gordonsville) were dismantled and brought to New Hampshire to monitor the aftershocks of the Gaza earthquake (January 19, 00:14 UT).

Station HL (Holmes Lake), closest to the epicenter, provided a wealth of data. During the two weeks following the main shock, aftershocks were recorded at HL at a rate of about 100 per day. The detection threshold is estimated to be magnitude -2. These aftershocks exhibit a wide range of S-P times (0.5 to 2.0 s) and S/P amplitude ratios (10.0 to 1.0). In addition, some events exhibit clear 0.5 to 1.0 s period fundamental-mode Rayleigh waves, which can be seen for events as small as magnitude -1 and as large as magnitude 2.5.

As of this writing (April 1982), we have determined epicentral locations for sixty aftershocks occurring between January 12 and 27 (see Figure 4.3).

The aftershocks are concentrated in an area of approximately 15 by 20 km, and range in focal depth from the surface to 15 km. (See also Figure 3.4 of Wetmiller.)

The participants in the MIT January field study included the author, Roger Buck, Paul Huang, Carl Codkin, George Keough, Scott Phillips, Karl Coyner, Stephen Bratt, and Jean Baranowski.

We are presently undertaking a comprehensive study of the aftershock data recorded by the temporary network. This includes determination of hypocentral locations, correlation of coda-wave excitation with earthquake magnitude, and compilation of frequency-magnitude statistics. During the summer months, we plan to return to the epicentral area to search for evidence of fault breakage or en-echelon faulting.

TABLE 4.1

Temporary Field Stations

Code	Area	Latitude (°N)	Longitude (°W)	Elev. (m)	Operator
NC	Nash Creek	47.920	66.048	15	EPB
FE	Flying Eddy	47.651	66.596	366	EPB
UP	Upsalquitch	47.807	66.879	45	EPB
MB	McGraw Brook	46.826	66.111	58	MIT and SUNY
PR	Plaster Rock	46.916	67.397	160	MIT
MC	Mt. Carleton	47.433	66.923	259	MIT
NI	Nictau	47.228	67.153	183	MIT
LL	Long Lake	47.057	66.933	380	MIT
HL	Holmes Lake	46.945	66.595	352	MIT, USGS and SUNY
LC	Loggie Camp	46.970	66.530	323	EPB and USGS
PC	Prince Camp	47.008	66.501	312	EPB and USGS
MR	Mitchell Road	47.033	66.607	457	EPB and USGS
RA	Renous Aerodrome	46.955	66.582	367	EPB
FL	First Lake	46.870	66.627	515	EPB
ML	Moose Lake	46.864	66.781	512	EPB
RR	Renous River	46.771	66.372	289	EPB
SR	Sevogle River	47.138	66.110	302	EPB
KLN	McKendrick Lake	46.843	66.372	411	EPB
CL	County Line	46.863	66.797	518	MIT
BB	Bubar Brook	47.255	66.831	366	MIT
DT	Doaktown	46.546	66.115	80	MIT
GV	Gordonsville	46.475	67.490	215	MIT

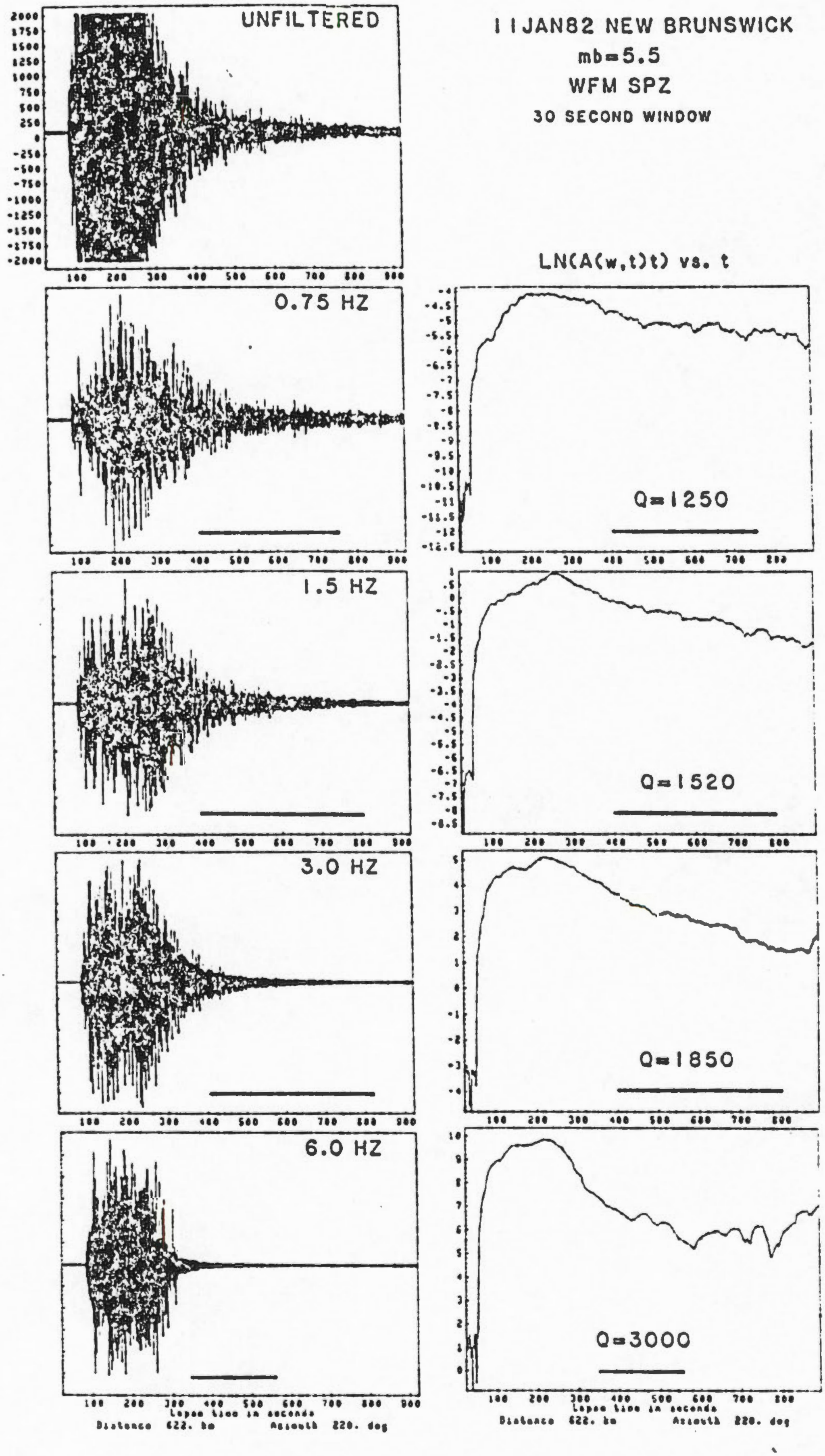
UNFILTERED
I I JAN82 NEW BRUNSWICK
mb=5.5
WFM SPZ
30 SECOND WINDOW
LN(A(w,t)t) vs. t
0.75 HZ
Q=1250
1.5 HZ
Q=1520
3.0 HZ
Q=1850
6.0 HZ
Q=3000
Lapse time in seconds
Distance 622. km
Azimuth 220. deg

Figure 4.1

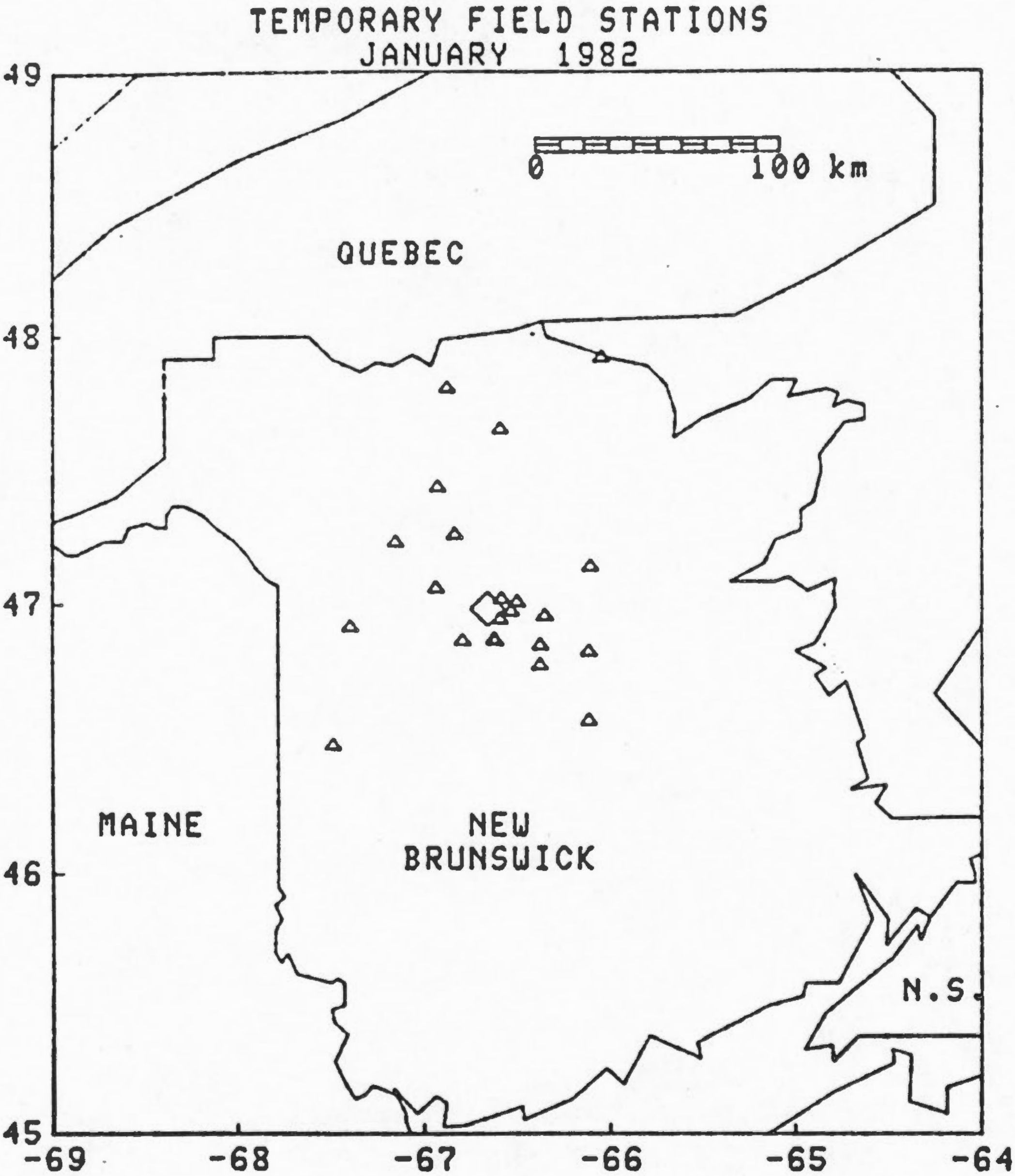
TEMPORARY FIELD STATIONS
JANUARY 1982
0
100 km
QUEBEC
MAINE
NEW
BRUNSWICK
N.S.
49
48
47
46
45
-69
-68
-67
-66
-65
-64

Figure 4.2

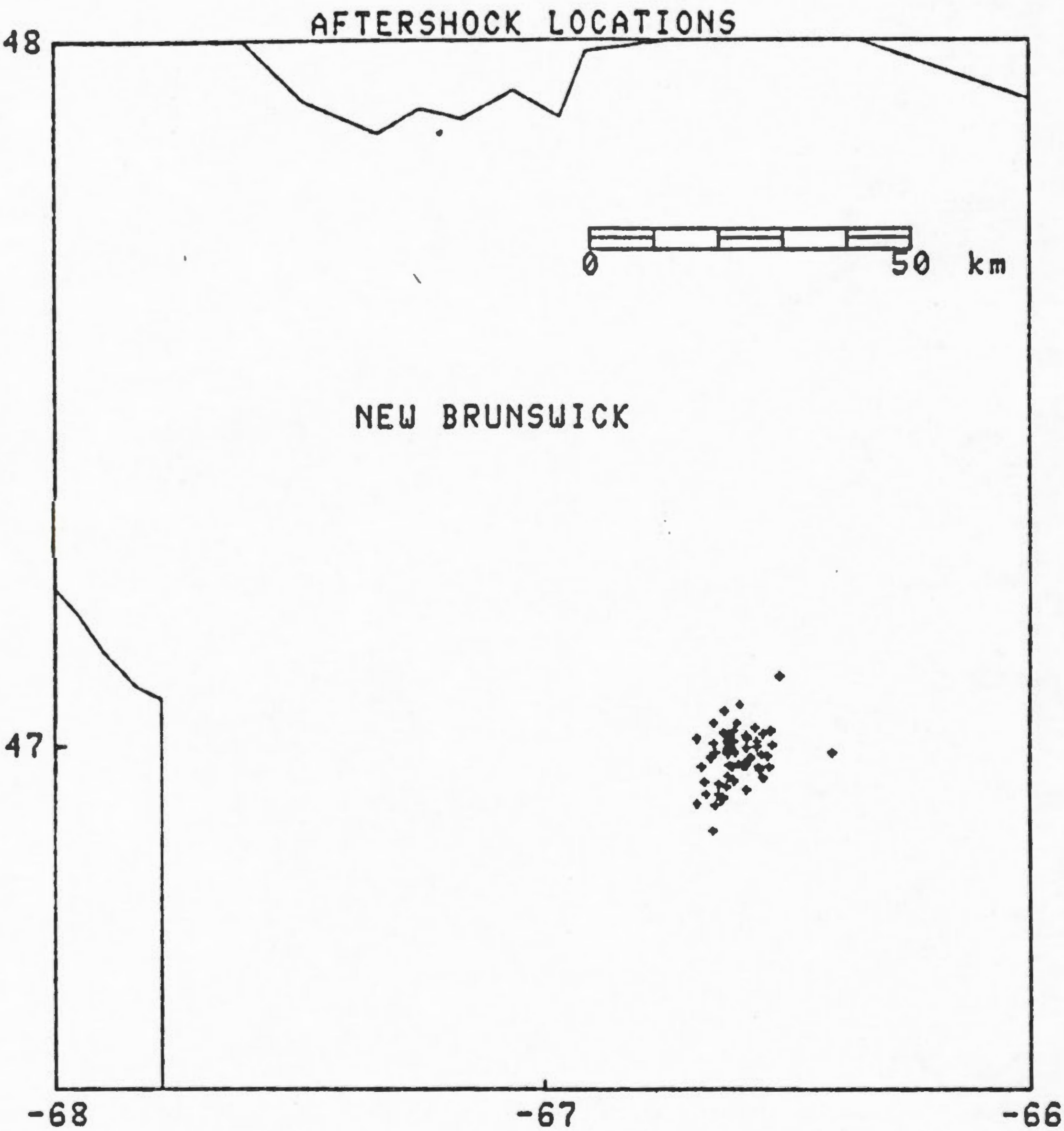

Figure 4.3

5. LOCAL MULTI-STATION DIGITAL RECORDINGS OF AFTERSHOCKS OF THE JANUARY 9, 1982 NEW BRUNSWICK EARTHQUAKE

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Energy, Mines and Resources
Ottawa, Canada K1A OY3

Responding to a request for instruments from the Earth Physics Branch of the Canadian Department of Energy, Mines and Resources, Ottawa, the U.S. Geological Survey, Menlo Park, California, dispatched nine Sprengnether DR-100* three-component digital portable seismographs and two staff members, Eugene Sembera and Edward Cranswick, to New Brunswick on January 13, 1982. The instruments are self-triggering, have 0.7 s of pre-event memory, and generally produce records of 6 to 10 s duration. The instruments, described by Fletcher (1982), had a sampling rate of 200.32 samples per second per component, and all but one of the instruments were equipped with antialiasing low-pass filters with 50-Hz corner frequencies. One instrument, installed at station C9V, had an antialiasing corner frequency of 70 Hz; on January 16-17 it was operated in a mode of sampling only the vertical component at 600.96 samples per second. Of the nine instruments sent to New Brunswick, six were successfully deployed in the field at four sites.

Figure 5.1 shows the locations of the four stations established in this aftershock investigation. Stations C7T, C8T, C9V and CBA correspond to sites LC, PC, HL and MR in Table 4.1 of Pulli and Figure 3.2 of Wetmiller. Station C7T (installed January 15) and station C8T (January 16) were each equipped with two digital recorders; one recorder was connected to a velocity transducer and the other to an acceleration transducer (force-balance accelerometer-FBA). Station C9V (also installed January 16) had only one velocity transducer, and station CBA (January 19) had only one acceleration transducer. No transducers were sited directly on bedrock outcrop, all were sited on or several centimeters below the frozen ground surface. According to bedrock-geologic maps and observation in the field, the transducers were separated from bedrock by thicknesses of Quaternary alluvium estimated to range from less than 1 to as much as 10 m. Velocity transducers were also installed at Flying Eddy and McGraw Brook (FE and MB, Table 4.1 of Pulli and Figure 3.3 of Wetmiller), but no useful data were obtained.

Because of the extreme winter weather conditions and associated instrument problems, an overall digital-recorder downtime of about 20 to 40 percent prevailed during the 7-day period of the aftershock study. However, for the duration of that period, from January 15 to 22, at least one instrument was running at all times. Therefore, all seismic activity during that time of magnitude greater than 2 has probably been recorded.

* Any use of trade names or trademarks in this report is for descriptive purposes only and does not constitute an endorsement by the U.S. Geological Survey.

A total of about 25 events were recorded at two or more of the four USGS stations. Of the 13 events recorded by three or more stations, 12 were located with the program HINV (a modified version of HYPOINVERSE; Klein, 1978) by means of a velocity model that consisted of a homogeneous half-space with a P-wave velocity of 6.2 km/s. Table 5.1 lists these 12 preliminary locations, which also are plotted in Figure 5.1. Hypocentral accuracy is not better than 0.5 km. One event that was recorded by all six instruments is not yet fully processed because of recording problems caused by instrument malfunction.

The largest event recorded, event D ($m_b(L_g)$ 3.5 at 13:33:56 G.M.T. January 17, was recorded by all five instruments in operation at that time. A foreshock of unknown magnitude, referred to here as event C, which occurred 57 s before event D, was recorded by the same instruments. Figure 5.2 compares the recordings of these two events; the traces and epicenters labeled "1" are those of the larger event (D), and those labeled "2" are those of the foreshock (C).

Figure 5.2a plots the vertical components of velocity for these two events. We noted that the traces at station C9V, at a rate of 600.96 samples per second, are visibly enriched with high frequencies in contrast to the traces at stations C7V and C8V. (Station C9V does not appear in Figures 5.2b through 5.2d because it recorded only vertical velocity).

The transverse (perpendicular to the source-receiver direction) horizontal component of velocity at station C7V shows a peak value of about 1.35 cm/s at the S-wave arrival of Event 1 ($m_b(L_g)$ 3.5) in Figure 5.2b. The transverse component of velocity for Event 1 is seen to be both higher in frequency and greater in amplitude at station C7V than at station C8V, possibly owing to site effects caused by differing thicknesses of alluvium.

For event 1 at station C7V a peak vertical acceleration of -80 cm/s^2 was recorded for the P-wave arrival (Figure 5.2c) and a peak transverse horizontal acceleration of 80 cm/s^2 for the S-wave arrival (Figure 5.2d).

Following the model described by Brune (1970), and averaging the observations of records at the two stations as described by Archuleta et al. (1982), we calculated source parameters for these two events as shown in Table 5.2.

This data set greatly increased the total number of digital recordings of eastern North American earthquakes and includes, to the best of our knowledge, the largest eastern North American event ever recorded by three-component digital instruments at short epicentral distances. In addition, the data set contains direct recordings of both acceleration and velocity for the same events at the same sites.

Please direct all inquiries about these digital data to: Edward Cranswick, USGS at the address above.

REFERENCES

Archuleta, R.J., Cranswick, E., Mueller, C., and Spudich, P., 1982. Source parameters of the 1980 Mammoth Lakes, California, earthquake sequence, Journal of Geophysical Research, 87, 4595-4607.

Brune J.N., 1970. Tectonic stress and the spectra of seismic shear waves from earthquakes, Journal of Geophysical Research, 75, 4997-5009.

Fletcher, J.B., 1982. A comparison between the tectonic stress measured in situ and stress parameters from seismic waves at Monticello, South Carolina: A site of induced seismicity, Journal of Geophysical Research (in press).

Klein, F.W., 1978. Hypocenter location program HYPOINVERSE part I: User's guide to versions 1, 2, 3 and 4, U.S. Geological Survey Open-File Report 78-694.

(See also the SSA abstract by Sembera et al. in Chapter 23.)

(The authors are also preparing a USGS Open-File Report on the New Brunswick aftershocks recorded by the six 3-component digital seismographs.)

FIGURE CAPTIONS

Figure 5.1

Computer-drawn sketch map of study area showing the four digital stations (solid diamonds) occupied in this study. Station instrumentation is described in the text, paragraph 2. Letters A to L denote locations of the 12 aftershocks listed in Table 5.1. Event D (largest symbol) and adjacent event C denote, respectively, the $m_b(L_g)$ 3.5 event and its foreshock discussed in the text and plotted in Figures 5.2a to 5.2d. Lines on map outline major bodies of water (streams and lakes) in the study area. Latitude and longitude boundaries are printed in the map corners.

Figure 5.2 (a, b, c and d)

Event time-history maps, each showing a 2.5 s sample of a single component of velocity or acceleration for the same two earthquakes. The component of motion is printed above each figure. Locations of the two events are marked by numbered stars. Corresponding recorded traces are numbered and plotted to the right of and just above and below the respective stations (solid diamonds). Events 1 and 2 are events D and C, respectively, of Figure 5.1 and Table 5.1. The amplitude and time scales used for the velocity and acceleration time histories are shown in the upper left of each figure. The label above the time axis indicates the up-trace orientation of each recorded component. Latitude and longitude boundaries are printed in the map corners.

Figure 5.2a - vertical velocity

Figure 5.2b - transverse component of horizontal velocity

Figure 5.2c - vertical acceleration

Figure 5.2d - transverse component of horizontal acceleration

TABLE 5.1

Preliminary Locations of Aftershocks

Event	Day	Time (G.M.T.)	Lat (N)	Long (W)	Depth (km)	Peak Acceleration (g)
A	17	$07^h39^m34.4^s$	46°59.6'	66°36.3'	6	0.006
B	17	12 24 47.7	46°59.2'	66°37.6'	7	0.012
C	17	13 32 59.9	46°59.6'	66°38.0'	3	0.035
D	17	13 33 56.2	46°59.3'	66°37.9'	4	0.083
E	17	14 08 46.7	46°58.7'	66°36.6'	5	0.025
F	18	11 44 26.8	46°59.2'	66°36.9'	5	0.005
G	18	19 34 49.2	47°00.1'	66°36.2'	6	0.028
H	20	10 00 10.0	47°00.2'	66°36.9'	7	0.049
I	20	23 40 16.5	46°58.9'	66°36.6'	6	0.008
J	20	23 40 41.5	46°58.4'	66°36.1'	6	0.009
K	20	23 40 43.5	46°59.0'	66°36.8'	5	0.008
L	21	00 39 55.7	46°59.0'	66°36.7'	5	0.023

TABLE 5.2

Preliminary Source Parameters

Event	Moment (10^{18} dyne-cm)	Source Radius (meters)	Stress Drop (bars)
C (2, Fig. 5.2)	0.3	75	31
D (1, Fig. 5.2)	400	110	130

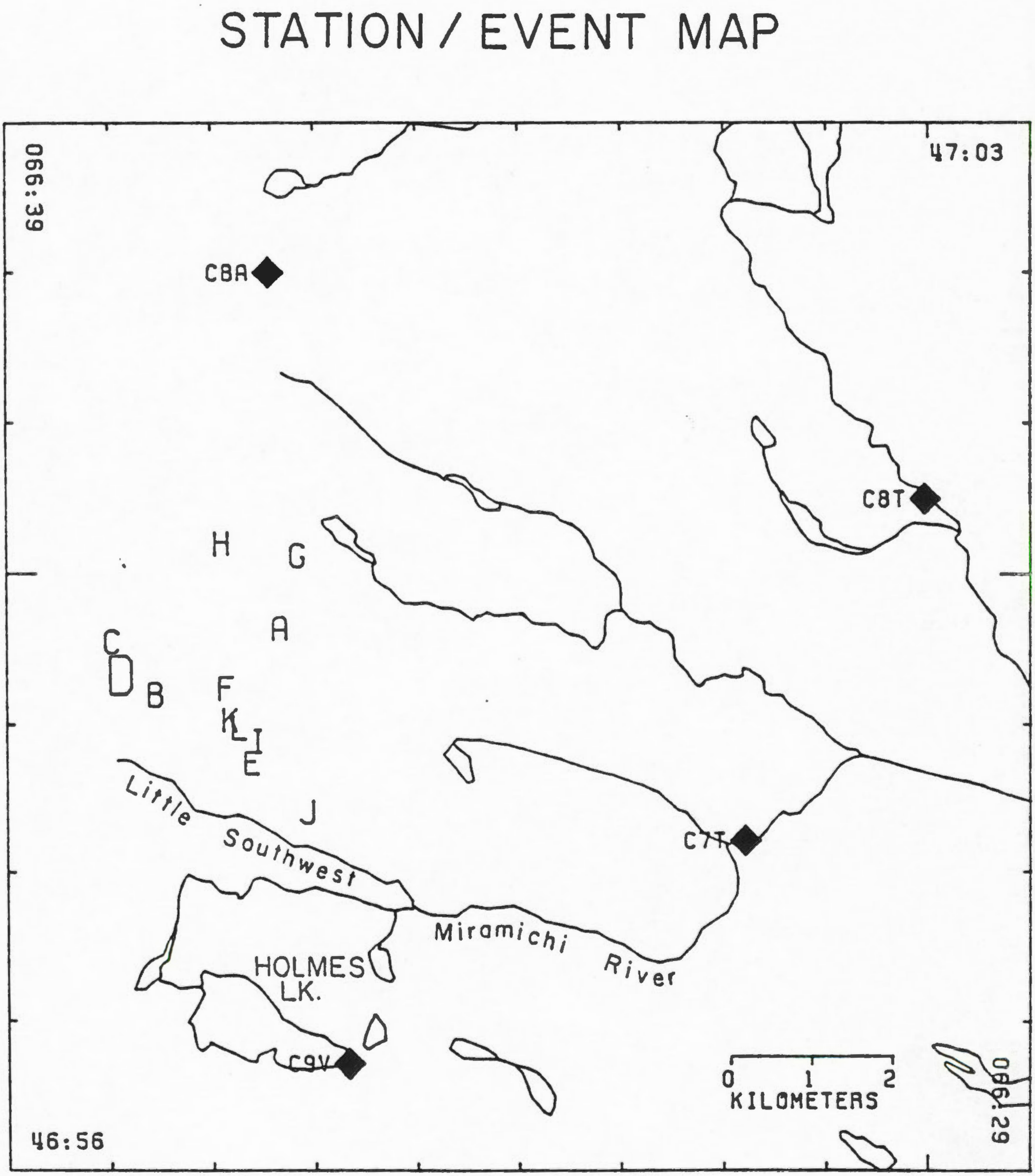
STATION / EVENT MAP
066:39
47:03
CBA
C8T
C7T
C9V
H
G
A
C
D
B
F
K
L
I
E
J
Little Southwest
Miramichi River
HOLMES
LK.
0 1 2
KILOMETERS
46:56
066:29

Figure 5.1

VERTICAL VELOCITY

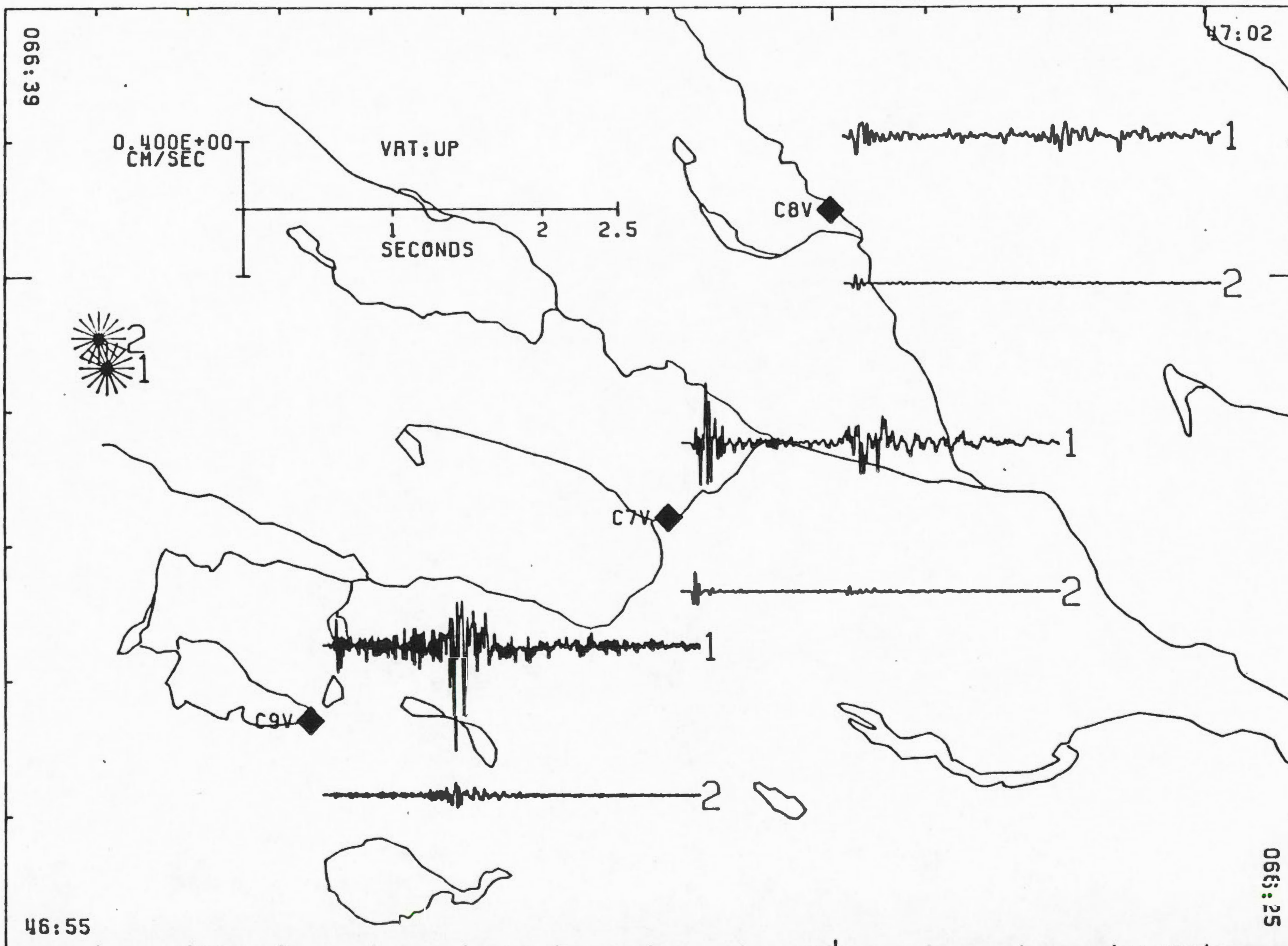

Figure 5.2a

TRANSVERSE VELOCITY

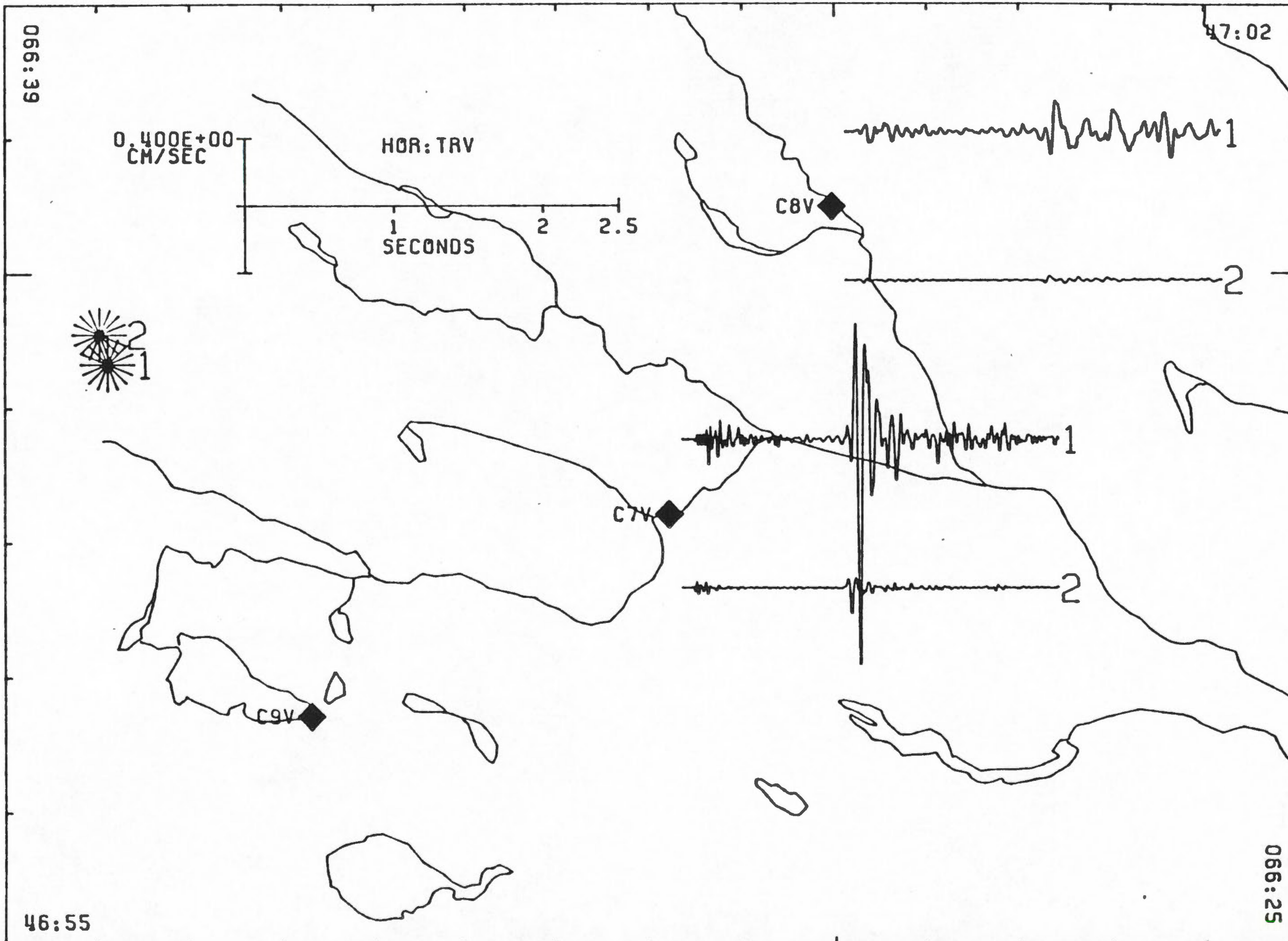

Figure 5.2b

VERTICAL ACCELERATION

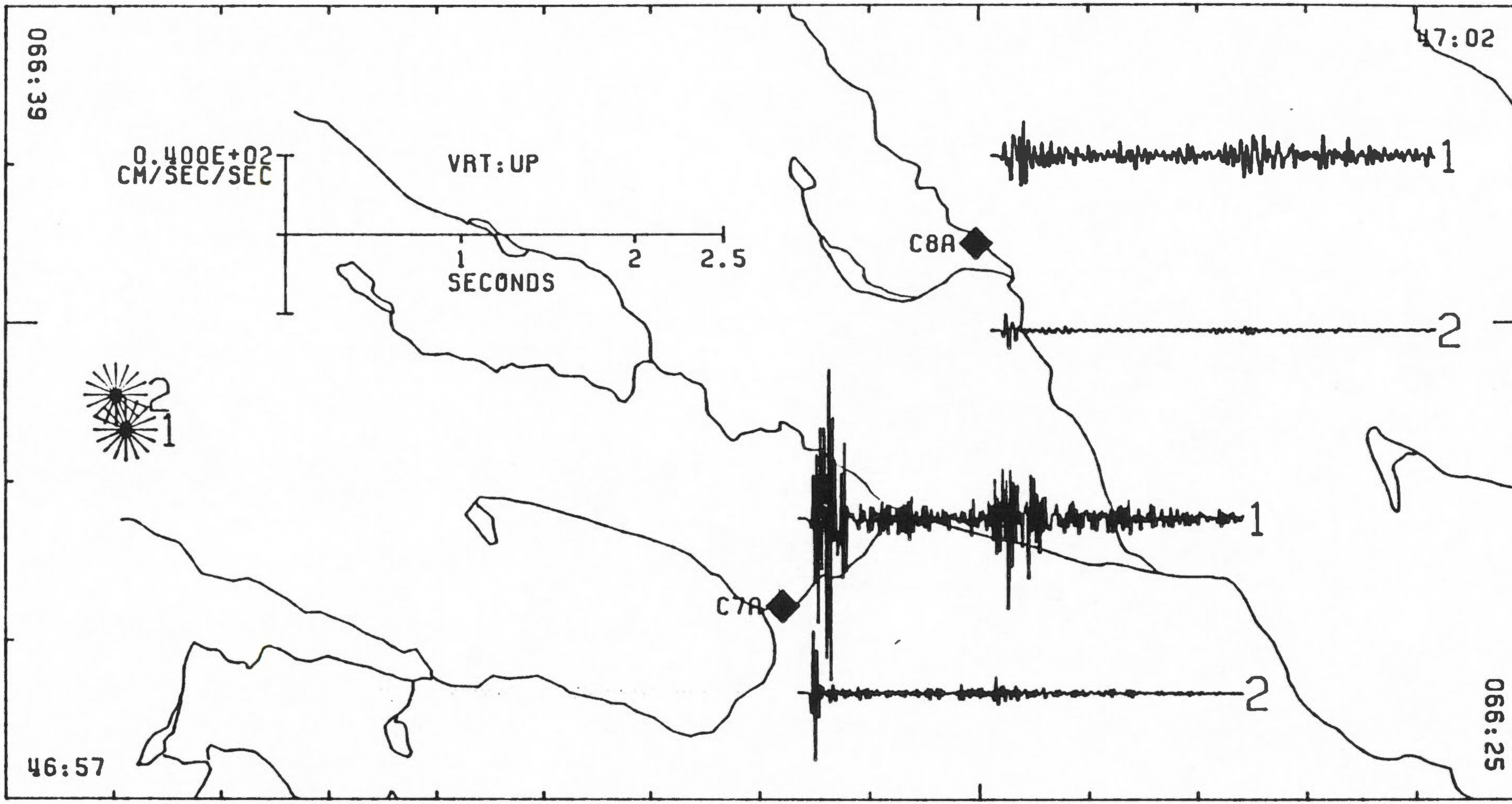

Figure 5.2c

TRANSVERSE ACCELERATION

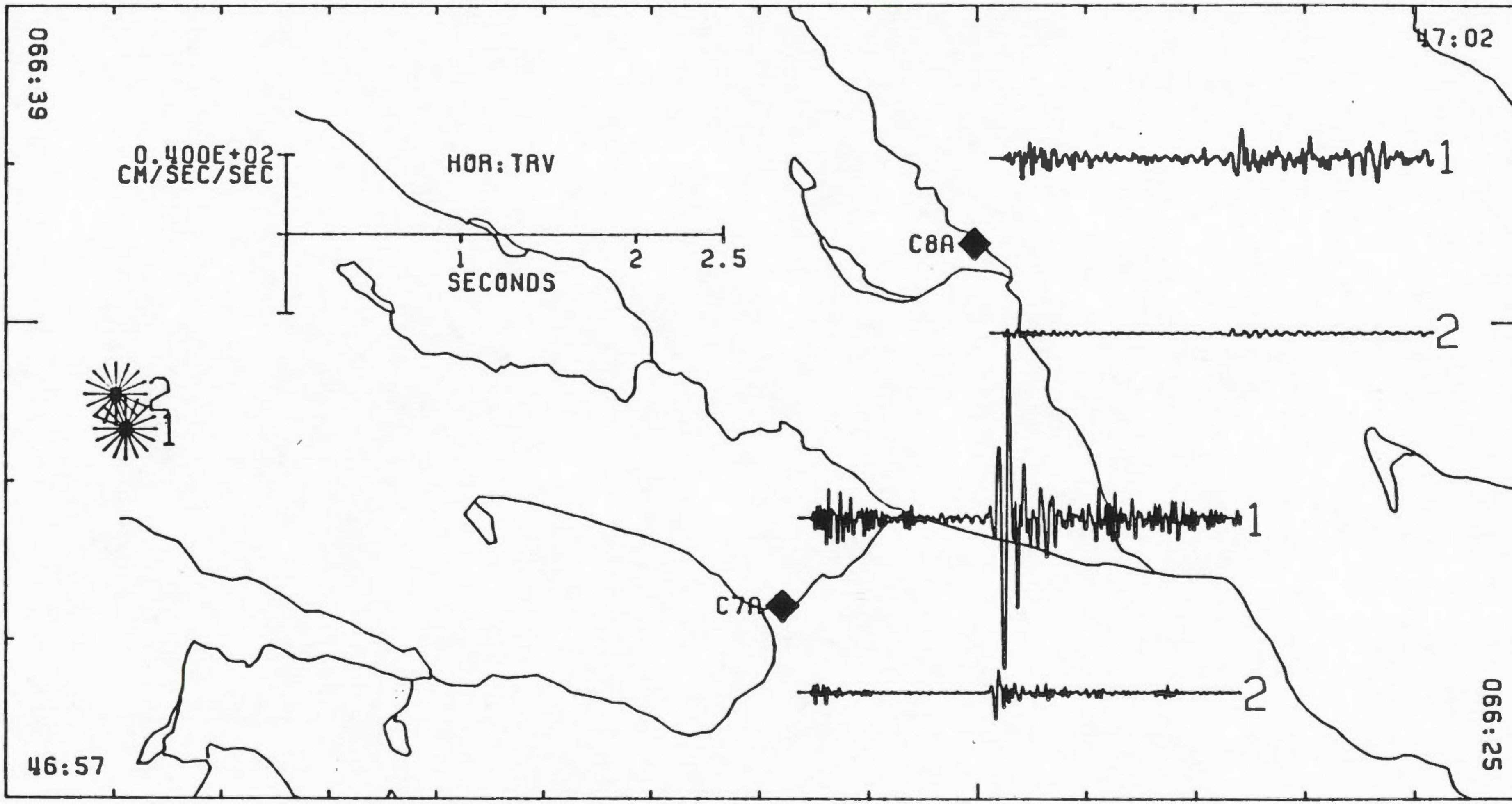

Figure 5.2d

6. ACCELEROGRAPH AFTERSHOCK MONITORING IN NEW BRUNSWICK

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After discussions with colleagues at MIT and LDGO during the week after the January 9, 1982 New Brunswick earthquake, it was decided that the incorporation of accelerographs into the aftershock monitoring was desirable. We have been using 3-component force-balance accelerometers (FBA) in conjunction with digital (12 bits) gain-ranged event recorders (all made by Terra Technology). Five recorders are deployed on sites in northern New York (three near Massena) and western New York (two near Attica). In 1981 a number of events were recorded on one or more of these recorders.

The second day after the decision was made, we drove to the northern New York sites, picked up the instruments and then drove on to Montréal where the flight was delayed one day due to severe weather in New Brunswick. Petruzzelli and three accelerographs arrived in Newcastle on January 16. One unit was deployed from January 17 through January 22 at McGraw Brook ranger station (NB-6), located approximately 24 km from the epicentres. The second unit operated from January 19 to 22 at Holmes Lake (NB-9), less than 2 km from the epicentres. The third unit was set up in a van on Mitchell Road (NB-11) on January 21. (See Figure 3.2 of Wetmiller and Table 4.1 of Pulli for station locations and coordinates. NB-6, NB-9 and NB-11 correspond to sites MB, HL and MR, respectively.)

The table below summarizes the number of records obtained at each station.

Station	Dates	Number of Events	Remarks
NB- 6	17-22	8	0.0002g a 0.001g
NB- 9	19-22	13	0.005g a 0.02g
NB- 11	21-22	0	all false triggers due to high wind

All stations operated with maximum gain, i.e., the least significant bit corresponds to 2.5 μg with 1 g full scale when gain ranged to the lowest gain. Analyses of these records are in progress. We intend to study the frequency characteristics of these events and possibly also attenuation using records from the two stations.

This field operation provided a good opportunity for testing the digital event recorders in a severe environment. It was determined that some heating is needed. While an external kerosene burner in a tent at close proximity was adequate, perhaps an internal electric strip heater with down jacket would make the operation easier.

The travel funds for the field work were provided by Lamont-Doherty Geological Observatory (LDGO) through Alan Kafka. Logistics in the field were provided by the Earth Physics Branch, EMR, through Robert J. Wetmiller. Without this help we could not have mounted this relatively successful venture.

7. AFTERSHOCK MONITORING

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Three portable three-component triggered digital stations were operated for varying periods by the Lamont-Doherty Geological Observatory (LDGO) at four sites in the epicentral region between January 13 and January 30 (Bubar Brook, Holmes Lake, Nictau and Plaster Rock - see Table 4.1 of Pulli). Unfortunately, few useful data were recorded.

Between January 15 and January 18, three earthquakes triggered a strong motion accelerometer (Kinemetrics SMA-1) (set at a trigger level of 0.04g) located at Holmes Lake about 8 km from the hypocenters. After January 18, the trigger level of this instrument was raised to 0.10g; no earthquakes were recorded between January 19 and February 6. On February 7 this instrument was installed at Bear Lakes (Site 7 in Table 8.1 of Munro and Pomeroy) as part of a cooperative network being run in the epicentral area. The trigger level was lowered to 0.01g. The instrument was triggered by aftershocks on March 31, April 2 and April 11. On April 28 the instrument was removed and returned to LDGO. A new SMA-1 belonging to the Earth Physics Branch was installed on April 28 at the same site.

8. THE NEW BRUNSWICK STRONG-MOTION ARRAY

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Following the earthquakes of January 9 and 11 in New Brunswick, the Earth Physics Branch (EPB) of the Canadian Department of Energy, Mines and Resources in cooperation with the U.S. Nuclear Regulatory Commission (USNRC) established a strong-motion array in the epicentral area. The on-going aftershock sequence provides a unique opportunity to obtain strong-motion records from earthquakes covering a wide spectrum of magnitudes, many of which may have similar source mechanisms.

Seven strong-motion instruments (accelerographs) were installed in early February using snowmobiles to reach some of the sites since logging roads are not normally kept open in winter. In early June five of these were moved to new sites, an eighth site was instrumented, and all instruments, except the first, were placed in vaults on bedrock. Site locations are included in Table 8.1 and plotted in Figure 8.1.

Five of the units were loaned from the USNRC, and one each from the United States Geological Survey (USGS) at Menlo Park and the Lamont-Doherty Geological Observatory (LDGO). At the end of April the latter unit plus one USNRC unit were replaced by EPB units. At the beginning of June the USGS unit was replaced by an EPB unit and an additional EPB instrument deployed. Current plans are to remove the four remaining USNRC units before winter, but to retain the four EPB units until at least the spring of 1983. A fifth EPB unit remains at the EPB in Ottawa ready for rapid deployment elsewhere in eastern Canada should the need arise.

The instrumentation at each site consists of a Kinemetrics SMA-1 three-component accelerograph unit with a range of 1 g and with a trigger sensitivity initially set at 0.01 g (1 percent of gravity), but lowered in early June to about 0.006 g. Power is obtained from automobile batteries. All EPB units record absolute time.

Since installation of the array, seven earthquakes with magnitudes ranging from $m_b(L_g)$ 3.4 to 4.8 have triggered the array, as summarized in Table 8.2. Records are being analyzed independently by D.H. Weichert (Pacific Geoscience Centre, EMR, Sidney, British Columbia V8L 3Z5) and by one of the authors (Pomeroy) and a joint report is planned for the autumn.

Table 8.1

New Brunswick Strong-Motion Array

Site	Name	Location (Lat N, Long W)	Installation (1982)	Site Condition
1	Holmes Lake	46° 56.73' 66° 35.67'	03 Feb. 20:00	massive concrete fireplace hearth
2	Mitchell Road	47° 02.05' 66° 36.62'	04 Feb. 16:30	granite outcrop
			04 June 18:20	relocated westward new longitude 66° 36.70'
3	Loggie Lodge	46° 58.15' 66° 31.74'	04 Feb. 20:45	major granite boulder
			05 June 16:33	site closed
4	Indian Brook	46° 58.73' 66° 34.85'	05 Feb. 20:00	granite boulder on gravel
			06 June 15:00	site closed
5	Tuadook River	46° 57.83' 66° 37.00'	06 Feb. 21:00	concrete pad on gravel
			05 June 14:50	site closed
6	McKendrick Lake	46° 50.64' 66° 22.30'	07 Feb. 15:30	granite outcrop
7	Bear Lakes	46° 55.71' 66° 29.08'	07 Feb. 18:30	concrete pad on gravel
			07 June 13:38	site closed
8	Hwy 108	46° 49.35' 66° 37.10'	08 June 17:27	bedrock
9	Hickey Lakes	47° 00.35' 66° 32.80'	05 June 18:10	bedrock
10	Bear Lakes II	46° 56.45' 66° 32.29'	07 June 15:14	bedrock
11	Loggie Lodge II	46° 58.35' 66° 31.81'	06 June 18:30	bedrock
12	Indian Brook II	46° 59.6' 66° 35.8'	06 June 15:47	bedrock

TABLE 8.2

New Brunswick Strong-Motion Records, February to July 1982

Date (U.T.) 1982		Preliminary Magnitude $m_b(Lg)$	Accelerographs Triggered
Near Holmes Lake			
31 March	21:02	4.8	Sites 1, 2, 3, 4 and 7
02 April	13:50	4.3	Sites 2 and 7
11 April	18:00	4.1	Site 7
28 April	06:36	3.4	Site 1
06 May	16:28	4.0	Sites 1, 2, and 3
28 July	05:35	3.7	Site 12
Near Trousers Lake			
16 June	11:43	4.6	Sites 2 and 12

MIRAMICHI, NEW BRUNSWICK

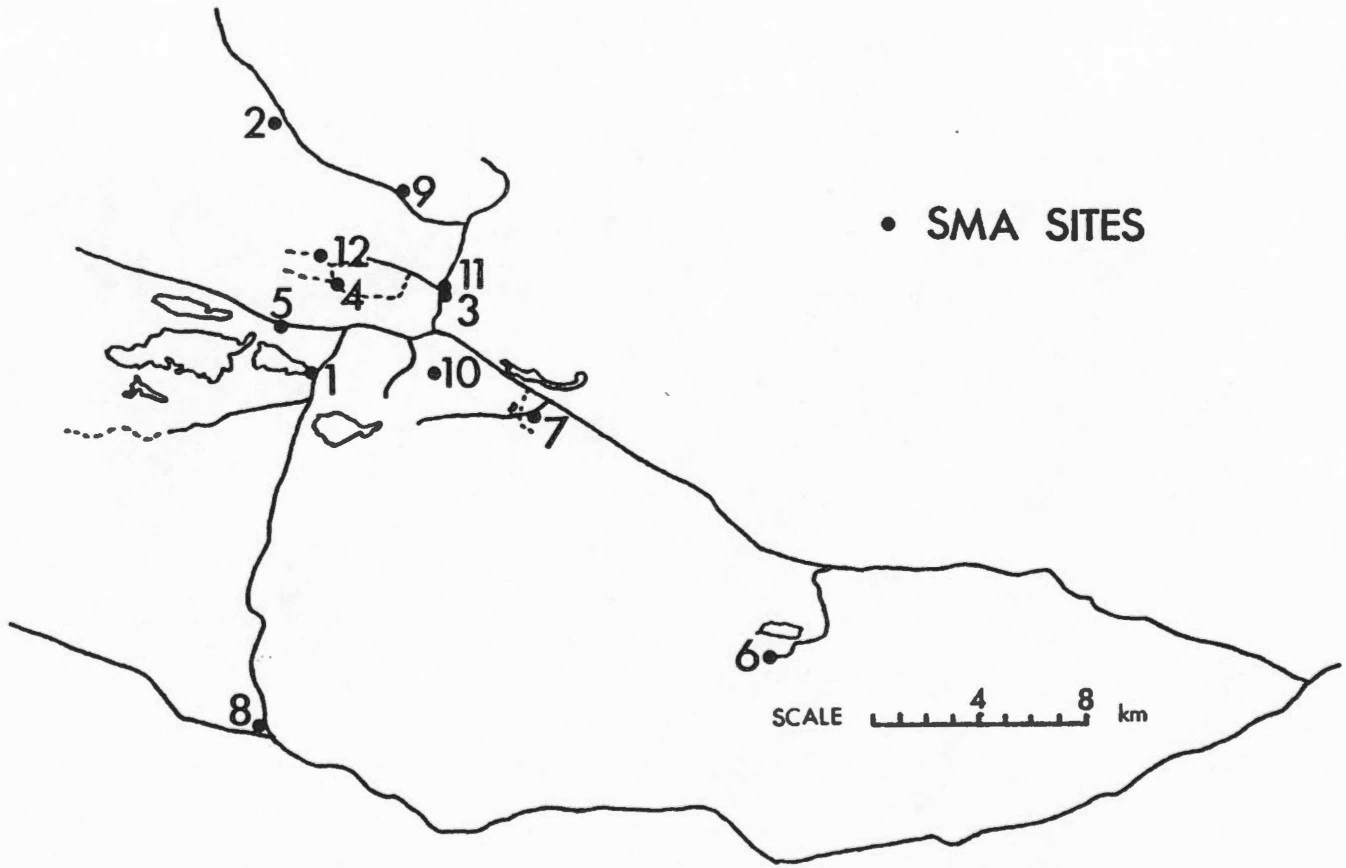

Figure 8.1

9. AFTERSHOCK SURVEY FOLLOWING THE 31 MARCH 1982 MIRAMICHI EARTHQUAKE

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Following the magnitude $m_b(Lg)$ 4.8 aftershock at 21:02 on 31 March, the field sites at Holmes Lake, Loggie Camp and Mitchell Road (see Table 4.1 of Pulli) were reoccupied by smoked-paper seismographs for a five-day period. During the final two days a site just to the north of Lyles Mountain was also occupied (46.990°N, 66.610°W, elevation 405 m). As many as one hundred small aftershocks were recorded on a single day's seismogram. More than 60 events have been located. The majority lie in a cluster of diameter 4 km in the northeast corner of the epicentral zone (4 km N-S, 6 km E-W) defined by the January aftershocks. All focal depths were shallower than 6 km. Further analysis of the aftershock sequence is continuing.

10. AFTERSHOCK SURVEY FOLLOWING THE 16 JUNE 1982, TROUSERS LAKE, NEW BRUNSWICK, EARTHQUAKE

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A minor earthquake, magnitude $m_b(Lg)$ 4.6, occurred on 16 June at 11:43 UT in the Miramichi region of north-central New Brunswick near Trousers Lake, about 30 km due west of the zone near Holmes Lake where aftershocks have been occurring since early January 1982. An aftershock survey was conducted near Trousers Lake from 17 to 23 June in order to investigate whether the Trousers Lake and Holmes Lake area earthquakes might be related.

Seven sites were occupied with five Sprengnether MEQ-800 smoked-paper seismographs. Coordinates are given in Table 10.1. The Long Lake site had been occupied by MIT (Massachusetts Institute of Technology) during the January survey. The other locations were new sites. The first station (OL) was installed on 17 June at 22:11 UT, 35 hours after the main shock. Sites GL and LL were moved to ETL and FOL on 20 June. Recording continued until 23 June at 16^h. The epicentral area consists of heavily-wooded rolling hills and small lakes. Although site selection was limited to areas adjacent to logging roads and trails, the field network enclosed the active area with all stations but GL located at epicentral distances of 3 to 6 km. The latter station, despite its greater distance (10 km), was one of the most sensitive.

Prior to the field survey, aftershocks occurred on 16 June at 15:41, $m_b(L_g)$ 3.0 and at 23:41, $m_b(L_g)$ 1.6. During the field period, 14 aftershocks from Trousers Lake were recorded, all of magnitude less than M_L 1, while almost 40 aftershocks from the Holmes Lake area, 30 km to the east, were recorded clearly, several with magnitude between $m_b(L_g)$ 2 and 3. No earthquakes were located between Trousers Lake and Holmes Lake, and no earthquakes were identified on individual field seismograms that might have originated in this area.

The Trousers Lake aftershocks were located at 47.01°N, 66.97°W with focal depth of 8 km and an uncertainty of about 1/2 km in the epicentre and about 1 km in depth. Slight variations in calculated coordinates were not considered significant. The aftershocks occurred essentially at a point source, which is not surprising considering the small magnitudes of the aftershocks and the modest size of the main shock. This result is consistent with aftershocks of minor earthquakes in other parts of eastern Canada.

TABLE 10.1

Temporary Seismograph Sites near Trousers Lake

Code	Name	Latitude (°N)	Longitude (°W)	Elevation (metres)
ETL	East Trousers Lake	46.992	66.927	400
FOL	Foot Lake	47.018	66.931	400
GL	Gulquac Lake	46.922	66.917	430
LL	Long Lake	47.057	66.933	380
OL	Ogilvie Lake	46.967	66.986	450
STL	South Trousers Lake	46.980	66.932	410
TL	Trousers Lake	47.018	67.003	410

11. REPORT ON AN EXAMINATION OF THE SURFACE EFFECTS OF A SERIES OF EARTHQUAKES IN NEW BRUNSWICK

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(Editor's note: The following report is an edited version of a memo written by Grant on January 25, just after his return from the Miramichi region.)

A survey was conducted from January 13 to 15, 1982 to determine what, if any, were the surface manifestations of a series of five earthquakes with magnitudes registering between 4.0 and 5.7 that occurred from January 9 to 13 in the interior northern highlands of New Brunswick. The epicentral area was examined by the author and Allen Seaman, Quaternary geologist, New Brunswick Department of Natural Resources (NBDNR). Using a 4-wheel drive vehicle we traversed all roads that had been cleared of snow over an epicentral distance of 50 km. We approached within 5 km of the epicentre which, by January 14, had been fixed at 47°00'N, 66°37'W.

Attention was paid to signs of disturbance of all natural and artificial features including snow and ice cover, road surfaces and structures, vegetation, buildings, and rock surfaces. As detailed below, surprisingly little could be detected despite the fact that slight damage (architectural only, not structural) occurred in communities 70 km from the epicentre. However, the apparent absence of, or failure to detect, surface signs near the epicentre, can be explained by a combination of the following four local factors.

Snow and Ice Cover

The heavy fall of powder snow that occurred shortly before the first earthquake (January 9, 11:53) was unfortunately subjected to a short period of rapid melting and disturbance by high winds, so that it was no longer possible to evaluate differential release from tree branches by the tremors. Peculiar surface patterns in the snow, noted independently by several observers and thought to result from shock-induced settlement by thixotropy and de-aeration, were carefully sectioned and found to be a meltwater effect from the earlier thaw.

Cracks in the crusted snow surface were not seen anywhere during the only day (January 13, initial day of survey) that intervened before the next snowfall. However, cracks in road ice were seen at one point 62 km from the epicentre and trending generally toward it. Tension cracks in lake and river ice were also seen, but only at one point 8 km from the epicentre, and this occurrence may have been due to lowering of the water level. Perhaps fortuitously, this feature also trended toward the epicentre.

Vegetation

Drop of dead branches from hardwoods, and of needles from tamarack, was not apparent, thus suggesting that ground surface accelerations were of quite low magnitude and frequency.

Structures

Though a main paved highway (Hwy 108) traverses the area, it passes through a game refuge where buildings are prohibited. Otherwise the area is a logging district in which the only camp consists of steel Quonset huts in which none of the minor damage, which was reported to have occurred in plaster-board housing farther away, could be registered.

Bedrock Surfaces

The area is largely rock-controlled topography with a nearly continuous till mantle. Consequently, rock exposures large enough to project through the 1^{+} m snow cover were extremely rare. Only three outcrops were seen and these had been disrupted by blasting so that evidence of recent displacement of the glacial pavement could not be differentiated.

In summary, surface manifestations were found to be virtually lacking given the snow cover and recent weather history. However, in view of the reported minor damage at greater distances, it is reasonable to suppose that some evidence will be found upon further examination shortly after snow melt. Specifically, one would examine glaciated rock surfaces along road clearings for signs of fracturing that crosscut lichen cover and bulldozer markings. Secondarily, there may be signs of groundwater expulsion in the surficial sediment. A follow-up survey in May is therefore recommended. Quaternary geological staff from NBDNR may be mapping in the vicinity this year and will make independent observations. In the meantime an examination of imagery at 1:12,000 obtained recently (January 19) by CCRS (Canada Centre for Remote Sensing) might reveal better some of the snow and ice fractures that might be expected. (See Adams, Chapter 14.)

An opportunity was taken on the final day to visit geological staff of NBDNR in Fredericton. With J.J. Chandra I examined large-scale Landsat images for unmapped structural lineaments, and compared geological, gravity and aeromagnetic maps. The epicentre seems to lie near the junction of two large magnetic features. According to the Geological Map of New Brunswick (1979), it lies on the contact between massive granite and cataclastic granite, a hypothetical locus of strain. However, this compilation map differs substantially from earlier maps (e.g. DREE, 1977; Skinner, 1974) so these discrepancies will have to be resolved before correlations with surface geology are sought. Lastly, an arcuate lineament 30 km to the west has been mapped by Chandra and inferred to mark the trace of an overthrust inclined to the east. If thin-skin tectonics are invoked, this failure plane may lie 5-10 km deep under the epicentre in which case surface dislocation might be more evident at greater distances from the epicentre.

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12. GEOLOGY IN THE VICINITY OF THE 1982 MIRAMICHI EARTHQUAKE

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The epicentre of the earthquake lies along the axis of the northwest-trending Miramichi Geanticline (Wade et al., 1977) or Massif (Fyffe et al., 1981). The Massif is underlain by Cambrian-Ordovician psammite and pelite, foliated Ordovician granite and massive Devonian granite (see Figure 12.1). The abundance of granitic rocks suggests the Massif is underlain by a thick continental crust.

The Devonian granite in the area is part of a 800 km^2 pluton that intrudes deformed Cambrian-Ordovician country rocks discordantly. The granite is a pink, coarse-grained, subporphyritic rock containing microcline crystals up to 3 cm in length; the phenocrysts rarely exhibit flow alignment. Biotite is the main mafic constituent but hornblende is present locally. Medium-grained equigranular red muscovite granite and fine-grained grey porphyritic biotite granite occur as dykes and irregular masses within the main granite. Numerous xenoliths of gabbro, ranging up to 3 km in width, are common in the southern portion of the pluton. The gabbro is net-veined by granite and grades to tonalite along its contacts with the main granitic mass. A ten-point Rb-Sr isochron of the various phases of the pluton yielded an age of 378 ± 7 Ma ($\lambda = 1.42 \times 10^{-11} a^{-1}$).

The country rocks have been metamorphosed to an alkali feldspar-cordierite-andalusite-biotite-muscovite hornfels up to 2 km from the pluton. Fibrolite is developed locally along the southern contact. This mineral assemblage together with the presence of primary muscovite in minor phases of the granite indicates crystallization of the granite at a depth between 10-15 km.

Faulting is known to affect some of the Devonian plutons within the Miramichi Massif. A major east-striking fault (Catamaran Fault) 20 km south of the epicentre displaces a granite pluton dated as 351 ± 7 Ma. The fault movement is right-lateral strike-slip with less than 10 km of offset.

The Devonian granite in the vicinity of the earthquake is generally massive and undeformed. However, during sampling of the granite for age-dating purposes in the summer of 1979 a narrow shear zone was observed in a new exposure on a logging road about 8 km northeast of the epicentre.

Overburden in the area is composed of a bouldery ablation till ranging from 0.5 to 1.5 m in thickness. This morainal deposit marks the eastern margin of a major Wisconsin ice sheet that existed in the Tuadook Lake area prior to 11,200 BP. Postglacial emergence had begun by 10,000 BP (Rampton and Paradis, 1981). Because of the extensive overburden, it is possible for a major shear zone in the area to go undetected.

A re-examination of bedrock exposures was done in the summer of 1982 and a more detailed version of Figure 12.1 is available from the author. The new map covers the area bounded by 46°57'N and 47°02'N and by 66°28'W and 66°39'W at a scale of 1:15,840.

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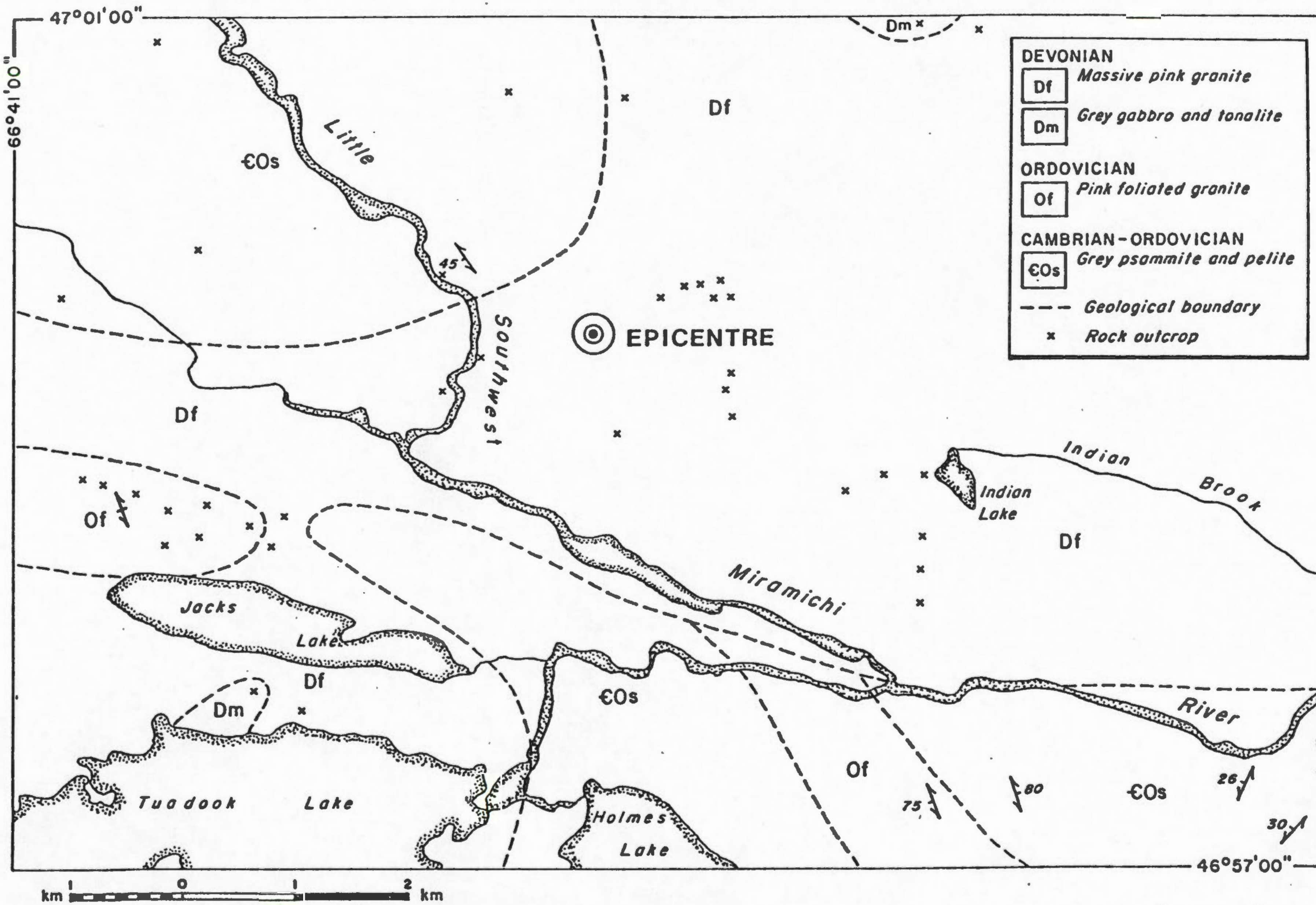

Figure 12.1 Geology in the vicinity of the 1982 Miramichi Earthquake

13. MAGNETIC AND GRAVITY STUDIES OF THE EPICENTRAL REGION OF THE 1982 MIRAMICHI EARTHQUAKE

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A contribution to our knowledge of subsurface geology in the epicentral region of the 1982 Miramichi earthquake can be obtained from an analysis of magnetic and gravity data. This type of study may reveal the presence of hidden fault zones that are without surface expression or individual subsurface plutons that may be acting as stress concentrators.

The epicentral region has been covered by two aeromagnetic surveys. One fluxgate magnetometer survey was flown in 1950 by the Geophysics Division, Geological Survey of Canada, and one rubidium-vapor magnetometer survey was flown in 1972 as a joint project of Energy, Mines and Resouces (EMR) and the New Brunswick Department of Natural Resouces, sponsored by the Canadian Department of Regional and Economic Expansion. The fluxgate magnetometer survey was flown at a nominal flight altitude of 500 feet above ground level with an average line spacing of 1/2 mile. Contour maps at 10-gamma intervals were published in 1953 at a scale of one inch to one mile (1:63,360). The epicentral region of the 1982 Miramichi earthquake is covered by Map 122G (Serpentine Lake) and Map 144G (Tuadook Lake). The high-sensitivity, rubidium-vapor magnetometer survey in 1972 was flown at 3000 feet above sea level (ground elevation in the epicentral region varies between 1000-1500 feet above sea level) with an average line spacing of 1000 feet. Maps contoured at 2-gamma intervals were published in 1975 at a scale of 1:25,000. The epicentral region is represented by Maps 21O/2a, 21O/2b, 21J/15g and 21J/15h.

Gravity data in the epicentral area are rather sparse. Gravity stations at 5 to 7 km intervals were observed in 1977 as part of a regional gravity survey by the Gravity Division, Earth Physics Branch, EMR (Open File No. 77-4). However, only a couple of stations lie close to the epicentre and a more extended coverage is needed.

Therefore a detailed gravity survey (station interval 1/4-1/2 km) was conducted during the summer of 1982 to complement existing data. In addition, *in situ* magnetic susceptibility measurements were also made on outcrops and samples were collected for density measurements to provide control for the quantitative interpretation of the gravity and magnetic data. The gravity survey was conducted within the area bounded by 46°55'N and 47°02'N and by 66°29'W and 66°40'W. A preliminary map has been produced at a scale of 1:20,000. Coverage was not uniform within the area, being limited largely to existing logging roads and bush trails.

A preliminary interpretation of the aeromagnetic data supports the idea that near-surface granitic rocks close to the epicentre are characterized by homogeneity and simple geological structure. A compilation of the 1st vertical-derivative values in the epicentral region based on Wallace and

Chandra (1981) is shown in Figure 13.1. The small derivative values and gentle gradients close to the epicentre contrast with the belt of larger derivative values and steeper gradients about 2 km to the south. This belt can be explained by the distribution of folded metasediments in this part of the region. Skinner (1975) reports that phyllite units in the metasediments contain finely disseminated crystals of magnetite and that paragneiss and amphibolite units contain up to 5% magnetite. The other smaller-amplitude derivative anomalies, with gentler gradients, around and to the north of the epicentre, suggest that crustal rocks at depth may be more heterogeneous than one is led to believe from surface exposures of granite. Whether the smaller anomalies can be explained by variations in the content of magnetic minerals in the granitic rocks, or whether it will be necessary to introduce blocks of denser and more mafic rocks into the model of the crustal structure, are questions that it is hoped to answer after the completion of summer fieldwork.

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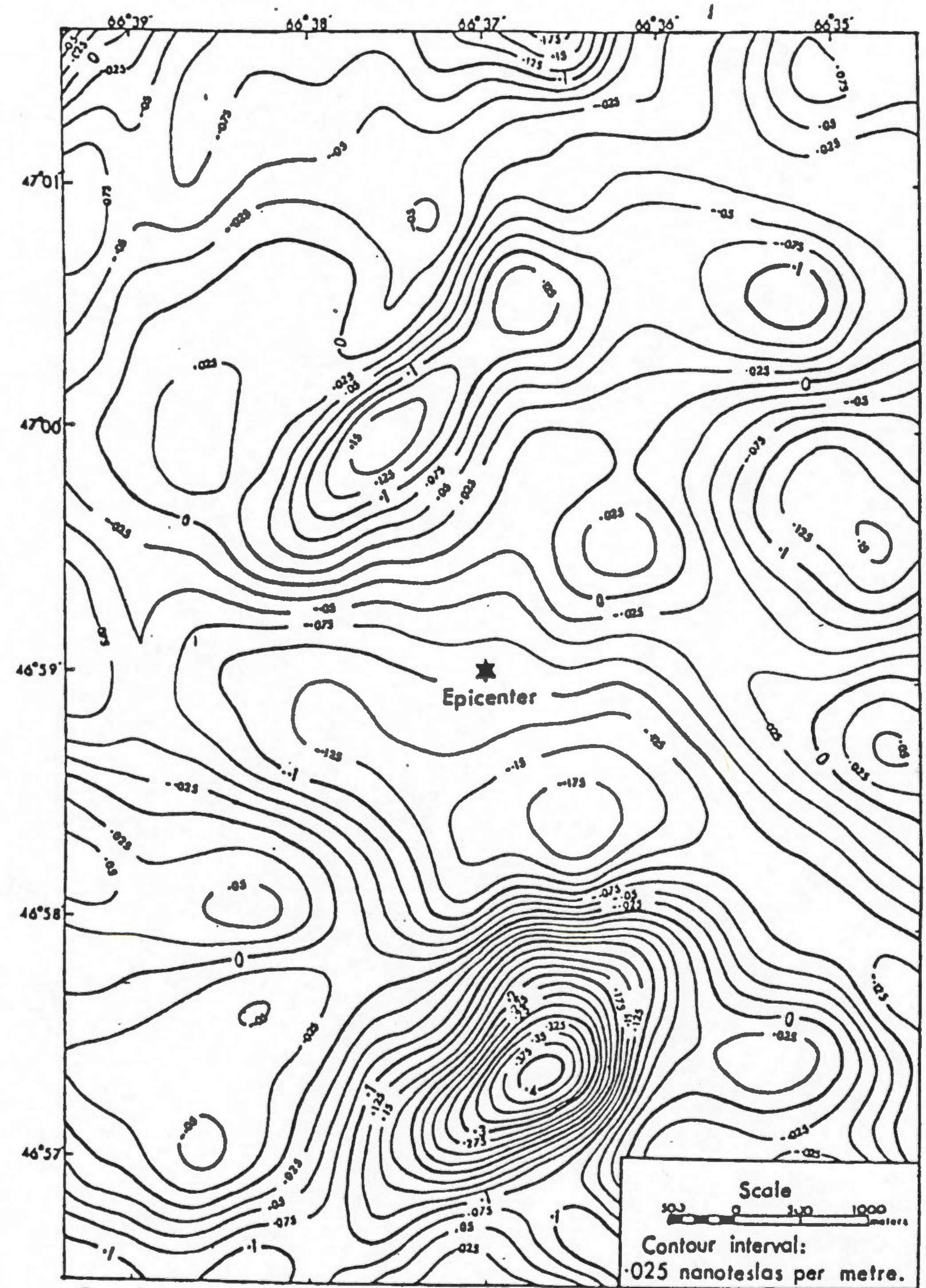

1st Vertical Derivative Map of Aeromagnetic Data

Figure 13.1

14. MIRAMICHI EARTHQUAKE - EPICENTRAL GEOLOGY, LINEAMENTS AND FIELD PLANS

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The geology of the epicentral region was mapped at 1:15,840 scale by L. Fyffe and G. Crouse in 1972-78 (New Brunswick Department of Natural Resources (NBDNR) maps L-11, L-12, M-11, M-12). In general terms the bedrock consists of a) deformed Cambro-Ordovician metasediments and an older "deformed" granite cut and intruded by b) a younger "undeformed" granite (Crocco, 1975). The epicentral area appears to lie almost entirely within the younger granite, and its southern edge is close to the east-west trending contact of the younger granite with the older deformed rocks (see Fyffe, Figure 12.1).

The deformed sedimentary rocks are moderately metamorphosed and tightly folded on mostly NW-trending axes. They are commonly magnetic and consequently produce characteristic anomalies on aeromagnetic maps. The deformed granites occur in extended lobes that are concordant with the Cambro-Ordovician rocks and have a foliation or gneissosity parallel to trends in these rocks (i.e. NW-NNW). They give a whole-rock Rb/Sr age of 479 ± 14 Ma (Fyffe et al., 1981).

The younger granites of the area are typically massive with no deformational fabric and they tend to occur as globular bodies. The epicentral area lies within an extension of a larger granite body to the north. At its southern edge it cuts the deformed sediments and granites discordantly. The lack of a strong deformation fabric within these granites implies that they are post-Acadian Orogeny (Crocco, 1975), and they give a whole-rock Rb/Sr age of 378 ± 7 Ma (Fyffe et al., 1981). To the north of the epicentral area, similar, undeformed granites are cut by several NW- to W-trending faults (Crocco, 1975); these faults may be the youngest structures so far recognized. L. Fyffe (Chapter 12) has observed a narrow shear zone in the granites near the epicentral area.

The epicentral region has been extensively glaciated, and the bedrock is mostly covered by till. The orientation of striae and drumlinoid features indicates the area was glaciated from the WNW (Rampton and Paradis, 1981). Since the original geological mapping there has been considerable logging in the area, and many new exposures along the logging roads may be available for mapping when the snow melts.

On the request of the Earth Physics Branch, the Canada Centre for Remote Sensing (CCRS) scheduled a flight over the epicentral area on January 13. However, aircraft problems and later bad weather in the epicentral area delayed the flight until January 19, and by then 0.5 m of fresh snow had fallen, effectively masking any subtle earthquake effects that might have been visible earlier. Between 1100 and 1300 A.S.T. on January 19, 245 km of north-south lines were flown at 7500' ASL (about 1900 m above average ground level) and were sufficient to cover a 25 km x 30 km region around the preliminary epicentre. During the flight, 9" x 9" black and white negatives were exposed to give stereoscopic coverage at a scale of about 1: 12,500 (CCRS air photograph rolls A40109 and A40110). At the same time a Multi-Spectral Scanner (MSS) recorded 10 visual and 1 infrared bands (CCRS tapes AR0521 and

AR 0522). Of the 267 negatives exposed, the 59 covering the region within 8 km of the epicentral area were printed and examined for earthquake effects and lineaments. The MSS infrared band was printed as "quick-look" imagery, and likewise only selected parts of it were scrutinized.

The resolution of the air photographs is such that the shadows cast on the snow by individual branches of isolated trees are clearly visible. Despite a careful search of the 20 photographs that covered the 4 km x 6 km epicentral area itself, no earthquake-related features were identified. While the infrared MSS did reveal areas of snow-free lake ice, no cracks were seen in them although cracking was reported by observers in the epicentral area.

A lineament map (Figure 14.1) has been prepared for the area within 8 km of the epicentre from the 59 photographs. The dominant trend of the linears is WNW, but as this is also the direction of glaciation, very little can be said about the implications for underlying faults or other lines of weakness. Three features lying east-west across the epicentre, two along unusually straight and incised river channels and the third in a probable bedrock furrow, are thought to have some greater structural significance. In contrast to the strong WNW trends, there are few north-south linears.

It is possible that the Miramichi earthquakes occurred on a gently-dipping fault that did not break the surface within the immediate epicentral area and indeed has no surface expression at all. Nevertheless rough calculations of the source volume expected for a magnitude 5.7 earthquake and the fact that the aftershocks are confined to the uppermost 6 km of the crust gave hope that a primary surface rupture might have been formed and might be found when the snow melted in the spring. Consequently EPB planned a cooperative field survey with the NBDNR to search for such a rupture, to map the geology of the epicentral region in further detail, and to perform various geophysical surveys. However, no substantial ground rupture was found during an examination in May.

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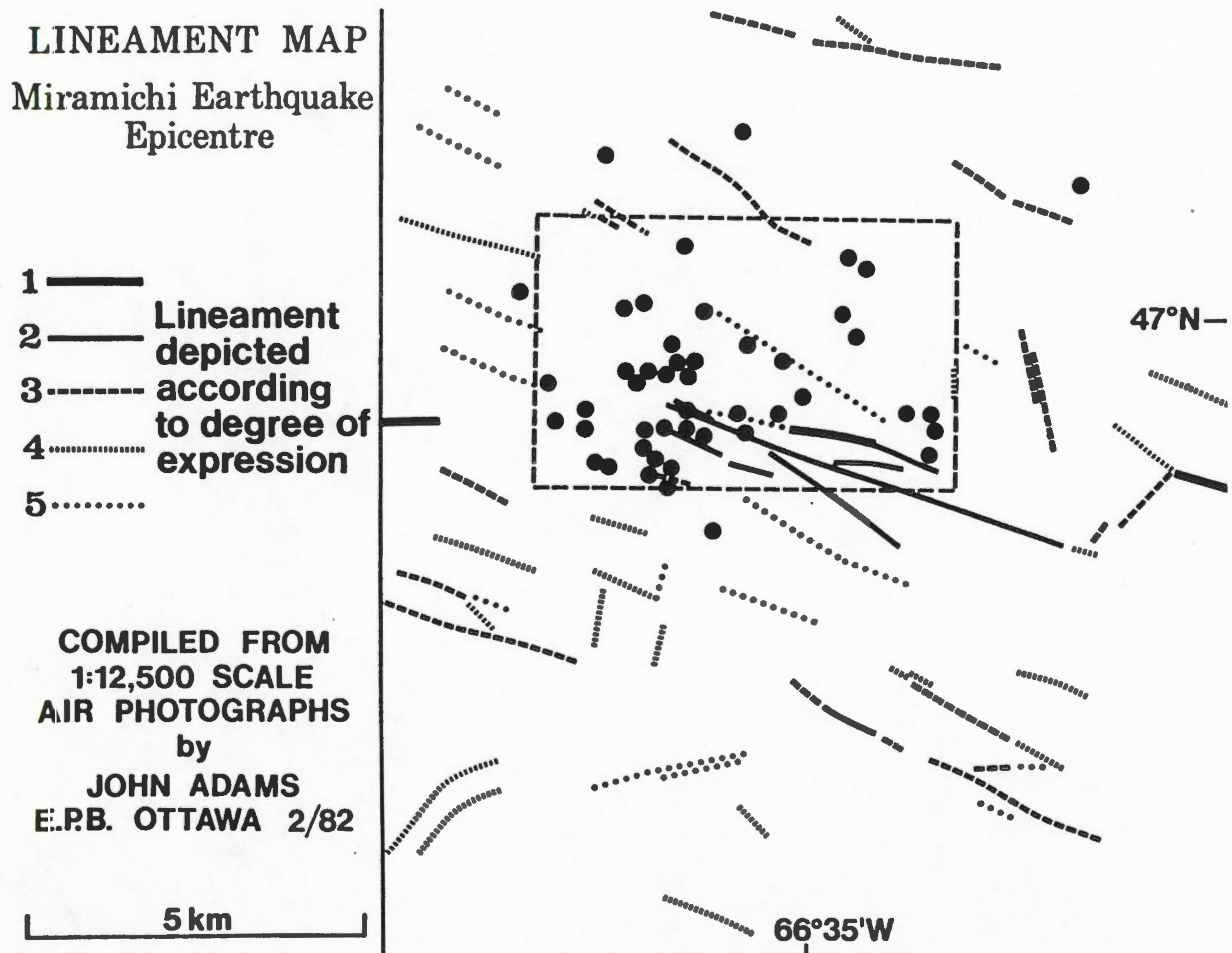
Figure 14.1 Lineament Map (solid circles represent preliminary locations of aftershocks on January 19-21, 1982)



15. FELT AREAS OF THE LARGER MIRAMICHI EARTHQUAKES OF JANUARY, MARCH AND APRIL 1982 AND OF THE TROUSERS LAKE EARTHQUAKE OF 16 JUNE 1982.

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Intensity surveys by questionnaire and letter were conducted in January, April and June 1982 to gather information on the extent of the felt area and the severity of shaking during several of the larger earthquakes in northcentral New Brunswick. The questionnaire is reproduced at the end of this chapter.

The first set of questionnaires was mailed shortly after 11 January to all postmasters in Atlantic Canada (i.e. New Brunswick, Prince Edward Island, Nova Scotia and Newfoundland) and in eastern Québec (from Québec City eastward). The questionnaire asked specifically for information on the earthquakes of 09 January 12:53 UT and of 11 January 21:41 UT (magnitudes m_b 5.7 and 5.4, respectively) and for information on any other earthquakes that had been felt. In addition to the postmasters, questionnaires were sent to the City or Town Engineer in the larger municipalities and to three CBC radio stations in Fredericton, Saint John and Moncton, New Brunswick. Listeners to these stations were invited to request and complete the questionnaires. A total of about 1600 questionnaires were distributed covering distances of 1000 km east and north of the epicentre, and 200 to 400 km in Canada south and west of the epicentre.

The second set of about 250 questionnaires was sent only to postmasters in New Brunswick on 02 April. This questionnaire also asked for information on two earthquakes - 31 March 21:02 UT and 02 April 13:50 UT, magnitudes $m_b(L_g)$ 4.8 and 4.3, respectively. An appeal was made through the media on 01 April for residents who had felt the earthquake of 31 March to write a letter to us stating where they had been at the time of the earthquake, what they had been doing and what they had felt. This request was communicated to the media through the provincial Emergency Measures Organization in New Brunswick, Prince Edward Island, Nova Scotia and the Gaspé region of Québec. About 150 letters were received, mainly from Prince Edward Island and New Brunswick. Some of these letters also contained observations about the January earthquakes.

A third set of questionnaires was sent to all postmasters in New Brunswick and Prince Edward Island on 17 June requesting information about the earthquake of 16 June 11:43, magnitude $m_b(L_g)$ 4.6.

Other earthquakes in northcentral New Brunswick have been felt locally from January to July 1982, but no other intensity surveys have been conducted by the Earth Physics Branch.

In completing the January questionnaires, respondents who felt both earthquakes did not always distinguish clearly between them. It was sometimes difficult to decide whether the reported effects were observed equally for both shocks. A similar problem was encountered with the March-April questionnaire. Only one earthquake was felt in June, so no ambiguity arose.

Contoured isoseismal maps showing Modified Mercalli intensities at each community will be published shortly. These isoseismal maps will include data from the United States gathered through questionnaire surveys by the U.S. National Earthquake Information Service (courtesy of Carl Stover) and by the Lamont-Doherty Geological Observatory (courtesy of Ellyn Schlesinger-Miller).

(See also the SSA abstract by Stevens in Chapter 23.)

Energy, Mines and Resources Canada / Énergie, Mines et Ressources Canada

Science and Technology / Science et Technologie

Dear Sir or Madam:

This office is seeking information on an earthquake which took place at the time and place indicated below. We wish to find out how strongly the shock was felt at different distances from the epicentre and to what distances it was noticeable. Thus if the shock was not felt in your community, this information is still valuable to us and we would appreciate your reply. It is not necessary to give your name, but please indicate your location at the time of the earthquake. A postage-paid return envelope is attached for your convenience. Please detach the envelope carefully before proceeding.

Please answer the following questions:

Cher Monsieur ou Chère Madame,

Nous cherchons à obtenir plus d'information sur le tremblement de terre qui a eu lieu à l'heure et l'endroit indiqués ci-dessous. Comme nous désirons étudier l'intensité en fonction de la distance, veuillez nous répondre, même si vous n'avez pas ressenti ce choc dans votre localité. Toute réponse, même négative, s'avère fort utile. Il ne vous est pas nécessaire de signer, mais nous vous prions de bien indiquer le nom de l'endroit où vous étiez au moment de la secousse. Pour plus de facilité, vous trouvez ci-joint une enveloppe affranchie. S.V.P., en tout premier lieu détacher l'enveloppe-réponse avec soin.

Veuillez répondre aux questions suivantes:

a) Name/Nom ______

Address/Adresse ______

City/Ville ______ County/Comté ______

Province ______ Postal Code/Code Postal ______

Telephone/Téléphone ______

b) Was the earthquake felt by anyone in your neighbourhood near the date and time indicated.

... No: Please refold and post for return mail.

... Yes: Date ______ Time ______ ... AM ... PM

Complete the PERSONAL REPORT if you felt the earthquake. If others felt the earthquake but you did not, skip the PERSONAL REPORT and complete the COMMUNITY REPORT. We would appreciate an early return. Thank you for your time and information.

Earth Physics Branch
Energy, Mines and Resources Canada

b) Est-ce que vous ou quelqu'un de votre voisinage avez ressenti un tremblement de terre à la date et à l'heure indiquées?

... Non: Veuillez plier le questionnaire et nous le retourner.

... Oui: Date ______ Heure ______ ... AM ... PM

Veuillez remplir la section intitulée RAPPORT PERSONNEL si vous avez ressenti le tremblement de terre. Si vous n'avez pas ressenti le séisme, mais si vous avez parlé à d'autres qui l'ont ressenti, veuillez passer à la section intitulée RAPPORT COLLECTIF. Nous vous prions de retourner le questionnaire le plus rapidement possible et nous vous remercions de nous fournir temps et renseignements.

Direction de la physique du globe
Énergie, Mines et Ressources Canada

Please indicate any changes in your mailing address.

Veuillez indiquer toutes corrections à votre adresse postale, s'il y a lieu.

Earthquake of / Tremblement de terre du

SAT JAN 09 AT 08:53 AST 1982	SAM 09 JAN A 08H53 HNA 1982
AND	ET
MON JAN 11 AT 17:41 AST 1982	LUN 11 JAN A 17H41 HNA 1982
DISTINGUISH CLEARLY BETWEEN	DISTINGUEZ ENTRE LES DEUX
THESE TWO IN YOUR REPLY.	DANS VOTRE REPONSE. AVEZ-
DID YOU FEEL OTHER QUAKES ?	VOUS REMARQUE D'AUTRES CHOCS?

(2)

PERSONAL REPORT

a) Did you personally feel the earthquake? ... No ... Yes
b) Were you awakened by the earthquake? ... No ... Yes
c) Were you frightened by the earthquake? ... No ... Yes
d) Were you at ... Home ... Work ... Other ______
e) Town and postal code of your location at time of earthquake ______
f) Nearest cross roads? ______
g) Check your activity when the earthquake occurred: ... Lying down ... Sitting ... Standing ... Walking ... Sleeping ... Driving (car in motion) ... Other ______
h) Were you ... Inside or ... Outside?
i) If inside, on what floor were you? ______
j) Vibration could be described as ... Light ... Gradual ... Abrupt ... Heavy
k) Was there any noise? ... No ... Faint ... Moderate ... Loud
l) Noise came from ... North ... South ... East ... West
m) Estimated duration of shaking ... Sudden, sharp (less than 10 sec.) ... Long (30-60 sec.)
n) Type of ground where earthquake was felt ... Don't know ... Sandy soil ... Marshy ... Fill ... Hardrock ... Clay soil ... Sandstone, limestone, shale

RAPPORT PERSONNEL

a) Avez-vous personnellement ressenti le tremblement de terre? ... Non ... Oui
b) La secousse vous a-t-elle éveillé? ... Non ... Oui
c) La secousse vous a-t-elle effrayé? ... Non ... Oui
d) Étiez-vous à ... la maison ... au travail ... autre ______
e) Nom et code postal du lieu où vous étiez au moment du séisme ______
f) L'intersection la plus proche? ______
g) Au moment du tremblement vous: ... étiez étendu ... étiez assis ... étiez debout ... marchiez ... dormiez ... conduisiez (en mouvement) ... autre ______
h) Au moment du tremblement vous étiez à ... l'intérieur ... l'extérieur
i) Si vous étiez à l'intérieur, à quel étage? ______
j) Selon vous, la vibration était ... légère ... graduelle ... brusque ... forte
k) Avez-vous perçu un bruit? ... Non ... faible ... modéré ... fort
l) Selon vous, le bruit venait du ... Nord ... Sud ... Est ... Ouest
m) Selon vous, la secousse fut ... soudaine, vive (moins de 10 sec.) ... longue (30-60 sec.)
n) Le sol où vous avez ressenti le tremblement de terre est ... inconnu ... sablonneux ... marécageux ... composé de remblai ... rocailleux ... argileux ... calcaire

PERSONAL COMMENTS

COMMENTAIRES PERSONNELS

COMMUNITY REPORT

Town and postal code of the community affected ______
Population ______
DO NOT include effects from other communities

1. Check one for each question that is applicable

a) The earthquake was felt by ... No one ... Few ... Several ... Many ... All
b) This earthquake awakened ... No one ... Few ... Several ... Many ... All
c) This earthquake frightened ... No one ... Few ... Several ... Many ... All

2. What indoor physical effects were noted in your community? ... None

a) Windows, doors, dishes rattled ... No ... Yes
b) Buildings creaked ... No ... Yes
c) Buildings trembled (shook) strongly ... No ... Yes
d) Hanging pictures (more than one) ... Swung ... Out of place ... Fallen

CONTINUE ON TO PAGE 3

RAPPORT COLLECTIF

Nom et code postal du lieu affecté par la secousse ______
Population ______
Veuillez exclure les effets provenant des villes et villages avoisinants.

1. Veuillez cocher l'adjectif qui correspond le mieux

a) ... Aucun ... Peu ... Plusieurs ... La plupart ... Tous ont ressenti la secousse
b) ... Aucun ... Peu ... Plusieurs ... La plupart ... Tous furent réveillés
c) ... Aucun ... Peu ... Plusieurs ... La plupart ... Tous furent effrayés

2. Quels sont les effets visibles, perçus à l'intérieur par vous et vos voisins, reliés au tremblement de terre? ... Aucun

a) Les fenêtres, les portes, la vaisselle ont vibré ... Non ... Oui
b) Les bâtiments ont craqué ... Non ... Oui
c) Les bâtiments ont vibré fortement ... Non ... Oui

CONTINUEZ À LA PAGE 3

3

e) Liquid in small containers ... Slightly disturbed ... Spilled
f) Window panes ... Few cracked ... Some broken ... Many broken
g) Were small objects (dishes, knick-knacks, lamps)
... Unmoved ... Moved ... Overturned ... Broken
h) Was light furniture or small appliances
... Unmoved ... Moved ... Overturned ... Damaged seriously
i) Was heavy furniture or appliances
... Unmoved ... Moved ... Overturned ... Damaged seriously
j) Did hanging objects, doors swing?
... No ... Slightly ... Moderately ... Violently
k) Can you estimate direction of swinging?
... No ... North/South ... East/West ... Other________
l) Pendulum clocks ... Faster or Slower ... Stopped

3. Indicate effects to interior walls and ceilings if any: ... None

a) Plaster/Stucco ... Large cracks ... Fell in large amounts
b) Wall panels ... Large cracks ... Fell in large amounts
c) Ceiling tiles ... Large cracks ... Fell in large amounts

4. What outdoor physical effects were noted in your community? ... None

a) Trees and bushes shaken ... Slightly ... Moderately ... Strongly
b) Standing vehicles rocked ... Slightly ... Moderately ... Strongly
c) Moving vehicles rocked ... Slightly ... Moderately ... Strongly
d) Water splashed onto sides of lakes, ponds, swimming pools
... No ... Yes
e) Elevated water tanks ... Cracked ... Twisted ... Fallen (thrown down)
f) Industrial cooling units ... Displaced ... Rotated ... Fallen
g) Tombstones ... Displaced ... Cracked ... Rotated ... Fallen
h) Chimneys
... Bricks loosened ... Twisted ... Some fallen ... Broken at roof line
... All fallen
i) Railroad tracks bent ... Slightly ... Greatly
j) Stone or brick fences/walls ... Open Cracks ... Fallen ... Destroyed
k) Underground pipes ... Broken ... Out of service
l) Highways or streets ... Large cracks ... Large displacements
m) Sidewalks ... Large cracks ... Large displacements

5. a) Check below any structural damage to buildings ... None

Foundation ... Cracked ... Destroyed
Interior walls ... Split ... Separated from ceiling or floor ... Fallen
Exterior walls ... Large cracks ... Bulged outward ... Partial collapsed
... Total collapsed
Building ... Moved on foundation ... Shifted off foundation

b) What type(s) of construction was the building that showed this damage?
... Wood ... Stone ... Brick veneer ... Other________
... Brick ... Cinderblock ... Reinforced concrete ... Mobile home

c) What was the type(s) of ground under the building? ... Don't know
... Sandy soil ... Marshy ... Fill ... Hard rock ... Clay soil
... Sandstone, limestone, shale

CONTINUE ON TO PAGE 4

d) Plus d'un cadre aux murs ... ont balancé ... se sont déplacés
... sont tombés
e) Du liquide dans des petits contenants ... s'est agité légèrement
... s'est renversé
f) Les vitres ... peu furent fêlées ... quelques-unes furent brisées
... plusieurs furent brisées
g) Les petits objets (vaisselle, bibelots, lampes) furent
... immobiles ... déplacés ... renversés ... cassés
h) Les meubles légers ou les petits appareils ménagers furent
... immobiles ... déplacés ... renversés ... sérieusement endommagés
i) Les meubles lourds ou les appareils ménagers furent
... immobiles ... déplacés ... renversés ... sérieusement endommagés
j) Les objets suspendus, les portes ont oscillé
... non ... légèrement ... modérément ... violemment
k) Selon vous, les oscillations étaient dans une direction
... inconnue ... Nord/Sud ... Est/Ouest ... autre________
l) Les horloges à balancier
... sont plus rapides ou plus lentes ... se sont arrêtées

3. Veuillez indiquer s'il y eut un effet sur les surfaces intérieures ... Aucun

a) plâtre/stuc ... larges fissures ... chûte importante de matériaux
b) panneau préfabriqué ("Gyproc")
... larges fissures ... chûte importante de matériaux
c) carreau de plafond ... larges fissures ... chûte importante de matériaux

4. Quels sont les effets visibles, perçus à l'extérieur, dans votre voisinage? ... Aucun

a) Les arbres et les buissons tremblèrent
... légèrement ... modérément ... fortement
b) Les véhicules à l'arrêt s'agitèrent
... légèrement ... modérément ... fortement
c) Les véhicules en mouvement s'agitèrent
... légèrement ... modérément ... fortement
d) L'eau fut projetée sur le bord des lacs, des étangs et des piscines
... Non ... Oui
e) Les réservoirs d'eau suspendus furent ... fendus ... tordus ... renversés
f) Les appareils industriels de refroidissement
... se sont déplacés ... ont pivoté ... sont tombés
g) Les pierres tombales
... se sont déplacées ... se sont fissurées ... ont pivoté ... sont tombées
h) Les cheminées subirent les dommages suivants ... décollement des briques
... pivotement ... chûte de certaines briques ... bris de la cheminée au niveau du toit ... chûte de toute la cheminée
i) Les rails de chemin de fer furent courbés ... légèrement ... sévèrement
j) Les murs ou les clôtures en pierre ou en brique
... se sont lézardés ... sont tombés ... sont détruits
k) Les canalisations souterraines
... se sont rompues ... sont devenues inutilisables
l) Les grandes routes et les rues ... se sont crevassées ... se sont déplacées
m) Les trottoirs ... se sont crevassés ... se sont déplacés

5. a) Veuillez cocher ci-dessous les dommages structuraux causés au(x) bâtiment(s)
... Aucun

fondations ... fissurées ... détruites
murs intérieurs ... fendus ... détachés du plancher ou du plafond
... tombés
murs extérieurs ... lézardés ... déjetés vers l'extérieur
... partiellement écroulés ... totalement écroulés
bâtiment ... déplacé sur les fondations ... jeté en bas des fondations

CONTINUEZ À LA PAGE 4

4

d) Was the ground: ... Level ... Sloping ... Steep?

e) Check the approximate age of the building:
... Built before 1935 ... Built 1935-65 ... Built after 1965

6. Check below any structural damage to ... None

a) Bridges/Overpasses ... Concrete ... Wood ... Steel ... Other________
Damage was ... Slight ... Moderate ... Severe

b) Dams ... Concrete ... Earth fill ... Other________
Damage was ... Slight ... Moderate ... Severe

7. What geologic effects were noted in your community? ... None

a) Ground cracks ... Wet Ground ... Steep slopes ... Dry and level grounds

b) Landslides ... Small ... Large

c) Slumping ... River bank ... Road fill ... Land fill

d) Were springs or well water disturbed ... Level changed ... Flow disturbed
... Muddied ... Don't know

e) Were rivers or lakes changed? ... Yes ... No ... Don't know

8. What percentage of buildings were damaged? ... None

a) Within 2 city blocks of your location
... None ... Few (about 5%) ... Many (about 50%)
... Most (about 75%)

b) In your community
... None ... Few (about 5%) ... Many (about 50%)
... Most (about 75%)

b) À quel genre de construction appartenait le(s) bâtiment(s) endommagé(s)?

... bois ... pierre ... revêtement de brique ... autre________
... brique ... bloc de ciment ... béton armé ... maison mobile

c) Quel genre de sol se trouvait sous le(s) bâtiment(s)?
... inconnu ... sablonneux ... marécageux
... composé de remblai ... rocailleux ... argileux ... calcaire

d) Est-ce-que le terrain était ... plat ... pente légère ... pente prononcée

e) Selon vous, le bâtiment fut construit ... avant 1935 ... entre 1935 et 1965
... après 1965

6. Veuillez indiquer, si besoin est, les dommages structuraux aux constructions suivantes: ... Aucun

a) ponts/viaducs ... béton ... bois ... acier ... autres________
Les dégâts étaient ... légers ... modérés ... importants

b) barrages ... béton ... remblayé de terre ... autre________
Les dégâts étaient ... légers ... modérés ... importants

7. Quels sont les effets géologiques remarqués dans votre voisinage? ... Aucun

a) crevasses dans le sol ... terrain mouillé ... pentes prononcées
... terrain sec et plat

b) glissements de terrain ... petits ... grands

c) affaissements ... bord de rivière ... remblai pour route
... remblai pour terrain

d) eau de source et de puits ... changement du niveau
... modification du débit ... présence de boue ... aucune opinion

e) les rivières et les lacs ont-ils changé? ... Oui ... Non ... aucune opinion

8. Quel est le pourcentage des bâtiments endommagés ... Aucun

a) À l'intérieur de 2 pâtés de maisons dans votre voisinage?
... aucun ... peu (environ 5%) ... plusieurs (environ 50%)
... la plupart (environ 75%)

b) Dans votre ville ou village?
... aucun ... peu (environ 5%) ... plusieurs (environ 50%)
... la plupart (environ 75%)

16. INTENSITY SURVEY OF THE JANUARY 9, 1982 NEW BRUNSWICK, CANADA, EARTHQUAKE

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We have collected over 1400 earthquake questionnaires for the New Brunswick, Canada earthquake of January 9, 1982. These felt reports have come from all of the New England states, as well as New York. Modified Mercalli intensities range from I (not felt) to V. Most people in Maine experienced intensity III-IV, and many were awakened by the earthquake. In the other states, most people experienced intensity II-III. The boundary of the felt area appears to run through southern Connecticut and Rhode Island to the south, and eastern New York to the west. We are compiling these data into an intensity map, along with the Canadian data collected by the Seismological Service of Canada, Earth Physics Branch.

(See also the SSA abstract by these same authors in Chapter 23.)

17. SURVEY OF BUILDING DAMAGE IN NEW BRUNSWICK CAUSED BY THE 1982 NEW BRUNSWICK EARTHQUAKE

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INTRODUCTION

A survey investigating the effects of the 1982 New Brunswick earthquakes on residential, commercial and institutional buildings was conducted by the authors during the week of January 25. Municipalities situated within a 110-km circle about the epicentre were visited. These included the three cities of Fredericton (110 km from the epicentre), Bathurst (100), and Campbellton (110); the four towns of Newcastle (80), Chatham (85), St-Léonard (100), and Grand Falls (85); and the six villages of Doaktown (60), Kedgwick (90), St-Quentin (80), Plaster Rock (60), Perth-Andover (85), and Bath (90). All are in Zone 2 of the seismic zoning map of Canada (design acceleration = 0.04 g, probability of exceedance 0.01 per annum). Most of the earthquake-related damage was noticed after the main shock (magnitude 5.7) on January 9 or the largest aftershock (magnitude 5.4) on January 11.

BUILDING CONTENTS

Items on Shelves Attendants at liquor stores in Doaktown, Kedgwick and Grand Falls reported that bottles rattled and clinked on their shelves but none fell over or off the shelves. The front of these shelves have raised edges, making it difficult for bottles to simply slide off. However, the same situation was repeated at retail stores that were visited - no merchandise fell down. In single-family residential structures, two people reported falling items. A curling trophy fell off a shelf in Plaster Rock and a preserve jar fell from a basement shelf in Perth-Andover.

Ceiling Tiles Flapping ceiling panels were noticed by sales personnel in single-storey retail stores in Doaktown and Chatham.

BUILDINGS

Summary The earthquakes did no serious damage to any of the buildings surveyed. Where there was damage, it was restricted to cracks in foundation walls (poured concrete, which is the most common, concrete-block or stone), concrete-block walls, plaster-lathe wood partitions and joints in gyproc panelling. No recent cracks were observed in exterior clay-brick veneer.

Aside from the production of some new cracks, the earthquakes tended to widen existing cracks, many of which were seen for the first time and therefore were assumed to have been caused by the earthquakes. One such crack, a construction joint in a concrete basement wall, was probably there since the building was built, although the person who pointed it out thought it was new.

Chimneys No brick chimneys fell down although there were some reports of falling bricks. This was surprising for many chimneys were in such poor condition that they appeared ready to collapse at any moment (Figure 17.1).

Buildings Surveyed The major buildings surveyed (ten in number) consisted of a five-storey office building, a four-storey senior citizens' home, two two-storey high schools, two two-storey hospitals, two two-storey post office buildings and two one-storey shopping malls. The oldest structure was approximately 25 years old. Most of the buildings had either a reinforced concrete or a structural steel frame. Concrete blockwork was often used for infill walls and partitions, and in a few cases for loadbearing walls.

Blockwork Cracks were observed in concrete blockwork (Figures 17.2 and 17.3). Many appear to be either existing shrinkage cracks or settlement cracks, which had been extended in size and length by the earthquakes, or previously repaired cracks that had reopened. Cracks were also seen at the intersection of interior partitions and exterior walls (Figure 17.4), and between 9-metre high exterior infill walls and vertical steel columns (Figure 17.5).

Many of the block walls lacked control joints and joint reinforcement, and some buildings were built on fill. Probably most of the older blockwork walls do not have the minimum horizontal and vertical reinforcement that is required by the 1980 National Building Code of Canada for Seismic Zone 2.

Stairwells Damage to stairwell walls was observed in two buildings. The first, a four-storey senior citizens' home in Bathurst, has a T-shaped plan view with a building separation joint the full height of the building near the stem of the tee. The top of the tee was built on fill and it appears to have moved relative to the other half of the building as a result of the earthquakes. A stairwell is adjacent to the separation joint (Figure 17.6a). The wall of the stairwell, adjacent to and parallel to the joint, is probably a plaster-finished concrete block wall. Based on the observed damage to this wall, it appears to be unintentionally connected across the separation joint (plans for the buildings have not yet been seen). The damage to the wall increased with storey level: hairline cracks in the plaster between the first and second floors, large visible cracks and spalled plaster between the third and fourth floors (Figures 17.6b to 17.6d).

In the second building, a two-storey hospital in Perth-Andover, the stairwell was located at the end of one of the hospital wings. The damage to the plaster-coated stairwell walls was less severe than that observed in the senior citizens' home (Figures 17.7a, 17.7b).

Gyproc Panels Damage to gyproc panels used as interior cladding was observed in several one- and two-storey retail stores. The most notable case occurred in a one-storey department store in Chatham. Vertical floor-to-ceiling cracks throughout the interior of the store occurred at vertical joints in the gyproc cladding attached to the exterior walls (steel frame with blockwork infill walls clad with brickwork) (Figure 17.8). The location of the cracks coincided with the location of movement joints in the exterior brick cladding.

COMMENTS ADDED BY THE EDITOR FROM CONVERSATIONS WITH THE AUTHORS

Except for Fredericton, few buildings in New Brunswick are higher than two storeys, and most buildings are wood-frame. All building damage observed could be classified as architectural or cosmetic damage. No structural damage was seen. Repairs could be made by a local tradesman, such as a painter. Not all cracks were sufficiently noticeable to require repair. In a few cases, steps were being taken to strengthen existing structures to comply with the seismic requirements of the current National Building Code of Canada.

In some cases it was reported that cracks had appeared only after the strong aftershock of Monday afternoon (January 11). These cracks had not been visible during a close inspection following the Saturday earthquakes (January 09).

Houses were not examined for lack of time. The numerous reports of "cracked basements" in various communities may be explained in part, at least, as a widening and/or lengthening of pre-existing shrinkage or settlement cracks that either were not noticed prior to the January earthquakes or were too small to have been seen even if the resident had looked.

(The authors are preparing a detailed report on their survey of building damage in New Brunswick, which will be issued as a Technical Note of the Division of Building Research, National Research Council of Canada.)

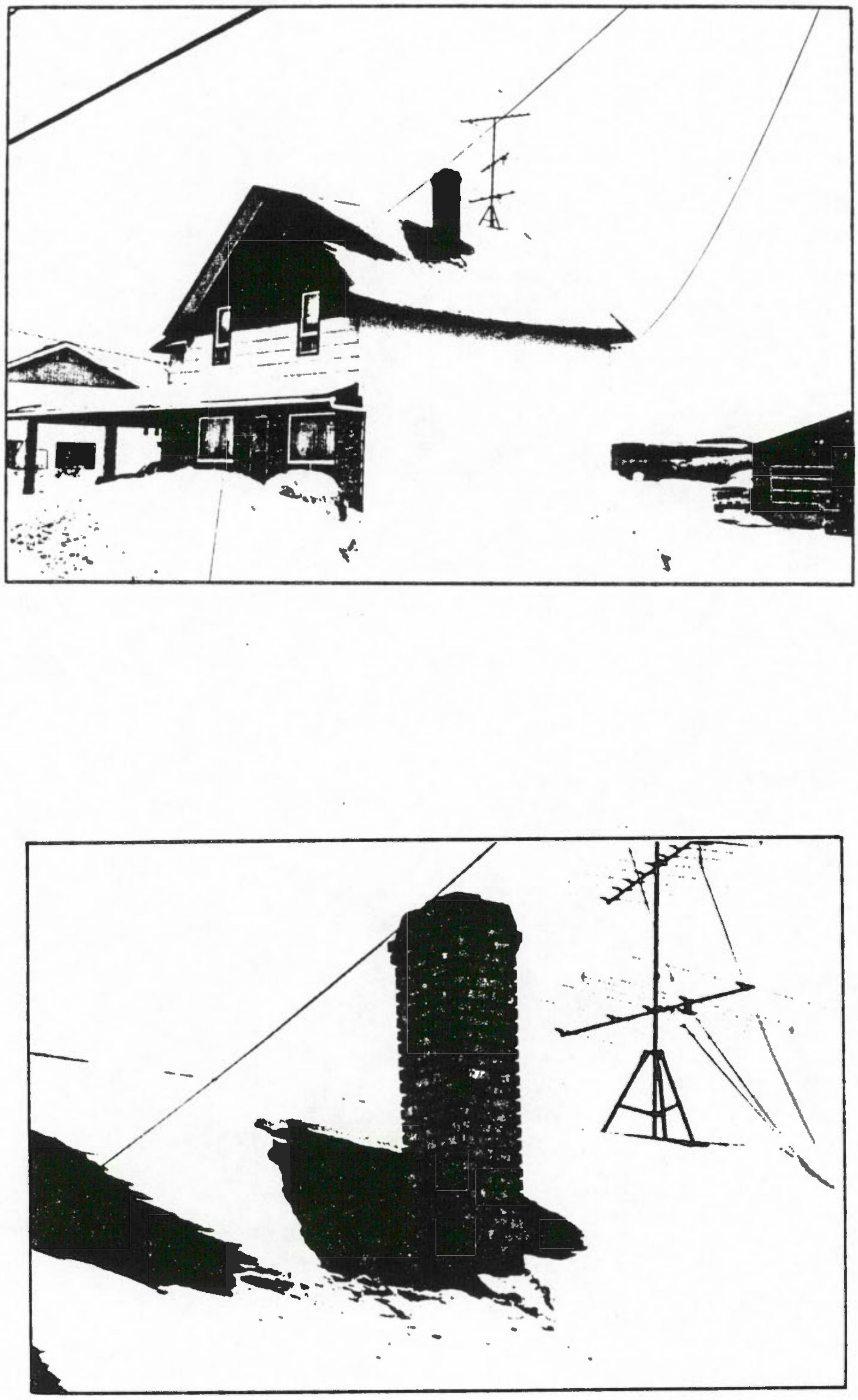
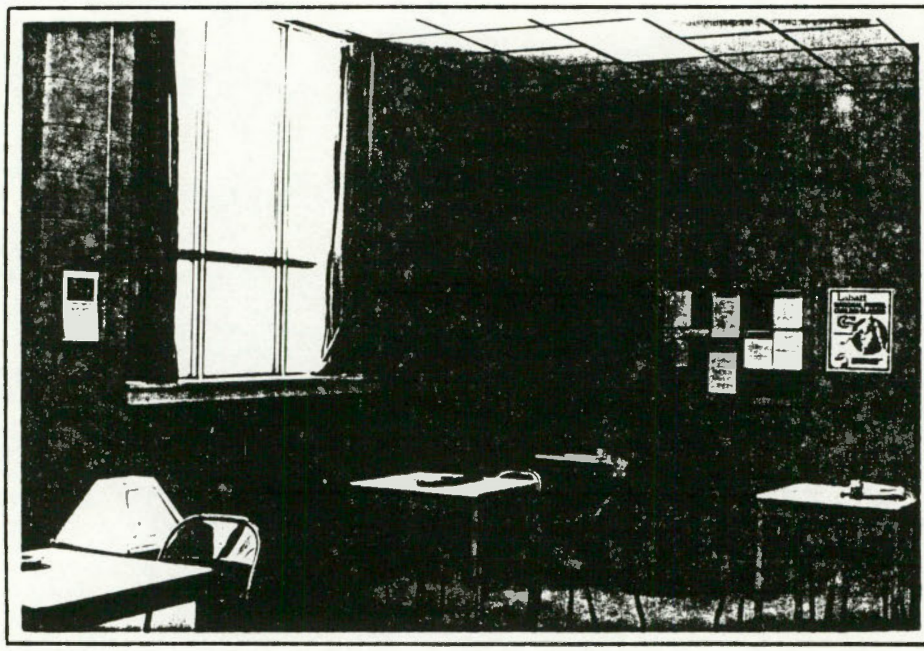


Figure 17.1 Pieces of the chimney have fallen off; chimney in poor condition



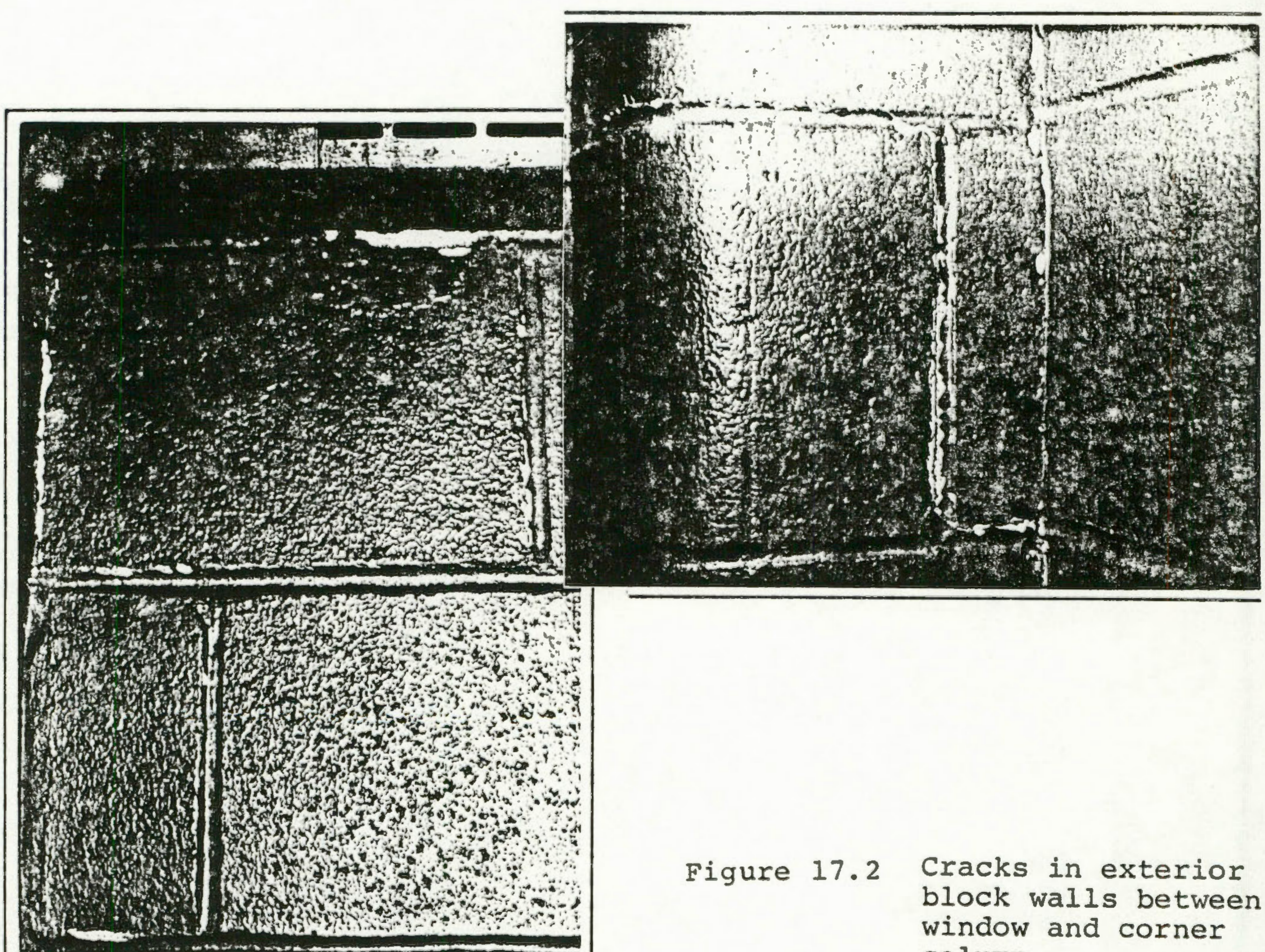
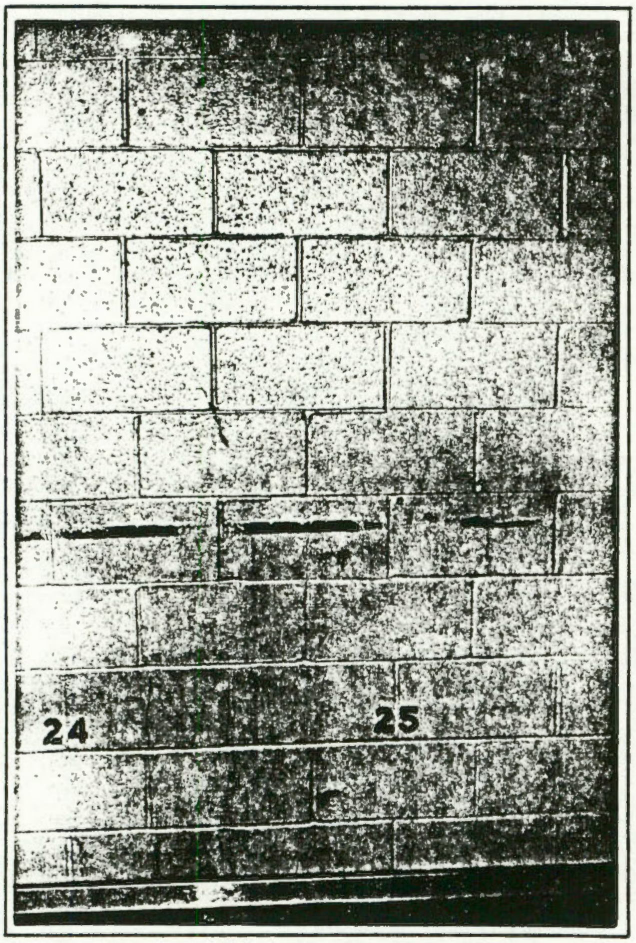


Figure 17.2 Cracks in exterior block walls between window and corner column.

Post Office, Newcastle



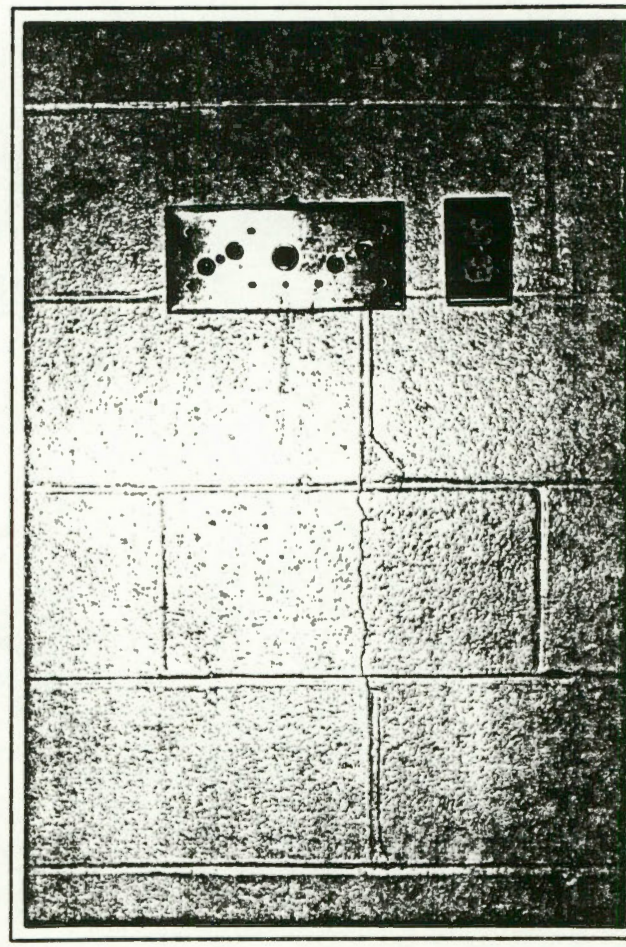


Figure 17.3 Cracks in 9m high, external, non-loadbearing, gymnasium walls.

School, Newcastle

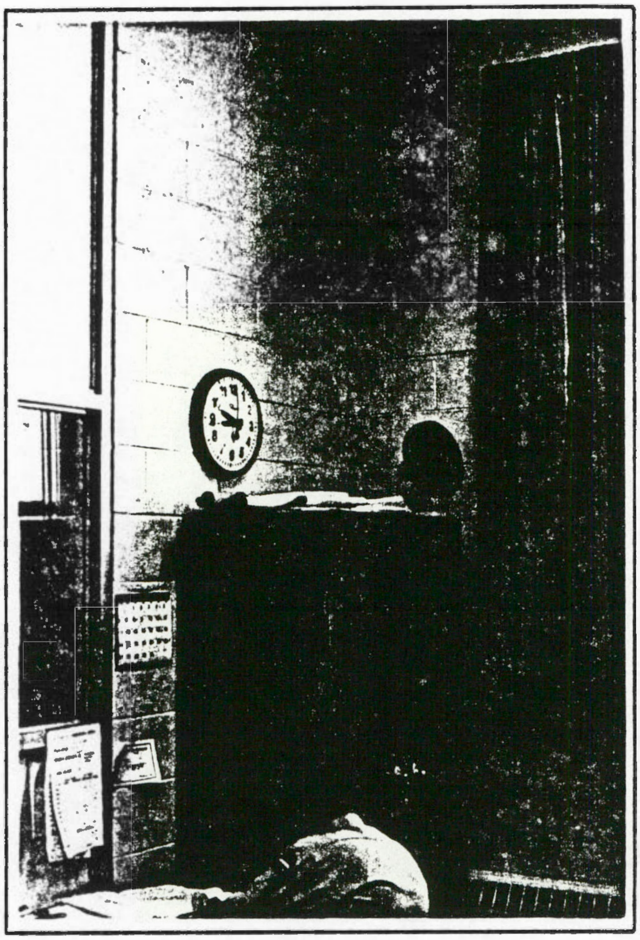


Figure 17.4 Vertical crack at junction of the internal block partition and the external block infill wall

Post Office, Newcastle

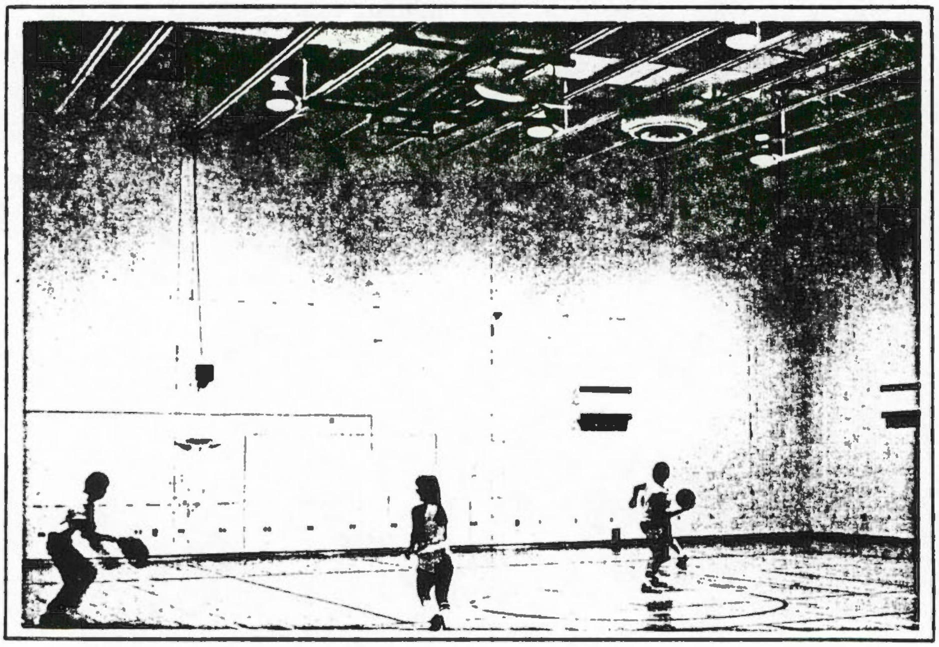


Figure 17.5 Vertical cracks at junction of 9m high, external, non-loadbearing, infill block walls and steel columns.

School, Newcastle

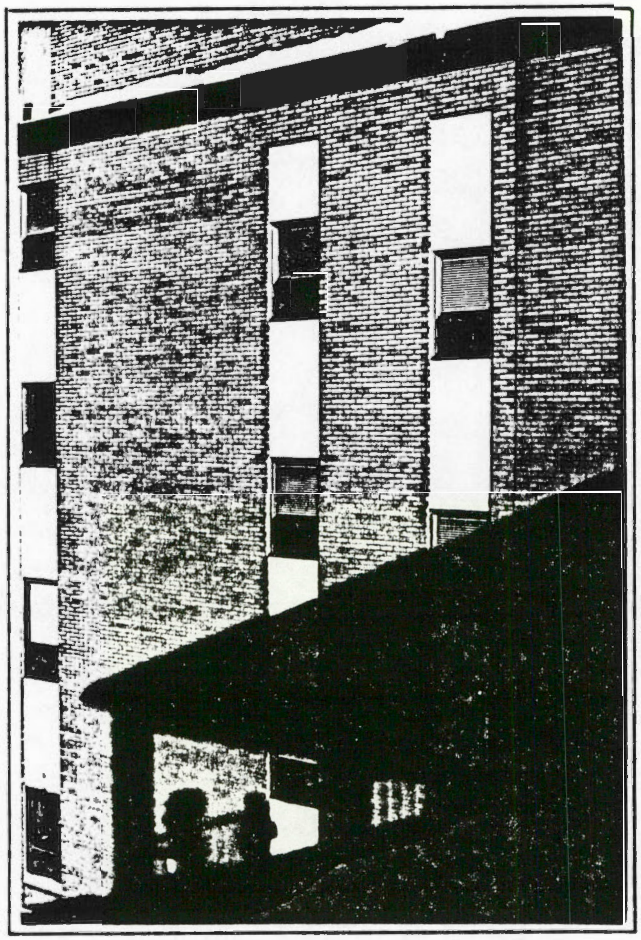


Figure 17.6a Vertical separation joint next to stairwell
Senior Citizens' Home, Bathurst

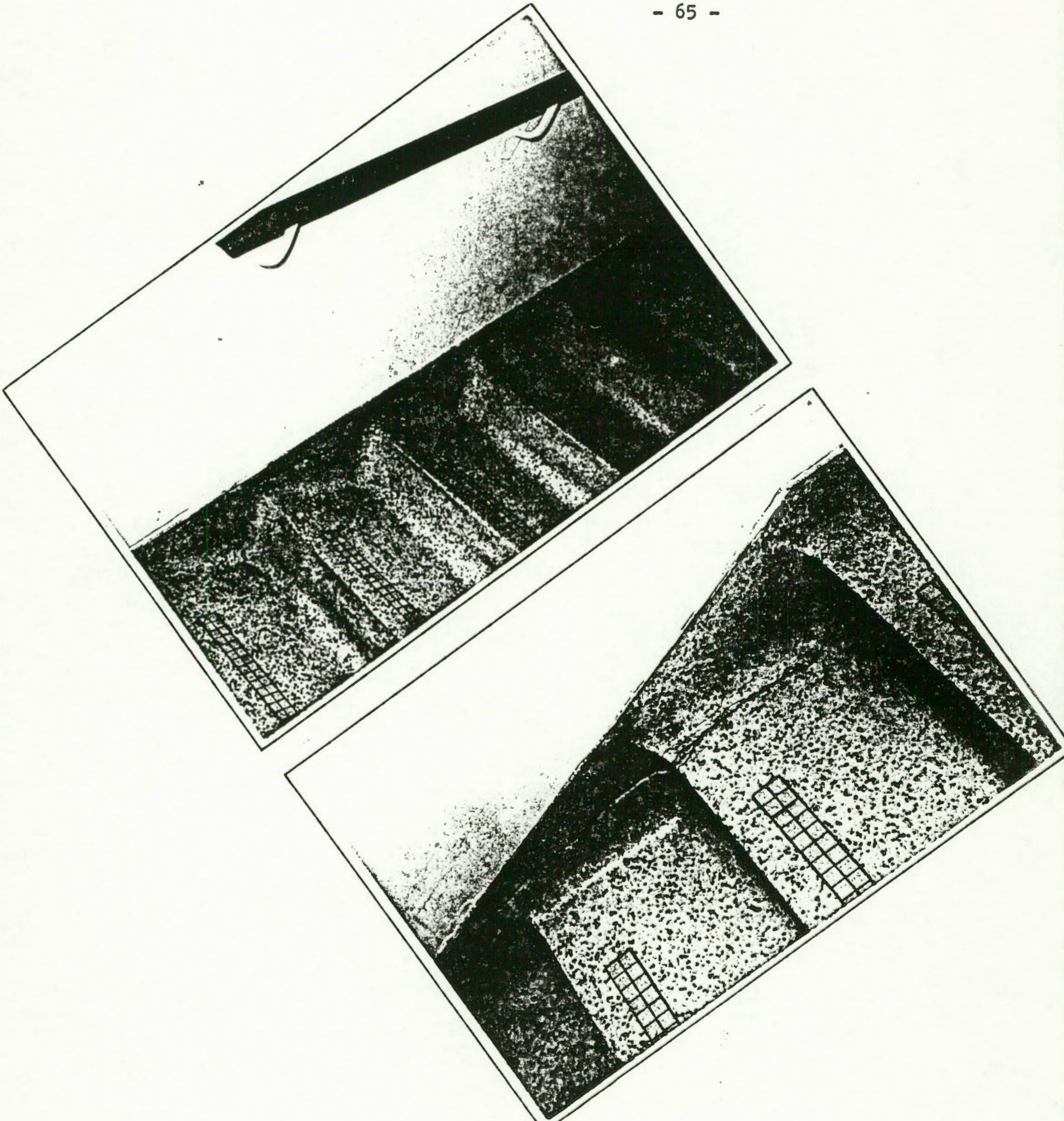


Figure 17.6b Cracking in steps along wall adjacent to the separation joint (between third and fourth floors). Earthquake widened existing cracks.

Senior Citizens' Home, Bathurst

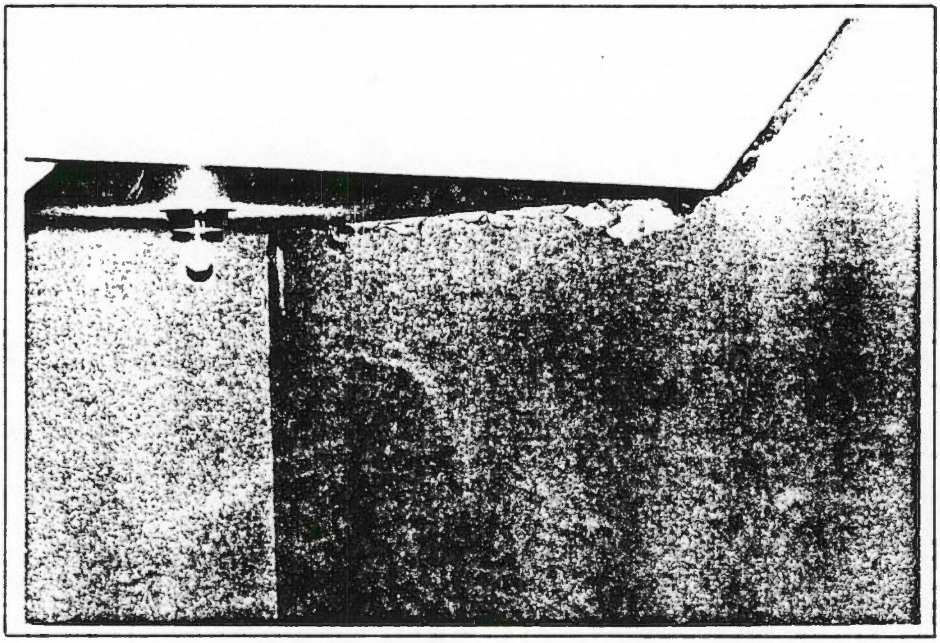
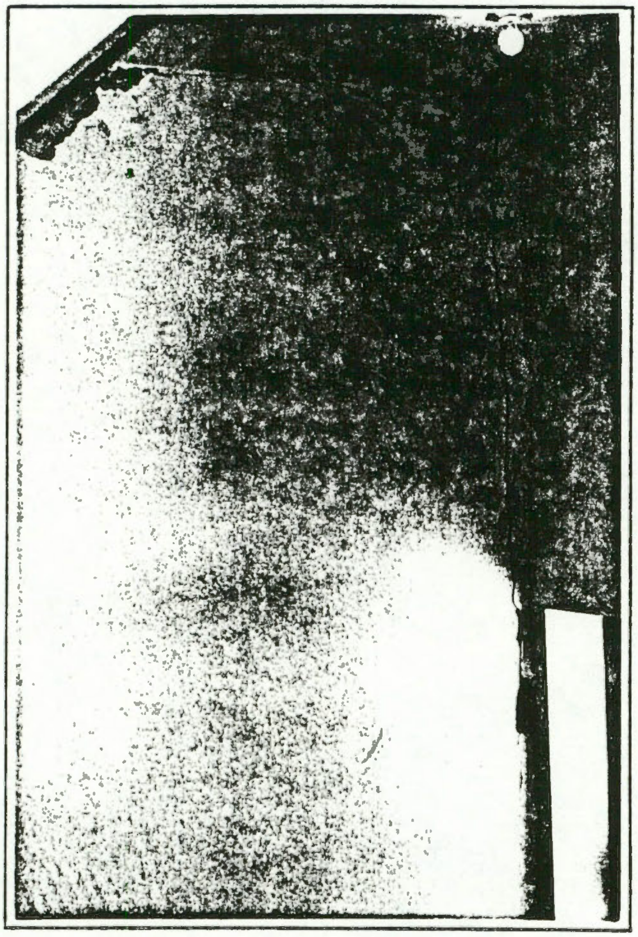


Figure 17.6c Cracking in stairwell wall next to separation joint (first landing between third and fourth floors)

Senior Citizens' Home, Bathurst



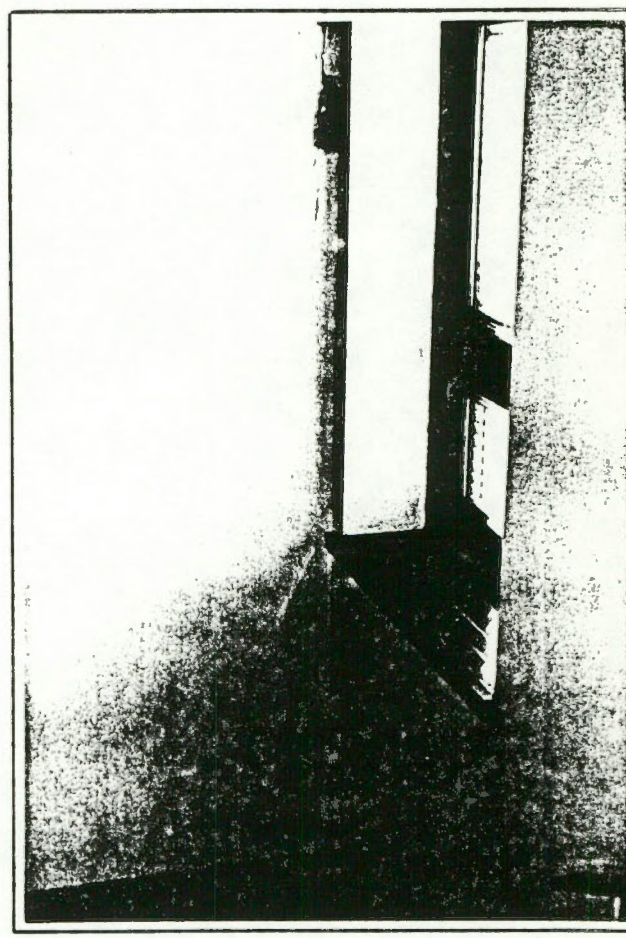


Figure 17.6d Cracking and spalling in stairwell wall next to building separation joint (second landing between third and fourth floors)

Senior Citizens' Home, Bathurst

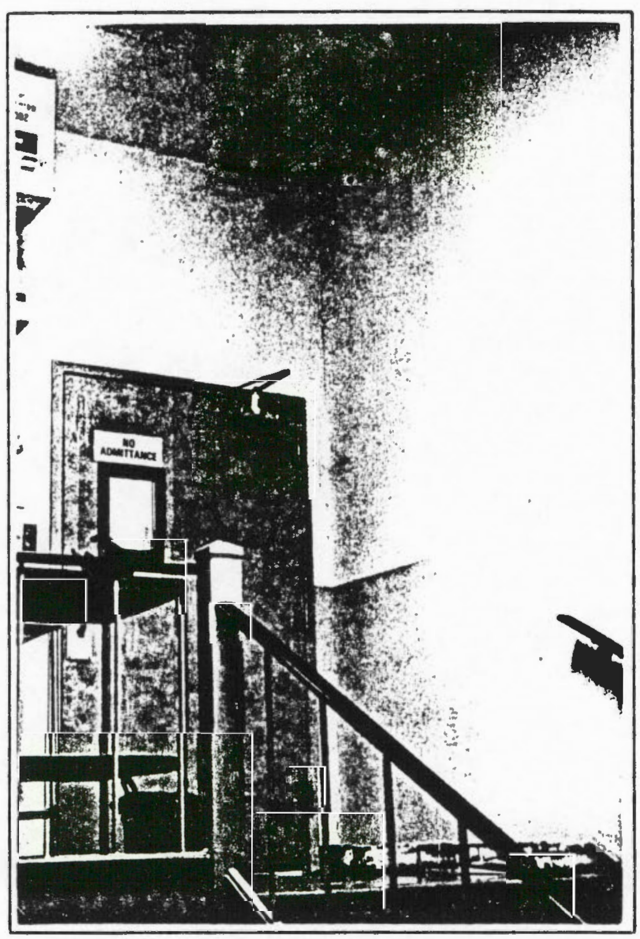
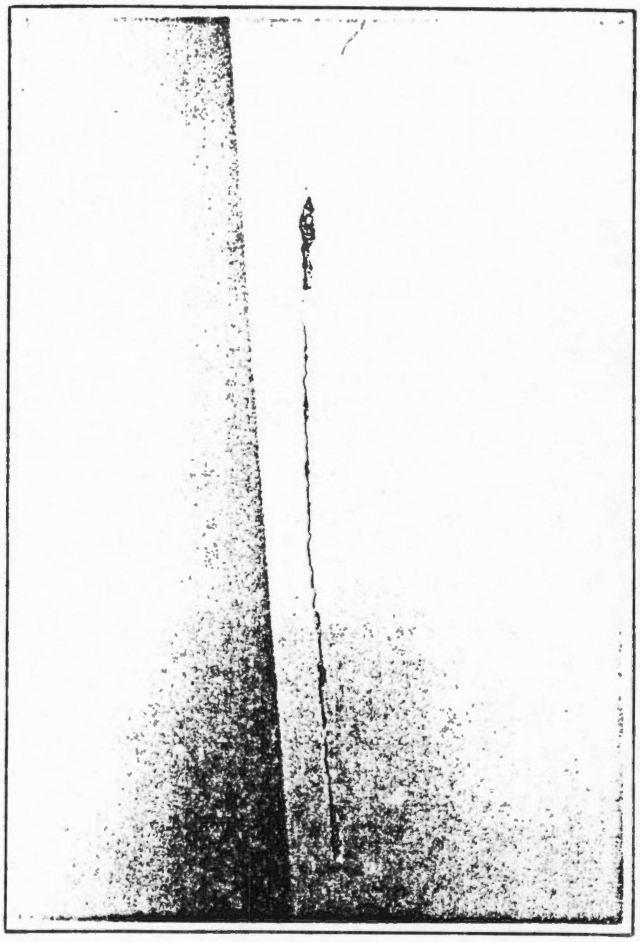


Figure 17.7a Cracking in stairwell (door to the second floor)

Hospital, Perth-Andover



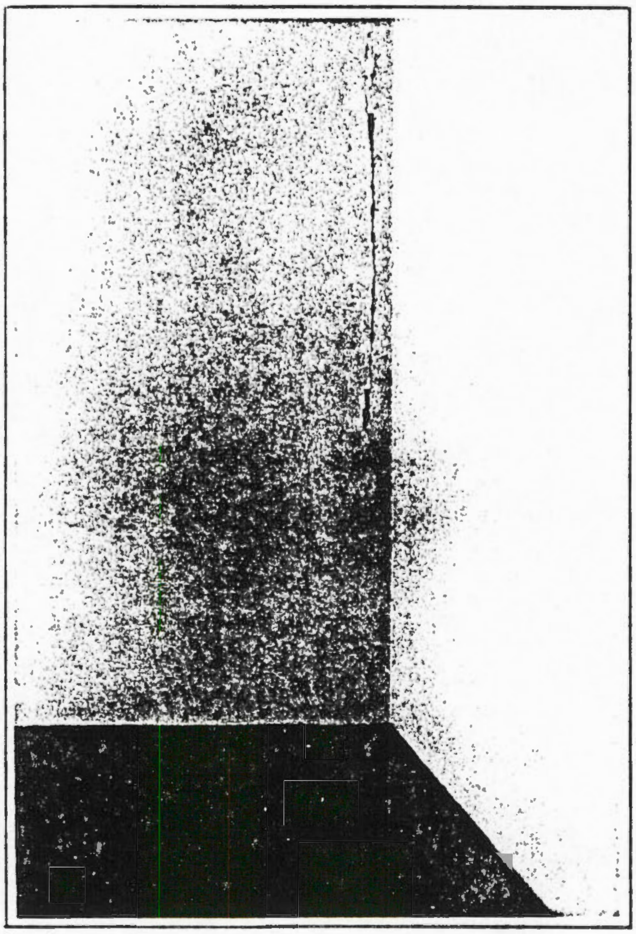


Figure 17.7b Cracking in stairwell wall above first landing.
Hospital, Perth-Andover

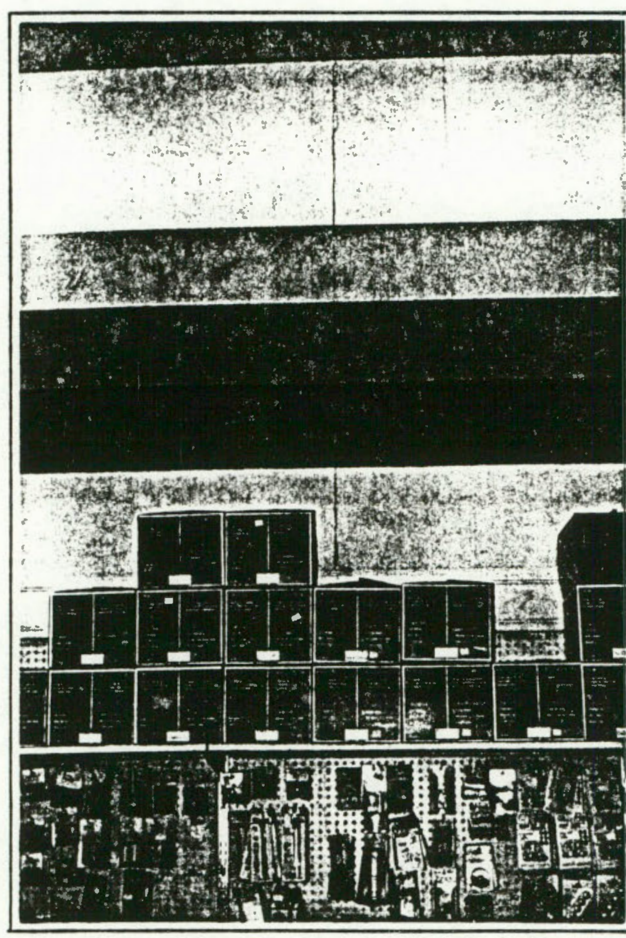


Figure 17.8 Vertical cracks in gyproc

Department store, Chatham

18. EFFECTS OF THE MIRAMICHI EARTHQUAKE IN NORTHEASTERN MAINE AND ADJACENT NEW BRUNSWICK

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INTRODUCTION

"Well, it's very scary. I know I'm glad I wasn't alone in the house when it happened 'cause I didn't know what to do - I just froze. I looked at my husband and said, 'What's going on?' and he said, 'Oh, it must be the snow plow.' And I said, 'No, it's not the snow plow.' And then he said, 'Snow must be coming off the roof', but I said, 'No, it's not that 'cause it's too cold.' And he said, 'I checked the pump in the basement. That was okay.' Then I looked at Ernest and said, 'You don't suppose it could be a tremor?' and never believed you know." (Bristol, New Brunswick, January 9, 1982).

Following the earthquake on the morning of January 9, the office of Walter Anderson, Maine State Geologist, served as a clearinghouse for damage reports from the State Highway Patrol and Civil Emergency Preparedness Agency. As soon as widespread reports of minor damage in eastern Maine were verified, a team was assembled to investigate earthquake effects on the west side of the epicentre in Maine and New Brunswick and to deploy portable seismographs in Maine. The team (W.A. Anderson, P.J. Barosh, G.L. Morrison, M.H. Pease, Jr., and J. Peterson) assembled the next day (January 10) at Presque Isle, Maine, where Dr. William Forbes of the University of Maine, Presque Isle, had collected local information with the considerable aid of Wayne Knight of radio station KCZX.

A survey was made of damage in the region around Presque Isle in northeastern Aroostook County, Maine, and in towns in New Brunswick west of the epicentre (Figure 18.1). Southeastern Aroostook County was investigated by Nancy A. Benn of the Civil Emergency Preparedness Agency and Washington County to the south by Caroline LePage of the Maine Geological Survey. Their observations are not included in this report. Earthquake questionnaires were also distributed throughout the State by the Maine Geological Survey.

This report will present a brief outline of effects in Aroostook County and adjacent New Brunswick. More detailed reports on damage and animal behaviour are in preparation and some follow-up studies are planned. The extremely cold weather, wind and snow cover hampered the investigation and prevented a planned traverse of the epicentral area.

INTENSITY

The earthquake was felt by nearly everyone in northern Maine and adjacent New Brunswick and sent many frightened people out into the streets despite the extremely cold weather. The most common reaction of residents was thinking that their furnace had blown up. The general Modified Mercalli intensity for the region appears to be V. Very little damage was done, but scattered local damage occurred in many towns within a 35-km wide belt through eastern Aroostook County, Maine, which is 90 to 160 km west of the epicentre, and in some towns in New Brunswick, 50 to 100 km west of the epicentre (Figure 18.1).

The epicentral area is forested wilderness with only scattered cabins (Figure 18.2). The reported damage appears to be uniform across the region surveyed without any perceivable increase towards the epicentre. In fact, greater effects were seen in Presque Isle, Maine, at 115 km, than at Plaster Rock, New Brunswick, (60 km), which is the closest town west of the epicentre. Only minor cracks in the roadway occurred at bridges along the Renous highway (Hwy 108) that passes about 17 km south of the epicentre.

TYPES OF DAMAGE

The most common type of damage reported is cracked and disturbed basement walls, and cracks in asphalt roads and parking lots (Figure 18.3). Other types are minor cracks in cinder block (Figures 18.4 and 18.5) and in brick walls and chimneys, broken windows, cracks in corners of plaster walls and molding seams, cracks in ground, loosened stovepipes, minor separation at bridge expansion joints, toppling of a few items from shelves and fallen woodpiles. A few minor fires were reported from loosened stovepipes. These observations are almost all from the main shock on January 9. Only very minor damage was reported from the large aftershock on January 11. There was considerable snow cover when our survey was conducted and more damage may be discovered after the spring thaw.

Many of the houses in the region are old and some of the basement cracks are almost certainly the widening and extension of previously existing ones. The observed road cracks were fresh (Figure 18.3) and only a couple could be ascribed to reopening of older frost cracks. Frost cracks can form from tensional forces in the ground due to rapid freezing. The unusually cold weather, reported to have caused the ground to freeze to a depth as much as 2.3 m at Caribou, Maine, may have created some tension that aided in forming the numerous cracks caused by the earthquake. Most of the observed cracks trend northerly.

OBSERVATIONS IN PRESQUE ILE, MAINE

The local minor damage at Presque Isle, Maine, is typical of the kind listed for the region, and the more major examples show some interesting features. One of the road cracks near Bucks Construction and Masonry Supplies passes under the building resulting in a broken plate glass window, but not in toppling any shelf items (Figure 18.6). The older campus buildings at the University of Maine, Presque Isle, have cracks that radiate from the corners of the buildings through the surrounding asphalt (Figure 18.7). One of the new buildings on campus, Folsom Hall, (Figure 18.8) has hairline cracks around and through cinder blocks (Figures 18.5 and 18.9) cracked seams (Figure 18.10) and cracked glass brick (Figure 18.11) on the third floor of the northeast wing. The walk in front of the Dunkin Donut, in the centre of town, rotated upward on its outer edge enough to break loose some floor tiles and throw the doorway out of alignment. The walk had been previously cracked and repaired.

OTHER EFFECTS

River and lake ice was not generally reported to have been affected by the earthquake; however, it was snow covered. At one place ice was heard to crack during the earthquake and at two other places ice cracks were attributed to the earthquake. A few small ice cracks, along which water squirted out, occurred on the South Renous River at the Renous highway (Hwy 108).

Strange animal behaviour was widely reported. This occurred the night before (January 8) around 10:30-11:30 p.m. E.S.T., shortly before the main shock (January 9) and during the felt earthquakes. A foreshock was recorded by the Weston seismograph network at 11:05 p.m. on January 8 with a magnitude too small to calculate; the threshold level is about magnitude 1.5 . A few reports described the animals as behaving in an unusual manner for three days prior to the earthquake.

The strange animal behaviour included unusually affectionate cats, haywire cats, weird dogs, rabbits not eating, cows refusing to be milked, horses staying out of the stables and a squirrel running and squeaking in an attic. Also "masses" of rabbits were seen on the streets of Presque Isle the night before and locally abundant fresh rabbit and rodent tracks were seen (Figure 18.12). Humans reacted to the earthquake in different ways (Figure 18.13). In addition, there is a report of goldfish that "have just been sitting on the bottom of the tank kinda glup, glup, glup".

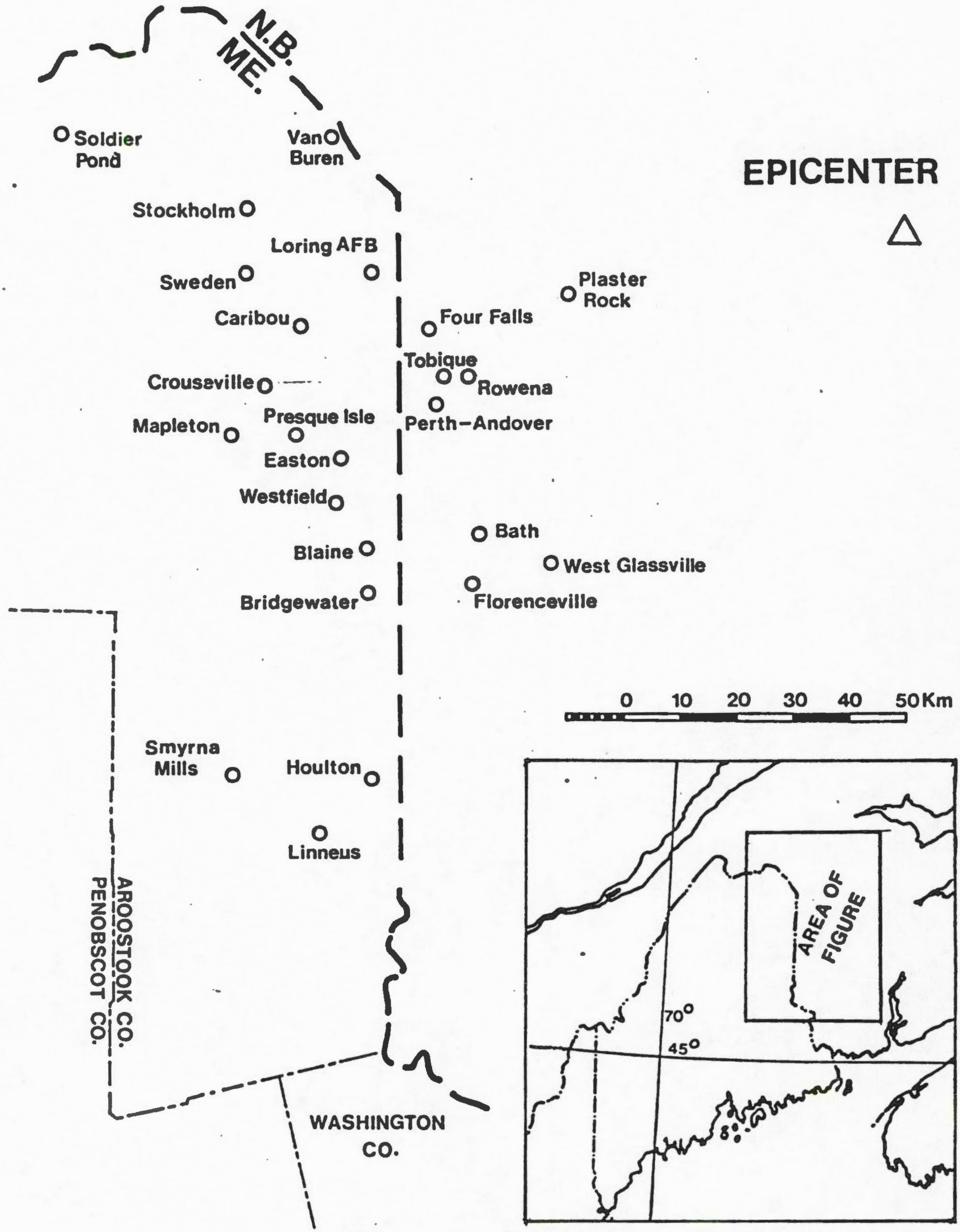


Figure 18.1 Map of northeastern Aroostook County, Maine and adjacent New Brunswick showing towns in which some damage occurred.

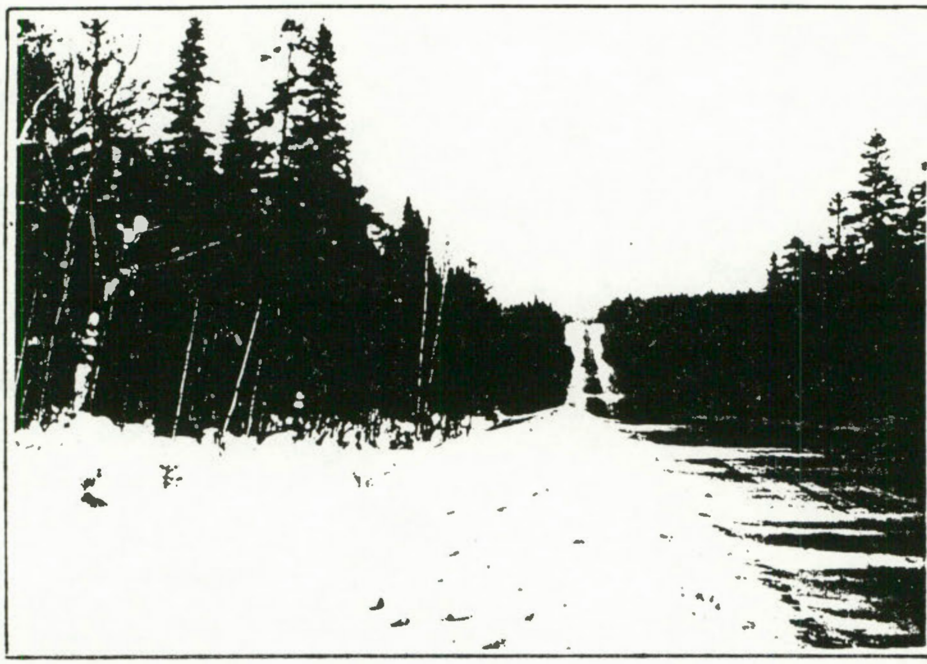


Figure 18.2 View east along Renous Highway 17 km south of the epicentral area in central New Brunswick.

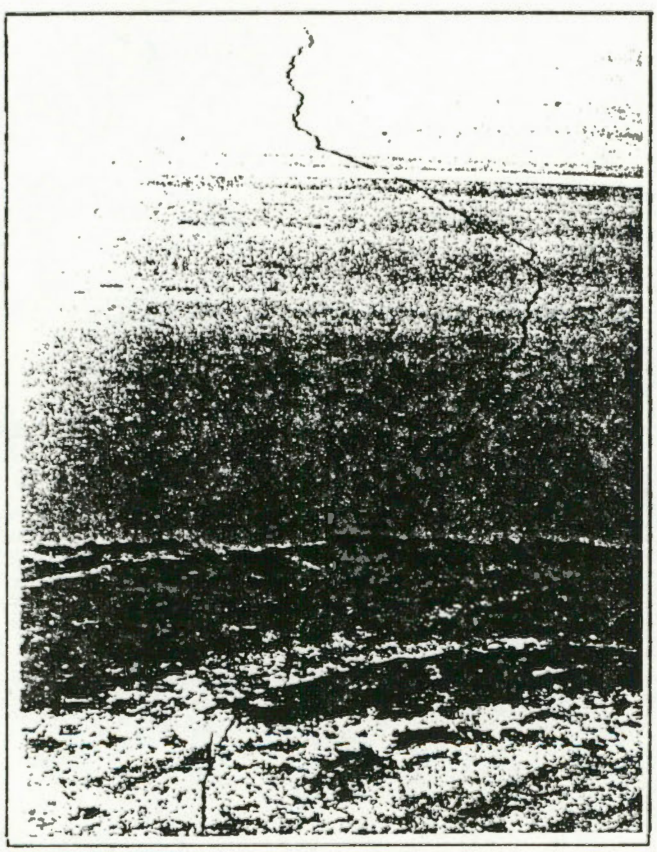
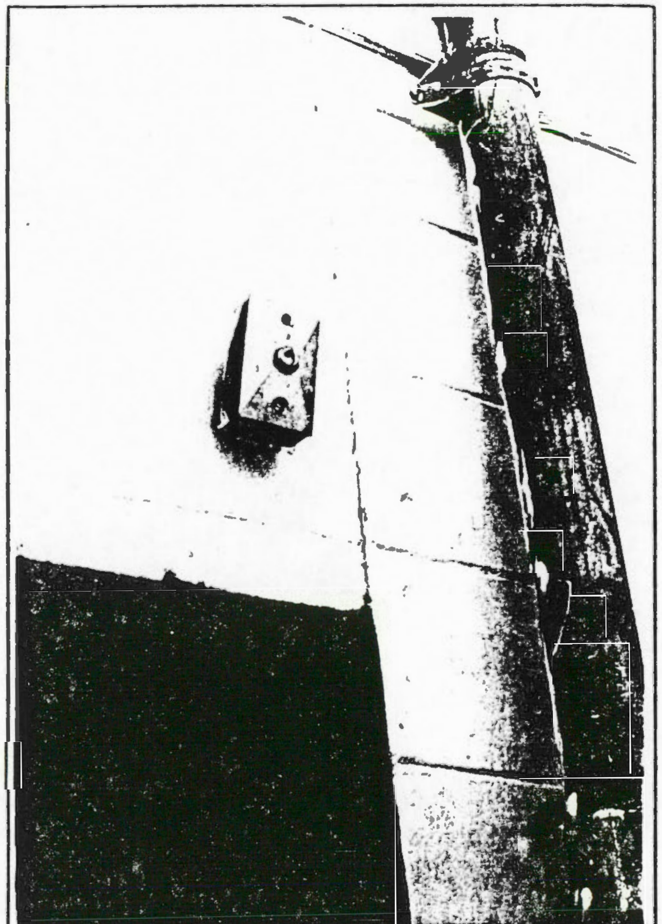


Figure 18.3 Crack across Route 163 near Bucks Construction and Masonry Supplies, Presque Isle, Maine.

4



5

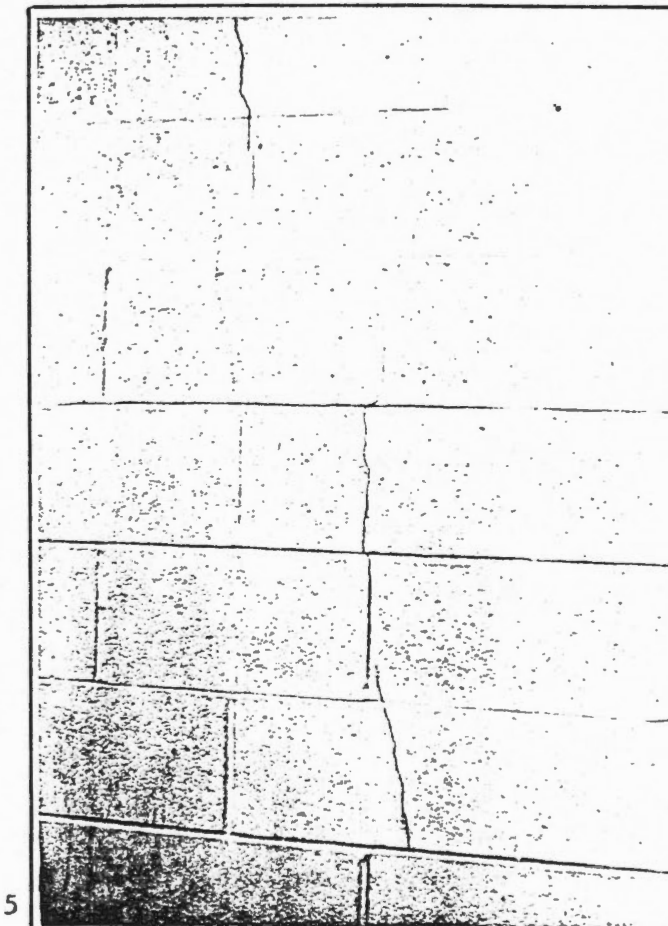


Figure 18.4 Mortar crack in cinder block wall, Dunkin Donut, Presque Isle, Maine.

Figure 18.5 Crack in third floor north wall of the east wing of Folsom Hall, University of Maine, Presque Isle. The upper left crack was present prior to the earthquake but may have been lengthened.

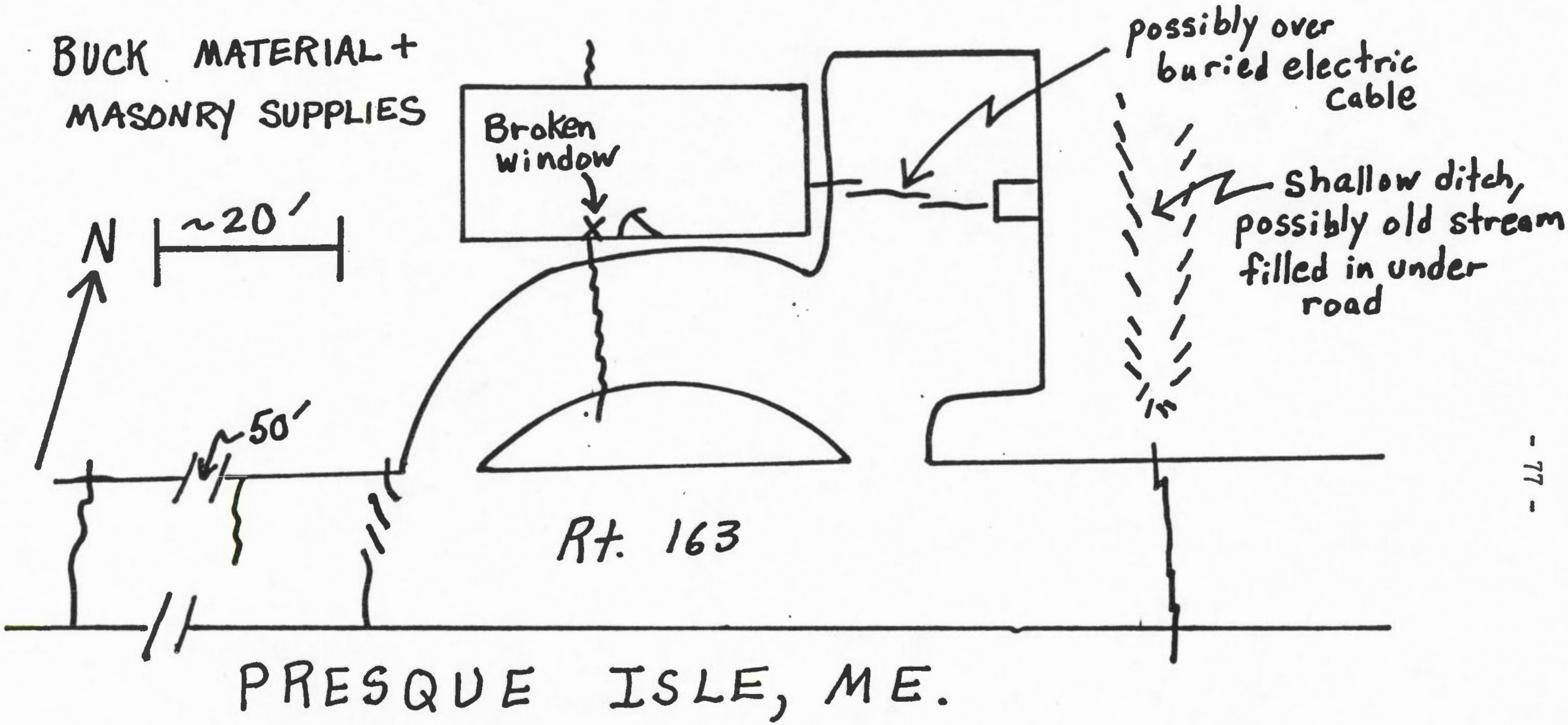


Figure 18.6 Sketch map of the area around Buck's Construction and Masonry Supplies, Presque Isle, Maine, showing damage.

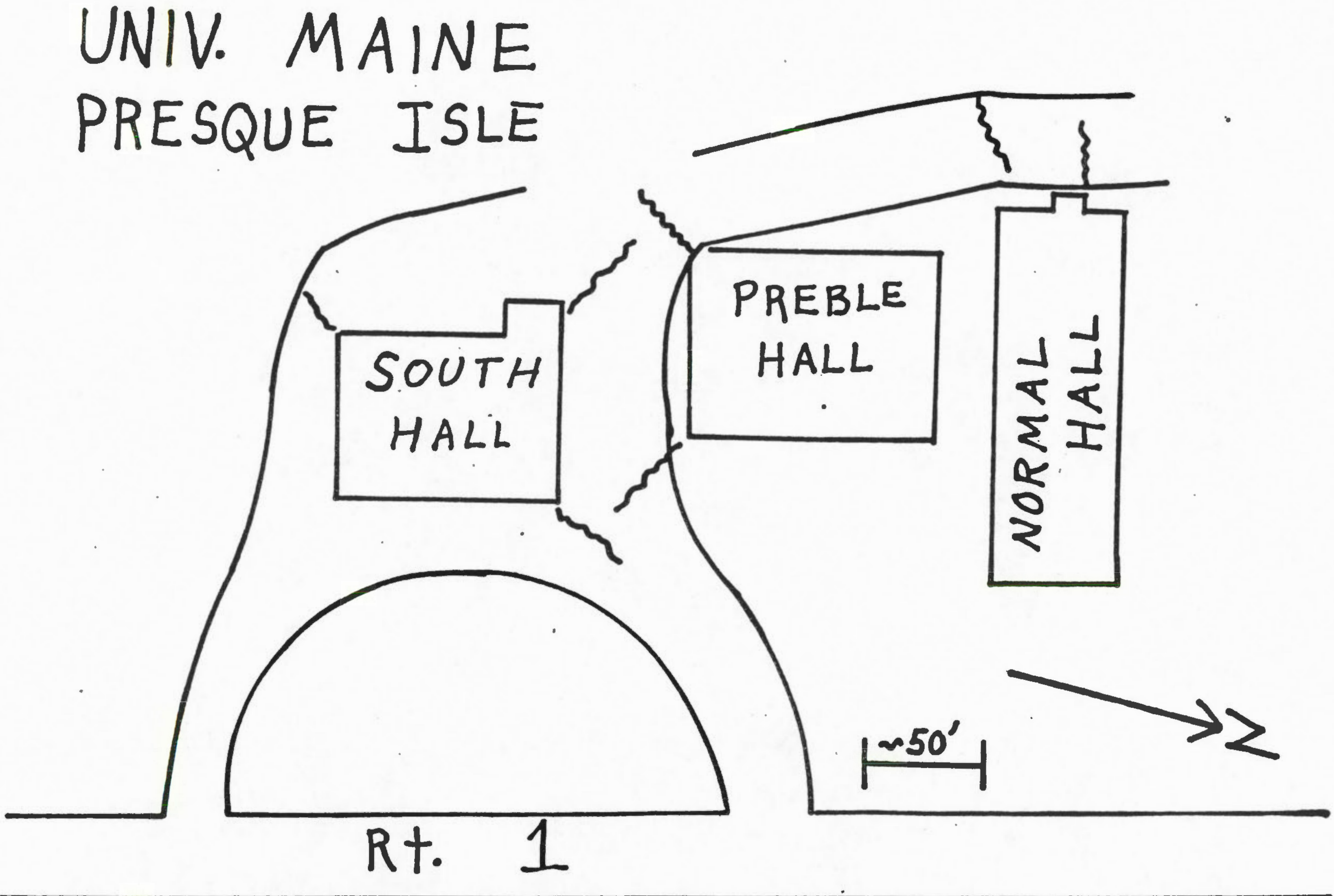


Figure 18.7 Sketch map of part of the University of Maine, Presque Isle, campus, showing cracks.

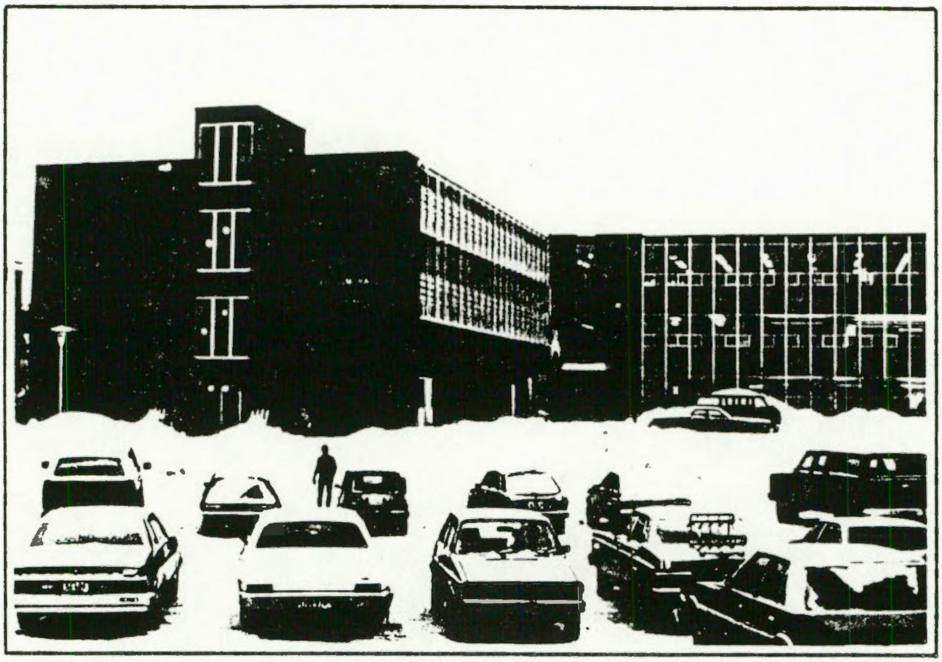


Figure 18.8 Folsom Hall, University of Maine, Presque Isle; view southeast. East wing on the left.

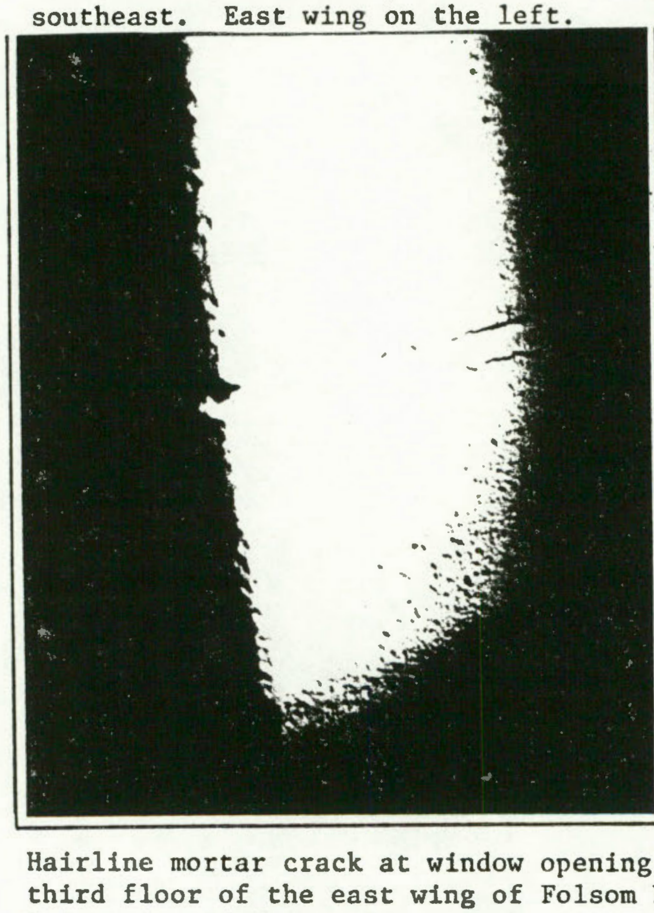
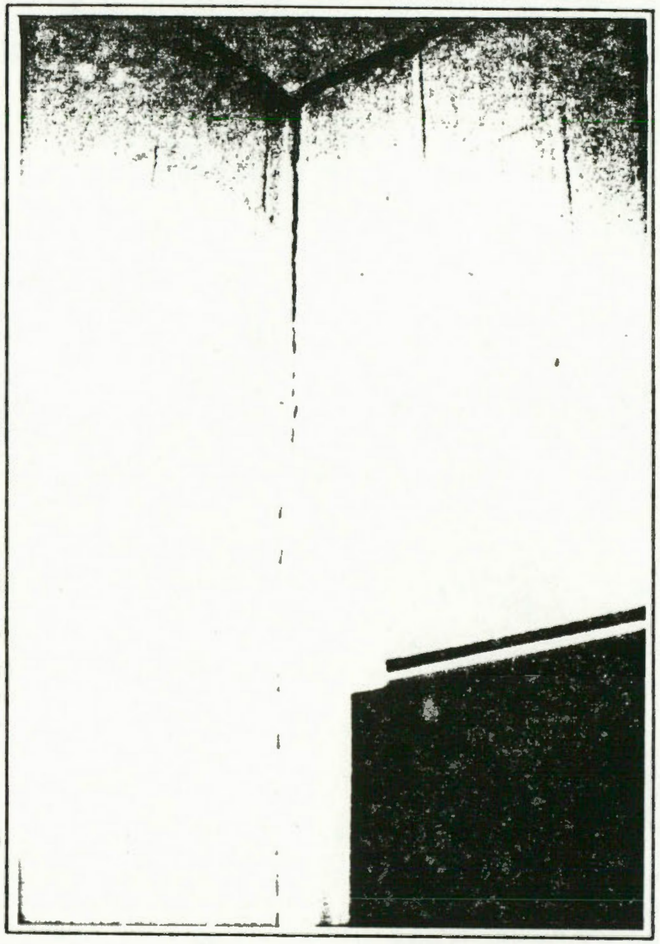


Figure 18.9 Hairline mortar crack at window opening, east side of the third floor of the east wing of Folsom Hall, University of Maine, Presque Isle.

10



11

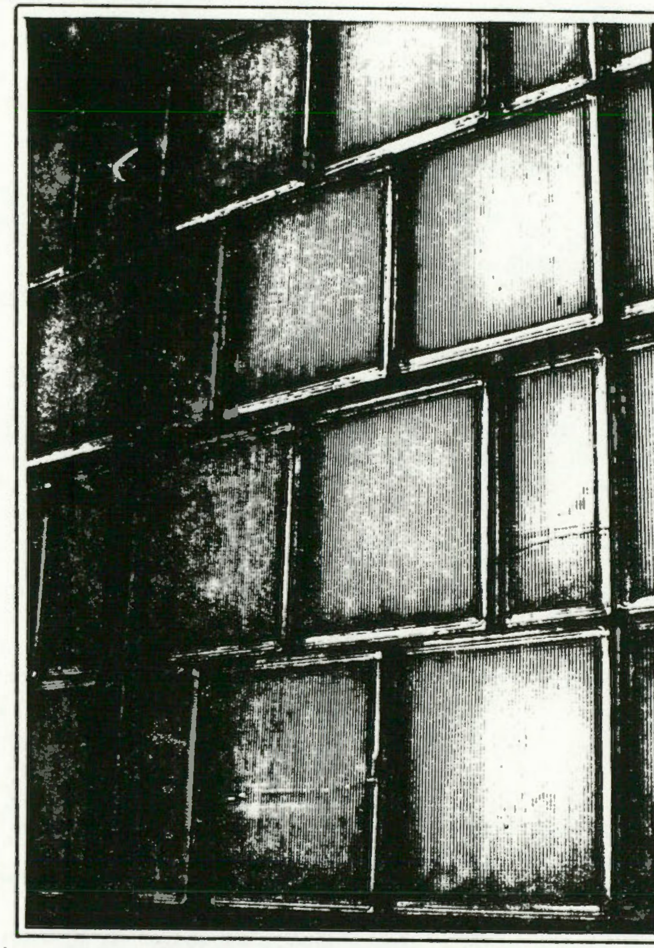


Figure 18.10 Cracked seam in northwest corner of third floor of the east wing of Folsom Hall, University of Maine, Presque Isle.

Figure 18.11 Cracked glass brick above windows on third floor of the east wing of Folsom Hall, University of Maine, Presque Isle.

Figure 18.12 Rodent tracks in snow at south edge of Presque Isle, Maine.

Figure 18.13 Earthquake sale, Fort Fairfield, Maine.

19. REPORT ON THE 1982 MIRAMICHI, NEW BRUNSWICK, EARTHQUAKE

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On January 9, 1982, an earthquake occurred in the central part of New Brunswick. It was reported that the epicentre was around the Holmes Lake area. Energy, Mines and Resources Canada informed my office that a team of seismologists from Ottawa would be arriving in Fredericton, New Brunswick that evening and would be proceeding to the earthquake area. I was asked to accompany them.

As a member of New Brunswick Emergency Measures Organization, my role in the Miramichi earthquake was to co-ordinate existing resources of the Province of New Brunswick, and to offer assistance to the Federal, Provincial and American scientists who were working near the epicentre. Because the earthquake occurred at a time when weather was a problem, it was necessary to ensure that roads were kept clear of snow and that transportation for the scientists was readily available when required. This necessitated contacting many Provincial Departments in the area, such as: Transporation, Natural Resources, and Municipal Affairs, as well as the Royal Canadian Mounted Police who constitute the provincial police force.

It was determined by the seismologists that the epicentre was near Holmes Lake, a remote, wooded, unpopulated area, liberally interspersed by rivers, streams and hills. The epicentre was approximately 100 km west of Newcastle, adding to the already difficult problem of keeping roads clear for daily travel in the area to check on scientific equipment. Unusually frigid temperatures (-20° to -40°C) also caused problems for the scientists and for co-ordination of the effort. It became necessary, to ensure the safety of everyone involved, to place some restrictions on travel from our base at Newcastle to the epicentral area.

Co-operation among everyone concerned made the job of co-ordinating resources much easier. The invaluable assistance of many employees of the Provincial and Federal Government Departments, and the awesome dedication of all the scientists proved to be an invaluable learning experience. I appreciated the opportunity to be on hand.

Since January I have continued to be involved in the co-ordination of scientists who are returning to the earthquake area for further studies.

(The author also wrote a report for the Premier of New Brunswick in late February. This report, which details the activities day-by-day from January 9 to February 5, shows how the field survey gradually expanded from a few Canadian scientists with three seismographs to a joint Canadian-American field project with participation by more than 16 Canadian and 10 American scientists and engineers and by countless employees of the Province of New Brunswick.)

20. THE MIRAMICHI EARTHQUAKES: THE MEDIA RESPOND TO AN INVISIBLE EMERGENCY

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INTRODUCTION

The Miramichi earthquakes of January 1982 in central New Brunswick were not a media event in the sense that the media took something otherwise unnoticed and played it up. They were, however, a media event in a number of other ways. Almost as soon as the first earthquake was over, there was a public demand for information and the media, especially radio, largely satisfied that demand. Not only that, there was a demand for specific information from emergency agencies such as fire, police and the provincial Emergency Measures Organization (EMO). The news media satisfied that demand as well. And, most important, the media, in satisfying these demands, used editorial discretion. They decided what version of the event would be disseminated and which sources would be used.

Why were the news media, especially radio, so important? One reason was that the official agencies - fire, police, EMO - found themselves frustrated. Since the earthquakes caused little damage and no injuries, these agencies had nothing to respond to. They had to deal with an information emergency, in a sense, an invisible emergency. They were not well-equipped to do that, but the media were. Equally important, while the emergency agencies, especially the provincial EMO and the federal Emergency Planning Canada (EPC) had difficulty communicating, the media did not. They worked smoothly together in meeting the demands for information.

When the first Miramichi earthquake occurrred on Saturday, January 9, some persons in New Brunswick realized almost immediately what was happening. They had experienced the noise and vibration of an earthquake elsewhere: in the Queen Charlotte Islands off Canada's west coast, in eastern Ontario during the forties, overseas during World War II. Others recalled the last earthquakes easily felt in New Brunswick, in 1925 and 1929.

Most persons, however, were caught unawares. Even if they had had earthquake experience, they needed time to apply it. Persons checked their furnace or an electrical appliance. They looked outside for a snowplow, truck or train or looked overhead for a jet. Having exhausted these possibilities, they either deduced what had happened or, more likely, asked someone. They also turned on the radio.

The immense amount of interpersonal activity that follows any unexpected event is called convergence. In some parts of New Brunswick, its effects were very clear. In Bathurst, for example, it was sufficient to "busy out" all downtown telephone exchanges for half an hour. It caused similar problems in parts of suburban Fredericton.

The first earthquake, therefore, triggered a massive search for information. This study is about that search for information and its effects. It is based on research conducted by the Emergency Communications Research Unit (ECRU) of Carleton University during the two weeks following the two most severe earthquakes. (The unit, which is funded by the federal crisis agency, Emergency Planning Canada, had been on stand-by since the autumn.) ECRU is an independent research unit which specializes in responding to unexpected events. Since it was formed in 1970, it has completed studies of everything from murders and hostage takings to fires and toxic spills, to snowstorms, a mudslide, a windstorm, a tornado and a building explosion.

METHOD

ECRU's approach to research involves three main thrusts (Scanlon and Taylor, 1977). First, data are collected from a sample of persons in the affected area. Secondly, the original sample interviews are followed up. Thirdly, interviews are done with persons not in the sample, persons drawn from key organizations relevant to the study being done.

ECRU researchers from Ottawa went to New Brunswick four days after the first earthquake and began to interview 60 people chosen at random in each of Plaster Rock, Bathurst and Fredericton. The selection of these communities and the original sample size were, of course, to some extent arbitrary. The village of Plaster Rock was selected because it is quite small (population just 1,201) and because it was the community closest to the earthquake's epicentre. It was assumed that any major problems would have occurred in that area. Bathurst, a small city northeast of the epicentre, was selected because it is a somewhat larger community (15,586 persons) and because its population - a mixture of English and French - gives it a different flavour. Fredericton (population 42,333) was selected because it was south of the epicentre and, as the provincial capital, offered a prospect for examining a different style of community. (It would have been necessary to do a number of the follow-up interviews in Fredericton in any case.)

RESULTS - INITIAL INTERVIEWS

The preliminary results from interviews in the three communities show the interpersonal communication. In all three communities, many persons had

Summary of Initial Interviews

How Information Was Acquired	Plaster Rock	Bathurst	Fredericton
Knew from experience	13.8%	10.5%	6.5%
Figured it out	19.0	31.6	11.5
Heard on radio	20.6	28.1	36.0
Heard from someone	44.8	28.1	42.6
Other	1.7	1.7	3.3

experience or figured it out or turned on the radio. But on the whole, learning from someone else was the most common way of finding out that an earthquake had occurred.

These figures are somewhat misleading. They don't show where the person who told someone got his or her information. Were, for example, the experienced people informing everyone else? Or did the word get around some other way?

RESULTS - FOLLOW-UP INTERVIEWS

ECRU traced all interpersonal connections to the ultimate source, sometimes adding as many as three extra interviews per sample point. (The tracing generated 163 additional interviews.) The results below suggest that radio is generally the most significant ultimate information source.

Summary of Initial plus Follow-up Interviews

Ultimate Source of Information	Plaster Rock	Bathurst	Fredericton
Someone with experience	20.7%	14.0%	8.2%
Someone who deduced	31.0	45.6	18.0
Radio	46.5	38.6	70.5
Other	1.7	1.8	3.3

RESULTS - NON-SAMPLE INTERVIEWS, INCLUDING MEDIA RESPONSE

The above figures still don't show where people went to confirm what they knew. (It was usually radio.) They also don't show what the emergency agencies were doing. To answer this latter question, ECRU also did non-sample interviews with officials in all three communities and with persons outside New Brunswick. (This meant 150 to 200 more interviews.)

Because there was no injury and no severe damage, agencies such as fire, policy or Emergency Measures, found themselves with nothing to respond to. Yet, in many cases, they received calls asking for information. Usually in emergencies they can answer such calls. This time they couldn't. They had no specific information and they had no scientific expertise. More important, they had no connections to such expertise. Like everyone else, they found themselves listening to the radio. In several places, after a while, they started telling callers: listen to the radio. In Bathurst the fire and police chiefs even went to the radio station to look at the news wires themselves.

In some ways, this process might seem unimportant; in fact, it is not. Emergency agencies which can't supply emergency-related information lose credibility if it appears they should be able to. The media would hardly expect scientific information from the fire or police departments. They would expect such data from the Emergency Measures Organization (EMO). EMO was therefore temporarily damaged to some extent because of its inability to get such information.

What happened? First, following the initial earthquake, the media individually and on a co-operative basis latched onto persons with expert knowledge. They called the U.S. National Earthquake Information Service in

Golden, Colorado, talked to Energy, Mines and Resources (EMR) in Ottawa and made contact with scientists at the University of New Brunswick in Fredericton. As soon as they got information - the magnitude of the earthquake and its epicentre - they reported it and passed it on to other media via the co-operative Canadian Press news agency. They were effective, fast and coordinated because they had previously established an on-going relationship with the key earthquake information sources.

While this was happening, the major emergency agencies, the provincial EMO and federal EPC, were not communicating. (There were a number of problems.) Not only that, neither agency made effective contact with the scientists at EMR until later on Satuday. The emergency agencies, therefore, were left behind because some of their emergency communications methods had not been tested regularly.

CONCLUSIONS

These findings are still preliminary; the detailed analysis is yet to come. (It includes data on the reaction to the large earthquake on Monday afternoon, January 11.) Despite their preliminary nature, however, the findings were sufficient for the two key emergency agencies, Emergency Planning Canada (the federal agency) and the Emergency Measures Organization (the provincial agency) to revise the way they communicate both with each other and with the scientists at EMR.

Information is important in emergency situations. The inability to acquire it and/or disseminate it can seriously affect the status of an emergency response organization.

REFERENCE

Scanlon, J. and Taylor, B., 1977. A stand-by research capacity, Mass Emergencies, 2, 35-41.

(The author, together with Kim Dixon and Scott McClellan, wrote a much more detailed paper with the same title for presentation in August 1982 at the World Congress of Sociology, Mexico City, Mexico.)

21. AN EXAMINATION OF THE DRY WELL PHENOMENON IN NORTHEASTERN NEW BRUNSWICK, WINTER 1982

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In early February 1982, the Water Resources Branch began receiving reports of water wells going dry in northeastern New Brunswick, largely in the area northwards and eastwards from Newcastle, within the area bounded by 46.6°N to 47.8°N and by 64.7°W to 65.7°W. A total of about 220 instances were reported up until the end of March.

The winter of 1981-81 was consistently cold with negligible melting of snow and no rain to recharge the groundwater system, although total precipitation was about average. Normally, a significant mid-winter thaw occurs sometime in January or February, often with rainfall. However, from mid-December 1981 until mid-March 1982, a period of three months, virtually no water from rain or melted snow penetrated the ground.

The occurrence of earthquakes in central New Brunswick on 9 and 11 January has been cited by many as the cause of the dry wells, despite the fact that the affected area lies from 60 to 150 km east and northeast of the epicentral region. The Groundwater Section of the Water Resources Branch, N.B. Department of the Environment, has maintained that below-average groundwater levels, which resulted from very low recharge in the affected area during the winter, are largely responsible for the problems, without discounting the possibility of a contributory effect by the earthquakes.

Data have been gathered from conversations with owners of private wells, generally shallow, and from continuously-monitored water-level recorders in some deep observation wells. These data are being analyzed and a detailed report will be issued.

22. DIGITAL DATA AVAILABLE FROM THE EASTERN CANADA TELEMETERED NETWORK FOR MIRAMICHI EARTHQUAKES

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Earth Physics Branch
Energy, Mines and Resources Canada
Ottawa, Canada K1A OY3

The Eastern Canada Telemetered Network (ECTN) has recorded several hundred Miramichi, New Brunswick, aftershocks with magnitudes ranging from 5.4 to slightly less than 1.0 and with epicentral distances from 25 to 1000 km. The smaller aftershocks are recorded only within New Brunswick. Figure 22.1 shows the ECTN configuration at the beginning of 1982.

In late January a station was added at McKendrick Lake, New Brunswick, about 25 km southeast of the active area (see KLN, Figure 3.3 of Wetmiller). Subsequently, a station was opened at Hauterive on the north shore of the St. Lawrence River, south of Manicouagan, and some changes have been made further west in Ontario.

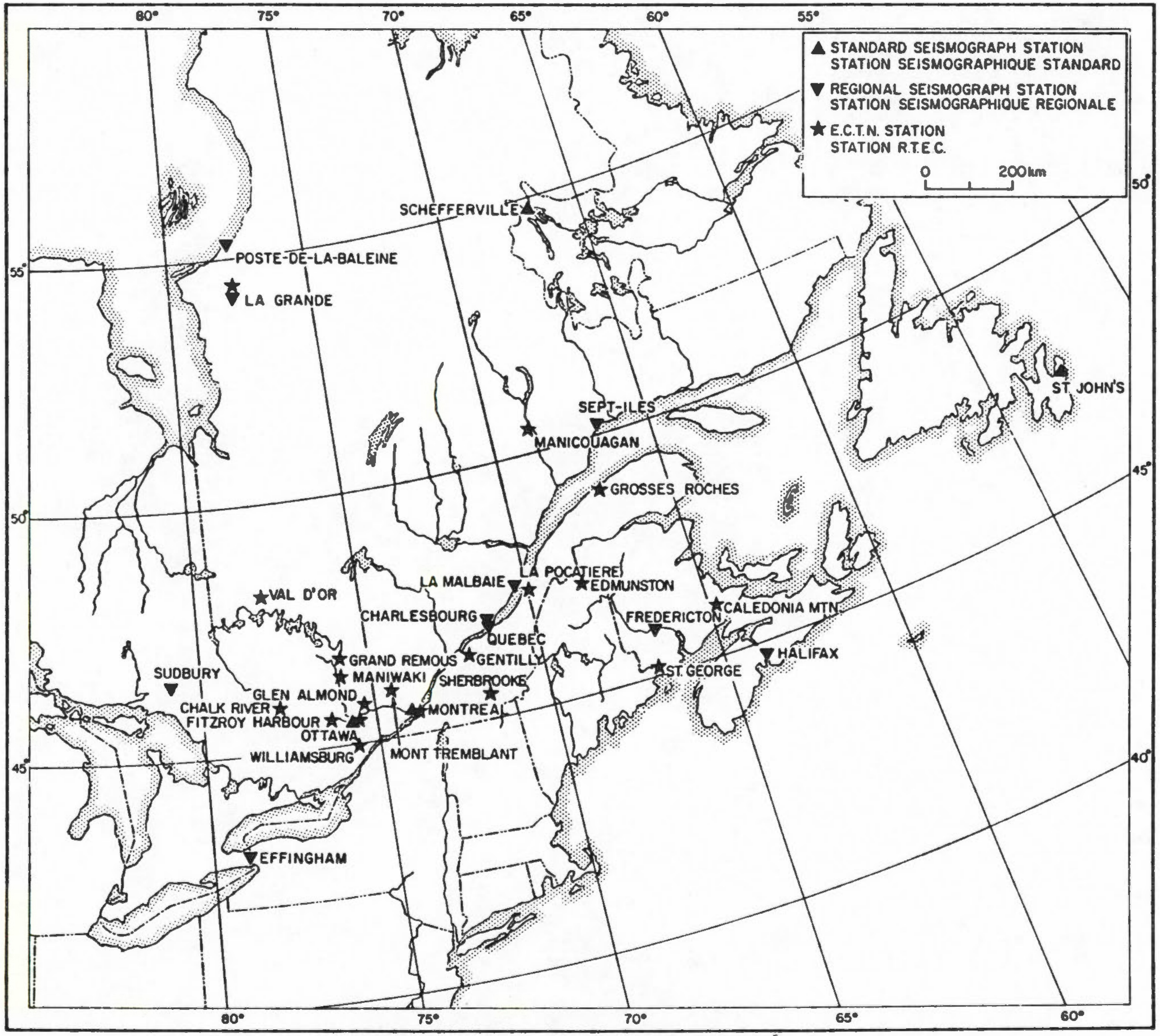
Each ECTN station except GAC includes a short-period vertical seismometer whose data are digitized at 60 samples/second and sent via telephone and/or radio link to Ottawa for recording. The Glen Almond (GAC) station consists of a modified SRO borehole seismometer whose three short-period components are digitized at 30 samples/second. Digital data from all ECTN stations are saved whenever a trigger occurs at any station. Further details on outstation components and digital data processing at the central recording laboratory in Ottawa may be found in Shannon et al. 1982.

The 1982 Miramichi digital event files begin on 09 January at 17:09 UT and include about 180 aftershocks during the rest of January. Due to a system malfunction, the ECTN had ceased to trigger several hours prior to the main shock at 12:53 on 09 January, although continuous analogue records are available for some of the stations. Eight months after the main shock, digital aftershock data are still being acquired almost daily.

Copies of any of these aftershock digital files may be obtained by contacting the author at the address above or at 613-995-5399. A charge is made for accessing and copying digital data. (Digital event files are also available for many other earthquakes recorded by the ECTN since 1974.)

REFERENCE

Shannon, W.E., Halliday, R.J., Schieman, D.R.J. and Munro, P., 1982. Canadian seismograph operations -1981/Annuaire séismographique du Canada - 1981. Seismological Series, Earth Physics Branch, no. (in press).



EASTERN CANADA TELEMETERED NETWORK - 1981
and other stations

Figure 22.1

23. ABSTRACTS OF PAPERS PRESENTED AT A SPECIAL SESSION ON NEW BRUNSWICK EARTHQUAKES HELD ON APRIL 19 DURING THE 1982 ANNUAL MEETING OF THE SEISMOLOGICAL SOCIETY OF AMERICA IN ANAHEIM, CALIFORNIA

INTRODUCTION

The 1982 Miramichi earthquakes began just one week before the abstract deadline for the annual meeting of the Seismological Society of America (SSA). It soon became apparent that this seismic activity was the most important to have occurred in eastern North America in several decades, both in terms of the number and the magnitude of the aftershocks, and in terms of the number of Canadian and American agencies who were participating in the field investigations.

Following a suggestion by Dr. Nafi Toksos of the Massachusetts Institute of Technology, Dr. Michael Berry of the Earth Physics Branch requested a special session on New Brunswick at the SSA annual meeting. The programme organizers graciously agreed to add a special session and ignore the abstract deadline. Since most of the abstracts were submitted too late for printing in the official programme (Earthquake Notes, vol. 53, no. 1), they are reproduced below. All the authors stressed that results presented in the abstracts and oral papers were preliminary due to the relatively short time (four months) between the onset of significant seismicity and the SSA annual meeting.

The abstracts are presented below in the same order in which the corresponding papers were read at the meeting.

THE MIRAMICHI, NEW BRUNSWICK, EARTHQUAKE SEQUENCE OF JANUARY 1982

1. FIELD INVESTIGATION AND HYPOCENTRAL DISTRIBUTION

WETMILLER, R.J., Earth Physics Branch, Energy, Mines and Resources Canada, 1 Observatory Crescent, Ottawa, Canada K1A OY3.

A magnitude m_b 5.7 earthquake took place in the Miramichi region of New Brunswick, Canada on 09 January 1982 at 12:53 U.T. and was followed by an extensive series of aftershocks. The Earth Physics Branch of the Department of Energy, Mines and Resources (Canada) conducted field studies of the aftershocks from 10 January to 06 February in cooperation with the U.S. Geological Survey (Menlo Park), the Massachusetts Institute of Technology, the Lamont-Doherty Geological Observatory, the State University of New York and the Bedford Institute of Oceanography. Twenty-nine separate recording sites, at epicentral distances from 1 to 110 km, were occupied with a variety of instruments including 28 seismographs (15 MEQ's, 8 DR-100's, 3 OBS's, 1 RMS and 1 ECTN station) and 14 accelerographs (4 DR-100's, 3 TerraTech's and 7 SMA's). Several hundred aftershocks, the largest magnitude m_b 5.4, occurred during the field survey and useful records were obtained by all the instrument types. In particular, the survey produced good multi-station digital records in both velocity and acceleration of at least 12 aftershocks, the largest magnitude m_b(Lg) 3.5, at distances less than 10 km, and 3 days of detailed monitoring of the aftershock zone by 3 MEQ's within 10 km. A partial analysis

of one of these day's records shows that 46 aftershocks are concentrated in an area approximately 4 km N-S by 6 km E-W centred near 46° 59'N, 66°36'W with focal depths from 0 to 6 km. Most of the recorders were removed from the field on 22 January, and presently the aftershocks are monitored by the ECTN station and the 7 SMA's all within 25 km.

2. FORESHOCKS AND AFTERSHOCKS OF THE NEW BRUNSWICK EARTHQUAKE OF JANUARY 9, 1982

EBEL, J.E. and VUDLER, Vladimir, Weston Observatory, Department of Geology and Geophysics, Boston College, Weston, MA 02193.

The New England Network of Weston Observatory recorded several foreshocks and numerous aftershocks of the New Brunswick earthquake of January 9, 1982 (at 12:53 UT). The stations in northern Maine (CBM, AGM and HNME), which are capable of detecting events of M_c less than 1.5 in the epicentral area, recorded three foreshocks to the main earthquake: two small events a little less than 9 hours before the main shock and a larger foreshock (M_c = 1.5) just 42 minutes before the main shock. Within 13 hours of the main shock the aftershock activity had decreased to an average of about 2 events per hour, and it continued at this level until the occurrence of the large aftershock on January 11 (21:41 UT). For several days after this event an average of about 10 aftershocks per hour were detected. During the first week after the main shock almost 1000 aftershocks were detected. A small earthquake (M_c = 2.1) was recorded from this general area on September 1, 1977. By comparing the record to similar-sized aftershocks of the 1982 event, it appears that the 1977 shock may have originated in a slightly different location.

3. SOURCE MECHANISM OF THE JANUARY 9, 1982 NEW BRUNSWICK EARTHQUAKE

TOKSOZ, M.N., PULLI, J.J., and NABELEK, J., Dept. of Earth and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, MA 02139.

Abstract not available.

4. AFTERSHOCKS OF THE NEW BRUNSWICK EARTHQUAKE OF JANUARY 9, 1982

PULLI, J.J., HUANG, P.Y. et al., Dept. of Earth and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, MA 02139.

Abstract not available.

5. THE MIRAMICHI, NEW BRUNSWICK, EARTHQUAKE SEQUENCE OF JANUARY 1982: INTENSITY DISTRIBUTION AND HISTORICAL SEISMICITY.

STEVENS, Anne E., Earth Physics Branch, Energy, Mines and Resources Canada, 1 Observatory Crescent, Ottawa, Canada K1A OY3.

Effects in Canada of the larger Miramichi, New Brunswick, earthquakes of 09 and 11 January 1982 have been determined by analysis of:

1. a questionnaire canvas by mail to all communities in the four Atlantic provinces and eastern Québec.
2. on-site engineering inspections of selected public buildings in New Brunswick.
3. a preliminary geologic survey of the epicentral area

4. low-level aerial photography (black & white, and multi-spectral scans) of the epicentral area
5. local newspaper reports.

The two largest events of 09 and 11 January were perceptible at ground level to 350 km in Canada, although not generally felt at these distances, and were noticed in some high-rise buildings as far as 700 km epicentral distance. Maximum observed intensity, experienced up to about 100 km and also including the epicentral region, was Modified Mercalli (MM) V. No structural damage occurred anywhere, although earthquake-induced hairline cracks were confirmed in a few buildings in various communities up to about 100 km epicentral distance.

Non-instrumentally located earthquakes on 22 October 1869 and 21 March 1904 caused isolated minor damage in southern New Brunswick and eastern Maine, compatible with maximum intensity MM VI. Non-instrumentally located earthquakes on 08 February 1855 and 02 July 1922, with maximum intensity MM V, may have occurred in the Miramichi area with magnitude at least 5.0.

6. THE CENTRAL NEW BRUNSWICK EARTHQUAKE SEQUENCE OF 1982: HISTORY, DISTRIBUTION OF INTENSITY AND TECTONIC ENVIRONMENT

DIMENT, W.H., STOVER, C.W., and KANE, M.F., U.S. Geological Survey, Box 25046, Federal Center, Denver, CO 80225.

Based on the historical and early instrumental seismic record as published in studies by W.E.T. Smith in 1962 and 1966 and the most recent results (1975-1981) of the Northeastern United States Seismological Network, the central New Brunswick earthquakes of 1982 appear to be located in a poorly defined northeasterly-trending zone of seismicity that extends from near the Maine border toward Miramichi Bay. The zone is close to the northwestern border of the Northern Appalachian zone as defined by P.W. Basham, D.H. Weichert, and M.J. Berry in 1979. The geological and geophysical expression, if any, of the zone of seismicity will be examined, particularly with regard to maps of gravity and elevation and their derivatives as constructed and reported by R.W. Simpson and others in a 1981 study, and with regard to the distribution of plutonic and volcanic rocks.

Early results of intensity surveys for the main shock (m_b 5.9) of 9 January 1982 suggest an intensity of about VII in the sparsely populated epicentral region and V-VI to about 150 km from the epicenter in New England. It was felt as far west as eastern New York. A preliminary estimate of the felt area is consistent with shocks of similar magnitude in New England and adjacent Canada.

7. SEISMOTECTONICS AND FOCAL MECHANISMS

HASEGAWA, H.S., Earth Physics Branch, Energy, Mines and Resources Canada, 1 Observatory Crescent, Ottawa, Canada K1A OY3.

During a 3-day interval commencing on January 9, 1982, 3 relatively large (magnitudes between 5 and 6) earthquakes occurred in the Miramichi region of New Brunswick in eastern Canada where, previously, the largest reported earthquakes fall in the 4-5 magnitude range. On the basis of preliminary data, well-constrained P-nodal solutions are determined only for the first (and largest) event, the m_b 5.7 earthquake that occurred at 12h53m52s on January 9: one fault plane strikes in an E-W direction with a steep dip to the south and the other, in a N-S direction with an intermediate dip to the west; the deviatoric compression vector plunges gently to the S-E, resulting in appreciable strike-slip and thrust components of relative motion on both planes. Aftershock activity outlines a region with lateral dimensions of 6km x 4km and a vertical extent of 6km at a shallow depth. On the basis of preliminary reports of focal depths, this earthquake sequence is migrating upwards, starting at about 10 km. The epicentral region is undergoing appreciable differential post-glacial uplift, which could generate significant shear stresses that could be a causative factor in generating this earthquake sequence. The presence of the Gaspé (free-air gravity anomaly) high to the north of the epicenter could effect gravitationally-induced stresses in the hypocentral region. The strong correlation between earthquake occurrence and a preliminary estimate of (solid earth) tidal stress implies the possibility of uniformly oriented weakened zones, such as an en echelon pattern in the epicentral region. If this is the case, then the ambient tectonic stress field is normal to the trend of the Appalachian fold belt.

8. TELESEISMIC STUDY OF THE CENTRAL NEW BRUNSWICK EARTHQUAKE OF 9 JANUARY 1982

CHOY, G.L., DEWEY, J.W., NEEDHAM, R.E., SIPKIN, S.A., and ZIRBES, M.D.,

U.S. Geological Survey, MS 967, Box 25046, Federal Center, Denver, CO 80225.

The New Brunswick earthquake of 9 January 1982 ($m_b = 5.9$) was well recorded at teleseismic distances. P-wave first motions indicate that the focal mechanism was characterized by one nodal plane that strikes N87°E and dips 70°S. The orientation of the other nodal plane is not well constrained by the data that are now available to us. A significant component of reverse faulting is required by presently available data; a significant component of strike-slip motion is also permitted, but not required by the data. We will attempt to obtain a more definitive focal mechanism by inverting P-wave amplitudes. We will estimate the focal depth of the main shock by waveform modeling of body waves, and we will use the method of joint hypocenter determination to locate the larger shocks of the aftershock sequence with respect to the main shock.

9. INTENSITY SURVEYS FOR THREE EASTERN NORTH AMERICA EARTHQUAKES IN JANUARY, 1982.

SCHLESINGER-MILLER, Ellyn, BARSTOW, Noel and KAFKA, Alan, Lamont-Doherty Geological Observatory, Palisades, N.Y. 10964.

In January of 1982, three significant earthquakes occurred, two in New Brunswick, Canada and one in New Hampshire. Immediately after each earthquake, we contacted local newspapers and requested the publication of our new earthquake questionnaire, which was devised to be concise (so that the newspeople would print it), and well suited for easy differentiation of intensities in the lower end of the Modified Mercalli scale (MM=I-VII). Returned questionnaires were evaluated according to a scheme that reduces subjectivity and inconsistency in the assignment of Modified Mercalli intensities. We then experimented with three different methods of displaying the assigned intensities on a map. On one we plotted the mode for each town, another, the mean for each town, and the third, the mode for all data that fell within a square of a grid pattern. Although the grid method gives a good general picture of the intensities, it sacrifices resolution and is not as visually informative because one cannot see where there is a lack of data. We feel that the best way of displaying intensity data is by plotting the mode for each town from which there are felt reports.

The New Brunswick earthquakes were felt throughout New England and into eastern New York. The southern boundary of the felt area appears to run through southern Connecticut and Rhode Island to the south, and eastern New York to the west. The New Hampshire earthquake of January 18 (local date) has a maximum intensity of V that surrounds the epicenter. The boundary of the felt area runs through southern Connecticut, central New York, southern Québec and south-central Maine. The preliminary data from the three recent earthquakes indicate that the relationship between their magnitudes and felt areas fits the general trend for eastern North America earthquakes.

10. LOCAL MULTI-STATION DIGITAL RECORDINGS OF THE NEW BRUNSWICK AFTERSHOCK SEQUENCE

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One week after the New Brunswick m_b 5.9 mainshock of January 9, 1982, the U.S. Geological Survey, in conjunction with the Canadian Department of Energy, Mines and Resources, Ottawa, installed 6 digital seismometers at 4 sites in the epicentral region. The instruments were Sprengnether DR-100 event-triggered three-component digital recorders with a sampling rate of 200 samples/s per component. Three instruments were equipped with acceleration transducers (FBA's) and three were equipped with velocity transducers. One velocity instrument was operated for one day in the mode of sampling only the vertical component at 600 samples/s with an anti-aliasing filter at 70 Hz, during which period it recorded a M_L 3.5 aftershock on January 17 located 2 km north of the station.

In the recording period January 15 to January 22, 2 events were recorded on six instruments, 7 events on five instruments, 2 events on four instruments, 5 events on three instruments, and 14 events on two instruments. Since two of the stations had two instruments apiece, one velocity and one acceleration, the above listing of recordings indicates about 15 locatable events. From S-P times, all events appear to be located within the 10 km diameter of the 4-station array. Redundancy of instrumentation at two stations allows the comparison of direct recordings of acceleration and velocity. Peak accelerations exceeding 0.05 g have been recorded on both vertical and horizontal components. Source parameters of the events will be presented and discussed.