

**MAGNEC**  
**AMNEC**

MULTI-AGENCY GROUP FOR NEOTECTONICS  
IN EASTERN CANADA

L'ASSOCIATION MULTIPARTITE POUR LA NÉOTECTONIQUE  
DANS L'EST CANADIEN

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# MAGNEC '90 Annual Report/ Rapport annuel de l'AMNEC 1990

November 1991  
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MAGNEC '90  
Annual Report

Rapport annuel de  
l'AMNEC 1990

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and

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Ottawa  
November 1991

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de l'énergie atomique

Ottawa  
novembre 1991

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## PREFACE

This is the third annual report of MAGNEC, the Multi-Agency Group for Neotectonics in Eastern Canada. The principal intent of the report is to provide information on the plans for the upcoming fiscal year and, by virtue of the short reports, to summarize the progress made in the previous year.

## Acknowledgements

The editors thank Miss Kerri Clarke, of the Geological Survey of Canada, who typed the report. In addition, the editors thank the contributors who provided camera ready copies of their abstracts and reports.

## PRÉFACE

Voici le troisième rapport annuel d'AMNEC, l'Association Multipartite pour la Néotectonique dans l'Est Canadien. Son but principal est de fournir des propos pour la prochaine année financière et, en vertu des mini-articles, de signaler les progrès de l'année précédente.

## Remerciements

Les rédacteurs remercient la secrétaire qui a dactylographié ce rapport, Mademoiselle Kerri Clarke, de la Commission géologique du Canada. Ils remercient également des collaborateurs qui ont fourni des copies de leurs rapports en forme prête à photographier.

J.A. Heginbottom  
J.L. Wallach



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## 1. MAGNEC 1990/L'AMNEC 1990

### Report of MAGNEC Activities

In 1990 MAGNEC continued toward its goal of integrating diverse geoscientific information in an attempt to improve estimates of seismic hazard in eastern North America. Geological studies were continued in the Charlevoix and Saguenay regions of Québec as well as along Lake Ontario, and geophysical work was conducted in different parts of Lake Ontario. Seismic events in western Quebec were evaluated and relocated.

In the Saguenay region, outcrop-scale brittle structures were the focus of investigations in both Precambrian and Ordovician bedrock, although mylonite zones were also documented; the latter may shed some light on the ultimate origin of the St. Lawrence Valley fault system. In addition to bedrock studies, liquefaction features were once again investigated, with a view to establishing criteria applicable to understanding paleoseismic (prehistoric) conditions.

A sand hill on the Gouffre River flood plain, in the Charlevoix Seismic Zone, was excavated to determine its origin. Seismicity was suggested as a possible mechanism for its formation, but there were not enough data from which to draw firm conclusions.

Lake Ontario was the subject of a one week long geophysical expedition which involved reconnaissance in the area extending from Bronte Point to Pickering, in the western part of the lake, and in the Rochester Basin, in the southeastern part of the lake. Information about suspected east-northeast oriented faulting in the unconsolidated sediments of the Rochester Basin was gathered and supported the findings resulting from a cruise in the same area during the previous year. The Bronte-Pickering section displayed, among other things, pop-ups in the bedrock which pierce the overlying lake-bottom sediments, and feather-shaped structures which are contained in the sediments. The latter, referred to as plumose structures, are parallel to the general orientation of the greatest principal horizontal compressive stress and may be indicators of neotectonic activity.

The locations of seismic events in western Quebec were re-evaluated with the results suggesting that the Central Metasedimentary Belt Boundary Zone and the lineament which forms the southeast arm of the Baskatong Reservoir may be seismically active.



## 2. PROGRAM 1991-1992/LE PROGRAMME DE 1991/1992

The 1991-92 program comprises the following activities:

### EASTERN CANADA GENERAL

1. Continued operation of the eastern Canada seismic network to detect and locate earthquakes in eastern Canada.
2. Continued monitoring of seismicity, in joint ventures, near La Grande, St.-Jean-des-Piles and Manicouagan (with Hydro-Québec); near Welcome (with Ontario Hydro); and at six stations in northern Ontario (with Atomic Eenergy of Canada Ltd., for the Nuclear Fuel Waste Management Program).

### SOUTHERN ONTARIO

1. Seismic monitoring in the region encompassing the Darlington and Pickering Nuclear Generating Stations, the objective being to detect microseismic events, if any.
2. Relocation of seismic events in the area surrounding, and including, western Lake Ontario.
3. Preliminary marine geophysics in Lake Ontario to document whatever features might be present in the lake bottom, particularly in the vicinity of some major geophysically expressed lineaments.
4. An assessment of liquefaction features in unconsolidated sediments along the Rouge River, in eastern Metro Toronto, to ascertain whether or not they were seismically induced.
5. Reconnaissance in Precambrian and Paleozoic rocks along the northward projection of the Niagara-Pickering Linear Zone into the Central Metasedimentary Belt Boundary Zone to find out if there is evidence of unhealed, brittle faulting within this zone.

## QUÉBEC

1. Field surveys and body wave modelling of the December 1989 Ungava earthquake, to improve knowledge of identified surface deformity, search for evidence of possible earlier events, and resolve discrepancies between surface faulting and the P-nodal mechanism.
2. Analyse coda Q series data for the Charlevoix region to determine possible temporal variations. Interpretation of such variations elsewhere have been used successfully in earthquake prediction.
3. Continue the search for, and evaluation of, liquefaction features induced by the 1988 Saguenay earthquake as well as by previous earthquakes.
4. An evaluation of one of the conical hills on the Gouffre River flood plain, in the Charlevoix seismic zone, in order to determine whether it formed as a consequence of seismic activity.
5. Documentation and interpretation of fractures and brittle faults in the Saguenay-Lac St-Jean region to try to determine the nature and chronology of brittle tectonics.

## EASTERN CONTINENTAL MARGIN AND ATLANTIC PROVINCES

1. Relocation studies of earthquakes off Newfoundland and Nova Scotia and analysis of historical seismicity data for New Brunswick, Newfoundland and Nova Scotia, to establish and assess seismotectonics and seismic hazards of the of the eastern and northern continental margins.

## PARTICIPATING AGENCIES IN 1990

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Atomic Energy Control Board,  
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Atomic Energy of Canada Limited, Ottawa,  
Ontario and Pinawa, Manitoba

Canada Centre for Remote Sensing, Ottawa,  
Ontario

Geological Survey of Canada, Ottawa, Ontario  
and Dartmouth, Nova Scotia

### Provincial

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York, Ontario

Ontario Geological Survey, Toronto, Ontario

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Westboro, Massachusetts

### American Agencies

NASA Goddard Space Flight Center,  
Greenbelt, Maryland

National Center for Earthquake Engineering  
Research, Buffalo, New York

United States Geological Survey, Reston,  
Virginia and Ithaca, New York



### **3. REPORTS AND ABSTRACTS/RAPPORTS ET RÉSUMÉS**

Note: The reports and abstract included in this section were largely prepared from camera-ready copies submitted by the authors.



HISTORICAL SEISMICITY OF NORTHERN AND EASTERN NEW BRUNSWICK  
1826-1866 AND 1944-1961 AND OTHER LISTED EARTHQUAKES 1867-1943.

K.B.S. Burke, J. Andersen and H. Hassan

Department of Geology, University of New Brunswick,  
P.O. Box 4400, Fredericton, New Brunswick E3B 5A3, Canada

DSS Contract Report for Geophysics Division, Geological  
Survey of Canada, 1 Observatory Crescent, Ottawa, 150 p.

The historical seismicity record for northern and central New Brunswick during the periods 1826 to 1867 and 1944 to 1961 has been studied by scanning available copies on microfilm of newspapers published in Chatham and Newcastle respectively. The newspapers Mercury and Gleaner were used for the earlier period and the North Shore Leader was used for the later period. Three previously unreferenced events in the region were found from the scanning procedure for the earlier period and three events from other localities in New Brunswick and Nova Scotia.

The three northern New Brunswick events, together with previously referenced events in the early nineteenth century and all earthquakes listed in the Canadian Earthquake Epicentral File (CEEf), were then subjected to lateral searches of contemporary newspapers and documents for descriptions of the effects of such events. Evidence was found for significant changes to CEEf listings of date, location, magnitude and time from this information. A chronological log, containing transcriptions of articles found related to the events and lists of the references searched, forms the bulk of this report.

The additional events found by the scanning procedure and the revisions to the CEEf confirm that the Central Highlands has been a region of continuing earthquake activity for the past 165 years.

## SOUTHEASTERN CANADIAN EARTHQUAKE ACTIVITY 01 JULY 1989 TO 30 JUNE 1990

by Janet Drysdale and Robert Wetmiller  
Geophysics Division, Geological Survey of Canada

In southeastern Canada, during the period from July 1, 1989 to June 30, 1990, 234 earthquakes were analysed for location and magnitude (Figure 1). Twenty-three earthquakes were magnitude 3.0 or greater; the largest, onshore, was magnitude 4.0 and occurred November 16 in western Québec about 50 km northwest of Maniwaki. Two other magnitude 4 events were located offshore on the Laurentian continental slope, one on August 21 and one on February 15.

Eighteen earthquakes were reported felt in southeastern Canada during this same period. They are summarized in Table 1.

Figure 1 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 Slope. However, activity in New Brunswick was more widespread than during previous years and significant seismic activity occurred on the Laurentian Slope in areas that had not been active previously. Periods with a higher rate of seismic activity occurred in August and April.

The most significant earthquake in eastern North America during the period was the magnitude 6.3 earthquake that occurred on December 25 in northern Québec's Ungava Peninsula. Although this earthquake took place outside the reporting area for this document, additional information is given below because of the rarity of such large events in eastern North America.

**West Québec:** On November 16, the West Québec seismic zone experienced the largest event onshore in eastern Canada (magnitude 4.0). The tremor was felt (Table 1), but only mildly. A field survey was not carried out and no foreshocks or aftershocks were detected by the Eastern Canadian Telemetred Network (ECTN). Following that event, activity throughout the zone showed an apparent decline until January. However, this decline coincided with a period of erratic service from ECTN radio-linked stations in the West Québec area and the failure of the GAC station, so the significance of the apparent decline is open to question. Swarm activity was observed near the Baskatong Reservoir in April. Otherwise, activity throughout the zone was scattered in space and time.

**Charlevoix, Québec:** Eighty-one earthquakes were located in the Charlevoix seismic zone during this period; six were reported felt (Table 1). The largest event, on

March 3, was only magnitude 3.6. It occurred at the extreme northern end of the seismic zone, north of the St. Lawrence 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:** Activity in the Lower St. Lawrence River seismic zone was moderate during this period. Twenty-three events were located, none of which were greater than magnitude 3.0. An unusual burst of events occurred during the month of September.

Detection and location of seismic events in the Lower St. Lawrence region was significantly reduced in this period as a result of the prolonged outages experienced at the MNQ and HTQ stations.

**New Brunswick:** As usual, persistent seismic activity occurred in the Miramichi aftershock zone, but, during this time period, more seismic activity was observed elsewhere in New Brunswick than in past years. Twenty-five events occurred within the aftershock zone; all were less than magnitude 3.0. Twenty-two events, including three 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 1).

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 Figure 1 because it is classified as a mining-induced event).

**Laurentian Slope:** Offshore seismicity was highlighted by a swarm of earthquakes in the Laurentian Channel, which began with a magnitude 4.5 event on February 2, 1989, the largest earthquake to occur on the southeastern Canadian continental margin since 1975. The swarm occurred in a hitherto aseismic region of the Laurentian Channel. The initial February 2 earthquake has been followed by a continuing series of smaller events, including a magnitude 4.0 earthquake on August 21. From the epicentres determined, the earthquakes lie in a northwest-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 that 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 in 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, Québec in the Lac-St-Jean region on October 18. The event was felt. Our investigation could

find no source of blasting to explain the event; thus it is assumed to be an earthquake.

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

**Ungava Peninsula, Québec:** Of special note during this period was the discovery of the surface fault break of an earthquake that occurred in northern Québec. This is the first time such a fault break has been identified in eastern North America and the fault scarp is one of the few surface fault breaks that have been produced by earthquakes in stable continental areas throughout the world. The magnitude 6.3 Ungava Earthquake of December 25 occurred in an area of northern Québec that had previously been recognized as a seismic zone, but historically had not experienced an event greater than magnitude 6.0. The earthquake followed a magnitude 5.1 foreshock 10 hours earlier. There were five earthquakes, magnitude 3 or greater, between the foreshock and the mainshock, and at least eight magnitude 3 or greater aftershocks in the 2 weeks following the mainshock, the largest being magnitude 4.4. Further details can be found in the abstract by Wetmiller and Drysdale on "The December 25, 1989 Ungava Québec Earthquake" in this volume.

**Sudbury Basin:** Mining-induced seismic activity in the Sudbury Basin was moderate during this period. Throughout the year 528, events (excluding known or suspected blasts) were located with the Sudbury Local Telemetred network (SLTN). Most of the events occurred in the vicinity of one of the 13 active mines in the area. The distribution showed two clusters, the larger cluster on the southern rim of the basin and the smaller cluster on the northwestern 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 during 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 over the past 2 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.

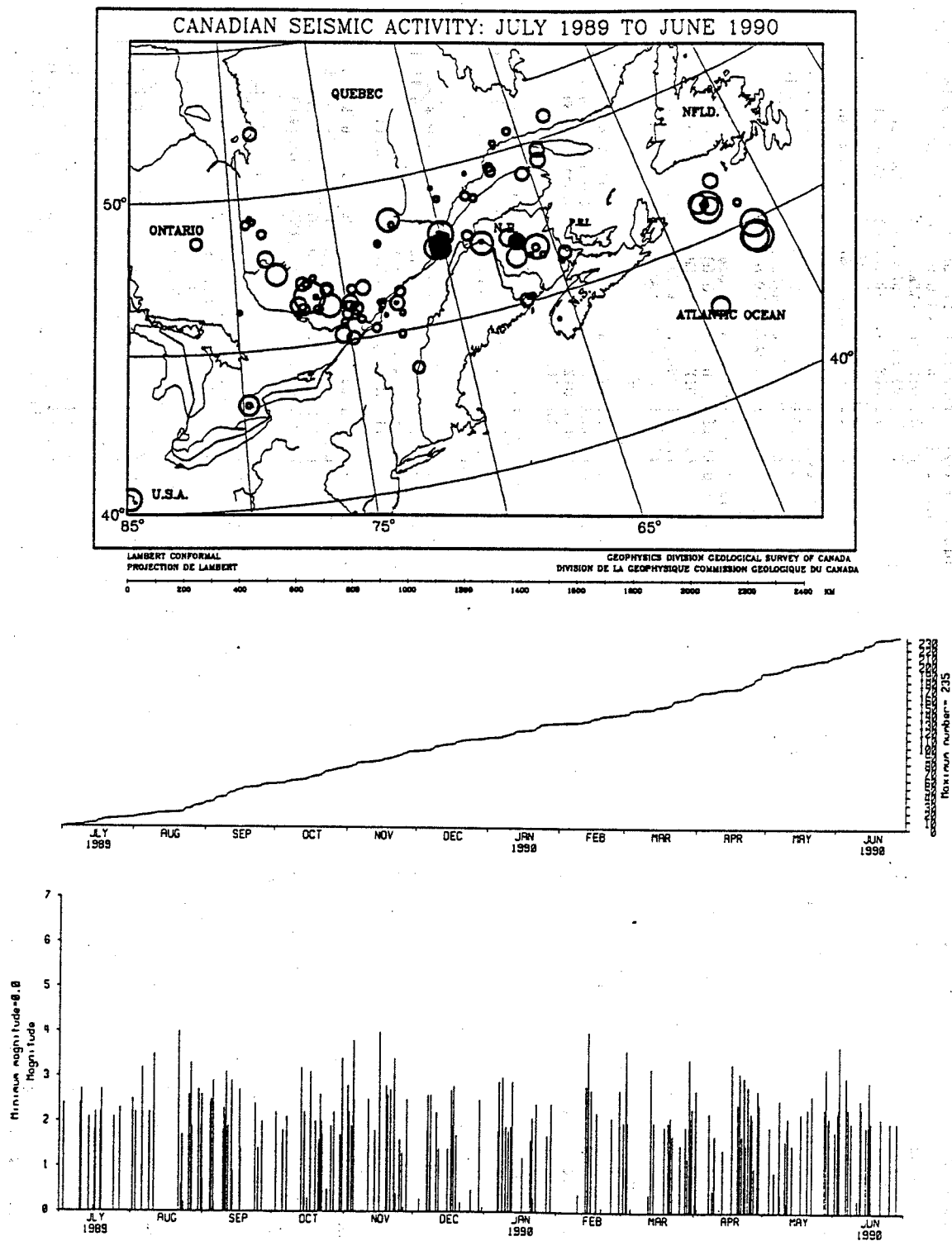


Figure 1. Summary of eastern Canadian seismic activity in 1989-1990. Shown below the map are graphs of the cumulative number of events that occurred and the magnitude-time history of the activity. Circle size is proportional to magnitude and range from 0 to 4.0.

TABLE 1

## FELT EARTHQUAKES IN SOUTHEASTERN CANADA

JULY 1989 - JUNE 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 NEAR 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				
	WESTERN LAKE ONTARIO. FELT IN THE HAMILTON-OKVILLE-MISSISSAUGA AREA.								
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 AND 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, QUE. 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				
	NEAR ROBERVAL, LAC SAINT-JEAN QUE. FELT (III) AT DOLBEAU, NORMANDIN, ROBERVAL, ST-FELICIEN, ST-PRIME, ST-EDWIGE.								
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 QUE. 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 PEMROKE 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 QUE. FELT MILDLY AT STE.AGATHIE AND ST.JOVITE								

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

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

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, QUE. 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

CHARLEVOIX, QUE. FELT IN LA MALBAIE  
AND POINTE-AU-PIC

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

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, QUE. 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 BOUESTOWN AND STANLEY.

3.3  
REANALYSIS OF THE 1963 BAFFIN ISLAND EARTHQUAKE ( $M_s$  6.2)  
AND ITS SEISMOTECTONIC ENVIRONMENT

Henry S. Hasegawa and John Adams<sup>+</sup>

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**ABSTRACT**

The 1963 Baffin Island earthquake of  $M_s$  6.2 is reanalyzed to determine whether or not it involved normal faulting, as previously suggested. The revised fault-plane solution has nodal planes with strike  $113^\circ$ , dip  $66^\circ$ , rake  $235^\circ$  and strike  $352^\circ$ , dip  $41^\circ$ , rake  $322^\circ$ . The T-axis trends  $227^\circ$  and plunges  $14^\circ$ , and the P-axis trends  $338^\circ$  and plunges  $55^\circ$ . Thus though this solution confirms normal faulting, it suggests a larger strike-slip component than most previous studies. The tension axis is oriented SW, which is normal to the NW geographic trend of Baffin Island. We consider that the normal-fault regime could be a transient phenomena related to extensional stress in the glacial forebulge presently centered over northeast Baffin Island, and is associated with incomplete postglacial rebound. However, future geophysical measurements such as heat flow, *in-situ* stress and vertical uplift rate, as well as more fault-plane solutions are required to test this hypothesis.

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1983: Stress estimate for the highest mountain system  
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in press: Reanalysis of the 1963 Baffin Island earthquake  
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Seismological Research Letters.

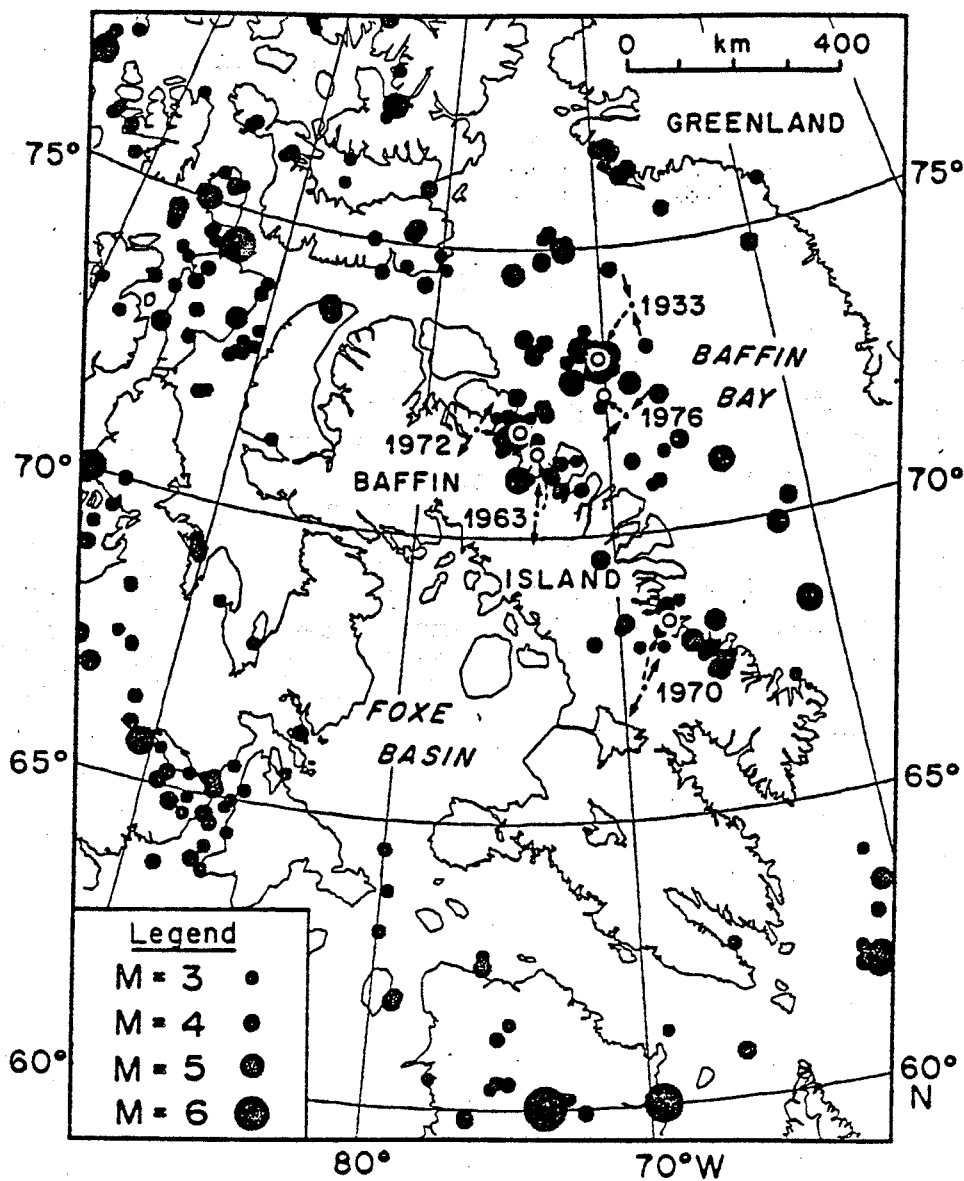


Figure 1 Seismicity (1978-1989) along Baffin Island and adjacent regions of northeast Canada. Superimposed are epicenters and deviatoric stress vectors for three earthquakes on Baffin Island and two under Baffin Bay.

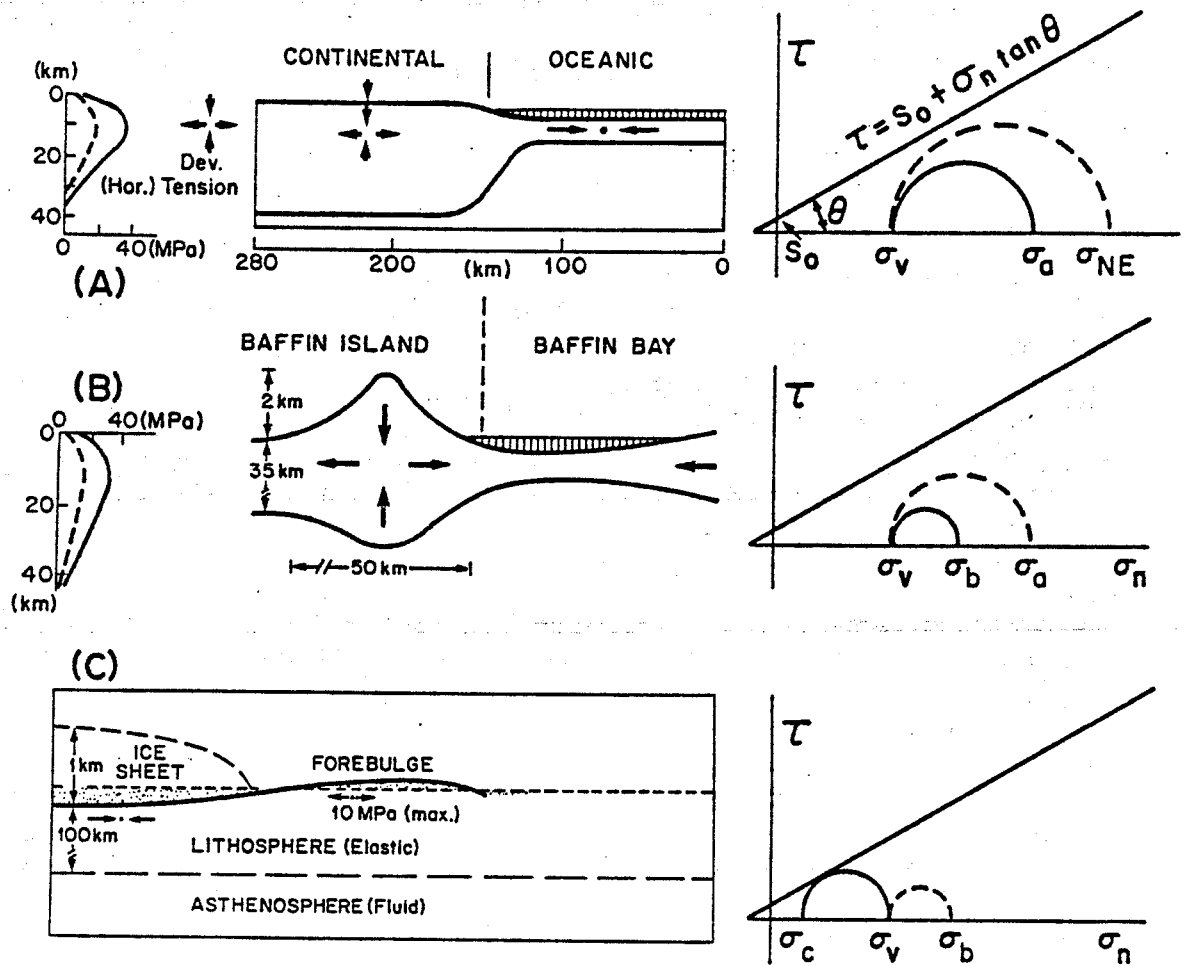


Figure 2 Composite phenomenological model to account for observed normal fault regime in northeast Baffin Island. Vertical profiles are normal to trend of Baffin Island, that is in SW-NE orientation (with SW to left). In part (A), which shows continent-ocean transition zone, continuous curve is from Bott and Dean (1972) and dashed curve is for Baffin Island. In part (B), which shows mountain and root, continuous curve is from Fukao and Yamaoka (1983) and dashed curve is for Baffin Island. Part (C) shows glacial forebulge (related to incomplete post-glacial rebound) centered along northeast Baffin Island and hypothetical ice load that can generate this pattern of rebound. Coulomb-Mohr diagram on right indicates changes in maximum principal stress due to locally generated deviatoric stress from  $\sigma_{NE}$  (tectonic component in NE direction) to  $\sigma_a$ , then  $\sigma_b$ , and finally to  $\sigma_c$ . Dashed lines show the previous positions.

## LE SÉISME DE MONT-LAURIER DU 19 OCTOBRE 1990

Maurice Lamontagne  
pour la Section de la sismologie

Commission géologique du Canada  
1 Place de l'Observatoire, Ottawa, Ont. K1A 0Y3

Le 19 octobre 1990 à 03:01 heure locale (07:01 temps universel) un tremblement de terre de magnitude  $m_N$  5,0 a secoué une partie de l'Ouest du Québec et de l'Est Ontario. Centré à environ 11 km au sud-ouest de Mont-Laurier, près de la municipalité de Lac-des-Iles, ce tremblement de terre représentait le plus fort séisme de la zone sismique de l'Ouest du Québec depuis celui de Cornwall en 1944 ( $m_N$  5,6). Le plus fort séisme connu pour cette zone est celui de 1935 au Témiscamingue ( $m_N$  6,2). Cet événement fait donc partie de cet ensemble diffus de séismes regroupés sous le nom de zone de l'Ouest du Québec (Figure 1), zone dans laquelle une moyenne d'environ trois séismes sont ressentis localement chaque année.

Le séisme de Mont-Laurier a été ressenti avec une intensité maximale de MM V sur l'échelle de Mercalli. On l'a ressenti aussi loin que Baie-Comeau au Québec et que Sarnia en Ontario. Près de l'épicentre, quelques dommages légers ont été rapportés incluant deux bris de tuyauterie à Mont-Laurier. Des dommages plus importants sont survenus à la mine de graphite de Lac-des-Iles où un four industriel particulièrement sensible aux vibrations a été endommagé, causant un arrêt de production de plusieurs jours. La distribution normale d'électricité a été affectée, parfois pendant quelques heures, à l'intérieur d'un rayon d'environ 100 km autour de l'épicentre. Cette panne n'était pas reliée à un bris d'équipement; elle était plutôt due au déclenchement des relais de gaz à l'intérieur des postes d'Hydro-Québec. (Hydro-Québec, 1990).

Le séisme a été enregistré par la majorité des stations du réseau sismographique canadien. La station la plus rapprochée de l'épicentre (GRQ, Grand-Remous à 25 km de l'épicentre), n'a détecté aucun précurseur au cours des jours précédant le séisme principal. Plusieurs dizaines de répliques ont suivi dont quatorze ont pu être localisées par le Réseau télémétrique de l'Est du Canada (RTEC) entre le 19 octobre et le 1<sup>er</sup> janvier 1991. Une seule a été ressentie localement.

Dans les heures qui suivirent le séisme, la Commission géologique du Canada (CGC) a dépêché une équipe de terrain afin d'installer le plus rapidement possible des sismographes portatifs pour l'enregistrement des répliques. Un premier appareil a pu être installé avant la tombée de la nuit le même jour. Au cours de la semaine qui suivit, la CGC a occupé jusqu'à 12 sites différents grâce à 16 sismographes portatifs à trois composantes PRS-4 et de 8 appareils analogiques à composante verticale MEQ-800 (<< smokers >>). Le levé de terrain s'est déroulé de façon idéale: les sites étaient à la fois accessibles et situés sur des affleurements rocheux ce qui leur procurait un bruit de fond remarquablement faible.

Ce faible bruit de fond a permis d'enregistrer de nombreuses répliques sismiques de

magnitude inférieure à  $m_N$  1.0. Vingt-quatre ont pu être localisées uniquement avec les enregistrements numériques, ce qui assure une grande précision quant à la mesure des temps d'arrivée des ondes. Quoique le modèle de vitesse demeure l'objet d'incertitude, la précision quant à la localisation des séismes serait meilleure que  $\pm 1$  km.

L'analyse préliminaire des données du choc principal et des répliques indique que le choc principal s'est produit à une profondeur d'environ 12 km, ce qui est dans la moyenne pour les séismes de cette région. Cette grande profondeur et la magnitude modérée du séisme excluent donc toute possibilité de trouver une rupture en surface. Dû à des premières-arrivées de la phase P plus ou moins claires et à une mauvaise disposition des stations par-rapport au séisme, le mécanisme au foyer pour le choc principal n'est pas très bien défini; deux patrons bien différents des plans nodaux peuvent être suggérés. Cependant, les deux possibilités présentent un mouvement de chevauchement, en accord avec les champs de contraintes connus pour l'Est du Canada.

Les répliques sont distribuées suivant un axe nord-sud à l'intérieur d'un rectangle d'environ 1 km par 3 km, avec des profondeurs focales variant entre 10 et 14 km. Sur une coupe est-ouest, les hypocentres définissent un plan sub-vertical. Cet alignement n'est en accord qu'avec un des deux mécanismes au foyer. Les mois à venir permettront de raffiner ces mécanismes et de compléter nos données hypocentrales.

Au point de vue géologique, ce séisme est localisé près de la frontière ouest de la ceinture métasédimentaire centrale de la Province de Grenville (voir Forsyth, 1981). Cet événement fait partie de cet ensemble diffus de séismes regroupés sous le nom de Zone de l'Ouest du Québec, qui n'a pu jusqu'ici être relié à aucun système tectonique particulier. Quoique la grande profondeur du séisme limite la portée des méthodes magnétiques et gravimétriques, les champs potentiels n'en seront pas moins examinés de près afin de déterminer l'existence de liens entre la sismicité et les failles de cette région. Ce séisme permettra donc d'accroître notre connaissance de cette zone sismiquement active.

Au point de vue social, ce séisme aura permis de constater une fois de plus l'impact d'un tremblement de terre sur la population locale. Le jour même du séisme et lors des jours qui suivirent, la Section de sismologie de la CGC a dû répondre à près d'une centaine de demandes d'information et d'entrevues de la part des médias. Dans la région de Mont-Laurier même, une psychose, qui n'était pas sans rappeler celle qui a suivi le séisme du Saguenay, était en train de se développer. Une soirée d'information organisée conjointement par le Centre local de services communautaires (CLSC) des Hautes-Laurentides à Mont-Laurier et la CGC, a permis de rassembler quelques 300 personnes et ce, cinq jours après le séisme. La conférence a de plus été diffusée à la télévision communautaire locale, permettant ainsi d'accroître l'auditoire. Tout comme lors du séisme du Saguenay (Lamontagne et Du Berger, 1990), cette expérience a illustré une fois de plus la nécessité pour les sismologues de rencontrer directement les gens sur place après un événement de plus d'intensité V sur l'échelle de Mercalli.

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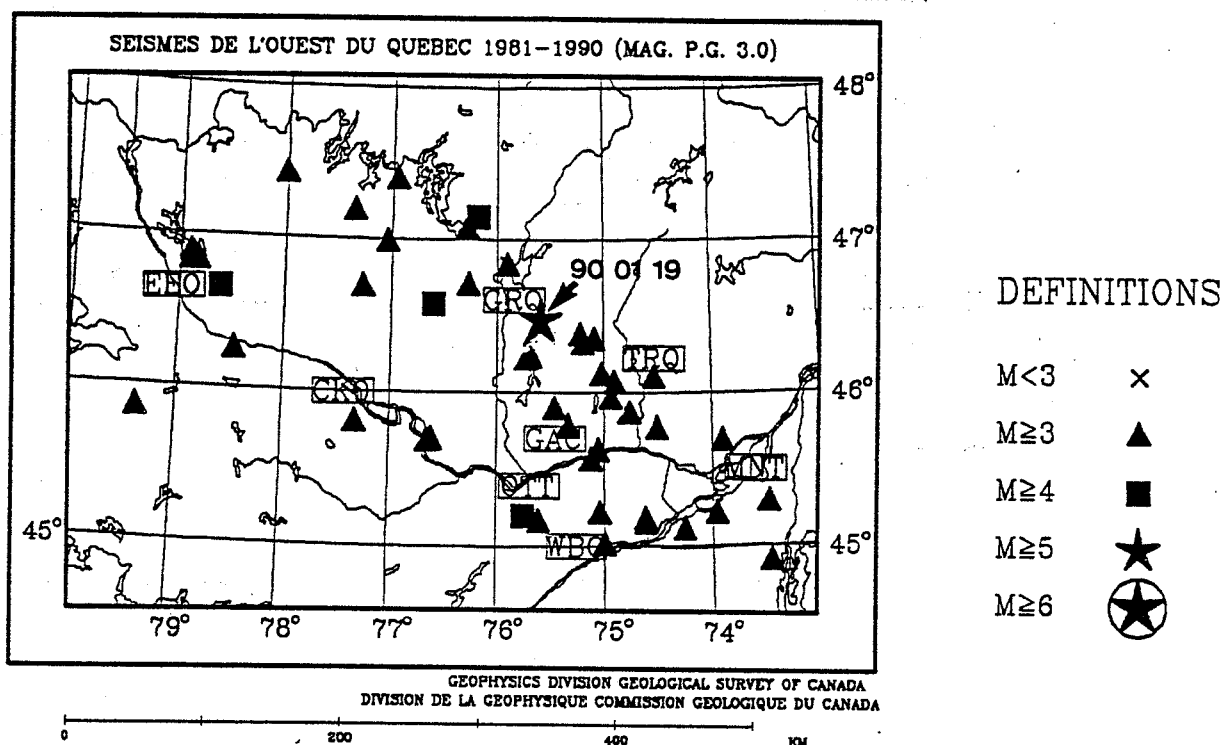


Figure 1:

Séismes de magnitude supérieure à 3.0 de la zone de l'Ouest du Québec pour la période 1981 à 1990. L'épicentre du tremblement de terre de Mont-Laurier (Étoile) est localisé à l'intérieur de la zone diffuse de séismes qui va de Montréal au réservoir Baskatong. Les stations du Réseau de télémétrie de l'Est du Canada sont aussi indiquées (MNT: Montréal; TRQ: Mont-Tremblant; WBO: Williamsburg; GAC: Glen Almond; OTT: Ottawa; GRQ: Grand Remous; CKO: Chalk River; EEO; Eldee). Le seuil de localisation des événements de cette région est d'environ magnitude 2,0.

# EARTHQUAKE LIGHTS AND NOVEMBER 1988 SEISMICITY IN THE SAGUENAY REGION, QUEBEC

Ouellet, Marcel

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Earthquake light (EQL) sightings, reported between November 1st 1988 and January 21st 1989, were found to be temporally associated with the seismicity of the Saguenay region which experienced its major shock ( $M=6.5$ ) on November 25th 1988. More than 52 aftershocks were recorded by the Eastern Canadian Telemetered Seismic portable network, distributed within the area of the epicenter, 24 hours after the November 23th foreshock ( $M=4.8$ ). These data allowed a detailed monitoring of the spatial (Fig. 1) and temporal (Fig. 2) distributions of 46 EQL reports. The uninhabited and forested epicentral area of that part of the Laurentian Canadian Shield Plateau, and the uneven spreading of the observers within the Saguenay-Lake-St. John regional Lowlands immediately to the North and Northwest, did not allow the identification of a dominant spatial pattern of the EQLs with the nearby ESE-WNW strike of the regional most prominent graben's faults. The present report corroborates the fact that EQLs are associated to earthquakes with magnitudes as small as one, and that they might precede the main shock in a time span of several days to a month. The formation mechanism of these luminous phenomena is still controversial. It appears to be directly associated with the electrification of fresh surfaces created by microcracking or by electrokinetic phenomena induced by groundwater flow in active seismic areas under tectonic strain.

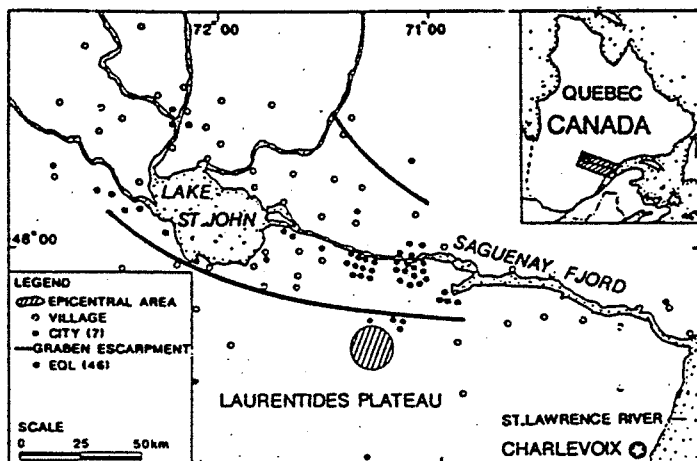


FIG. 1 The Saguenay-Lake Saint John region, showing the epicentral area of the November 1988 earthquakes as well as the EQL sightings and population spatial distributions.

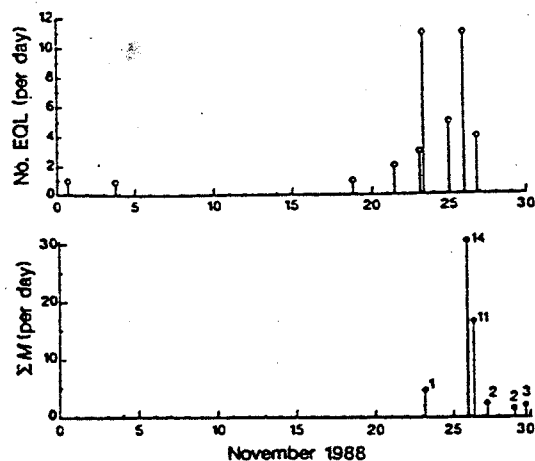


FIG. 2 November mean daily temporal distributions of the number of EQLs reported per day (O) (top) and the sum of the daily magnitudes of seismic events (bottom). ●, No. of seismic events per day.

NEW FOCAL MECHANISMS FOR SOUTHEASTERN  
CANADIAN EARTHQUAKES  
JULY 01 1989 TO JUNE 30 1990

Robert Wetmiller, John Adams and Wayne McNeil  
Geophysics Division, Geological Survey of Canada

ABSTRACT

In this period, ten events were analyzed for P-nodal mechanisms. The fault-slip and stress parameters determined from the analyses are summarized in Table 1 and the P-nodal solutions that were found are shown in Figure 1. Although lying outside the area of this report, p-nodal solutions for the two Ungava region earthquakes on December 25 are also included in Table 1. 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. Two events showed poorly defined normal fault mechanisms, one in the West Québec zone and one in New Brunswick. Normal fault mechanisms are rarely defined in Eastern Canada.

Table 1:  
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

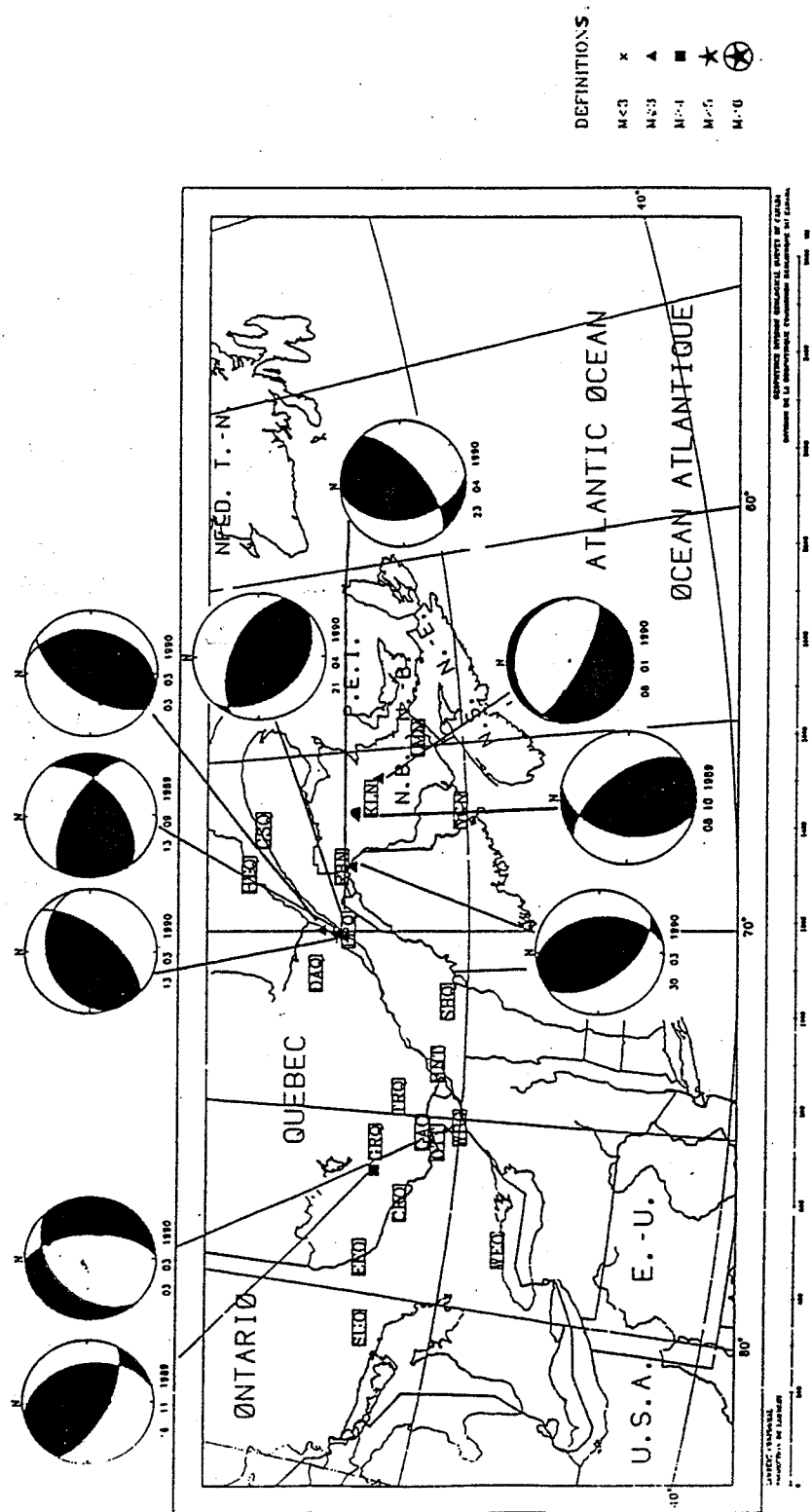


Figure 1: New focal mechanisms for southeastern Canada described in this report. Shown are equal-area lower-hemisphere projections of the focal mechanism. The compressional quadrant is shaded black.

Table 1:  
Fault-Slip and Stress Parameters From P-Nodal Solutions  
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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

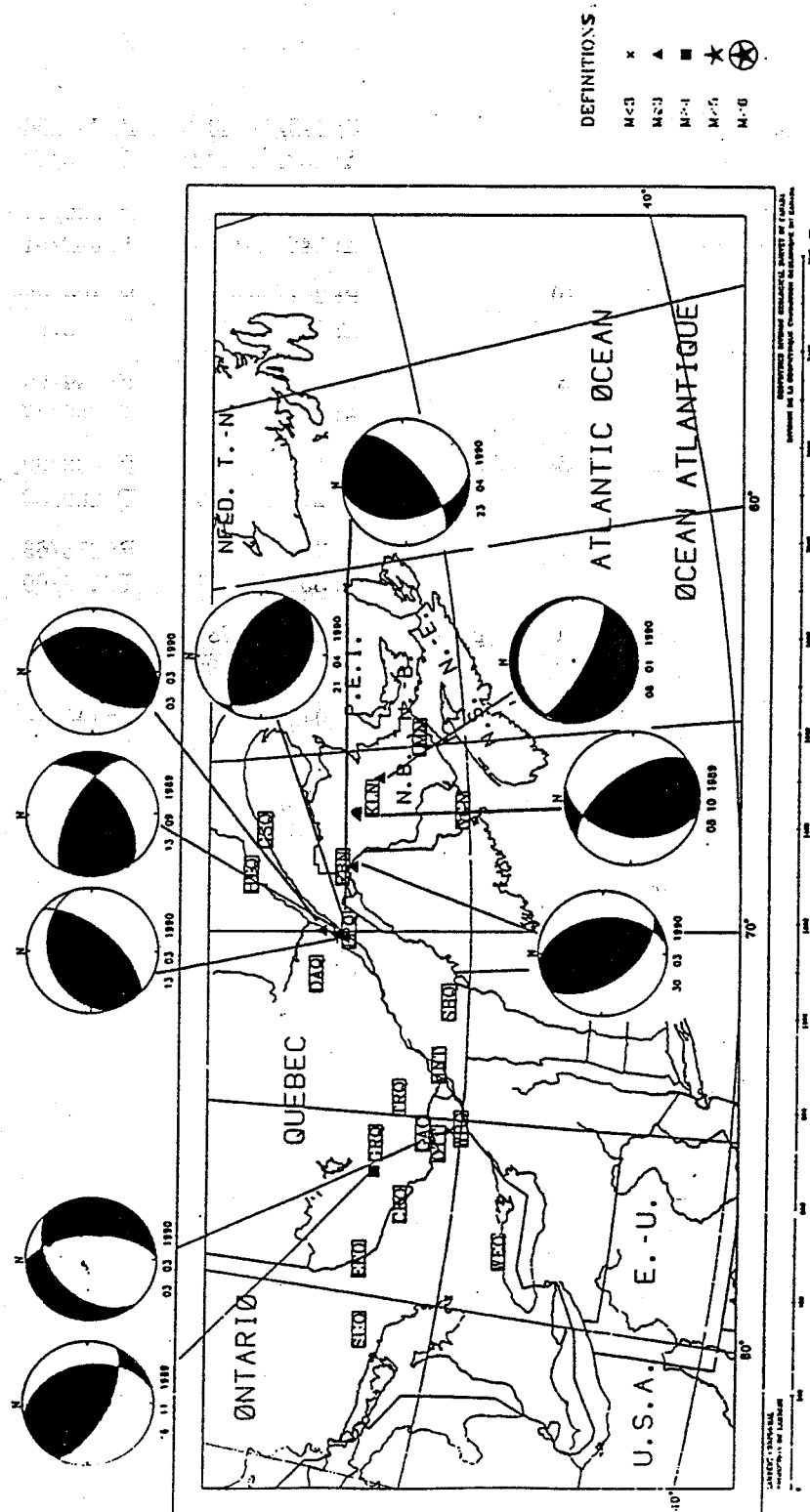


Figure 1: New focal mechanisms for southeastern Canada described in this report. Shown are equal-area lower-hemisphere projections of the focal mechanism. The compressional quadrant is shaded black.

## THE DECEMBER 25, 1989, UNGAVA QUÉBEC EARTHQUAKE

by Robert Wetmiller and Janet Drysdale  
Geophysics Division, Geological Survey of Canada

The magnitude 6.3 Ungava Earthquake of December 25, 1989, occurred in an area of northern Québec that had previously been recognized as a seismic zone (Figure 1), but historically had not experienced an event over magnitude 6.0. The earthquake followed a magnitude 5.1 foreshock 10 hours earlier. There were five earthquakes, magnitude 3 or greater, between the foreshock and the mainshock, and at least eight magnitude 3 or greater aftershocks during the 2 weeks following the mainshock, the largest being magnitude 4.4. The epicentre was in the middle of the unpopulated Ungava Peninsula of northern Québec; the nearest populated centres were small coastal settlements. Intensity questionnaires were sent to the postmasters of about 100 communities in northern Québec, the Northwest Territories, northern Ontario and Labrador. The mainshock was felt moderately at Kangirsuk (Payne Bay), the closest community, 200 km to the east; quite strongly in Kuujuaq (Fort Chimo), at a distance of 360 km; and not at all at Iqaluit (Frobisher Bay), 500 km from the epicentre. The maximum intensity felt was MM IV, as shown in Figure 2. The felt area was considerably smaller than that of the magnitude 6 Saguenay Earthquake of November 25, 1988, and it appears to be more consistent with the Ungava event's local magnitude than with its teleseismic magnitude.

Frigid temperatures ( $-35^{\circ}\text{C}$ ), short daylight (<3 hours/day), and the remote location of the event precluded an immediate field aftershock study; however, the Geophysics Division (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. A. 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 cessation of aftershock activity 6 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.

At the aftershock zone, the field party discovered the surface fault rupture caused by the earthquake. 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 5.5 km, trending an average of  $038^{\circ}$  (concave to the northwest), and centred at  $60.12^{\circ}\text{N}$ ,  $73.60^{\circ}\text{W}$ . 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, tapering to less than 0.3 m

at each end. As well as the deformed shorelines, fault scarps along the fault trace between adjoining lakes, torn muskeg above some traces, sand volcanoes, mud boils, freshly cracked boulders, a partly drained lake, a left-lateral surface strike-slip fault, and new springs were observed. Two lakes were discoloured by seismically-injected silt. Further details on the fault break can be found in Adams et al. (1990).

Very detailed monitoring along the fault scarp was conducted in the aftershock zone from July 19 to 23. Seismic activity was very low during the 4-day period and only 45 small aftershocks were located; all had a magnitude of less than 1.0 (Figure 1). (No aftershocks of magnitude 3.0 or greater have occurred in the Ungava sequence since April 1990.) The activity found was not uniformly distributed along the fault scarp, but was concentrated in a teardrop pattern within about 3 km of the southern end of the surface break near the site of a left-lateral offset of the fault. Most of the events had focal depths of less than about 2 km; many were less than 0.5 km. A few events with focal depths as deep as 8 km were found a few kilometres west of the surface fault trace. Analysis of the seismicity data collected is not yet complete. Preliminary results were reported at the meeting of the Eastern Section of the Seismological Society of America in Blacksburg, Virginia in October.

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Adams, J., Wetmiller, R. J., Drysdale, J. A., and Hasegawa, H. S. 1991. The first surface rupture from an earthquake in eastern North America: Geological Survey of Canada, Paper 91-1C p. 9-15.

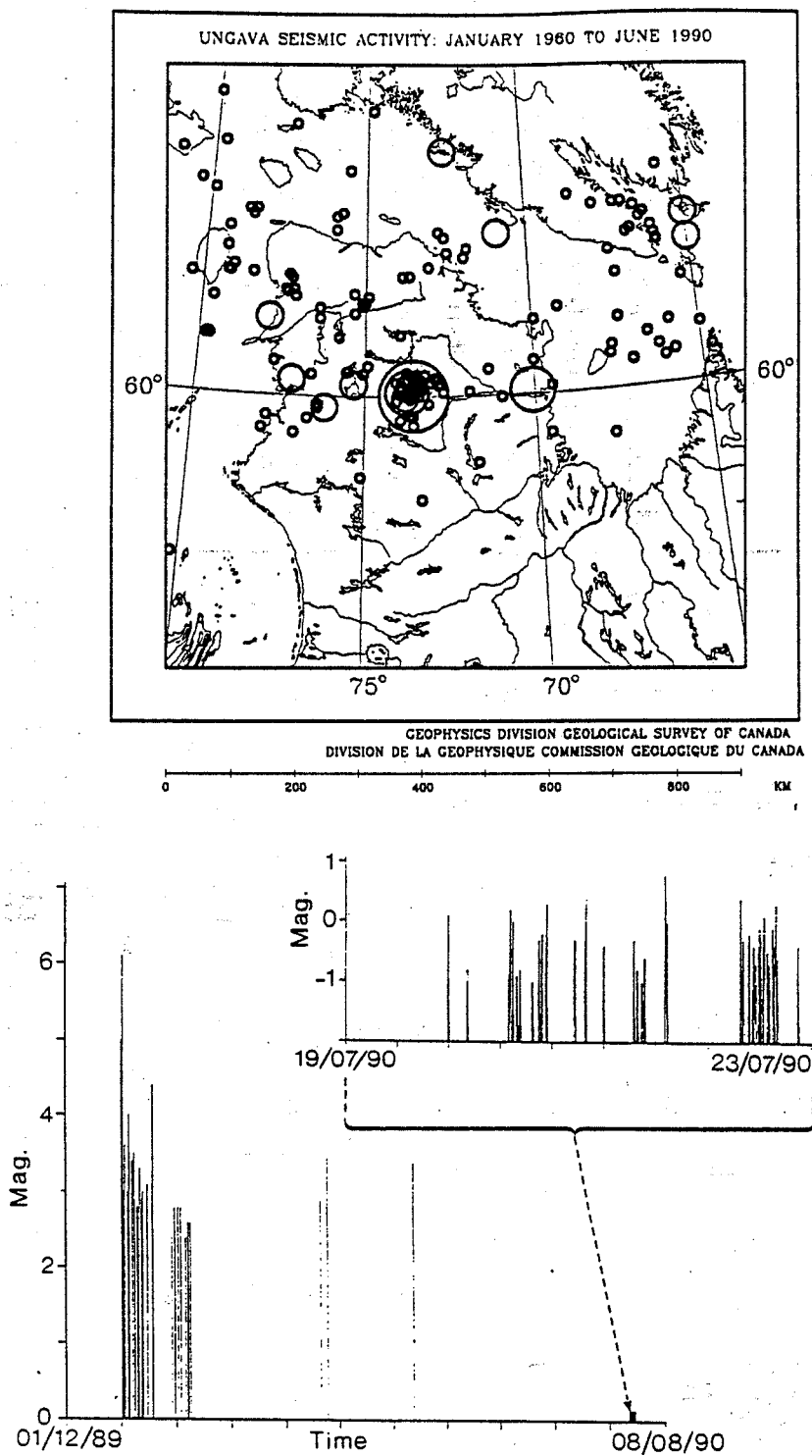


Figure 1. Summary of Ungava seismic activity since 1960. The graphs below the map show the magnitude-time history of the events in the sequence detected by the permanent network and (in the insert) the magnitude-time history of aftershock activity recorded during the field survey in July.

# UNGAVA 25-12-89, 6.3 MS

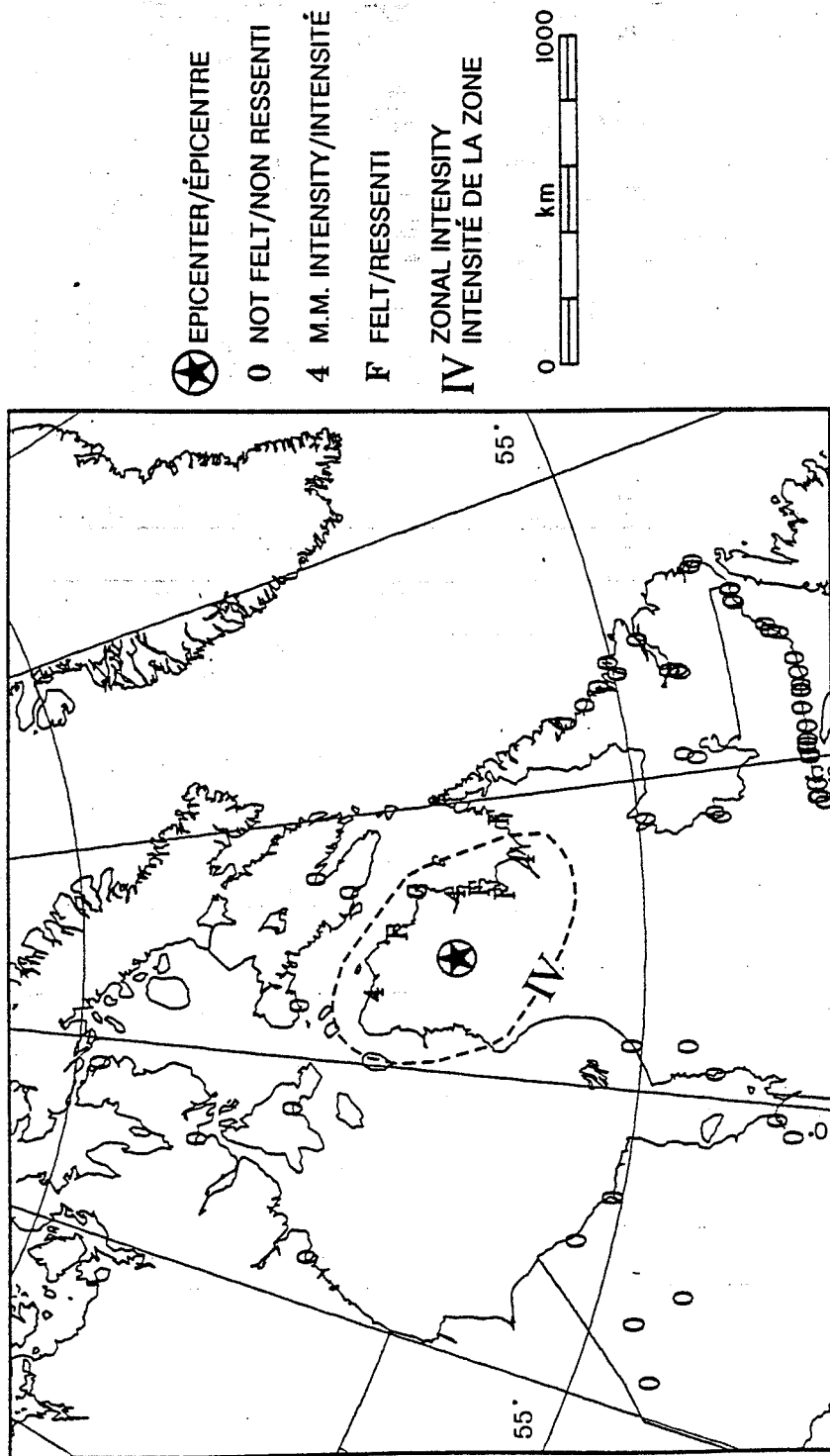


Figure 2. Felt area of the Ungava Earthquake.

**GLACIGENIC POSTGLACIAL FAULTING AT SAINT JOHN, NEW BRUNSWICK****B.E. Broster and K.B.S. Burke**

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**Atlantic Geology, 1990  
Volume 26, p. 125-138, (1990)**

Displaced glacial striae were examined at outcrops within the central area of Saint John, New Brunswick. Displacements are mostly confined to north-facing slopes of small bedrock hills left after the glacial erosion of Cambrian-Early Ordovician rocks in the southeast limb of a syncline. The striae are generally offset by high-angle reverse faults a few metres in length and with throws up to 60 mm. The faults trend parallel to bedding and dip southward at angles similar to the dip of individual beds.

The displacements have long been considered as evidence of postglacial tectonic stresses in the area. However, from a detailed analysis of the extent and orientation of the small faults, we propose that the displacements represent the response of multilayered sedimentary rocks with anisotropic strengths, to differential rates of glacitectonic loading and unloading. Therefore, the last major displacements likely occurred very soon after deglaciation of the area.

## PROGRESS REPORT ON MANITOULIN ISLAND POPUPS

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While engaged in a study of raised shorelines on Manitoulin Island, observations have been made of evidence of rock disturbance. Rock disturbance of post-glacial age could affect the interpretation of tilted water planes.

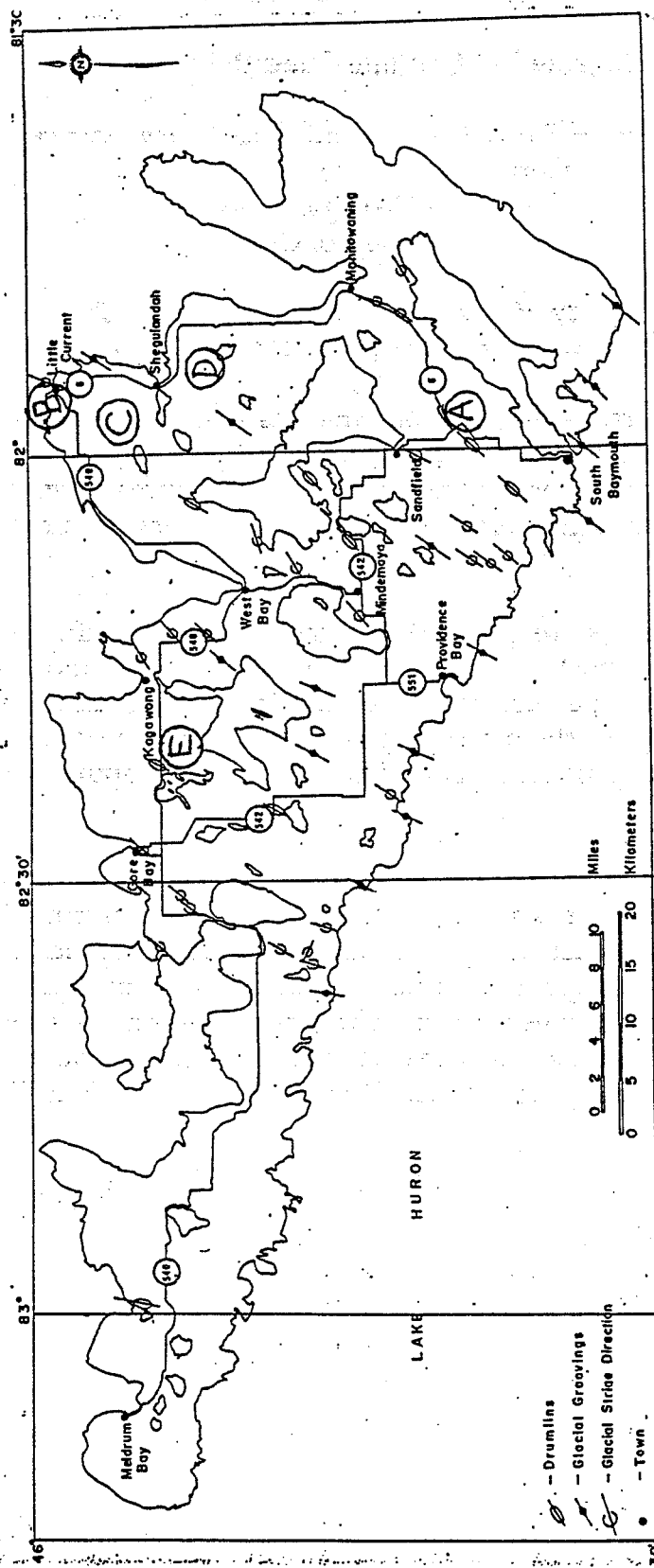
Locations of features are shown on the accompanying map. A short popup (A) was reported by M. Johnson, Ontario Geological Survey, in southeastern Manitoulin and it was visited and photographed; it trends northwest-southeast. A second one of uncertain location on the south shore in the western part of the Island, has not yet been visited. Another reported feature near Gore Bay could not be found.

A northerly-trending fault (B) of small displacement was found at Little Current. In a nearby poor exposure a sulphide-oxidized zone at right angles may mark another fault. Limestone near this has numerous vertical parallel calcite-filled fractures.

Several small ridges of varying trend lacking rock exposures, but perhaps of popup origin, are located on the high plateau south of Little Current (C). On the rock upland south of Sheguiandah is a well-formed low popup (D). The main part trends north but at the south end it curves to the southeast.

The largest popup is north of Kagawong Lake (E). Over two kilometres long and up to two metres high, it is the largest ever seen by the author. There are a few small offsets along its length, which consistently trends northwest-southeast.

All observed features are in limestone (Ordovician) or dolostone (Silurian), the principle exposed rock lithologies of the Island. None have been reported or observed in shale, but it has limited areas of outcrop.



**Bedrock popups in south-central Ontario -- Symptoms  
of crustal hypertension**

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**Geological Society of America, Annual Meeting, St. Louis, MO;  
Abstracts with Programs, vol. 21, no. 6, p A19, 1989**

During the past 30 years, geological mapping has revealed various kinds of bedrock disturbances. Several faults display small offsets of unknown age. More numerous low anticlines or popups are either evident in vertical exposures a few metres deep or as surface ridges 1 to 2 m high, commonly visible as linears on air photos and on the ground.

Known popup occurrences are grouped in areas of shallow drift. One is known from Silurian dolostone, but most are in Upper Ordovician shale and Middle Ordovician limestone. Some are at the surface of the Halton Till plain and on the glacial Lake Iroquois plain and were clearly formed in postglacial time. One disturbs the glacial Lake Algonquin shoreline so postdates about 10,000 B.P. The popup in Silurian dolostone occurred in 1949.

Similar popups are well known as abrupt stress-release events in quarrying. Natural popups, some of which (perhaps all?) occurred in postglacial time, indicate a state of high stress in the crust which, along with possibly related seismic events, should be of concern to planners and engineers because of possible structural damage when release takes place. Recent earthquakes with epicentres near western Lake Ontario and recently discovered lake floor sediment disturbances may be related evidence of crustal stress release. More detailed mapping of such features and search for additional occurrences are of high priority.

# ASSESSMENT OF BEDROCK DEFORMATIONS IN PRINCE EDWARD COUNTY, EAST-CENTRAL ONTARIO AND THEIR TECTONIC IMPLICATIONS

G. H. McFall

Ontario Geological Survey<sup>1</sup>

The Paleozoic succession of east-central Ontario is, on a broad regional scale, generally flat-lying to very gently dipping at about 2 to 3 degrees to the south. The Paleozoic rocks of region are cut by several major faults which suggests a Phanerozoic rejuvenation of earlier structures as they can be linked to terrane boundaries and mylonite zones in the exposed Precambrian basement to the north.

On a more local scale, deformation of the strata in the form of faults, pop-ups and folds have been observed and documented in previous reports. More detailed information on these structures can be found in the following reports and publications: McFall and Allam (1990), McFall and Allam (in press), McFall (1990), and previous MAGNEC Annual Reports. A comparison of the data from widely separated locations within the county yields an interesting consistency of orientations. A summary of the structural information is illustrated in Figure 1.

Folds were measured in the Consecon and Mountain View quarries located in the west and north-central parts of the county respectively. The general trend is northwest, although the folds at Consecon generally trend 310° and those at Mountain View generally trend 342°. Pop-ups, which are also compressional structures, have been identified in the southern part of the county. There are 7 to 9 structures on land and possibly two more offshore. Like the folds, pop-ups generally trend northwest but have two orientations, one at 290° and the other at 335°.

Local faults occur in the southeastern part of the county at Long Point. Three normal faults trend roughly northwest-southeast and dip to both the northeast and southwest. Conjugate low angle reverse faults also trend northwest-southeast. Strike-slip faults have been observed in two fracture zones. They strike east-west and have sub-horizontal slickensides.

A Middle Jurassic (173 my) (Barnett et al. 1984) ultramafic dyke cuts the exposed strata in the Picton Quarry, which is centrally located in the county. The dyke trends east-west (090°/76°) and, along with the country rock, is cut by east-west trending fractures that exhibit sub-horizontal slickensides suggesting a post-emplacement fault zone (McFall 1990). A second fault, with sub-

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horizontal slickensides indicating left-lateral movement and trending northeast-southwest ( $238^{\circ}/78^{\circ}$ ) was also observed in the quarry but its intersection with the dyke could not be observed.

Generally, all the folds, pop-ups, normal and reverse faults that have been observed in the county trend northwest-southeast (Figure 1). The strike slip faults, with the exception of one in the Picton Quarry, trend east-west. The orientation and sense of movement on the fault that trends  $235^{\circ}$  is similar to faults documented in the Salmon River area (McFall this report) 25 km north of the county. The present stress orientation (P-stress), as measured at the Roblindale Quarry (McKay 1986, McKay and Williams 1988) about 25 km northwest of Prince Edward County, is  $030^{\circ}$  and the glacial striations indicate that the ice flow directions were from the east-northeast and east-southeast (Gorrell 1989)(Figure 1). The structures are more consistent with the present regional stress orientation than with any stresses that may have resulted from ice movement. This also suggests, although not conclusively, that the structures may have formed or been reactivated more recently (post-Cretaceous) than previously interpreted (post-Ordovician) (Liberty 1963).

Barnett, R.L., Arima, M., Blackwell, J.D., and Winder C.G.; 1984: The Picton and Varty Lake ultramafic dykes: Jurassic magmatism in the St. Lawrence Platform near Belleville, Ontario; Canadian Journal of Earth Sciences, Volume 21, pp. 1460-1472.

Liberty, B.A. 1963: Geology of the Tweed, Kaladar and Bannockburn map-areas, Ontario, Geological Survey of Canada, Paper 63-14, 15 p.

McFall, G.H.; 1990: Faulting of a Middle Jurassic, ultramafic dyke in the Picton Quarry, Picton, southern Ontario; Canadian Journal of Earth Sciences, Volume 27, pp. 1536-1540.

McFall, G.H. and Allam, Ahmed; 1990: Neotectonic investigations in southern Ontario: Prince Edward County - Phase I; Atomic Energy Control Board, Technical Report INFO 0343.

McFall, G.H. and Allam, Ahmed; in press: Neotectonic investigations in southern Ontario: Prince Edward County - Phase II; Atomic Energy Control Board, Technical Report.

McKay, D.A.; 1986 Roblindale Quarry Stress Measurements, Preliminary Evaluation - Phase I; Ontario Hydro Research Division Report 86-43-P, 143 p.

McKay, D.A. and Williams, J.B.; 1988: Roblindale Quarry Stress Measurements, Preliminary Evaluation - Phase II; Ontario Hydro Research Division Report 88-113-P, 90 p.

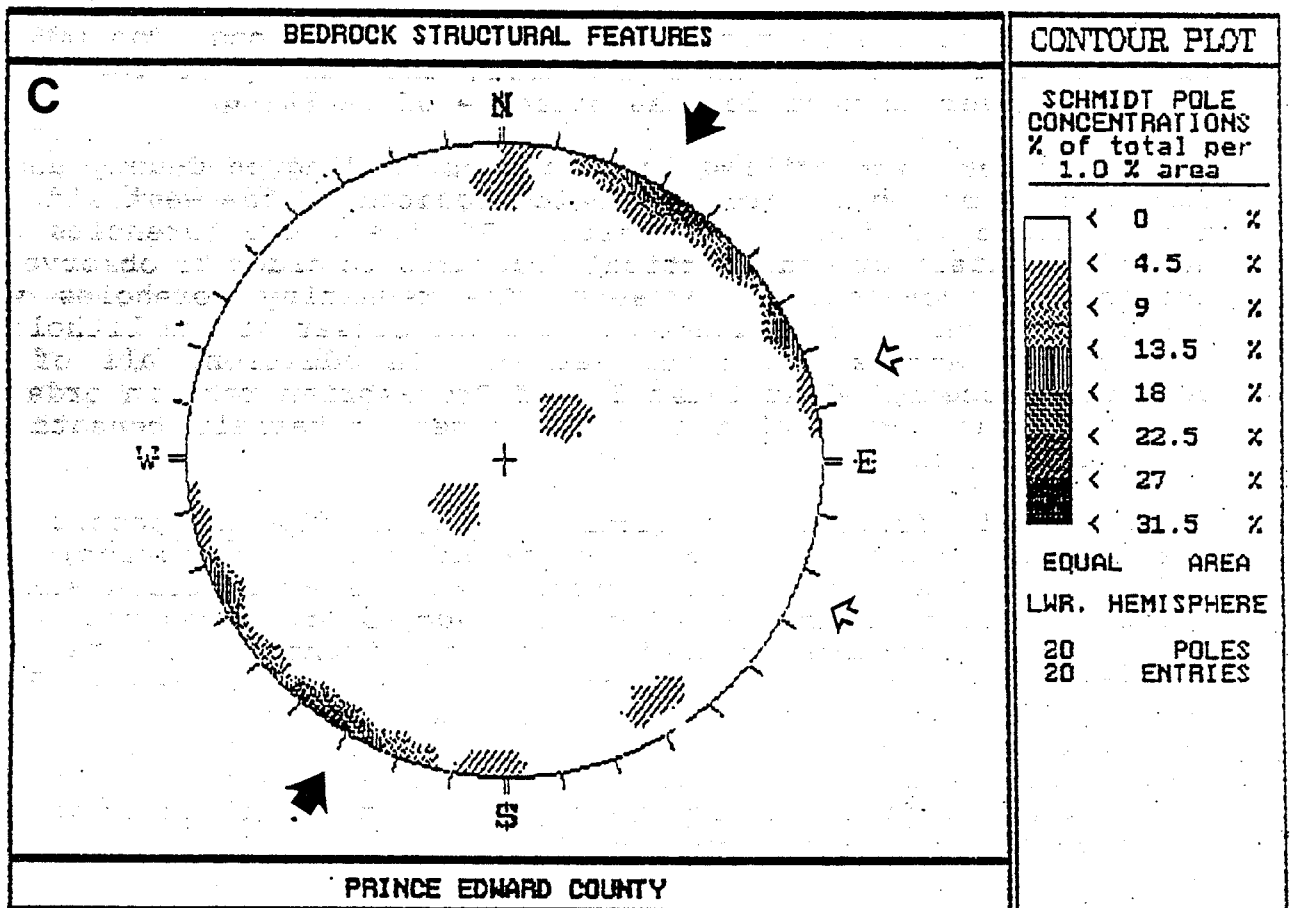
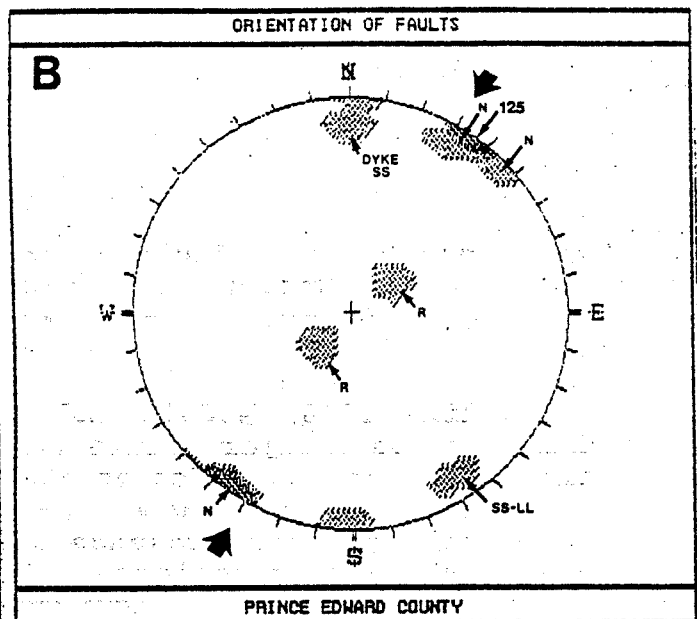
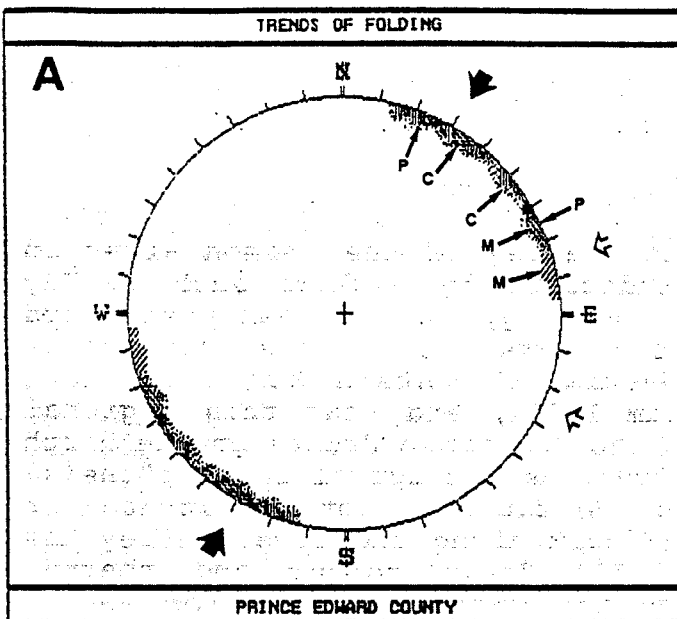


Figure 1: Equal area net, lower hemisphere projection of bedrock structural features in Prince Edward County, southern Ontario: A) trends of folds and pop-ups, B) orientations of faults, C) composite plot of folds, pop-ups and faults. (M = Mountain View, C = Consecon, P = popup, N = normal fault, R = reverse fault, SS = strike-slip fault, LL = left lateral movement, closed arrows = present P-stress orientation, open arrows = glacial striation direction)

## PRELIMINARY RESULTS OF THE SALMON RIVER DRILLING PROGRAM

G. H. McFall

Ontario Geological Survey<sup>1</sup>

The presence of a fault along the valley of the Salmon River in east-central Ontario has been indicated by workers such as Kay (1942) and Liberty (1963). More recently, it has been postulated that this fault is the northeastern extension of the seismically active Clarendon-Linden Fault System of western New York State (Fakundiny 1978, McFall and Allam 1990), and that this regional fault may be a major suture (like the Grenville Front) in the North American plate (Culotta et al. 1990). As the actual fault plane(s) have not been documented, and as the fault is not illustrated on regional maps, the presence of a fault along the river valley has recently been questioned. 1:10,000 false colour and thermal infrared photography, acquired by the Ontario Centre for Remote Sensing in 1985, shows more detailed definition of the fault trace thereby aiding the targeting of drilling operations. The OGS has undertaken a drilling programme along the valley of the Salmon River in order to test for the presence of faulting.

The boreholes were drilled in Lennox and Addington County and in Hastings County with three boreholes located on the west side and two on the east side of the valley. Of these, two boreholes were angled to intersect near-vertical fractures in order to observe any evidence of movement if present. The remaining boreholes were vertical to test for evidence of vertical offset of the lithologic marker beds across the river valley. In addition, all of the boreholes penetrated at least 3 m of Precambrian rock in order to determine the composition of the basement materials beneath the Paleozoic cover.

Slickensided fracture surfaces in both the Paleozoic and Precambrian rocks and zones of cataclasis (brecciation) were observed in the core. The elevation of the Precambrian surface varies, up to a maximum of 80 m, both across and along the length of the valley portion studied. Varying thicknesses of the basal sandstones (Shadow Lake Formation) and carbonates of the Gull River and Bobcaygeon Formations comprise the Paleozoic section. The dominant rock types encountered in the Precambrian were granitic gneiss and metasediments with the depth of weathering of the Precambrian surface varying greatly. As yet, detailed logging of the core has not been completed.

At the same time as the drilling programme, the exposures of the Paleozoic rocks in the vicinity of the boreholes were examined, fracture orientations were measured, and evidence of faulting was documented. The dominant fracture orientations are east-west ( $274^{\circ}/81^{\circ 2}$ ) and northeast-southwest ( $029^{\circ}/90^{\circ 2}$  and  $240^{\circ}/83^{\circ 2}$ ,

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<sup>2</sup> Right hand rule

averaging  $217^{\circ}/90^{\circ 2}$ ), with northwest-southeast ( $301^{\circ}/90^{\circ 2}$ ) being less common (Figure 1). These fracture orientations are similar to the major fracture trends and the orientation of the Middle Jurassic dyke and a post-emplacement fault in the Picton Quarry (McFall, 1990) about 25 km to the south in Prince Edward County.

Brittle folding, zones of cataclastic deformation (brecciation), and fractures with prominent slickensided surfaces were observed (Figure 2) in the surface exposures. The latter two observations confirm movement on the fractures and support the interpretation of faulting. The slickensided surfaces observed in the outcrops indicate left lateral displacement. Both the orientation and the sense of movement are similar to a second fault, which appears to cut the Jurassic dyke, documented in the Picton Quarry (McFall 1990). This sense of movement cannot easily be rationalized by the dominantly compressional and tensional stress orientations of the Paleozoic and Mesozoic but it is in keeping with the more recent stress orientations for the area ( $030^{\circ}$ ) (McKay 1986, McKay and Williams 1988). It may therefore be construed that movement on the faults along the Salmon River occurred during post-Cretaceous time.

Fakundiny, R.H., Myers, J.T., Pomeroy, P.W., Pferd, J.W., and Nowak, T.A. 1978: Structural Instability Features in the Vicinity of the Clarendon-Linden Fault System, Western New York and Lake Ontario; in J.C. Thompson, ed. Advances in Analysis of Geotechnical Instabilities, Solid Mechanics Division, Study No. 13, University of Waterloo Press, Waterloo, Ontario, pp. 121-178.

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<sup>2</sup> right hand rule

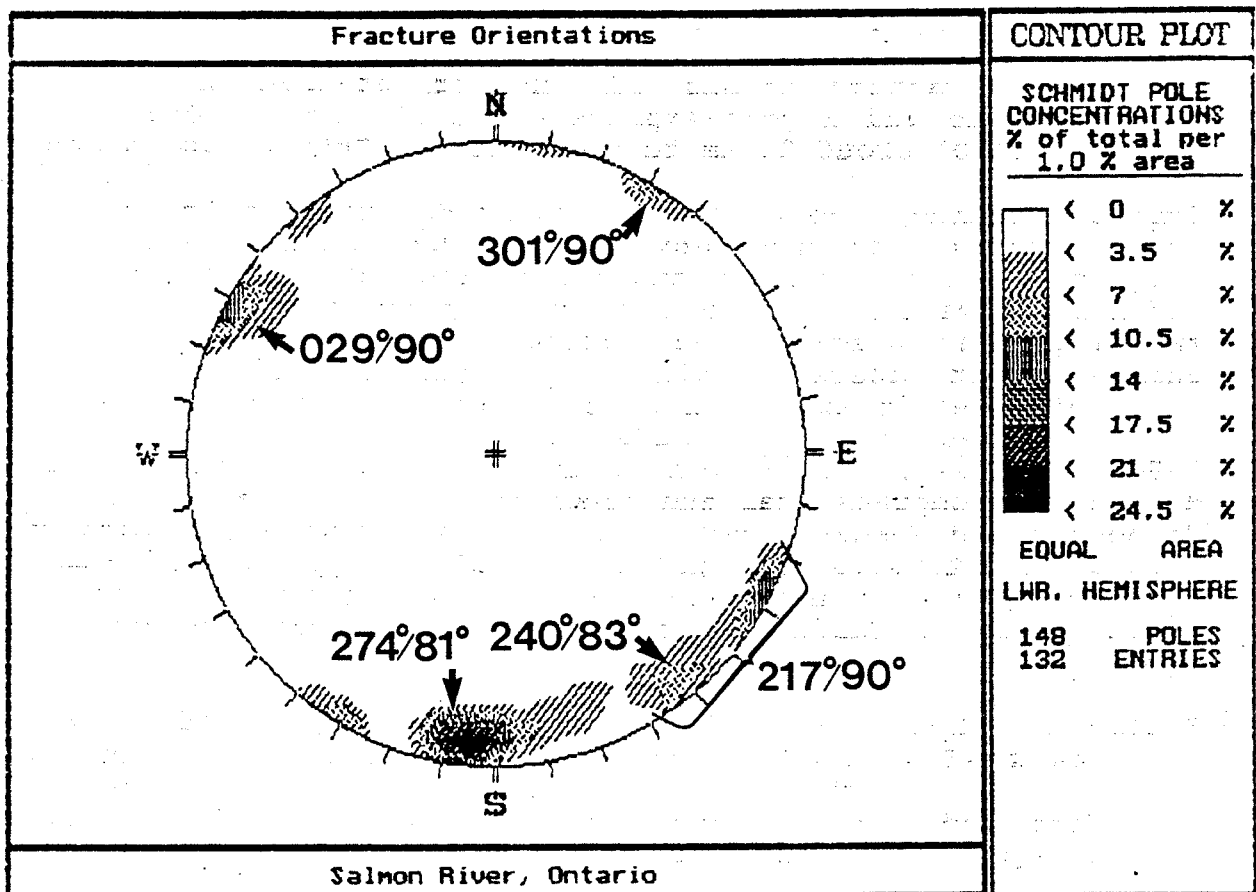


Figure 1: Equal area net, lower hemisphere projection of fractures measured in the Salmon River Area.

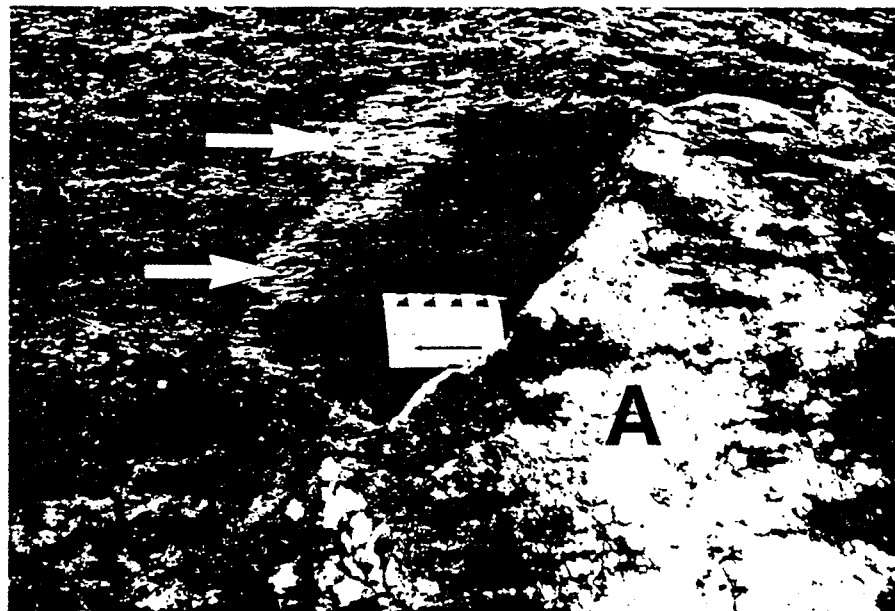


Figure 2: Fracture surface with prominent slickensides (arrows) and calcite cemented breccia (A) with slickensided clasts.

## MAPPING REGIONAL STRESS PROVINCES IN CANADA - A PROGRESS REPORT

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\*\*Geological Survey of Canada, Calgary, Alberta

## Abstract

In recent years, sufficient in-situ stress data (borehole breakouts, earthquake focal mechanisms, overcoring measurements, and various geological indicators) have become available in Canada and adjacent areas in the U.S.A. for stress regimes to be delineated in enough detail to permit the definition of stress provinces (Fig.1). Five stress provinces have been recognized in Canada on the basis of principal stress relationships and orientation. They are: the Mid-Plate Stress Province, the Cordilleran Extensional Stress Province, the Pacific Northwest Stress Province, the Cascadia Convergence Stress Province and the Queen Charlotte Stress Province. The regional consistency and configuration of horizontal stresses within the provinces suggest that the regional stress fields have a contemporary plate tectonic origin. The present synthesis can be used as a general guide to the expected principal stress orientations in virgin rock at a specific site.

## Résumé

Dans les années récentes, nous avons obtenu au Canada, et dans les régions adjointes des États Unis, une distribution de données des contraintes naturelles de la croûte suffisant pour distinguer les provinces de contrainte (Fig.1). Nous avons défini cinq telles provinces au Canada avec référence aux relations entre les contraintes principales et leurs directions. Ce sont: la Province de Contrainte de la Plaque Médiale, la Province de Contrainte Extensionnelle de la Cordillera, la Province de Contrainte du Pacifique North Ouest, la Province de Contrainte de Convergence du Cascadia et la Province de Contrainte de la Reine Charlotte. La consistance régionale et la configuration des contraintes horizontales dans les intérieurs de ces provinces suggèrent que les champs régionaux des contraintes naturelles ont leurs origines associées avec les mêmes forces contemporaines qui bougent les plaques tectoniques. La synthèse que nous présentons ici peut être utilisé comme un guide général des orientations anticipées des contraintes principales pour des roches verges à un site spécifique.

Reference: Adams, J., and Bell, S., 1990. Mapping regional stress provinces in Canada - a progress report: p. 3-12 in Herget, G., Arjang, B., Bétournay, M., Gyenge, M., Vongpaisal, S., and Yu, Y.S. (eds.) Proceedings of a speciality conference "Stresses in Underground Structures", October 2-3, 1990, Ottawa, Ontario.

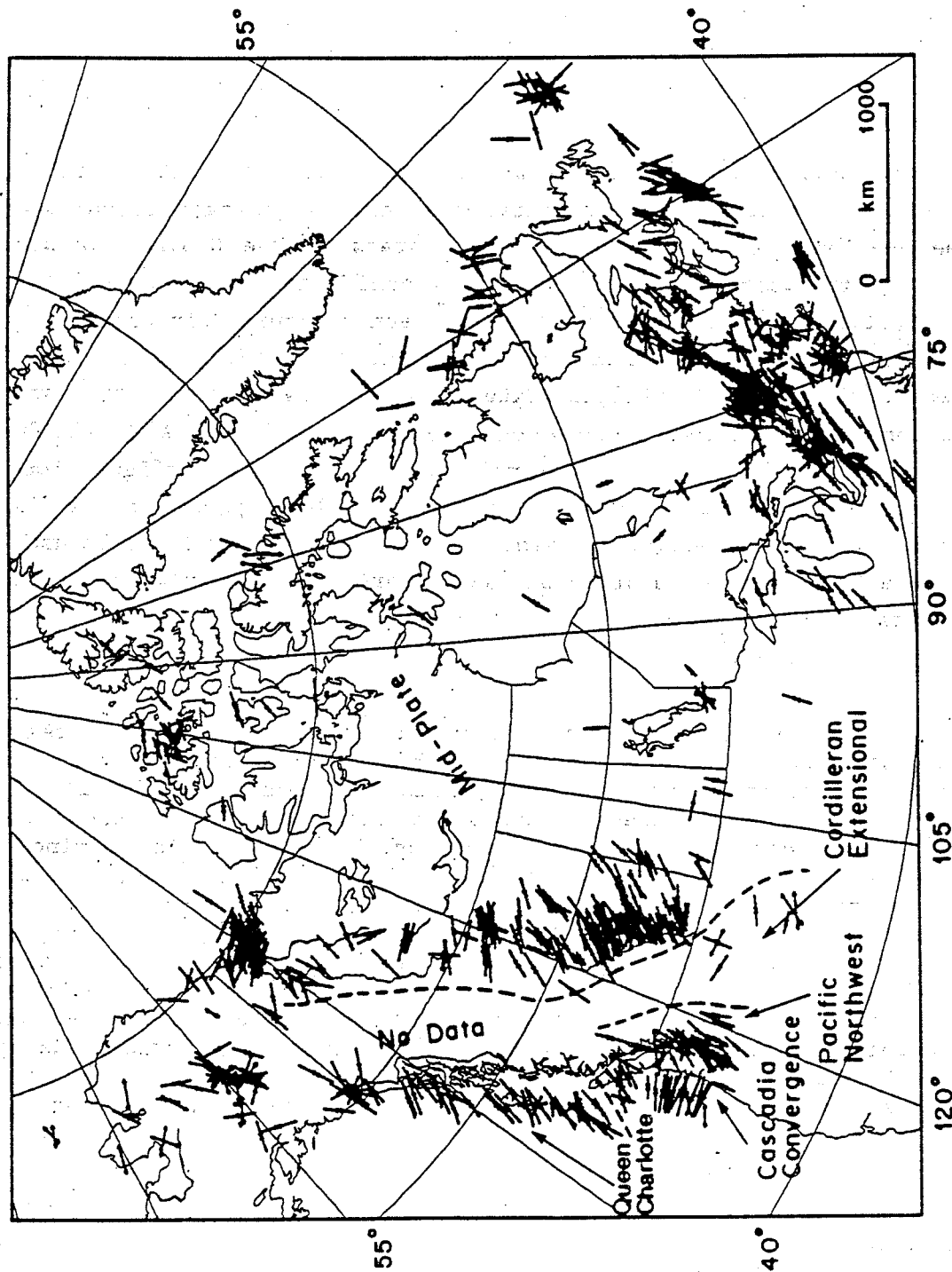


Fig. 1. Canadian Stress Provinces. Bar length is proportional to data quality and inward pointing arrows indicate directions of maximum horizontal compression,  $S_{Hmax}$ . The surface traces of stress province boundaries are dashed to indicate that there is uncertainty about their exact locations.

## DO THE ROCKS REMEMBER? HOW CONTEMPORARY ARE REGIONAL STRESSES IN CANADA?

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\*\*Geological Survey of Canada, Calgary, Alberta

\*Geological Survey of Canada, Ottawa, Ontario

## Stresses in Underground Structures

Proceedings of a specialty conference, CANMET, Ottawa, October 1990

## Abstract

Five stress provinces have been recognized in Canada on the bases of principal stress relationships and orientation. The regional consistency, recent age and the configuration of horizontal stresses within these provinces suggest that the regional stress fields have a plate tectonic origin. This implies that any stresses due to former geological events have not been locked-in, and that it is the fate of all ancient applied stresses to fade away relative to contemporaneous stress fields. The regional compilation has also shown that local anomalies exist with respect to principal stress orientations. In one case, lateral heterogeneity of elastic properties is the suspected cause; in others, faults acting as free surfaces are believed to reorient stresses locally (Fig.1), and some anomalous stress orientations may represent "ghosts" of past earthquakes (Fig. 2). In no case does there appear to be a strong case for invoking relict stresses as an explanation.

## Résumé

On a désigné cinq provinces de contrainte naturelle au Canada avec l'aide des relations entre les contraintes principales et leurs directions. La consistance régionale, l'âge récent, et la configuration spatiale des contraintes horizontales dans ces provinces suggèrent qu'elles sont d'origine tectonique globale. L'implication de cette conclusion est qu'il n'existe plus de contraintes formées par les événements géologiques anciens, et que les champs anciens ne sont pas reliés aux champs contemporains. Notre compilation régionale a démontré que les anomalies locales des directions horizontales de contrainte existent en quelques parts au Canada. Un exemple particulier peut être causé par une hétérogénéité latérale des propriétés élastiques; dans d'autres situations, nous croyons que certaines failles agissent comme surface libres et réorientent les contraintes (Fig. 1), et d'autres anomalies directionnelles peuvent représenter l'empreinte d'un tremblement de terre pré-historique (Fig.2). Nous n'avons pas trouvé aucun cas d'évidence directe permettant d'invoquer l'action des contraintes anciennes comme explication pour les anomalies directionnelles des contraintes.

Reference: Bell, J.S., and Adams, J., 1990. Do the rocks remember? How contemporary are regional stresses in Canada? p. 13-22 in Herget, G., Arjang, B., Bétournay, M., Vongpaisal, S., and Yu, Y.S. (eds.) Proceedings of a speciality conference "Stresses in Underground Structures", October 2-3, 1990, Ottawa, Ontario.

Fig. 1

Anomalous  $S_{Hmax}$  orientations near the Murre Fault in the Jeanne d'Arc Basin, indicated by breakouts. It is believed that the Murre Fault, which can be traced to within 600 m of the sea floor, may be acting as a free surface and deflecting stresses in nearby rocks. Note that the anomalous  $S_{Hmax}$  trajectories near the Murre Fault trend approximately normal to its trace. The fault trace shown is where the fault cuts late Tertiary units; it is a listric structure and bends under the wells in which anomalous  $S_{Hmax}$  orientations were recorded.

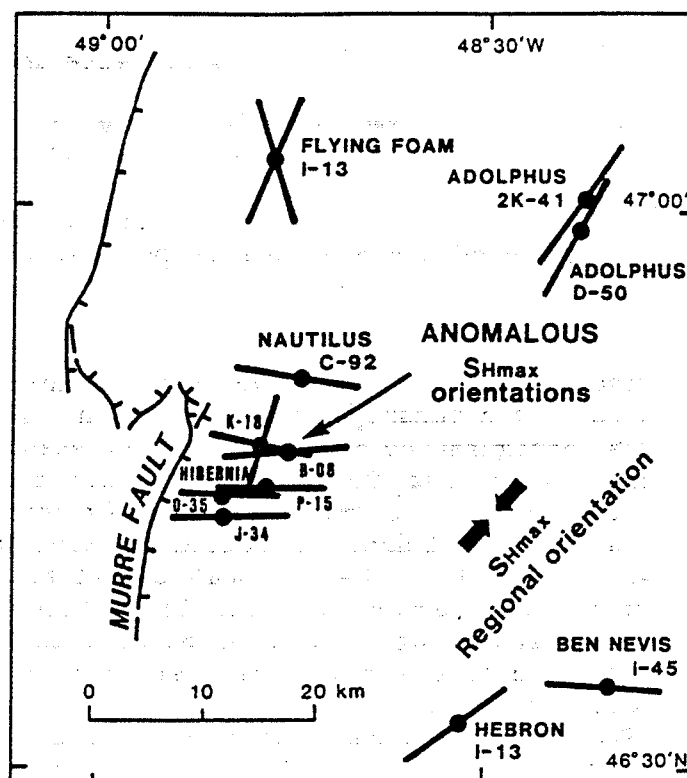
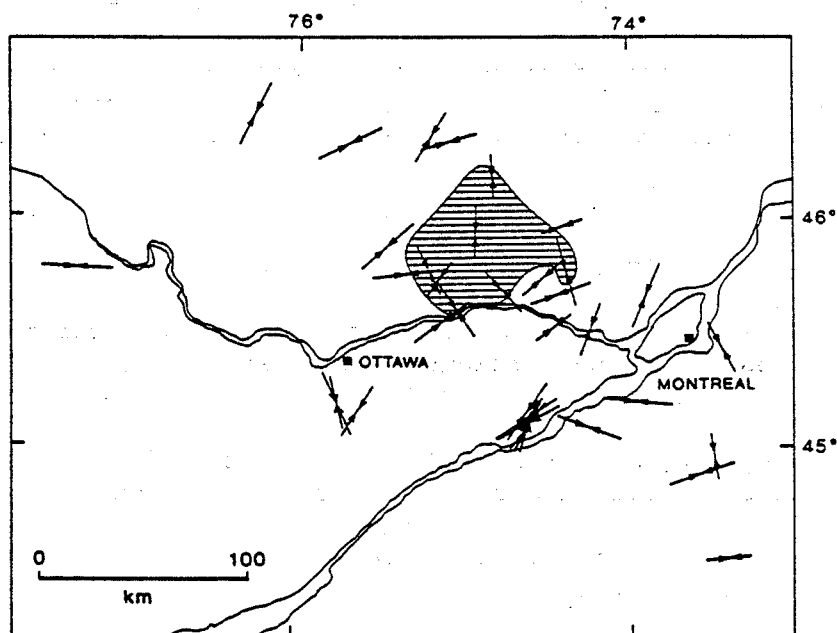


Fig. 2

$S_{Hmax}$  axes in the Ottawa-Montreal region of southeastern Canada inferred from earthquake focal mechanisms deeper than 9 km. The striped area with orthogonally anomalous NW-SE horizontal compression directions may represent the "ghost" of a large prehistoric earthquake.



## JOINTING WITHIN THE SURFICIAL GLACIAL SEDIMENTS AND BEDROCK OF SOUTH-CENTRAL ONTARIO

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Environmental Applications Group Ltd., Toronto, Ontario

During the summer 1989, extensive field work was carried out to determine the regional character of jointing within the surficial glacial sediments and bedrock of south-central Ontario. At a total of forty sites, the bedrock or sediment characteristics were described, and the orientation (strike and dip) and quality (staining and extent) of near vertical joints were determined.

From this field work, three regional joint sets were identified. Within the bedrock, joint sets were oriented northeast / southwest, northwest / southeast and north / south (Figure 1). The glacial sediments also showed three regional joint sets, which were oriented northeast / southwest, northwest / southeast, and a weaker, poorly defined north / south trend (Figure 2). The reasonably good correlation between the joint orientation trends within the bedrock and glacial sediments, suggests that the joints may have propagated from the bedrock into the glacial sediments.

A comparison between the regional jointing pattern identified within the bedrock and glacial sediments of south-central Ontario, and the orientation of stress release or related structures, suggests that the regional pattern of jointing may be controlled by the regional stress field. However, the orientation of joints at any individual site may also be controlled by such 'local' factors as face orientation, direction of glacial ice movement and lithology, and by randomly oriented joints formed as the results of physical and chemical weathering, synaeresis, subglacial deformation and stress relief.

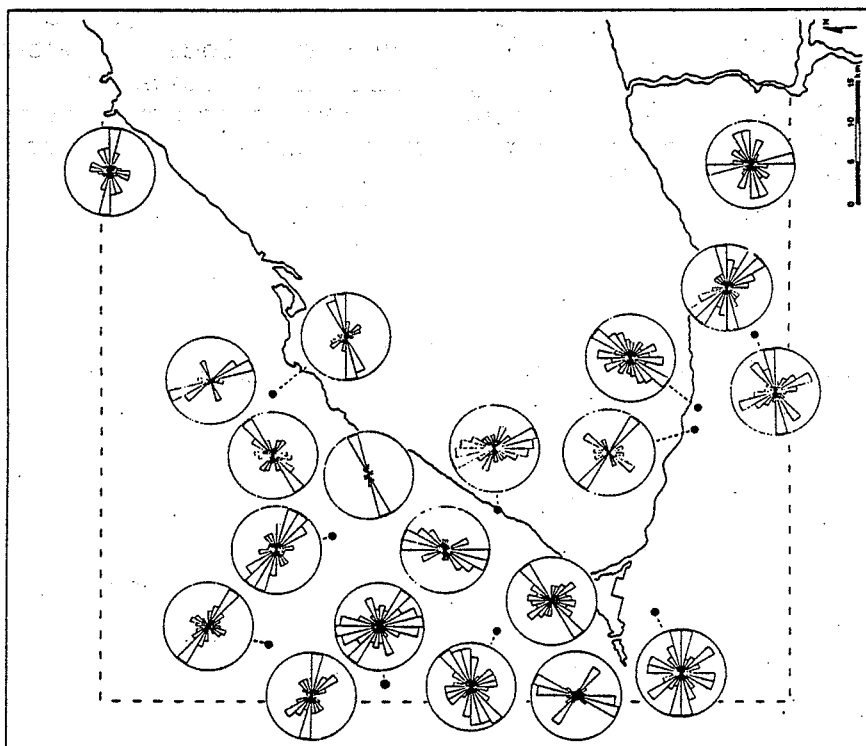


Figure 1: Compilation of Joint Orientation Measurements within the Bedrock of South-Central Ontario.

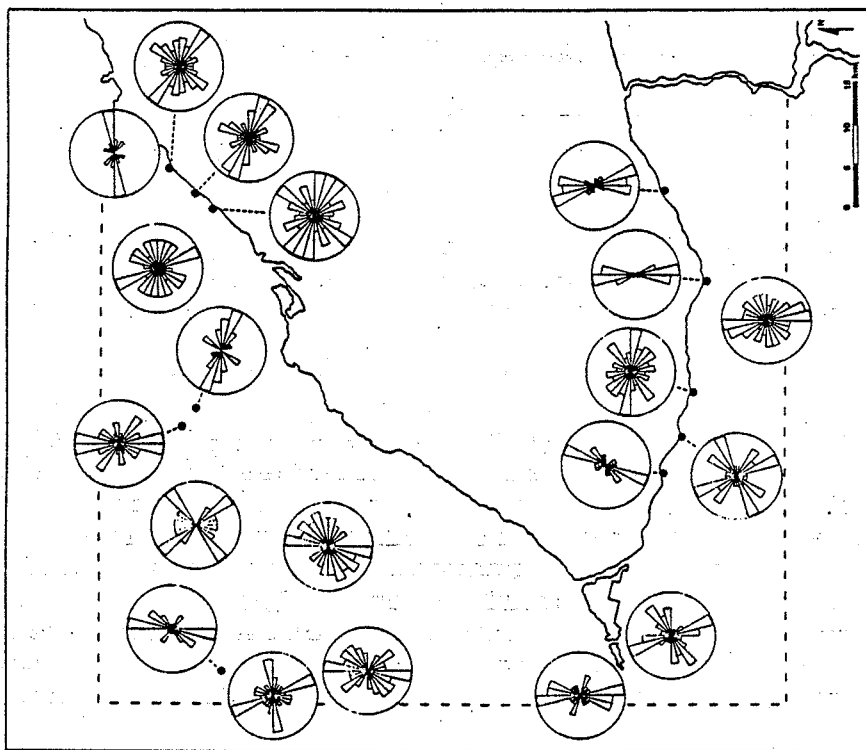


Figure 2: Compilation of Joint Orientation Measurements within the Surficial Glacial Sediments of South-Central Ontario.

# GEOMORPHIC SELECTION EFFECTS IN LINEAMENT MAPPING USING ORBITAL RADAR AND LANDSAT IMAGERY \*

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\* To be presented at IGARSS '90, College Park, Md., May, 1990

## Abstract

Orbital remote sensing has been widely used to map lineaments since becoming available on a routine basis with the launch of ERTS-1 (now Landsat) in 1972. This paper reports an unexpected and important selection effect discovered during a series of investigations of structure on the Canadian Shield using orbital radar (SIR-B and Seasat) and Landsat imagery.

The radar investigations were carried out as part of the Shuttle Imaging Radar-B (SIR-B) program, using data from the 41-G Shuttle mission of October, 1984. The objective of the Canadian Shield experiments was primarily to investigate the structure and origin of the Grenville and Nelson Fronts, hypothesized by some to be sutures along which the Churchill, Superior, and Grenville Provinces had been joined by terrane accretion. The Landsat investigation was begun in 1981 with the objective of testing the theory that lineaments fit a global orthogonal regmatic shear system. Both investigations achieved their nominal objectives and the results have been published in the open literature. However, a by-product has been the demonstration that geomorphic processes can severely bias lineament mapping, and in fact structural mapping in general, using orbital imagery.

Orbital radar with suitable look directions and angles should in principle be useful for low-relief, forested areas such as the Canadian Shield, and in fact has been effective. However, it has been found that major structural features, including the Grenville Front, the Nelson Front, the Kapuskasing Zone, and many greenstone belt faults of the Superior Province, are essentially invisible on radar imagery even with illumination normal to their trends. Field investigation reveals the reason for this to be that these compressional features are not susceptible to differential erosion. The Grenville Front, for example, generally consists of a zone of mylonite as resistant as the adjacent rock, frequently more so. The Nelson Front reveals similar lithology.

Extracted from Proceedings, IGARSS '90, 10th Annual International Geoscience and Remote Sensing Symposium, V.III, p.2103, 1990

Landsat MSS imagery (60 low sun angle Band 7 scenes) of the Canadian Shield permitted construction of lineament maps covering portions of all tectonic provinces. Most lineaments were found, where field-checked, to be mafic dykes, extension fractures parallel to such dykes, or other types of extension fracture such as normal faults of the St. Lawrence rift system. However, the Grenville and Nelson Fronts were in many areas invisible on Landsat imagery for the same reasons cited above for the radar data. The narrowness of these features, a few tens of meters in many areas, also makes them difficult to detect on orbital imagery with ground resolution of the same order.

It has thus been demonstrated that, for areas of low relief and uniform radar roughness like the Canadian Shield, lineament delineation on orbital imagery tends to be strongly biased toward extensional fractures, which are geomorphically emphasized by differential erosion. Reverse faults, overthrusts, and wrench faults, in contrast, are not inherently susceptible to such erosion, and are frequently not visible on the imagery. It is recommended that allowance for this selection effect be made in structural investigations, and especially that adequate field checking of photogeologic maps be provided for. It is further recommended that orbital radar coverage be planned with multiple look directions, and near-vertical illumination (18 to 23° look angles), to compensate for the geomorphic bias discussed here.

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# REMOTE SENSING STUDIES OF CANADIAN SHIELD TECTONICS AT THE NASA GODDARD SPACE FLIGHT CENTER \*

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Goddard Space Flight Center (Code 922)  
Greenbelt, Maryland 20771 Dec. 1990

Several research projects focussed on tectonics of the Canadian Shield have been or are being carried out at the NASA Goddard Space Flight Center, in cooperation with the Canada Centre for Remote Sensing and the Canadian Space Agency.

## Landsat Study of Regional Fracture Patterns

The regmatic shear theory, holding that the Earth's crust is broken by a relatively simple primary fracture pattern, is still a working hypothesis (Haszeldine, 1990) for localization of mineral deposits, oil and gas fields, earthquakes, and various neotectonic structures, though commonly termed "basement tectonics" in recent years. To test this theory, a GSFC group assembled sixty low sun angle Landsat MSS scenes of the Canadian Shield, including all the Stockwell provinces, and compiled lineament maps from each (Lowman et al., 1987). Lineaments were drawn on acetate overlays, using standard photogeologic techniques, and manually digitized. Histograms were then produced using an HP-3000 computer and rose diagrams drawn from these. Composite rose diagrams for the Shield are shown in Fig. 1. Limited field checking was carried out between 1984 and 1989 in Manitoba, Ontario, and Quebec. The main conclusions reached were the following.

**First**, the great majority of lineaments mapped are the geomorphic expression of **brittle fractures** forming a natural class (not a selection artifact), characterized by straightness, narrowness, length, and steep dip. Such fractures pervade the Shield, though often not shown on published maps because evidence of offset is lacking. **Second**, the great majority of these fractures are **extensional**: joint sets, zones of joints, or normal faults. In the field, most show no evidence of faulting, such as slickensides, gouge, or drag. The inferred extensional nature is conditional, in that differential erosion favors extensional fractures over compressional ones such as thrusts or wrench faults (Lowman, 1990). The Grenville and Nelson Fronts and the Kapuskasing Zone, locally mylonitic reverse faults, have no geomorphic expression in many areas because they are not picked out by erosion. A **third** conclusion is that many lineament maxima (Fig. 1) are the expression of Precambrian **diabase dyke swarms**. Many of these dykes are

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paralleled by unfilled extension fractures. It was suggested that the association of dyke swarms and extension fractures might result from formation of both over mantle plumes. In a more general paper, Lowman (1989) suggested that this association was part of the Earth's "second differentiation," an evolutionary stage common to all silicate planets.

The most general conclusion of this study was that **there is no unified Shield-wide lineament pattern, i.e., no** regmatic shear system, although in view of the possible geomorphic bias toward extensional fractures, this conclusion is a tentative one. It can be said definitely, however, that if there is a regmatic shear system, it is not what we see on the Landsat pictures.

An interesting contradiction exists between the apparent extensional origin of most visible lineaments and the compressional nature of focal mechanisms on the eastern Shield (Adams, 1990). Most earthquakes in eastern Canada appear to result from thrusts, strike-slip faults, or a combination of the two. This includes even events in the St. Lawrence Valley, structurally a rift. Furthermore, regional compression prevailed throughout the Precambrian, as shown by greenstone belt structures, the Grenville and Nelson Fronts, and the Kapuskasing Zone. Kamineni et al. (1990) have recently shown evidence for pervasive horizontal compression in the early Proterozoic. One possible explanation of the contradiction is that, as discussed above, compressional fractures are not as well expressed geomorphically as extensional ones. This implies that the visible fractures are not those responsible for earthquakes. Another possibility is that the Landsat-visible lineaments formed under tension, but are currently being reactivated under compression.

#### **SIR-B Investigation of the Canadian Shield**

A nearly-completed Canadian-American Shuttle Imaging Radar experiment carried on the 1984 41-G Shuttle mission has proven very valuable in technique development for future radar studies of Shield tectonics. Main results have been summarized in Lowman et al. (1987) and Masuoka et al. (1989). The most important implication for neotectonic studies of the Shield and similar terrain by orbital radar is that illumination azimuth biasing, already known to radar users as the "cardinal effect," is unexpectedly strong for orbital radar over areas like the Shield: heavy forest cover, low relief, and geomorphology developed by differential erosion rather than directly by tectonism. Illumination azimuth biasing is so strong over areas imaged by SIR-B that on the average **half** the structures, those parallel to the illumination direction, will be missed unless brought out by differences in roughness or dielectric constant. This finding dictates that for effective structural mapping of the Shield

by orbital radar, at least two illumination directions, as close to orthogonal as possible, are mandatory. The poor physiographic expression of major compressional features, discussed above, lends emphasis to this recommendation, which has obvious implications for the planning of future orbital radar programs such as RADARSAT.

### **C-band SLAR Study of the Sudbury Structure**

As part of the Canadian ERS-1 radar investigation, the Canada Centre for Remote Sensing has flown the Sudbury Basin with C- and X-band radar (Slaney and Misra, 1988). Two frames of this imagery have been used for a study of the original shape of the Sudbury Structure (Lowman, in press). The objectives were to evaluate simulated orbital radar over the ERS-1 test area, and to test the theory that the North Range of the Sudbury Structure is original, i.e., not the result of tectonic deformation. It is widely believed that the Structure is the result of a Proterozoic impact, but its apparent elliptical shape has been cited as an argument against impact. The outline of the South Range is clearly the result of Penokean deformation, and the C-band radar was used to test the interpretation (Rousell, 1984) that the North Range has not been similarly deformed.

The investigation showed, by use of the radar imagery for a field reconnaissance, that the outline of the North Range is in fact the original outline, not the result of tectonism. This implies an **elliptical shape for the original crater**, since a circular crater of this radius would reach impossibly far to the south (Rousell, 1984). However, it has been shown that elliptical primary impact craters are common on Mars, and at least two such craters exist on the Moon (Schiller, Messier A). The shape of the Sudbury Structure can not, therefore, be cited as evidence against impact.

The C-band SLAR images proved to be an extremely valuable aid to field work, permitting quick location of several previously unmapped lineaments that proved to be diabase dykes or extensions of known dykes. The azimuth biasing noted in orbital SAR appears negligible for airborne SAR, probably due to the higher range and azimuth resolution. It is clear that radar offers a valuable tool for studies of neotectonics on the Shield and elsewhere in Canada.

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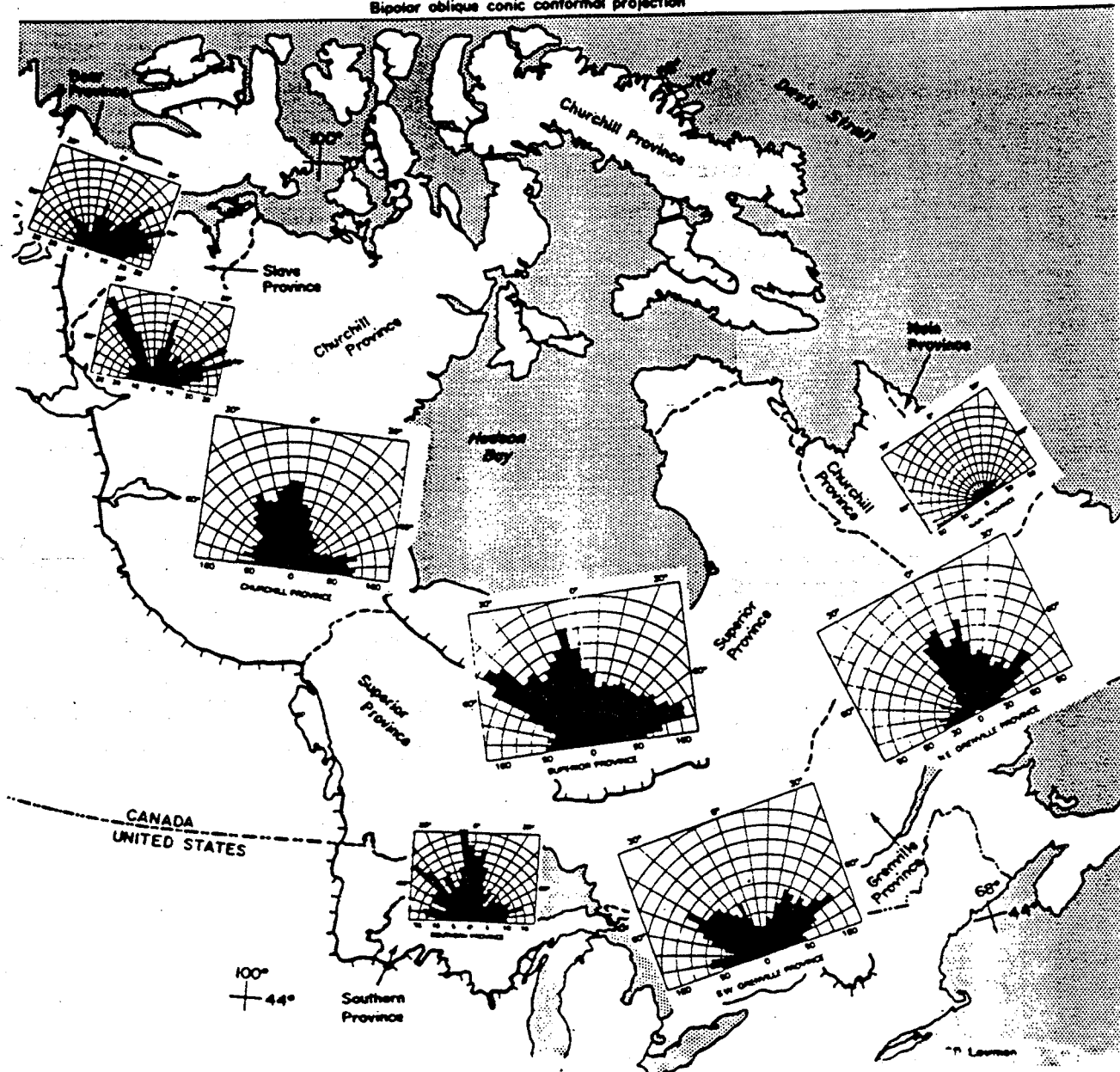
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province boundary

shield boundary

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Bipolar oblique conic conformal projection



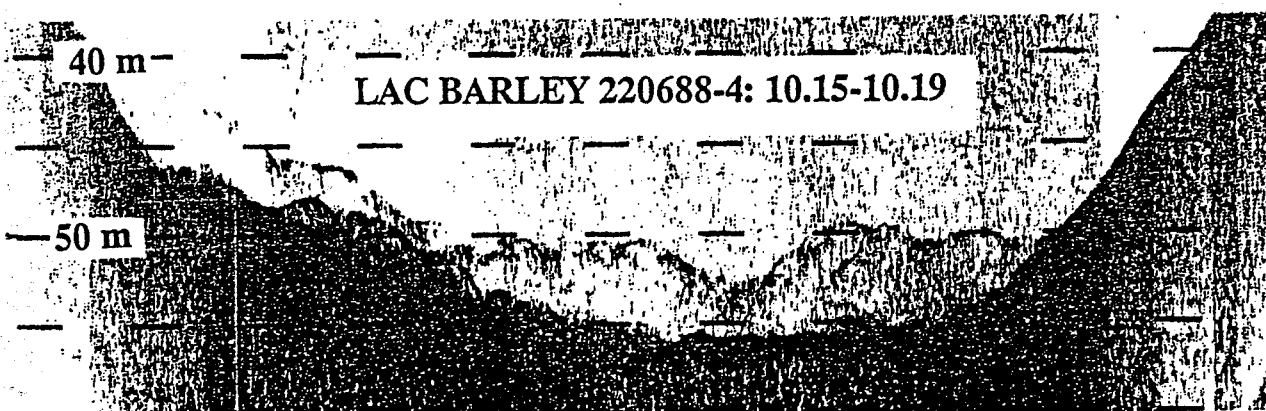
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SUB-AQUATIC SEDIMENT AVALANCHINGS IN LACUSTRINE BASINS  
OF THE CHARLEVOIX HIGHLANDS, QUEBEC

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During the summer of 1988 four head-water lakes (Barley, Des Martes, Petit Malbaie, Porc-Epic) from the Charlevoix Highlands were investigated by mean of a low frequency (3.5 kHz) subbottom profiler. In the profoundal zone of all of them a thin (<5 m) blanket of gyttja is covering the glacio-lacustrine sediments. Slumps from the steep sloping bottom giving rise to hummocky structures within the deeper zone are common in all of them. We were unable to find any evidence which might directly relate the origin of these sediment avalanchings to seismic shocks. Aseismic gravity sub-aquatic slumps initiated by currents or ground waters are also possible mechanisms which cannot be ruled out.



Representative profile of lake bottoms from the Charlevoix Highlands  
(Vertical scale = 5 m; horizontal scale = 60 m).

# Surficial Geology, Pockmarks, and Associated Neotectonic Features of Passamaquoddy Bay, New Brunswick, Canada

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Geological Survey of Canada, Open File 2213, 45 pp. June 1990

## SUMMARY

Passamaquoddy Bay is a large estuary located in southwestern New Brunswick, covering an area of approximately 575 km<sup>2</sup>. In 1988, the Atlantic Geoscience Centre and the Geophysics Division, Geological Survey of Canada, conducted a marine geological-geophysical survey in the bay and the adjacent St. Croix River (Fader, 1989). The survey was undertaken with high-resolution seismic reflection profilers, together with a 100 kHz sidescan sonar and seabed samplers. During the survey, an unexpected discovery of pockmarks and plumose structures, covering a large area of the seabed of Passamaquoddy Bay was made.

The pockmarks cover a total area of 87 km<sup>2</sup> or about 15% of the seafloor of the bay, occurring in two large areas, in the north central and southwest parts of the bay. About 1320 pockmarks, covering an area of 13 km<sup>2</sup>, were recorded during the survey by sidescan sonar. Calculations show that there are approximately 11,000 pockmarks in the bay. Five plumose structures have been interpreted on sidescan sonograms in Passamaquoddy Bay. They are 100 to 250 m long and 40 to 65 m wide, with no apparent relief on seismic reflection profiles and echograms.

Variations in the forms of the pockmarks, their distribution, and mechanisms for their formation are considered in the report. Possible relationships of both the pockmarks and the plumose structures to neotectonic features of Passamaquoddy Bay and the surrounding land and islands are discussed.

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**4. REPORTS SUBMITTED TO MAGNEC/RAPPORTS SOUMIS A L'AMNEC**

1. DEFORMED GLACIAL DEPOSITS OF PASSAMAQUODDY BAY AREA, NEW BRUNSWICK: PRODUCTS OF SEISMIC SHAKING? by Stephen Kumarapeli, Concordia University; prepared for the Directorate of Research and Safeguards, Atomic Energy Control Board, 63 pp. AECB INFO-0373 (MAGNEC Contribution 90-01).

#### ABSTRACT

The New Brunswick-Maine border area, centred around Passamaquoddy Bay, is characterized by a distinctly higher level of seismic activity compared with the very low level background activity of the region. In this same general area post-glacial deformation, including faulting, has been observed in glaciofluvial and ice contact deposits and the possibility that these structures may in some way be related to neotectonic movements in the area has been suggested. A study was undertaken to document these structures and to investigate their origin.

The studies show that structures related to collapse of sediments due to melting of buried ice masses are the most prominent post-depositional structures in the glacial sediments. A second group of structures includes failure phenomena such as slumping. These require the action of a mechanism leading to reduction of sediment strength which could be achieved by seismic shaking. However, such failure phenomena could also be brought about by non-seismic processes, thus a unique interpretation of these structures is difficult, if not impossible.

Since seismic shaking is the most effective, regionally extensive trigger of a broad group of failure phenomena in soft sediments, the related structures are usually spread over a large area, but are restricted to a very short time gap. Although the establishment of such space and time relationships may be feasible, for example in extensive lake deposits, it is difficult to do so in patchy, laterally variable deposits such as the glacial deposits in Passamaquoddy Bay area.

2. RELOCATIONS OF SEISMIC EVENTS IN WESTERN QUEBEC by A.A. Mohajer, University of Toronto and Seismican Geophysical Ltd.; prepared for the Directorate of Research and Safeguards, Atomic Energy Control Board, 17 pp. AECB INFO-393 (MAGNEC Contribution 90-02).

#### ABSTRACT

An attempt has been made to improve the seismological database by recomputing hypocentres of previous earthquakes. Original seismographic records in the Record Centre of the National Archives of Canada for the events that occurred prior to 1960 were examined. A sensitivity analysis was carried out on the basis of the new phase readings. The results show that the inaccuracies in locations of older events are related to biases in the geometrical spread of the seismographic stations and time base corrections. Consistency in phase identification has some bearing on data improvement, but it is usually masked by other sources in hypocentre computations.

A detailed study of the recomputed locations of the earthquakes in western Quebec, together with lineaments expressed geologically, geophysically and physiographically reveal several active linear features in this region. One conspicuous northwest seismic linear coincides with the Baskatong Reservoir structural lineament. Another seismic trend appears to be spatially related to the northeast-oriented, western boundary of the Central Metasedimentary Belt (CMB).

3. NEOTECTONIC INVESTIGATIONS IN SOUTHERN ONTARIO: PRINCE EDWARD COUNTY - PHASE II; by G.H. McFall and Ahmed Allam, Ontario Geological Survey, Toronto, Ontario; prepared for the Directorate of Research and Safeguards, Atomic Energy Control Board, June, 1991, 97 pp. plus Appendices AECB INFO-0343-2 (MAGNEC Contribution 90-03).

#### ABSTRACT

This report summarizes the preliminary results of geological and geophysical investigations and offshore side scan sonar surveys of the bedrock and unconsolidated sediments in Prince Edward County, southern Ontario, by the Ontario Geological Survey in 1989. Investigations were focused on deformations in the bedrock and the surficial deposits. Some of these deformations may be neotectonic in origin. Low magnitude seismicity in the Prince Edward County region appears to be spatially related to a major regional fault system that crosses Lake Ontario and consists of the seismically active Clarendon-Linden Fault System in New York State, the Picton-Napanee and Rideau Faults, the Frontenac-Sharbot Lake Terrane Boundary and the assumed Salmon River Fault in Ontario.

Detailed observations were made in the Long Point study area and the Mountain View and Picton Quarries. Bedrock structural features were documented including: joints, normal, reverse and strike-slip faults; brittle folds; and a Jurassic age ultramafic dyke.

Detailed refraction seismic surveys were conducted across a local fault and possible fold structures. Magnetic surveys, conducted in conjunction with the offshore side scan sonar surveys, documented large magnetic anomalies southeast of Point Petre and at the northeast end of Long Reach.

Side scan sonar surveys of the lake bottom to the east of Point Petre confirm the presence of pop-ups in that area of the lake bottom which is immediately adjacent to where pop-ups are observed on land. The pop-ups present in the lake bottom have similar orientations to those mapped in the study area.

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