GEOLOGICAL SURVEY OF CANADA

OPEN FILE 2369

Eastern Canadian Seismic Studies, July 1989 to June 1990

R.J. Wetmiller, J.A. Lyons, W.E. Shannon, P.S. Munro, J.T. Thomas, M.D. Andrew, S.P. Lapointe, M. Lamontagne, C. Wong, F.M. Anglin, J. Adams, M.G. Cajka, W. McNeil, J.A. Drysdale

1991

Geological Survey of Canada Open–file – 2369

EASTERN CANADIAN SEISMIC STUDIES
July 1989 – June 1990

Prepared by

R.J. Wetmiller, J.A. Lyons, W.E. Shannon,
P.S. Munro, J.T. Thomas, M.D. Andrew, S.P. Lapointe,
M. Lamontagne, C. Wong, F.M. Anglin, J. Adams,
M.G. Cajka, W. McNeil and J.A. Drysdale

Geophysics Division
Geophysics and Marine Geoscience Branch
Geological Survey of Canada
Department of Energy, Mines and Resources
Ottawa, Ontario
K1A 0Y3
CANADA

January 1991

ABSTRACT

Earthquake activity and the operation of digital seismograph stations in south–eastern Canada during the one–year period from July 01, 1989 to June 30, 1990 are described. The Geophysics Division of the Geological Survey of Canada operated a network of 19 telemetered seismograph stations (ECTN) from eastern New Brunswick to eastern Ontario as well as two autonamous local telemetered networks: one in the Charlevoix region of Québec (CLTN: six 3–component stations) and the other in the Sudbury region of Ontario (SLTN: three single–component stations). The Division also operated a network of 19 strong–motion accelerographs centred around the Charlevoix region of Québec. Analysis of the seismic data was carried out in the earthquake datalab at the Geophysics Division in Ottawa using dual PDP 11/73 computers for acquisition, a VAX 11/750 computer for archiving, a MicroVAX II computer for seismicity analysis and display and a SUN 4/280 computer as a database server. In the area covered by the report there were 234 earthquakes documented, 23 were magnitude 3.0 or greater. Eighteen of the earthquakes were reported felt. The largest event onshore in southeastern Canada was a magnitude 4.0 event in western Québec, north of Ottawa, on November 16, 1989. The first surface fault break from an earthquake in Canada was found in extreme northern Québec by a Geophysics Division field party in July, 1990. The 5.5 km surface rupture was caused by a magnitude 6.2 earthquake on December 25, 1989.

RÉSUMÉ

L'activité séismique du sud–est du Canada, ainsi que l'opération des stations numériques séismiques sont décrites pour la période d'un an allant du 1^er^ juin 1989 au 30 juin 1990. La Division de la géophysique de la Commission géologique du Canada, a établi un réseau de 19 stations séismographiques télémétrées (RTEC) de l'est du Nouveau-Brunswick à l'est de l'Ontario. De plus, elle a établi deux réseaux locaux autonomes: un réseau dans la région du Charlevoix au Québec (RTLC : six stations de 3 composantes) et un réseau dans la région de Sudbury en Ontario (RTLS: 3 stations à une composante). La Division a aussi établi un réseau de 19 accélérographes pour l'enregistrement des mouvements forts, centré sur la région de Charlevoix au Québec. Au centre d'analyse de la Division de la géophysique à Ottawa, l'analyse des données séismiques a été faite en utilisant deux ordinateurs PDP 11/73 couplés pour l'acquisition des données, un ordinateur VAX 11/750 pour l'entreposage des données, un ordinateur MicroVAX II pour l'analyse et la graphie séismiques et un ordinateur SUN 4/280 pour servir de base de données. Dans la région couverte par ce rapport, 234 tremblements de terre sont décrits, dont 23 d'une magnitude égale ou supérieure à 3.0. De ces 234 tremblements de terre, 18 ont été ressentis. Sur la partie continentale du sud-est du Canada, le plus grand évènement a été de magnitude 4.0 dans l'ouest du Québec, au nord d'Ottawa, le 16 novembre 1989. La première rupture de la surface provoquée par un tremblement de terre jamais trouvé au Canada a été trouvée dans l'extrême nord du Québec par une équipe de terrain de la Division de la géophysique en juillet 1990. La rupture mesurait environ 5.5 km et a été produite par un tremblement de terre de magniture 6.2, enregistré le 25 décembre 1989.

CONTENTS

FIGURES

TABLES

EASTERN CANADIAN SEISMIC STUDIES

July 1989 – June 1990

1. INTRODUCTION

This is a progress report of work carried out under the terms of a research agreement entitled the *Canadian Seismic Agreement* between the U.S. Nuclear Regulatory Commission (USNRC), the Canadian Commercial Corporation and the Geophysics Division of the Geological Survey of Canada (GD/GSC) during the period from July 01, 1989 to June 30, 1990. The *Canadian Seismic Agreement* helped to support generally the operation of various seismograph stations in eastern Canada and the collection and analysis of earthquake data for the purpose of mitigating seismic hazards in eastern Canada and the northeastern U.S. The specific activities carried out in this one–year period are summarized below under four headings; Eastern Canada Telemetered Network and local network developments, Datalab developments, strong–motion network developments and earthquake activity.

Activities undertaken by GD (formerly the Earth Physics Branch) under this contract from 1979 to 1985 have previously been described in a Technical Report Covering 1979–1985 (NUREG/CR–4317 Vol. 1), in the previous Annual Reports of this series (NUREG/CR–4573 Vols. 1, 2, 3 and 4), for 1985–86, 1986–87, 1987–88 and 1988–89 and in the regular quarterly reports issued under terms of this agreement. During the period of this report, the contract resources were spent on operation and maintenance of the Eastern Canada Telemetered Network (ECTN), development of special purpose local network systems, servicing and maintenance (by contract) of the strong–motion seismograph network in eastern Canada, operation and expansion of the Ottawa Datalab and earthquake monitoring and reporting. The development of the local networks for the Sudbury (SLTN) and Charlevoix (CLTN) areas are reported on here because they are closely linked to ECTN developments although they are supported in whole or in part by other sources.

Of special note in this period was the discovery of the surface fault break of a recent earthquake in northern Quebec. This is the first time that a surface break has been identified unequivocally in eastern North America and the fault scarp is one of a very few surface fault breaks that have been produced by earthquakes in stable continental areas throughout the world.

In this period a modification to the *Canadian Seismic Agreement* was prepared that extended the terms of the agreement to the end of 1990. However, USNRC support of eastern Canadian seismicity studies will cease after that time and a reduction in the level of seismic monitoring will be necessary because of the loss in funding. GD has negotiated an agreement with Hydro–Québec for support of ECTN stations in that province that will partially offset the loss, but it seems likely that GSQ will have to be closed because of the high cost of telemetry from that site. All ECTN sites in New Brunswick (EBN, KLN, LMN and GGN) may have to be closed by the end of 1990 unless alternative support can be found.

At the same time, GD has obtained special funding from within GSC to establish a national network of broad–band satellite–linked seismograph stations across Canada to replace the obsolete Canadian Standard Seismograph Network. Some of the stations planned for this new network in eastern Canada will offset the reduction in ECTN coverage.

In September, 1989 GSC was reorganized and GD was incorporated in a new Branch called the

Geophysics and Marine Geoscience Branch which includes the main Canadian government marine science laboratories on both the west and east coasts. The reorganization had no effect on the work carried out under the *Canadian Seismic Agreement* by GD but should be noted for administrative purposes.

2. ECTN AND LOCAL NETWORK DEVELOPMENTS

ECTN now consists of 19 short–period vertical outstations which monitor seismic activity in eastern Canada from northeastern Ontario to eastern New Brunswick (Fig. 1 and Table 1). The SRO–type borehole triaxial, short– and long–period outstation, GAC, at Glen Almond, Quebec was closed on February 19 because of continuing technical problems and the ECTN station, EBN, at Edmundston, N.B. was closed on May 2 for financial considerations.

ECTN outstations transmit seismic data in real time to a central processing facility in the Ottawa Datalab by either dedicated telephone lines (Fig. 2) or by UHF radio links (Fig. 3). Data are sampled at 60 Hz at each outstation using a 12–bit A/D converter with a four–stage gain-ranging scheme which gives a dynamic range of 96, 108 or 126 db depending on the type of outstation, Mk 1, 2 or 3.

ECTN data are integrated with the data from two local digital telemetered networks, SLTN in Sudbury, Ontario (Fig. 4a) and CLTN in La Pocatière, Québec (Fig. 4b), which are designed to provide enhanced seismic monitoring within their local areas. Each local network has a complete seismic processing facility located on site which can operate the array and store triggered event data. At SLTN it is also possible to carry out routine analysis of the events.

SLTN was completed in April, 1987, as part of an expanded program of rockburst monitoring of 15 active mines in the Sudbury, Ontario area (Fig. 4a) supported jointly by EMR, the Canadian mining industry and the Ontario provincial government. The array consists of three Mark III outstations sampling at 60 Hz. and linked by dedicated telephone lines to the local processor at the Science North Museum in the city of Sudbury. The processing facility forms part of a popular public display in the museum, featuring continuous monitors of the three outstations and an automatic display of the last triggered event on the graphics terminal (Fig. 5). There is also a link provided to Laurentian University in Sudbury for inspection and acquisition of current events.

SLTN files follow the route

PDP–11/73 ::::::::::::DEMSA ::::::::::::MVAX3

to Ottawa where they are analyzed on MVAX3 concurrently with ECTN and CLTN events. DEMSA is a new communication server which has handled SLTN data since May 1989 and also handles DATAPAC connections to the computing facilities. In Ottawa SLTN files are systematically screened and noise files eliminated, location and magnitude are calculated for any well recorded events and P–nodal analyses are carried out. The affected mines are surveyed for information about the nature, depth and effects of the seismic events they have experienced and the information collected is stored in the seismicity database along with the hypocentral parameters. GD circulates comprehensive quarterly reports of all the information collected to the mining community.

CLTN became fully operational on October 30, 1987 replacing the older analogue array which had

Table 1: Canadian Telemetered Networks 1989/90

Code	Station Mk	Name	Lat. °N	Long. °W	Elev. m	Operating Dates start - stop
			ECTN			
OTT	1	Ottawa	45.3942	75.7167	077	02/24/74-04/25/78
						01/26/79–
MNT	2	Montréal	45.5025	73.6230	112	02/24/74–
MNQ	3	Manicouagan	50.5333	68.7744	564	11/27/74–
GAC	–	Glen Almond	45.7033	75.4783	062	10/26/79–02/19/90
LPQ	3	La Pocatière	47.3408	70.0094	126	06/06/80–
SBQ	3	Sherbrooke	45.3783	71.9264	265	08/12/80–
WBO	3	Williamsburg	45.0003	75.2750	085	12/09/80–
CKO	3	Chalk River	45.9944	77.4500	190	01/12/81–
TRQ	3	Mont–Tremblant	46.2222	74.5556	853	03/16/81–
GRQ	3	Grand–Remous	46.6067	75.8600	290	03/16/81–
GSQ	3	Grosses–Roches	48.9142	67.1106	398	10/28/81–
EBN	2	Edmundston	47.4620	68.2420	195	10/28/81–05/02/90
GGN	3	St. Georges	45.1170	66.8220	030	10/28/81–
LMN	3	Caledonia Mt.	45.8520	64.8060	363	10/28/81–
KLN	3	McKendrick L.	46.8433	66.3717	411	01/28/82–
HTQ	3	Hauterive	49.1917	68.3939	123	04/15/82–
WEO	3	Welcome	44.0186	78.3744	149	04/30/82–
JAQ	3	La Grande–3	53.8022	75.7211	366	02/26/85–
EEO	3	Eldee	46.6411	79.0733	398	03/08/84–
DPQ	3	St–Jean–des–Piles	46.6804	72.7774	167	01/20/88–12/15/88
						02/27/89–
DAQ	3	Lac Daran	47.9644	71.2425	939	12/15/88–
			SLTN			
SUO	3	Chief L. Road	46.4027	81.0068	252	12/16/84–
SZO	3	Chicago Mine	46.4380	81.4960	312	01/24/87–
SWO	3	Joe Lake	46.7330	80.9990	372	05/27/87–
			CLTN			
A11	3		47.2430	70.1970	045	10-30-87–
A16	3		47.4680	70.0100	022	10-30-87–
A21	3		47.7040	69.6900	000	10-30-87–
A54	3		47.4570	70.4130	384	10-30-87–
A61	3		47.6940	70.0910	358	10-30-87–
A64	3		47.8270	69.8910	137	10-30-87–

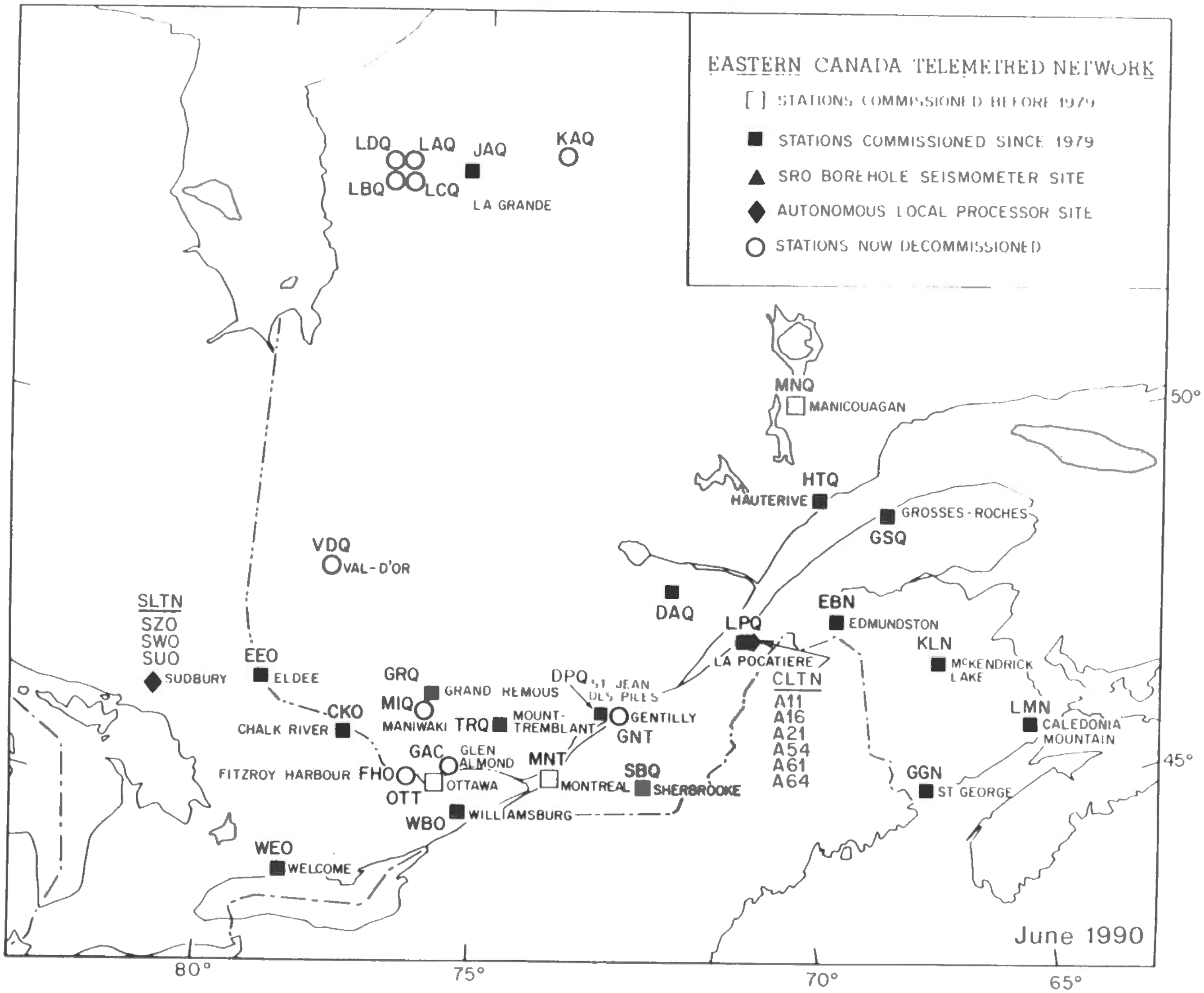

Figure 1. Seismograph stations supported by the Canadian Seismic Agreement.

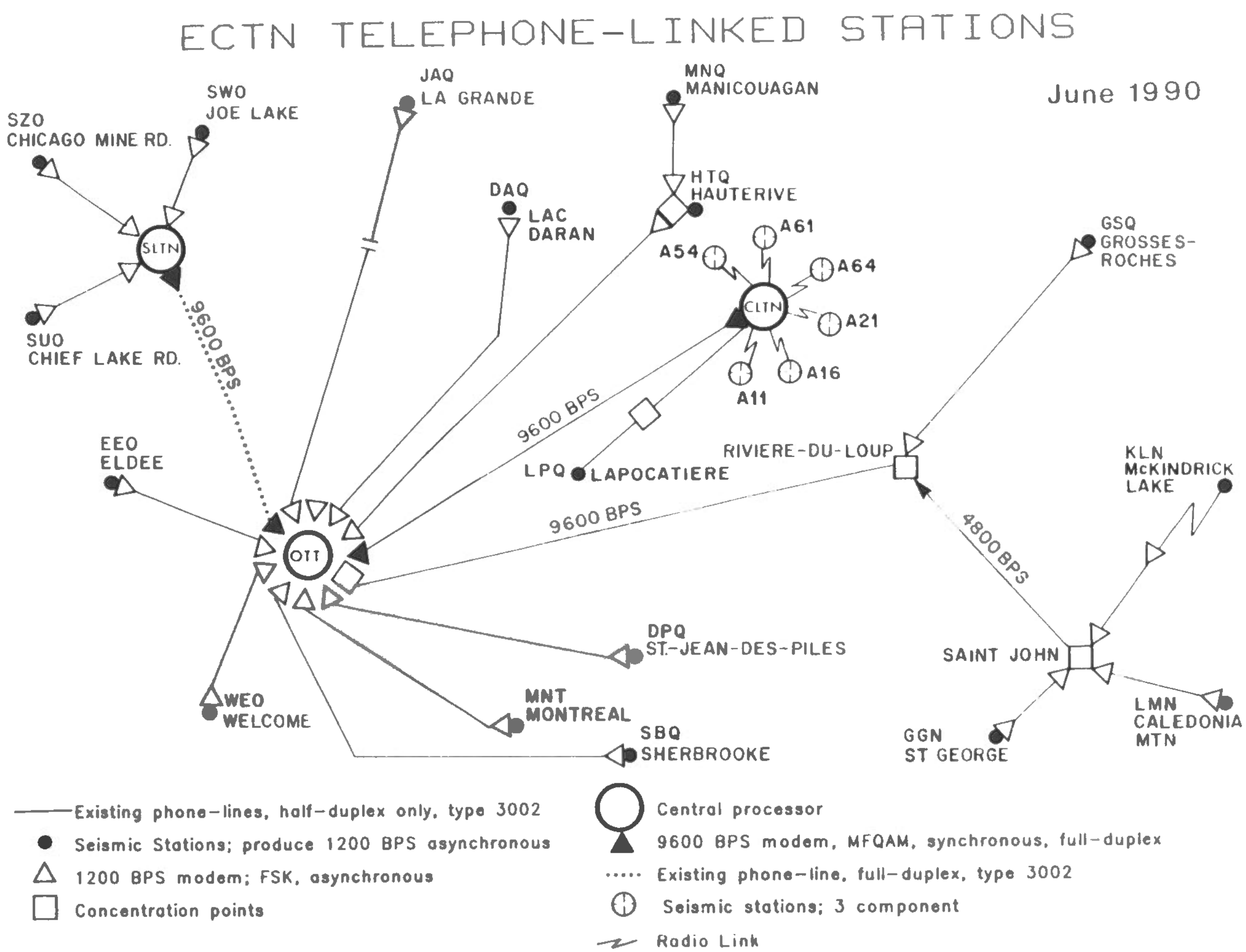

Figure 2. Block diagram of telephone-links for ECTN stations, SLTN stations and the CLTN processor.

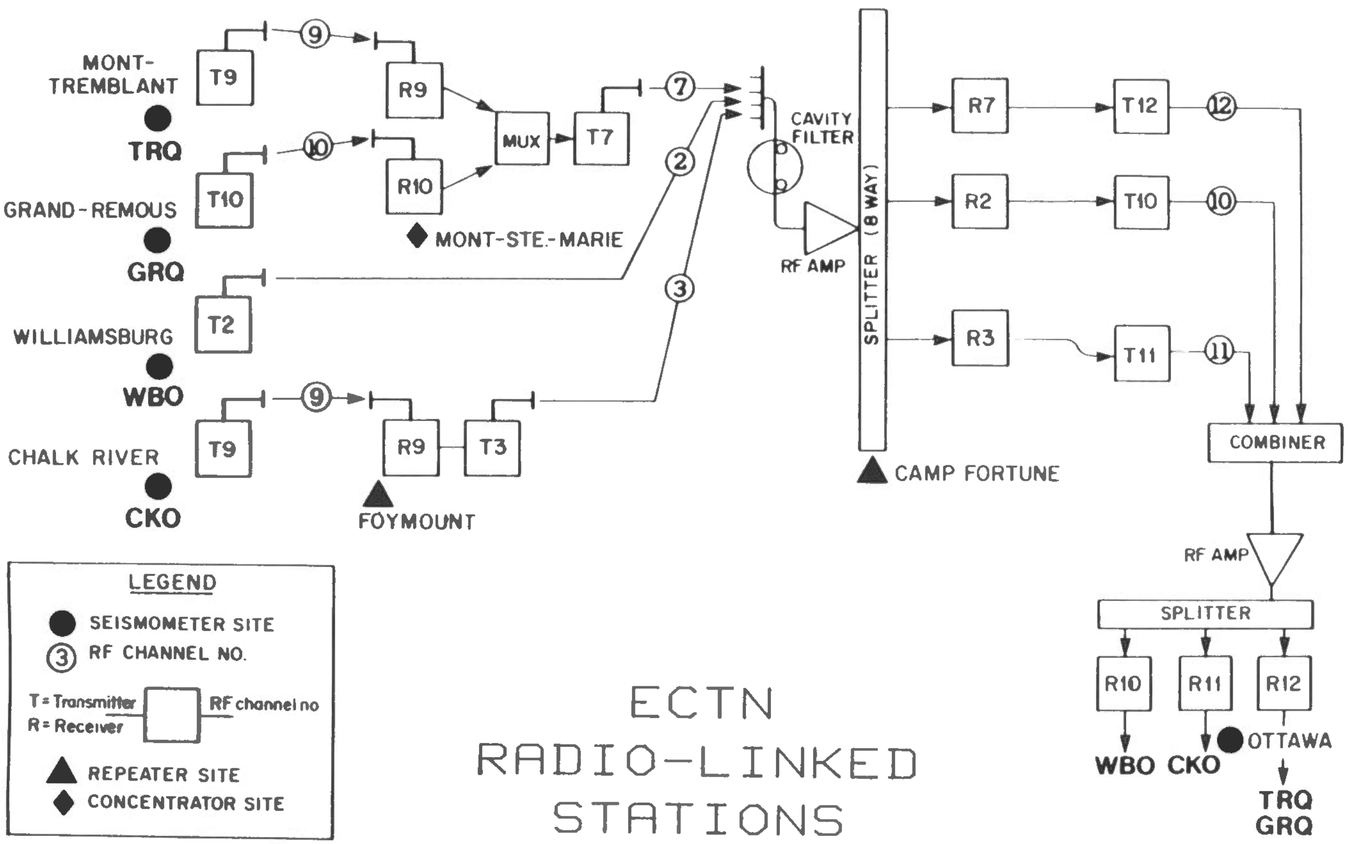

Figure 3. Block diagram of radio-links for ECTN stations.

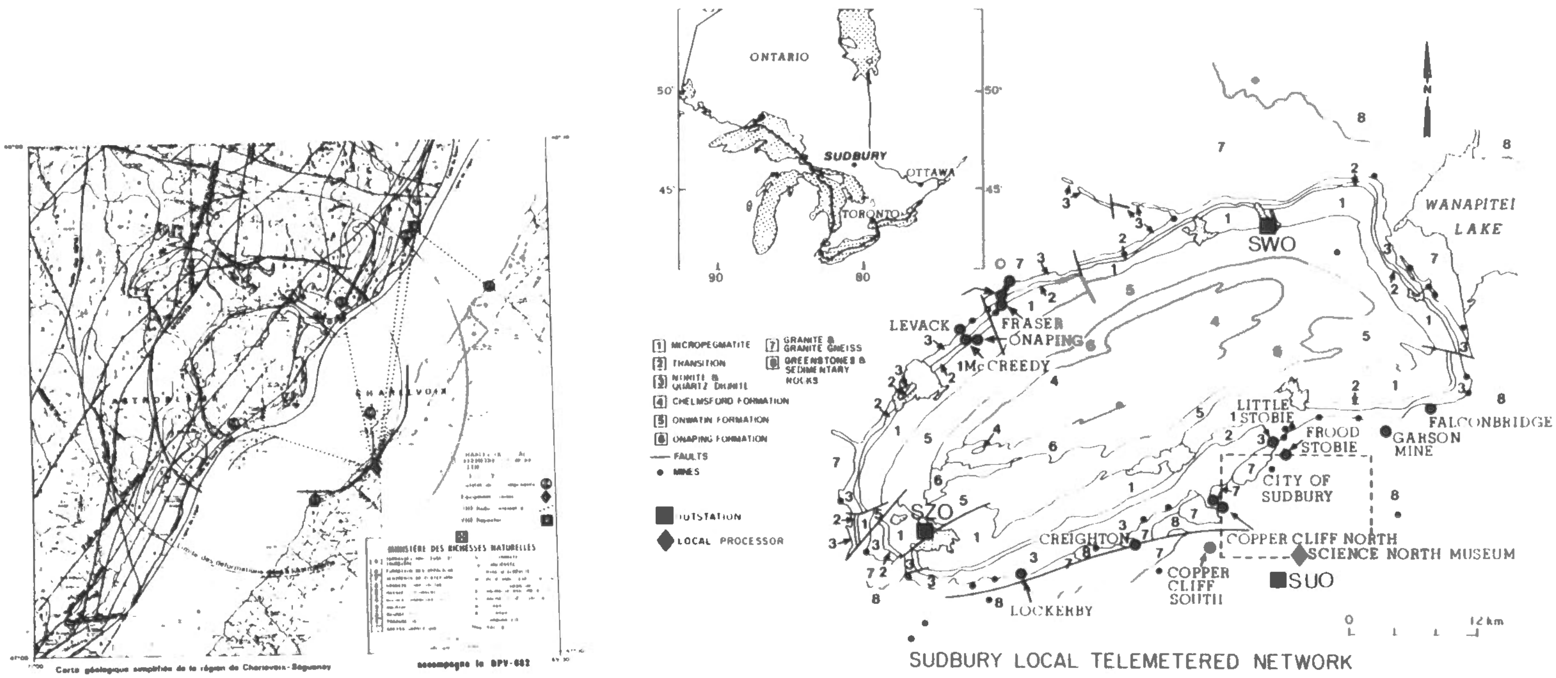

Figure 4. Maps of the Charlevoix (A) and Sudbury (B) Local Telemetered Networks.

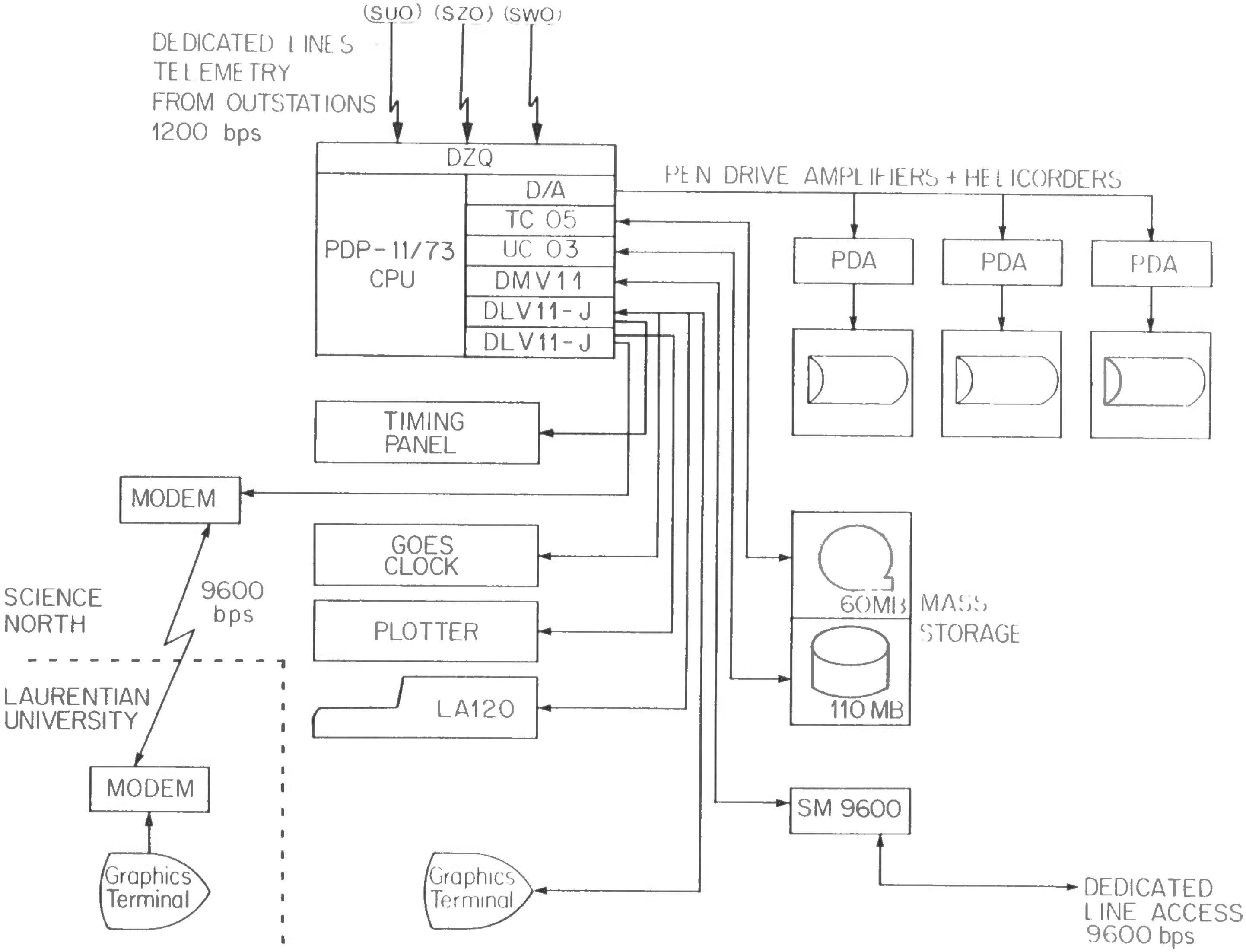

Figure 5. Block diagram of SLTN equipment.

SUDBURY LOCAL
TELEMETRED NETWORK

operated at the same sites since 1977. CLTN consists of 6 Mark III 3-component outstations (Fig. 4b) each sampling at 80 Hz and transmitting data to the local processor at La Pocatière, Québec via UHF radio-links. Each signal has a dynamic range of 126 db with a sample resolution of 1 count/nm/sec. A two-station coincidence requirement has been imposed on the CLTN trigger algorithm in order to reduce the number of false alarm triggers. CLTN event files also have a 15-sec pre-trigger buffer instead of the 60-sec buffer used for ECTN files. Figure 6 shows the layout of the array.

CLTN event files are automatically transferred to Ottawa on a dedicated telephone line for analysis. The files follow the route

LSI–11/73::::::::::::DEMSA::::::::::::MVAX3

to Ottawa. CLTN event files, including teleseisms, are analyzed on MVAX3 concurrently with ECTN and SLTN files and are appended to any corresponding ECTN files in Ottawa before archiving.

ECTN Performance: Table 2 shows the down-times for individual ECTN stations over the past five years. JAQ, EEO, HTQ, MNQ, LMN, GGN and KLN all experienced a significant amount of down-time in this period, as did all the radio-linked stations – CKO, WBO, GRQ and TRQ. In addition, service from GAC was effectively lost entirely after September. Causes for the loss of service for individual stations are described in the following sections.

Polarity of all vertical ECTN components was confirmed regularly in this period by systematically inspecting the first breaks of well recorded teleseisms or nuclear tests. No polarity reversals were identified.

Radio-linked Outstations: WBO, CKO, TRQ and GRQ experienced a lengthy service interuption starting on November 21 because of interference problems at the Camp Fortune repeater. The outstations appeared to be functioning normally, but no signals could be passed through Camp Fortune. The equipment there was removed and returned to the GD instrument lab for repairs and calibration. Several malfunctions were identified and repaired and the cavity filter was retuned. The Camp Fortune transmitter was reinstalled on January 25 and regular service from TRQ, GRQ, WBO and CKO resumed on February 5.

The repeater at Mont-Ste-Marie was serviced on September 26. The transmitter frequency was changed from channel 7 to channel 4 and the output power was boosted to 1.44 watts on February 01. These changes improved the signal margins at Camp Fortune for GRQ and TRQ by almost 2 db resulting in fewer missed samples during transmission.

The repeater at Foymont transferring CKO data to Camp Fortune was serviced on October 31.

TRQ was upgraded to a Mark III station on September 20, GRQ on October 12, CKO on October 23 and WBO on October 27.

Telephone-linked Outstations: The performance of the SRO station at GAC deteriorated significantly during September. The short-period signal became very spikey, and the long-period signal very wavy. Extensive trouble-shooting was carried out to determine the cause of the problems and it was finally determined that they rested in the down-hole equipment. The down-hole electronic package could not be recovered and repaired, so the SRO station had to be abandonned and re-

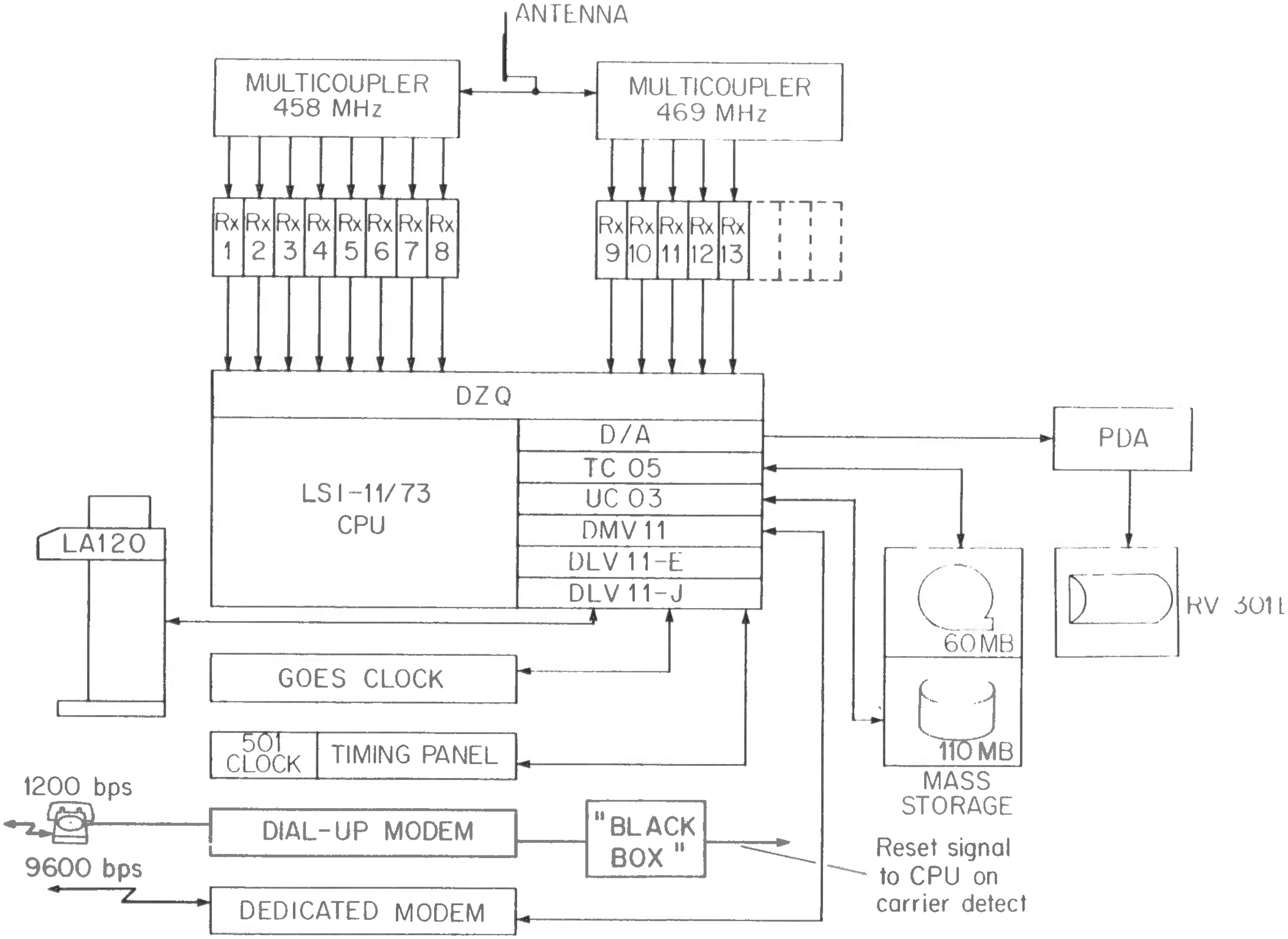

Figure 6. Block diagram of CLTN equipment.

CHARLEVOIX LOCAL TELEMETRED NETWORK

Table 2
Down–time for ECTN stations
1983–1987

STATION	% Down–Time 89	88	87	86	85	84	83	Comment
	Telephone–linked Stations							
OTT	1.2	0.0	0.3	2.9	2.3	3.9	7.5	direct connection
MNT	0.3	0.1	0.1	0.2	0.4	0.1	0.8	direct line
SBQ	0.3	1.3	3.9	0.6	0.2	0.1	0.0	direct line
EEO	10.	7.3	6.5	1.6	1.4	2.1	—	direct line
WEO	5.5	1.2	2.1	5.0	2.5	5.8	1.1	direct line
HTQ	16.	0.6	0.3	15.	7.2	1.3	0.2	direct line
MNQ	25.	0.6	7.8	24.	34.	1.8	0.4	via Hauterive
EBN	1.5	5.2	2.2	2.5	6.4	4.3	0.9	via Riv.–du–Loup
GSQ	3.3	1.8	1.8	3.7	2.6	2.1	0.6	via Riv.–du–Loup
LPQ	5.3	4.5	2.3	4.0	4.0	9.0	5.4	via Riv.–du–Loup
LMN	16.	1.8	1.9	2.2	8.4	13.	11.	via St. John and Riv.–du–Loup
GGN	23.	7.1	0.9	3.5	1.8	1.9	0.9	via St. John and Riv.–du– Loup
KLN	18.	7.4	1.1	2.2	1.5	3.1	11.	short radio link via St. John and Riv.–du–Loup
JAQ	33.	36.	6.8	3.0	11.	13.	5.0	short radio link
DPQ	14.	8.4						direct line
GAC SPZ	4.7	3.4	3.6	2.5	5.5	4.2	2.8	direct line
	Radio–linked Stations							
CKO	13.	7.3	5.2	15.	10.	32.	5.7	via Foymont and Camp Fortune
WBO	12.	3.7	7.3	20.	10.	18.	5.8	via Camp Fortune
GRQ	15.	19.	15.	20.	15.	10.	23.	via Camp Fortune
TRQ	13.	19.	15.	21.	22.	11.	54.	via Camp Fortune

placed by a surface seismograph. A new broad-band system employing Streckheisen seismometers, a prototype station for the new national network of broad-band seismograph stations in Canada, was assembled and installed in the mine adjacent to GAC during the summer of 1990. Broad-band data were transmitted to an IBM PC in the Ottawa datalab by telephone line for a short period of time as a test and software to convert the signal to SAM-type files was written and tested. The transmission of data from the new system has now been halted pending the completion of a satellite communication link from the Ottawa datalab to the GAC broad-band station and the acquisition of new computer systems to process the data.

The transmission of data from the GAC SRO station was halted on February 19.

ECTN stations, JAQ, MNQ and HTQ, all in northern Québec, experienced a significant disruption in service in this period because of continuing labour problems at Hydro-Québec. JAQ performance began to deteriorate on August 20 and ran only intermittently after that time. The signal, when received, was very spikey. The poor performance may have been related to power supply problems, which have occurred at JAQ in the past, but it is still under investigation. JAQ went finally out of service on September 8, MNQ followed on October 9 and HTQ on November 7. The stations could not be serviced because GD could not obtain access to the sites during this labour dispute.

Supermodems at Saint John, N.B. and Rivière-du-Loup, Qué. both failed in this period and had to be replaced, leading to a lengthy interuption of service from the stations in New Brunswick whose data pass through these supermodems. The supermodem at Saint John was replaced on July 11 and the one at Rivière-du-Loup was replaced on September 15.

The signals from the New Brunswick stations KLN, GGN and LMN, which now have to pass through the new supermodem at Saint John, also now have frequent transmission spikes, the cause of which is still under investigation.

KLN also began to operate intermittently and finally went down completely on January 23. On February 12, KLN was serviced and the station was converted to a Mk 3 station. WEO was serviced on October 24 and a subsequent trip was made on November 22 to convert the station to low power and to change its batteries. The signal from WEO was lost on March 6 and could not be re-established until March 30.

The seismometer vault at DAQ was moved 400 feet away from the adjacent microwave tower in order to improve the quality of the signal from this site. The station was calibrated on August 2.

LPQ has been plauged with spiking problems in this period. The problems are believed to be related to the auxiliary 2400-baud channel on the CLTN supermodem which now brings the signal to Ottawa. The problem is still under investigation.

The "Zap Trap" lightning protector at EEO was triggered 14 times in this period. The instrument was not damaged by any of the lightning strikes but experienced a series of minor interuptions as a result.

SLTN Developments: SLTN had a clock malfunction and the timing for the data from July 31 to August 1 was unreliable. The transmission line linking SLTN to GD was out of service from February 26 to March 4. Data were stored on the SLTN processor until the transmission line was repaired and regular service resumed. No data were lost in the process. The SLTN processor system disk failed on May 11. A spare disk was installed on May 15.

SUO was out of service from March 28 to 30. SZO trigger level was raised from 3 to 4 on June 28.

Mr. S. Lapointe retired as a temporary part–time analyst for SLTN data at the end of August to return to school. Mr. W. McNeil was hired as a permanent part– time analyst for SLTN on December 1. The backlog of data that had accumulated as a result of the absense of an analyst was eliminated and SLTN data analysis is again being done routinely.

CLTN Developments: Outstations were serviced in July. Site 61 had been damaged by a lightning strike. The vertical and east–west components were repaired in July, the north–south component could not be repaired until October.

A remote boot facility was added to the CLTN processor in July.

Mr. F. Anglin continued to be responsible for analysis of the CLTN data.

3. DATALAB DEVELOPMENTS

ECTN data are received in the Ottawa Datalab by dual PDP–11/73 microcomputers (Fig. 7) where acquisition software demultiplexes the seismic data, produces formatted one–second data buffers of the network data, stores the data in a 5–minute ring buffer on disk and produces a number of continuous visual monitors of individual channels on helicorders. A separate TRIGGER program continuously monitors the incoming data and, when the trigger conditions are satisfied for any single trace, creates an event file of the entire network data on disk. The overall process is controlled by a Network Configuration File (Table 3). The ECTN event files are then automatically scanned for noise files (typically those triggered by transmission glitches), which are segregated and the remaining files finally transferred via Ethernet to MVAX3 for analysis. The two 11/73 processors work independently of each other thus providing an important degree of redundacy for the acquisition system.

On MVAX3 (Fig. 8) the triggered event files are processed by a series of automatic programs (CAUSMO) which monitor the file transfers from the 11/73 processors, issue alerts on the computer systems for mutli–station–trigger files and plot and scale the transferred files for the network analysts' attention. Each network's files (ECTN, CLTN and SLTN) go through a similar process. The analysts then identify all the valid seismic events in each day's files, including files containing teleseismic signals, and save them, combining the ECTN, CLTN and SLTN files for common events into one file as required in the process. Copies of all the saved files are returned to OTTVAX for archiving on magnetic tape while those containing local seismic events are analysed on MVAX3 using SAM to scale phase times and amplitudes and LOC to locate the hypocentres. The hypocentral data are stored in the database facility for future reference and for prepartion of the quarterly seismic bulletins which are distributed regularly to a wide variety of users both inside and outside of Canada.

Hardware Developments: During the year the PDP–11/34 minicomputer was retired. High–perforamnce STC tape drives were shared between the OTTVAX and the SUN 4/280 waveform server via the "pass–through" mode function of the Aquidneck OAS–150 optical archiving system. This system was purchased last year to playback the 12 " 3.2 Gigabyte WORM optical disk platters created by the Yellowknife Array systems. A QMS 820 Turbo PostScript laser printer has been acquired and connected to the waveform server.

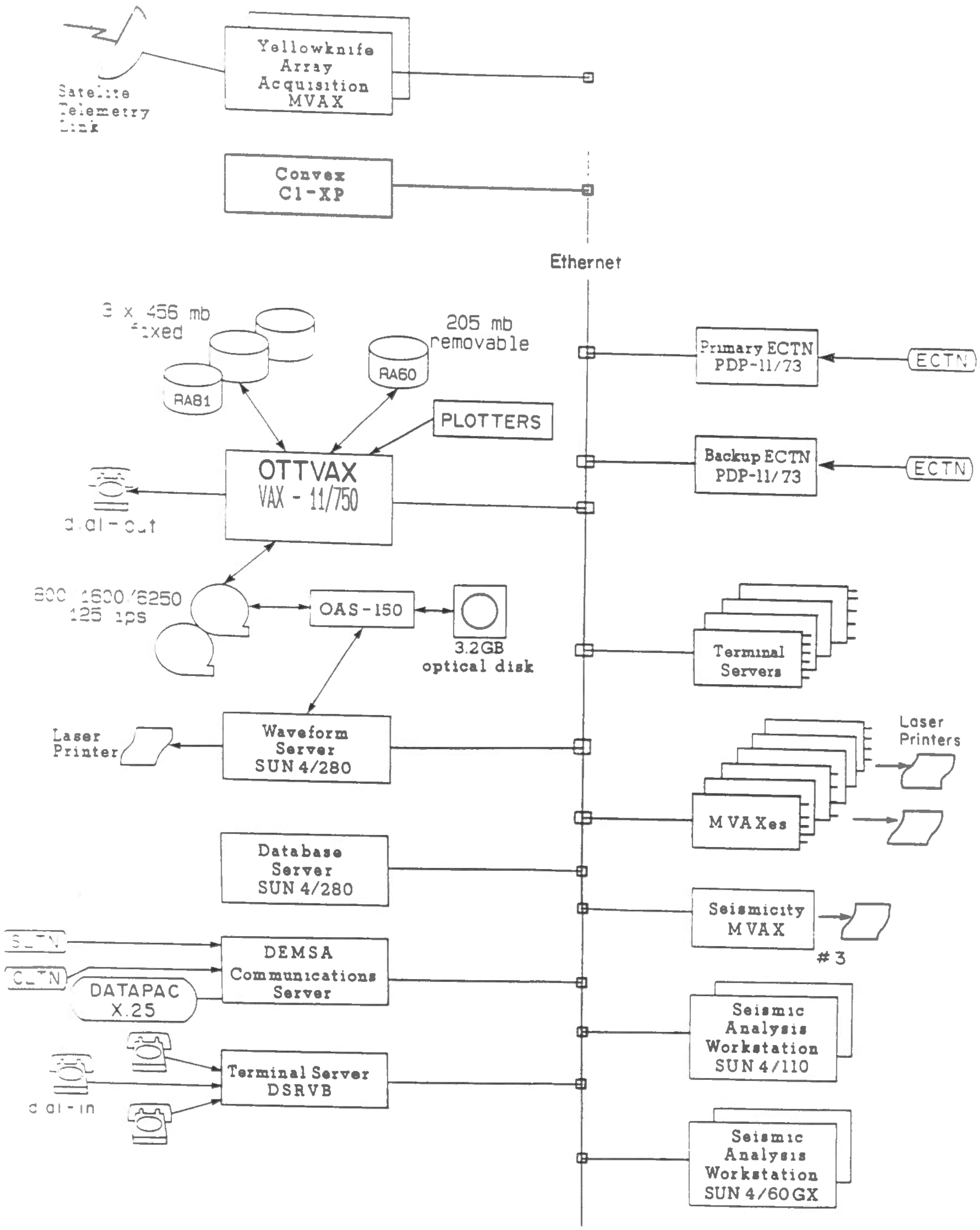

Figure 7. Block diagram of Ottawa Datalab computing facilities.

Table 3

ECTN Network Configuration File: September, 1990

Network Name:	ECTN	D/A Channels:	12
DZ Units:	4	Ring Buffer:	300 s
Pre–trigger:	60 s	Post–trigger:	30 s
Save after:	1	Initial LTSD:	30
LTSD Constant:	3	Time Base:	60
Interupt Rate:	60	Processor:	B
Mode:	P	Console:	3

L	C	STN	CP	BD	D	S	F	TC ms	SEN nm/s	A	G	E	LVL	RAT	CF1 hz	R1	CF2 hz	R2	STC sec	LTC min
1	1	OTT	SZ	1200	2	60	2	-56	10.0			1	4.0	08	2.	1.2	04.	1.35	1.10	4.27
2	1	MNT	SZ	1200	2	60	1	-60	10.0			1	4.0	20	2.	1.2	04.	1.35	1.10	4.27
3	1	EEO	SZ	1200	2	60	2	-60	01.1	6	3	0	3.0	40	4.	1.2	10.	1.80	1.10	4.27
4	1	DPQ	SZ	1200	2	60	2	-61	01.1	7	2	1	3.0	20	4.	1.2	10.	1.80	1.10	4.27
5	1	SBQ	SZ	1200	2	60	2	-69	01.1	10	1	1	4.0	20	2.	1.2	10.	1.35	1.10	4.27
7	1	WEO	SZ	1200	5	60	5	-66	01.1	9		1	4.0	30	2.	1.2	04.	1.35	1.10	4.27
8	1	FCC	SZ	1200	5	60	5	-250	01.1			1	3.0	20	4.	1.2	10.	1.80	1.10	4.27
9	1	MNQ	SZ	2400	14	60	5	-98	10.0			0	3.0	18	4.	1.2	10.	1.80	1.10	4.27
9	2	HTQ	SZ			60	3	-70	10.0			1	4.0	10	3.	1.2	08.	1.50	1.10	4.27
10	1	WBO	SZ	1200	2	60	5	-52	01.1		0	1	4.0	15	4.	1.2	10.	1.80	1.10	4.27
11	1	CKO	SZ	1200	2	60	5	-62	01.1	5	2	1	4.0	10	4.	1.2	10.	1.80	1.10	4.27
12	1	TRQ	SZ	2400	14	60	5	-87	01.1			1	4.0	10	4.	1.2	10.	1.80	1.10	4.27
12	2	GRQ	SZ			60	5	- 87	01.1	11	3	1	4.0	10	4.	1.2	10.	1.8	1.10	4.27
13	1	GSQ	SZ	4800	234	60	3	-216	10.0	2	2	0	4.0	8	3.	1.2	08.	1.80	1.10	4.27
14	1	GGN	SZ	4800	234	60	5	-294	1.10	4	2	1	4.0	15	3.	1.2	08.	1.80	1.10	4.27
14	2	LMN	SZ			60	3	-294	10.0	1	3	1	4.0	10	3.	1.2	08.	1.80	1.10	4.27
14	3	KLN	SZ			60	5	-294	1.10	3	3	1	4.0	30	3.	1.2	08.	1.80	1.10	4.27
15	1	LPQ	SZ	2400	14	60	5	-216	1.10	8	1	1	4.0	30	3.	1.2	08.	1.80	1.10	4.27
16	1	DAQ	SZ	1200	2	60	5	- 61	1.10	12	2	1	3.0	20	4.	1.2	10.	1.80	1.10	4.27

L:	line number	C:	channel	BD:	baud rate	D:	packet code
F:	format flag	SEN:	bit resolution	A:	analog chan.	G:	analog gain
E:	error log off	LVL:	trigger level	RAT:	trigger ration	CF:	filter freq.
R:	filter radius	STC:	short–term const.	LTC:	long–term const.	S:	sampling
CP:	component					TC:	time corr.

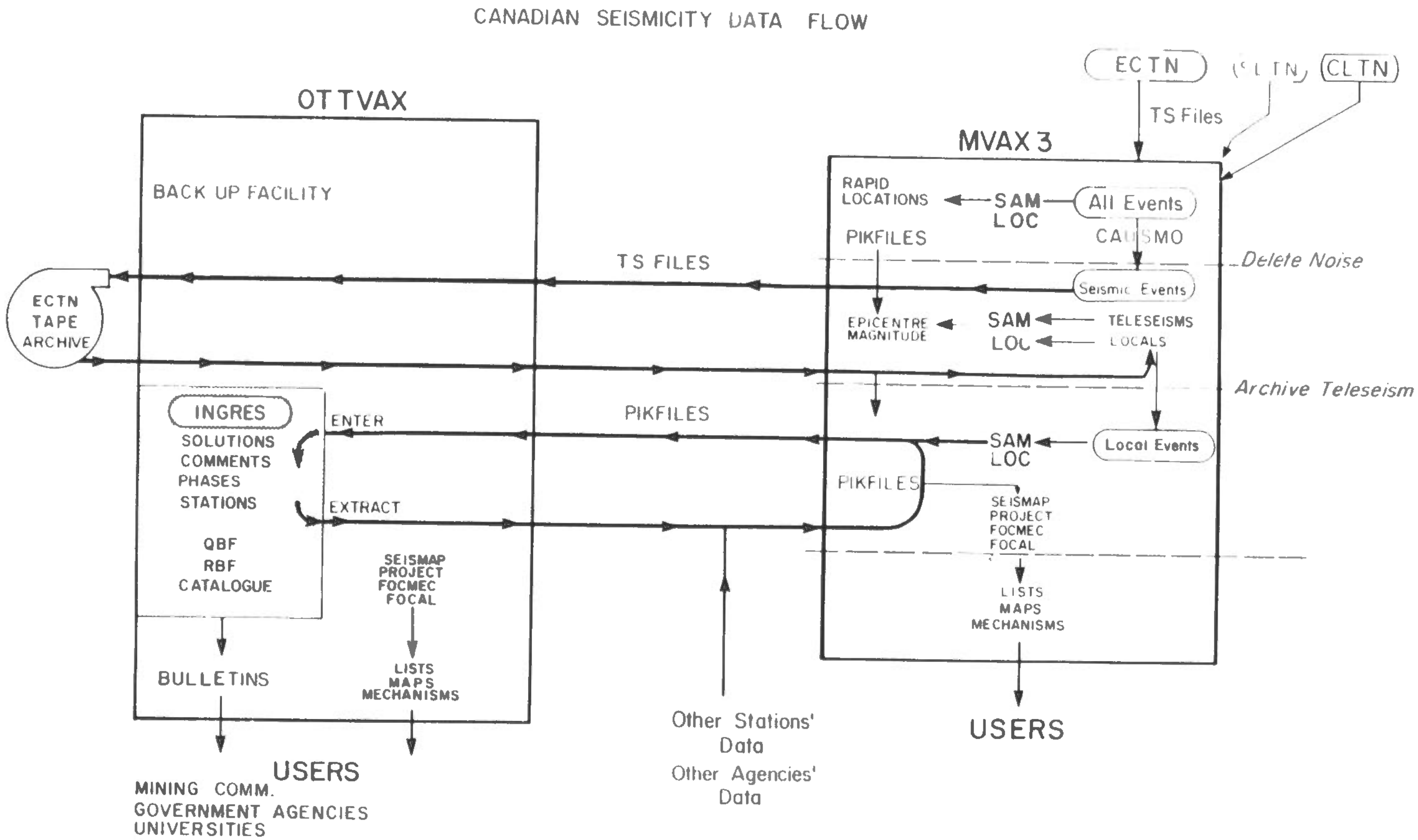

Figure 8. Block diagram of ECTN data flow.

Two SUN 4/60 GX colour workstations have been acquired as additional development platforms and are connected to the Local Area Network. Finally, the synchronous DECnet Wide Area Network connection for CLTN was moved from the OTTVAX to the DEMSA router. The fourth port on the DEMSA is now used for a dedicated 9600 baud synchronous DECnet connection to a MicroVAX II located at the Blackburn Geophysical Instrumentation Laboratory (not shown on the Figure).

Acquisition Software: A persistent bug in the DEMUX program which creates the ECTN, CLTN and SLTN triggered time series files was identified and corrected in this period. Basically, the problem arose for multi–station triggers when one or more of the first triggers were deemed to be noise by the automatic discrimination code. The DEMUX program purported to truncate the time series from the front to remove the false detections and update the trigger sequence list and start–of–data pointers accordingly. While DEMUX did update the pointers, it did not in fact delete any data, leading to an inconsistancy between the actual and reported start of the data on the disk. The timing would be relatively correct for the individual network data but shifted from U.T. by an arbitrary time corresponding to the time between the triggers.

The source of the problem was identified in January and corrected on February 13. It is unclear how long this problem had been present.

Another less serious bug was uncovered and corrected in TRIGGR at the same time. TRIGGR used to turn off early for multi–station triggers spaced several seconds apart, providing less than the nominal 30 seconds of post–trigger buffer.

Analysis Software: SAM was modified to read 3–letter SEED–format channel designators from YKA files (eg. BHZ for the broad-band vertical channels, SHZ for the short–period vertical channels and EHZ for the high frequency vertical channels). An appropriate transfer function for use in SAM was defined for each of the YKA channel types. For multiple station triggers, SAM used to remove from the trigger list all but the last occurrence; it now preserves the first occurrence. Minor modifications were also made to SAM to improve its handling of teleseismic waveforms.

Database Facilities: The Current Seismicity Database (CSDB) was used routinely in this period to store and update information about local earthquakes determined from ECTN. This database facility only contains the last two years of Canadian earthquake data and is optimized for current seismicity needs. The quarterly Bulletins and Summaries of earthquake activity distributed by GD were generated directly from this facility,

The CSDB was copied from the OTTVAX to a SUN 4/280 workstation (SUNDBS) for testing and development. Preliminary testing shows an improvement of performance of 4 to 20 times. The OTTVAX CSDB database is still being used for routine seismicity needs while development of a much faster seismicity database facility on the SUN systems continued to progress in this period.

On the SUNDBS the database facility (Fig. 9) has been re–organized around five local databases, CSDB, CEDB, INT6, STRESSDB and ANALOGREC. STRESSDB is the Canadian STRESS database converted from OTTVAX under DATATRIEVE to SUNDBS under INGRES. The ANALOGREC database (inventory of Canadian analog seismograph records) has also been moved onto the SUNDBS from a PC. The intensity tables previously held in the CEDB have been separated from the main database into the new database named INT6.

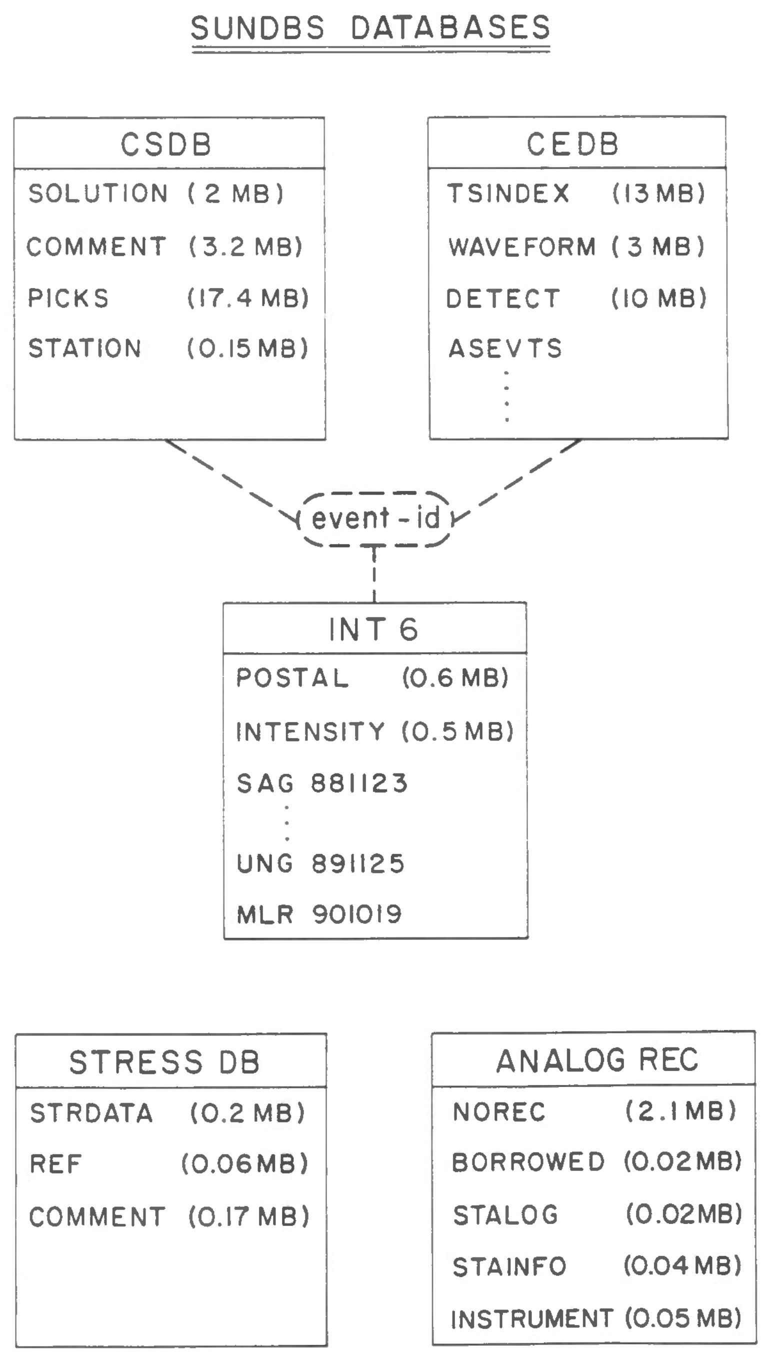

Figure 9. Block diagram of new Canadian Earthquake Database.

CEDB on SUNDBS now contains only information on ECTN and YKA time series files and detections including header information for all existing YKA tapes. YKA data files are now being stored on optical disks and an index of the disks will be stored in the CEDB in the near future.

SUN Operating System 4.0.3 and Fortran 1.2 were installed on the SUNBDS. INGRES Release 6 has been implemented on the systems providing faster response times and the ability to define null values in any field. Procedures were set up on SUNDBS to enter PIK files automatically into the database, similar to procedures used on MVAX3 and OTTVAX.

Questionnaires for the intensity survey of the Ungava Peninsula earthquake were prepared directly from the database.

4. STRONG–MOTION NETWORK DEVELOPMENTS.

The Eastern Canada Strong Motion Seismograph Network, supported by the *Canadian Seismic Agreement*, consists of 19 sites centered around the Charlevoix region of Québec (Fig. 10). The instruments are all Kinemetrics SMA–1 three–component analogue accelerographs (Table 4). Regular servicing of the network is carried out twice yearly by Geonetics Engineering Inc. of Ottawa under contract to GD.

The network was complemented with five additional SMA–1 accelerographs installed in the epicentral region of the Saguenay earthquake during the week of November 28, 1988. These units remained in place until the beginning of August when they were serviced and removed. No accelerograms were produced by these units. Three SSA–1 recorders owned by Lamont–Doherty Geological Observatory remain in the epicentral area.

The GD network was last serviced in May, 1990. No records were produced by the network since prior servicing in October, 1989. The next service trip is scheduled for October, 1990.

5. EARTHQUAKE ACTIVITY JULY 01 1989 TO JUNE 30 1990

Under the terms of the Canadian Seismic Agreement, seismic data, provisional hypocentres and magnitudes for eastern Canadian and northeastern U.S. earthquakes are distributed quarterly to operators of the northeast U.S. seismic networks in the form of the ECTN Bulletin. The October to December 1989 Bulletin has been distributed and the January to March 1990 Bulletin will be issued shortly.

The most significant earthquake in eastern North American during this period was the magnitude 6.2 earthquake December 25 in extreme northern Québec, on the Ungava Peninsula as described in the previous quarterly report. Although this earthquake took place outside the usual reporting area for this document, additional information is given below because of the rarity of such large events in eastern North America.

In the area covered by this report during the period from July 1, 1989 to June 30, 1990, 234 earthquakes were analysed for location and magnitude. They are shown in Figure 11 and listed in Table 5. Twenty-three earthquakes were magnitude 3.0 or greater; the largest, onshore, was magnitude 4.0 and occurred November 16 in western Quebec about 50 km northwest of Maniwaki. Two other magnitude 4 events were located offshore on the Laurentian slope, one on August 21 and one on February 15.

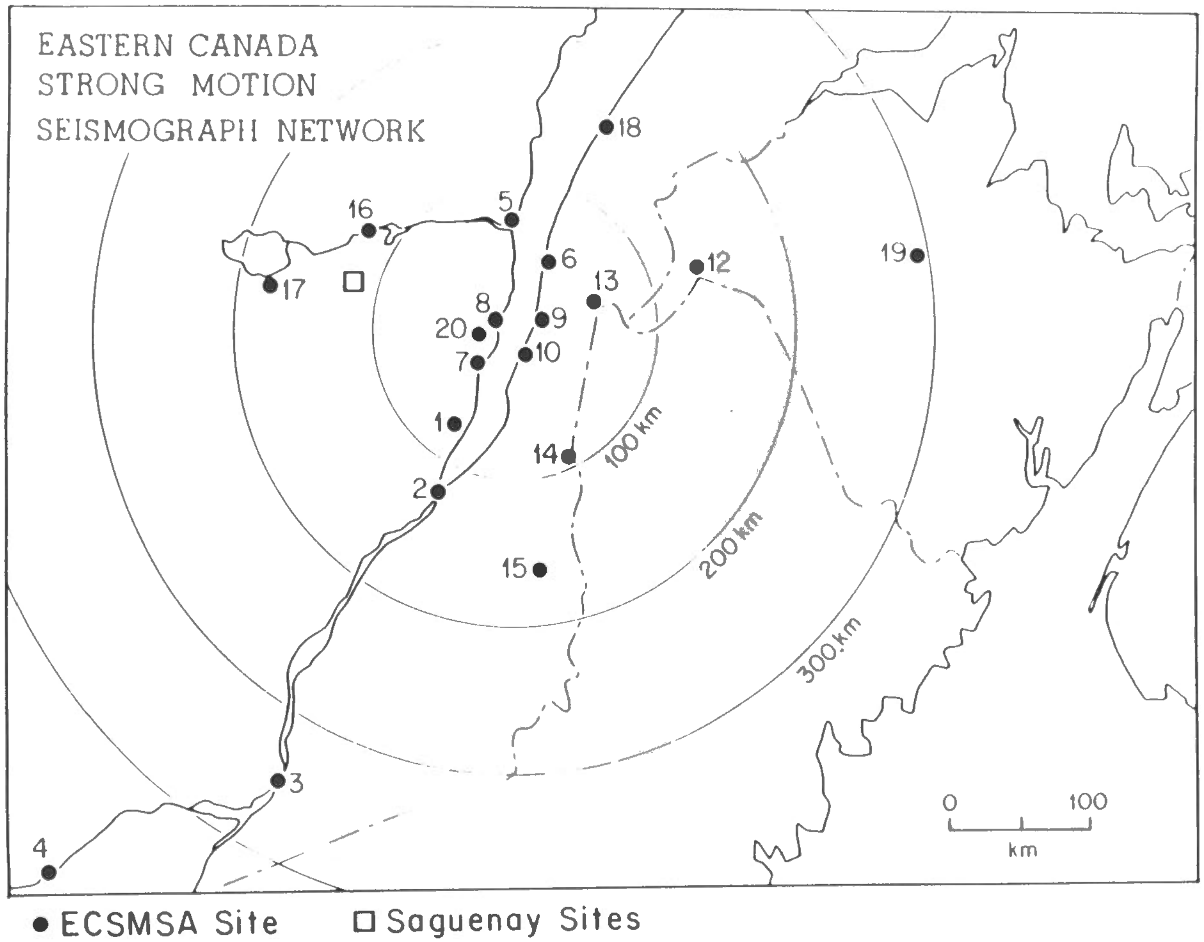

Figure 10. Strong-motion seismographs in eastern Canada supported by the Canadian Seismic Agreement.

Table 4.
Eastern Canada Strong Motion Seismograph Network
June 1990

No.	Location	Date	Coord	Instr.	Sens.	Trigger	Building	Foundation
1.	St-Ferréol,Qué.	1/66	47.1256 70.8282	SMA-1 TCG-1B	1 g	0.0072 g	Underground seismic vault. Instrument on concrete pier.	bedrock
2.	Québec,Qué.	6/67	46.7782 71.2749	SMA-1 TCG-1A	1 g	0.0065 g	3-storey, reinforced concrete. Instrument on concrete pier on basement floor slab.	bedrock
3.	Montréal, Qué.	12/73	45.5025 73.6230	SMA-1 TCG-1A	1 g	0.0049 g	4-storey steel frame, curtain wall, poured concrete. Instrument in basement seismic vault.	bedrock
4.	Ottawa, Ont.	8/84	45.3942 75.7167	SMA-1 TCG-1A	1 g	0.0105 g	Underground seismic vault. Instrument on concrete pier.	bedrock
5.	Tadoussac, Qué.	5/79	48.1432 69.7189	SMA-1 TCG-1B	1 g	0.0101 g	Concrete pier to bedrock in crawl space of 1-storey bldg.	bedrock
6.	Rivière-du-Loup,	6/80	47.8356 69.5379	SMA-1 TCG-1B	1 g	0.0108 g	Two-storey rein forced concrete Instrument on basement slab.	bedrock
7.	Baie-St-Paul, Qué.	10/82	47.4423 70.5069	SMA-1 TCG-1B	1 g	0.0090 g	Two-storey brick building. Instrument on basement slab.	alluvium valley
8.	La Malbaie, Qué.	9/67	47.6553 70.1527	SMA-1 TCG-1B	1 g	0.0112 g	1-storey steel frame, masonary walls. Instrument on concrete pier on basement floor slab.	bedrock
9.	St-Pascal, Qué.	10/69	47.5257 69.8045	SMA-1 TCG-1B	1 g	0.0050 g	1-storey reinforced concrete and masonary. Instrument on concrete basement floor slab.	bedrock
10.	Rivière-Ouelle,	8/84	47.4757 69.9961	SMA-1 TCG-1B	1 g	0.0108 g	Above ground seismic vault	bedrock
12.	Edmundston, N.B.	8/84	47.4614 68.2411	SMA-1 TCG-1B	1 g	0.0103 g	Above ground seismic vault	bedrock
13.	St-Eleuthère, Qué.	8/84	47.4950 69.3628	SMA-1 TCG-1B	1 g	0.0059 g	Above ground seismic vault	bedrock
14.	Ste-Lucie-de-Beauregard, Qué.	8/84	46.7414 70.0172	SMA-1 TCG-1B	1 g	0.0105 g	Above ground seismic vault	bedrock
15.	St-Georges, Qué.	8/84	46.1399 70.5799	SMA-1 TCG-1A	1 g	0.0132 g	Above ground seismic vault	bedrock
16.	Chicoutimi-Nord, Qué.	9/84	48.4902 71.0123	SMA-1 TCG-1A	1/2 g	0.0045 g	Outcrop in basement of two-storey wood frame house.	bedrock
17.	St-André-du-Lac-St-Jean, Qué.	9/84	48.3248 71.9917	SMA-1 TCG-1A	1 g	0.0054 g	Above ground seismic vault	bedrock
18.	Rimouski, Qué.	9/84	48.4452 68.4822	SMA-1 TCG-1B	1 g	0.0035 g	Above ground seismic vault	bedrock
19.	Miramichi, N.B. 'Loggie Lodge II'	10/86	46.9729 66.5293	SMA-1 TCG-1A	1 g	0.0105 g	Above ground seismic vault	bedrock
20.	Les Éboulements, Qué.	6/85	47.5496 70.3273	SMA-1 TCG-1B	1 g	0.0075 g	Above ground seismic vault	bedrock

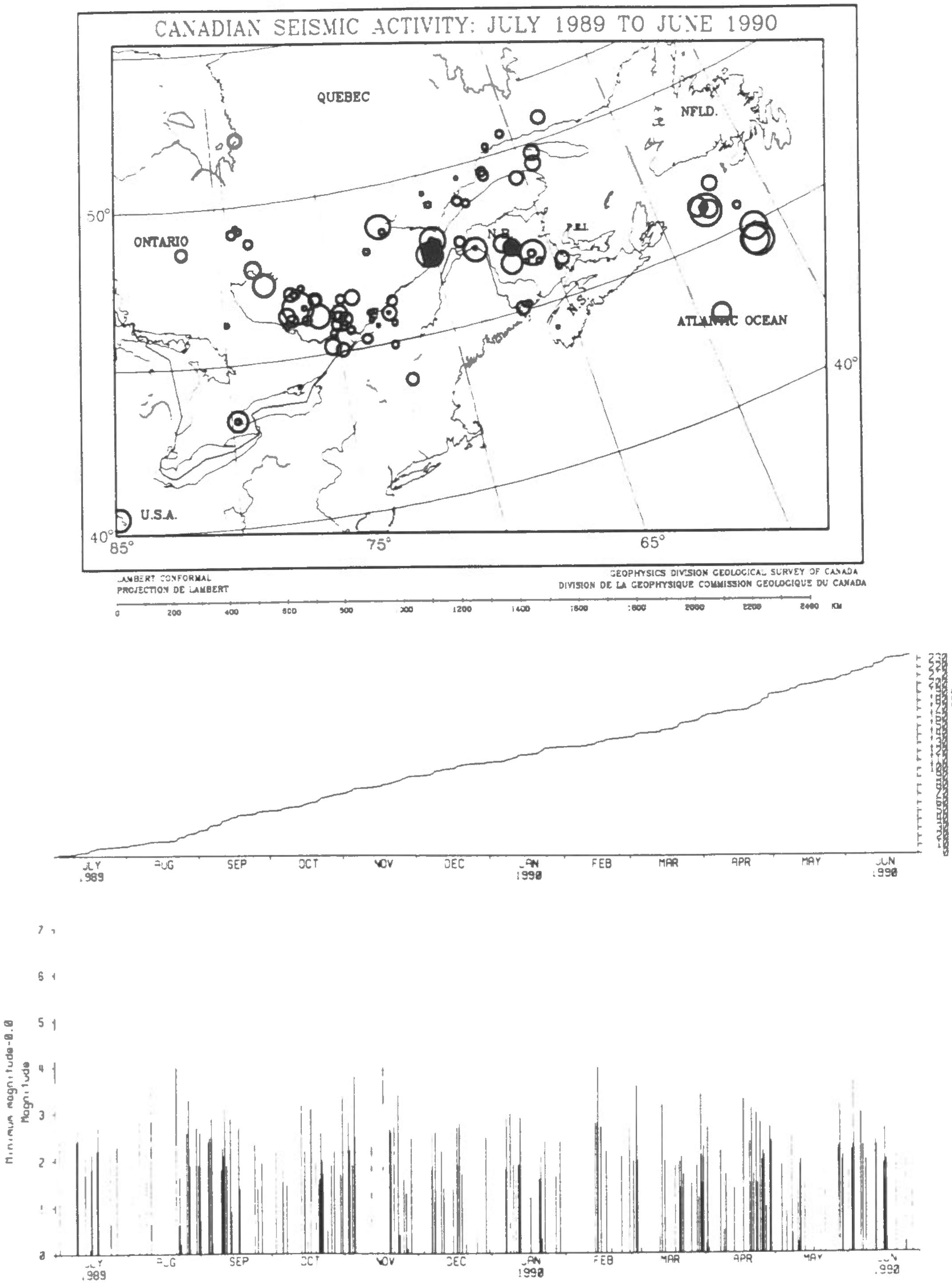

Figure 11. Summary of eastern Canadian seismic activity in 1989–90. Shown below the map are graphs the cumulative number of events that occurred and the magnitude–time history of the activity. Circle size is proportional to magnitude.

TABLE 5 / TABLEAU 5
LIST / LISTE
EASTERN CANADIAN EARTHQUAKES: JULY 1989 - JUNE 1990

40.00 ≤ LATITUDE ≤ 55.00
-85.00 ≤ LONGITUDE ≤ -51.00

JUL/JUIL 1989 - JUN/JUIN 1990

#	DATE	H M S	LAT	LONG	Z	MAG	Q
001	1989/07/02	20:26:02.7	47.010	-76.649	18.0	2.4MN	*
002	1989/07/09	22:04:56.4	46.635	-74.630	18.0	2.4MN	*
003	1989/07/10	16:38:27.5	52.132	-78.629	18.0	2.7MN	
004	1989/07/14	00:26:01.4	47.411	-70.313	11.9	2.1MN	*
005	1989/07/15	20:55:54.5	49.814	-68.701	1.0	0.1ML	
006	1989/07/16	12:23:08.5	45.445	-75.971	20.3	1.8MN	*
007	1989/07/16	16:44:24.6	47.000	-66.600	5.0	2.2MN	*
008	1989/07/18	22:53:36.4	48.489	-72.232	18.0	2.2MN	*
009	1989/07/19	11:58:55.3	45.061	-74.878	0.0	2.7MN	
010	1989/07/24	17:02:11.5	46.099	-57.992	18.0	2.1MN	
011	1989/07/27	09:48:56.0	50.571	-65.485	18.0	2.3MN	
012	1989/08/01	23:42:19.1	47.710	-69.881	11.4	2.5MN	*
013	1989/08/03	02:33:27.2	47.962	-73.061	18.0	2.2MN	*
014	1989/08/05	21:07:58.0	43.287	-79.761	5.0	3.2MN	
015	1989/08/09	04:09:51.3	43.287	-79.761	5.0	2.2MN	
016	1989/08/10	21:17:42.5	46.660	-65.788	5.0	3.5MN	*
017	1989/08/11	00:46:13.0	45.832	-7[illegible]1	18.0	1.8MN	*
018	1989/08/21	18:16:09.0	45.979	-57.879	18.0	4.0MN	*
019	1989/08/22	17:38:26.5	47.306	-70.378	8.2	0.6ML	*
020	1989/08/22	20:35:36.7	47.441	-70.347	7.5	0.3ML	*
021	1989/08/23	05:14:33.2	49.324	-66.607	18.0	1.7MN	*
022	1989/08/23	18:01:22.2	47.469	-70.047	7.2	0.2ML	*
023	1989/08/26	03:39:15.1	47.000	-66.600	5.0	2.6MN	*
024	1989/08/26	04:42:17.3	46.362	-65.611	18.0	2.2MN	*
025	1989/08/27	02:07:35.8	47.420	-78.007	18.0	3.3MN	
026	1989/08/27	11:32:40.4	48.114	-71.066	17.5	1.9MN	*
027	1989/08/30	08:25:48.6	47.660	-70.054	20.6	2.7MN	*
028	1989/08/31	08:44:04.7	47.460	-70.113	11.2	1.9MN	*
029	1989/08/31	19:44:20.5	47.613	-70.285	22.2	2.6MN	*
030	1989/08/31	22:59:25.0	47.854	-69.723	10.4	0.7ML	*
031	1989/09/04	12:12:11.9	45.261	-73.773	18.0	2.4MN	*
032	1989/09/04	20:33:08.6	46.297	-72.422	18.0	2.5MN	*
033	1989/09/04	21:58:08.5	47.668	-70.126	9.1	0.3ML	
034	1989/09/05	16:30:24.6	47.964	-78.459	18.0	2.9MN	*
035	1989/09/05	20:04:41.3	49.587	-66.897	18.0	2.4MN	*
036	1989/09/06	01:51:11.1	47.408	-70.328	10.6	0.2ML	*
037	1989/09/09	23:16:27.5	49.153	-67.267	18.0	1.8MN	*
038	1989/09/10	09:21:42.5	48.745	-68.050	18.0	2.3MN	
039	1989/09/10	14:42:57.0	48.756	-68.019	18.0	1.5MN	*
040	1989/09/11	01:22:56.0	46.545	-76.324	18.0	2.1MN	*
041	1989/09/11	09:21:03.1	46.174	-58.149	18.0	3.1MN	*
042	1989/09/12	05:06:55.6	49.081	-66.458	18.0	1.9MN	*
043	1989/09/13	14:55:23.6	47.570	-70.039	14.8	2.9MN	*
044	1989/09/14	05:23:30.0	47.424	-70.381	13.2	0.9ML	*
045	1989/09/15	02:16:01.0	47.487	-70.067	14.8	0.0ML	*
046	1989/09/17	07:15:59.3	47.590	-70.014	9.9	0.1ML	*
047	1989/09/17	08:16:39.2	50.760	-63.378	18.0	2.7MN	*
048	1989/09/17	14:21:28.8	47.715	-69.733	16.2	1.4ML	*
049	1989/09/23	23:00:29.8	48.883	-68.393	18.0	2.4MN	*
050	1989/09/25	06:48:24.9	49.107	-67.818	18.0	1.4MN	*
051	1989/09/25	06:57:05.4	49.029	-67.863	18.0	1.4MN	*
052	1989/10/02	21:00:03.1	46.050	-57.900	18.0	2.2MN	
053	1989/10/05	16:26:38.1	47.561	-69.913	14.2	1.5MN	*
054	1989/10/05	21:10:58.0	47.000	-66.600	5.0	1.8MN	
055	1989/10/07	13:41:01.0	46.005	-74.781	18.0	2.1MN	
056	1989/10/09	04:43:22.7	47.389	-70.300	11.0	-.4ML	*
057	1989/10/13	14:04:42.8	47.393	-70.133	22.7	3.2MN	*
058	1989/10/14	23:38:25.5	47.733	-70.190	3.4	1.6MN	*
059	1989/10/15	02:46:37.9	50.319	-66.368	18.0	2.2MN	*
060	1989/10/16	11:01:34.9	47.614	-70.206	16.3	0.3ML	*
061	1989/10/17	12:42:59.8	42.859	-59.096	18.0	3.2ML	
062	1989/10/19	17:07:28.9	45.793	-73.456	18.0	2.0MN	*
063	1989/10/21	01:59:08.2	47.594	-69.893	14.7	1.5MN	*
064	1989/10/21	02:33:38.6	46.676	-66.594	18.0	1.6MN	*
065	1989/10/21	20:29:44.3	43.291	-71.910	2.5	2.7MN	*
066	1989/10/22	06:27:00.0	49.372	-69.966	18.0	2.0MN	*
067	1989/10/22	17:43:22.1	47.069	-69.534	18.0	1.7MN	*
068	1989/10/24	15:21:50.6	47.542	-70.188	15.9	0.5ML	*
069	1989/10/26	06:29:33.0	47.000	-66.600	5.0	1.9MN	*
070	1989/10/27	12:51:05.5	47.172	-76.355	18.0	2.2MN	
071	1989/10/30	04:56:54.9	47.782	-69.929	16.7	1.7MN	*
072	1989/10/31	04:50:03.5	48.666	-72.328	18.0	3.4MN	*
073	1989/11/02	12:34:02.5	46.648	-74.103	18.0	2.8MN	*
074	1989/11/03	03:15:13.5	47.000	-66.600	5.0	2.2MN	*
075	1989/11/04	00:43:37.2	47.000	-66.600	5.0	1.9MN	*
076	1989/11/04	21:56:54.8	44.530	-56.403	18.0	3.8ML	*
077	1989/11/04	23:25:43.5	46.216	-75.723	7.9	3.4MN	*
078	1989/11/05	06:11:09.9	45.854	-74.980	12.1	2.5MN	*
079	1989/11/11	09:19:37.5	47.000	-66.600	5.0	2.5MN	*
080	1989/11/14	03:49:59.8	47.436	-68.414	18.0	1.8MN	
081	1989/11/16	08:44:37.2	46.075	-75.666	18.0	1.9MN	*
082	1989/11/16	09:24:51.7	46.576	-76.602	18.0	4.0MN	*
083	1989/11/19	06:32:35.6	46.708	-57.204	18.0	2.8ML	
084	1989/11/19	20:29:29.1	48.616	-81.747	18.0	2.6MN	*

#	DATE	H M S	LAT	LONG	Z	MAG	Q
085	1989/11/21	02:45:18.7	45.995	-74.514	18.0	2.7MN	*
086	1989/11/22	23:02:51.6	47.455	-70.345	8.1	3.4MN	*
087	1989/11/23	13:08:56.9	47.542	-70.298	11.3	0.4ML	*
088	1989/11/25	00:33:49.6	47.551	-70.247	13.6	-.2ML	*
089	1989/11/25	05:33:10.9	47.551	-69.987	14.8	1.6MN	*
090	1989/11/26	04:24:51.1	47.674	-70.075	13.3	1.3MN	*
091	1989/11/26	18:17:39.3	47.527	-70.048	12.3	0.1ML	*
092	1989/11/28	08:49:24.3	47.666	-68.771	11.8	2.5MN	*
093	1989/12/03	18:33:35.6	47.586	-69.951	16.0	0.3ML	*
094	1989/12/07	06:06:16.0	45.924	-65.686	18.0	1.8MN	*
095	1989/12/07	08:42:52.4	47.000	-66.600	5.0	2.6MN	*
096	1989/12/08	12:15:15.1	47.000	-66.600	5.0	1.1MN	
097	1989/12/08	15:57:17.7	47.000	-66.600	5.0	1.8MN	
098	1989/12/08	17:20:34.4	47.701	-70.064	10.3	2.6MN	*
099	1989/12/11	04:56:35.6	47.896	-69.961	10.0	2.2MN	*
100	1989/12/12	04:31:38.8	48.076	-71.188	29.0	1.4MN	*
101	1989/12/16	02:18:20.7	47.000	-66.600	5.0	1.4MN	*
102	1989/12/17	14:22:18.0	49.075	-65.400	18.0	2.7MN	*
103	1989/12/17	17:08:18.9	47.519	-70.362	5.9	1.9MN	*
104	1989/12/18	14:55:35.6	47.387	-70.154	18.2	2.8MN	*
105	1989/12/19	12:55:36.7	48.374	-70.439	18.0	1.7MN	*
106	1989/12/21	12:11:28.0	47.701	-70.073	10.8	0.2ML	*
107	1989/12/26	04:32:53.1	47.455	-70.453	6.9	0.5ML	*
108	1989/12/29	15:32:57.6	47.499	-70.145	5.3	2.5MN	*
109	1989/12/31	02:34:53.9	47.451	-70.343	7.6	0.1ML	*
110	1990/01/06	21:56:23.5	47.000	-66.600	5.0	1.8MN	
111	1990/01/07	06:57:55.0	46.349	-77.155	18.0	2.9MN	*
112	1990/01/08	21:40:26.9	47.196	-66.928	18.0	3.0MN	*
113	1990/01/10	09:21:18.5	47.000	-66.600	5.0	1.9MN	*
114	1990/01/11	07:15:12.2	47.454	-70.347	8.3	1.8MN	*
115	1990/01/12	11:30:53.6	47.460	-70.045	11.7	1.9MN	*
116	1990/01/12	14:39:40.9	47.000	-66.600	5.0	1.8MN	
117	1990/01/13	02:19:56.5	46.200	-74.779	17.9	2.9MN	*
118	1990/01/17	04:37:25.0	47.407	-70.300	8.1	0.0ML	*
119	1990/01/20	19:59:46.0	46.030	-64.900	10.0	1.6MN	
120	1990/01/21	13:43:26.8	46.030	-64.900	10.0	2.1MN	
121	1990/01/21	14:31:24.0	47.598	-70.239	11.9	-.5ML	*
122	1990/01/21	23:12:49.5	47.450	-70.041	8.9	0.3ML	*
123	1990/01/23	05:23:30.9	49.128	-79.281	18.0	2.4MN	*
124	1990/01/23	07:57:57.0	47.483	-70.443	7.0	-.1ML	*
125	1990/01/27	20:45:51.7	47.449	-70.078	14.5	1.7MN	*
126	1990/01/29	16:30:22.4	46.129	-74.847	18.0	2.4MN	*
127	1990/02/10	11:04:34.4	47.387	-70.258	13.6	0.4ML	*
128	1990/02/11	04:49:47.9	47.403	-70.390	7.6	-.1ML	*
129	1990/02/13	21:40:02.8	49.695	-64.331	18.0	2.8MN	*
130	1990/02/14	15:21:04.9	49.363	-64.445	18.0	2.8MN	*

#	DATE	H M S	LAT	LONG	Z	MAG	Q
131	1990/02/15	00:09:28.3	44.455	-56.332	18.0	4.0ML	*
132	1990/02/16	03:44:38.5	47.023	-76.866	18.0	2.7MN	*
133	1990/02/18	11:55:17.7	49.200	-78.948	18.0	2.2MN	
134	1990/02/18	11:56:38.5	49.316	-79.073	18.0	2.1MN	
135	1990/02/20	14:00:50.3	47.679	-69.926	9.1	0.1ML	*
136	1990/02/24	21:58:22.9	46.080	-73.290	18.0	2.1MN	*
137	1990/02/28	06:55:16.9	46.217	-64.618	18.0	2.7MN	*
138	1990/03/03	01:12:34.8	45.203	-75.307	18.0	2.9MN	*
139	1990/03/03	02:06:03.3	47.856	-69.977	20.8	3.6MN	*
140	1990/03/03	15:17:54.1	47.699	-70.083	8.4	2.0MN	*
141	1990/03/05	00:25:12.1	47.654	-69.902	7.6	0.1ML	*
142	1990/03/12	16:20:03.0	47.695	-70.086	5.7	0.4ML	*
143	1990/03/13	18:49:40.5	47.534	-70.137	15.2	2.4MN	*
144	1990/03/13	19:10:39.3	47.534	-70.136	15.3	3.2MN	*
145	1990/03/15	00:24:22.3	47.000	-66.600	5.0	2.0MN	*
146	1990/03/19	07:13:37.4	45.597	-74.655	18.0	1.9MN	*
147	1990/03/19	11:05:39.2	47.480	-69.989	7.4	1.8MN	*
148	1990/03/21	01:14:21.5	47.000	-66.600	5.0	1.5MN	
149	1990/03/21	01:39:10.3	47.000	-66.600	5.0	1.6MN	
150	1990/03/21	03:57:29.3	47.305	-68.190	18.0	2.0MN	*
151	1990/03/21	15:39:26.7	47.000	-66.600	5.0	1.4MN	
152	1990/03/21	21:33:29.1	46.458	-66.159	18.0	2.1MN	*
153	1990/03/26	03:17:53.9	47.000	-66.600	5.0	1.5MN	*
154	1990/03/28	10:18:57.6	46.506	-76.643	18.0	1.9MN	
155	1990/03/29	04:55:01.8	47.000	-66.600	5.0	1.2MN	
156	1990/03/30	01:54:08.7	47.248	-68.201	10.4	3.4MN	*
157	1990/03/30	09:31:30.5	47.000	-66.600	5.0	2.1MN	*
158	1990/03/30	18:56:53.8	47.484	-70.101	15.8	1.5MN	*
159	1990/03/31	06:05:34.2	47.621	-70.159	9.3	2.3MN	*
160	1990/04/01	14:44:51.6	47.551	-70.039	14.1	0.2ML	*
161	1990/04/01	19:13:05.3	45.084	-66.912	10.0	2.7MN	
162	1990/04/02	07:54:06.7	47.393	-70.282	10.3	0.1ML	*
163	1990/04/07	13:30:56.8	47.573	-69.953	11.3	2.2MN	*
164	1990/04/08	22:18:14.4	47.470	-70.044	9.5	0.5ML	*
165	1990/04/09	19:26:14.7	46.169	-64.810	18.0	1.7MN	
166	1990/04/13	13:11:35.0	47.385	-70.266	10.4	1.4MN	*
167	1990/04/17	10:27:36.3	40.460	-84.850	18.0	3.3MN	
168	1990/04/20	04:16:35.4	45.805	-74.649	20.1	2.4MN	*
169	1990/04/20	20:23:57.1	47.650	-69.897	12.8	1.5MN	*
170	1990/04/21	01:23:04.1	47.553	-70.070	9.6	3.1MN	*
171	1990/04/21	22:45:51.5	48.431	-64.395	18.0	1.7ML	
172	1990/04/23	00:28:04.7	47.409	-70.179	7.9	3.0MN	*
173	1990/04/23	16:12:47.6	45.744	-65.282	18.0	1.5MN	
174	1990/04/24	13:46:20.1	45.938	-72.650	18.0	2.8MN	*
175	1990/04/25	08:44:20.8	45.959	-64.850	18.0	2.0MN	*
176	1990/04/25	21:01:56.4	47.929	-65.808	18.0	1.7MN	*

#	DATE	H M S	LAT	LONG	Z	MAG	Q
177	1990/04/25	21:11:03.8	46.180	-75.115	18.0	2.2MN	*
178	1990/04/25	21:12:01.7	48.068	-65.098	18.0	1.7MN	
179	1990/04/26	09:11:54.8	46.272	-80.188	18.0	2.0MN	*
180	1990/04/27	03:28:09.8	46.363	-72.372	18.0	1.0ML	
181	1990/04/28	20:57:06.4	46.740	-75.787	18.0	2.5MN	*
182	1990/04/28	21:15:05.8	46.740	-75.787	18.0	2.7MN	*
183	1990/04/28	21:20:04.9	46.740	-75.787	18.0	1.5MN	*
184	1990/04/28	22:51:11.8	46.740	-75.787	18.0	0.2ML	
185	1990/04/29	00:14:29.3	47.618	-70.167	11.3	1.7MN	*
186	1990/04/29	11:42:27.4	46.141	-76.271	18.0	2.4MN	*
187	1990/05/03	20:34:28.0	47.000	-66.600	5.0	1.9MN	*
188	1990/05/06	02:04:43.5	47.514	-70.377	3.2	0.9MN	*
189	1990/05/07	08:54:04.8	48.041	-71.126	28.0	-.1ML	
190	1990/05/08	09:18:56.5	46.103	-74.829	18.0	2.5MN	*
191	1990/05/08	12:11:31.0	47.479	-69.977	10.6	0.4ML	*
192	1990/05/10	20:01:05.9	47.446	-70.048	8.7	1.6MN	*
193	1990/05/11	05:04:09.1	47.611	-70.248	10.1	0.2ML	*
194	1990/05/11	17:41:14.3	47.447	-70.066	6.1	1.9MN	*
195	1990/05/11	22:22:41.0	45.175	-66.774	18.0	2.1MN	
196	1990/05/13	18:28:02.5	45.645	-75.034	18.0	1.5MN	*
197	1990/05/17	13:48:24.8	49.005	-69.777	18.0	2.2MN	
198	1990/05/17	15:27:03.1	45.160	-66.626	1.0	2.2MN	*
199	1990/05/20	12:20:15.1	45.604	-75.160	18.0	2.3MN	*
200	1990/05/22	08:11:42.7	46.188	-76.935	18.0	2.6MN	*
201	1990/05/22	12:21:09.7	47.535	-70.029	7.4	0.5ML	*
202	1990/05/28	02:35:21.5	46.644	-65.841	18.0	2.3MN	
203	1990/05/28	04:06:45.4	46.343	-64.782	18.0	1.9MN	*
204	1990/05/28	18:22:51.5	46.514	-66.796	18.0	3.2MN	*
205	1990/05/29	21:53:46.4	45.620	-73.244	18.0	2.0MN	*
206	1990/05/30	02:50:53.5	47.529	-69.971	11.4	2.1MN	*
207	1990/06/01	20:07:02.5	46.665	-72.104	18.0	1.8MN	*
208	1990/06/02	18:55:20.0	45.601	-72.495	0.0	2.2MN	
209	1990/06/03	03:40:14.8	45.619	-74.378	18.0	2.3MN	*
210	1990/06/03	08:59:21.5	47.765	-69.856	18.6	0.5ML	*
211	1990/06/03	15:09:45.6	44.888	-56.244	18.0	3.7ML	*
212	1990/06/04	20:28:47.8	48.857	-72.551	18.0	1.0MN	*
213	1990/06/06	16:57:46.8	45.979	-57.723	18.0	3.0MN	*
214	1990/06/07	12:22:49.1	45.711	-56.522	18.0	2.3ML	*
215	1990/06/08	15:17:58.4	49.602	-68.142	18.0	2.0MN	
216	1990/06/08	19:16:38.1	47.989	-66.089	18.0	1.9MN	*
217	1990/06/11	10:12:15.9	47.646	-69.906	10.7	0.3ML	*
218	1990/06/12	14:50:01.5	47.000	-66.600	5.0	0.5ML	
219	1990/06/12	15:46:15.6	47.481	-70.114	23.1	0.3ML	*
220	1990/06/12	16:19:54.2	49.450	-66.869	18.0	2.5MN	
221	1990/06/12	21:32:34.8	44.921	-72.667	18.0	2.3MN	*
222	1990/06/14	23:19:49.0	47.600	-65.750	1.0	1.9MN	
223	1990/06/16	03:33:32.4	47.000	-66.600	5.0	1.9MN	
224	1990/06/16	13:48:05.8	47.000	-66.600	5.0	2.9MN	*
225	1990/06/17	00:47:22.1	46.291	-80.179	18.0	1.5MN	
226	1990/06/17	03:23:37.4	45.861	-73.432	18.0	2.0MN	*
227	1990/06/17	08:51:16.9	47.559	-70.032	10.8	0.3ML	*
228	1990/06/18	07:00:16.6	47.587	-70.244	12.7	-.2ML	*
229	1990/06/21	08:17:46.0	46.060	-73.446	18.0	2.1MN	
230	1990/06/24	11:08:58.1	49.379	-78.479	18.0	1.9MN	
231	1990/06/24	11:11:59.3	49.423	-78.554	18.0	2.0MN	
232	1990/06/25	03:51:55.3	47.645	-69.856	16.2	0.2ML	*
233	1990/06/25	10:00:58.2	45.951	-72.682	18.0	2.0MN	
234	1990/06/28	01:43:43.4	45.956	-77.213	18.0	2.0MN	*

Eighteen earthquakes were reported felt in southeastern Canada in this same period. They are summarized in Table 6.

Figure 11 shows that the general pattern of activity has continued to be similar to that of previous years with seismic activity concentrated in the recognized seismic zones of West Québec; Charlevoix, Québec; Lower St. Lawrence, Québec; Miramichi, N.B.; and the Laurentian Continental Slope. However, activity in New Brunswick was more wide spread than in the previous report periods and significant seismic activity occurred on the Laurentian Continental Slope in areas which had not been active previously. Periods with a higher rate of seismic activity occurred in August and April.

West Quebec: The West Quebec zone (Fig. 12) experienced the largest event onshore in eastern Canada (magnitude 4.0) on November 16. The termor was felt (Table 6) but only mildly. A field survey was not carried out and no foreshocks or aftershocks were detected by the network. Following that event the activity throughout the zone showed an apparent decline until January. However, this decline coincided with the period of erratic service from ECTN radio– linked stations in the West Quebec area and the failure of GAC, so the significance of the decline is open to question. Swarm activity was observed near the Baskatong Reservoir in April. Otherwise, the activity throughout the zone was scattered in space and time.

Charlevoix: Eighty–one earthquakes were located in the Charlevoix seismic zone (Fig. 13) during this period; six were reported felt (Table 6). The largest event on March 3 was only magnitude 3.6. It occurred at the extreme north end of the seismic zone, north of the river. The remaining activity did not show significant clustering in space or time, but the rate of activity appeared to be 'low' in July and August at the start of the reporting period, recovering at the end of August to a more normal pace. Parts of the seismic zone remained aseismic throughout the year.

Lower St. Lawrence: The activity in the Lower St. Lawrence seismic zone (Fig. 14) was moderate in this period. Twenty–three events were located, of which none were greater than magnitude 3.0. An unusual burst of events occurred in the month of September.

The detection and location of seismic events in the Lower St. Lawrence region was significantly degraded in this period by the prolonged outages experienced at the MNQ and HTQ stations.

New Brunswick: As usual, peristent seismic activity occurred in the Miramichi aftershock zone, but, in this year, more seismic activity was observed elsewhere in New Brunswick than in past years (Fig. 15). Twenty–five events occurred within the aftershock zone; all were less than magnitude 3.0. Twenty–two events, including 3 with magnitude 3.0–3.5, were located in other parts of New Brunswick, outside the aftershock zone. Two of the larger events were reported felt (Table 6).

The largest rockburst in some years occurred in Brunswick Mines near Bathurst on July 19. The event was magnitude 3.1 and caused some damage in the mine. (It is not plotted on the Figure because it is classified as a mining–induced event).

Laurentian Slope: Offshore seismicity was highlighted by a swarm of earthquakes in the Laurentian Channel (Fig. 11), which began with the magnitude 4.5 event on February 2, 1989 (see last year's report), the largest earthquake to occur on the southeast Canadian continental margin since 1975. The swarm occurred in a hitherto aseismic region of the Laurentian Channel. That initial earthquake has been followed by a continuing series of smaller events including a magnitude 4.0

TABLE 6 / TABLEAU 6
NATIONAL SUMMARY / SOMMAIRE NATIONAL
EASTERN CANADIAN EARTHQUAKES: JULY 1989 - JUNE 1990

FELT / RESSENTI

40.00 ≤ LATITUDE ≤ 55.00
-85.00 ≤ LONGITUDE ≤ -51.00

JUL/JUIL 1989 - JUN/JUIN 1990

\# DATE H M S LAT LONG Z MAG Q

001 1989/07/19 11:58:55.3 45.061 -74.878 0.0 2.7MN
RMS= 0.66 ERR= 0 0.018 0.022 6.5 0.2 NO= 11 18 8
WESTERN QUEBEC ZONE
CORNWALL, ONT.
FELT AND HEARD LOCALLY
IN CORNWALL AND LONG SAULT.
HEARD LIKE A TRUCK PASSING BY.

002 1989/08/05 21:07:58.0 43.287 -79.761 5.0 3.2MN
RMS= 0.30 ERR= 0 0.007 0.013 G 0.2 NO= 14 21 14
FELT
IN THE HAMILTON-OAKVILLE-MISSISSAUGA
AREA.
WESTERN LAKE ONTARIO.

003 1989/08/30 08:25:48.6 47.660 -70.054 20.6 2.7MN *
RMS= 0.05 ERR= 0 0.002 0.003 0.3 0.2 NO= 6 12 8
CHARLEVOIX, QUE.
FELT
HEARD IN SAINT-IRENEE, SAINT-HILARION,
POINTE-AU-PIC, LA MALBAIE AND
ON ILE AUX COUDRES

004 1989/08/31 19:44:20.5 47.613 -70.285 22.2 2.6MN *
RMS= 0.11 ERR= 0 0.005 0.007 1.0 0.0 NO= 7 11 5
CHARLEVOIX, QUE.
FELT
AT BAIE-SAINT-PAUL, ON ILE AUX COUDRES,
LES EBOULEMENTS, SAINT-IRENEE
AND SAINT-HILARION.

005 1989/10/13 14:04:42.8 47.393 -70.133 22.7 3.2MN *
RMS= 0.12 ERR= 0 0.004 0.007 0.8 0.2 NO= 6 12 7
CHARLEVOIX, QUEBEC
FELT ON THE NORTH SHORE
AT ST-HILARION, BAIE-SAINT-PAUL,
LA MALBAIE, LES EBOULEMENTS.

006 1989/10/31 04:50:03.5 48.666 -72.328 18.0 3.4MN *
RMS= 0.57 ERR= 0 0.018 0.015 G 0.3 NO= 16 29 17

\# DATE H M S LAT LONG Z MAG Q

NEAR ROBERVAL, LAC SAINT-JEAN
FELT (III)
AT DOLBEAU, NORMANDIN, ROBERVAL,
ST-FELICIEN, ST-PRIME, ST-EDWIDGE.

007 1989/11/04 23:25:43.5 46.216 -75.723 7.9 3.4MN *
RMS= 0.07 ERR= 0 0.006 0.005 7.6 0.4 NO= 3 6 10
WESTERN QUEBEC
FELT (III)
AT BLUE SEA LAKE, MESSINES
LAC BOILEAU, AND STE.THERESE,

008 1989/11/16 09:24:51.7 46.576 -76.602 18.0 4.0MN *
RMS= 0.23 ERR= 0 0.011 0.007 G 0.3 NO= 6 11 14
WESTERN QUEBEC
50 KM NW OF MANIWAKI
FELT MILDLY AT MANIWAKI, QUE.
A FEW REPORTS FROM PEMBROKE
AND OTTAWA, ONT.

009 1989/11/21 02:45:18.7 45.995 -74.514 18.0 2.7MN *
RMS= 0.26 ERR= 0 0.006 0.010 G 0.1 NO= 8 14 6
WESTERN QUEBEC
FELT MILDLY AT
STE.AGATHE ET ST.JOVITE

010 1989/11/22 23:02:51.6 47.455 -70.345 8.1 3.4MN *
RMS= 0.08 ERR= 0 0.002 0.004 0.6 0.1 NO= 7 14 15
CHARLEVOIX-KAMOURASKA, QUE.
FELT (IV)
IN BAIE-ST-PAUL, LA MALBAIE,
LES EBOULEMENTS, ST-IRENEE
FELT (III)
IN ST-HILARION,
AND ON THE SOUTH SHORE AT
ST-PASCAL, RIVIERE-OUELLE, KAMOURASKA.

011 1989/12/11 04:56:35.6 47.896 -69.961 10.0 2.2MN *
RMS= 0.21 ERR= 0 0.012 0.011 G 0.1 NO= 5 10 3
CHARLEVOIX, QUE.
REPORTED FELT
CHARLEVOIX LOCAL NETWORK DOWN

012 1990/03/03 02:06:03.3 47.856 -69.977 20.8 3.6MN *
RMS= 0.09 ERR= 0 0.004 0.005 0.4 0.2 NO= 8 15 22
CHARLEVOIX, QUE.
AFTERSHOCK AT 02:09
FELT IN CHARLEVOIX
FROM SAINT-SIMEON TO LES EBOULEMENTS
ALSO REPORTED FELT IN RIVIERE-DU-LOUP

```
  #   DATE       H  M  S     LAT     LONG     Z   MAG   Q

013 1990/03/03 15:17:54.1  47.699  -70.083  8.4 2.0MN  *
    RMS= 0.04 ERR=  0  0.001 0.001  0.1 0.4 NO=  8 16  3
           CHARLEVOIX, QUEBEC
           FELT AT SAINT-HILARION AND
           LES EBOULEMENTS

014 1990/03/13 19:10:39.3  47.534  -70.136 15.3 3.2MN  *
    RMS= 0.08 ERR=  0  0.002 0.003  0.5 0.3 NO=  7 14 13
           NEAR LA MALBAIE
           FELT IN LA MALBAIE AND POINTE-AU-PIC
           CHARLEVOIX, QUE.

015 1990/04/01 19:13:05.3  45.084  -66.912 10.0 2.7MN
    RMS= 0.85 ERR=  0  0.050 0.048    G 0.2 NO=  8 16 15
           SOUTHERN N.B.
           FELT IN ST.GEORGES, ST.ANDREWS
           FELT AND HEARD IN BACKBAY
           FIXED DEPTH

016 1990/04/21 01:23:04.1  47.553  -70.070  9.6 3.1MN  *
    RMS= 0.04 ERR=  0  0.001 0.002  0.3 0.4 NO=  8 15  2
           CHARLEVOIX, QUE.
           FELT AT ST-HILARION, LA MALBAIE
           POINTE-AU-PIC, LES EBOULEMENTS.

017 1990/04/23 00:28:04.7  47.409  -70.179  7.9 3.0MN  *
    RMS= 0.06 ERR=  0  0.002 0.002  0.7 0.2 NO=  8 13  6
           CHARLEVOIX-KAMOURASKA, QUEBEC.
           FELT LOCALLY
           AT L'ILE AUX COUDRES, SAINT-HILARION,
           LES EBOULEMENTS, SAINT-IRENEE,
           BAIE-SAINT-PAUL,
           LA MALBAIE AND POINTE-AU-PIC.

018 1990/05/28 18:22:51.5  46.514  -66.796 18.0 3.2MN  *
    RMS= 0.57 ERR=  0  0.011 0.015    G 0.2 NO= 10 22  9
           CENTRAL N.B.
           FELT TO INTENSITY MM (IV)
           REPORTED FELT BY A CREW OF TREE
           PLANTERS APPROX. 3 KM NW OF THE
           EPICENTRE. THEY HEARD A RUMBLING SOUND
           AND FELT THE GROUND SHAKING.
           NOT REPORTED FELT IN BOIESTOWN AND
           STANLEY.
```

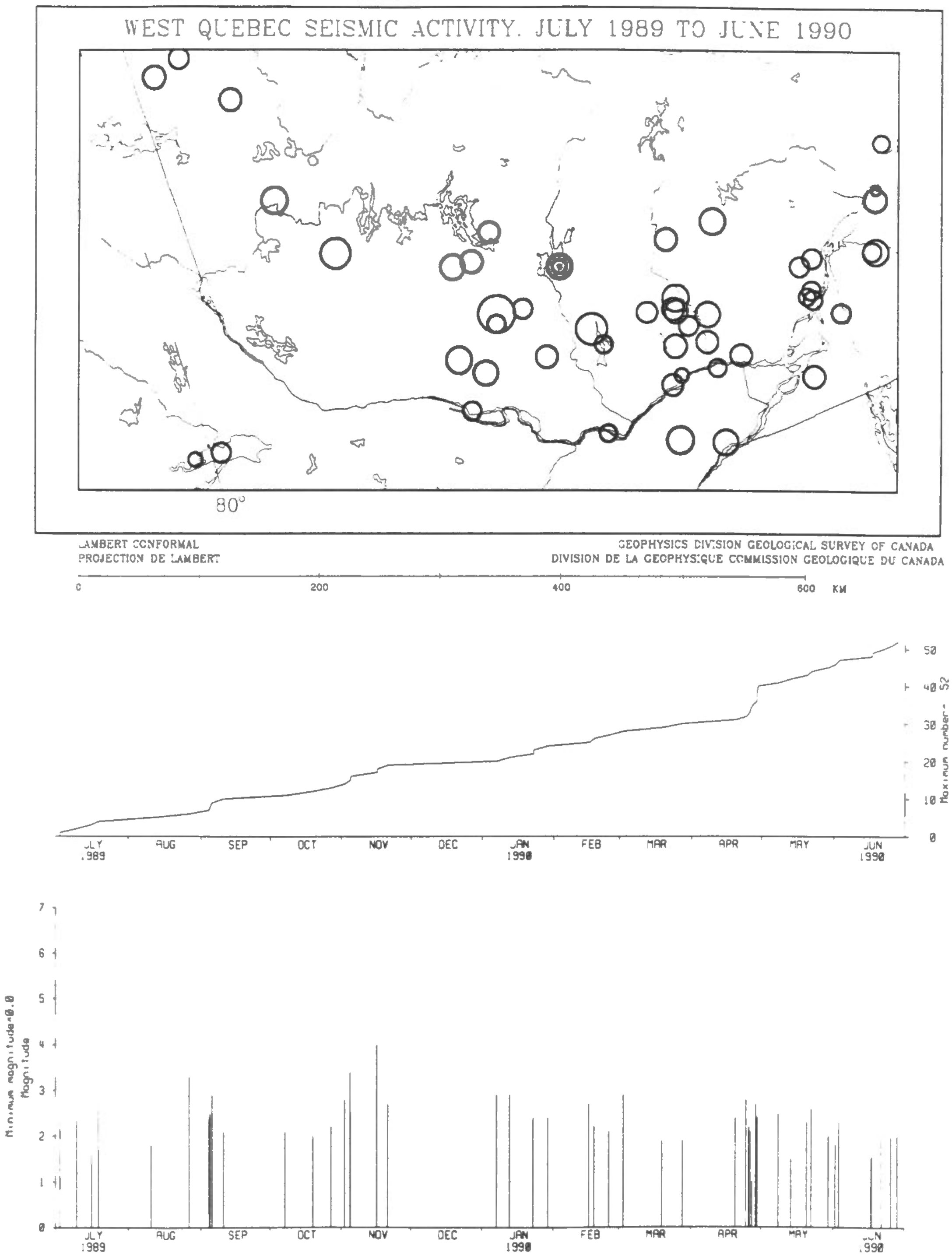

Figure 12. Summary of West Quebec seismic activity in 1989–90 as in Fig. 11.

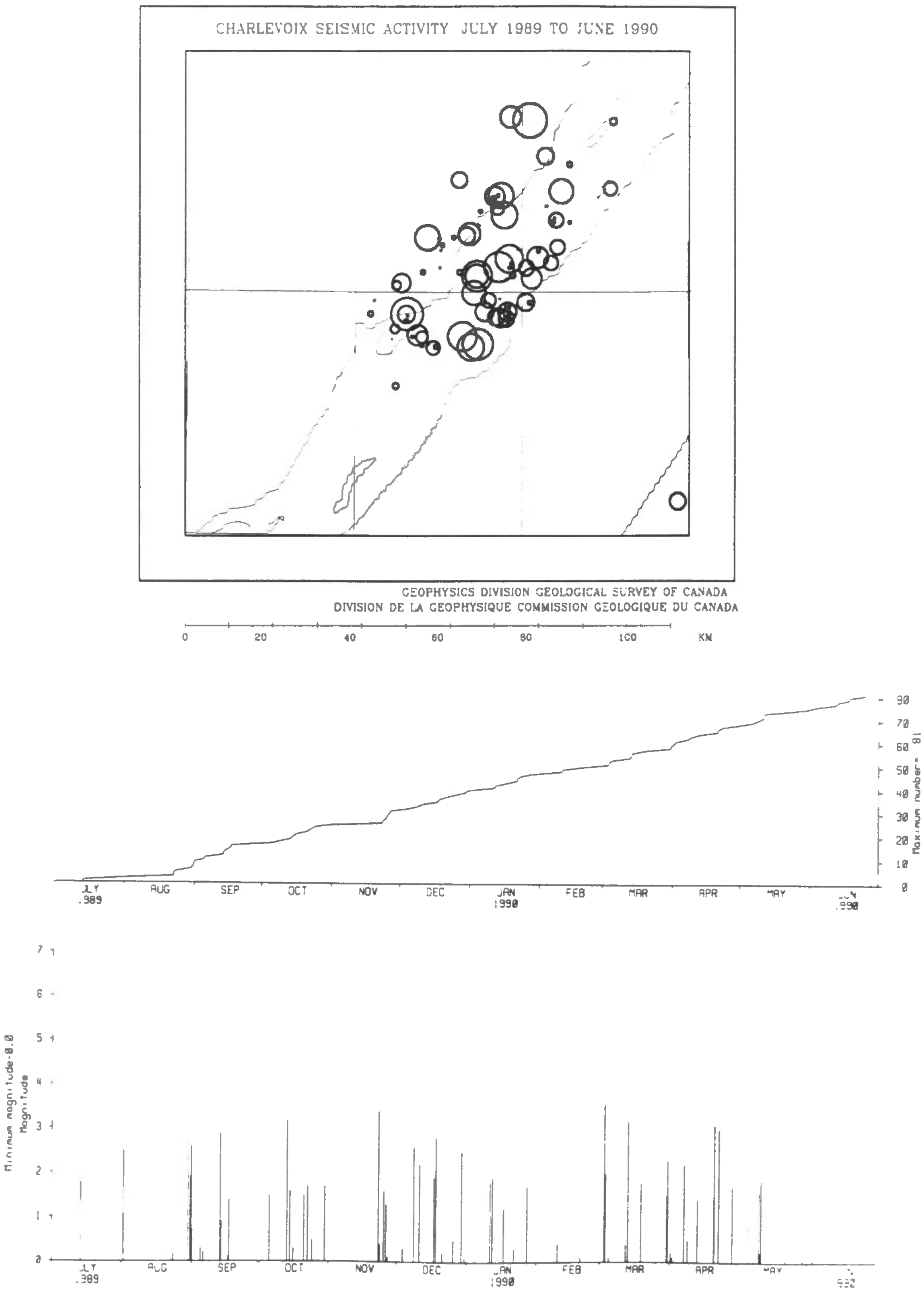

Figure 13. Summary of Charlevoix seismic activity in 1989–90 as in Fig. 11.

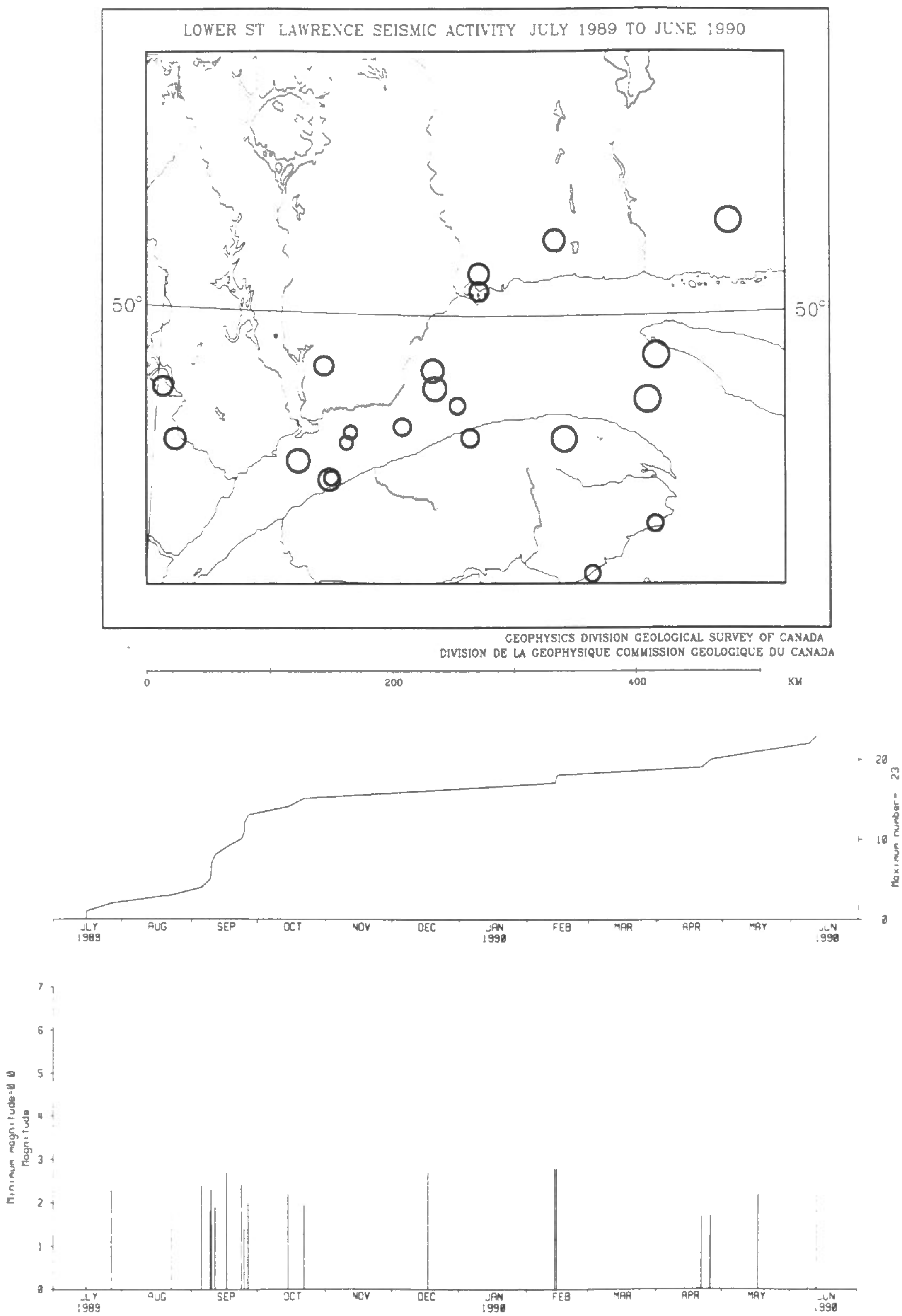

Figure 14. Summary of Lower St. Lawrence seismic activity in 1989–90 as in Fig. 11.

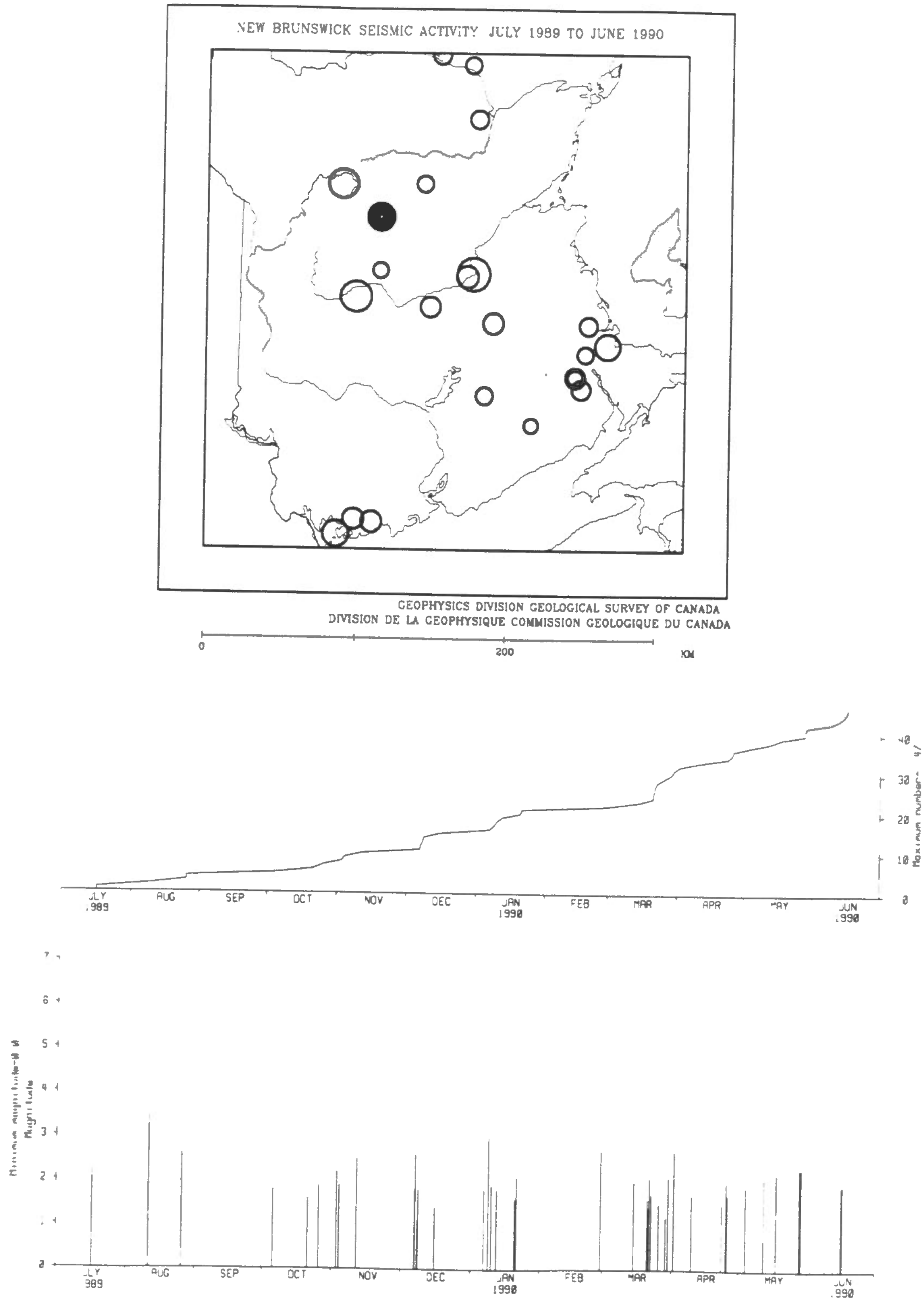

Figure 15. Summary of New Brunswick seismic activity in 1989-90 as in Fig. 11.

earthquake on August 21. From the epicentres determined, the earthquakes lie in a NW-trending ellipse about 25 km long by 15 km wide. On February 15 a magnitude 4.0 earthquake occurred on the Laurentian slope in the area which has been most active historically. Most recently on June 6 there was a magnitude 3.0 earthquake in the same area.

Other areas: A magnitude 3.2 earthquake on August 5 at 21:07 U.T. was felt in the Hamilton–Oakville–Mississauga area at the west end of lake Ontario. A previous earthquake from this area took place July 23, 1987 and had a similar magnitude of 3.4. A magnitude 3.4 event took place at night in an unusual area near Roberval, Quebec in the Lac–St–Jean region on October 18. The event was felt (Table 6). Our investigation could find no source of blasting to explain the event and the event is assumed to be an earthquake.

Only three aftershocks were recorded from the epicentral region of the Saguenay earthquake (November 25, 1988, magnitude 6) in this entire year. The largest was magnitude 1.9.

Ungava Peninsula: The magnitude 6.2 Ungava Earthquake of December 25 occurred in an area of northern Quebec that had previously been recognized as a seismic zone (Fig. 16), but historically had not experienced an event over magnitude 6.0. The earthquake followed a magnitude 5.1 foreshock 10 hours earlier. There were 5 earthquakes, magnitude 3 or greater, between the foreshock and the mainshock, and at least 8 magnitude 3 or greater aftershocks in the two weeks after the mainshock, the largest being magnitude 4.4. The epicentre was in the middle of the unpopulated Ungava Peninsula of northern Quebec; the nearest population centres were small coastal settlements. Intensity questionnaires were sent to the postmasters of about 100 communities in northern Quebec, Northwest Territories and Labrador. The mainshock was felt moderately at Kangirsuk (Payne Bay), the closest community at 200 km to the east, quite strongly in Kuujjuaq (Fort Chimo) at 360 km, and not felt at all at Iqaluit (Frobisher Bay) at 500 km. The maximum intensity felt was MMIV as shown in Figure 17. The felt area was considerably smaller than that of the magnitude 6 Saguenay Earthquake of November 25, 1988 and appears to be more consistent with the Ungava event's local magnitude than with its teleseismic magnitude.

Temperatures (-35°C), short daylight (<3 hr/day), and remoteness precluded an immediate field aftershock study, however, GD conducted a survey from July 9 to 24, 1990. The field party was led by R. J. Wetmiller, and field investigators included John Adams, J. Drysdale, and M. Lamontagne. The survey, which relied exclusively on helicopters to deploy equipment, was hampered by strong winds in the epicentral area and the almost total cecession of aftershock activity six months after the mainshock. However, the aftershock zone was found from the very low level of seismic activity (all less than magnitude 2.0) that persisted (Figure 16).

At the aftershock zone the field party discovered the surface fault rupture caused by the earthquake (Figure 18). The Ungava earthquake, the largest in North America east of the Rockies since 1963, thus becomes the first earthquake in eastern North America confirmed to have produced surface faulting. The fault break was traced over a length of 8.5 km (Fig. 18), trending an average of 038° (concave to the northwest), and centred at 60.12°N, 73.60°W. The fault trace uplifted lake shorelines near the fault, allowing the extent and pattern of the vertical deformation to be determined. The sense of displacement on the fault was thrust faulting with the southeast side upthrown. The maximum throw was 1.8 m along a central 1 km segment, and the throw tapered to less than 0.3 m at each end. As well as the deformed shorelines, there were fault scarps along the fault trace between adjoining lakes, torn muskeg above some traces, sand volcanoes, mud boils, freshly cracked

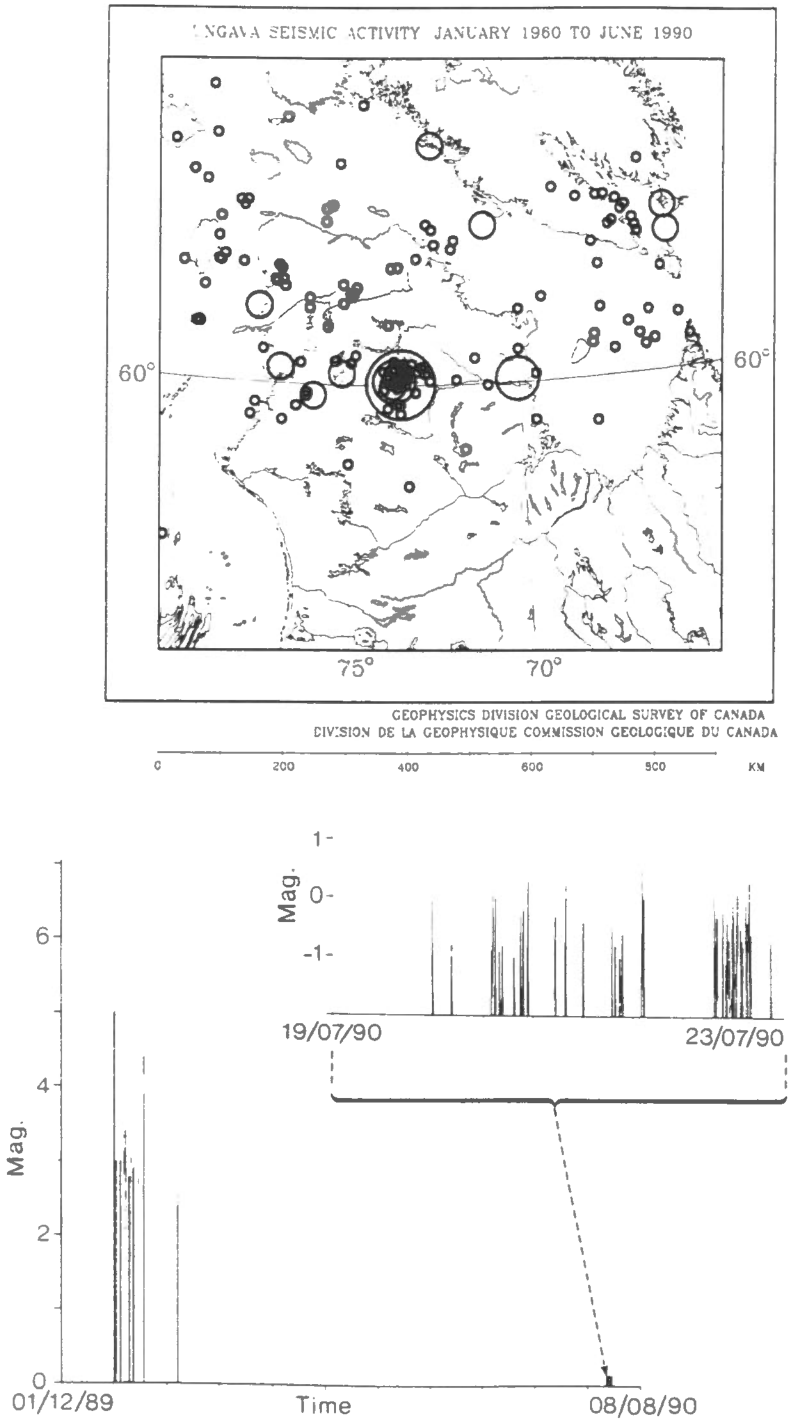

Figure 16. Summary of Ungava seismic activity since 1960. The graphs below the map show the magnitude–time history of the events in the sequence detected by the permanent network and (in the insert) the magnitude–time history of aftershock activity found by the field survey in July.

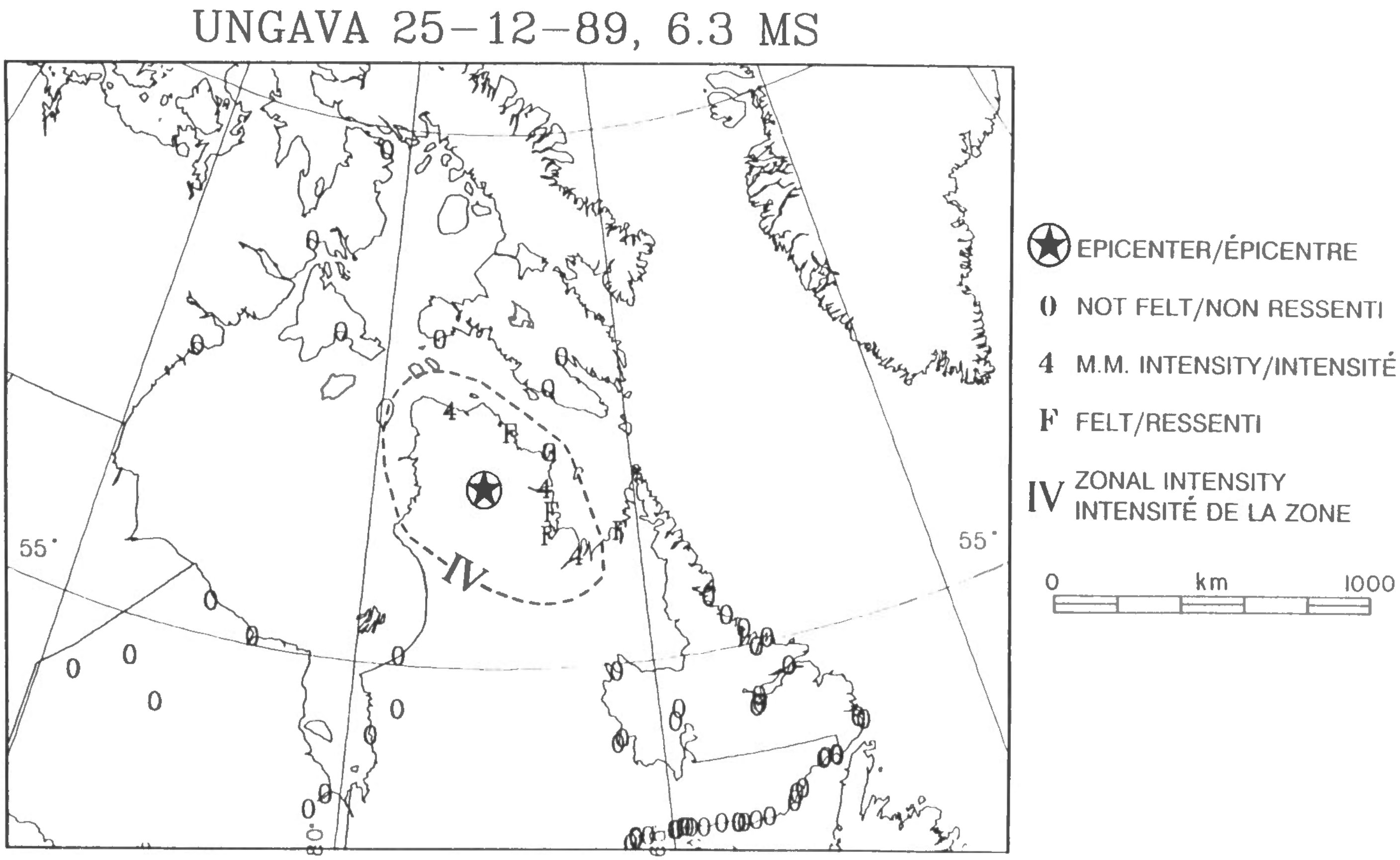

Figure 17. Felt area of the Ungava earthquake.

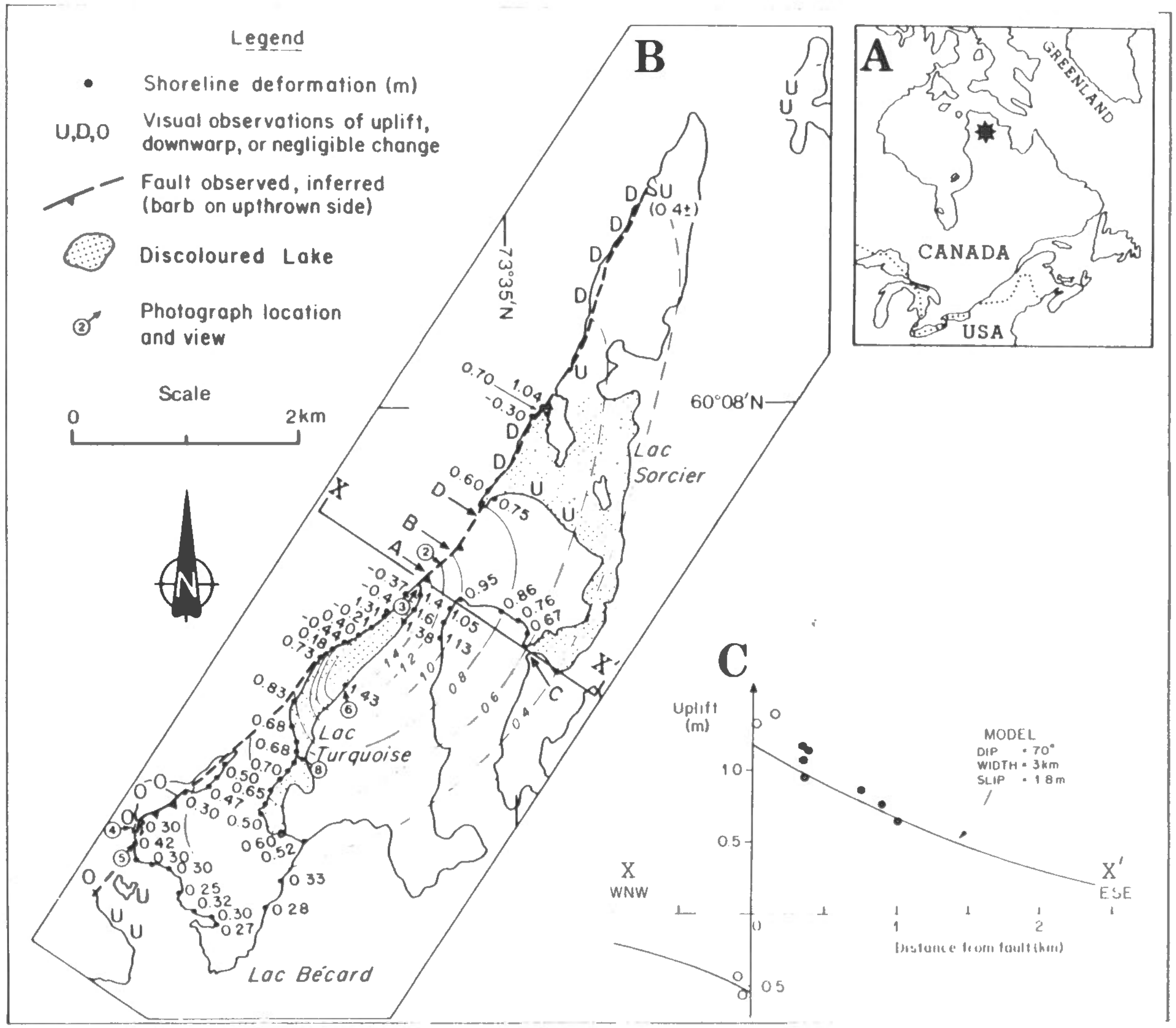

Figure 18. The location (A), distribution of deformation associated with Turquoise Lake Fault Scarp (B) and uplift profile (C) across the fault trace (from Adams et al., 1990).

boulders, a partly-drained lake, a left–lateral surface strike–slip fault, and new springs. Two lakes were discoloured by seismically–injected silt.

Sudbury Basin: Mining–induced seismic activity in the Sudbury Basin was moderate in this period (Fig. 19). Through the year 528 events (excluding known or suspected blasts) were located with SLTN. Most of the events occurred in the vicinity of one or another of the thirteen active mines in the area. The distribution showed two clusters, the larger cluster on the southern rim of the basin, with the other smaller cluster on the northwest rim. The overall rate of seismic activity showed a slight increase in January reflecting the general resumption of full scale operations by many of the mining companies after a 'slow' summer period. The largest event in the year (magnitude 3.6) occurred on October 30 at the Creighton Mine where it was strongly felt. This was the largest seismic event to occur at the Creighton Mine in the past two years. The event was described as a 'fault–slip' event by the company, as opposed to a 'burst' into the mining cavity. A reverse–type solution seemed to be indicated by the data but they were too sparse to define the solution reliably.

Mechanism Studies: Sixteen events in this period were analyzed for P–nodal mechanisms, however, reliable solutions could not be determined for four. The fault–slip and stress parameters determined from the analyses are summarized in Table 8 and the P–nodal solutions that were found are shown in Figure 20. The two Ungava events, which lie outside the area of this report are not included. The solutions found were generally reverse–fault ones with a varying small strike–slip component, which is the norm for events in this region. The four solutions analysed in the Charlevoix Seismic Zone showed a variety of fault–strike and stress directions over a small area, which has been observed before and suggests a complex tectonic setting. One event in the West Quebec zone and one event in New Brunswick showed unusual normal fault mechanisms.

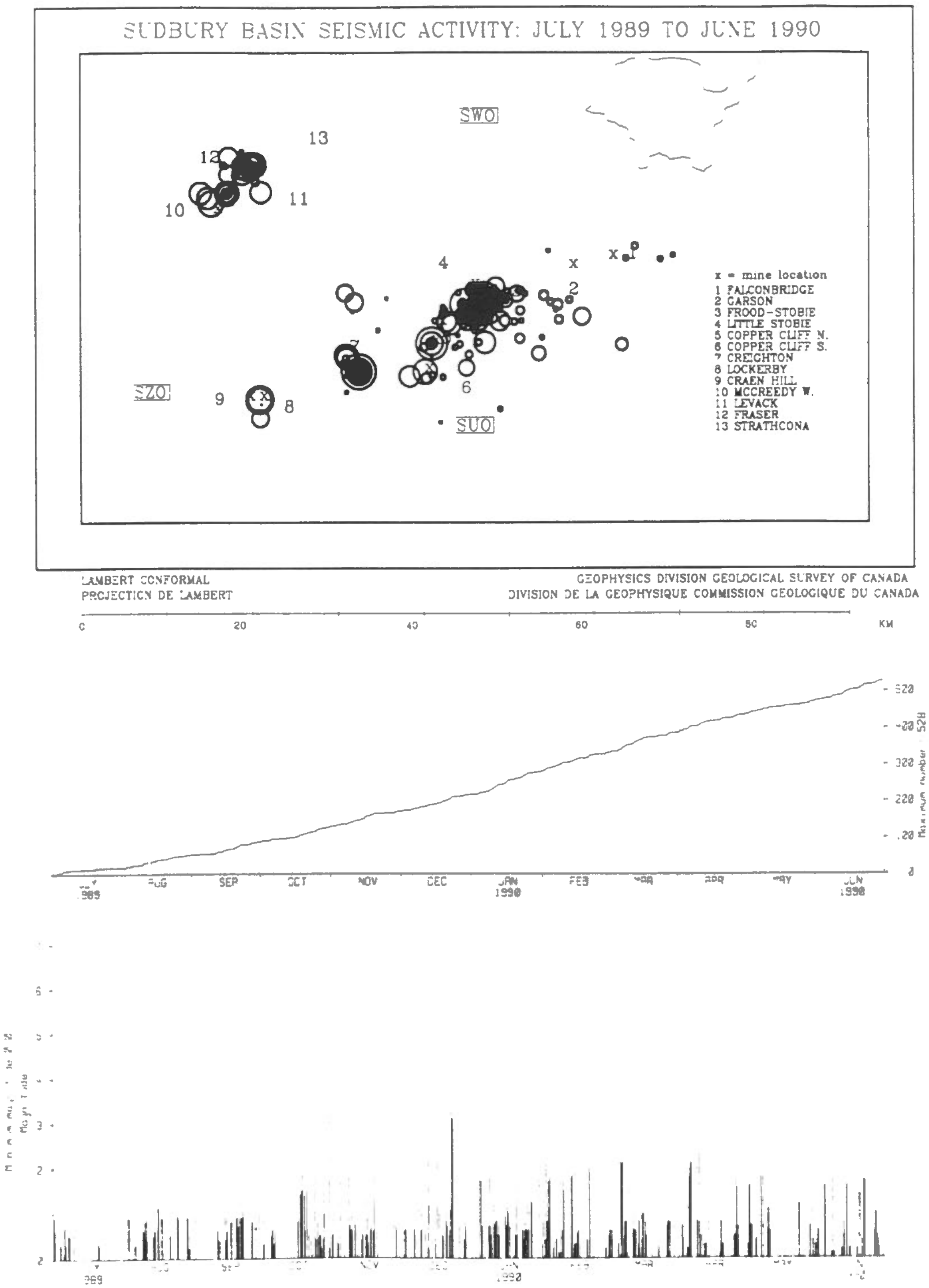

Figure 19. Summary of seismic activity in the Sudbury Basin 1989–90 as in Fig. 11.

Table 8: Fault–Slip and Stress Parameters From P–Nodal Solutions
July 1, 1989 to June 30, 1990

Date	Time	Polarities	Solutions	Errors	Comment	Nodal Planes str/dip/rak	Stress Axes az/pl
1989/08/10	21:17	16	1	2		P: 324/59/60 A: 191/42/129	P: 74/09 T: 182/63
1989/09/13	14:55	12	1	0		P: 042/57/40 A: 288/57/140	P: 345/00 T: 255/50
1989/11/16	09:24	20	1	2		P: 116/63/62 A: 346/38/133	P: 226/14 T: 342/61
1989/12/25	04:25	46	2	10		P: 251/54/46 A: 129/54/134	P: 190/00 T: 100/56
1989/12/25	14:24	144	1	8		P: 235/53/62 A: 096/45/122	P: 344/05 T: 085/67
1990/01/08	21:40	16	1	5	poor	P: 116/75/-85 A: 277/16/-109	P: 033/60 T: 202/30
1990/03/03	01:12	15	1	1		P: 226/42/-50 A: 358/59/-120	P: 218/63 T: 109/09
1990/03/03	02:06	16	23	1	poor	P: 214/61/78 A: 057/31/109	P: 312/15 T: 097/72
1990/03/13	19:10	12	2	1		P: 042/61/73 A: 260/36/126	P: 145/14 T: 268/65
1990/03/30	01:54	10	3	0		P: 145/52/71 A: 352/42/112	P: 246/05 T: 354/74
1990/04/21	01:23	14	15	1		P: 297/51/77 A: 137/41/105	P: 036/05 T: 152/79
1990/04/23	00:28	13	1	0		P: 174/41/41 A: 051/65/123	P: 117/13 T: 007/57

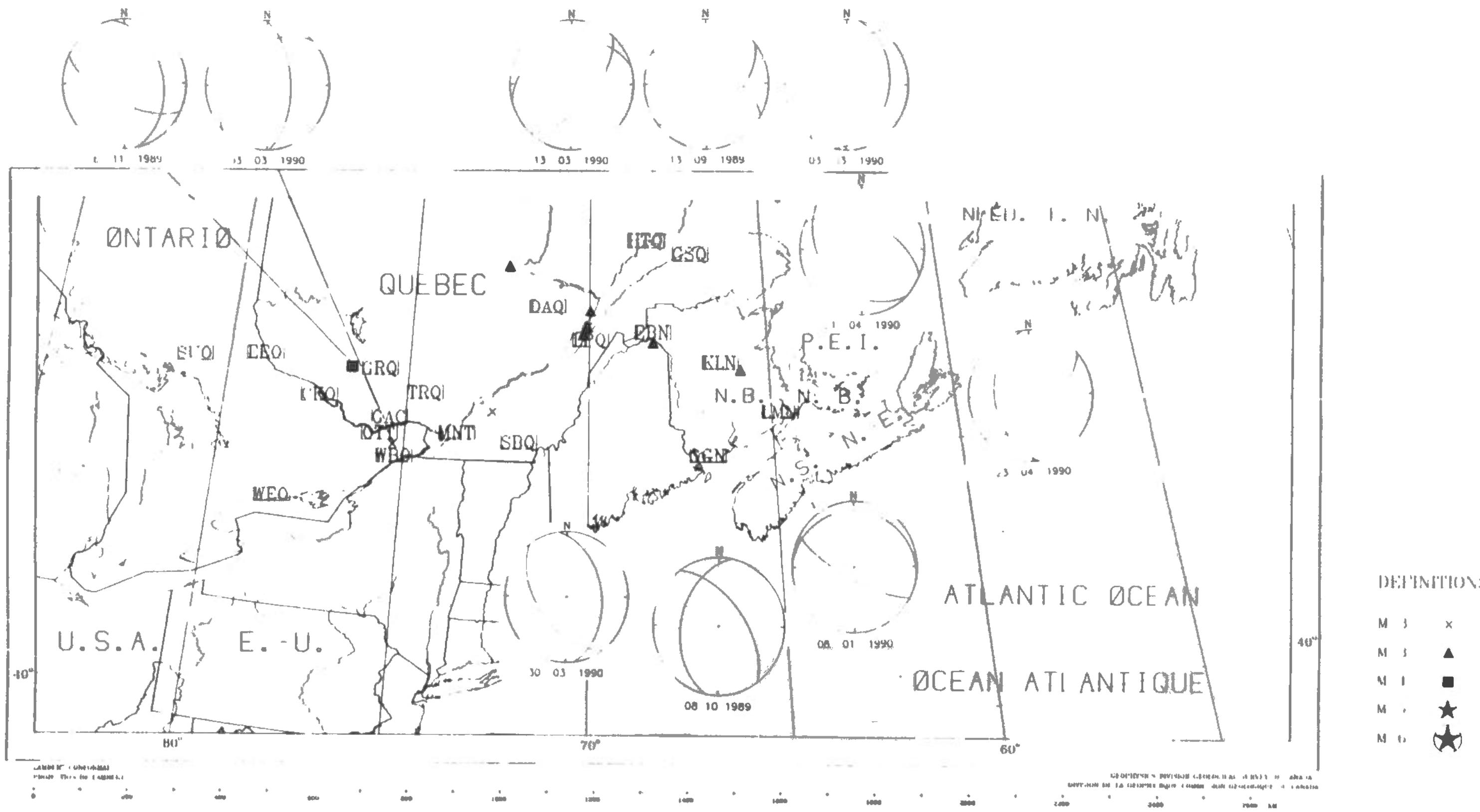

Figure 20. Mechanism solutions determined for earthquakes in 1989–90.

6. BIBLIOGRAPHY OF PUBLICATIONS ON EASTERN CANADIAN SEISMICITY AND RELATED TOPICS BY GEOPHYSICS DIVISION (1989/90).

The data provided by ECTN and the local networks form the basis for a wide variety of seismological research projects carried out by GD staff into the seismicity, seismic source properties and seismic hazards of eastern Canada; a summary of such publications, either submitted or issued in this period, is given in the following bibliography.

Adams, J. and S. Bell, 1990. Crustal stresses in Canada, in Slemmons, D.B., Engdahl, E.R., Blackwell, D. and Schwarz, D., Eds., Neotectonics of North America: Boulder, Colorado, Geological Society of America, Decade Map Volume.

Anglin, F.M., R.J. Wetmiller, R.B. Horner, G.C. Rogers and J.A. Drysdale, 1990. Seismicity Map of Canada. Geological Survey of Canada, Geophysical Atlas Map 15, Scale 1:10M, Ottawa.

Burke, K.B.S., R.J. Wetmiller, M. Lamontagne, M.J. Carr, and C. Hickey, 1989. Microearthquake survey of the Miramichi, New Brunswick, epicentral region, 1989. Canadian Journal of Earth Sciences, 26, p. 2567–2577.

Drysdale, J.A., 1990. Southeastern Canadian earthquake activity: January 01, 1988 to September 30, 1989. Geological Survey of Canada Current Research, Paper 90–1A, p. 67–71.

Du Berger, R., D.W. Roy, M. Lamontagne, G. Woussen, R.G. North and R.J. Wetmiller, 1989. The Saguenay (Quebec) earthquake of November 25, 1988: Seismological Data and Geological Setting. Tectonophysics, (in press)

Hasegawa, H.S., 1990. Mining related seismic source mechanisms and ground vibrations, Geological Survey of Canada Current Research, Paper 90–1A, p. 57– 65.

Hasegawa, H.S. and J. Adams, 1990. Re–analysis of the 1963 Baffin Island earthquake (Ms 6.2) and its seismotectonic environment. Seismological Research Letters, 61, p. 181–192.

Lamontagne, M., P. Morel–à–l'Hussier and A.E. Stevens, 1989. Séisme en direct. Géochronique/Actualités géologique, 32, p 4.

Lamontagne, M., R.J. Wetmiller and R. Du Berger, 1990. Some results from the November 25, 1988 Saguenay (Quebec) earthquake. Geological Survey of Canada Current Research, Paper 90–1B, p. 115–121.

Stevens, A.E., 1989. A critical review of the Wallach Report of May, 1989 entitled "Newly Discovered Geological Features and their Potential Impact on Darlington and Pickering". Geophysics Division Internal Report, 89–6, p.

Wetmiller, R.J. and J. Adams, 1990. An earthquake doublet in the Charlevoix seismic zone, Quebec. Geological Survey of Canada Current Reseach, Paper 90–1B, P. 105–113.

Wetmiller, R.J., J.A. Lyons, W.E. Shannon, P.S. Munro, J.T. THomas, M.D. Andrew, M. Lamontagne, C. Wong, F.M. Anglin, M. Plouffe, S.P. Lapointe, J. Adams and J.A. Drysdale, 1990. Eastern Canada Seismic Studies, July 1988 to June 1989. Geological Survey of Canada Open–file, 2134, 54 p.

Yamasaki, K. and H.S. Hasegawa, 1990. Deformation of non–uniform viscous lithosphere: with special reference to seismogenic stress in southeastern Canada. Tohoku Geophysical Journal, 33, p. 23-42.