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GEOLOGICAL-SEISMOLOGICAL EVALUATION OF EARTHQUAKE HAZARDS AT EISENHOWER AND SNELL LOCKS, SAINT LAWRENCE SEAWAY, MASSENA, NEW YORK

by

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13. ABSTRACT (Maximum 200 words)

There were no active faults either at the Eisenhower and Snell Lock sites or in the general area. The locks were determined to be in a seismic hotspot termed the Massena zone. The zone was given a floating earthquake of Modified Mercalli (MM) intensity of VIII which is the threshold of damage to properly built structures. Parameters for a Maximum Credible Earthquake (MCE) were assigned as horizontal peak motions of 0.83 g for acceleration, 35 cm/sec for velocity, and 12.4 sec for duration. The Operating Basis Earthquake (OBE) was assigned 0.46 g, 24 cm/sec, and 8.8 sec, respectively. A set of six accelerograms with response spectra was selected to be used with these parameters.

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PREFACE

The Waterways Experiment Station (WES) of US Army Corps of Engineers was authorized to conduct this investigation by the US Army Engineer District, Buffalo, on 12 February 1990 by DA Form 2544, No. NCB-DA-90-16EJ as part of the study entitled "Structural Evaluation of Eisenhower and Snell Locks, Saint Lawrence Seaway, Massena, New York." This investigation was conducted to provide the seismic ground motion parameters for the seismic analysis of Eisenhower and Snell Locks.

Dr. E. L. Krinitzsky of the Geotechnical Laboratory (GL) at WES performed the geological-seismological evaluation and wrote the report. The project was under the general direction of Dr. William F. Marcuson III, Chief, GL.

COL Larry B. Fulton, EN, was Commander and Director of WES during the preparation of this report. Dr. Robert W. Whalin was Technical Director.

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GEOLOGICAL-SEISMOLOGICAL EVALUATION OF EARTHQUAKE HAZARDS AT EISENHOWER AND SNELL LOCKS, SAINT LAWRENCE SEAWAY, MASSENA, NEW YORK

PART I: INTRODUCTION

Purpose and Scope

1. The purpose of this investigation is to evaluate the earthquake hazards at Eisenhower and Snell Locks along the Saint Lawrence Seaway and to provide time histories for earthquake ground motions that represent the cyclic shaking that would be felt in the free field on bedrock at the lock sites. Ground motions defined by this study are for use in the engineering-seismic evaluation of the respective locks.

2. This study consists of both a geological and a seismological analysis and consists of the following: (a) a geological evaluation of fault activity at the sites and in the region, (b) a seismological appraisal of the historic seismicity in the region, (c) an interpretation of seismic source areas and maximum earthquakes with their prospects for recurrence, and (d) attenuated peak ground motions at the sites with time histories for analogous cyclic shaking. The ground motions that are specified are in accordance with the requirements mandated by ER 1110-2-1806 of 16 May 1983.

Study Area

3. The areas covered by this study are the sites of the Eisenhower and Snell locks near Massena, New York, and the general region including the St. Lawrence Valley which has been a source of major historic earthquakes.

4. Figure 1 shows the locations of the Eisenhower and Snell Locks on the Long Sault Canal. These locks were formerly called the Robinson Bay and Grass River locks, respectively. The Long Sault Canal, and its locks, was built to permit navigation to bypass a series of dams and powerhouses on the St. Lawrence River by providing a route below them between the power pool upstream and the St. Lawrence downstream over a total elevation change of 82 ft.

PART II: GEOLOGY AND TECTONICS

5. The Eisenhower and Snell lock chambers are founded on bedrock. Soil cover was excavated to provide the sites. The geologic setting and its associated tectonism can be described as follows.

Stratigraphy

6. The stratigraphy in the study area is shown in Table 1. The valley of the St. Lawrence River contains alluvial deposits in the form of bedded, discontinuous layers of clays and sands. Additionally, there are glacial tills that are heterogenous in composition with stiff clays, sands and an abundance of boulders. Together these comprise Quaternary deposition that lies unconformably over Ordovician and Cambrian rocks. The extent of the latter deposits is shown in Figure 2 taken from Isachsen and Fisher (1970). The thicknesses of these deposits in the Massena area are shown in Table 1 based on the determinations by Berkey (1945) from borings made during the exploration stage for the Long Sault Canal. These rocks are predominantly bluish gray, massive, crystalline limestones and dolomites with intervals of thick to thin sandstones and thin shale partings in sections of the carbonate rocks. The rock floor for both the Eisenhower and Snell locks is the Chazy formation.

7. Further descriptive information on the stratigraphy and tectonism in the study area is contained in Appendix A by Patrick J. Barosh. Figure A9 presents Berkey's (1945) stratigraphic column for the Massena area.

Structure

8. Figure 2 shows Ordovician and older rocks as forming a large gentle syncline. Its axis parallels the St. Lawrence Valley. Berkey (1945) determined from borings that these beds in the Massena area lie almost horizontal, with a gentle dip that is in a westerly direction. Berkey noted also from a line of borings made along the length of the Long Sault canal that though these beds are generally uniform in their bedding and are only very gently deformed into a dipping syncline, they are also warped locally in places and

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have been broken and displaced along fault zones that contain gouges of crushed rock resulting from the fault movements.

9. The geologic sections presented by Berkey (1945) show no faulting at the site of Eisenhower lock (Robinson Bay lock on Berkey's drawing) but there is a pronounced vertical fault zone at approximately the site of the Snell lock (shown as Grass River lock). Berkey examined the borings in which he encountered the crushed zone at the Grass River site. He summarized that the fault movement is ancient, in origin, probably associated with the early uplift of these rocks during past geologic time. He observed that the fault movement is certainly pre-glacial in age since there was no evidence of displacement at the base of the glacial deposits. On the other hand the planes of movement have not been subsequently recemented. Such evidence suggests that deformation has occurred at various times in the past including possible movements in recent pre-glacial time.

10. Whether or not the fault identified above can be the locus of current earthquakes is a question that cannot be answered from the current evidence, however, that possibly exists.

11. An examination was made at WES, for this study, of photographs of the foundation excavations at Eisenhower and Snell locks. The photographs showed no presence of fault planes and no fault gouge in the bedrock over which the locks were built. Additionally, there was no evidence seen in airphotos of active faults breaking the surface anywhere either in the vicinities of the locks or in the region. We must assume that earthquakes which have occurred in the Massena area have done so with no manifestation in the surficial geology.

PART III: SEISMICITY

12. Figure Al shows the distribution of felt earthquakes in northeast-
ern United States and adjacent parts of Canada. Massena lies in a belt of
diffuse earthquakes that trend northwest to southeast in a broad zone.
Massena also lies in the trend of another belt of earthquakes that extends
along the St. Lawrence valley from northeast to southwest. The earthquakes in
the St. Lawrence trend are found in groups that are both denser than those of
the NW-SE trend and are less continuous.

13. Barosh in Appendix A shows that the above trends are evident in the
regional structure based chiefly on mapped and inferred faults and including
the trend of the St. Lawrence valley itself. However, there is only a diffuse
relationship between the structural grain in this region and the occurrences
of earthquakes. In this region, earthquakes can be inferred to result from
one or more of the following possible causes:

    a. Focusing of regional compressive stresses along the boundaries
        of heterogeneous rock masses and release of these stresses by
        movement through reactivation of ancient faults.

    b. Possible small-scale introduction of magma at depth with an
        accompanying buildup of stresses.

    c. Focusing and release of regional stresses along ancient rifts
        which remain as zones of crustal weakness.

    d. Slow, very broad regional compression causing reactivation of
        ancient thrust faults in the region.

    e. Extensional movement along a sagging graben with activation of
        normal faults.

14. There is no way that all of these theories can apply everywhere
since the extensional and the compressional postulations contradict each
other. Also, each of these theories can be interpreted as meaning that a
major earthquake can happen at a location where no historic earthquake has
occurred. That idea, though reasonable on the face of it, must be handled
with care because it can mean that large earthquakes will happen almost every-
where in this region and that is not what we observe elsewhere in the world.

15. Appendix B contains a review of the seismicity made by Martin
Chapman of the Seismological Observatory at Virginia Polytechnic Institute and
State University. Definitions of earthquake terminology are contained in
Appendix C.

16. Massena and Cornwall experienced an appreciable earthquake on
4 September 1944. About 90 percent of the chimneys were damaged or destroyed
and other noncritical damage was extensive. The quake was felt northeast to
Maine, west to Michigan and extended over nearly all of Maryland and
Pennsylvania. Chapman shows the Massena earthquake as M - 5.8 in the Electric
Power Research Institute Catalogue and an M - 5.0 by Ebel et al. (1986).
Chapman's Figure B7, based on an interpretation by Schlesinger-Miller et al.
(1983) gives the Massena event a maximum Modified Mercalli (MM) intensity of
VII. Barosh, in Figure A5, assigns an intensity of MM VIII. MM VIII,
described in Appendix C, represents the threshold of damage in properly built
structures. Though serious damage was not experienced, the extremely wide-
spread occurrence of minor damage is the basis for MM VIII. MM VIII had pre-
viously been assigned in an isoseismal map (Figure A3) by Bodle in 1941 and
(Figure A4) by Milne in a map of 1949.

Seismic Source Zones and Maximum Earthquakes

17. A seismic source zone is an inclusive area over which an earthquake
of a given maximum size can occur anywhere. That earthquake is a floating
earthquake. A seismic zone is supplemental to and can include faults that are
the sources of earthquakes. The purpose of such zones is to avoid surprises.
The zones are essential in areas such as eastern United States where earth-
quakes take place but the causative faults cannot be recognized.

18. The seismic zone as constructed in this report represents present-
day tectonism. These are zones that are not determined by tectonic and phys-
iographic provinces or regional geologic structure since those are products of
past tectonism. The seismic source zone is definable by what we know of his-
toric earthquakes and by present-day seismicity in the form of microearth-
quakes that are recorded by instrumental arrays.

19. Criteria for developing zonations are:

   a. Zones that have great activity should be as small as possible.
       They are likely to be caused by a definite structure, such as a
       fault zone or a pluton, and activity should be limited to that
       structural association. Such a source may be a seismic
       hotspot. A seismic hotspot requires locally large historic
       earthquakes, frequent to continuous microearthquakes and a well
       defined area. Maps of residual values for magnetometer and
       Bouguer gravity surveys may provide structural information to
       corroborate the boundaries of hotspots.

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      b. One earthquake can adjust a boundary to a seismic zone but cannot create a zone.

      c. The maximum felt earthquake is equal to or less than the maximum zone earthquake.

      d. The maximum zone earthquake is a floating earthquake, one that can be moved anywhere in that zone.

      e. Assignment of the maximum zone earthquake is judgmental.

20. Figure 3 shows seismic zones with Modified Mercalli intensity values for maximum floating earthquakes. These are zones for eastern United States.

21. Note that Massena is shown as a small zone with a maximum potential of MM VIII. This zone lies along a trend where Niagara-Attica to the southwest has a MM VIII and to the northeast there is Montreal with MM VIII and La Malbaie-Charlevoix with X. The Massena potential is exceeded in eastern United States only by the New Madrid, Anna, Giles County, Charleston and Cape Ann sources.

22. Barosh in Figure A25 provides an independent seismic zonation in which he relates seismicity to geology and structure. Essentially Barosh indicates an MM VIII at Massena within a relatively small source area similar to the interpretation in Figure 3.

23. Figure 3 shows that earthquakes from other source zones that would be felt at Massena can be represented by the Montreal zone, MM VIII at a distance of about 80 km, and La Malbaie-Charlevoix, MM X at 380 km. Using intensity attenuations for eastern United States published by Chandra (1979), the Montreal source would be reduced by two intensity units to MM VI at Massena; and the La Malbaie-Charlevoix source would be reduced four units to MM VI at Massena. An intensity of MM VI, as noted in Appendix C, represents a few instances of fallen plaster or damaged chimneys. The damage is slight, barely with cosmetic effects. Thus it was not judged necessary to require that a distant earthquake be tested for at the Massena sites.

24. Thus it was determined that the Massena sites should be tested for the effects of an earthquake occurring in the immediate vicinity and having a damage potential of MM VIII.

Recurrence of Earthquakes

25. Mitronovas (1982) made a study of recurrences of earthquakes in New York State. The areas that he selected are shown in Figure 4. Note that Massena is located in Area B. Figure 5 shows recurrence progressions that Mitronovas developed for the above areas. The linear trends in Figure 5 were obtained by plotting for each area the intensities versus cumulative numbers of earthquakes per 100 years that were as large as and smaller than a given intensity. The resulting trends are guides to the mean recurrence intervals for earthquakes of given intensities.

26. The results from the Mitronovas study are also presented in Table 2. Area B, where Massena is located, has an observed recurrence of an MM VIII earthquake once every 112 years and a calculated probability that at least one event greater than MM VIII should have occurred during the past 250 years. The latter determination is part of the conception in probability theory that no earthquake is the largest but that earthquakes of all sizes can happen everywhere given sufficient time, as is shown in Table 2. This concept of increasingly larger potential earthquakes is not accepted in this report. It is a judgmental matter that MM VIII is the largest earthquake that can reasonably be expected at Massena.

27. The analysis in Appendix B includes the Massena sites in an area termed the Adirondack Mountain-Western Quebec Zone. Recurrences for earthquakes are given for this zone. MM VIII for a shallow earthquake can be placed conservatively between M - 5.5 to 6.0, for which the recurrence is once every 65 to 130 years. Chapman, in Appendix B, projects to 1,000 years following the practice in probabilistic analyses and suggests that M - 6.8 would be conservative for the life of a structure.

28. The problem with probability theory is that it provides no cutoff, yet in areas of the world with 2,000 to 3,000 years of historic record such cutoffs are an essential and universal part of the experience. Nor do our engineering structures have a life that is 1,000 years, rather it is more on the order of 100 to 150 years. The postulated earthquakes also would occur anywhere within the large areas that were selected for calculation rather than specifically for a particular engineering site.

29. Thus both the Mitronovas and the Chapman estimates for MM VIII carry enormous uncertainties for application in Massena. The Massena hotspot

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itself may not have recurrence attributes resembling those found in the much larger areas that were used for calculations. However, to perform a recurrence analysis solely for the hotspot at Massena is not feasible because there is an insufficiency of data. Mitronovas (1982) shows that for all of New York State there were 335 known felt earthquakes between 1721 and 1980, but that number shrinks between 1721 and 1920 to 59, and from 1721 to 1840 to only 15. In the Massena hotspot, the earliest record of an earthquake is in 1867, cf Stover et al. (1987).

30. The above interpretations suggest that it is a very conservative assumption that an MM VIII earthquake might occur at Massena once in a century and this occurrence would be also once in the life of each of the respective structures.

PART IV: EARTHQUAKE GROUND MOTIONS

Maximum Credible Earthquake (MCE)

31. The Maximum Credible Earthquake (MCE) is defined as the largest earthquake that can reasonably be expected. The largest earthquake interpreted for the Eisenhower-Snell sites is an earthquake originating within the Massena seismic source shown in Figures 3 and A25. The largest earthquake in this source is MM VIII. Ground motions originating from source areas other than Massena would either have earthquakes no stronger than Massena or they would be attenuated to a level at which they could do no damage to the locks. Thus an earthquake from La Malbaie-Charlevoix with MM X at the source would be attenuated to MM VI at Massena. MM VI poses no possibility of damage to the locks since its characteristics are seen only as minor cracks in plaster and corresponding cosmetic effects. Those effects would be registered on soft ground, not on the massive limestones of Ordovician age on which the locks are built. Additionally, there is no evidence of displacements by faulting beneath the locks. Though faults exist in the vicinity, the absence of faults beneath the lock structures precludes there being permanent displacement from earthquake-related movements. Also, where the faults were encountered, there was no evidence of geologically recent movement.

32. Thus, the MCE is taken to be a floating earthquake at the sites, with MM VIII for rock, and with no expectation of fault displacement beneath the structures. In order to encompass the considerable dispersion that occurs in ground motion data, the motions for the MCE are taken at mean plus S.D.

Operating Basis Earthquake (OBE)

33. The Operating Basis Earthquake (OCE) is an earthquake that allows damage, providing there is no hazard to human life, and permits the structure to remain operational with repairs. Further, it is an earthquake that is expected to occur during the life of the structure. The life of the structure for purposes of this report is taken at 100 years. The recurrence of the MCE, to the best of our knowledge, is somewhere on the order of 100 years. Thus the earthquakes for the OBE and MCE are the same. However, since the OBE is

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less critical than the MCE, the motions for the OBE can be taken as the mean of the dispersion in the data.

Field Conditions

34. Ground motions from an earthquake source using MM intensity are characterized as being either <u>near field</u> or <u>far field</u>. Ground motions are different for each field type. Near field motions, those originating near the earthquake source, are characterized by a large dispersion in the peak ground motions which are caused by complicated reflection and refraction patterns, focusing effects of the waves, impedance mismatches and resonance effects. In contrast, the wave patterns for far field motions are more orderly and they are more muted or dampened so that they are better predictable.

35. The limits of the near field are variable, depending on the severity of the earthquakes. The relationship between earthquake magnitude (M), epicentral intensity, and the limits of the near field are given in the following set of relations (from Krinitzsky and Chang 1987).

Near Field Limits

M	MM Maximum Intensity, Io	Distance from Source, km
5.0	VI	5
5.5	VII	15
6.0	VIII	25
6.5	IX	35
7.0	X	40
7.5	XI	45

36. Near field conditions are specified only when the site of interest is located within or near a seismic hotspot. The Massena source qualifies as a seismic hotspot since it is a pocket of relatively move severe and more concentrated seismicity than what is generally found in the region. The Eisenhower and Snell sites are located within the Massena hotspot.

Recommended Peak Motions

37. The parameters for earthquake motions specified in this report are those for peak horizontal acceleration, velocity, and duration. Duration is the time interval in which the ground motion is equal to or above 0.05 g. Values that are specified are for free-field motions on rock (hard site) at the surface and for shallow earthquakes, those with focal depths above 20 km.

38. The ground motion parameters are determined from the Krinitzsky-Chang (1987) intensity curves. The near field curves for acceleration, velocity, and duration are presented in Figures 6, 7, and 8. Values in the charts are specified for the mean and mean plus one standard deviation. The values in these charts are derived from a world-wide data base of ground motions and represent the statistical levels for the spread in motions for the different intensity levels (Krinitzsky and Chang 1987). Also shown on the charts are catalogue numbers and peak motions for six recommended accelerograms and response spectra. Table 3 lists these records along with the corresponding peak motions on the Krinitzsky-Chang curves for MM VIII, and the correction, or scaling factor, for adjusting the record to the curves. The curves are presented as mean and mean plus on S.D. Also, shown are the magnitudes and focal depths of the respective earthquake records.

39. The recommended MM VIII motions in Table 3 and Figures 6 to 14 are for the MCE. The same motions are appropriate for an OBE. Alternatively, the OBE can be adjusted to a lower value as needed on the basis of an engineering decision. For the Massena area, the MCE is recommended at the mean + standard deviation and the OBE at the mean.

40. The records presented in Table 3 are not the only records that may be used. Other records can be fitted to the given parameters. The accelerograms should be for analogous conditions, such as size of earthquake, focal depth (whether shallow or deep), distance from source, site condition, etc. Differences between peak values of an accelerogram and those selected parameters are accommodated by changing the scale of the accelerogram for motions other than duration. To adjust duration, parts of the accelerogram must be repeated or removed. The caution is to avoid scaling changes that are greater than two times since larger changes will affect the spectral composition.

Comparison with Other Assigned Motions

41. The nearest nuclear power plants, James A. Fitzpatrick and Nine Mile Point, located on the shores of Lake Ontario, are 200 km distant from the Massena area. They also are in a comparatively aseismic area in which the maximum intensity is MM VI compared with MM VIII at Massena. Thus design values for nuclear power plants in the region are not relevant for comparison with structures in the Massena area.

42. A comparison can be made with motions that were assigned by Weston Geophysical Corporation (1987) for the Long Sault Dike. Their site on the dike is about two miles from the Eisenhower Lock and their motions are presented in Table 4. The m_b of 5.8 represents the Massena earthquake of 1944 and that event determined the MCE. Table 5 shows motions used in this report.

43. The Weston motions were developed in combination with synthetic accelerograms generated by the SIMQKE, Simulation of Earthquake Ground Motions, computer program by Gasparini et al. (1976). The accelerograms are synthesized by combining sinusoidal motions with pseudo-random phase angles, and by adjusting the resulting trace by a user specified function that represents the changes in ground motion with time. The resulting values for parameters as shown in Table 4 are not directly comparable with the parameters. for this study in Table 5. The frequency bands differ. Those in this study include more of the high frequency components of motion that occur in actual records. As a consequence, the horizontal peak accelerations are much higher than Weston though the energy levels involved may not be greater.

PART V: CONCLUSIONS

44.   A seismic zone was designated for the Massena area, in which the Eisenhower and Snell Locks are located, based on the geology and seismic history.   A floating earthquake of MM VIII was assigned to this zone.   No evidence of faults was found at the lock sites nor were there any active faults that can be related to the floating earthquake.   It was also determined that there are no distant sources of earthquakes that would introduce significant ground motions at the sites.

45.   Though the rhythm of recurrence for maximum earthquakes at the sites is uncertain, there is a possibility that the maximum earthquake of MM VIII could recur in 100 years, which is within the life of the structure. Thus the MM VIII earthquake is both a maximum credible earthquake (MCE) and an operating basis earthquake (OBE).   Motions for the MCE were taken at the mean + standard deviation on the Krinitzsky-Chang (1987) charts of horizontal ground motions versus MM intensity, and motions for the OBE were taken at the mean.   The resulting parameters for peak motions are those found in Table 5.

46.   A group of six analogous strong motion accelerograms and their response spectra were selected for the above parameters of horizontal ground motion.   If vertical motions are desired, they may be taken as two-thirds of the horizontal.

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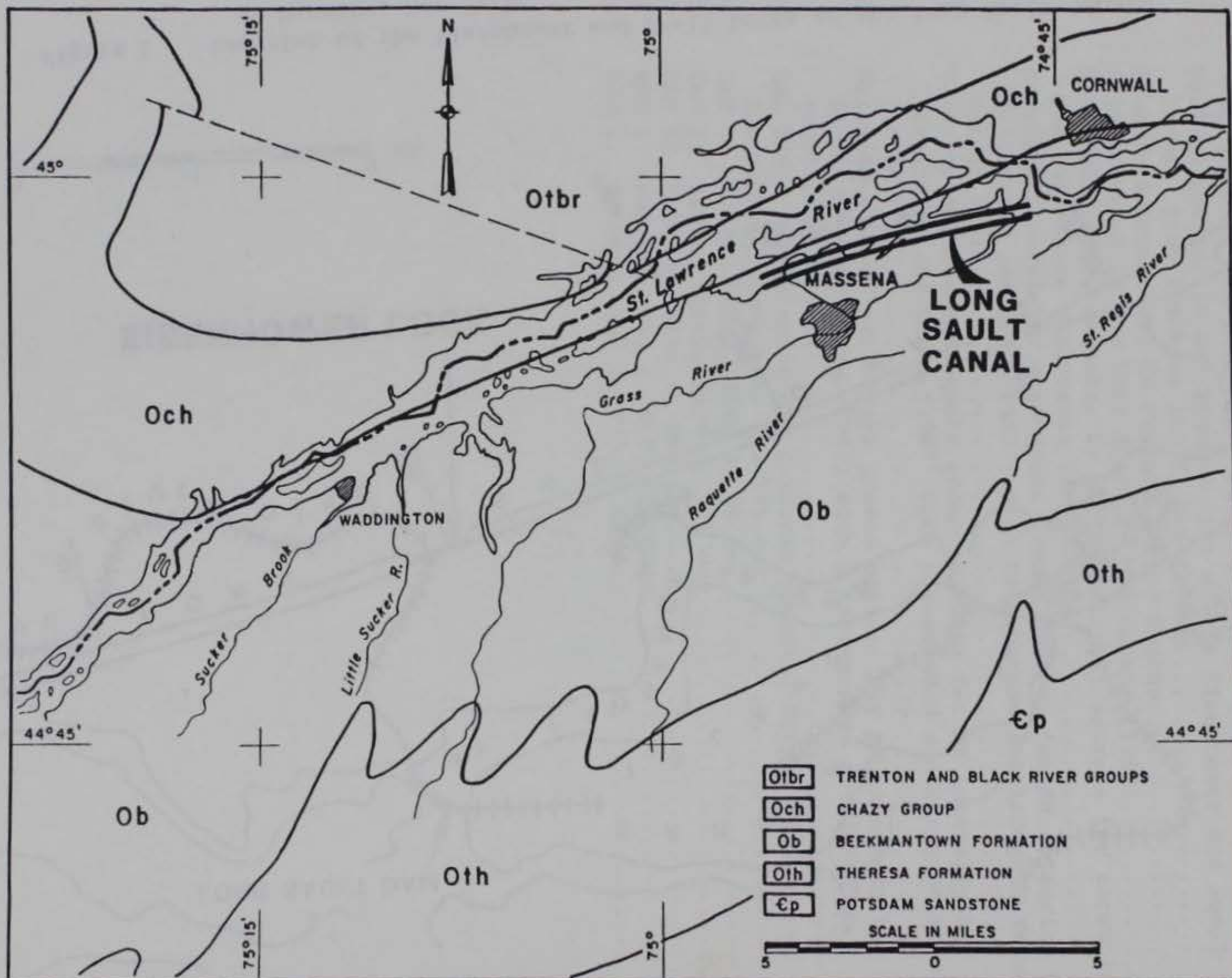
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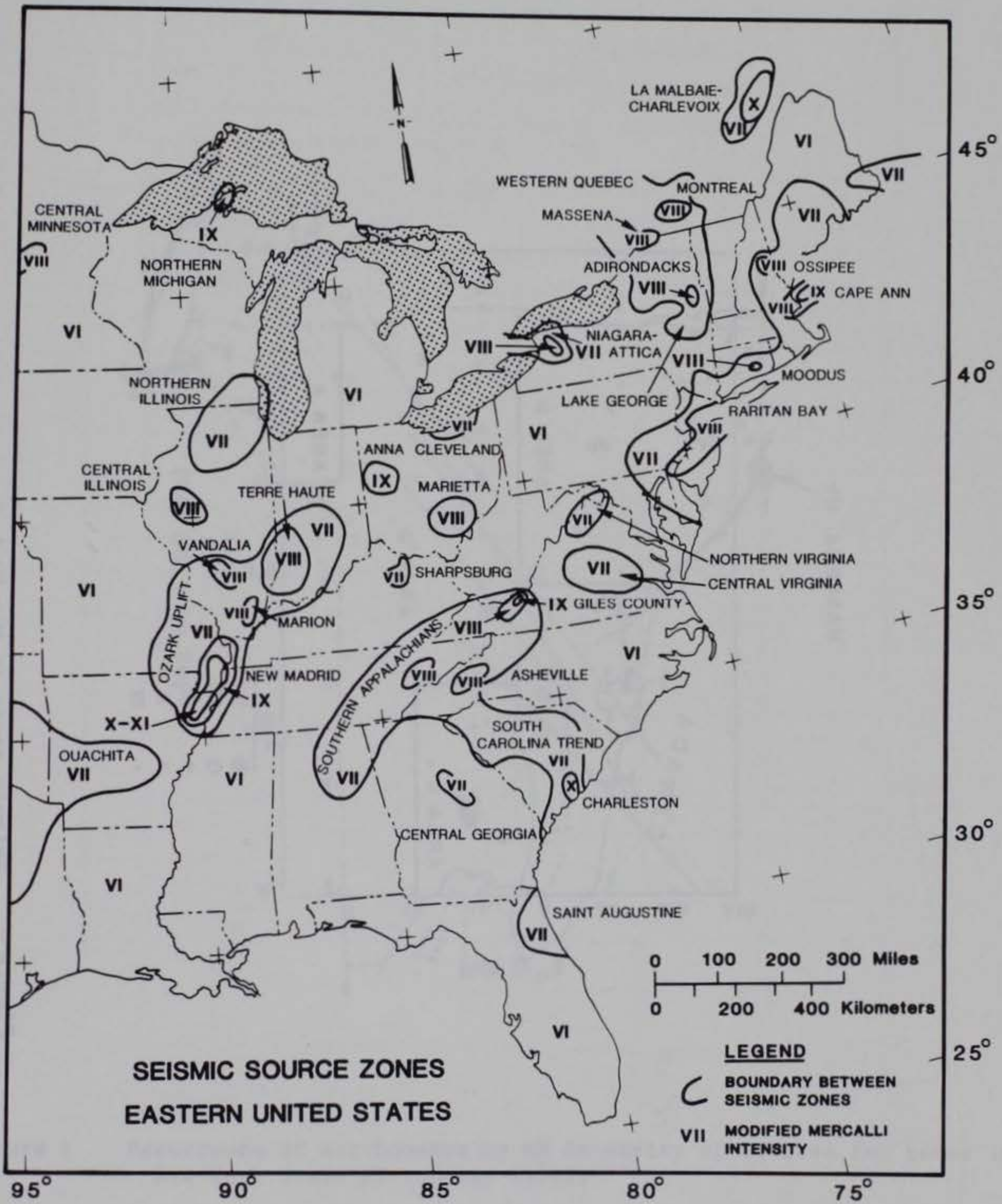
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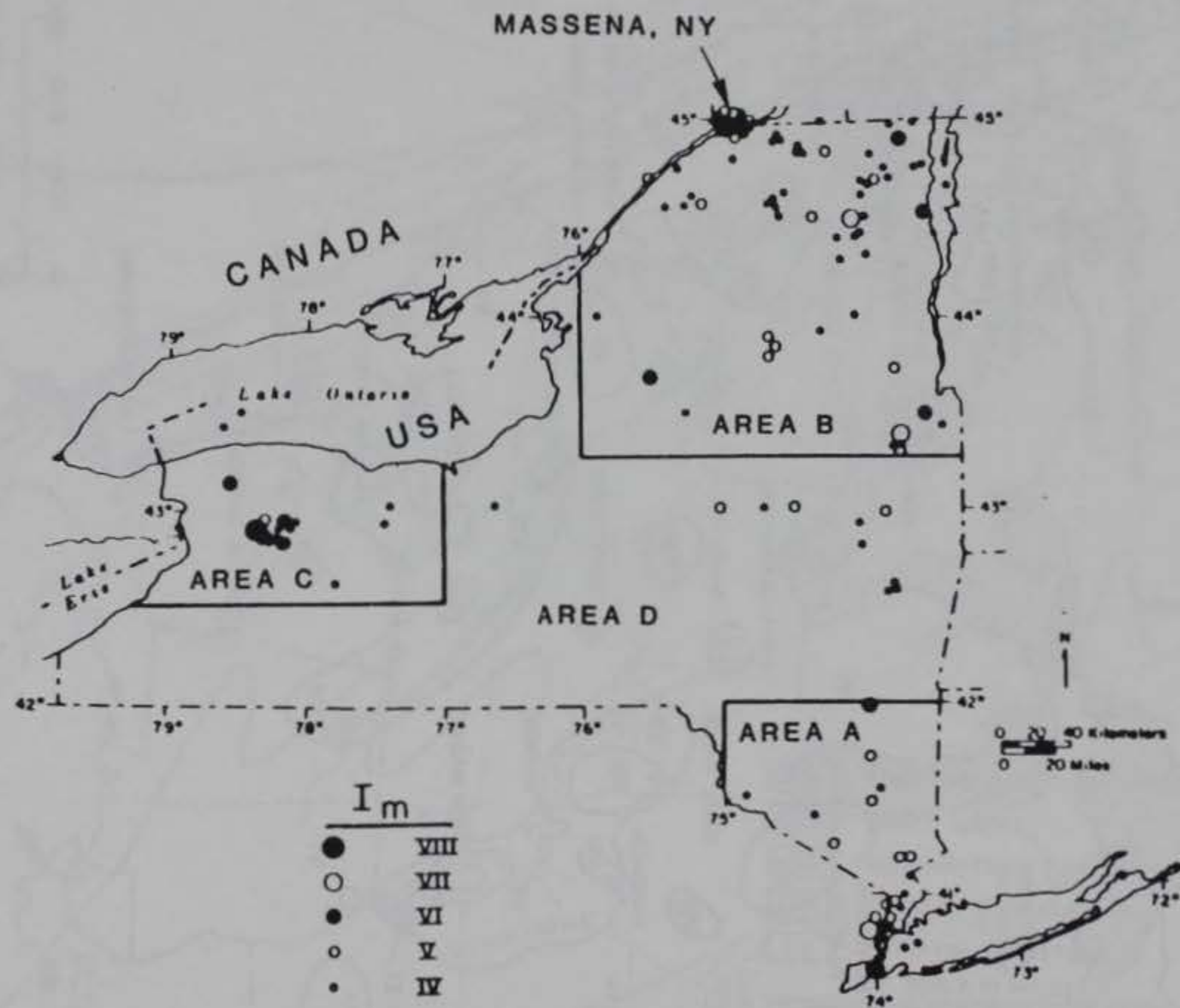
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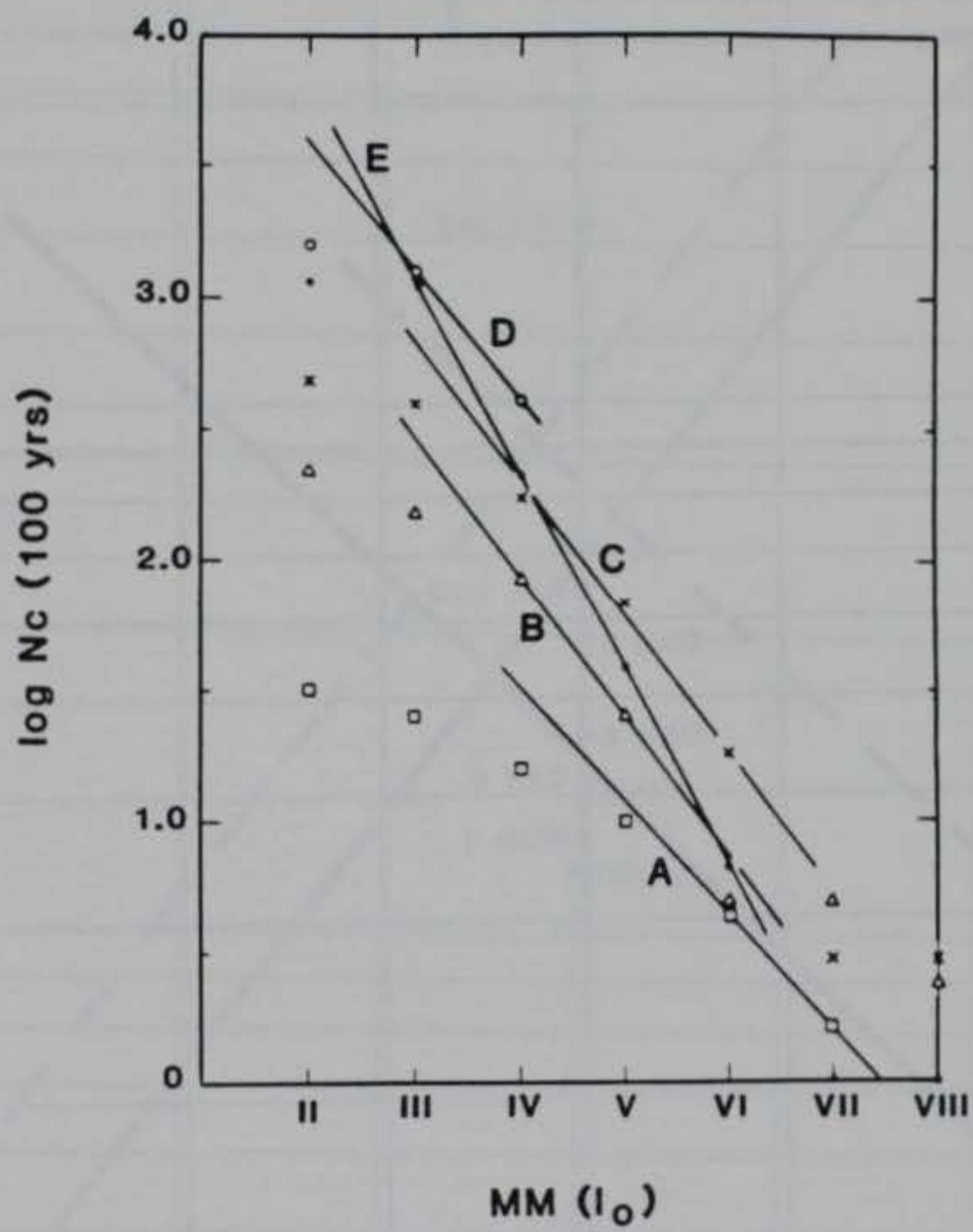
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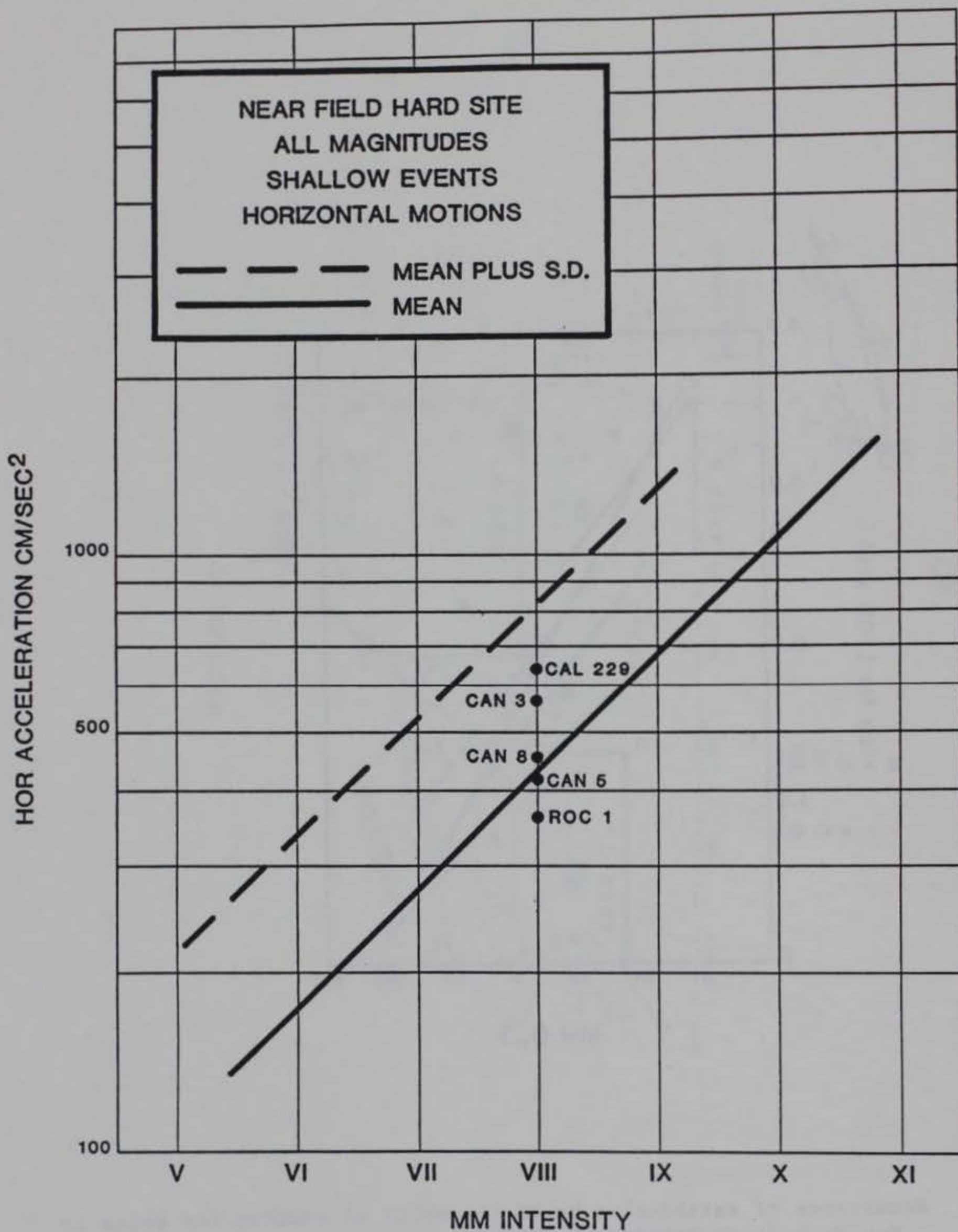
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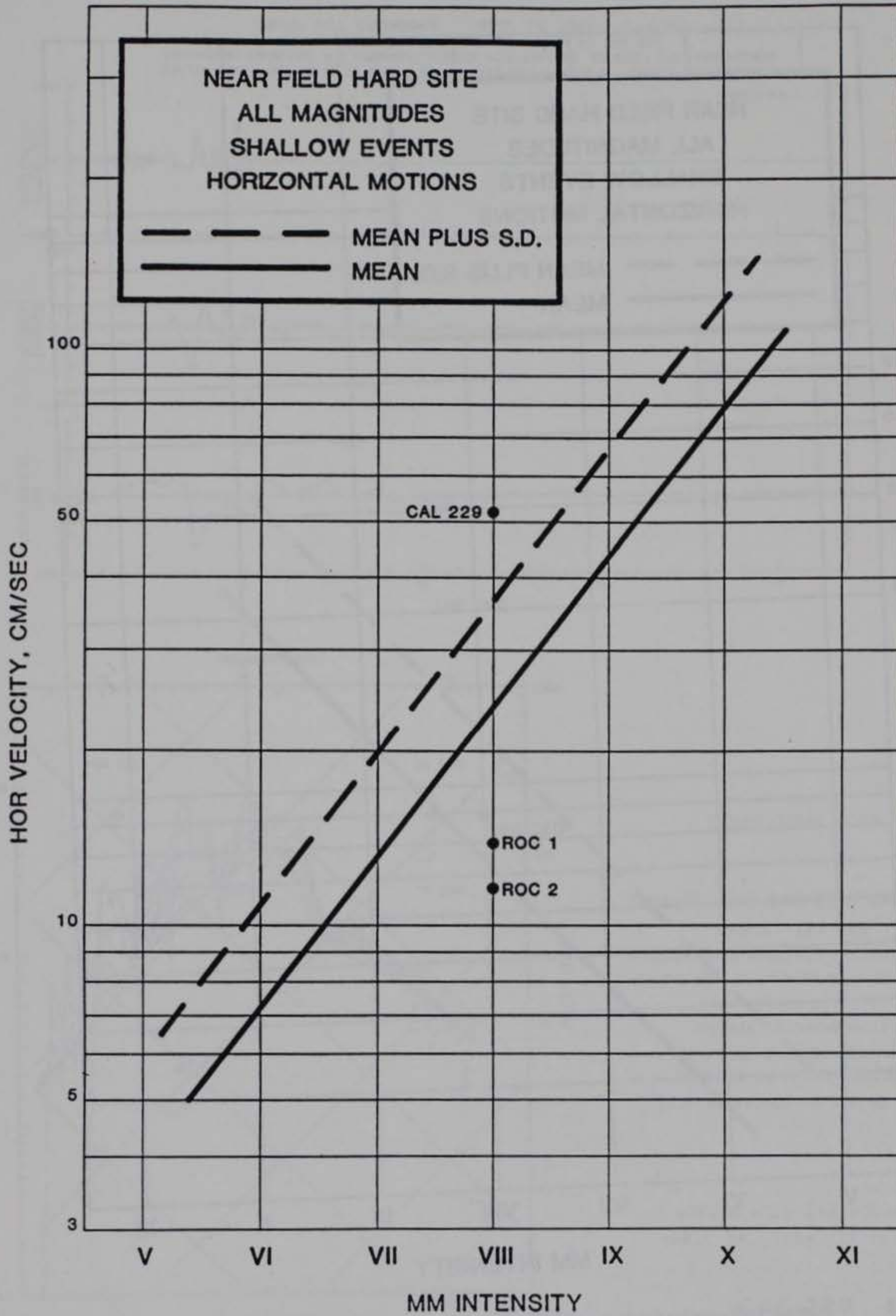
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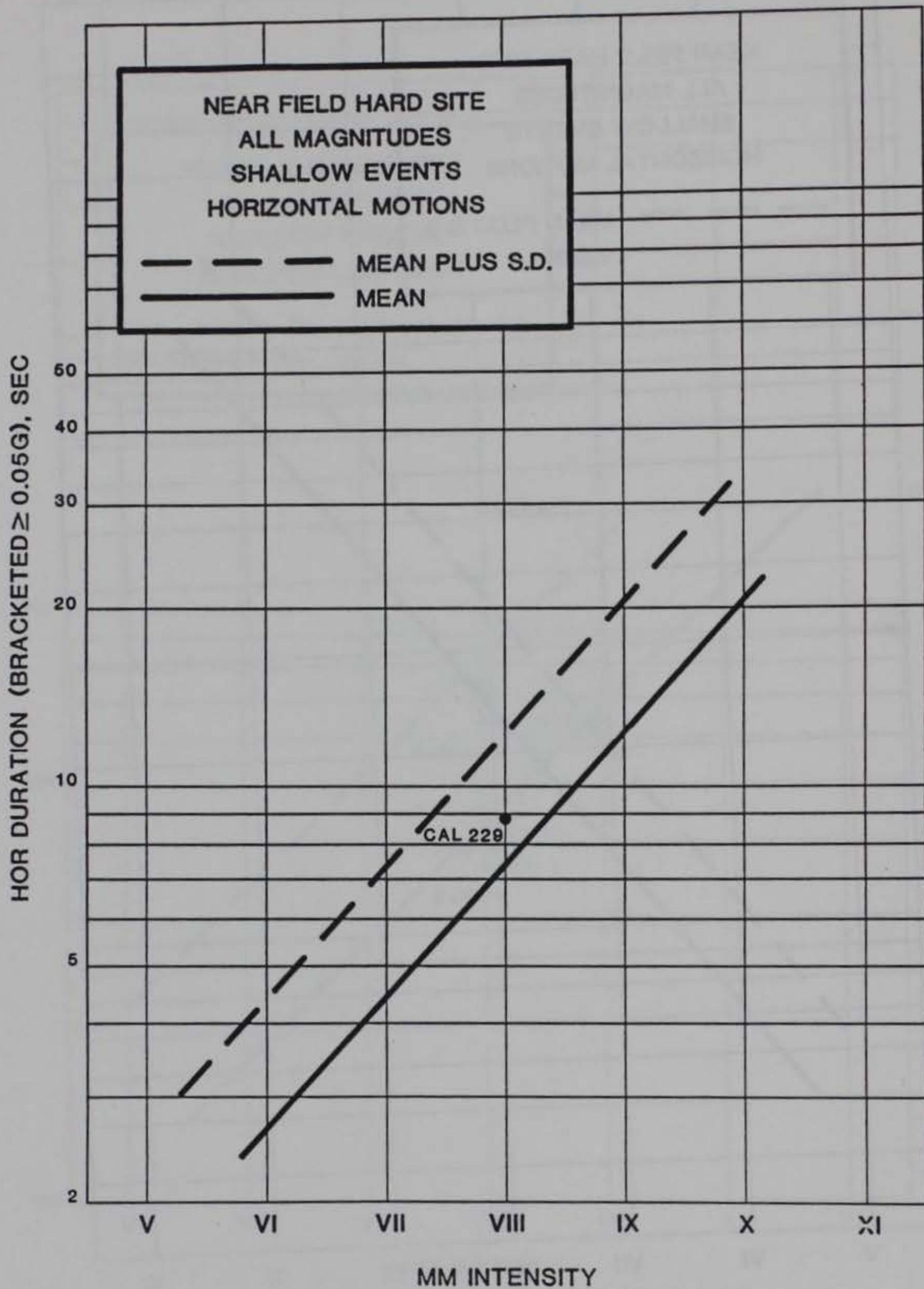
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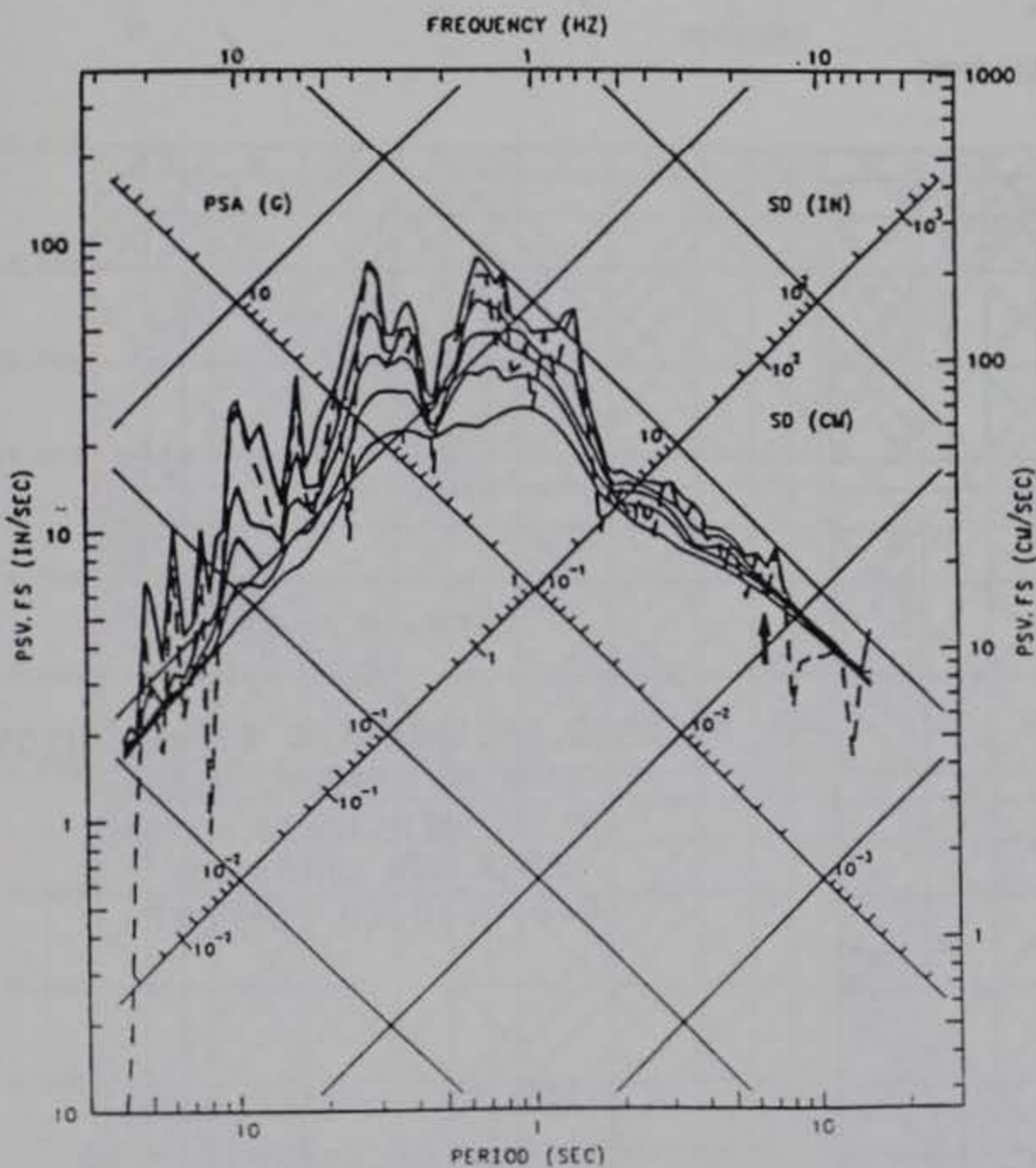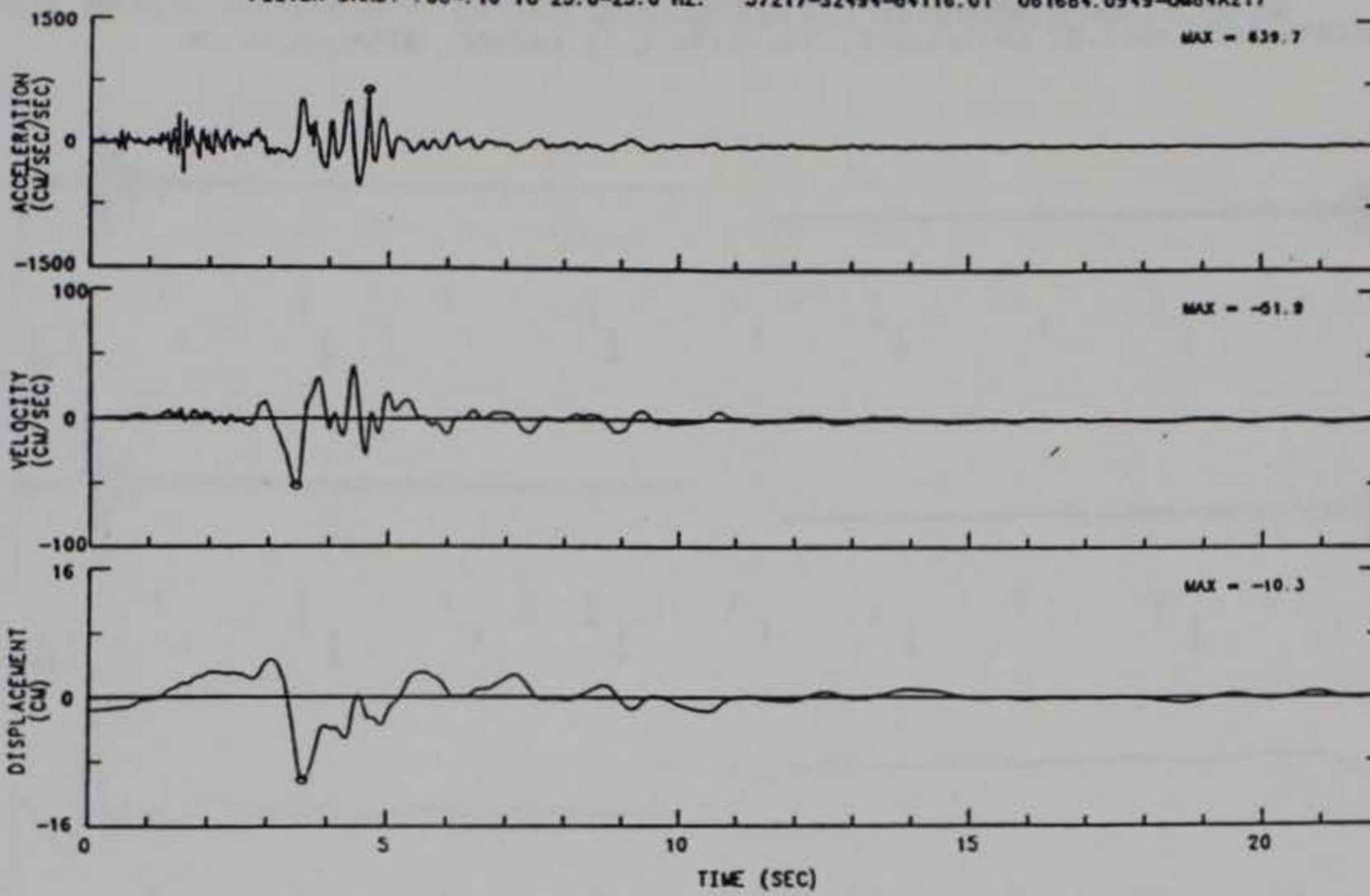
Figure 9   CAL 229:   Accelerogram and response spectra, Morgan Hill
            Earthquake, Coyote Lake Dam, 195 deg

Figure 10   CAN 3:   Loggie Lodge, Site 3, 99 deg

CORRECTED ACCELERATION, VELOCITY, AND DISPLACEMENT, 200 PPS
SITE 4: INDIAN BROOK
321 DEGREES
EARTHQUAKE OF MARCH 31, 1982 - 2102:20UTC
BUTTERWORTH AT 1.0 HZ, ORDER = 4
PEAK VALUES: ACCEL=416.75 CM/SEC/SEC, VELOCITY=2.72 CM/SEC, DISPL=0.06 CM

SECONDS

VELOCITY RESPONSE-CM/SEC

UNDAMPED NATURAL PERIOD-SECONDS
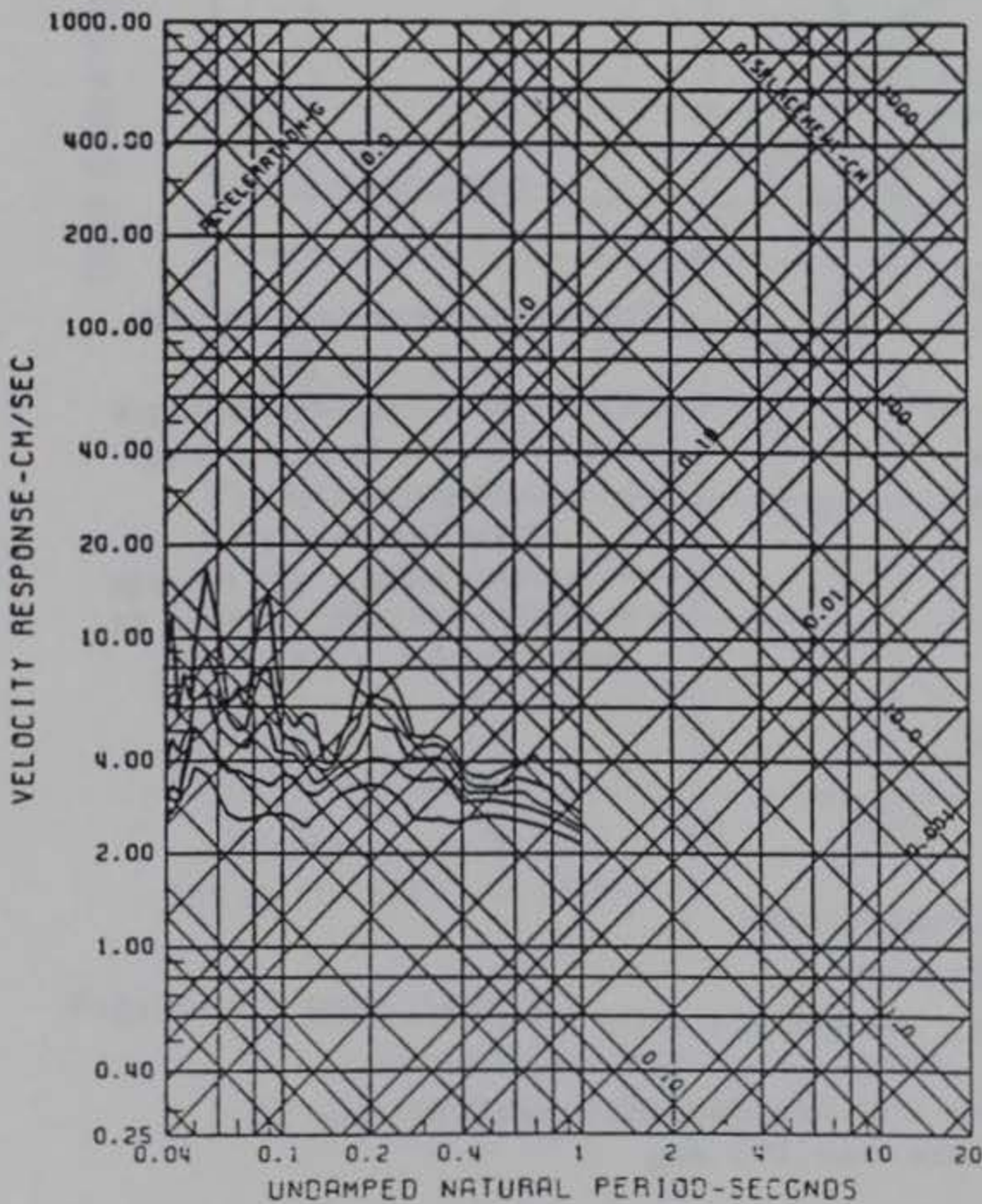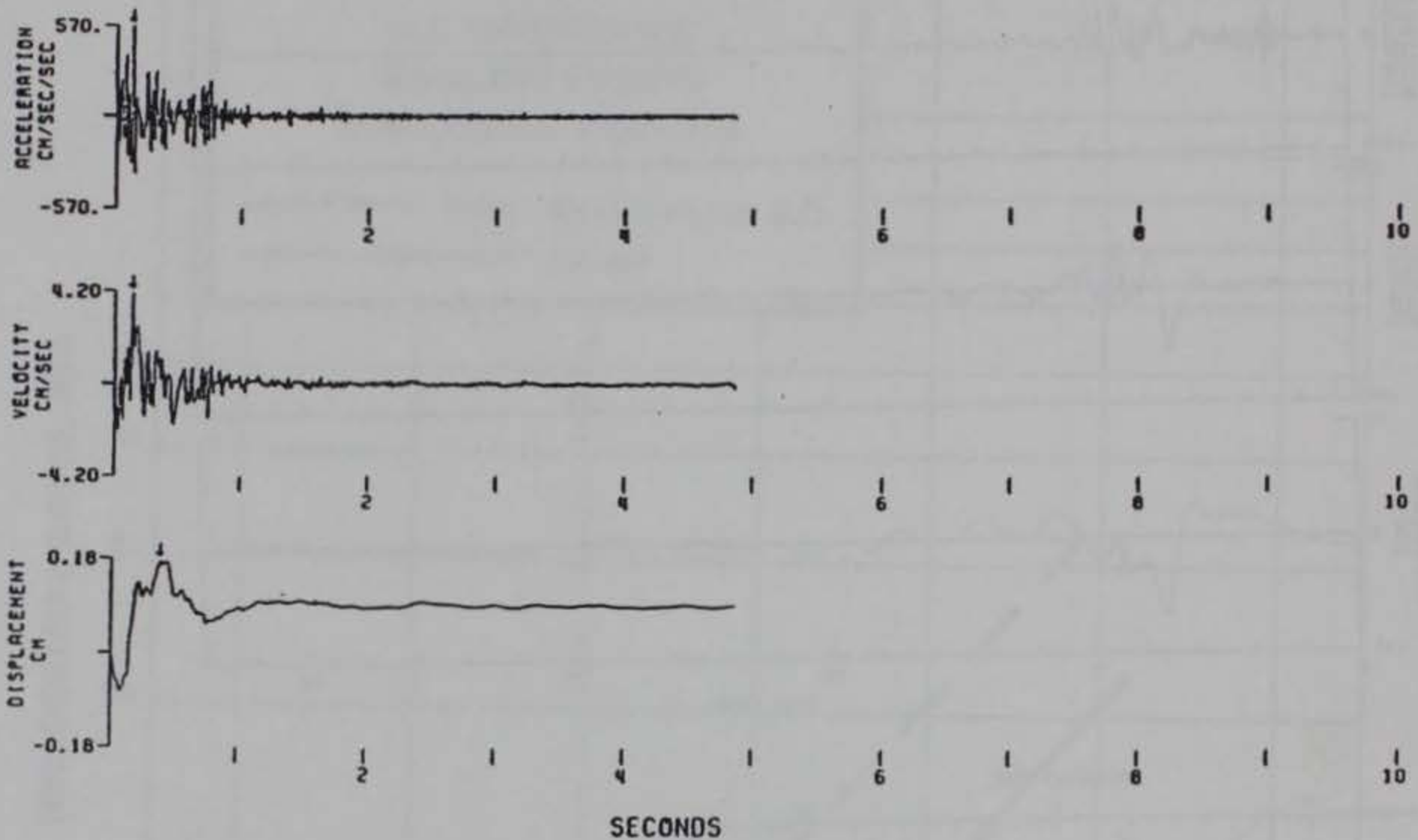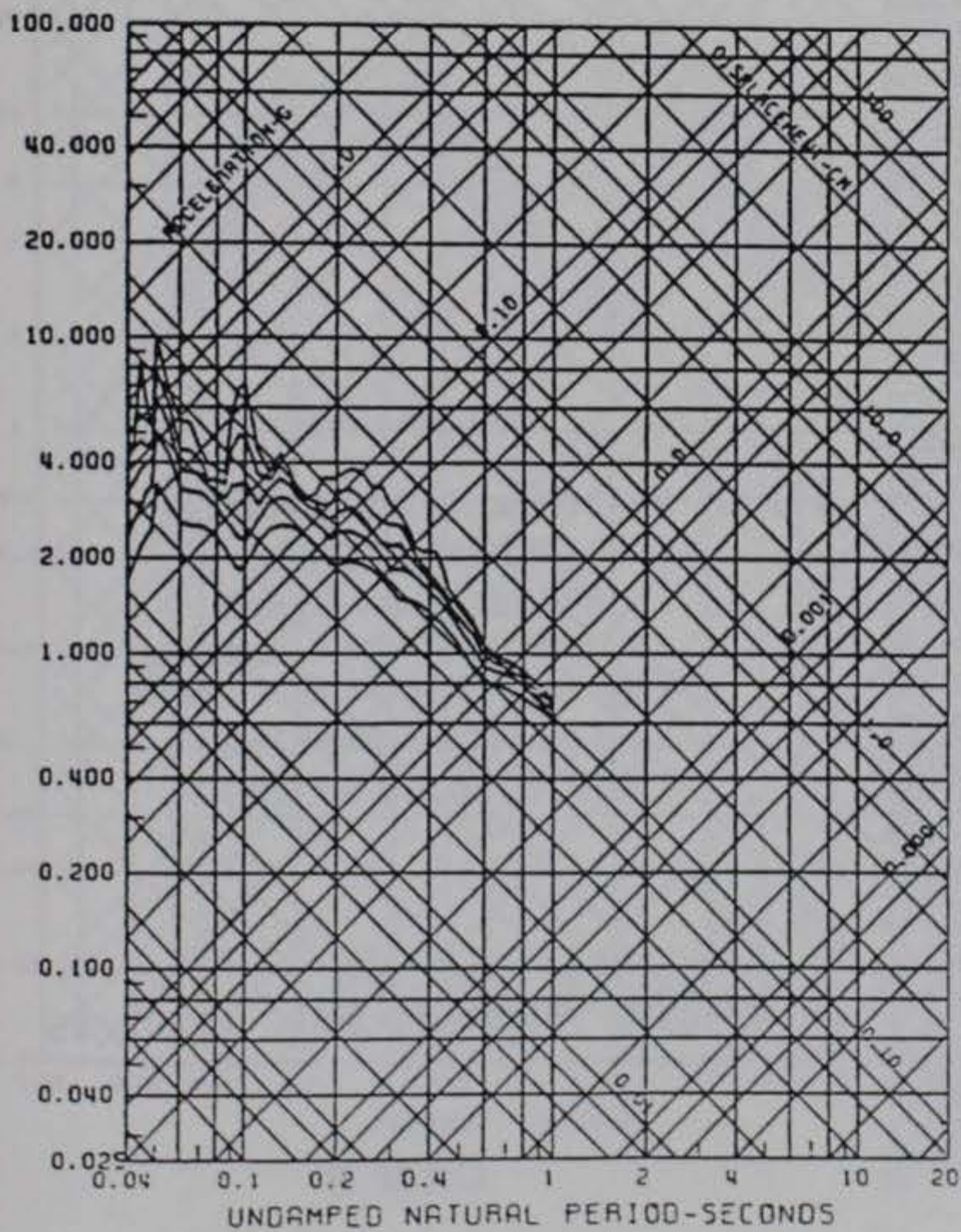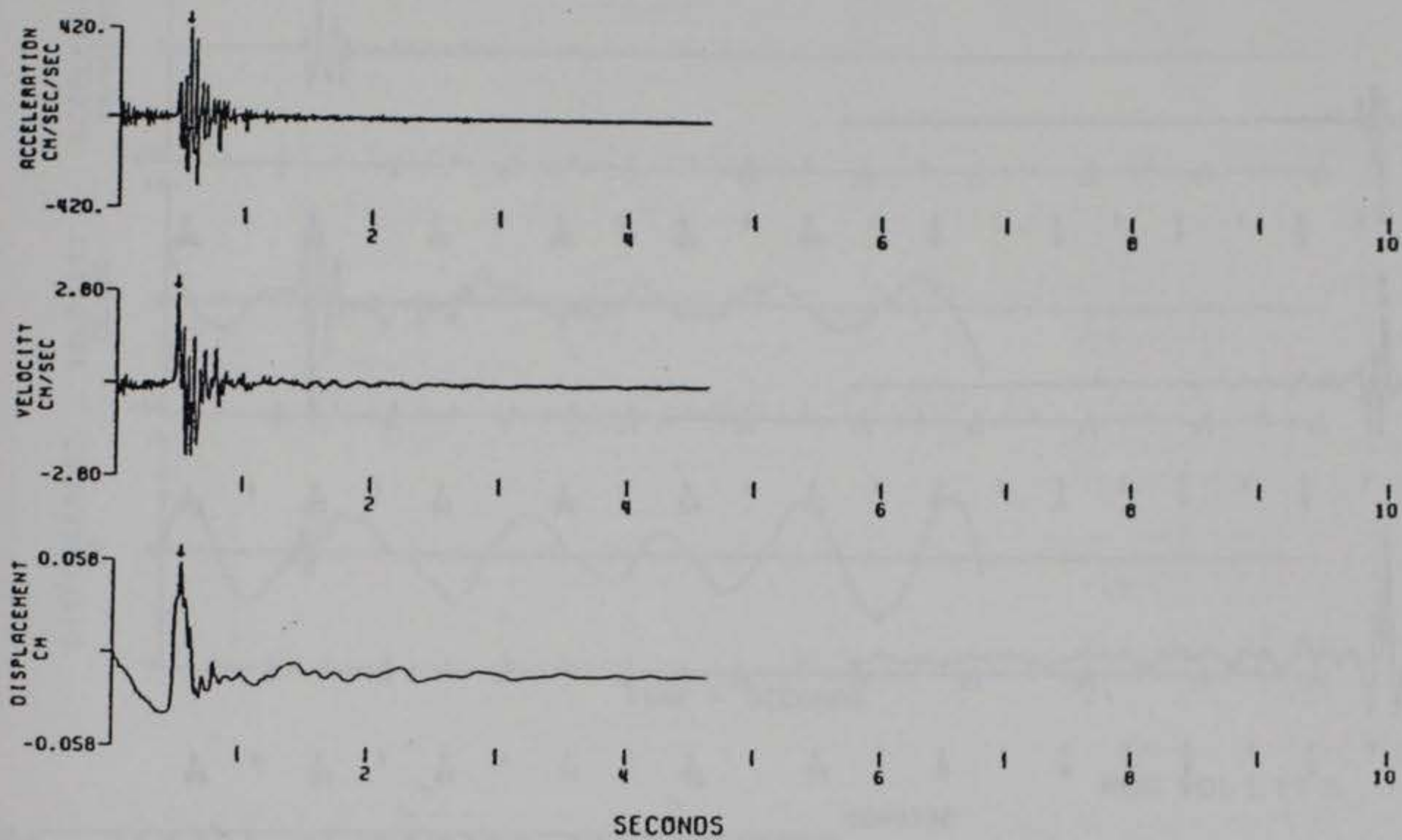
EPB OF 82-31

SEISMIC ENGINEERING BRANCH/USGS
FILTERS: BUTTERWORTH, ORDER 4,
1.000 HZ: ANTIALIAS 50 - 100 HZ
CRITICAL DAMPING
0,2,5,10,20 PERCENT

SITE 4: INDIAN BROOK
3/31/82, 21 2:20UTC 321

CAN 5

Figure 11   CAN 5:   Indian Brook, Site 4, 321 deg

CORRECTED ACCELERATION, VELOCITY, AND DISPLACEMENT 200.00 SPS
SITE 2, NAHANNI, NWT
240 DEGREES
EARTHQUAKE OF NOVEMBER 9, 1985 - 0446 GMT
BUTTERWORTH AT .50 HZ, ORDER 4
PEAK VALUES: ACCEL=-450.96 CM/SEC/SEC, VELOCITY=5.86 CM/SEC, DISPL=0.19 CM
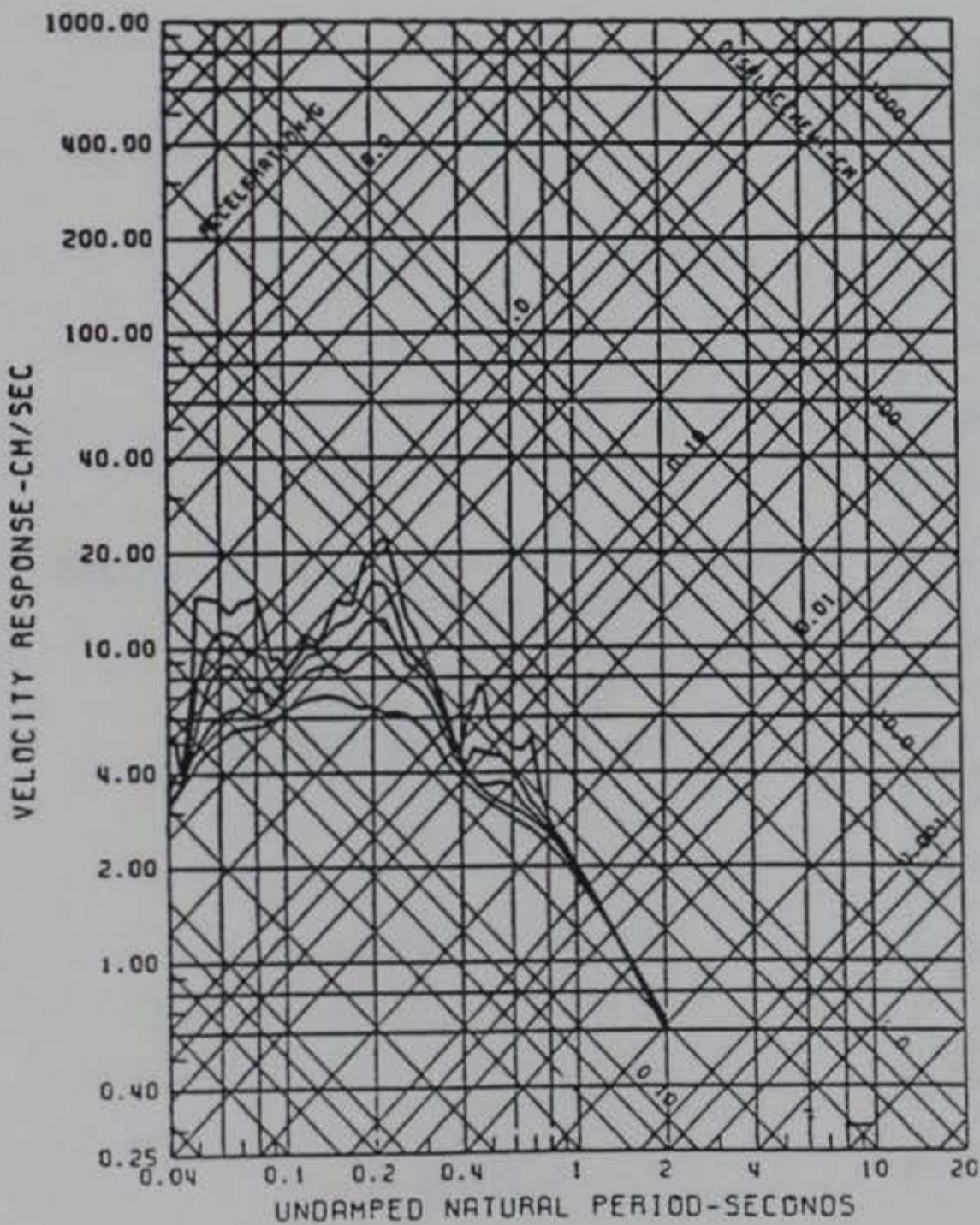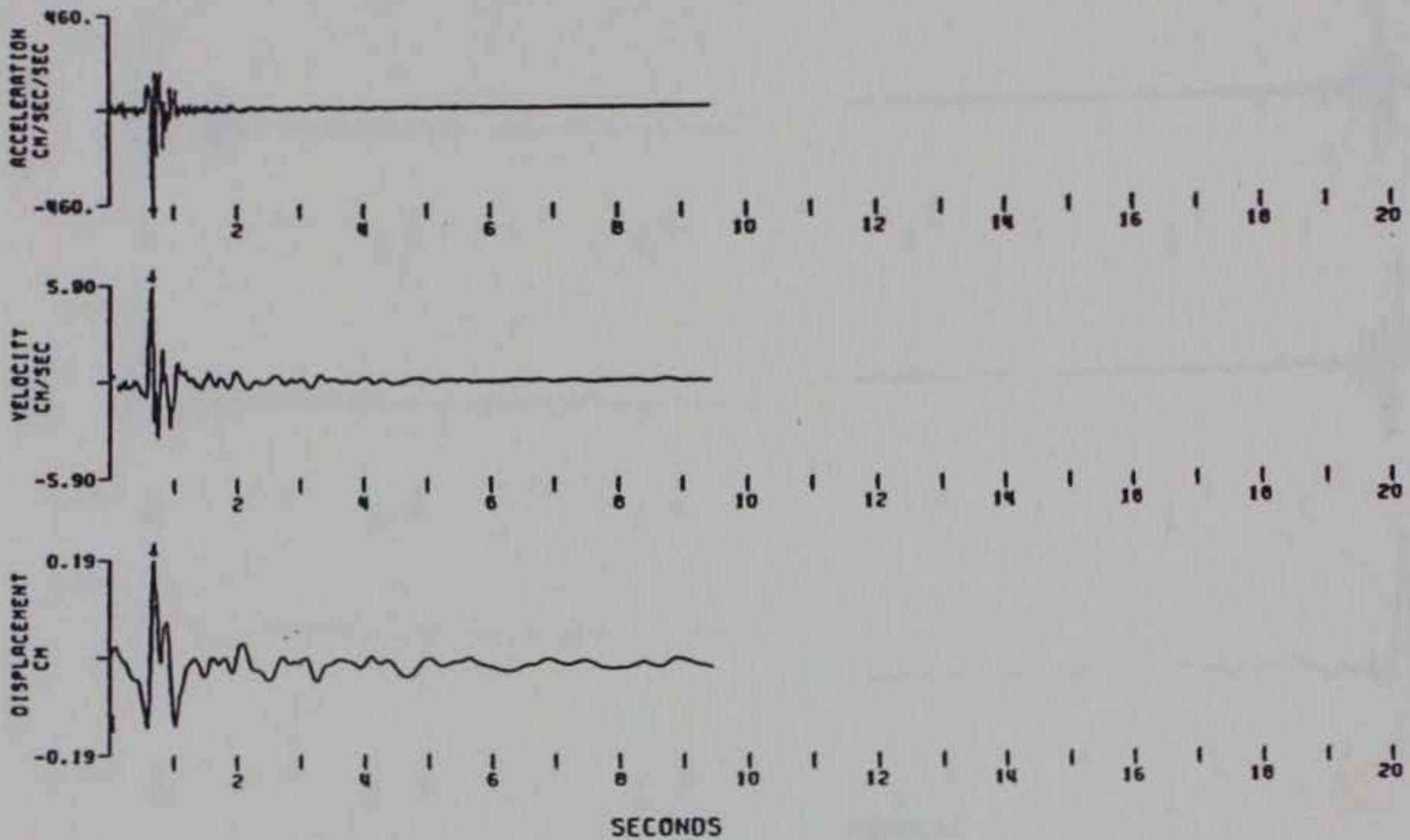
OFR-86-1-PGC

NATIONAL STRONG MOTION
DATA CENTER
0446UTC 240 DEGREES
FILTERS: BUTTERWORTH, ORDER 4
0.500 HZ: ANTIALIAS 50 - 100 HZ
CRITICAL DAMPING
0.2.5.10.20 PERCENT

SITE 2, NAHANNI, NWT, 11/09/85

CAN 8

Figure 12   CAN 8:   Nahanni, Site 2, 240 deg

EARTHQUAKE OF APL 14.1976 - 1400 GMT
TQ760414-026 WANCHIU   COMP N90W
PEAK VALUES ACLN= 360.2 CM/SEC/SEC VELO=13.8 CM/SEC DISP=2.1 CM
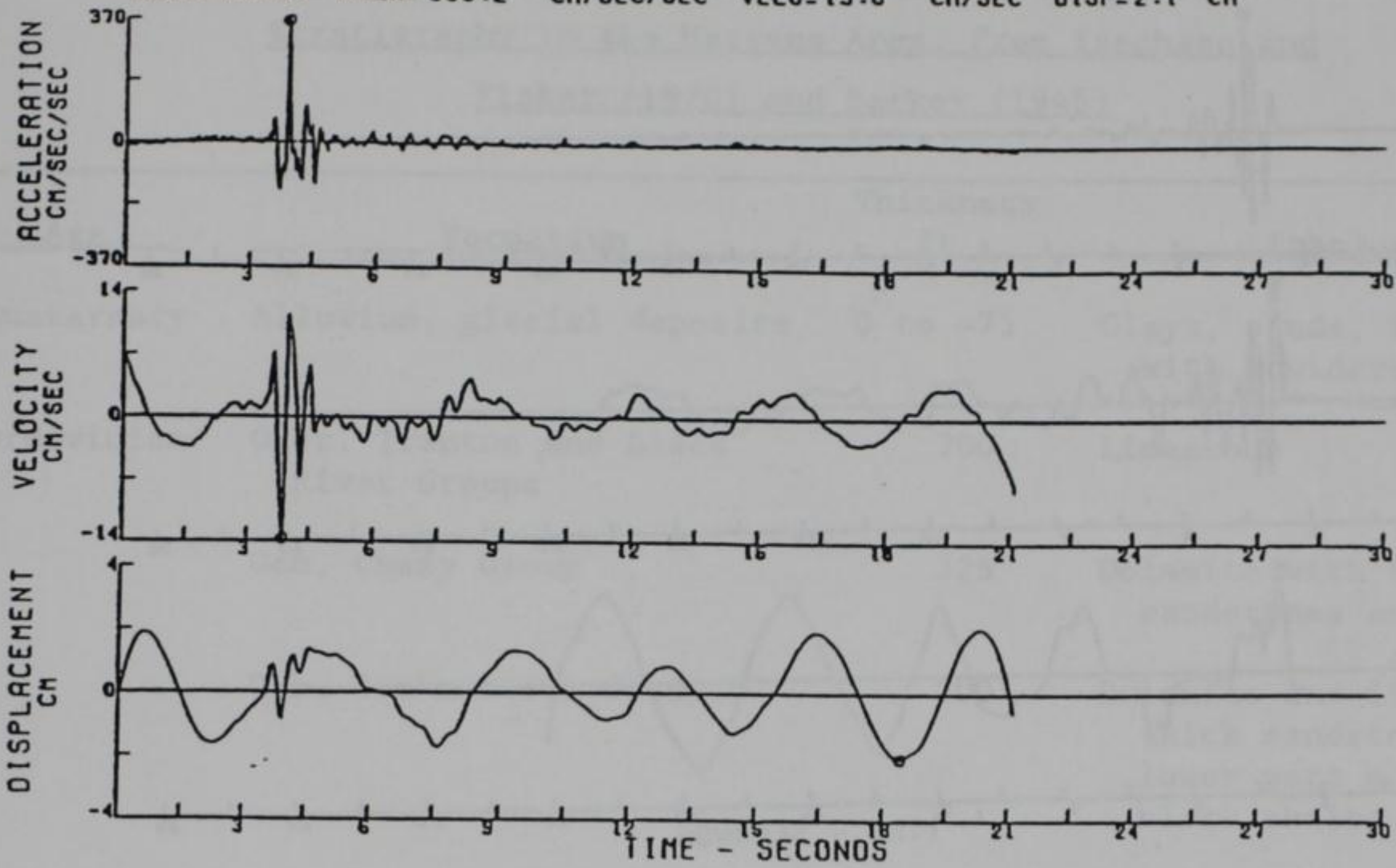
ROC VOL I, PT B
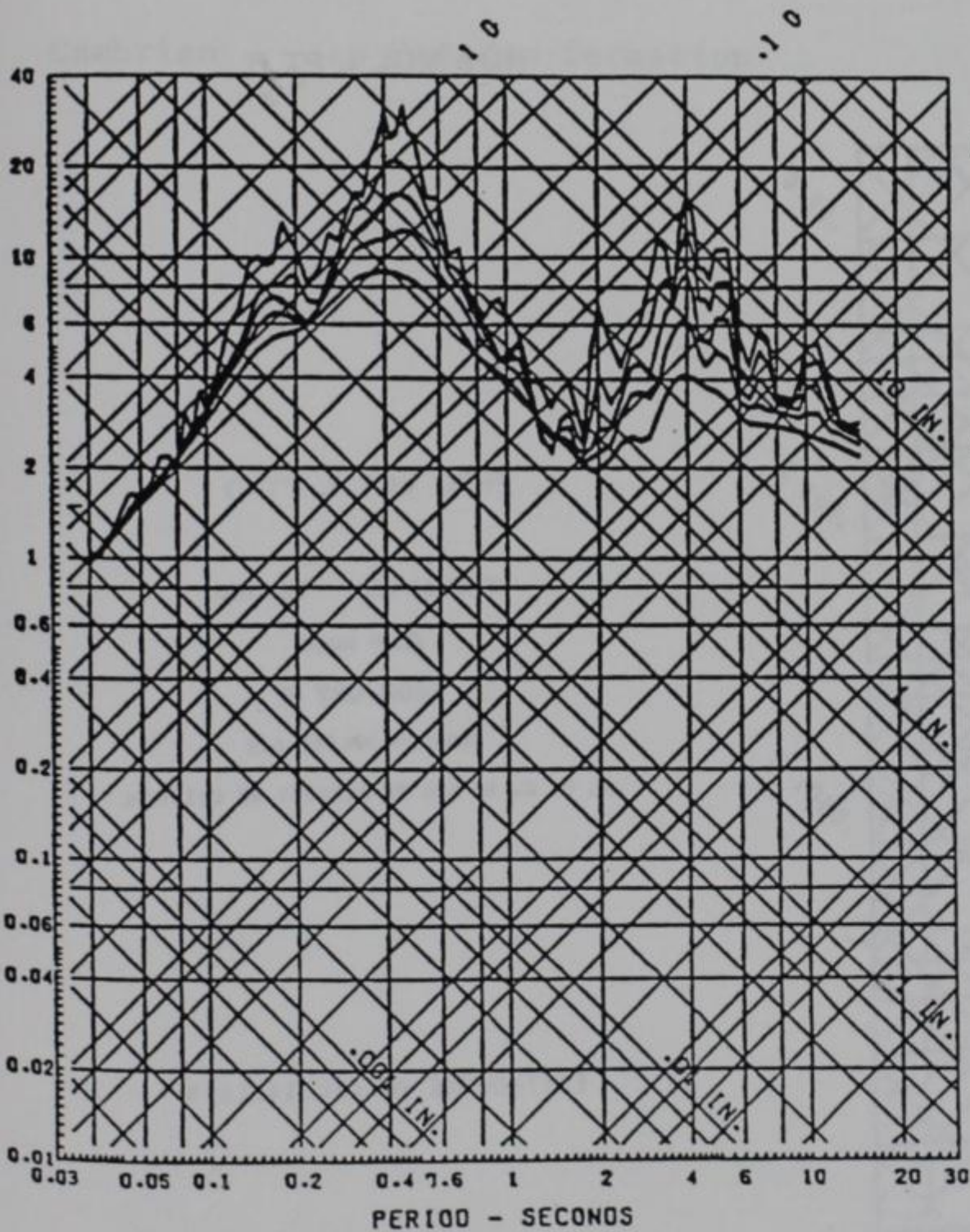
ROC VOL I, PT D

TQ760414-026   WANCHIU

COMP N90W

1400 GMT 8

DAMPING VALUES ARE

0, 2, 5, 10 AND 20 PERCENT OF CRITICAL

EARTHQUAKE OF APL 14.1976

ROC 1

Figure 13   ROC 1: Wanchiu, Vol 1, P+D, 270 deg

EARTHQUAKE OF APL 14,1976 - 1400 GMT
TQ760414-026 WANCHIU   COMP NOOE
PEAK VALUES ACLN=299.0 CM/SEC/SEC VELO=11.6 CM/SEC DISP=1.7 CM
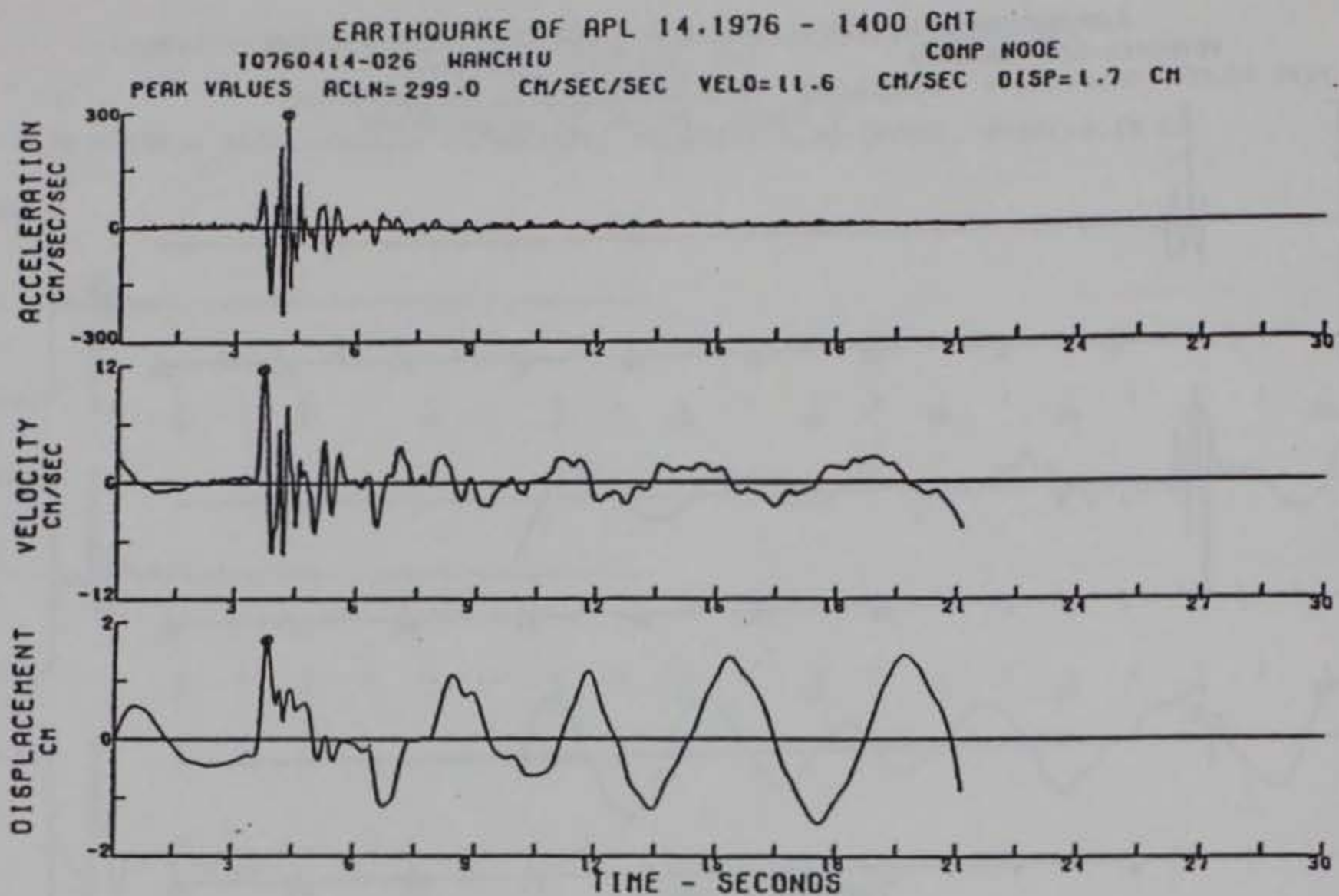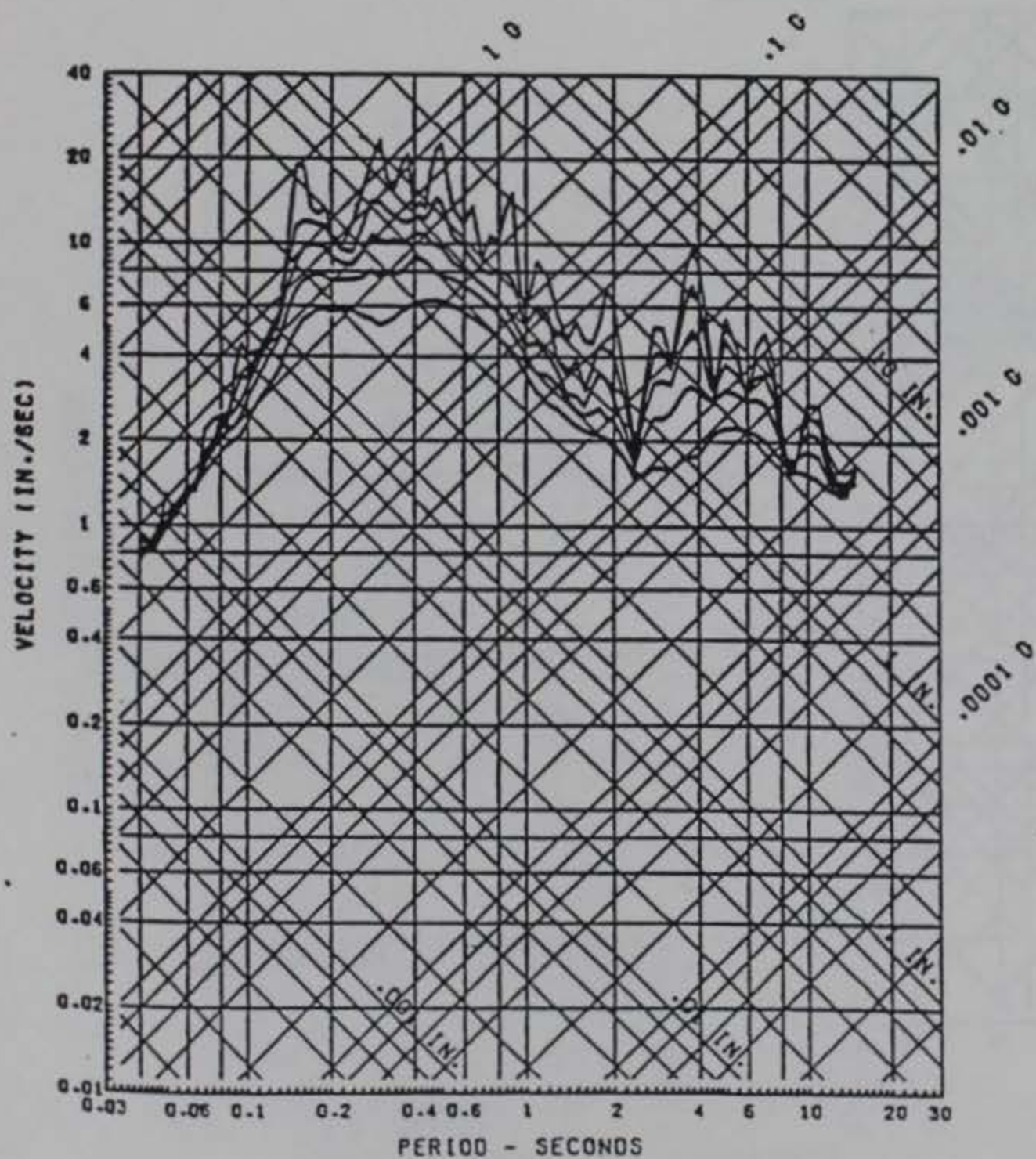
ROC VOL I, PT B

ROC VOL I, PT D

TQ760414-026   WANCHIU
COMP NOOE
1400 GMT 8
DAMPING VALUES ARE
0, 2, 5, 10 AND 20 PERCENT OF CRITICAL

EARTHQUAKE OF APL 14,1976

ROC 2

Figure 14   ROC 2: Wanchiu, Vol 1, P+D, 0 deg

Table 1

Stratigraphy in the Massena Area, from Isachsen and Fisher (1970) and Berkey (1945)

Age	Formation	Thickness ft	Lithology
Quaternary	Alluvium, glacial deposits	0 to ~75	Clays, sands, till with boulders
Ordovician	Otbr, Trenton and Black River Groups	700	Limestone
	Och, Chazy Group	325	Dolomite with thin sandstones and shales
	Obk, Beekmantown Group	500	Dolomite and limestone, thick sandstone in lower part and thin black shales at top
	Oth, Theresa formation	?	Dolomite, sandstone
Cambrian	ϵp Potsdam formation	?	Quartz-cemented sandstone

Table 2

Mean Recurrence Times of Earthquakes in New York State as a Function of Size of Earthquake, by Mitronovas (1982)

| Size | | Total NYS | | Area A | | Area B | | Area C | | Area D | |
M	I_m	Calc.	Obs.[1]	Calc.	Obs.	Calc.	Obs.	Calc.	Obs.	Calc.	Obs.
2.3-3.2	IV	0.59	0.59	3.7	4.0	1.1	0.9	5.0	5.0	10.0	7.3
3.2-4.0	V	2.2	2.0	12.0	10.0	3.6	3.2	16.0	16.0	34.0	27.0
4.0-4.8	VI	7.8	8.9	37.0	40.0	11.0	20.0	51.0	27.0	119.0	<u>0.88</u>
4.8-5.7	VII	28.0	42.0	117.0	125.0	36.0	83.0	164.0	250.0	411.0	<u>0.46</u>
5.7-6.5	VIII	103.0	125.0	370.0	<u>0.49</u>	112.0	250.0	524.0	250.0	1426.0	<u>0.16</u>
6.5-7.3	IX	376.0	<u>0.51</u>[2]	1170.0	<u>0.19</u>	355.0	<u>0.50</u>	1675.0	<u>0.14</u>	4930.0	<u>0.05</u>
7.3-8.1	X	1360.0	<u>0.17</u>	3700.0	<u>0.07</u>	1117.0	<u>0.20</u>				

Recurrence Time (years) for Events $\geq I_m$

[1]Observed between 1900-1980 for $I_m \leq$ VI and between 1730-1980 for $I_m >$ VI.
Numbers underlined: Probability that at least one event ($\geq I_m$) should have occurred during the past 250 years assuming Poisson distribution (only for those I_m not yet observed).

Table 3

Eisenhower-Snell Site: Recommended Accelerograms for a Modified Mercalli Intensity VIII, Near Field, Hard Site, and Shallow Earthquake

Int	Mag	Hypo km	Acc gal	Mean gal	Scale x	Plus Sigma	Scale x	I.D. No.
VIII	4.8	8	564	450	0.80	815	1.45	CAN 3
VIII	4.8	8	417	450	1.08	815	1.95	CAN 5
VIII	4.8	12	451	450	1.00	815	1.81	CAN 8
VIII	6.3	24	360	450	1.25	815	2.27	ROC 1
VIII	6.2	26	640	450	0.70	815	1.27	CAL 229

Int	Mag	Hypo km	Vel	Mean Vel	Scale x	Plus Sigma	Scale x	I.D. No.
VIII	6.3	24	11.6	23.5	2.03	35.0	3.02	ROC 2
VIII	6.3	24	13.8	23.5	1.70	35.0	2.54	ROC 1
VIII	6.2	26	51.9	23.5	0.45	35.0	0.67	CAL 229

Int	Mag	Hypo km	Dur sec	Mean Dur	Scale +, -	Plus Sigma	Scale +, -	I.D. No.
VIII	6.2	26	8.8	7.2	-1.6	12.4	+3.6	CAL 229

Note: 980 gals = 1 g.

Table 4

Earthquake Ground Motions for Soil at Long Sault Dike at Mile 101

(Figure 1), by Weston Geophysical Corporation (1987)

Earthquake	Magnitude m_b	Hypocentral Distance km	Dominant Frequency Band H_z	Hor Peak Accel g	Duration sec
OBE	5.5	5-30	2-8	0.14	15-20
MCE	5.8	5-30	2-8	0.25	15-20
Near Field MCE	4-4.5	0.5-10	15-40	0.50	1-2

Table 5

Earthquake Ground Motions for Rock at Eisenhower

and Snell Locks (Figure 1)

Earthquake	MMI_o	Hypocentral Distance km	Dominant Frequency Band H_z	Hor Peak Accel g	Hor Peak Vel cm/sec	Duration ≥ 0.05 G sec
OBE (Mean)	VIII	10-15	2-25	0.46	24	8.8
MCE (Mean + S.D.)	VIII	10-15	2-25	0.83	35	12.4

APPENDIX A: REGIONAL STUDY OF THE SEISMICITY AND NEOTECTONICS
IN THE AREA OF THE EISENHOWER AND SNELL LOCKS ON THE
ST. LAWRENCE SEAWAY NEAR MASSENA, NEW YORK

REGIONAL STUDY OF THE SEISMICITY AND NEOTECTONICS IN THE AREA OF THE

EISENHOWER AND SNELL LOCKS ON THE ST. LAWRENCE SEAWAY

NEAR MASSENA, NEW YORK

Patrick J. Barosh and Associates

35 Potter Street

Concord, MA   01742

September, 1990

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REGIONAL STUDY OF THE SEISMICITY AND NEOTECTONICS IN THE AREA OF THE
EISENHOWER AND SNELL LOCKS ON THE ST. LAWRENCE SEAWAY
NEAR MASSENA, NEW YORK

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ABSTRACT

The Eisenhower and Snell locks on the St. Lawrence Seaway near Massena,
New York lie at the intersection of two major seismic zones. These are the
northwest-trending Southwest Quebec and the Arkansas-St. Lawrence zones. The
zones correspond with normal fault systems, that are respectively, the
Ottawa-Bonnechere graben and the St. Lawrence Valley rift system. Faults of
these two systems intersect at Massena. The principal southern fault of the
Ottawa-Bonnechere graben, the Gloucester fault zone, that is down to the
northeast, extends southeastward through the Massena area. There it
apparently intersects with northeast-striking faults along the southeast side
of the St. Lawrence river. Fault breccia found at Massena probably belongs to
faults of both zones. Movement at this intersection apparently caused the
1944 Massena-Cornwall earthquake. Uplift and tilting along the Gloucester
zone could explain the present-day southwest-tilt along the St. Lawrence river
and be related to the current rise in the Adirondack uplift to the southeast
of Massena.

The intensity VIII Massena-Cornwall earthquake is the largest on record
in the area. The intensity is unusually high for the magnitude. This
principally is due to amplification of the ground motion from local deposits
of Pleistocene marine clay, that is also subject to liquefaction and slumping.
The intensity on moderately firm ground did not exceed VII, and no other
recorded earthquakes in the Ottawa-Bonnechere graben have exceeded VII. A
maximum credible earthquake assignment of intensity VIII on moderately firm
ground is considered conservative for the Massena area.

INTRODUCTION

This report is to provide a regional analysis of the seismicity, crustal movement and causative structures in order to determine the maximum credible earthquake for the Eisenhower and Snell locks on the St. Lawrence Seaway near Massena, New York. The Massena area is the site of an intensity VIII earthquake that struck September 5, 1944. It is the most devastating earthquake reported in New York State. Over $17,000,000 worth of damage at current value, occurred in a relative small area; yet little is known of the cause of the earthquake or the potential for future shocks.

A great deal of geologic work has been done in the regions around Massena. The Ottawa region has been studied intensively from the early days of the Canadian Survey. The south and east sides of the Adirondack Mountains also have received considerable attention as has the St. Lawrence Valley beyond Montreal. The north side of the Adirondack Mountains, however, is one of the least known areas in New York State and the poor exposures in adjacent Canada has limited work there. The exploratory work for the seaway provides the greatest source of data on the Massena area. For the most part then the study of the Massena area must be approached from the knowledge gained in the adjacent areas.

In a similar way, little has been done specifically on the Massena area to understand its seismicity. Massena has tended to be peripheral to studies focused on adjacent active areas. These general studies, though have revealed relations important for Massena. The 1944 earthquake was, fortunately, well described and provides considerable data for analysis.

SEISMICITY

Massena is situated in the most diffuse region of earthquake activity in eastern North America. This broad zone of seismicity extends across all of

southwest Quebec to Vermont (Fig. 1). It forms the northwest end of the "Boston-Ottawa" seismic zone and is generally referred to as the Southwest or West Quebec seismic zone, with or without an Adirondack subzone.

Most of the earthquake activity of New York occurs in the part of this zone extending across the Adirondack region and the most continuously active area within the region is around Massena. The largest historic earthquake in New York occurred between Massena and Cornwall in 1944 and the Massena area and the Attica area in southwest New York are the two most important seismic areas in the State. The Massena area has been known to be active since the historic earthquake records for the northern New York region began in the 1860's (Nottis, 1983). The active area has no precise boundaries, but within a circle of 12.5 miles radius around the Massena - Cornwall area about 40 earthquakes have been reported, not counting the more than 69 aftershocks of the 1944 earthquake.

MASSENA-CORNWALL EARTHQUAKE

An earthquake struck the Massena, New York - Cornwall, Ontario area on September 5, 1944 at 12:38:45.7 local time (4:38:45.7 UT) that was widely felt and caused considerable damage in the epicentral area, but no fatalities. The field effects were studied by Hodgson (1945a and b), Legget (1944), and Berkey (1945) and a summary prepared by Milne (1949). Additional work on its location and magnitude was done by Dewey and Gordon (1984) and Street and Turcotte (1977). The epicenter was instrumentally located at 44°58.5'N ±3.4' (44.975° ±0.057) latitude and 74° 53.9'W ±5.2' (74.893°W ±0.87) longitude by Milne (1949) and adjusted eastward to 44.958°N ±0.1 and 74.723°W ±0.1 by Dewey and Gordon (1984). The field survey of the damage placed it near Massena Center which is between the two instrument locations (Hodgson, 1945a) (Fig. 2). The new location may be too far east, as it is at the edge of the damaged
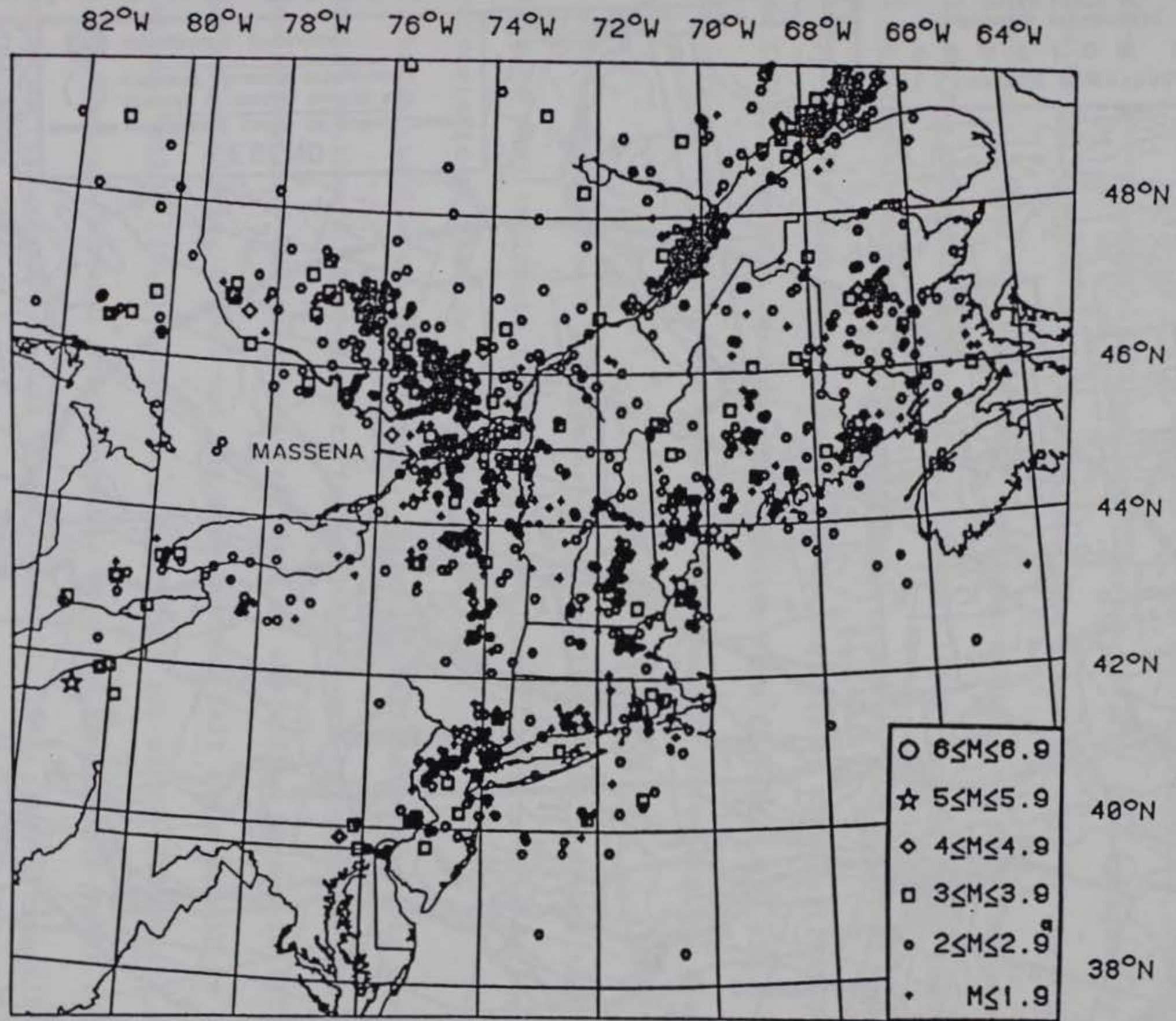
Figure 1. Map of the northeastern United States and adjacent Canada showing earthquake epicenters during the period October 1975 to September 1987 (Ebel, 1990).

LEGEND

━ ━ ━ APPROXIMATE LIMITS OF MARKED DAMAGE

◯ CENTERS OF SPECIAL DAMAGE AND
APPARENT MAXIMUM DISTURBANCE

⊗ APPROXIMATE EPICENTER

ST. LAWRENCE RIVER PROJECT
L O C A T I O N   M A P

SHOWING APPROXIMATE
OUTER LIMITS OF
MARKED EARTHQUAKE DAMAGE
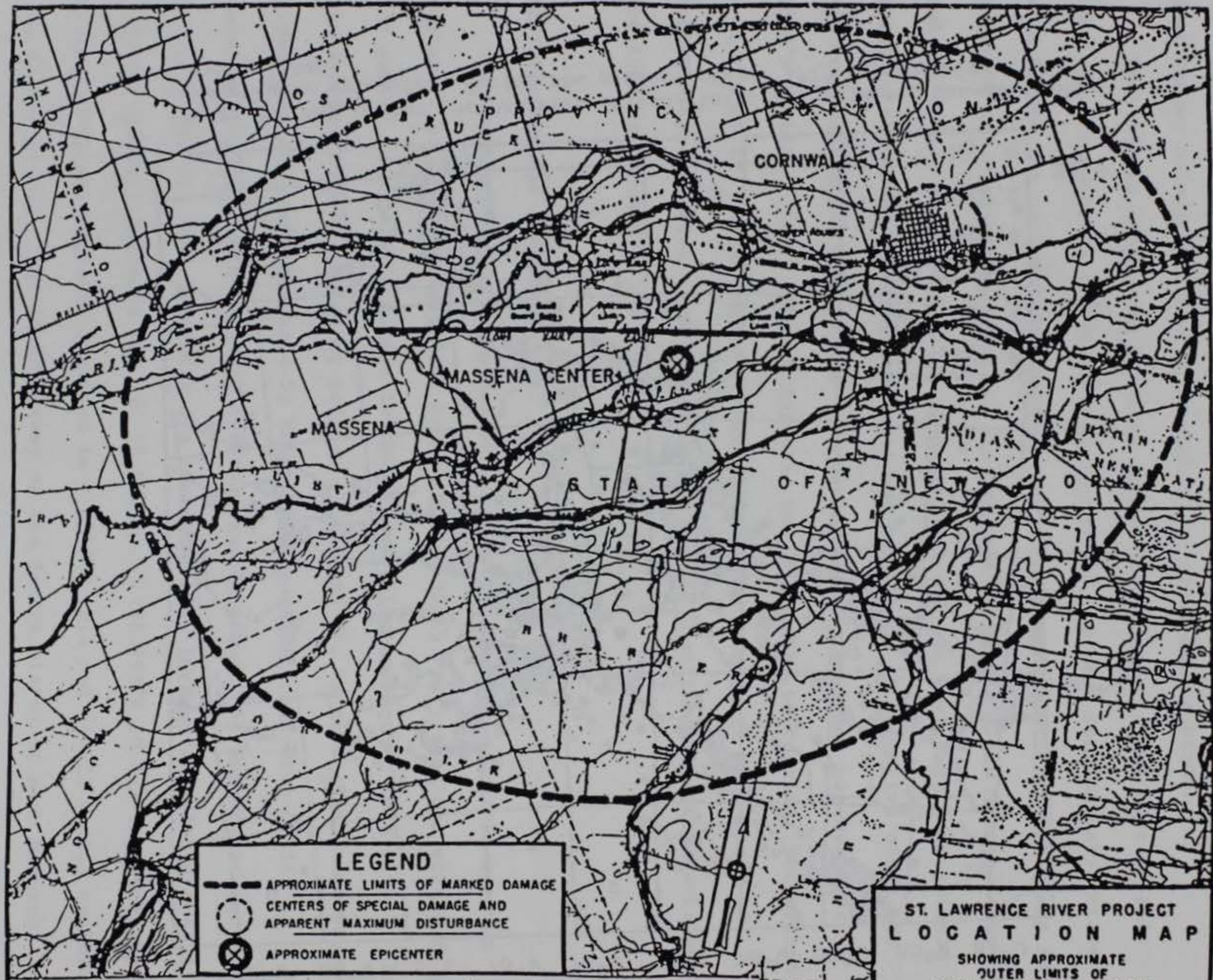
Figure 2.   Map of northern New York and adjacent Canada showing limits of
marked damage in the epicentral area of the 1944 Massena-Cornwall earthquake
(Barken, 1945).

area. The depth was indicated at between 17 and 36 km by Milne (1949) and recomputed by Dewey and Gordon (1984) to about 12 km.

The magnitude has slipped from that first determined by Gutenberg at 6.5 M_L (in Milne, 1949) to 5.9 M_L (Gutenberg and Richter 1956) and later to a 5.8 Mn from a reevaluation by Street and Turcotte (1977). The assigned epicentral intensity has also varied. The intensity is listed as VIII by the U.S. Coast and Geodetic Survey and subsequent listings, although it is mistakenly shown as IX on the original isoseismal map (Bodle, 1946). Milne (1949) preferred to call it slightly over VII. The epicentral intensity and amount of damage seemed unusually high for an earthquake of its size by Hodgson (1945a) and Milne (1949), who both considered it smaller than the intensity VII Timiskaming earthquake (given a 6.25 M_L magnitude by Gutenberg and Richter, 1954).

The earthquake made a large bang and rumbling noise that startled and frightened many residents (Berkey, 1945; Hodgson, 1945a). This is commonly a characteristic of shallow earthquakes.

The earthquake was widely felt. It was perceived westward to central Illinois, southward to southeast Virginia, northward to James Bay and eastward to New Brunswick. The estimated felt area in the United States is 175,000 square miles (Bodle, 1946), but the more distant felt areas appear to be neglected. Milne (1949) estimated a total felt are of 800,000 square miles.

The Massena-Cornwall earthquake was preceded by possible small foreshocks recorded on February 18, August 9 and August 10, 1944. Another possible one occurred a few minutes past 7:00 p.m. (23:00 UT) the night of September 4 when a disturbance was seen on the still waters of Lake Placid, New York (Milne, 1949).

Forty aftershocks were recorded to November 1, 1944 another 20 to the end of 1946 and several more to September 1969 (Stover and others, 1987). The

strongest were experienced at 5:51 a.m. (8:51:06 UT) on September 5 and 7:25
p.m. (23:24:50.4 UT) on September 9, 1944 (Hodgson, 1945a; Milne, 1949; Dewey
and Gordon, 1984). These had magnitudes of 4.5 Mn and 4.0 Mn (4.6 M_L and 4.1
M_L) respectively (Basham and others, 1979; Smith, 1966) . The aftershock of
September 9 is mistakenly listed in Stover and others (1987) as having an
intensity "nearly equaled the intensity of the main shock", that is VIII,
whereas the meaning in the reference cited is to the first large aftershock
(see Hodgson, 1945a; Bodle, 1946). It had an intensity of IV or V.

Damage

The damage was unusually high for an earthquake of this size. It was
estimated to total $2,000,000 for Massena and Cornwall which would equal over
$17,000,000 today. The high damage is attributed to both the local ground
conditions and concentration of buildings near the epicenter (Milne, 1949),
although it is an area of relatively small towns and villages. Description of
the damage is found in Berkey (1945), Hodgson (1945a and b), Legget (1944),
and Bodle (1946).

The principal area of damage could be defined by damaged chimneys and
rotated and overthrown gravestones. It formed an eliptical area 25 by 20
miles wide centered south of the St. Lawrence river (Berkey, 1945), although
this neglects the damage mentioned at Brasher Falls and Winthrop farther south
(Fig. 2). Including these would make the area nearly circular. The damage
tapered off markedly at this boundary and beyond it obviously weak chimneys
and structures appeared undamaged (Hodgson, 1945a).

No houses were destroyed or collapsed, but almost all sustained some
damage. In Cornwall "practically everyone of the town's 3081 buildings was
damaged, although only a few to any serious extent" (Legget, 1944). "Major
damage appears to have occurred at schools, churches and like establishments

with over-large rooms. Many of the badly damaged buildings are old, and numerous damaged private houses are built of brick, some of the walls being veneer construction without cross-bracing or heads. A few such buildings were badly wrecked, with cracked and bulged walls which in some cases had to be protected by emergency braces and otherwise guarded." (Berkey, 1945). The most common damage was to chimneys above the roofline which were loosened or even wrecked, but more commonly shifted or turned. About 2,000 chimneys were destroyed or damaged enough to require repairs in both Massena and Cornwall and many structures were rendered unsafe for occupancy until repaired. This amounted to about 90 percent of the chimneys in Massena and a similar high percentage in Cornwall. Considerable numbers of cemetery monuments were rotated or toppled in the epicentral area and their manner of displacement received considerable study. There was also considerable loss of shelf goods, broken windows, damaged plumbing, and cracking of brick and plaster walls and foundations.

"Substantial, well constructed buildings sustained comparatively light damage, and even large manufacturing plants, several of which are located in the district, escaped with surprisingly small damage. The large smoke-stacks connected with certain of these plants were not wrecked, although one, at least, required repair. A reconnaissance of damage of this sort leads to the general conclusion that buildings with brick walls have suffered most, chiefly due to poor construction. In some cases stonewalls were affected the same way and for the same reason. Frame and stucco buildings appear to have escaped injury more successfully, although inside damage occurred in the whole range of buildings, especially those not thoroughly braced. ---the much more substantial engineering structures came through with surprisingly little injury. ---the Cornwall Canal, which follows immediately along the north side of the river with a final lock at Cornwall ---stands 25 or 30 feet above the

water level of the river immediately adjacent with only a narrow embankment between; yet its walls are not noticeably damaged. It has continued to operate as usual..." (Berkey, 1945).

No indications of surface fault displacement were recognized, but cracks from liquefaction occurred about one mile north of Massena Center on a terrace of Robinson Creek. There three cracks opened 1-2" and two spouted considerable water and carried fine silty sand to the surface (Berkey, 1945; Hodgson, 1945a).

Many shallow wells in the overburden went dry in the epicentral area and a new spring opened in a bedrock well in Basher Falls. Changes in water levels were noted on stream gaging stations across New York to Long Island (Bodle, 1946).

The damage showed many peculiar fractures that must be related to the direction of travel and character of the surface waves from the earthquake. The rotation of most cemetery monuments on the Canadian side of the St. Lawrence was counterclockwise whereas it was clockwise on the United States side (Hodgson, 1945a). Twisting of chimneys also showed this. Most of the toppled monuments fell to the east. The degree to which shelf goods and books were displaced depended on which direction the shelf faced. North of Massena Center north facing shelves were effected the most, east facing to a slightly lesser degree and south and west facing the least (Berkey, 1945).

Isoseismal Pattern

The initial isoseismal map produced by the U.S. Coast and Geodetic Survey (Bodle, 1946) is extremely generalized and shows the intensities too high (Fig. 3). Milne (1949) produced a much better one, that is, however, still too generalized (Fig. 4). Redrawing the data for the United States shows a much more complex pattern that brings out new features (Fig. 5).

Figure 3. Isoseismal map of the United States portion of the 1944 Massena-Cornwall earthquake (Bodle, 1946).

Figure 4. Isoseismal map of the 1944 Massena-Cornwall earthquake (Milne, 1949).
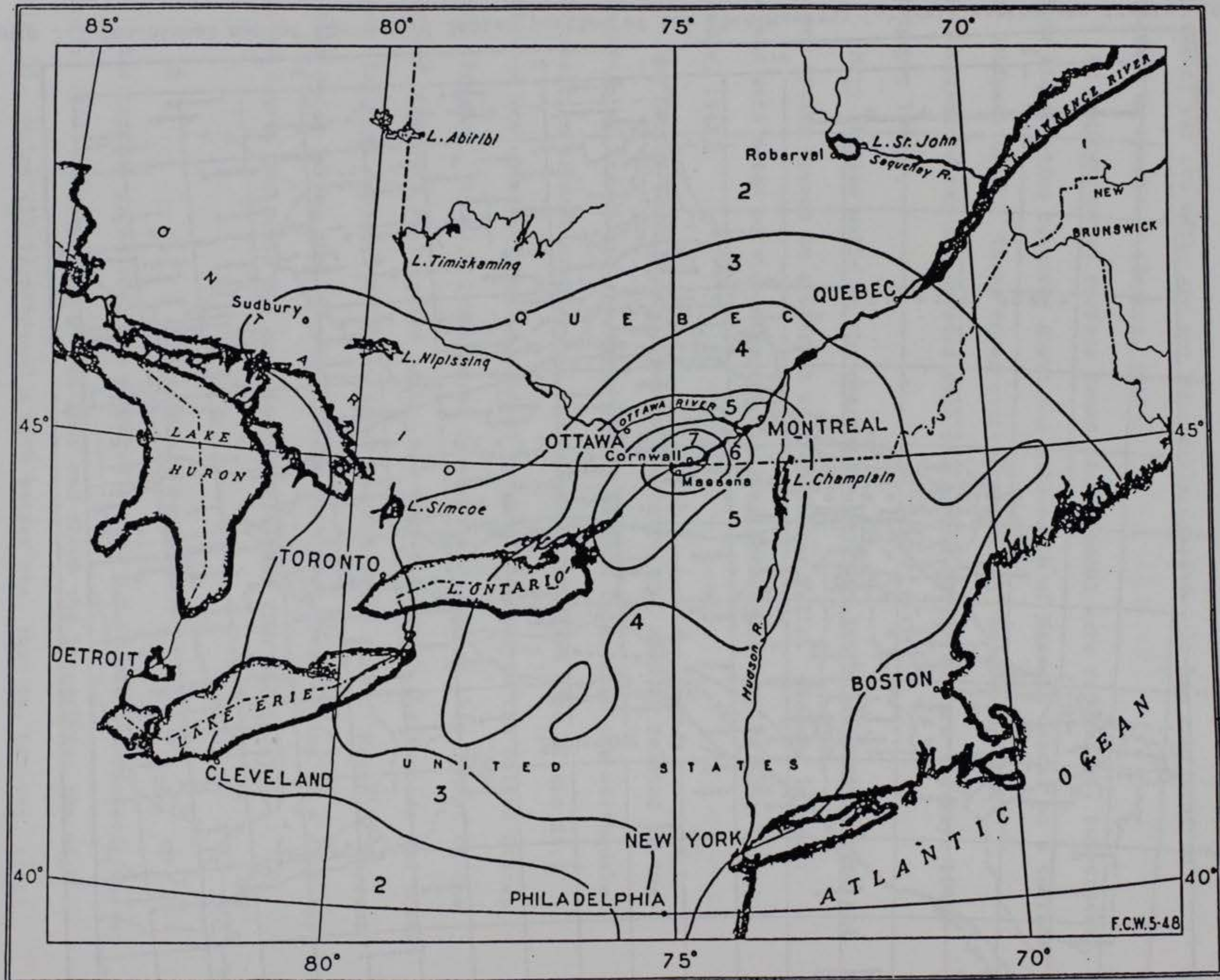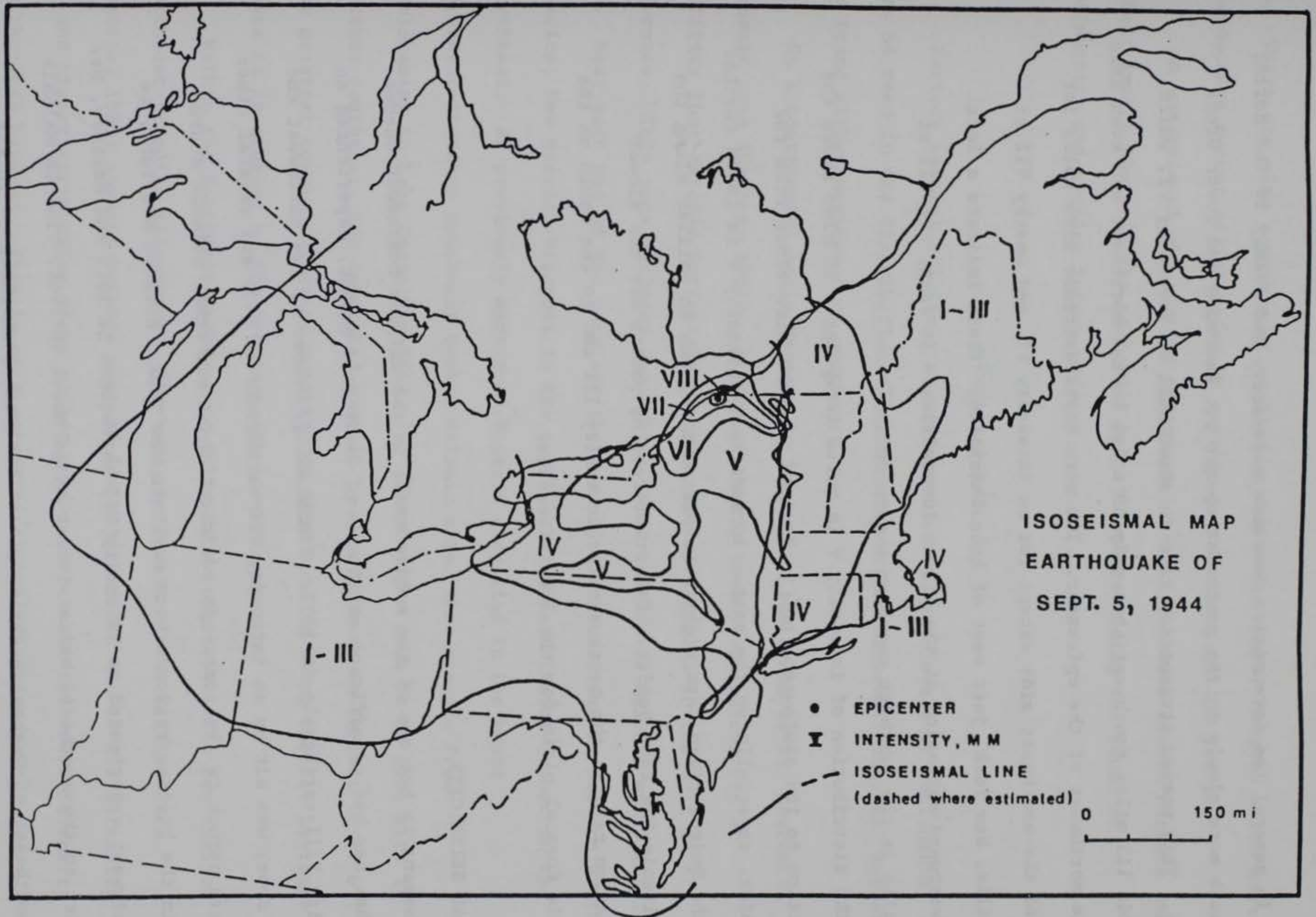
Figure 5. Isoseismal map of the United States portion of the 1944
Massena-Cornwall earthquake, revised.

In general the intensities decrease moderately and evenly to the north, but much more slowly to the southwest up the St. Lawrence and lower Great Lakes. This uneven attenuation rate is shown well by intensity VI, which extends 115 miles southwest, but only 40 miles to the northeast and even less to the northwest of the epicenter. The more rapid decrease also holds for most of the southwest side except for an intensity VI, and nearby VII at Keesville, New York, just west of Lake Champlain. These indicate a local southwestward extension of the higher intensities. In fact, the VII at Keesville is the farthest one from the epicenter.

The distribution of intensity V is quite irregular. It also shows the projection to the southwest, but is limited in other directions from the epicenter, especially on the east. In addition, intensity V is found further down the Hudson river than might be expected and forms an outlier along the Pennsylvania-New York border. Other interesting points are the slower attenuation rate to the northwest for intensity III and to the south on the Atlantic Coastal plain for the low intensities.

REGIONAL SEISMICITY

Massena is but one of the active areas in the diffuse Southwest Quebec zone that has had significant earthquakes. Montreal, Quebec, experienced an intensity VIII earthquake in 1732. Timiskaming, Quebec at the northwest end of the zone, was hit by an intensity VII earthquake in 1935 and several other VIIs have struck in the zone. In addition, there are other seismic source areas in the broader region around northern New York. Attica, New York, to the southwest experienced an intensity VII earthquake in 1929 and Ossipee, New Hampshire to the southeast had a similar sized shock in 1940. The La Malbaie area, northeast of Quebec is the only area with major earthquakes in the region and has experienced a few that reached intensity IV to X since 1534 or

5. There are also a number of smaller active areas nearer Massena which have produced a number of intensity VI earthquakes in the past 130 years.

An analysis of the spatial relations of the epicenters around Massena and their impact there in the past will help in understanding the cause of seismicity and predict future effects.

Regional Patterns

Various spatial relations at different scales and levels of confidence can be seen in the distribution of seismicity around Massena. They all appear to trend either northwest or northeast.

On a continental scale Massena is located on the Arkansas-St. Lawrence seismic zone (Barosh, 1981). A line of nearly evenly spaced centers of activity that extends northeastward from central Arkansas to the Gulf of St. Lawrence. This zone includes the Attica, Montreal and La Malbaie areas (Fig. 1). Near each end of the zone are the two major source areas in eastern North America; New Madrid, Missouri in the southwest and La Malbaie, Quebec in the northeast. As previously mentioned Massena also lies in the broad northwest-trending Southwest Quebec seismic zone, that extends from Timiskaming to Lake Champlain (Fig. 1). The Ossipee area is on line with it farther southeast, but separated from it by a quiet zone in Vermont (Fig. 6). The greatest concentration of activity in this zone is along the St. Lawrence where it is crossed by the Arkansas-St. Lawrence zone.

Within the Southwest Quebec zone there is a suggestion of a few smaller northwest-trending alignments. The zone, northwest of the St. Lawrence (Nottis, 1983) appears to have most of its activity and all of its intensity VI and higher earthquakes along either border with scattered lower intensity earthquakes between. This is as a series of irregular concentrations rather than a line. One trend extends northwest from Montreal and the other from

A21
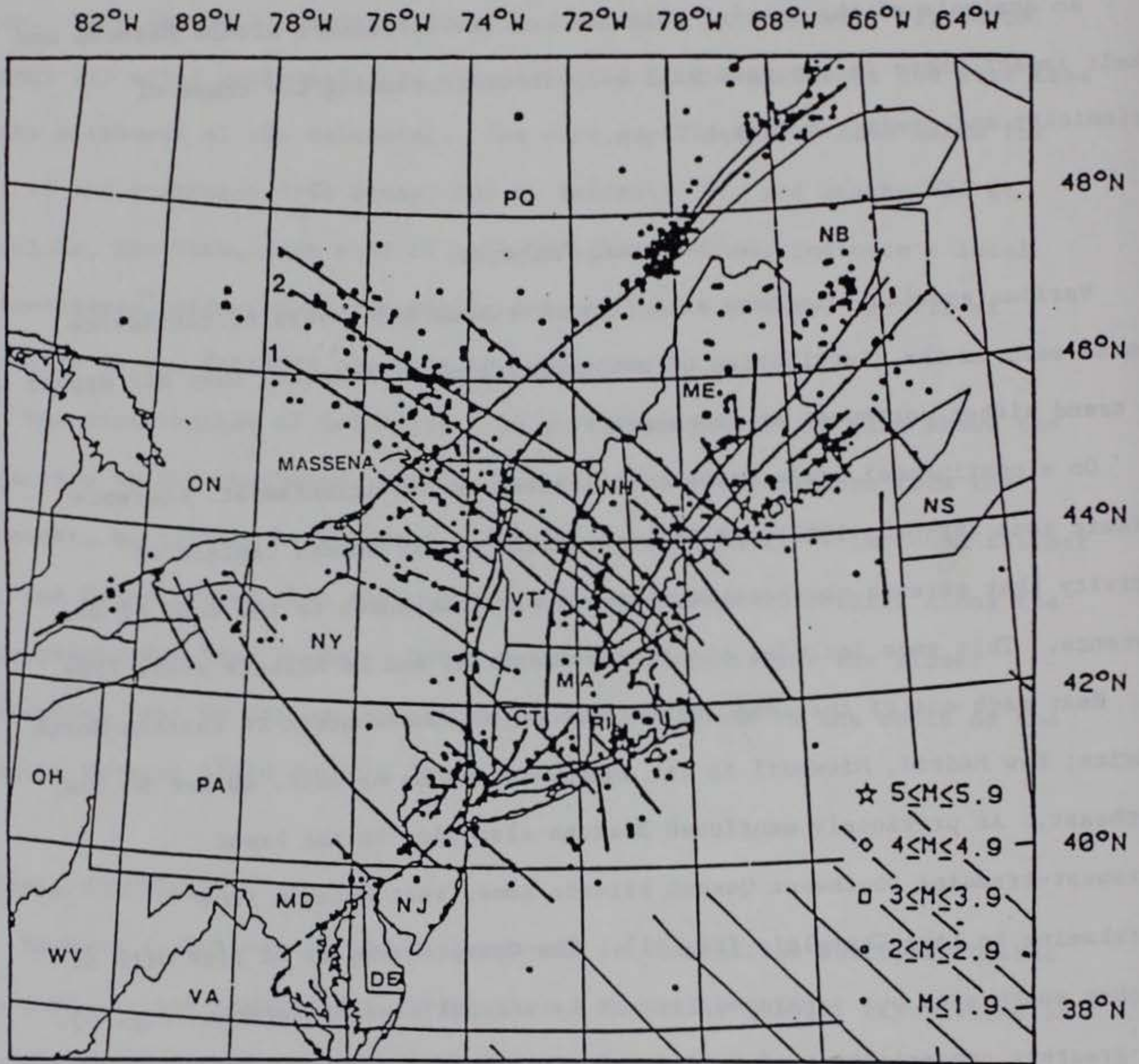
Figure 6. Map of the northeastern United States and adjacent Canada showing earthquakes during the period October 1975 to March 1984 (Foley and others, 1985), generalized fault and probable fault zones spatially related to earthquakes (solid lines), border of the Coastal Plain deposits (dashed line) and offshore transform fracture zones (Klitgord and Behrendt, 1979) (from Barosh, 1986, 1990). Explanation: 1, Massena trend; 2, Montreal trend.

Massena (Fig. 6) passing through a cluster of activity at Ottawa, along the Ottawa river near Pembrook and at Timiskaming. The trend from Montreal, that has experienced more intensity V plus earthquakes, has been quite active since 1975, whereas the trend through Massena has not (Fig. 1). In northern New York the earthquakes are scattered and the trends are not as cleanly separated, but the areas of larger earthquakes and concentration of activity appear aligned. Southeast from Massena is a cluster of activity just south of Malone and farther southeastward at Lyon Mountain and an intensity VI earthquake occurred a little further southeast at Keesville. These clusters trend about N60°W.

Southwest of Massena there is a smaller concentration of activity that is centered around Canton, New York and extends to the St. Lawrence at Ogdensburg. It is elongated to the northwest and parallel to the trend through Massena.

Maximum Experienced Intensity

The maximum effects on the Massena area from earthquakes recorded in the past shows the combined effects of near and distant earthquakes and provides the minimum intensity to prepare for in the future. Isoseismal data does not exist for all the known larger earthquakes and must be estimated in part. The map only definitively represents the last 130 years, except for the Montreal area which extends back 330 years. The map is dominated by the effects from the 1944 Massena-Cornwall earthquake and the 1732 intensity VIII and four other VII earthquakes around Montreal and the intensity VII shock near Ottawa. The effects from the more distant earthquakes within the Southwest Quebec zone or the more distant source areas are less than the local events. Even the 1925 intensity IX shock near La Malbaie only caused intensity IV in the Montreal-Massena region (Smith, 1962) and the 1935 Timiskaming earthquake an
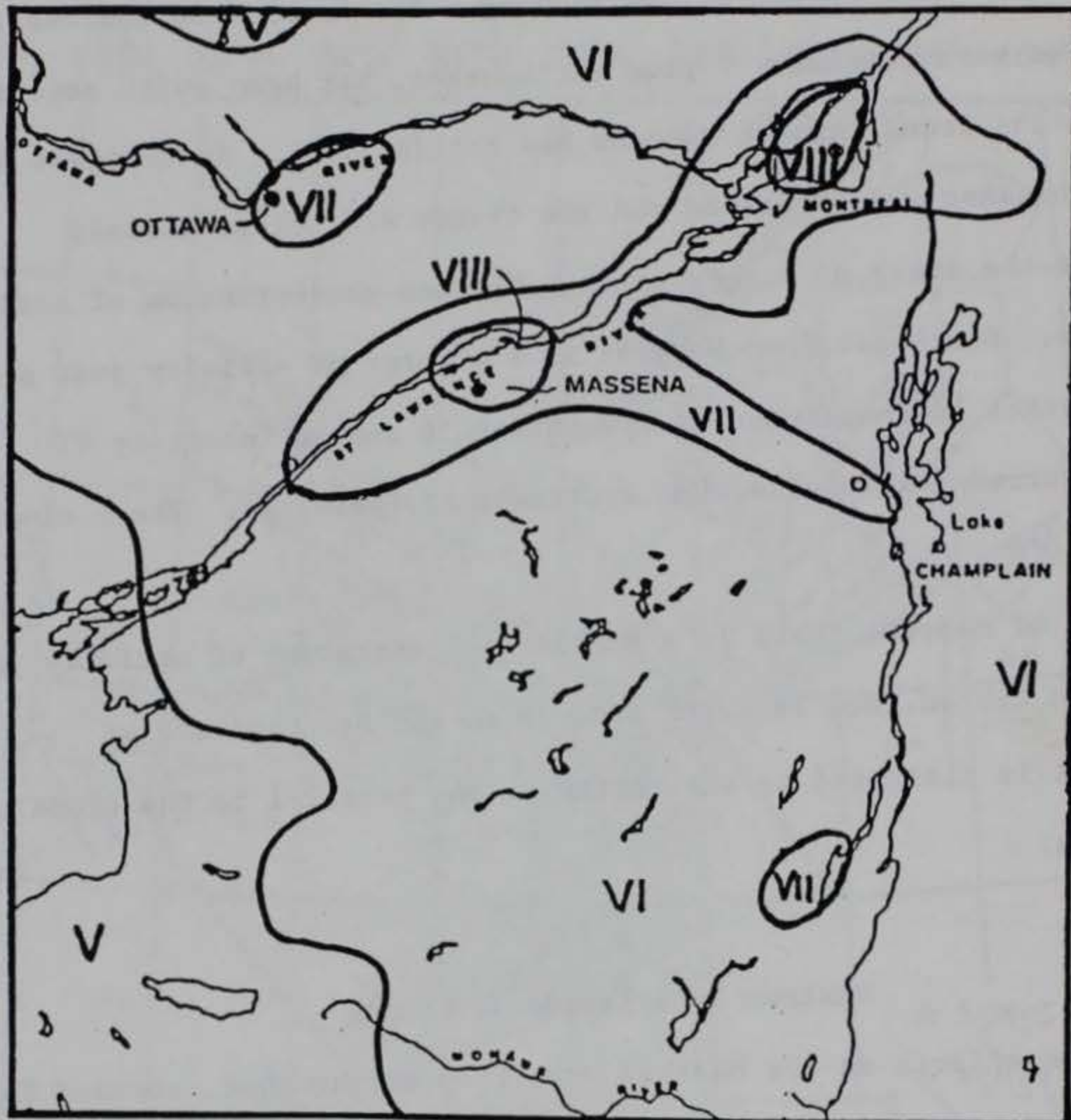
Figure 7. Map of northern New York and adjacent areas showing the maximum experienced intensity from historic earthquakes.

intensity V. Even if the size of the La Malbaie seismic area is a little larger, as suggested after the recent 1989 Saguenay earthquake, there would be no practical difference at Massena.

Isoseismal maps do not exist for all the older earthquakes and must be estimated. Used are the generalized map of the 1732 earthquake (Leblanc, 1981), the 1935 Timiskaming map (Smith, 1966) as a substitute for the 1861 Ottawa event, conservative estimates for the other intensity VII earthquakes in southern Quebec, the revised map for the Massena earthquake and some data from a few smaller events.

The results indicate almost the entire region from Ottawa to Lake Champlain has experienced intensity VI, and intensity VII has occurred along most of the St. Lawrence river and in short extensions to the southeast of it (Fig. 7). Intensity VIII occurs only in the Massena-Cornwall and Montreal areas. Such a map is probably representative of the past 230 years, as it is unlikely that any intensity VIIs or higher earthquakes, that might change the pattern significantly , have been missed since then.

GEOLOGIC SETTING

BEDROCK GEOLOGY

Massena lies in a basin formed by the intersection of two structural and topographic troughs at the southern edge of the Canadian Shield. The basin is nearly surrounded by Precambrian rock. One trough trends northeast and is drained by the St. Lawrence River and the other trends northwest and is followed by the upper part of the Ottawa River (Fig. 8).

The lowland basin consists of Early Paleozoic strata overlying Precambrian granitic and metamorphic rock and capped by Pleistocene surficial deposits (Fig. 9). It is part of a zone of strata that extends down the St. Lawrence River and generally is situated between the southeast margin of the

Figure 8. Map showing the Ottawa-St. Lawrence lowland basin, surrounding
Precambrian rocks (ruled lines) and position of structural troughs (heavy
lines with ticks) (modified from Wilson, 1946).

AGE		FORMATION	THICK-NESS	DESCRIPTION
PLEISTOCENE AND RECENT		CHAMPLAIN CLAY	0-75'+	Lead-gray, plastic clay with some silt and fine sand, especially near the bottom and at the top. Contains scattered marine fossils. Occurrence limited to swales and valleys between morainal ridges of till.
		GLACIAL OUTWASH	VARIES GREATLY	Chiefly sand deposited by glacial streams near the ice front and outwash from morainal deposits
		GLACIAL TILL	0-125'+	An unassorted mixture of clay, silt, sand, gravel and boulders with rarely small lenses or pockets of sand. Compact, tight and relatively impervious for the most part. Also known as "boulder clay" and "hard pan". Generally good foundation material.
ORDOVICIAN				MAJOR UNCONFORMITY
		TRENTON AND BLACK RIVER	700'	Gray limestone with some interbedded shale, sandstone and dolomite. Absent in all areas involving construction for the St. Lawrence River Project although they do extend south to the Canadian bank of the river for some distance opposite Croil and Long Sault Islands.
				MINOR DISCONFORMITY
		CHAZY	325'	Light gray to almost black dolomite and limestone with occasional thin beds of sandstone and shale. Very similar to the underlying Beekmantown. No open cavernous conditions of any importance known. The bedrock surface at the sites of all the principal structures of the St. Lawrence River Project, except the Iroquois Dam, is in this formation. The approximate elevation of the bottom is as follows: At Long Sault Dam Site 65 feet below sea level At Barnhart Island Powerhouse 15 " " " " At Robinson Bay Lock 15 feet above " " At Grass River Lock 60 " " " "
				DISCONFORMITY
		BEEKMANTOWN	500'	Gray to almost black dolomite and limestone with thick beds of sandstone in the lower part and thin beds of black shale near the top. Rusty colored on weathered surfaces. Not known to be cavernous, but does contain a few calcite-filled cavities. The bedrock surface at the Iroquois Dam Site is near the top of this formation. It will not be penetrated by any of the other structures of the project.
CAMBRIAN		POTSDAM	0-250'	Chiefly a quartz-cemented, hard, flinty sandstone predominantly white to gray and reddish. Will not be reached by any of the structures of the St Lawrence River Project.
PRE-CAMBRIAN				MAJOR UNCONFORMITY
		GRENVILLE SERIES	UNKNOWN (At least thousands of feet)	Highly metamorphosed sediments (limestones, quartzites, schists and gneisses) intruded by various types of igneous rocks. This formation is the basement of the local geologic column

ST. LAWRENCE RIVER PROJECT

LOCAL GEOLOGIC COLUMN

150   0   150   300'

VERTICAL

Figure 9. Stratigraphic column for the Massena, New York area (Berkey, 1945).

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Canadian Shield on the northwest and the Appalachian Mountains on the southeast (Fig. 10). Here, however, a southeast extension of the Canadian Shield, that cumulates in the Adirondack uplift, forms the southern border of the zone. A low lying part of this extension of Precambrian, the Frontenac axis, barely separates the rock in the basin from similar strata in the lowland area around Lake Ontario to the southwest (Figs 8 and 10).

These early Paleozoic strata are within a northeast-trending trough that has been compared with the East African Rift System and referred to as the St. Lawrence Valley Rift System (Kumarapeli and Saull, 1966; Kumarapeli, 1978 and 1986). The system displays a notable series of southeast dipping normal faults along the northwest side of the St. Lawrence. Faults of this system are seen at the east end of the basin (Wilson, 1946) (Fig. 11) and on the Frontenac axis (Ontario Geological Survey, 1976). The low point in the trough, where it crosses the Frontenac axis is just southeast of the St. Lawrence. There the Paleozoic strata nearly cover it. A northeastward projection of this trough axis would pass near Massena.

Several northeast-trending faults have been mapped on the axis southwest of Canton, New York. Some of these are normal faults (Carmichael and others, 1987) and part of the St. Lawrence Valley system (Fig. 11). These strike towards the Massena area. However, the mapping has been insufficient and the exposures too poor to characterize these faults well and follow them to the northeast. The faults parallel the St. Lawrence and a series of small stream valleys to the southeast of it, such as the Grass River and lower Raquette and St. Regis Rivers near Massena. Such subparallel valleys form a zone about 12 miles wide along the southeast side of the St. Lawrence river. No comparable zone is seen northwest of the St. Lawrence. These stream channels appear to represent fault zones, although some could be due to Pleistocene deposition and channeling. Some of the fault breccia and deep channels encountered in
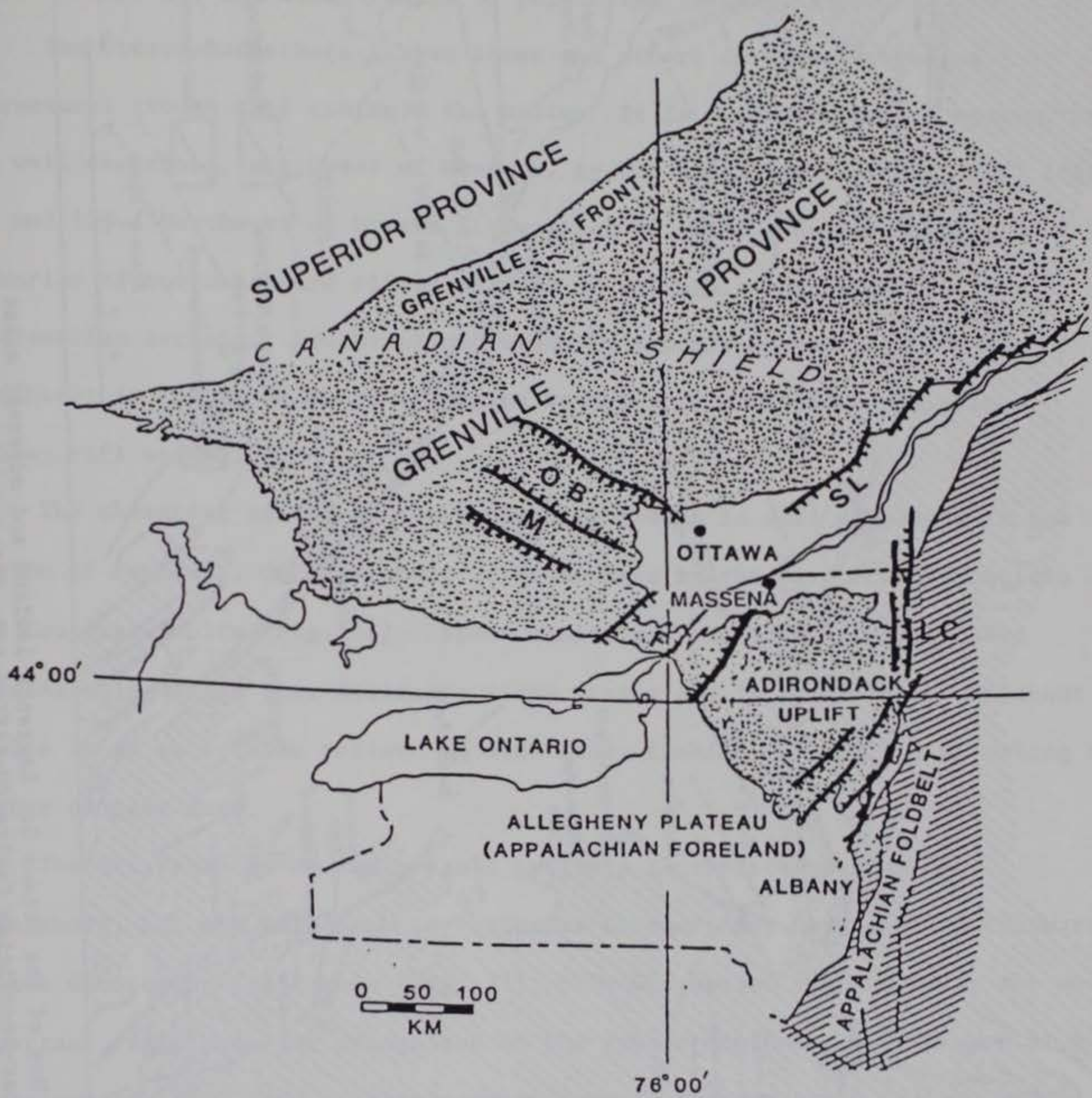
Figure 10. Map of New York and adjacent regions showing geologic provinces. Explanation: O-B, Ottawa-Bonnechere graben; S.L., St. Lawrence Valley rift system; L.C., Lake Champlain-Lake George graben; M, Madawaska highlands; F, Fontenac axis (Modified from Isachsen, 1982).
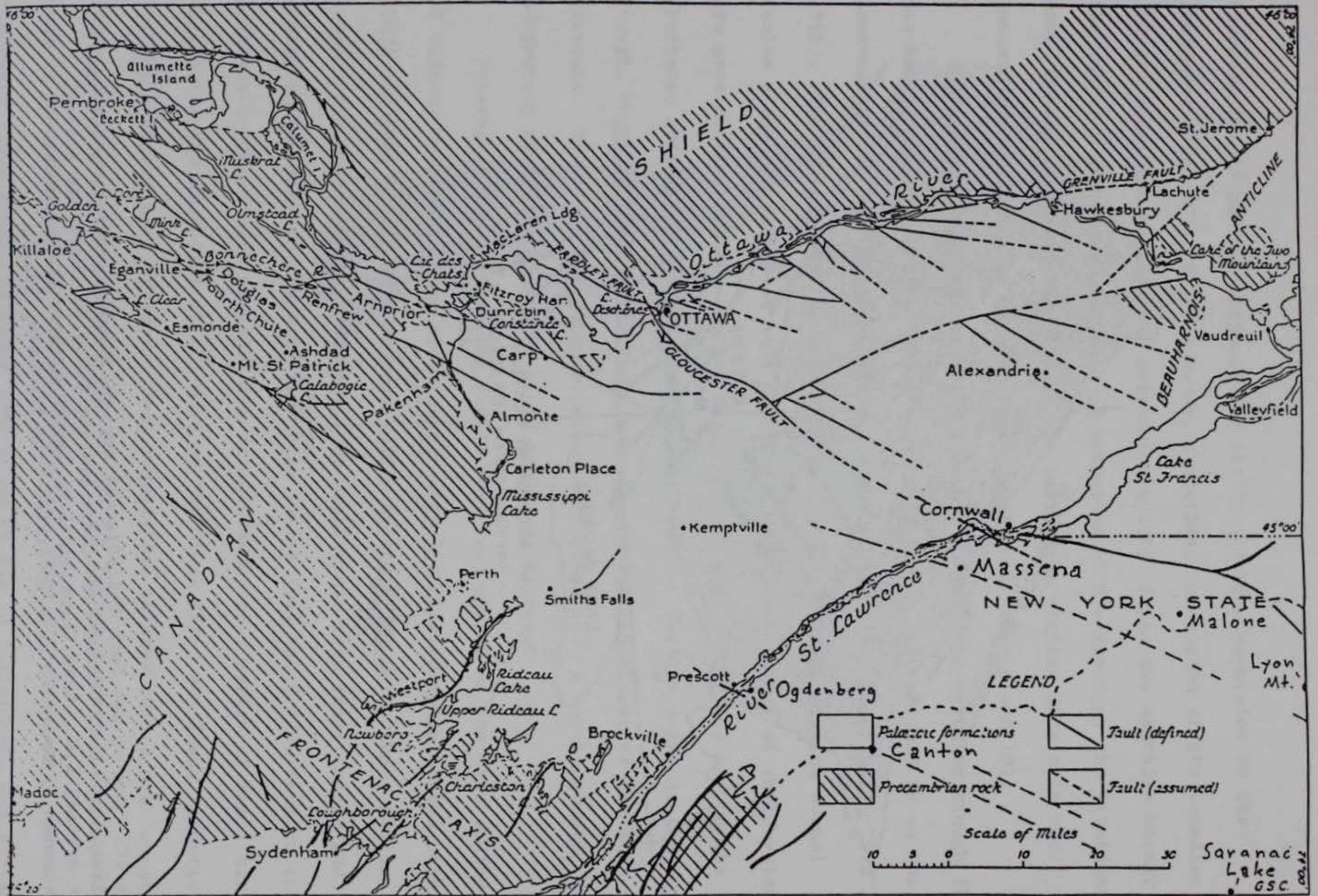
Figure 11. Map of the Ottawa-St. Lawrence lowland and adjacent areas showing post-Ordovician faults (Modified from Wilson, 1946) with data from Isachsen and McKenolree, 1977 and Isachsen and Fisher, 1970).

the exploratory drilling for the locks and dams of the St. Lawrence Seaway

near Massena may lie along faults of this trend (Berkey, 1945).

The Ottawa-Bonnechere graben forms the other, northwest-trending,

structural trough that controls the basin. It is a complex graben system that

is well described, northwest of Massena, by Kay (1942) and Wilson (1946) (Figs

11 and 12). Northwest of Ottawa it is about 40 miles wide and is displayed by

a series of northeastward tilted slivers of Paleozoic rock within a

Precambrian terrain. Southeast of Ottawa it appears to splay out to the

northeast in the basin where it begins to interact with the St. Lawrence

Valley rift system.

The character of the Ottawa-Bennechere graben is well displayed in the

region of Pembroke, Ontario where it is bounded by the St. Patrick Mountain

and Coulonge faults (Fig. 12). These faults and the others locally have

considerable offset that decreases along strike and is picked up by adjacent

faults in an en echelon pattern or some other fashion (Wilson, 1946) making a

rather complex zone.

The St. Patricks Mountain fault projects southeastward towards

Ogdensburg, but the main down to northeast movement may have shifted eastward

to the Gloucester fault zone (Fig. 11). The Gloucester fault zone is the most

important fault thus far recognized in the graben southeast of Ottawa. It has

a maximum of 1,800 feet of displacement down to the northeast (Wilson, 1946).

It trends towards the Massena-Cornwall area and may connect with one plotted

there (Isachsen and McKendree, 1977), probably on the basis of the fault

breccia found in drilling near the Lock site (Berkey, 1945). Another lies

near Massena with the same sense of displacement (Wilson, 1946) and may be

part of the same fault system. A topographic lineament extends from the

mapped fault across New York to south of Malone. Another fault lies to the
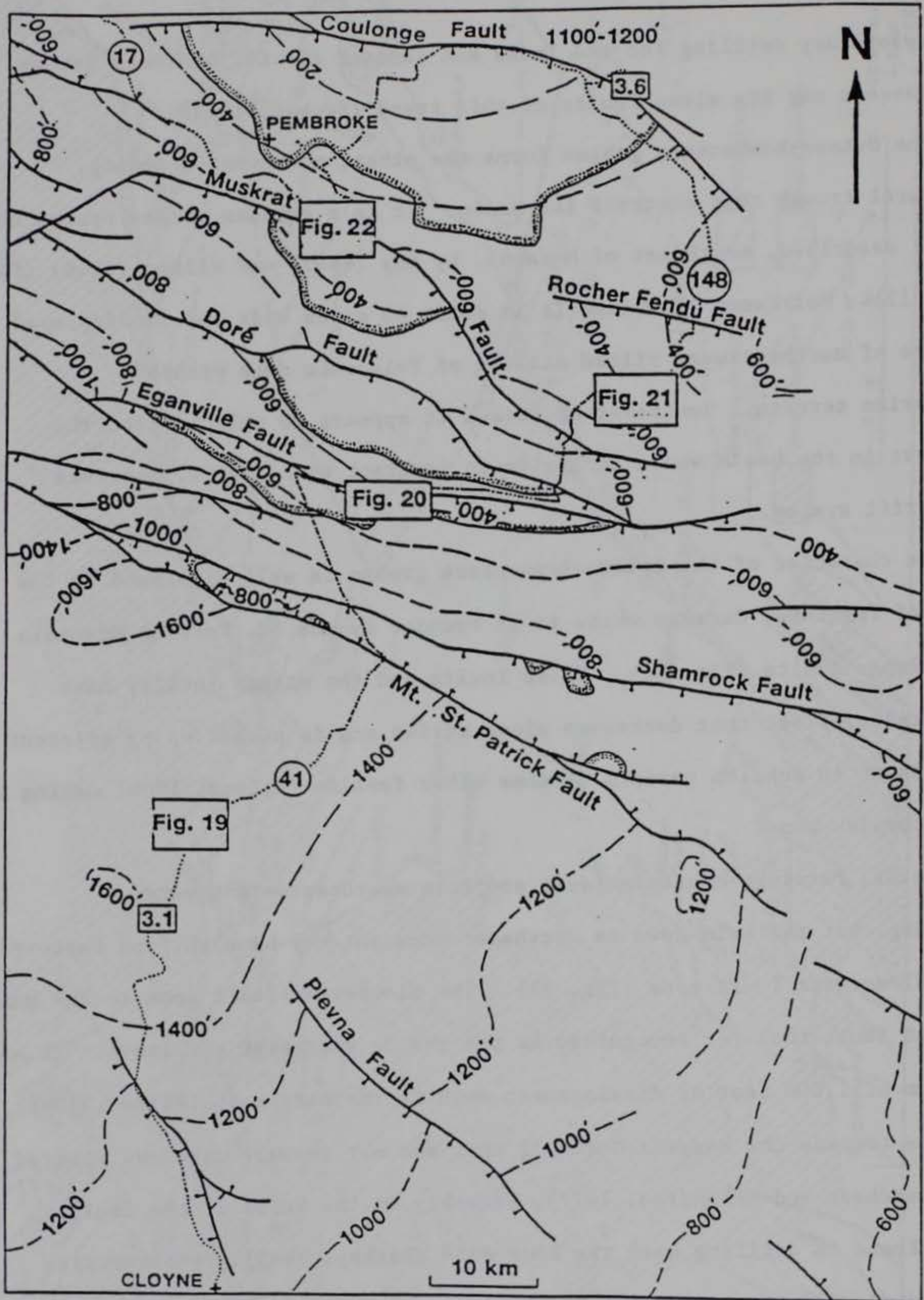
Figure 12. Map of the Cloyne-Pembroke area of Ontario and Quebec showing the Ottawa-Bonnechere graben and Madawaska highland (Carmichael and others, 1987). Explanation: heavy lines, major dip-slip faults; stippled lines, outlines of Ordovician strata; dashed lines, structure contours of pre-Ordovician surface of the Precambrian rock.

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north and intersects the St. Lawrence at the east side of Cornwall (Isachsen and Fisher, 1970). These faults may be all a part of a single complex zone.

These three faults encompass the bend in the St. Lawrence River in the Massena-Cornwall area and are probably responsible for it. Also, the rapids here could be on the upside of a relative down to the northeast displacement across these faults and the broader basin of Lake St. Francis to the northeast on the downside.

The available information, thus shows that the Massena-Cornwall area lies at the intersection of northeast-trending faults near the axis of the basin and the principal southern most known fault zone of the Ottawa-Bonnechere graben. The fault zones found in exploratory drilling for the locks and attendant construction (Berkey, 1945) are probably related to both sets. The fault breccia here is both cemented and open and show evidence of repeated movements. The faults of both sets are indicated to be normal. The slickensides seen in the Ottawa-Bonnechere graben showed down dip movement (Kay, 1942). Those seen in the drill near Massena also had a lateral component of movement (Berkey, 1945) and these are perhaps related to the St. Lawrence Valley system. Post-Cretaceous movement is known to have occurred along both these graben systems (Kay, 1942, Barosh, 1981, Carmichael and others, 1987, Kumarapeli, 1978, 1986).

Considerable numbers of post Precambrian brittle faults are apparently present in northern New York, but relatively few of them are mapped. Many are shown on the southeast side of the Adirondack Mountains where most of the work has been done and a like number should be found elsewhere (Fig. 13). The faults are generally poorly exposed in the region and especially difficult to locate in the lowland areas where there is extensive surficial cover. Most have been recognized where the Precambrian-Paleozoic contact is seen to be offset and relatively few found without an offset contact for a guide. The
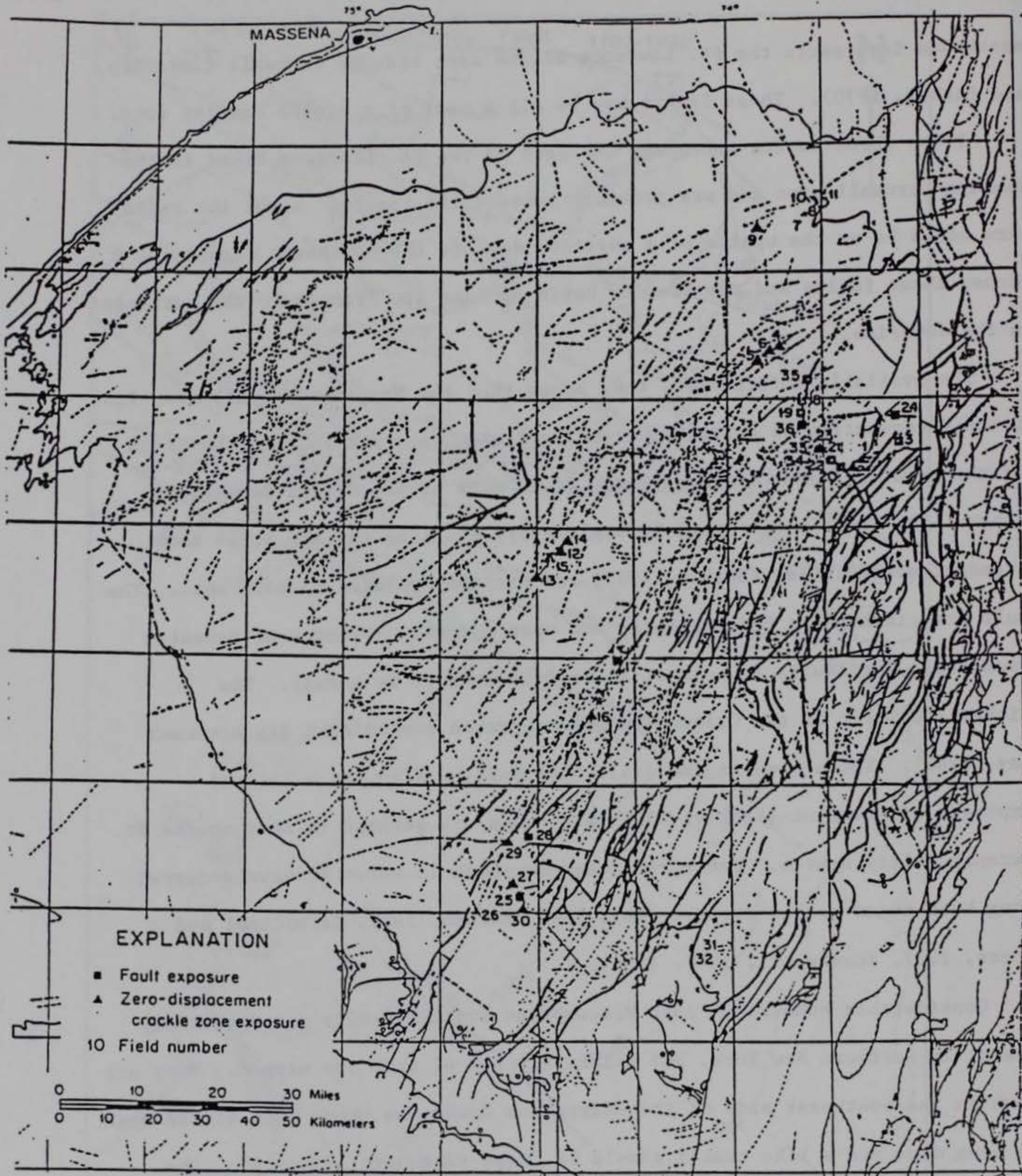
Figure 13. Map of the Adirondack region of New York showing brittle
structures (Isachsen and others, 1983), Explanation: solid lines, mapped
faults, dashed lines, inferred faults.

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faults, however, are well expressed topographically where there is relief and therefore topographic lineaments may be considered probable faults (Kay, 1942; Isachsen and McKendree, 1977). Many of these probable faults are compiled along with mapped faults for the Adirondack region (Isachsen and McKendree, 1977), but many more are present in the northern part.

The Adirondack uplift is bordered on the east by the north-trending Lake Champlain-Lake George graben system. This is the third great graben system in the region. It continues north and intersects the St. Lawrence system east of Montreal, Quebec. Faults splay off this system to the south and extend southwest across the southeast half of the Adirondack Uplift. These normal faults have tilted large blocks and dominate the topography in this part of the uplift (Kay, 1942).

In the northern part of the uplift lesser numbers of northeast-trending faults are present and many, probably small, faults, that trend N40-45° W are shown by nearly parallel stream channels. The N60W-trending lineaments that extend from the faults at Massena are anomalous to this pattern. Another N60W zone of en echelon lineaments passes through the Canton, New York area to the south (Fig. 11). A similar trending break in the magnetic pattern on the St. Lawrence near Ogdensburg (Revetta and others, 1975) may also represent a fault in this zone. These and other zones are suggested from the geophysical data (Barosh, 1985) (Fig. 14). Close to the Canadian border is a zone of nearly east-trending lineaments, that may be akin to the east-trending faults to the north in eastern Ontario (Fig. 11).

The Adirondack uplift thus is not a simple dome, but one strongly modified by normal faulting on the east and southeast, to some extent on its northwest side and apparently by at least minor normal faulting along its north edge.
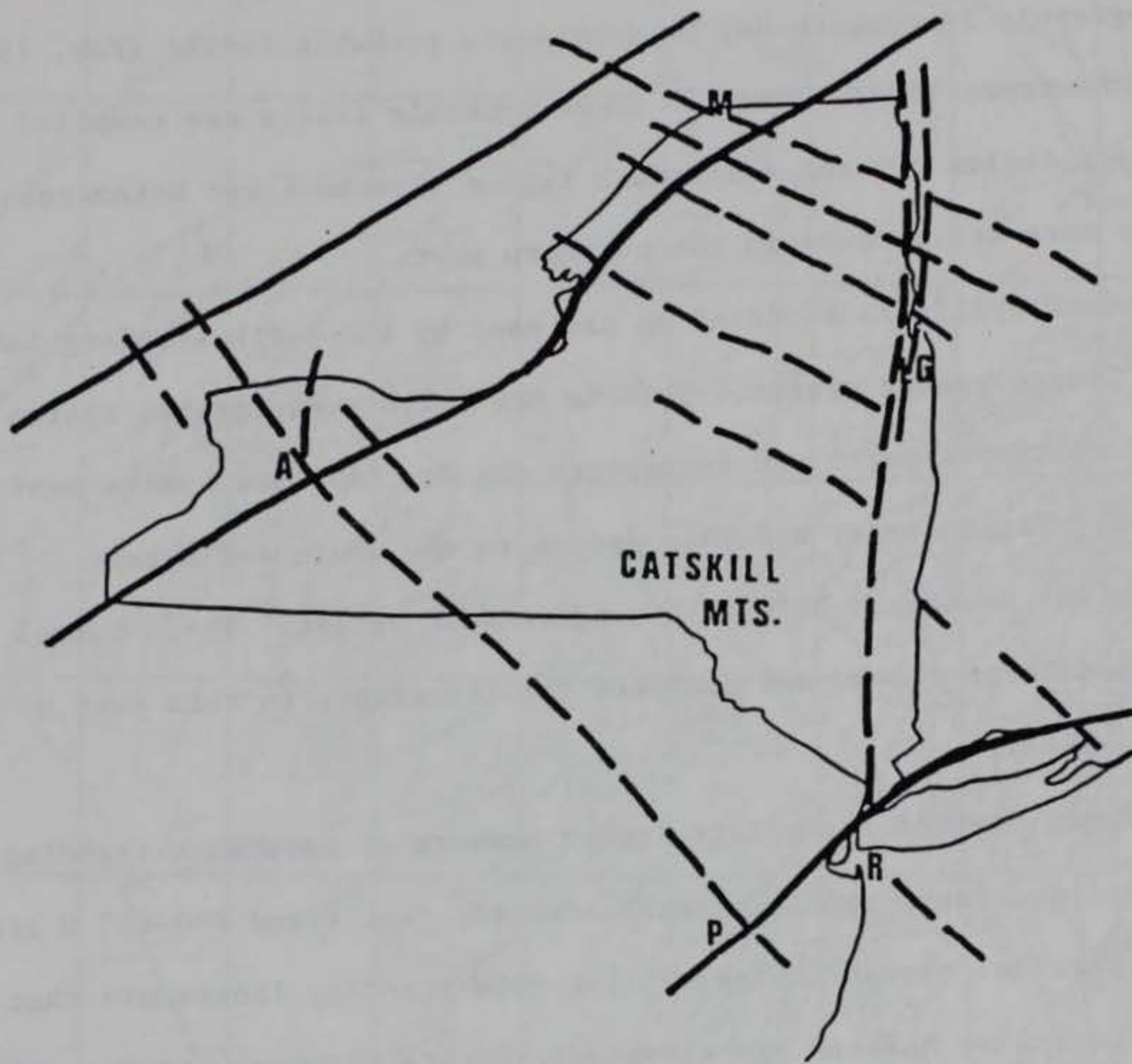
Figure 14. Sketch map of New York showing probable fault zones that may
localize present day movement causing earthquakes (Barosh, 1985).
Explanation: dashed lines-fault zones; solid lines, St. Lawrence trough
interior and boundary of Coastal Plain near coast; M, Massena; A, Attica; G,
Lake George; P, Philadelphia; and R, Raritan Bay.

The Madawaska highlands between the Ottawa-Bonnechere graben and Lake Ontario are also due to a combination of normal faulting and arching (Kay, 1942) (Figs. 10 and 15). The faults in the hilly region northeast of the graben and north of Ottawa are not well documented as there are few good marker units to show offsets. The topography of this part of southwest Quebec shows numerous prominent lineaments subparallel to the graben. The zone is nearly 90 miles wide and its northeast border is marked by a prominent change to generally northeast stream trends. This change must represent some kind of structural zone.

SURFICIAL GEOLOGY

The surficial material in the region consists of the usual Late Pleistocene till, scattered overlying outwash and local lake deposits, that were formed locally at the edge of the ice as it retreated across the region, and very local Holocene sand and gravel deposits, that lie along the larger streams and rivers. A more unusual deposit is the Champlain marine clay that has caused many engineering problems across the region.

When the St. Lawrence Valley became free of ice as glaciers melted about 12,000 years ago, the sea rushed in and filled valleys in the still depressed crust. The area around Lake Champlain became the site of a wider and deeper Champlain Sea. Arms of the sea extended up the St. Lawrence and Ottawa rivers above Montreal and many low lying areas were flooded. A medium- to dark-gray maine silty and sandy clay was deposited in it. In places the clay lies over earlier fresh water lake sediments. As glacial rebound took effect the region rose above the sea, which was also rising, draining the marine waters and exposing the clay (Fig. 16).

In the Massena area there are irregular deposits of till capped by outwash and, in low lying areas, the Champlain clay (Fig. 17). The sand to

QUEBEC | O N T A R I O | N E W YORK

| LAKE ONTARIO HOMOCLINE

| LAURENTIAN HIGHLANDS | OTTAWA-BONNECHERE GRABEN | MADAWASKA HIGHLANDS | CASHEL PENEPLANE | PALEOZOIC PLAIN | LAKE ONTARIO |

2000'
0'
-2000'
-4000

Mohawkian limestones *

Top Albion

Top Trenton

0   20   40

Aproximate horizontal scale
in miles
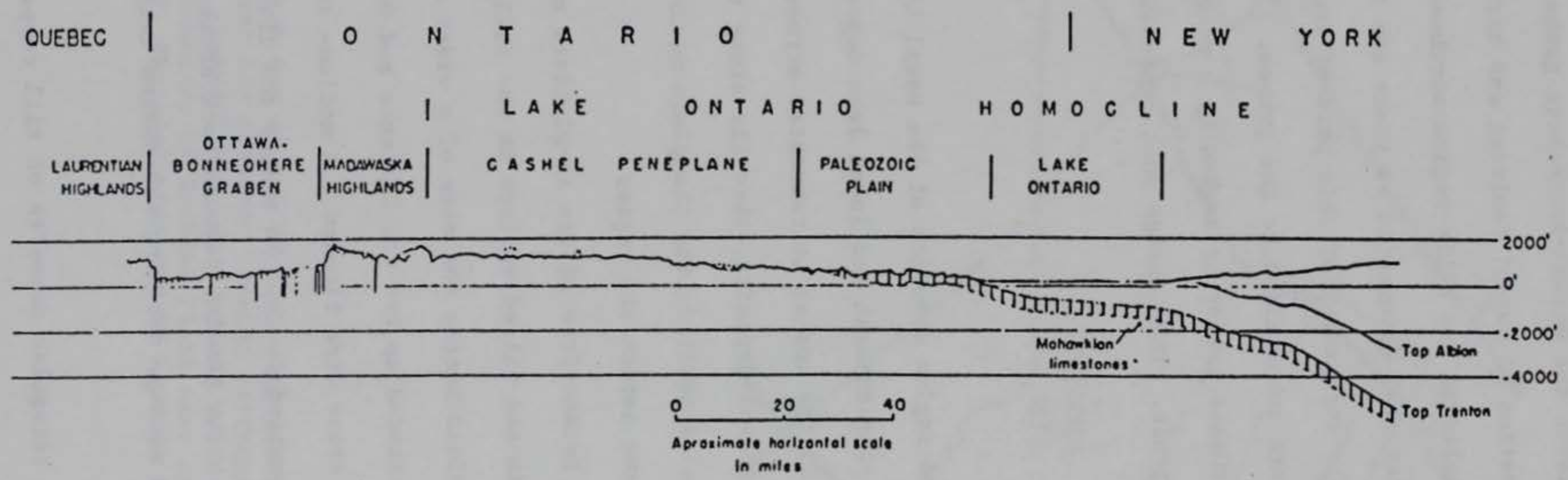
Figure 15. Geologic structure section from the Ottawa river, on the north to central New York on the south (Kay, 1942).
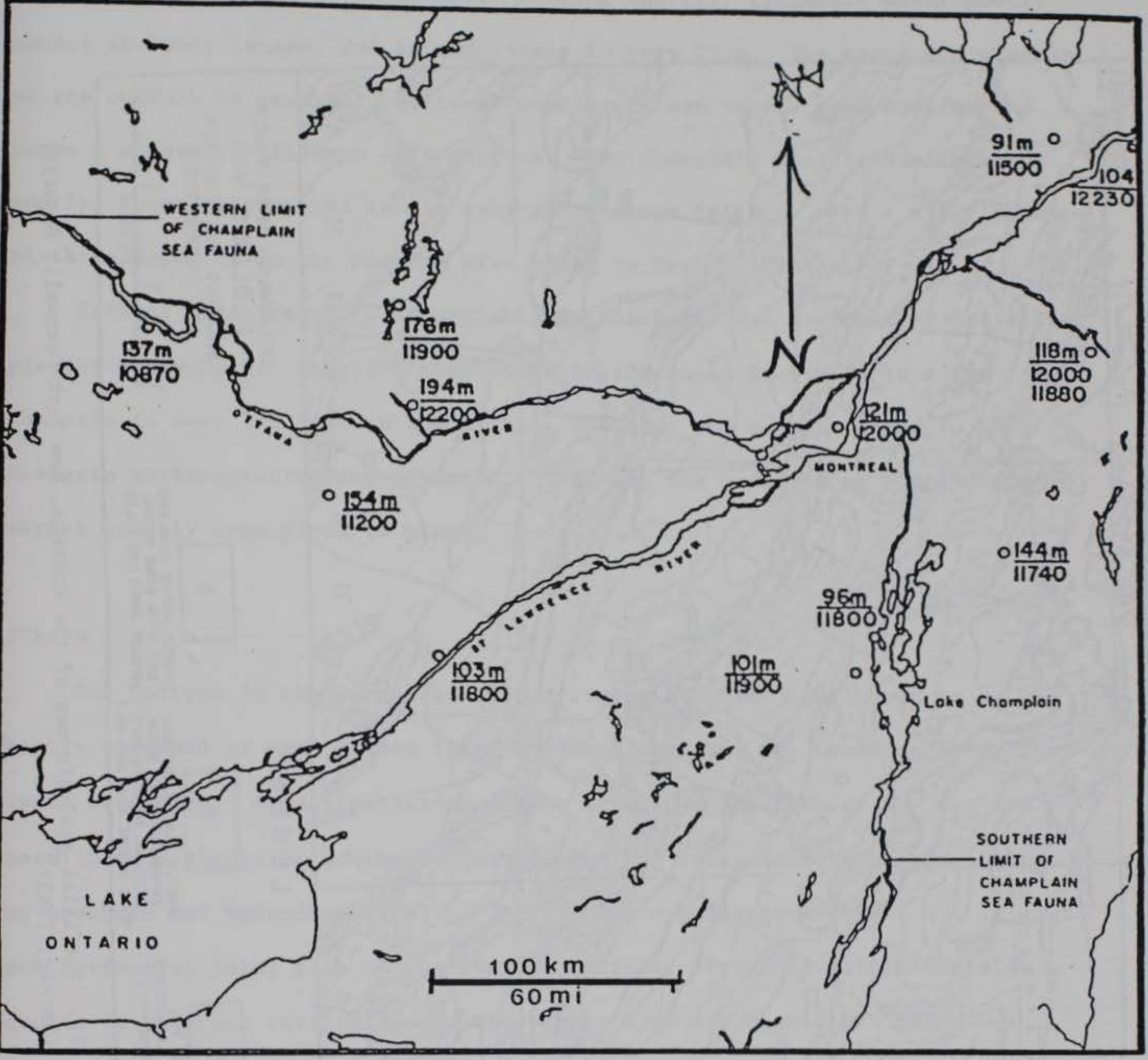
Figure 16. Map of northern New York and adjacent areas showing altitude (in
meters) and age (in C 14 years) of Champlain sea deposits (modified from
Pardi, 1982).
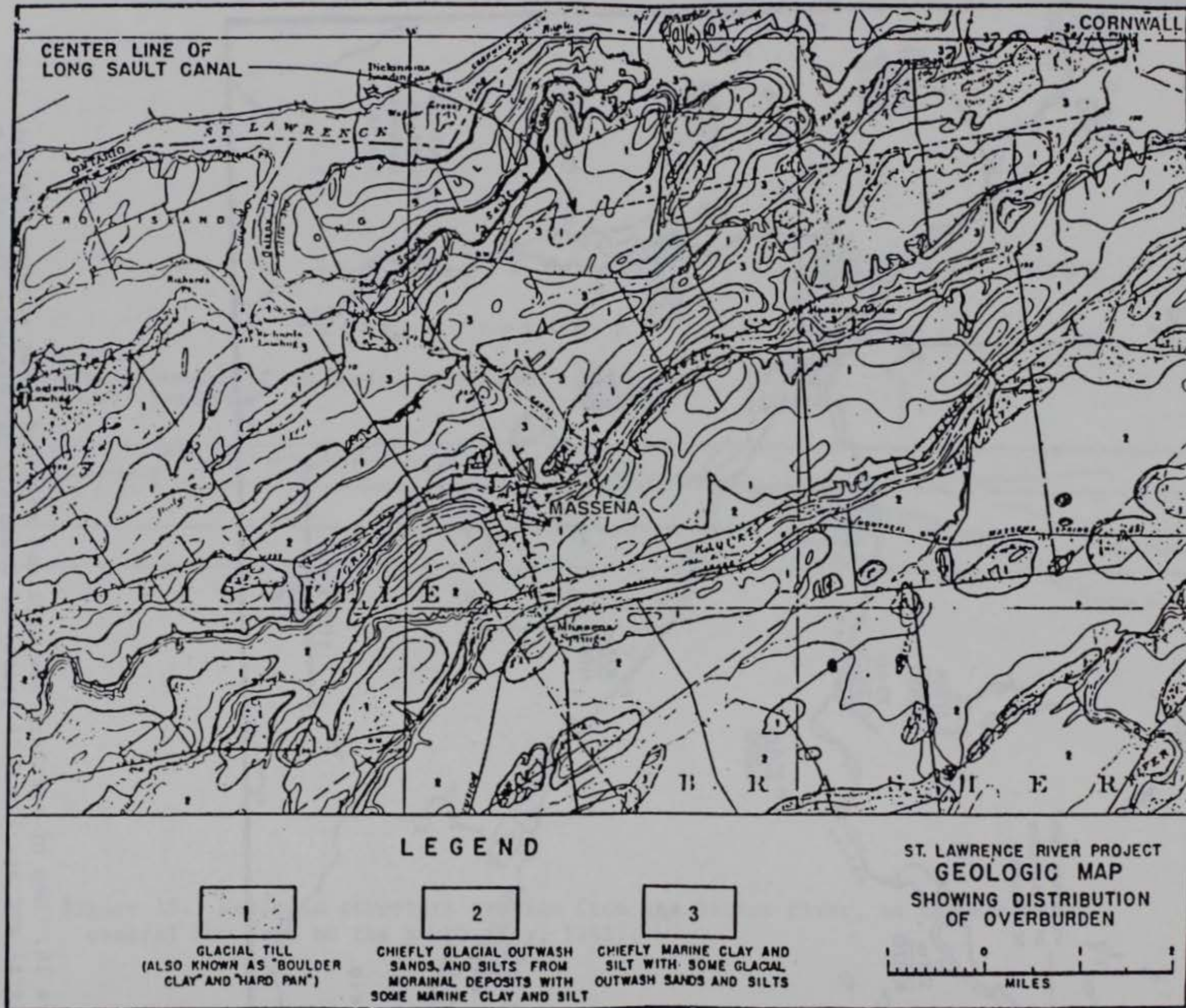
Figure 17. Surficial geologic map of the Massena, New York-Cornwall, Ontario area (Berkey, 1945).

clay mixture with scattered boulders forming the till transmits water poorly
except in sandy lenses, and is moderately to very firm. The sands and gravels
of the outwash is generally quite permeable and can make a good aquifer and
forms a moderately firm to soft surface. The Champlain clay transmits water
poorly, forms soft ground and is subject to slope failure. For a description
of these deposits in the Massena area refer to Berkey (1945).

Each of these deposits is variable in thickness and are usually not all
present everywhere. Together they range in thickness from zero in a few river
channels to over 100 feet in thickness. The clay and outwash tends to form
elongate northeast-trending deposits. Overall, the material at the surface
varies greatly from place to place.

STRAIN

The bedrock in the northeast United States has been long known to be
highly strained in many places (Barosh, 1986c) and the St. Lawrence River area
is no exception. A manifestation of this strain in the form of pop ups are
seen in many places in southeast Ontario and New York and several are plotted
by Isachsen and McKendree (1977). The pop ups usually form in a
sub-horizontal joint slab on the bedrock surface. Pressure within the slab
causes it to crack vertically and the broken ends are pushed or "popped"
upwards. Sometimes the slab does not break but bows upward leaving a hollow
beneath. Berkey (1945) shows a photograph of such a hollow near Massena.

The high strain in the rock in New England can generally be shown to be
residual strain from Late Precambrian and early Paleozoic tectonic events
(Barosh, 1986c). The pop ups are related to strain release, but may also have
an extra component of stress from the weathering of constituent minerals at
the surface and their subsequent expansion. They tend to be related to
sheeting or exfoliation type jointing. Although pop ups can be triggered by

seismic waves, as seen at the Nevada Test Site, there is no known relation of their distribution and seismicity. However, the highly strained rock may cause added problems in deep excavations and tunnels

CRUSTAL MOVEMENT

Crustal movement is taking place in the region around Massena as shown by changes in releveling surveys and lake levels. This is apparently resulting from both waning uplift due to glacial rebound, and tectonic forces. Near the end of the Precambrian the rock was worn smooth except for an occasional hill a few hundred feet high (Kay, 1942) and this surface serves as a datum plane for warping that has occurred since. It appears that nearby elevated portions of this surface are still rising.

The Canadian Shield and the northeastern United States have risen in post-Pleistocene time about a center in Hudson Bay due to glacial unloading and produced a general southerly tilt. Thus, the Champlain marine clay that was deposited near sea level around Massena in the Late Pleistocene is now over 200 feet in altitude, despite the rise in sea level since its deposition (Fig. 16). Its surface would provide an excellent control for deformation were it defined more closely. The Canadian Shield is still rising in a similar manner although the movement due to unloading is essentially complete farther south in the United States. The movement is still centered around Hudson Bay and thus causes a general tilt to the southeast towards Massena, where it may have a small effect (Vanicek and Nagy, 1980) (Fig. 18).

The upwarped Precambrian surface in the Adirondack Mountains is indicated to be still rising at a rate of 3.7 mm/yr (Isachsen, 1975, 1981, Barnett and Isachsen, 1980) (Figs 19 and 20). This is unrelated to ice unloading and must be tectonic in nature. The arching across the Adirondack uplift is well shown along its east side and is greatest adjacent to its higher parts. The arching
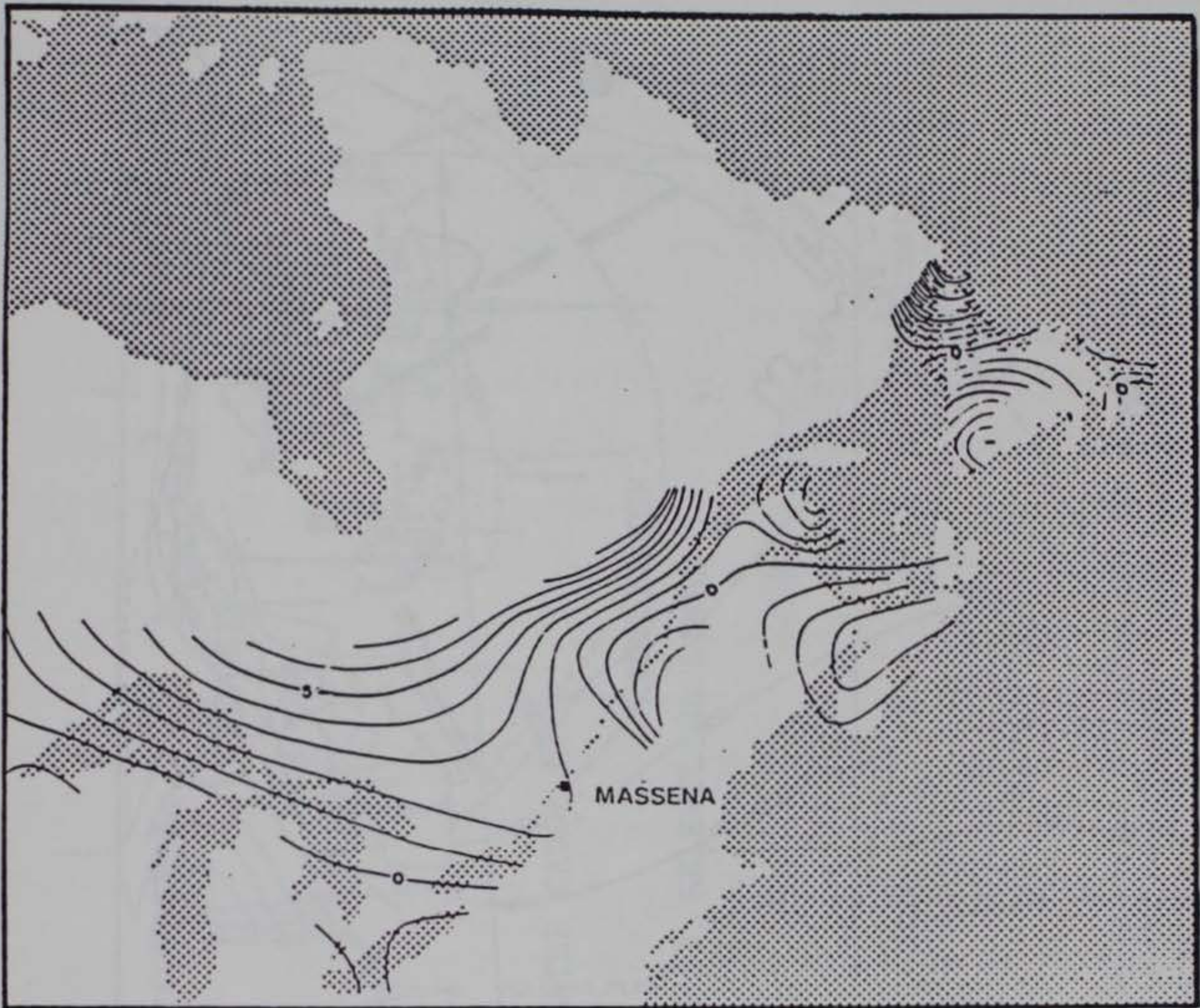
Figure 18. Map of southeastern Canada showing apparent vertical movement of the crust in millimeters per year (modified from Vanicek and Nagy, 1980).
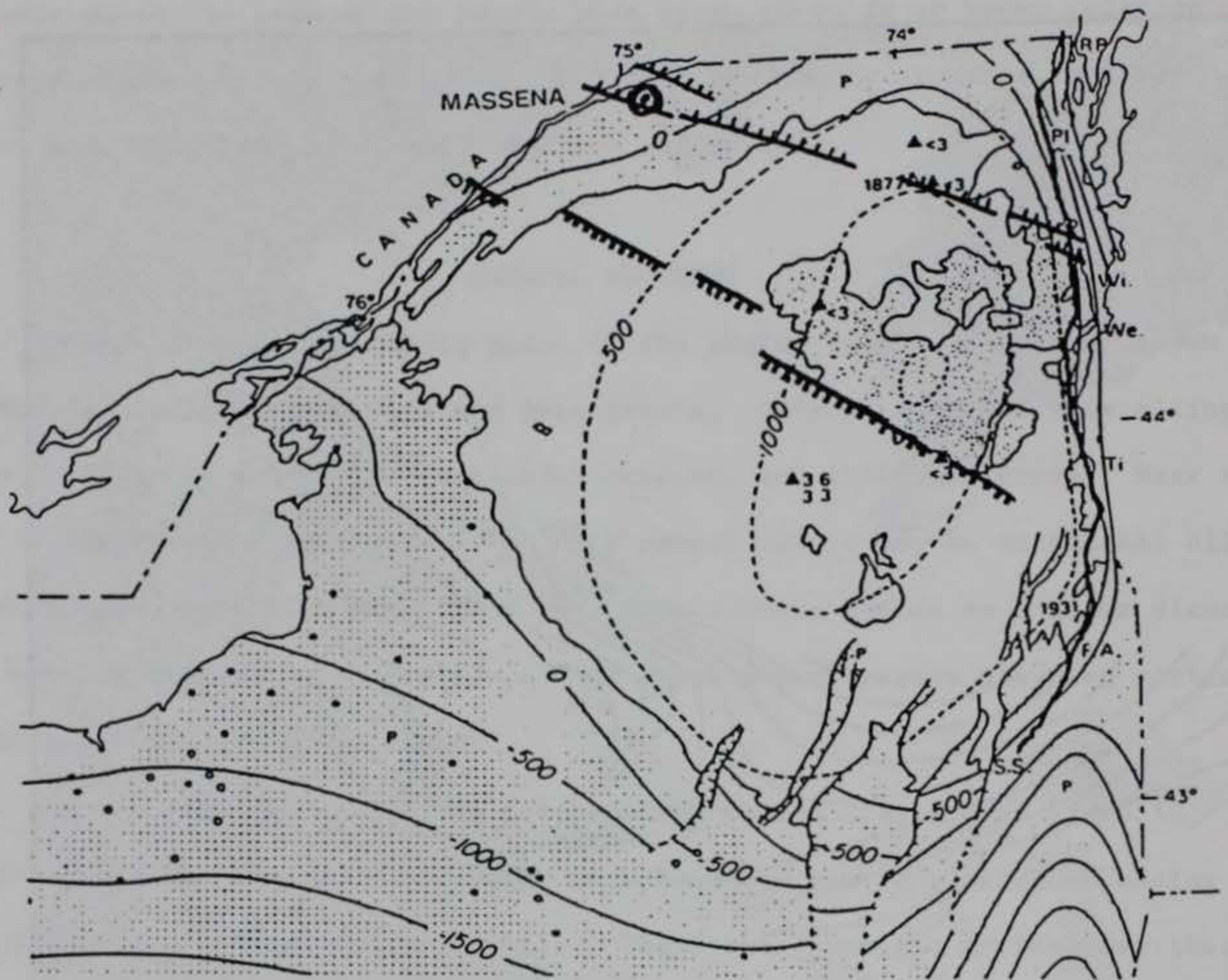
EXPLANATION

P	Paleozoic strata
	Proterozoic metamorphic rocks; anorthosite suite stippled
—— ---	Structure contour, in meters, on Proterozoic basement, with reference to sea level; dashed where reconstructed.
	Prominent normal fault which involves downdropped Paleozoic rocks
	Releveled

Drill hole:

• Penetrates basement

○ Depth to basement inferred

Earthquake:

▲3.6 site and magnitude of event which occurred between 1955 and 1973

△1877 site and date of intensity VII event

N

0 10 20 30 40 50 Kilometers
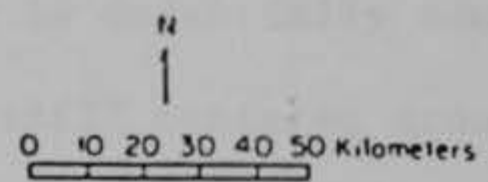
Figure 19. Map of northern New York showing structural configuration of the Adirondack uplift and location of releveled line (Isachsen, 1975). Explanation: Heavy lines with ticks, border of theoretical horst.
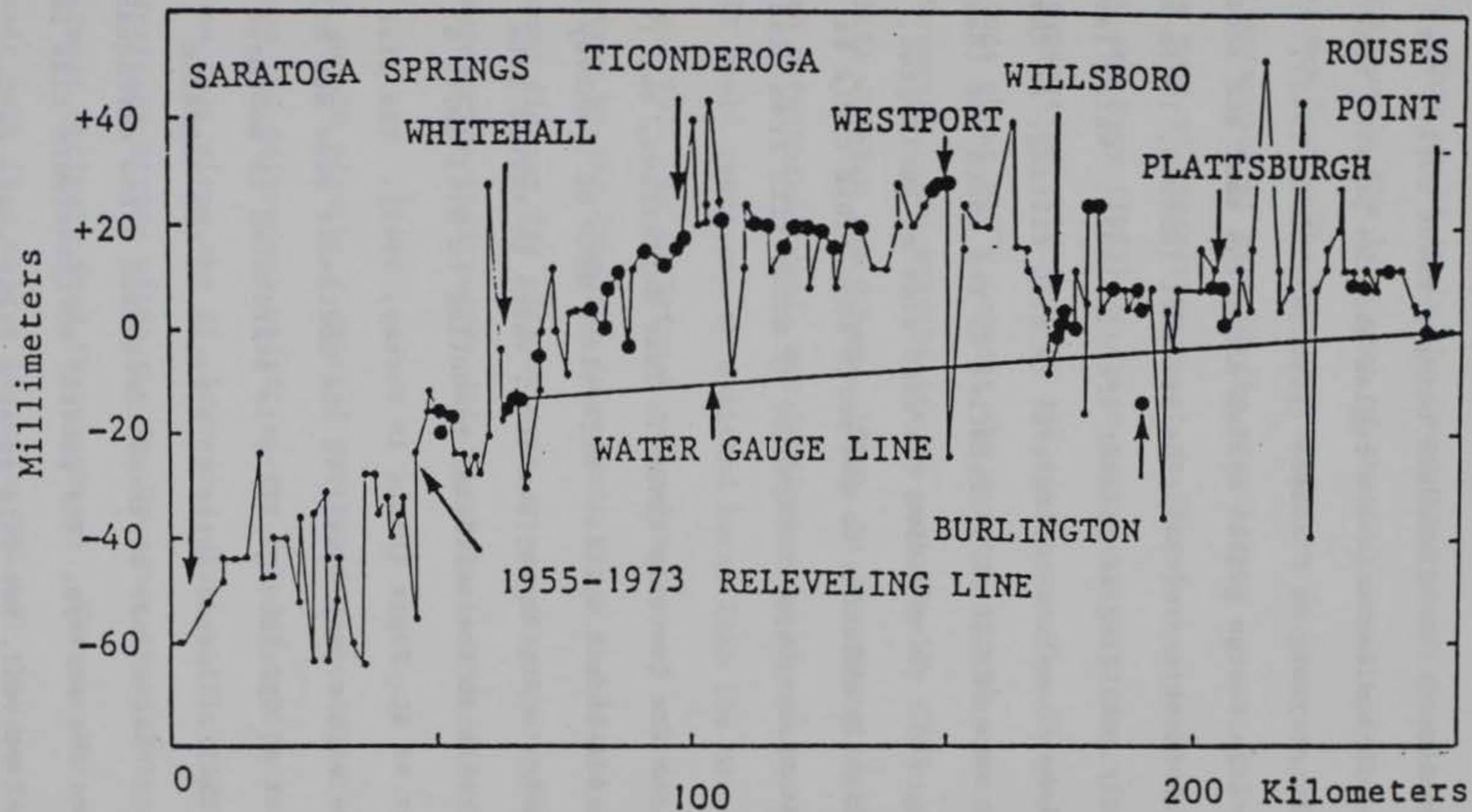
Figure 20. Altitude changes in releveled line along the east side of the Adirondack uplift adjusted to the Lake Champlain water level gauge profile line for the same period (Barnett and Isachsen, 1980). See Fig. 19 for location.

ends to the north at Willsboro, New York, where Lake Champlain widens out to the north. Most of the uplift is indicated to be in the eastern half of the anorthocite complex, that forms the core of the uplift (Pardi, 1982) (Fig. 19). There is no indication of the Adirondack being present during the deposition of the Paleozoic sediments in the region and the present rate of uplift suggests it may be as young as Pliocene (Isachsen, 1975, 1981).

The Lake Champlain-Lake George graben system along the east and southeast sides of the uplift has indications of Holocene movement (Barosh, 1986a and c) and is probably relatively subsiding at present (Pardi, 1982). Water levels at gauging stations on Lake Champlain indicate it is also tilting, as the north end is rising at a rate of 0.7 mm/yr relative to the south end (Barnett and Isachsen, 1980) (Fig. 20). In addition the east side at Burlington, Vermont is going down slightly relative to the north end. This could be caused by tectonic movements, perhaps accompanied by minor tilt from glacial rebound.

The movement along the St. Lawrence River is less definitive, but it can be fitted to that in the Adirondack uplift. Releveling data of a survey along the river from Lake Ontario to St. Regis, New York, which is across from Cornwall, shows a slight rise to the northeast amounting to 0.43 mm/yr at Ogdensburg and 1.65 mm/yr at St. Regis (Moore in Berkey, 1945). The rise forms a fairly even slope with a jump upward to the northeast near Red Mills, which is 7 miles northeast of Ogdensburg. This is attributed to movement across a fault (Berkey, 1945). Indeed there is a break in the magnetic pattern in the river here, that trends north-northwest and a few earthquakes occurred near here between the surveys. The general northeastward rise has been attributed to glacial rebound, but this is at a right angle to the general movement both in the past and present. In addition, the rate of uplift given for Quebec, Quebec much farther to the northeast (Moore in

Berkey, 1945) is only two/thirds of that for St. Regis, not more as might be expected. Another explanation would be uplift and tilting, related to normal faulting, such as that between the Ottawa-Bonnechere graben and Lake Ontario (Fig. 15). This would imply the level line would drop beyond St. Regis and making it resemble the line east of the Adirondack uplift with its drop at Willsboro, New York. The movement along the St. Lawrence may thus be a northwest extension of part of the rise of the core of the Adirondack uplift and such a zone of greater movement on the north side of the uplift is shown by Vanicek and Nagy (1980) in their regional study (Fig. 18). Geologic evidence supporting this is that the rising anorthosite core of the Adirondack uplift trends about N60°W towards the stretch of river between Ogdensburg, New York and Cornwall. The anorthosite is geologically the highest raised portion of the uplift (Bohlen and Others, 1980), is discordant to the other Precambrian structural trends and is flanked by lineaments that are probably faults. It could represent an uplifted horst like the Matawaska highlands (Figs. 15 and 19). An additional releveling survey was done near the St. Lawrence River by the Canadian government after the 1944 earthquake, but the changes found did not fit with offsets expected by the investigators (Hodgson, 1945a). Recovering this survey data may help in understanding the movements here.

There should also be a general northwest component of tilt towards Massena from the Adirondack uplift as the rate of uplift in its center is greater than that along the St. Lawrence. Such a tilt might help explain the peculiar drainage divide along the St. Lawrence river. The drainage into the river is almost entirely from the southeast. Whereas the drainage divide on the northwest bank lies only a few miles inland. The rest of the surface water on this side flows north into the Ottowa river. A more local fit of the

releveling data by Pardi (1982) than that of Vanicek and Nagy (1980) did indicate relative subsidence in the vicinity of the St. Lawrence.

In summary, considerable crustal movement is happening in the region. The Canadian Shield is tilting to the southeast, the Adirondack uplift rising and the Lake Champlain-Lake George graben system and the St. Lawrence lowland subsiding. The movement in the Adirondack uplift is not a simple doming, but more likely one that bulges out to the northwest. This could be due to a rising and slightly tilting northwest-plunging central horst containing the anorthosite core rock (Fig. 19). Massena may lie at the northern edge of the extension of this horst. A slight sideways tilt of the horst movement may explain the slight southwest tilt along the St. Lawrence river upstream from Massena, and a small fault offset, down to the southwest, near Red Mill, New York, may mark its southern edge. The northeast side of the uplifted horst is where Lake Champlain widens to the north and probably also where the St. Lawrence widens downstream of Massena to form the Lake Francis basin.

GEOLOGIC ANALYSIS OF ISOSEISMAL PATTERNS AND LOCAL VARIATIONS OF INTENSITY

The isoseismal pattern is a function of the attenuation rate of seismic waves modified by geologic structure and local ground conditions. Local variations in intensity that are usually too small to show on the regional pattern are due to varying ground conditions and quality of construction. Analysis of the intensity can therefore lead to a better understanding of the earthquake effects and clues to its causative structure.

The pattern of the 1944 Massena-Cornwall earthquake (Fig. 5) shows similarities with those of other large earthquakes in southeast Canada; an elongation of the isoseismals southwestward over the upper St. Lawrence and lower Great Lakes, a southward extension down the Atlantic coast and a change at southeast New England. These correspond, respectively, to the St. Lawrence

Valley rift system, the softer ground of the Atlantic coastal plain and a change in structural blocks at the southeast side of the northern Appalachian Mountains. The 1944 event also shows an eastward cut off and southward extension of intensity V at the Lake Champlain-Lake George graben system and an outlier of intensity V along the river lowlands near the New York-Pennsylvania border. Most importantly the inner isoseismals show both a southwest extension up the St. Lawrence and a southeast one towards Lake Champlain. The inner isoseismal pattern commonly reflects the causative structure, although it may be reinforced by softer ground along a fault zone.

The southwestward extension of isoseismals is common for even small earthquakes along the St. Lawrence (Fig. 21). It is not merely due to the presence of softer sediments in the river valley as the extension is not usually northeastward down the river or into side valleys which contain similar soft sediments. The pattern, thus, appears at least partly related to a causative structure.

There are also other earthquakes in the region with inner northwest-trending isoseismal patterns that are aligned or closely parallel to the southeast extension of the high intensities of the 1944 earthquake. The 1935 Timiskaming earthquake showed an elongation of both the intensity V and VI isoseismals, that follow the Ottawa-Bonnechere graben to the Massena area (Fig. 22). Small earthquakes southeast of Massena also show this pattern (Fig. 23). There are no zones of soft ground in northern New York to explain this.

These regional patterns are very different from the very local ones in the Massena-Cornwall area that are due to local ground conditions. The damage in the epicentral area of the 1944 earthquake is reported to be very patchy and related to the type of surficial material found locally (Fig. 17). Buildings on the Champlain clay were particularly vulnerable. A
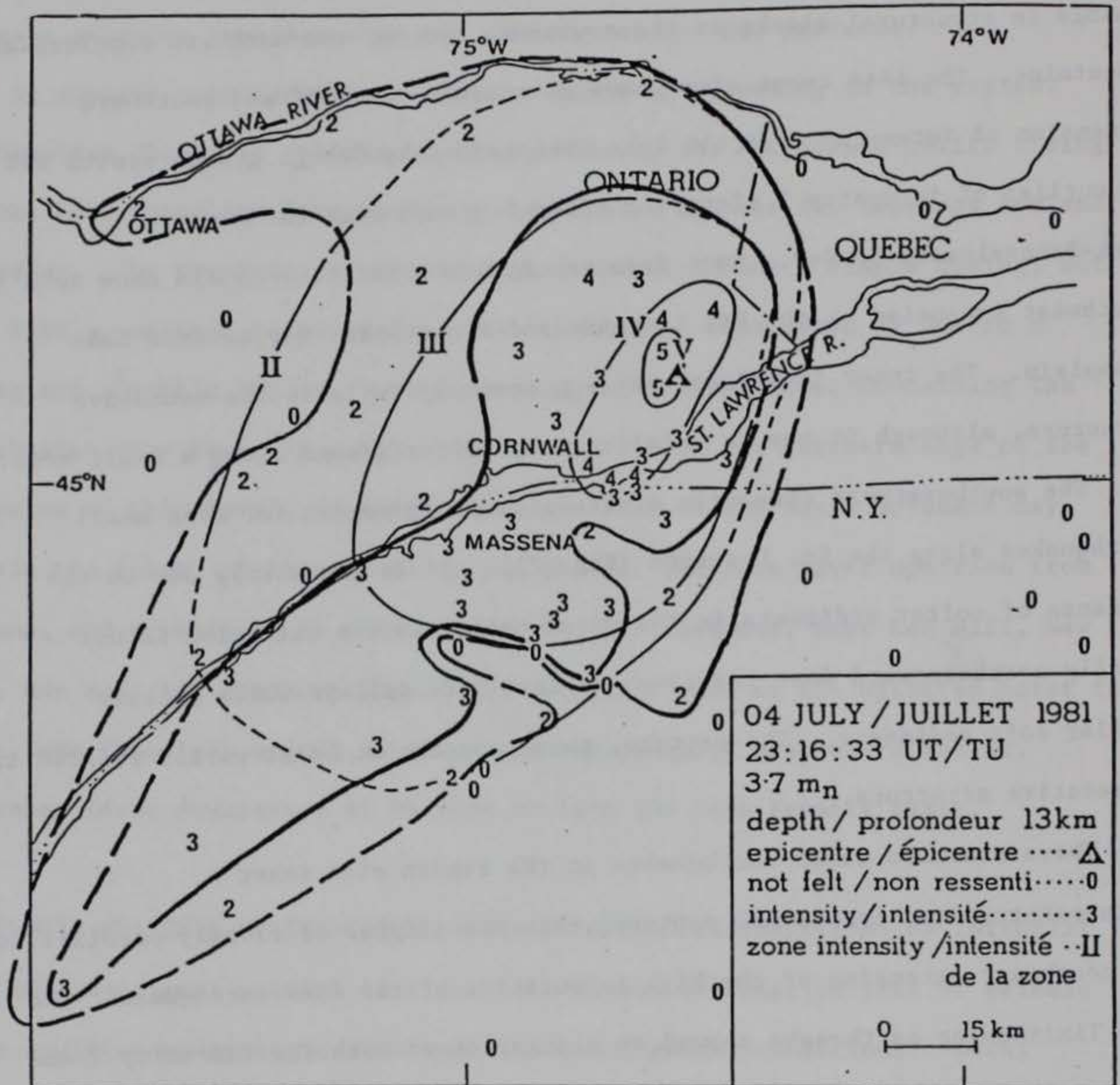
Figure 21.   Isoseismal map of the 1981 Cornwall, Ontario earthquake (modified from Drysdale and others, 1982).   Explanation: thin lines, isoseismal boundaries of Drysdale and others, 1982; thick lines, revised isoseismal boundaries.
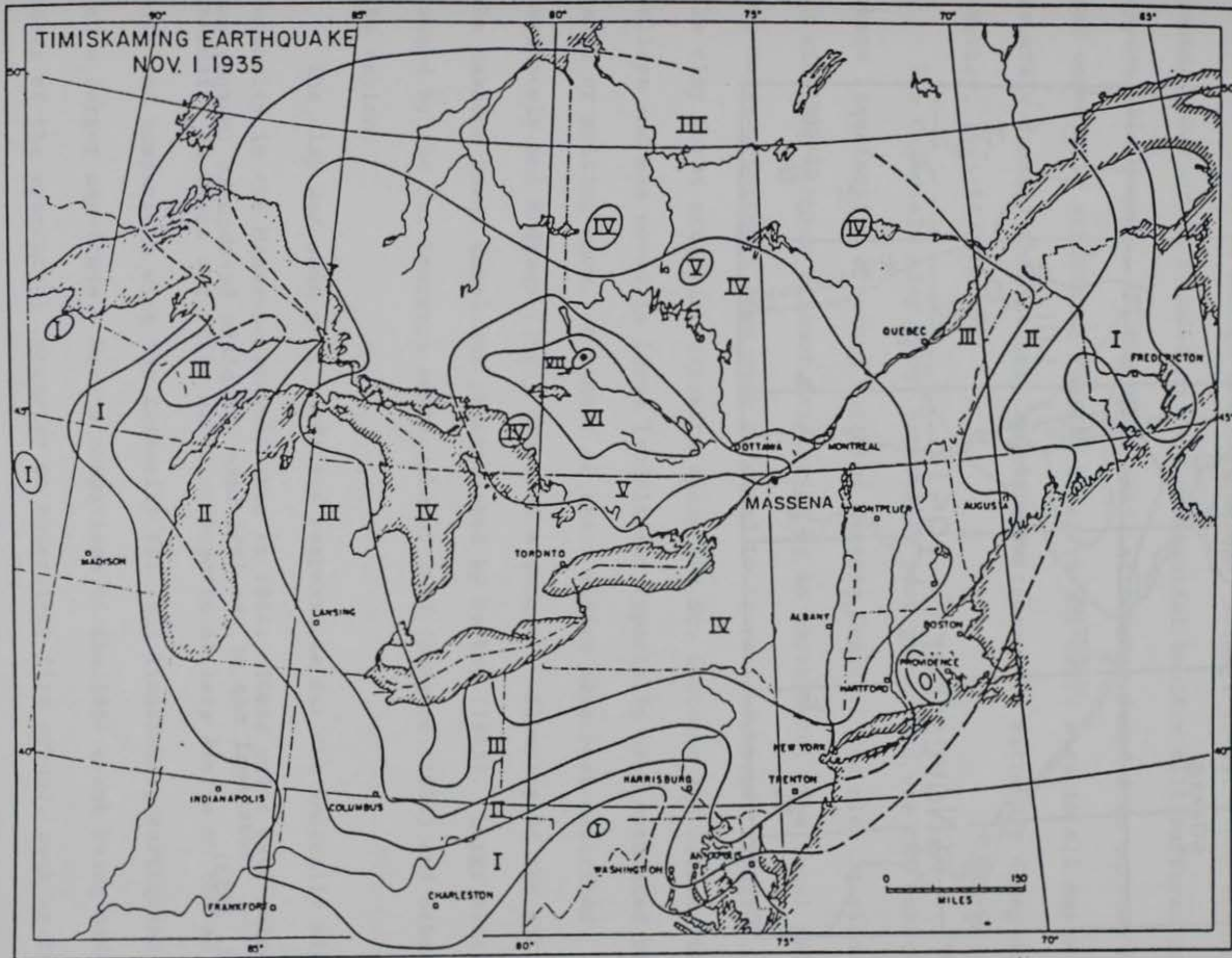
Figure 22.   Isoseismal map of the 1935 Timiskaming earthquake (Smith, 1966).
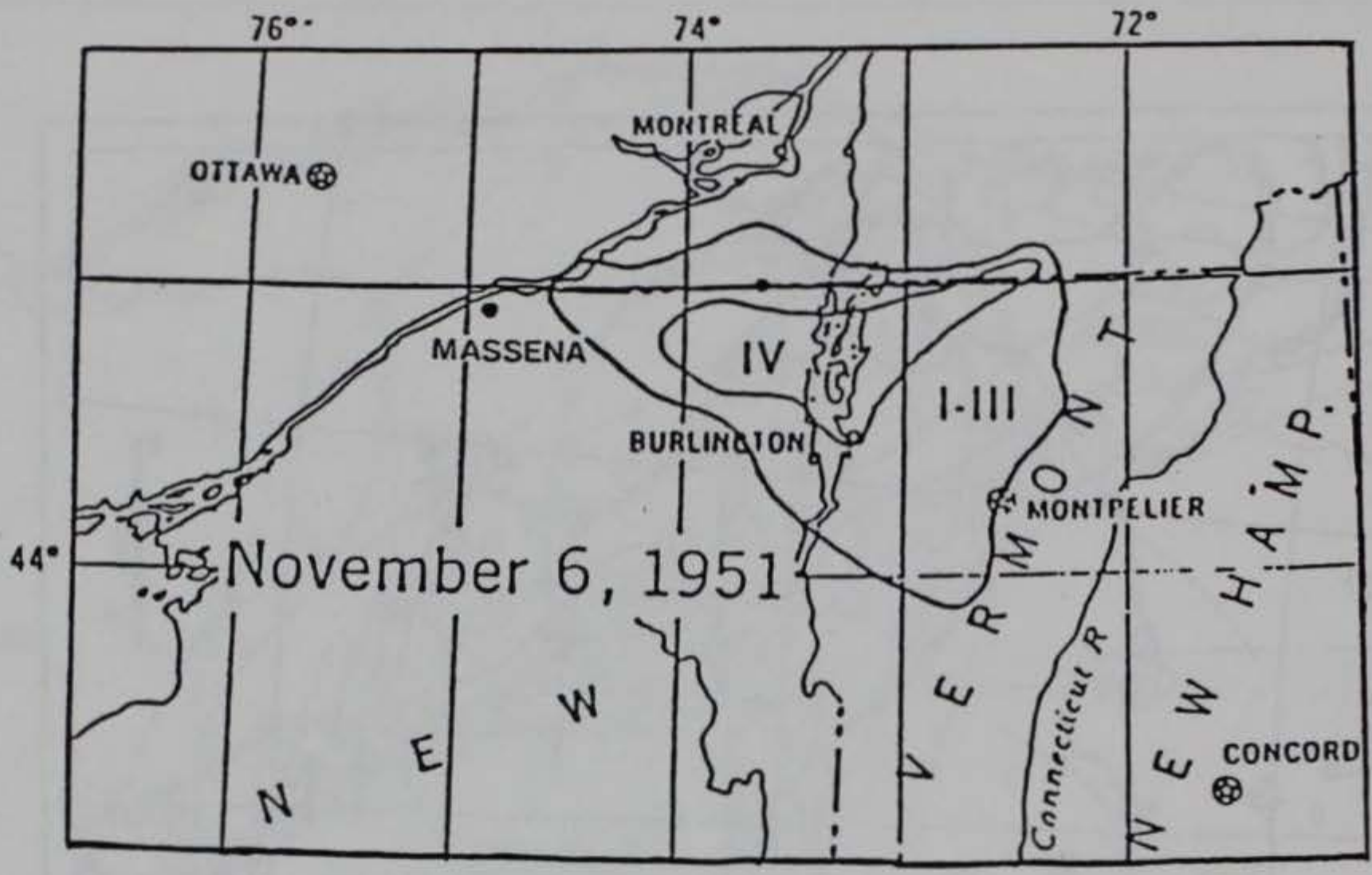
Figure 23. Isoseismal map of the 1951 Lake Champlain Earthquake (Murphy and Cloud, 1953).

northeast-trending zone through Cornwall that is over clay was especially damaged; cemeteries in clay were badly damaged whereas a nearby one on glacial drift had almost no damage (Hodgson, 1945a, Berkey, 1945). "--no structures founded on rock or founded on very substantial boulder till suffered any appreciable damage. On the other hand, structures founded on outwash sands and especially structures founded on silts and clays were in all cases more severely damaged than others, and in some cases were extremely damaged." (Berkey, 1945).

The Champlain clay forms especially poor ground and was the substratum where liquefaction occurred north of Massena Center. The clay is also prone to slumping with or without triggering by an earthquake. The local people in the Massena-Cornwall area even referred to it as "quicksand" (Hodgson, 1945a). The clay forms extensive deposits along the St. Lawrence and Ottawa river valleys and has moved in large landslides, especially when saturated by heavy rains or melting snow. A number of these slides have been described separately and Hodgson (1927) prepared a summary. Slumping of the clay along the Massena Power Canal was photographed by Berkey (1945). Large slides were caused by the St. Lawrence earthquake of 1663 (Hodgson, 1928) and others in the region.

The clay and some soft sands are responsible for the unusually high intensity in the Massena-Cornwall area in 1944. These units have raised the intensity at least one unit, based on reports of less damage on the adjacent till and comparison with the intensity VII 1935 Timiskaming earthquake, that had a larger magnitude. Were a comparison of the 1944 event being made on the basis of the epicentral intensity on moderately firm ground, such as till, then an intensity VII would be appropriate.

CAUSE OF EARTHQUAKES

The cause of earthquakes in the Massena area can be sought several different ways in regions where surface faulting has not been observed to be associated with seismic events. These are the analysis of the distribution of seismicity, relation of seismicity with faults, isoseismal patterns, crustal movement, focal plane solutions and nearby or regional relations.

The distribution of seismicity does not reveal any close alignment of epicenters delineating a particular active fault, however, it does show that Massena lies at the intersection of two major zones of seismicity: the northeast-trending Arkansas-St. Lawrence zone and the northwest-trending Southwest Quebec zone. These two major seismic zones correspond with two structural zones with normal faults: the northeast-trending St. Lawrence Valley rift system of Kumarapeli and Saul, (1966) and a northwest-trending system that includes the Ottawa-Bonnechere graben of Kay (1942) (Barosh, 1981, 1986a and c), (Forsyth, 1981) (Fig. 24). Faults have yet to be mapped along the northeast side of the graben, but the stream pattern strongly suggests their presence and the change in pattern at the border of the zone must represent some structural boundary (Fig. 24). The Ottawa-Bonnechere graben zone coincides with a northwest trending alignment of concentrations of epicenters that includes the concentration at Massena. The Ottawa-Bonnechere zone appears to extend to Lake Champlain passing along the active areas of northern New York (Figs. 6, 11, and 24). This also is roughly aligned with fracture zones that continue across New England to the coast and have seismicity associated with them in central New Hampshire (Barosh, 1986b) (Fig. 6).

Another major graben system in the region is the north-trending Lake Champlain-Lake George graben system. It corresponds with some mild seismic activity and serves as the southeast boundary of the Southwest Quebec zone.
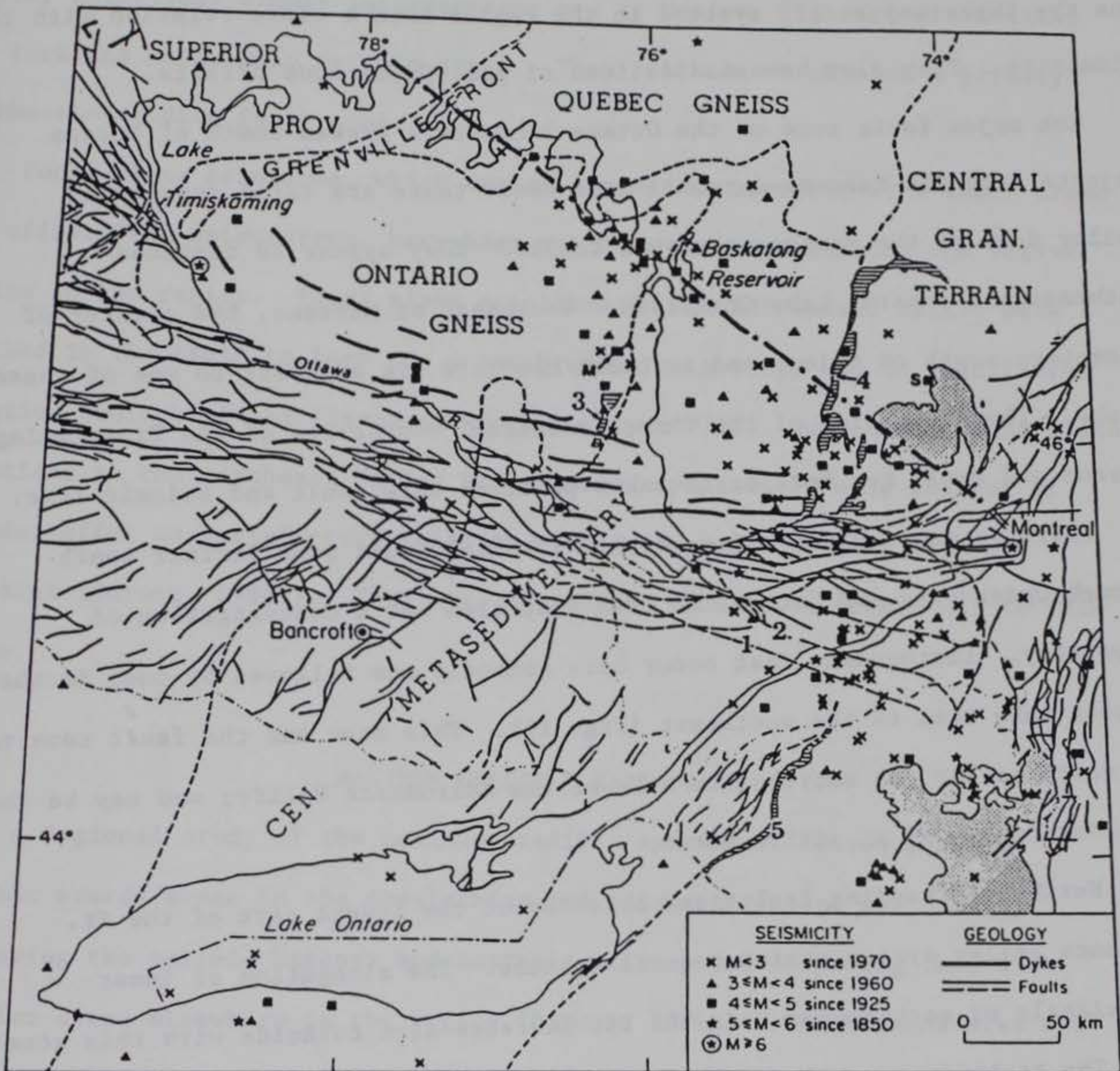
Figure 24. Map of southwestern Quebec, eastern Ontario and northern New York showing relations of mapped faults, dikes and earthquakes in the southwest Quebec seismic zone (Forsyth, 1981). Dot-dashed line shows approximate position of pronounced change in stream trends.

Thus the three major rift systems in the region show a close relation with the seismicity. They also have indications of post-Cretaceous offsets.

The major fault zone of the Ottawa-Bonnechere graben south of Ottawa projects into the Massena-Cornwall area where there are three apparently similar down to the northeast normal faults. They appear to continue southeastward towards Lake Champlain. Southeast of Massena, the cluster of epicenters south of Malone and at Lyons Mountain lie adjacent to one of these breaks. The elongation of the inner isoseismal boundaries of the Timiskaming, Massena and small New York earthquakes parallel this fault and seismic zone.

There is some evidence for another parallel fault zone farther south through Ogdensburg and Canton, an area that also has a concentration of seismicity. Earthquakes that occur here commonly are followed by ones in the Saranac Lake area to the southeast (Fig. 11). This zone and the fault zone to the north border the anorthosite core of the Adirondack Uplift; and may be the flanking faults of an active horst.

Northeast-trending faults and axis the of the lowest part of the St. Lawrence Valley system strike towards Massena. The elongation of inner isoseismals of earthquakes near the St. Lawrence also coincide with this zone.

The tectonic crustal movements in the region are consistent with the rising of the core of the Adirondack uplift with relative subsidence of the Lake Champlain-Lake George and St. Lawrence Valley rift systems. The core may be rising as a tilted horst flanked by active fault zones.

Thus, the seismic activity at Massena can be attributed to a zone of N60°W normal faults, down to the northeast, that are part of the Ottawa-Bonnechere graben system, where they intersect a zone of northeast trending faults lying just southeast of the St. Lawrence river (Fig. 11).

Seismicity caused by movement at such structural intersections appears to be the normal case in the eastern United States (Barosh, 1986a and c, 1990).

Similar relatively simple intersections are at Moodus, Connecticut, Attica, New York and Anna, Ohio seismic areas. They all seem to envolve a primary northwest-trending fault zone.

Focal plane solutions, which are an attempt to reconstruct a fault trend and offset from seismograms, have been put forth as representing the active faults in the region. Focal plane solutions in the Adirondack uplift were checked in the field to look for a match with the geology and no significant relation could be found (Isachsen and Geraghty, 1979). Subsequent focal plane solutions in the northeast United States show an extremely wide scatter of trends, offer no satisfactory relation with geology and to vary with the preparer (Barosh, 1986c). They are, therefore, considered irrelevant to this study.

MAXIMUM CREDIBLE EARTHQUAKE

A regional study of the maximum credible epicentral earthquakes for seismic source areas in the Appalachian and adjacent regions was made by reviewing the seismic history and tectonic setting and comparing them with similar areas elsewhere in the region (Barosh, 1986a). The Massena area was judged to have a maximum credible event of VIII in this regional study (Fig. 25). The more detailed analysis done for this study indicates the intensity VIII is a more conservative estimate than previously considered.

First, there is no nearby area with more violent activity that might arguably migrate towards it. The intensity VIII event at Massena is the highest intensity earthquake in the area. The Montreal area has had earthquakes as high as VIII, but no greater and it is doubtful that any great earthquakes could have been missed in this region in the past 400 years.

Second, the seismic record at Massena does not portend a larger earthquake. In general the larger the earthquake the greater numbers of
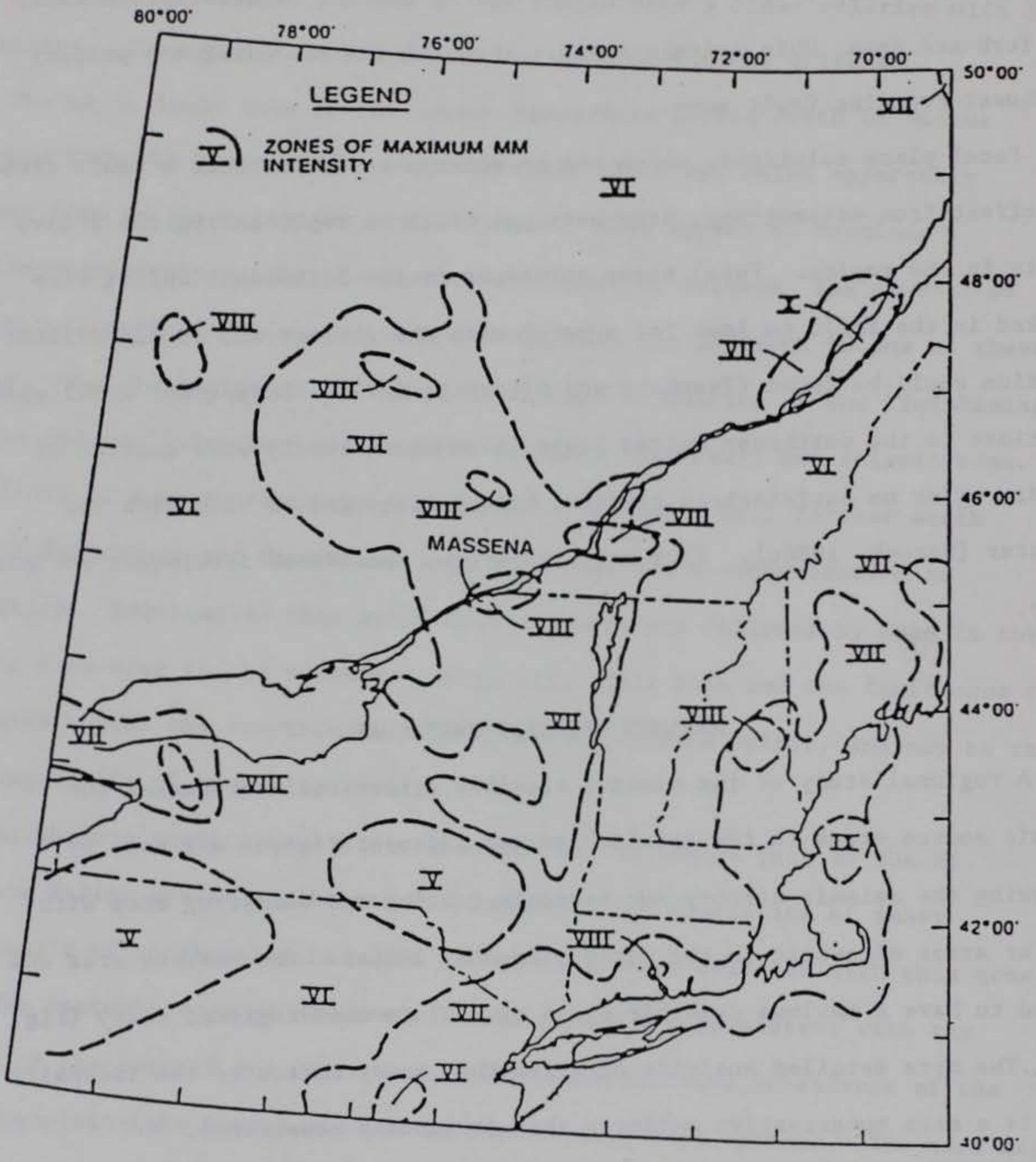
Figure 25. Map of northeastern United States and adjacent Canada showing maximum credible epicentral intensity (modified from Barosh, 1986a).

smaller ones in the vicinity. There are no clusters of intensity VII or even VI earthquakes to make one expect the potential for a very large earthquake.

Thirdly, other areas in the same tectonic setting have not had larger intensity earthquakes. There are at least nine other areas of similar tectonic setting in the Southwest Quebec seismic zone that have only experienced intensity VI or VII earthquakes in the last 130 years. The Montreal area, that has a setting most like Massena, it has experienced only one intensity VIII earthquake in over 330 years, although it lies in a more active northwest-trending zone of seismicity than Massena. This is the only other intensity VIII earthquake in the Southwest Quebec zone and it too may show the effects of poor ground. Fourthly, the intensity VIII at Massena is due to amplification by the Champlain clay and is anomalously high. The intensity on moderately firm ground should not have exceeded VII and the intensity VII Timiskaming earthquake was a stronger earthquake. The maximum credible earthquake needs to be taken as that on moderately firm ground.

Thus, an assignment of an intensity VIII on moderately firm ground for the maximum credible epicentral earthquake is one intensity unit higher than on record and is considered a very conservative assignment.

CONCLUSIONS

The Massena area lies at the intersection of two major seismic source zones; the northeast trending Arkansas-St. Lawrence zone and the northwest-trending Southwest Quebec zone. Both these zones coincide with zones of normal faults. Massena is near the southwest border of the Southwest Quebec zone and in the Ottawa-Bonnechere graben that controls the seismicity along the border. Massena appears to be on an extension of the Gloucester fault zone, a northwest-trending normal fault zone, that is down to the northeast, where it intersects an apparent zone of northeast-trending faults along the southeast side of the St. Lawrence river. The fault breccia found

in exploratory drilling for the seaway may belong to both sets of faults. These faults are probably involved in controlling part of the crustal movement occurring in the region that is raising the Adirondack uplift.

The Massena-Cornwall earthquake was apparently controlled by movement at the fault intersection and the high intensities followed both trends. The epicentral intensity VIII of this earthquake is unusually high due to the presence of poor ground formed mainly by the Late Pleistocene Champlain clay. The Champlain clay is subject to liquefaction, under earthquake loading, and is prone to slumping with or without an earthquake trigger. The maximum intensity on moderately firm ground is not greater than VII. This earthquake is the largest in the area and a maximum credible epicentral intensity, for moderately firm ground, of VIII is one higher and is conservative.

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APPENDIX B: A REPORT ON THE SEISMICITY OF NEW YORK,
NEW ENGLAND, AND SOUTHEASTERN CANADA

A REPORT ON THE SEISMICITY OF
NEW YORK, NEW ENGLAND AND SOUTHEASTERN CANADA

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SCOPE OF WORK

This report discusses the seismicity of New York, New England and southeastern Canada. The principal topics addressed are the delineation of seismic zones, state of stress in those zones, and focal depths of the earthquakes. Earthquake frequency of occurrence versus magnitude relationships are developed for each seismic zone, using the earthquake catalog compiled by the Electric Power Research Institute (EPRI). An estimate of the maximum earthquake for each seismic zone is also provided.

Appendix 1 lists the geographic coordinates of the polygon vertices used to define the boundaries of the seismic zones delineated here. Appendix 2 is a chronological listing of earthquakes from the EPRI catalog, sorted according to seismic zone. The earthquakes have been interpreted as "independent" events: i.e., minor members of earthquake swarms, foreshocks and aftershocks are not included.

INTRODUCTION

Woollard (1965) suggested a major seismic zone in Eastern North America, extending from the upper St. Lawrence River to New Madrid, Missouri. Sbar and Sykes (1973) proposed the existence of a Boston-Ottawa seismic zone, defined largely on the basis of a belt of seismicity extending from near Boston through the Adirondack Mountains to Ottawa and beyond, to approximately the Kirkland Lake area. Sbar and Sykes (1973) and Diment et al (1972) proposed that the Boston-Ottawa zone was related to an inland extension of the Kelvin transform fault. Later, Sykes (1978) proposed that the seismicity in the zone is more likely related to reactivation of zones of weakness created during the last orogeny.

More recent studies, incorporating instrumental data from regional network monitoring in both Canada and the northeastern U.S. separates a southeasterly Appalachian zone in New England from a series of at least three individual seismic zones lying along the St. Lawrence valley (e.g. Basham et al., 1979; Yang and Aggarwal, 1981).

In the following, the delineation and characterization of seismic zones will be discussed, drawing largely from published results of Basham et al (1979), Hasegawa (1986) and Wahlstrom (1987), in regards to geological structure, state of stress, earthquake focal mechanisms and focal depths. The estimation of earthquake recurrence rates for the various zones will make use of the seismicity catalog developed by the Electric Power Research Institute (EPRI) and results obtained by Basham et al (1979).

SEISMIC ZONES

Figures 1 and 2 show the seismicity of the study area, contained in the EPRI catalog, along with the seismic zones herein delineated. Figure 3 is the map of instrumentaly determined epicenters developed by the northeastern U.S. seismic network operators (Weston Observatory, 1990).

ADIRONDACK MTN. - WESTERN QUEBEC ZONE

This seismic zone includes earthquakes occurring in the Adirondack Mountains of New York and a dense group of epicenters along and to the north of the Ottawa River in western Quebec. The major part of the seismicity occurs in the roughly N-S trending Grenville metasedimentary belt, north of Ottawa, rather than in the roughly E-W trending belt of Precambrian and Paleozoic faults of the Ottawa-Bonnechere graben. The faults of the graben seem to form a diffuse sourthern boundary of the seismicity. Figure 4, from Basham et al (1979) and Figure 5, from Wahlstrom (1987) show the major geological features of this area.

Instrumental data derived from seismic networks operated by the Geophysics Division, Geological Survey of Canada, and by the Lamont-Doherty Geological Observatory have made possible the determination of 30+ (as of 1987) focal mechanism solutions for the northern New York - western Quebec area. The results are discussed in detail by Wahlstrom (1987). Figure 6, from Wahlstrom (1987) shows these focal mechanism solutions. Included are results by Wahlstrom (1987) and previously published results by

Yang and Aggarwal (1981), Schlesinger-Miller et al (1983), Horner et al (1978,1979), and Seeber and Coles (1984). The majority of events are located at mid-crustal depths (10-20 km) and exhibit primarily reverse or mixed reverse/strike-slip motion on medium to steeply dipping planes. The maximum compressive stress for the majority of events is subhorizontal and trends NE-SW. This is particularly the case in northern New York and along the St. Lawrence. This stress orientation is to be expected from ocean-ridge spreading, and is consistently observed over large areas of eastern North America. However, several earthquakes to the northeast of Ottawa exhibit a predominantly N-S direction of maximum compression, indicating some local deviation from the regional trend.

The most significant, well-located earthquakes in this seismic zone were the November 1, 1935 shock near Timiskaming, and the September 5, 1944 shock near Cornwall, Ont./Massena, NY. The Timiskaming event was located at the extreme western end of the seismic zone, and its inclusion in the zone proper is debatable. Instrumental data yield an average mb magnitude of 6.1. The shock was recorded in North America and Europe, and the mechanism derived by Ebel et al (1986) is consistent with reverse motion on steeply dipping planes, striking either NW-SE or NE-SW. The Cornwall/Massena shock is listed as M=5.8 in the EPRI catalog, but Ebel et al (1986) find an average magnitude nearer to 5.0. Figure 7 shows an isoseismal map of this event, taken from Schlesinger-Miller et al (1983). Instrumental data for this shock are limited, suggesting only that P wave polarities were consistent with more recent shocks along the St. Lawrence and in northern New York: i.e., NE trending maximum compressive stress

(Ebel et al 1986).

The EPRI catalog lists 288 independent earthquakes occurring in this zone between 1661 and 1984. The catalog was examined on a decade-by-decade basis, using one-half magnitude intervals, to estimate the time intervals over which the catalog listing was complete for various magnitudes. The results are as follows:

Magnitude	Completeness Period (yr)	N (events/yr)
M≥3.0	10	5.50
M≥3.5	50	2.30
M>4.0	70	0.843
M≥4.5	90	0.167
M≥5.0	130	0.0692
M≥5.5	130	0.0154
M≥6.0	130	0.0077

The least squares estimate of the recurrence relation is Log N = 3.81 - 1.00 M, where N is the average number of earthquakes per year with magnitudes greater than or equal to M. This applies to the entire zone, with area 147,000 sq km. M is considered to be equivalent to 1 Hz instrumental magnitudes (mb or Mlg) up to approximately M=7.0. Figure 8 plots the above relationship. For comparison, Basham et al (1979) give Log N = 3.41 - 0.94 M, area = 160,000 sq km, for this seismic zone.

The largest shock known to have occurred in the zone was the 1935 earthquake near Timiskaming. The magnitude has been estimated as mb=6.1 (EPRI; Ebel et al ,1986). Estimating a

maximum magnitude shock for hazard mitigation purposes is difficult (almost arbitrary) because no clearly defined relationships between the geological structure and seismicity of the area have been discovered. The historical record indicates the capability of large shocks (M>6), and the fact that the earthquakes occur to mid-crustal depths does not provide a useful upper bound estimate for magnitude. A conservative estimate for the largest event likely to be experienced during the lifetime of a facility might be the event with a 1000 yr return period: the above relationship indicates that this would be M=6.8. For the purpose of constructing a probabilistic hazard map of eastern Canada, Basham et al (1979) employed M=7.5 for the maximum earthquake in this zone.

CHARLEVOIX ZONE

The Charlevoix seismic zone in the St. Lawrence valley is the most active seismic zone in the study region. At least four earthquakes of magnitude 6 or greater have occurred in the zone since 1650. The March 1, 1925 earthquake (M=6+) in this zone is the largest to have occurred in eastern North America in this century.

Instrumentally located low-level seismicity occurs primarily beneath the north shore of the St. Lawrence river between Baie-St-Paul and La Malbaie, within the Precambrian rocks at depths from 5 to 20 km (Leblanc et al 1973; Leblanc and Buchbinder, 1977; Anglin, 1984). The contact (Logan's Line) between the Precambrian "basement" and Paleozoic rocks of the

Appalachian province lies in the river, and dips to the sourtheast. The seismic zone lies within a mid-Paleozoic impact structure, the fractures of which can be mapped on the north shore of the St. Lawrence. However, Anglin (1984) notes that most of the seismicity in the zone occurs along pre-existing steeply dipping border faults of the St. Lawrence rift, which strike in the direction of the valley, and that large portions of the impact structure are aseismic. Figure 9, taken from Hasegawa (1986) shows the extent of the Charlevoix zone. Relocations of some of the larger shocks·occurring since 1924 by Stevens (1980) fall into two groups coinciding with the ends of the active micro-earthquake zone.

The faults trending along the St. Lawrence valley were generated under extensional stresses when the proto-Atlantic ocean opened between 600-700 MYA. Because earthquakes are non-uniformly distributed along the valley, Hasegawa (1986) argues that there must be neotectonic processes in the seismogenic regions that are reactivating these ancient zones of weakness. Hasegawa (1986) notes that the Charlevoix zone is exceptional because other meteorite impact sites in Canada are aseismic. Apparently, the impact reactivated the steeply dipping zones of weakness (initially normal faults) trending along the St. Lawrence valley. In the impact area, these reactivated faults are probably more permeable than elsewhere, and are more susceptible to infiltration of water and deep pore pressure changes.

The EPRI catalog lists 114 independent earthquakes in the Charlevoix zone occurring between 1663 and 1984. The results of the completeness examination are:

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Magnitude	Completeness Period (yr)	N (events/yr)
M≥3.0	10	2.0
M≥3.5	60	0.8
M≥4.0	60	0.42
M≥4.5	80	0.138
M≥5.0	80	0.050
M≥5.5	130	0.0308
M≥6.0	130	0.0231
M≥6.5	130	0.0154

For M≥3.0, through M≥6.0, the recurrence relation is Log N = 2.29
-0.68 M, which is plotted in Figure 10. In deriving this
relationship, a search area of 17,500 sq km was used (as shown in
Figure 1). The great majority of these shocks occurred within the
considerably smaller area (approximately 6,500 sq km) shown in
Figure 9. Basham et al (1979) give Log N = 2.26 - 0.71 M, and an
area of 6,500 sq km for this zone.

The March 1, 1925 Charlevoix earthquake was certainly felt
over more than 3.3 million sq. km, and it has been argued that
the total felt area could have been as great as 5.2 million sq.
km. Ebel et al (1986) estimates mb=6 3/4 and Ms=6 1/2, from
instrumental recordings of this shock. The EPRI catalog lists
M=6.5. Extrapolation of the above recurrence relationship to the
1000 yr return period indicates M=7.8. This number should not be
interpreted as mb, but rather as Ms, because of saturation of the
mb scale. Basham et al (1979) employed M=8.0 (Ms) as a maximum
magnitude for this zone in their probabilistice hazard assesment

for eastern Canada.

The length of the Charlevoix microearthquke zone is approximately 80 km. The relocations of Stevens (1980) suggest that larger shocks nucleate at either end of the seismic zone. For the purpose of estimating a maximum event, assume that the entire microearthquake zone marks a potential fault plane 80 km long, dipping 70 degrees to the southeast, and capable of rupture between depths of 5 and 20 km. This defines a rupture surface 80 km long and 16 km wide. Bonilla et al (1984) give the following relationship between magnitude (Ms) and fault area: M = 4.36 + 1.055 Log A. For the Charlevoix zone, the estimate of A is 1280 sq km, yielding a magnitude of M=7.6. This estimate assumes that the earthquake does not rupture outside the zone of recent low-level seismicity.

ST. LAWRENCE RIFT

This seismic zone coincides with the St. Lawrence valley between the Adirondack-western Quebec and Charlevoix zones. Figure 1 shows that it has substantially lower activity than either of those zones. However, it features the same class of geological structures believed to be responsible for seismicity at Charlevoix: ancient normal faulting associated with the St. Lawrence rift. Its relative lack of seismicity may be attributed to the lack of an impact structure or other mechanism by which the faults of the rift system may be reactivated in the modern stress field.

The EPRI catalog lists only 38 shocks in this zone between

1665 and 1984. The completeness results are as follows:

Magnitude	Completeness Period (yr)	N (events/yr)
M≥3.0	70	0.386
M≥3.5	70	0.186
M≥4.0	120	0.0083
M≥4.5	120	0.0083

The least squares regression gives Log N = 3.44 - 1.27 M, for an area of 21,600 sq km (Figure 11).

The largest earthquake to have occurred within this zone was probably an intensity VI MM shock on April 20, 1864. The EPRI catalog estimates the magnitude of this shock as M=4.8. The 1000 yr shock derived from the above recurrence relationship is M=5.0, which is too low to be considered a maximum magnitude for this zone, because of the geological similarity and proximity to the Charlevoix zone. A more appropriate estimate for the maximum event might be obtained by increasing the historical maximum shock by at least 1 magnitude unit: i.e., M=6.0+. The occurrence of the M=6.0, November 25, 1988 Saguenay earthquake, approximately 80 km northwest of the Charlevoix zone, demonstrates that magnitude 6 shocks can occur well outside active seismic zones in southeastern Canada.

LOWER ST. LAWRENCE ZONE

This zone is defined on the basis of a rather diffuse pattern of earthquakes occurring north of the Gaspe penninsula, primarily beneath the lower St. Lawrence river (Figure 1).

Hasegawa (1986) considers these earthquakes as possibly occurring on faults with the same trend as the St. Lawrence valley, i.e., faults striking in the NE-SW direction.

The EPRI catalog lists 77 independent earthquakes occurring in the zone, between 1859 and 1984. An examination of this list resulted in the following:

Magnitude	Completeness Period (yr)	N (events/yr)
M≥3.0	20	1.35
M≥3.5	40	0.70
M≥4.0	60	0.27
M≥4.5	70	0.057
M≥5.0	70	0.014

Linear regression gives Log N = 3.31 - 1.01 M, for the 60,200 sq km area (Figure 12). For comparison, Basham et al (1979) find Log N = 3.13 - 1.03 M, for an area of 33,000 sq km.

The largest shock to have occurred in this zone was on June 23, 1944, and the magnitude listed in the EPRI catalog is 5.1. Extrapolation of the above recurrence relation to the 1000 yr return period indicates a magnitude of M=6.2. Basham et al (1979) employed M=6.0 as the maximum magnitude for this seismic zone.

APPALACHIAN FORELAND - GASPE PENNINSULA

This seismic zone is defined primarily on the basis of its low level of seismicity. Both the St. Lawrence valley to the north and the Appalachian province of New England to the south and east feature a higher level of seismic activity.

The EPRI catalog lists 30 independent earthquakes in this zone, occurring between 1843 and 1984. The recurrence statistics are as follows:

Magnitude	Completeness Period (yr)	N (events/yr)
M≥3.5	60	0.283
M≥4.0	60	0.117
M≥4.5	60	0.0167

The least squares estimate of the recurrence relation is Log N = 3.83 - 1.23 M, for an area of 105,000 sq km (Figure 13).

The largest shock to have occurred in this zone is the June 15, 1973 earthquake on the Quebec-Maine border. The magnitude of this shock is listed as 4.8 in the EPRI catalog. The 1000 yr event derived from the above relation above is M=5.6. Increasing the maximum historical event by one unit gives m=5.8, which is probably a better estimate for the maximum shock for this zone.

APPALACHIAN ZONE

This zone includes the Appalachian geologic province of New England and eastern Canada. Earthquakes in this region occur at depths from near surface to at least 20 km. Focal mechanism solutions indicate primarily a NE-SW trending maximum compressive stress , and motion is mostly thrust and mixed thrust/strike-slip (Yang and Aggarwal, 1981; Pulli and Toksoz, 1981).

The EPRI catalog lists 516 independent earthquakes in the Appalachian zone from 1627 to 1984. The examination of this

listing for completeness gave the following results:

Magnitude	Completeness Period (yr)	N (events/yr)
M≥3.0	10	6.7
M≥3.5	130	1.42
M≥4.0	130	0.362
M≥4.5	130	0.0692
M>5.0	130	0.0231

The least squares estimate of the recurrence relation is Log N = 4.54 - 1.25 M, for a total area of 342,000 sq km (Figure 14).

Important earthquakes in this seismic zone have occurred on Nov. 18, 1755 off Cape Ann, Mass. (M=5.8?); Oct. 22, 1869 in the Bay of Fundy (M=5.6); March 21, 1904 in southeastern Maine (M=5.8); Dec. 20, 1940, Lake Ossippee, New Hampshire (M=5.4) and Jan. 9, 1982 in central New Brunswick (M=5.7). The above recurrence relation indicates M=6.0 as the 1000 yr earthquake. The historical maximum + one unit estimate is 6.8, which is probably a better estimate for the maximum event for the zone.

NEW YORK ZONE

This seismic zone includes central and western New York and Lake Ontario. Seismicity within this region is generally low-level and diffuse: however, the area in western New York, near Attica, has experienced a higher level of seismicity. Fletcher and Sykes (1977) associated some of the low-level seismicity near Attica, NY with stress release along the NNE trending Clarendon-Linden fault. Herrmann (1978) examined the focal mechanisms of two of the larger events in the area and

obtained N-S and E-W trending nodal planes. The northerly trending, steeply dipping plane (mostly strike-slip motion) parallels the Clarendon-Linden feature, but the E-W trending plane lies along a diffuse trend of seismicity. Thus, the capability of the Clarendon-Linden feature remains equivocal.

The EPRI catalog lists 87 independent earthquakes in this zone from 1796 to 1984. The completeness examination gave the following results:

Magnitude	Completeness Period (yr)	N (events/yr)
$M \geq 3.5$	80	0.413
$M \geq 4.0$	80	0.163
$M \geq 4.5$	80	0.050
$M \geq 5.0$	80	0.025

The least squares estimate of the recurrence relation is Log N = 2.52 - 0.83 M, for an area of 211,000 sq km (Figure 15).

The largest shock in this zone occurred on August 12, 1929, near Attica, NY, with maximum intensity VIII MM. The EPRI catalog lists the magnitude of this shock as 5.1. It was felt over-an. area of 130,000 sq km. Herrmann (1978) notes that some of the more recent earthquakes in the Attica area have shallow (<5 km) focal depths, and suggests that this may explan the high (VIII MM) epicentral intensity of the 1929 shock. The above recurrence relation indicates that the 1000 yr event for this zone is M=6.7. However, if the seismicity in western New York is causally associated with the Clarendon-Linden feature, then a substantially larger shock could be hypothesized, in view of the 100+ km extent of that feature.

CRATON ZONE

This zone includes portions of Quebec and Ontario north of the seismic zones previously described. The region has a general low level of seismicity. The EPRI catalog lists 39 independent earthquakes (1887-1984) in this region. A completness analysis gives the following recurrence results:

Magnitude	Completeness Period (yr)	N (events/yr)
M≥3.0	10	1.0
M≥3.5	40	0.475
M≥4.0	40	0.175
M≥4.5	40	0.025

The least squares regression of the above yields Log N = 3.26 - 1.05 M, for an area of 441,000 sq km (Figure 16).

The largest shock listed in the EPRI catalog for this zone occurred on Nov. 5, 1944 with an estimated magnitude of 4.4. The 1000 yr event, based on the above relationship, is M=6.0. However, on Nov. 25, 1988, a magnitude 6.0 (mb) shock occurred in the Saguenay River region of Quebec, approximately 80 km northwest of the Charlevoix seismic zone. Prior to this earthquake, the area had experienced a low level of historic seismicity. On the basis of the Saguenay shock, and also because the 1935 Timiskiming event occurred at the extreme western end of the Adirondack-western Quebec zone, a maximum magnitude of M=6.5 for the Canadian craton is not unreasonable.

SUMMARY

Eight seismic zones have been delineated in this study. They are listed below along with the Log N versus M recurrence relations, areas, and estimated maximum magnitude event.

Adirondack - Western Quebec:
   Log N = 3.81 - 1.00 M, Area = 147,000 sq km., Mmax = 6.8 (mb).

Charlevoix Zone:
   Log N = 2.29 - 0.68 M, Area = 6,500 sq km., Mmax = 7.6 (Ms).

St. Lawrence Rift:
   Log N = 3.44 - 1.27 M, Area = 21,600 sq km., Mmax = 6.0 (mb).

Lower St. Lawrence Zone:
   Log N = 3.31 - 1.01 M, Area = 60,200 sq km., Mmax = 6.2 (mb).

Appalachian Foreland - Gaspe Penninsula:
   Log N = 3.83 - 1.23 M, Area = 105,000 sq km., Mmax = 5.8 (mb).

Appalachian Zone:
   Log N = 4.54 - 1.25 M, Area = 342,000 sq km., Mmax = 6.8 (mb).

New York Zone:
   Log N = 2.52 - 0.83 M, Area = 211,000 sq km., Mmax = 6.7 (mb).

Craton Zone:
   Log N = 3.26 - 1.05 M, Area = 441,000 sq km., Mmax = 6.5 (mb).

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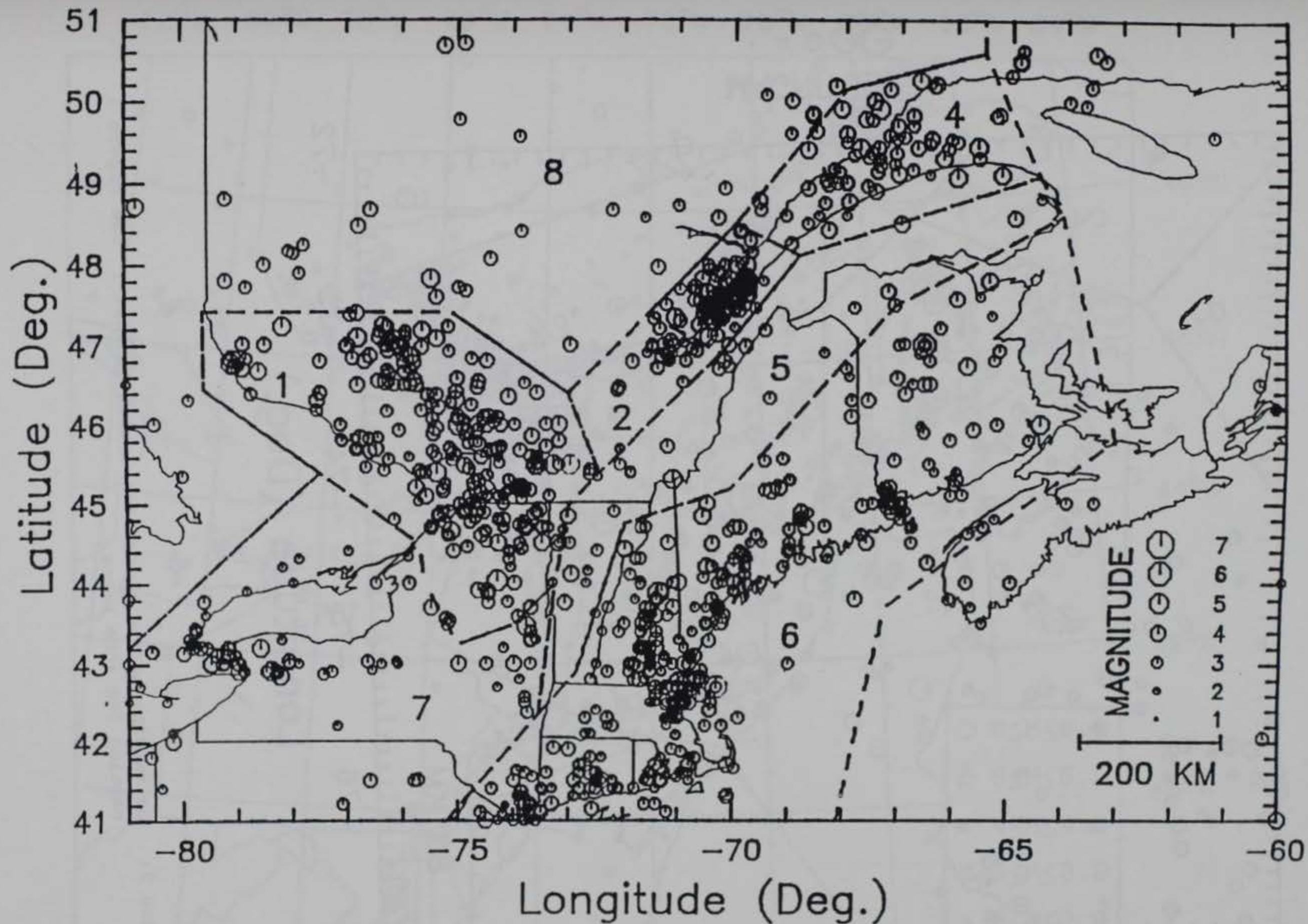
Figure 1: Seismicity of the study area (prior to 1984). Seismic zones described in the text are indicated by the dashed lines. Numbered zones are referred to in the text as follows: (1) Adirondack-western Quebec, (2) St. Lawrence rift, (3) Charlevoix, (4) Lower St. Lawrence, (5) Appalachian Foreland - Gaspe Penninusula, (6) Appalachian, (7) New York, (8) Craton.
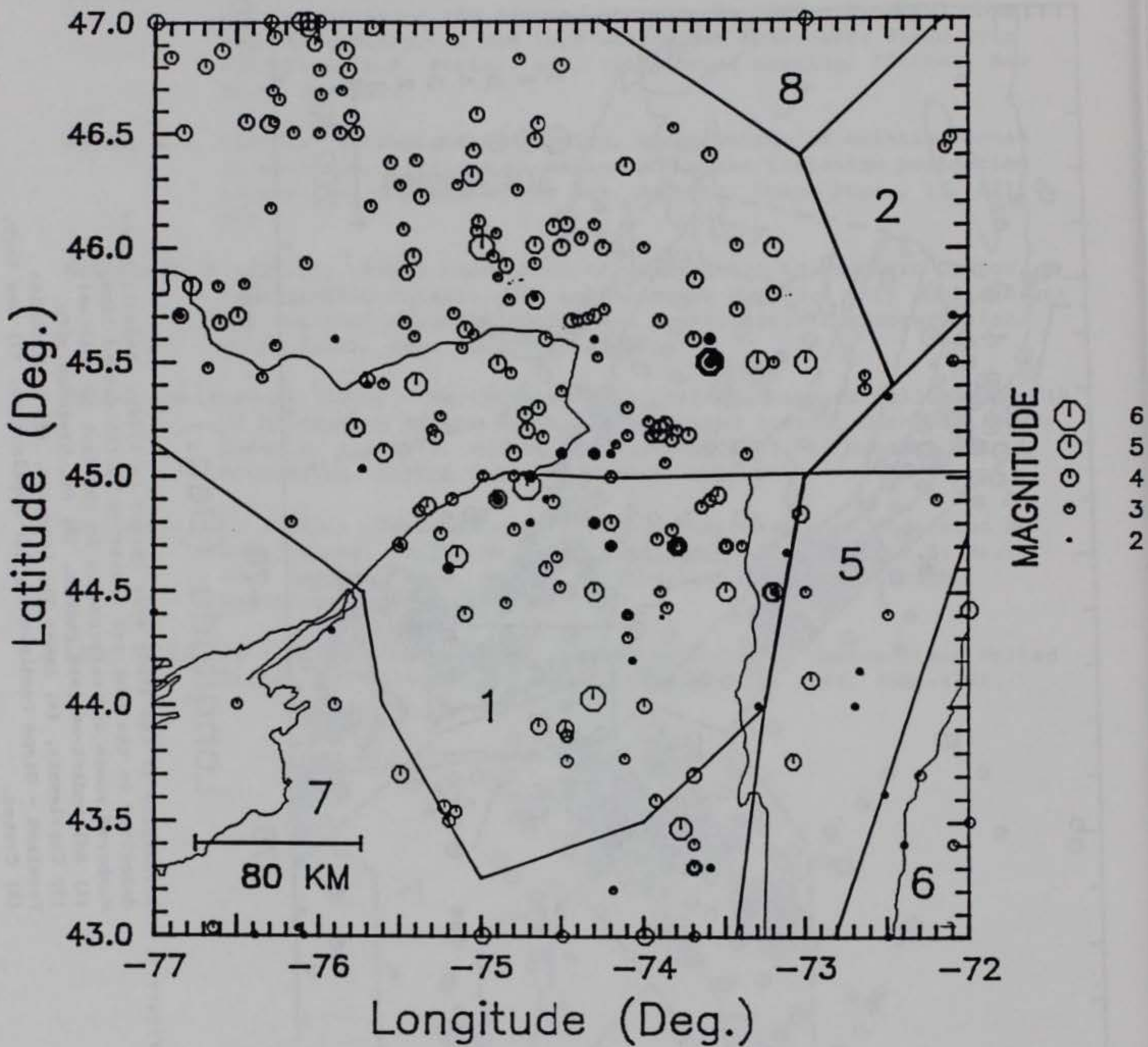
Figure 2: Seismicity of the study area (prior to 1984). See figure 1 caption for zone names.
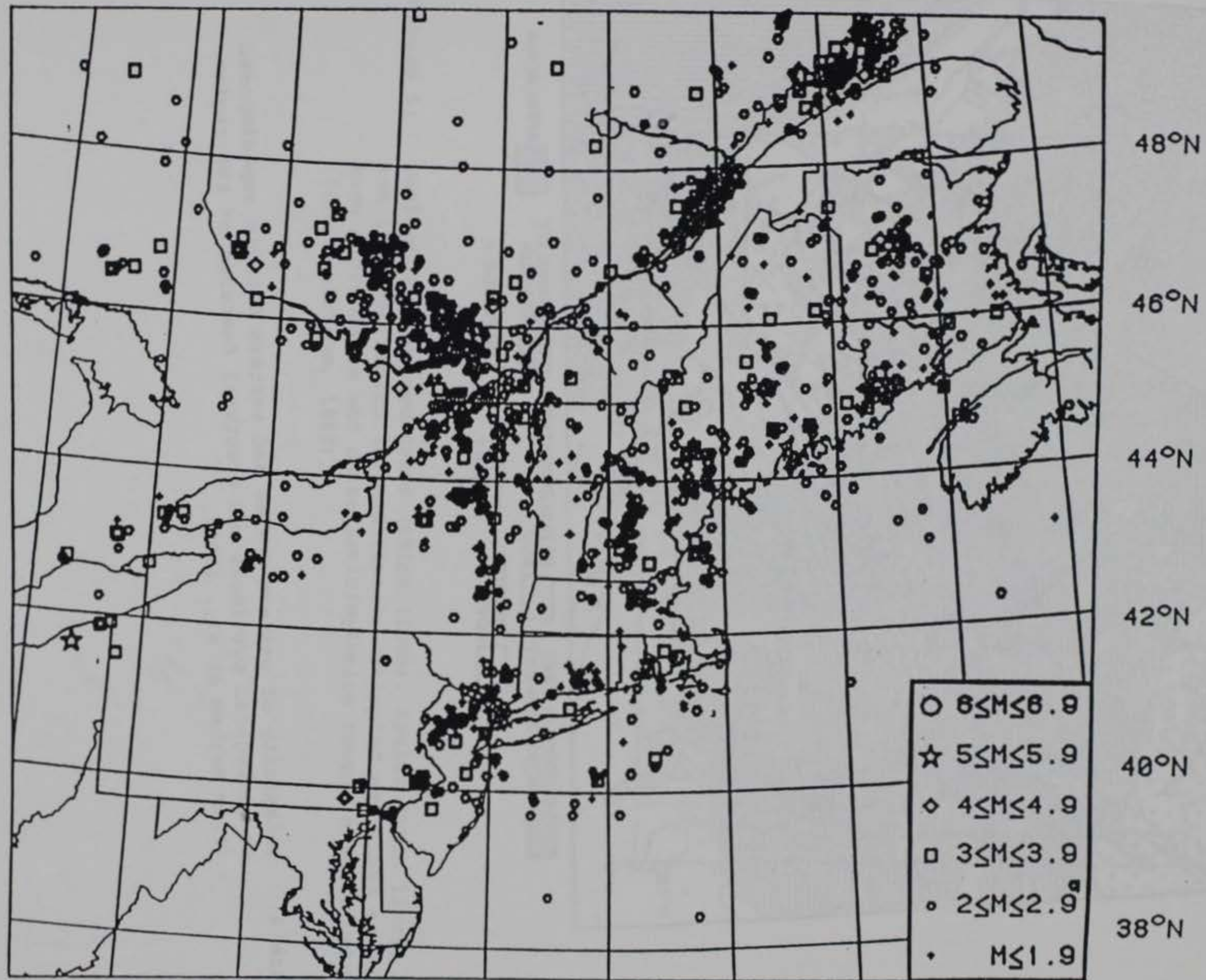
Figure 3: Earthquake epicenters (1975-1987) instrumentally located by the Northeastern U.S. seismic network (Weston Observatory, 1990).
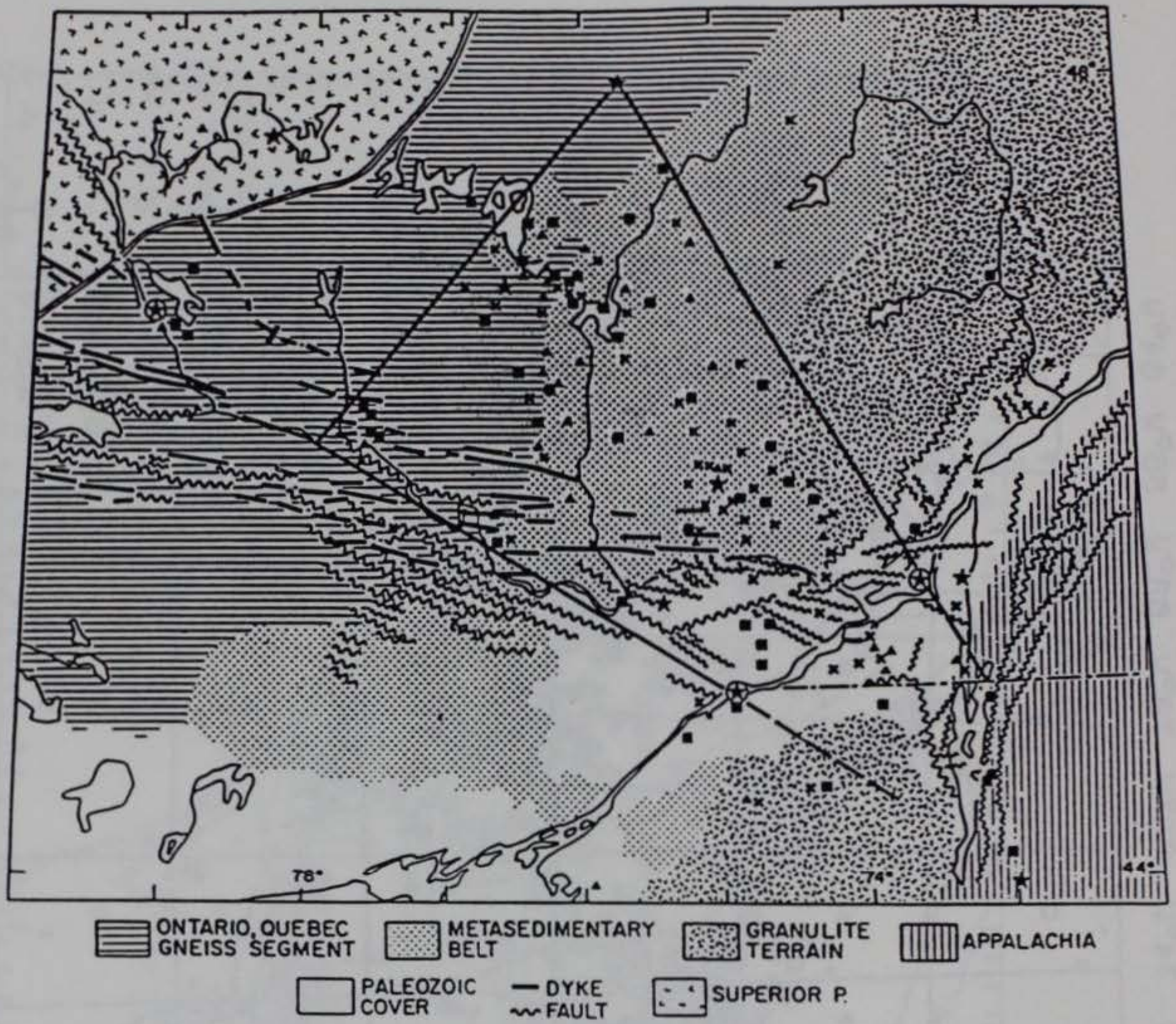
Figure 4: Seismicity of western Quebec and eastern Ontario superimposed
on geological provinces and sructural features of the region:
(from Basham et al., 1979).
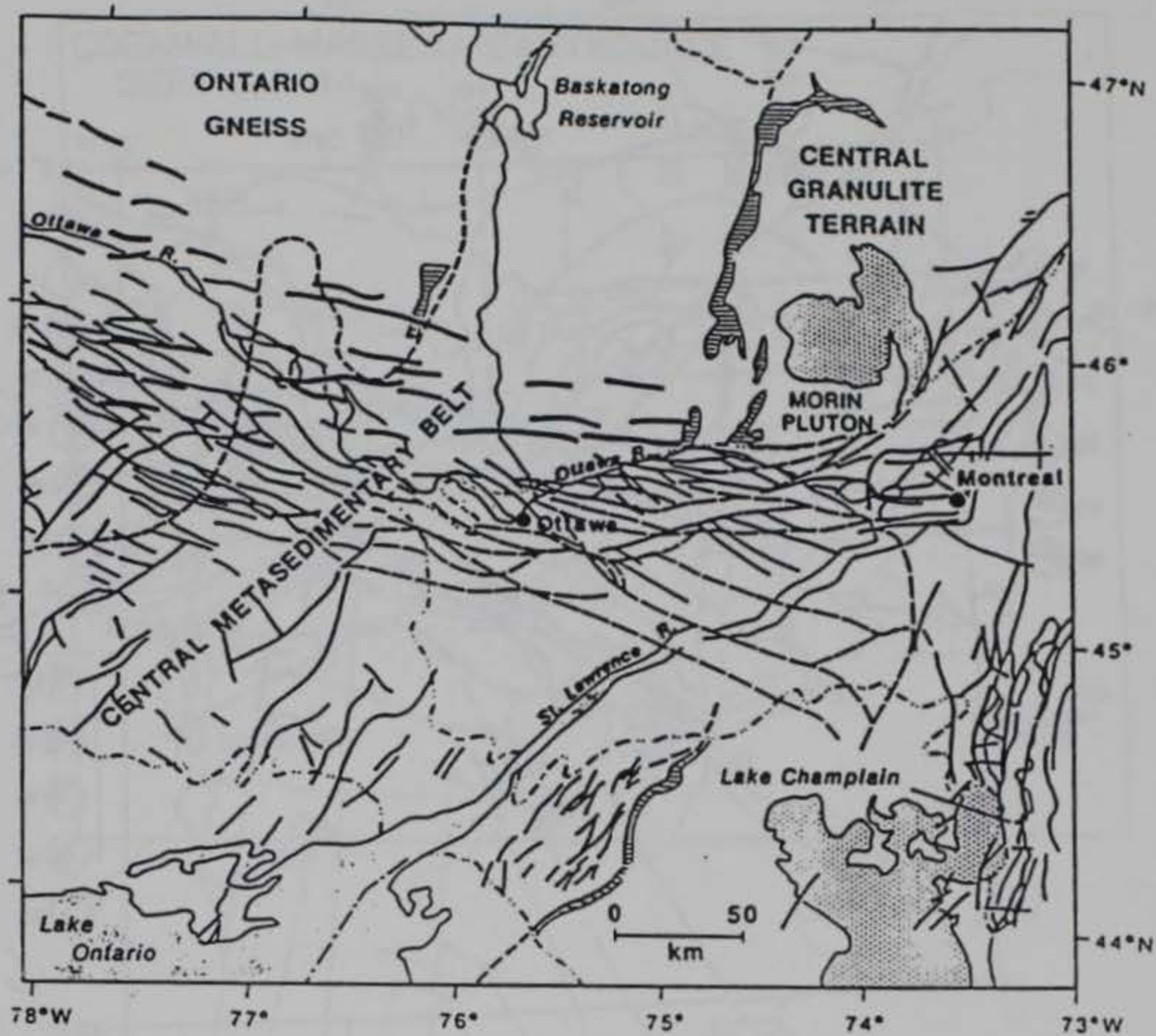
Figure 5:   Geologically mapped dykes (thick lines), faults (thin lines)
and inferred faults (dashed lines). Stippled and lined areas
show anorthosite and cataclastic/mylonite zones, respectively:
(from Wahlstrom, 1987).
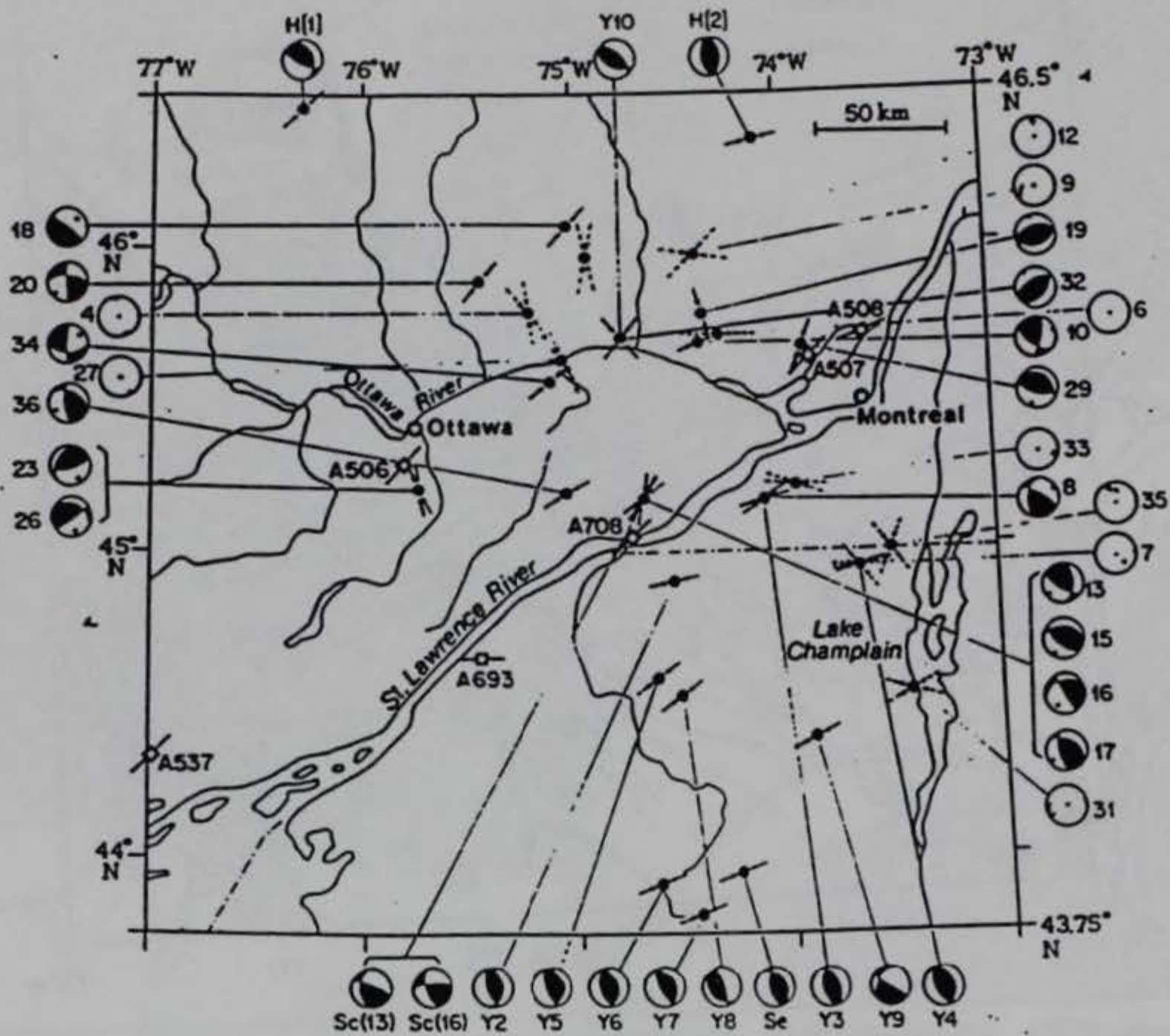
Figure 6: Earthquake focal mechanism solutions and orientations of maximum compressive stress axes (arrows), from Wahlstrom, (1987). Focal spheres are lower hemisphere, equal area projections, with tensional axes darkened.
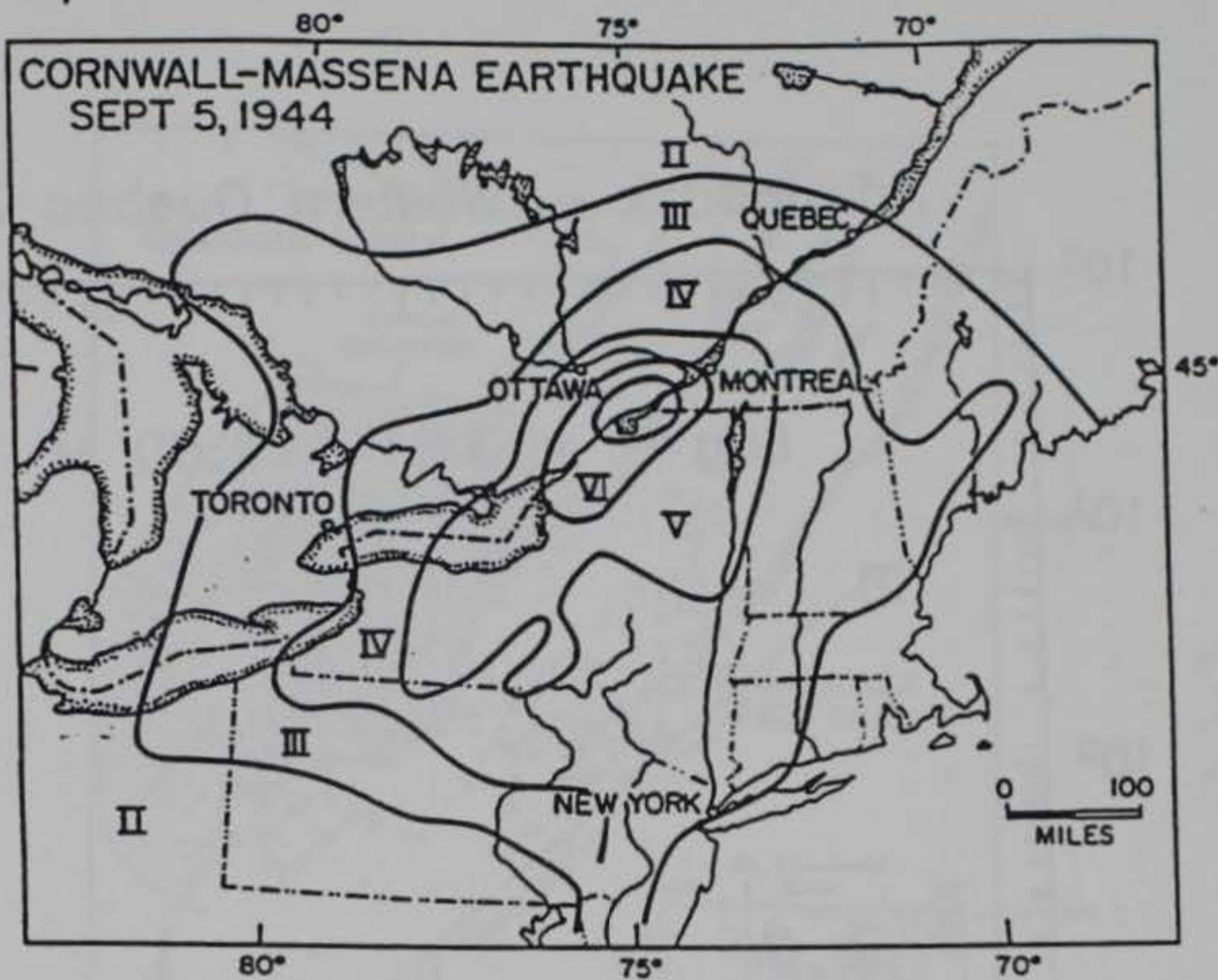
Figure 7:   Isoseismal map (MM) of the Sept. 5, 1944 Cornwall/Massena
             earthquake: (from Schlesinger-Miller et al., 1983).
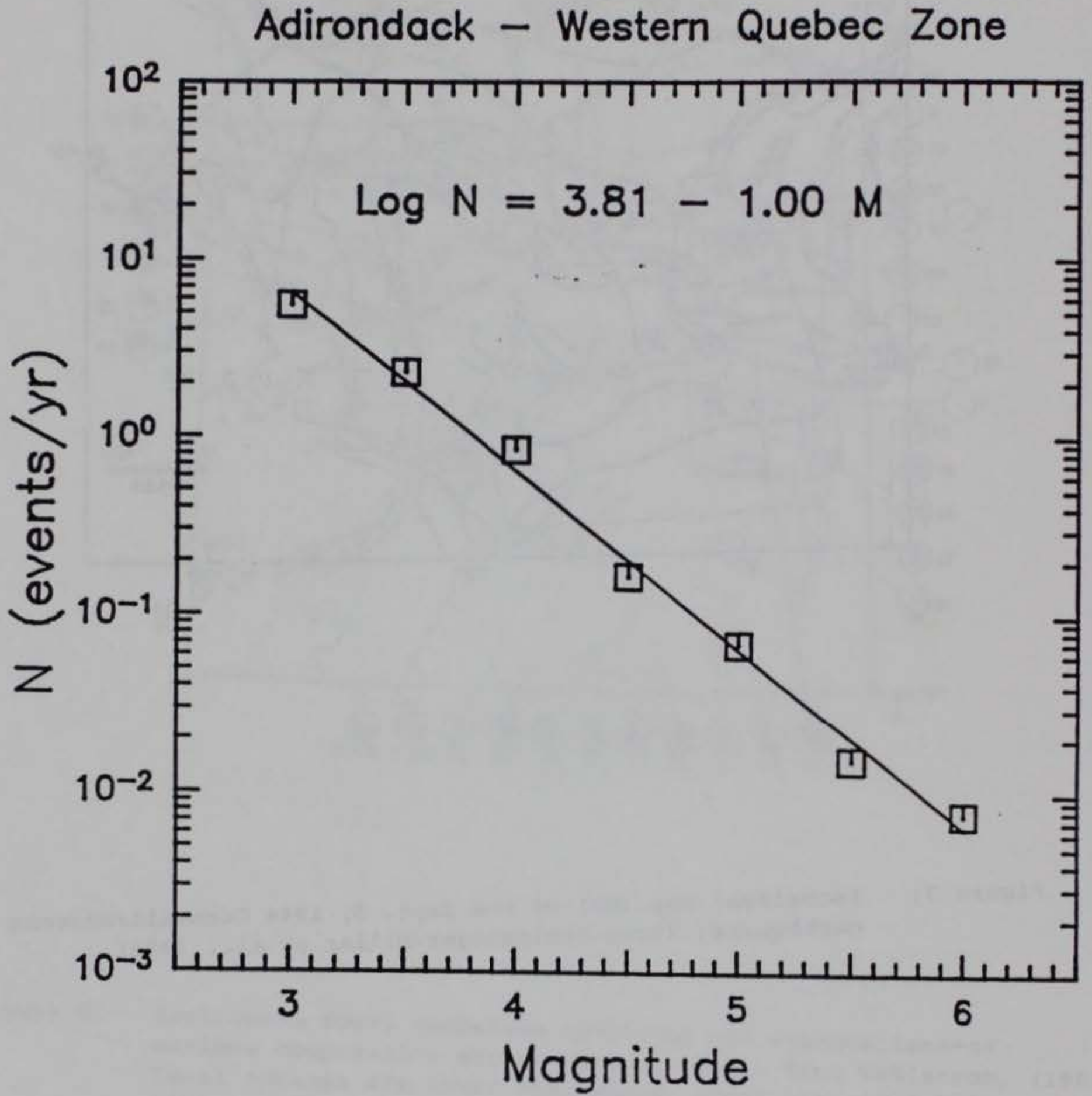
Figure 8: Recurrence relation for the Adirondack-western Quebec zone.
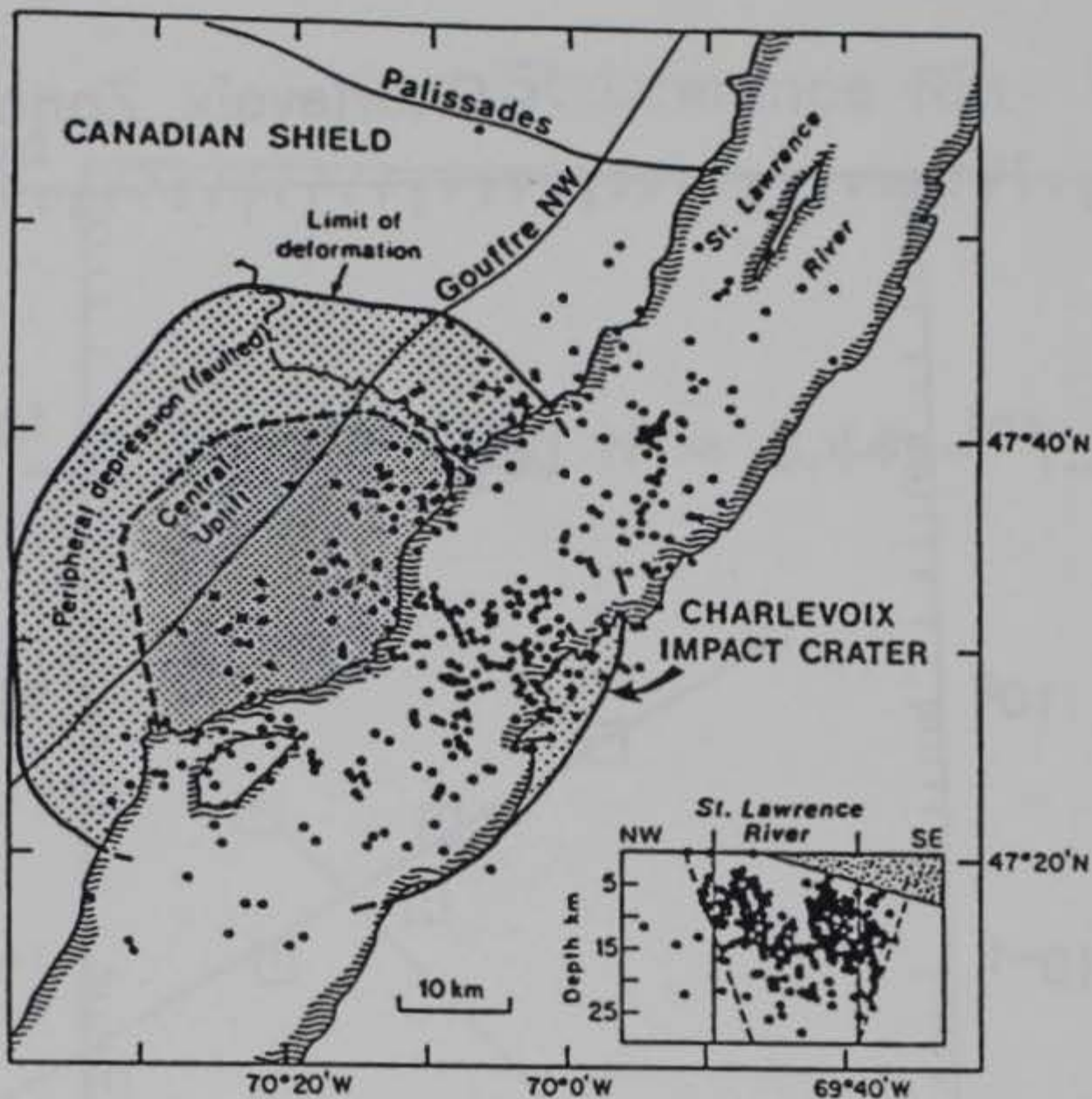
Figure 9:   Charlevoix zone seismicity and impact feature with faults that
             delimit seismicity along SW and NE boundaries. Inset shows
             hypocenters projected onto NW-SE vertical profile across river,
             with shaded area denoting Paleozoic sediments: (from Hasegawa,
             1986).
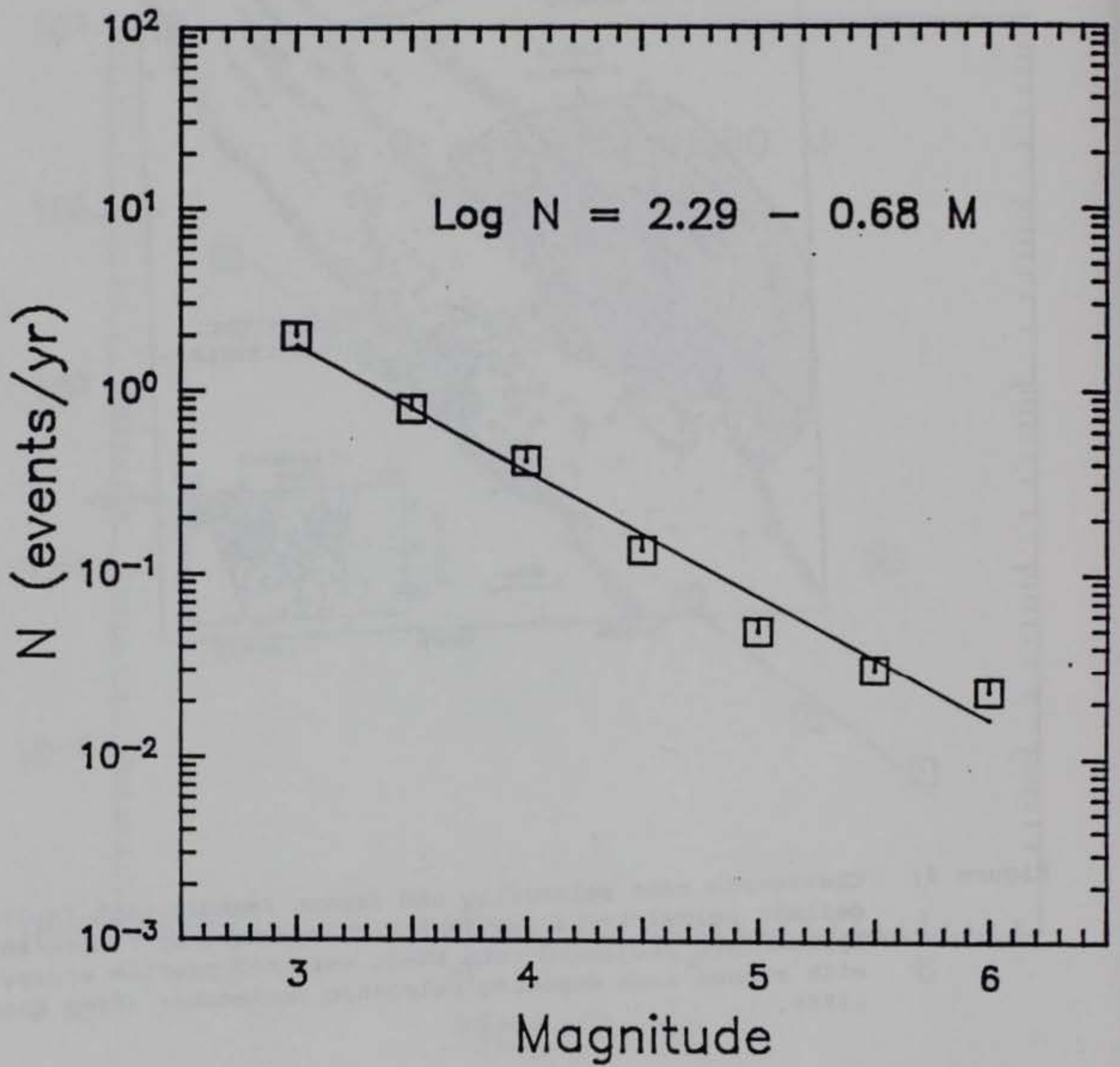
Figure 10: Recurrence relation for the Charlevoix zone.
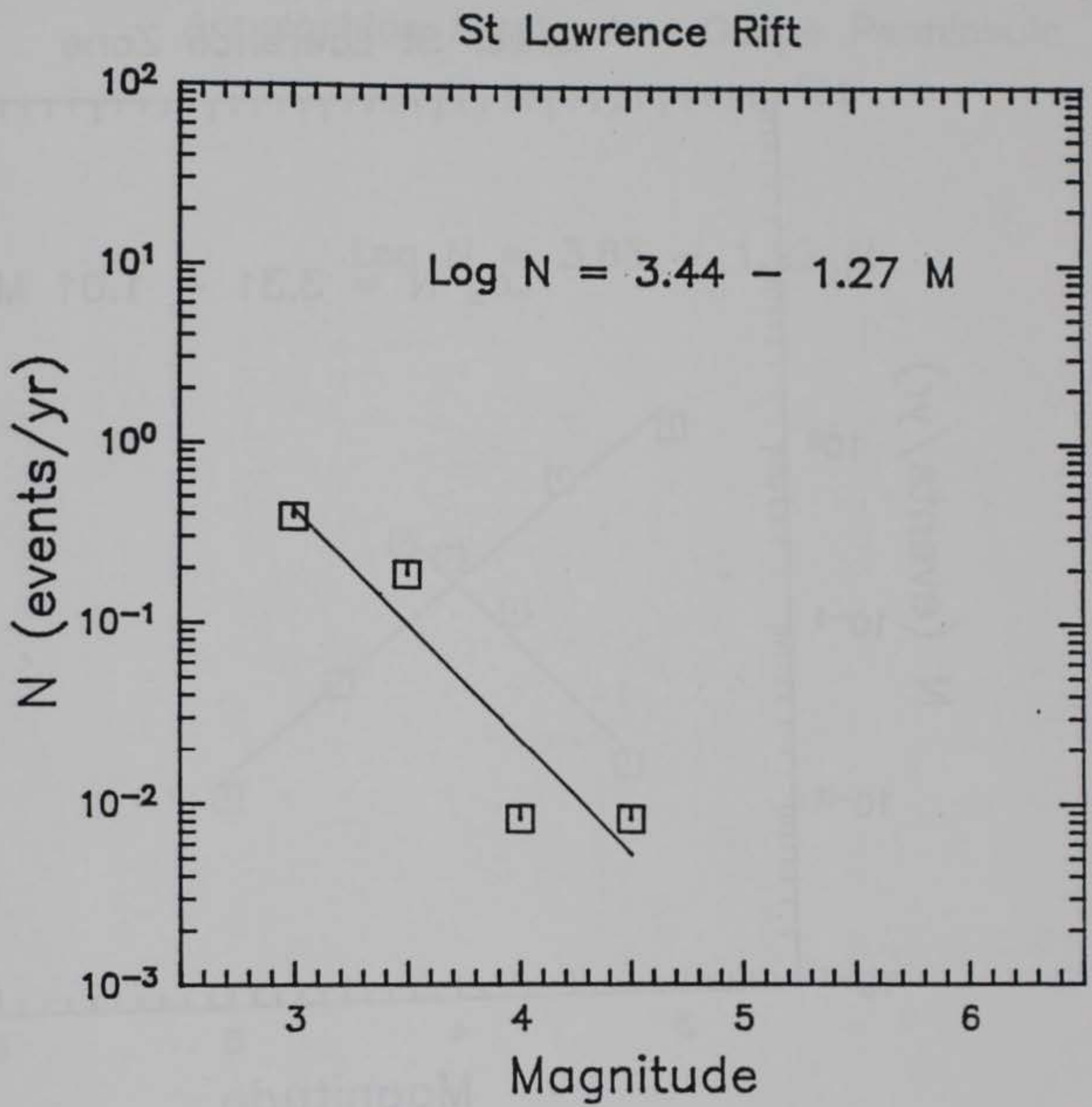
Figure 11:   Recurrence relation for the St. Lawrence rift zone.

Lower St Lawrence Zone

Log N = 3.31 − 1.01 M
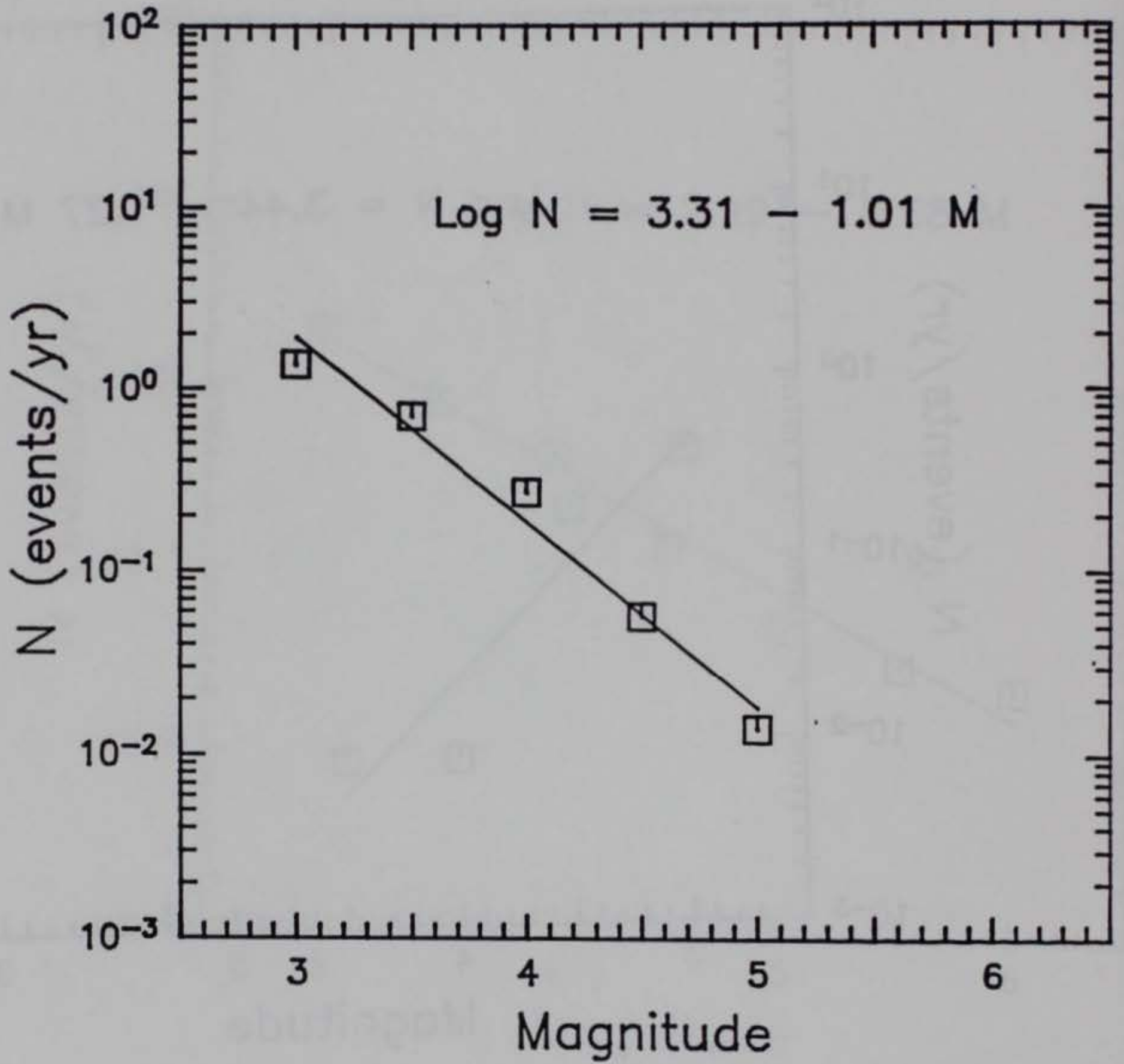
Figure 12:   Recurrence relation for the Lower St. Lawrence zone.
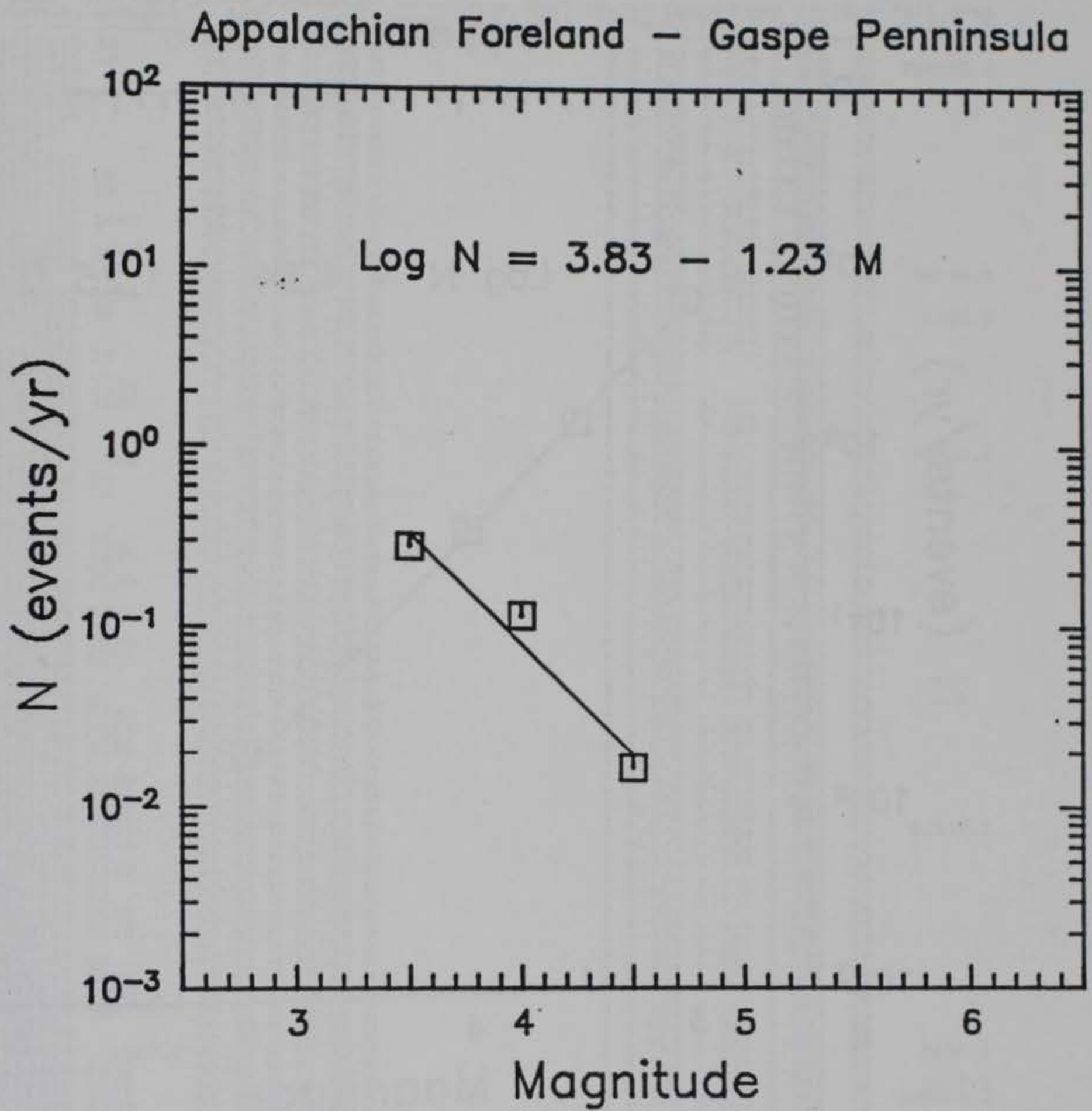
Figure 13:   Recurrence relation for the Appalachian Foreland-
Gaspe Penninsula zone.
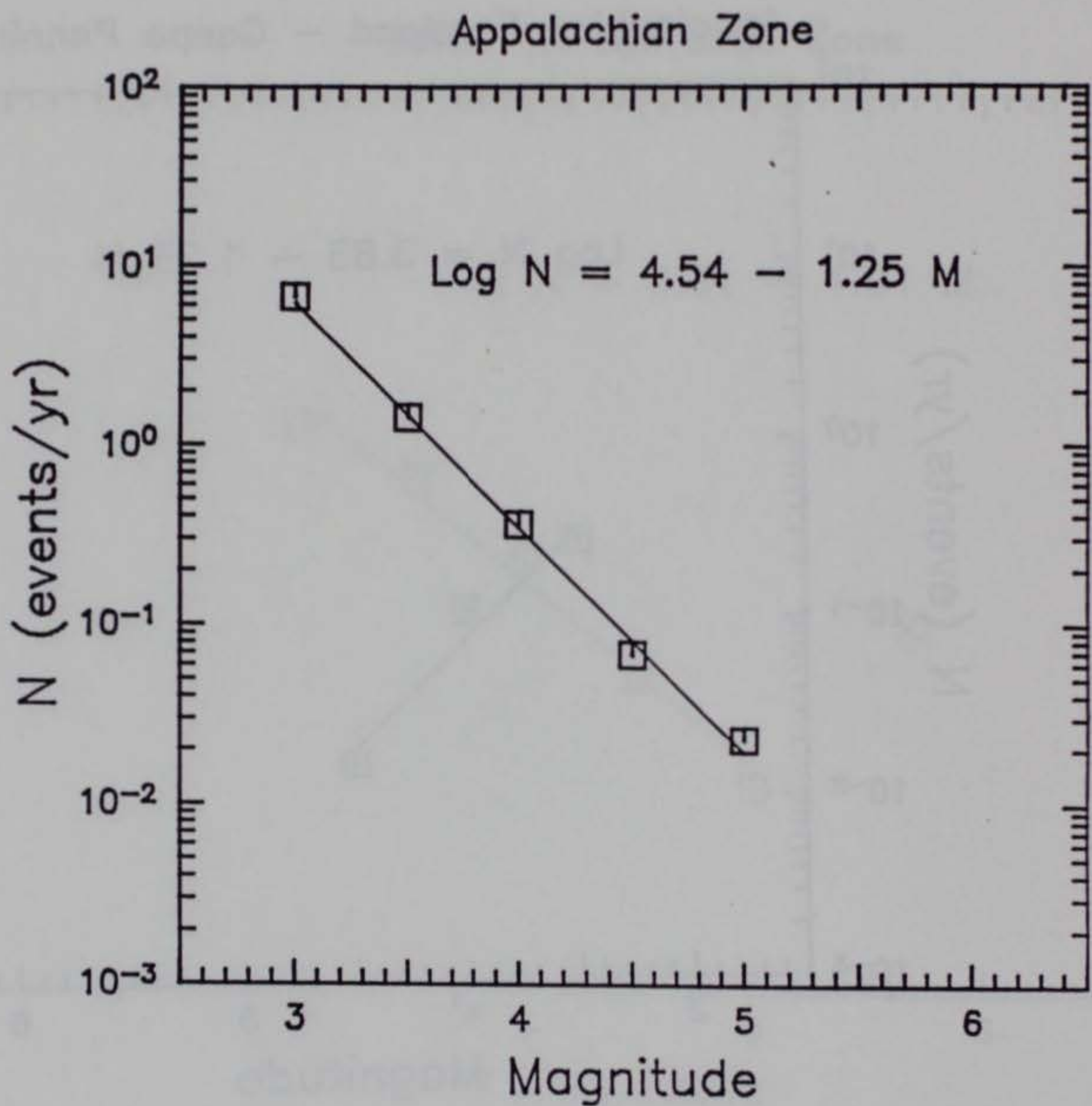
Figure 14: Recurrence relation for the Appalachian zone.

22-SEP-90   18:08:49 for the program RHGEN

Input data from file......: ADIRONDACKS W QUEBEC MI.EPRI

Lab		I- Date -IOT (UCT)I		---- Hypocenter ----			IError (km)		IHyI	-- Magnitudes ---			IInt	Felt Area
		YearMoDy	HrMnSec	Lat		Lon	Depth	ERH	ERZ	LS	MagTS	MagTS	MagTS	S	(mi2) S
EP	M	16610210	12	45.50 N	73.00 N										
EP	M	17320916	16	45.50 N	73.60 N					I	4.9XI	5.7II	5.4BI	7I	
EP	U	18160909		45.50 N	73.60 N						5.7XI	5.8XI	5.8BI	6I	765875.I
EP	I	18190815		45.60 N	74.30 N						2.9XI	3.0II	3.4BI	4I	
EP	M	18191110		45.50 N	73.60 N						2.5XI	3.0II	3.0BI	3I	
EP	M	18421109		46.00 N	73.20 N						4.3XI	5.0II	4.8BI	6I	
EP	U	184411		45.50 N	73.60 N						3.1XI	5.0II		6I	
EP	I	184711		45.50 N	73.60 N						2.5XI	3.0II	3.0BI	4I	
EP	I	18480523		45.50 N	73.60 N						2.5XI	3.0II	3.0BI	3I	
EP	I	18481211	08	45.50 N	73.60 N						2.5XI	3.0II	3.0BI	3I	
EP	I	18510130	22	45.60 N	74.30 N						2.5XI	3.0II	3.0BI	3I	
EP	I	18511225		44.00 N	73.30 N						2.5XI	3.0II	3.0BI	3I	
EP	I	18520211	1040	45.60 N	73.60 N						2.5XI	3.0II	3.0BI	3I	
EP	I	18541204		45.10 N	74.20 N						2.5XI	3.0II	3.0BI	3I	
EP	I	18550113	1040	45.60 N	73.60 N						2.5XI	3.0II	3.0BI	3I	
EP	M	18610712		45.40 N	75.40 N						4.9XI	5.0XI	5.0BI	6I	93786.I
EP	M	186110		45.60 N	73.70 N						4.1XI	4.4II	4.2BI	4I	
EP	M	18641021	0910	45.50 N	73.60 N						4.7XI	4.7II	4.6BI	4I	76786.I
EP	M	18671218	08	44.65 N	75.15 N						4.8XI	5.0II	4.8BI	5I	
EP	M	18710103		45.60 N	74.60 N						3.7XI	4.4II	4.2BI	5I	
EP	I	18730321		45.50 N	73.60 N						2.5XI	3.0II	3.0BI	3I	
EP	M	18730425	19	44.80 N	74.20 N						4.1XI		4.2BI	4I	
EP	I	18730430		45.00 N	74.70 N						4.1XI		3.6BI	4I	
EP	M	18730930	1150	45.50 N	73.20 N						4.1XI		3.6BI	4I	
EP	M	18730930	1150	46.50 N	76.00 N						4.1XI		3.6BI	4I	
EP	I	18731104		44.50 N	73.20 N						3.7XI	3.0II	3.0BI	4I	
EP	I	18750430		45.10 N	74.50 N						2.5XI	3.0II	3.0BI	4I	
EP	M	18771104		45.20 N	73.90 N						4.8XI	5.0II	5.0BI	6I	84861.I
EP	I	18771114	1440	45.00 N	74.70 N						2.5XI	3.0II	3.0BI	3I	
EP	I	18771218	06	45.70 N	76.85 N						2.5XI	3.0II	3.0BI	3I	
EP	M	18771218	10	45.70 N	76.85 N						3.7XI	4.3II	4.2BI	5I	
EP	M	18790611		45.60 N	73.60 N						4.1XI		3.6BI	4I	
EP	M	18800531		45.20 N	75.30 N						4.1XI	4.7II	4.6BI	4I	
EP	M	18800722	07	45.40 N	75.70 N						2.5XI	3.0II	3.0BI	3I	
EP	M	18800906	0530	45.20 N	73.80 N						3.1XI	3.7II	3.6BI	4I	
EP	I	18800906	07	45.00 N	74.70 N						2.5XI	3.0II	3.0BI	3I	
EP	M	18811204	2330	45.10 N	74.20 N						2.5XI	3.0II	3.0BI	4I	
EP	M	18850312		45.10 N	74.50 N						3.5XI	3.7II	3.6BI	4I	
EP	I	18841024	0515	45.10 N	74.20 N						2.5XI	3.0II	3.0BI	3I	
EP	I	18841024	14	45.10 N	74.20 N						2.5XI	3.0II	3.0BI	3I	
EP	I	18850203	0520	45.10 N	74.20 N						2.5XI	3.0II	3.0BI	3I	
EP	I	18850225	0530	45.10 N	74.20 N						2.5XI	3.0II	3.0BI	3I	
EP	M	18850323		45.10 N	74.20 N						2.5XI	3.0II	3.0BI	3I	
EP	M	18860812		46.00 N	74.00 N						3.1XI	3.7II	3.6BI	4I	
EP	I	18880111	09	45.80 N	77.10 N						3.1XI		3.6BI	4I	
EP	I	18880302	2130	45.10 N	74.20 N						2.5XI	3.0II	3.0BI	3I	
EP	I	18900926	0803	45.50 N	73.60 N						2.5XI	3.0II	3.0BI	3I	
EP	I	18901029	2230	45.60 N	75.90 N						2.5XI	3.0II	3.0BI	3I	
EP	I	18921226		45.10 N	74.30 N						2.5XI	3.0II	3.0BI	3I	
EP	M	18931127	1650	45.50 N	73.30 N						4.9XI	5.7II	5.4BI	7I	
EP	I	18940827	0544	45.50 N	73.60 N						2.5XI	3.0II	3.0BI	3I	
EP	I	18951209	0525	45.50 N	73.60 N						2.5XI	3.0II	3.0BI	3I	
EP	M	18970323	2307	45.50 N	73.60 N						4.6XI	5.0XI	4.7BI	6I	23127.I
EP	M	18970528	0316	44.50 N	73.50 N						4.3XI	4.5II	4.8BI	6I	
EP	M	18980107	06	45.10 N	74.30 N						3.1XI	3.7II	3.6BI	4I	
EP	M	19031225	1230	44.70 N	75.50 N						3.7XI		4.2BI	5I	
EP	M	19061117	14	45.61 N	75.41 N						3.1XI	3.7II	3.6BI	4I	
EP	M	19071114	05	45.47 N	76.68 N						3.7XI		4.2BI	5I	
EP	M	19080616	2041	45.10 N	74.80 N						3.7XI		3.6BI	4I	
EP	M	19080717	0710	45.43 N	76.35 N						3.1XI	3.7II	3.6BI	4I	
EP	I	19080816		44.67 N	73.15 N						2.5XI	3.0II	3.0BI	3I	
EP	M	19090201	04	45.51 N	73.57 N						4.5XI	5.0II	3.0BI	4I	
EP	M	19090201	0820	45.51 N	73.57 N						3.1XI	3.7II	3.6BI	4I	
EP	M	19090510	0120	46.10 N	74.30 N						3.1XI		3.6BI	4I	
EP	M	19091210	062410.0	45.40 N	75.60 N						3.1XI	3.7II	3.6BI	4I	
EP	I	19100303		44.20 N	74.07 N						2.5XI	3.0II	3.0BI	3I	
EP	I	19110129		44.70 N	75.50 N						4.1XI	4.4LI	4.2BI	5I	3130.I
EP	M	19130429	2857.0	44.87 N	75.33 N						4.1XI	3.7II	3.6BI	4I	
EP	M	19130608	0630	45.68 N	74.40 N						5.3XI	5.5LI	5.4BI	7I	2319.I
EP	M	19130810	0515	44.00 N	75.00 N						5.3XI	5.5LI	5.4BI	7I	188862.I
EP	M	19140210	1831	46.00 N	75.00 N						3.7XI	4.3II	4.2BI	5I	
EP	M	19140214	0934	46.40 N	73.60 N						3.1XI		3.6BI	4I	
EP	M	19150221	2341	44.70 N	73.40 N						3.9XI	4.0XI	4.2BI		
EP	M	19160424	160745.0	47.00 N	77.00 N						3.7XI	4.3II	4.2BI	5I	
EP	M	19170126	1935	46.80 N	74.50 N						4.2XI	4.0II	4.3BI	5I	14027.I
EP	M	19170522	09 26.0	45.10 N	75.60 N						4.4XI	4.0II	3.9BI	5I	
EP	M	19201108		46.01 N	73.43 N						3.7XI	4.0II	4.2BI	5I	
EP	M	19210827	081216.0	47.00 N	76.00 N						3.7XI		4.2BI	5I	
EP	M	19221208	2124	44.40 N	75.10 N						4.0XI	4.7II	4.5BI	6I	
EP	M	19240715	10	45.70 N	76.50 N						3.1XI		3.6BI	4I	
EP	M	19260127		44.30 N	74.10 N						3.1XI		3.6BI	4I	
EP	M	19260823	1640	45.80 N	77.10 N						3.1XI		3.6BI	4I	
EP	M	19270312	2212	44.60 N	75.20 N						4.3XI	4.1LI	4.4BI	6I	11485.I
EP	M	19271024	11	44.70 N	73.80 N						2.5XI	3.0II	3.0BI	5I	
EP	M	19280318	1525	44.50 N	74.30 N						2.5XI	3.0II	3.0BI	3I	
EP	I	19290605	07	44.80 N	74.30 N						4.5XI	4.5LI	4.0BI		
EP	M	19301102	0235	44.80 N	74.30 N						3.7XI	3.8LI	4.0BI		
EP	M	19310923	224737.0	47.00 N	76.07 N						3.1XI		3.6BI	4I	
EP	M	19320309	052338.8	46.47 N	74.67 N						2.5XI	3.0II	3.0BI	3I	
EP	I	19321207	0315	44.40 N	74.10 N						3.7XI	3.8LI	4.0BI		
EP	M	19330121	160439.5	45.30 N	74.65 N						2.5XI	3.0II	3.0BI	3I	
EP	I	-19330225	0232	45.03 N	75.73 N						2.5XI	3.0II	3.0BI	3I	
EP	I	19330520	1957	44.80 N	74.70 N						3.8XI	3.9LI	4.1BI		
EP	M	19340714	044840.0	45.42 N	75.70 N						4.4XI	4.5LI	4.5BI	6I	7698.I
EP	M	19340415	0258	44.70 N	73.80 N						2.5XI	3.0II	3.0BI	3I	
EP	I	19340415	1805	44.80 N	74.30 N						2.5XI	3.0II	3.0BI	3I	
EP	I	19340605	2011	44.80 N	74.30 N						3.1XI		3.0BI	4I	
EP	M	19350128	06	44.80 N	74.30 N						2.5XI	3.2II	3.0BI	3I	
EP	I	19350128	090132.0	44.80 N	74.30 N										

There have been   100 events listed so far.

Lab	Date YearMoDy	OT (UCT) HrMnSec	Hypocenter Lat	Lon	Depth	Error (km) ERH	ERZ	Hy LS	Magnitudes MagTS	MagTS	MagTS	Int S	Felt Area (mi2) S
EP M	19351101	060340.0	46.78 N	79.07 W				I	6.0XI	6.2NI	6.1BI	7I	627045.I
EP M	19351102	143158.0	47.23 N	78.17 W				I	4.7?I	4.9NI	4.8BI		
EP M	19351127	193100.4	46.80 N	79.10 W				I	3.9?I	4.1N?	4.0BI		
EP	19551215	1015	46.78 N	79.07 W				I	2.5XI	3.0II	3.0BI	3I	
EP	19560621	0340	44.70 N	74.20 W				I		3.0II		3I	
EP	19560621	0420	44.70 N	74.20 W				I				4I	
EP	19370310	0529	44.60 N	74.20 W				I				4I	
EP	19371106	143120.6	46.78 N	75.82 W	24.0			I		4.0LI	4.2BI		
EP	19371112	165731.5	46.10 N	74.47 W	1.0			I					
EP	19380106	132842.3	45.90 N	75.18 W				I					
EP	19380124	052902.0	45.57 N	76.27 W				I					
EP	19380223	175635.7	46.38 N	75.40 W				I					
EP	19380505	5300.3	45.37 N	74.50 W				I					
EP	19380907	231818.9	45.87 N	74.90 W				I		3.4?I	3.3BI	4I	
EP	19381118	221906.0	44.75 N	75.25 W				I		4.2?I	4.3BI	5I	
EP	19381126	074757.5	47.03 N	76.20 W				I					
EP	19390516	2021	46.40 N	75.50 W				I					
EP	19390601	0356	44.60 N	75.20 W				I	2.5XI	3.0II	3.0BI	3I	
EP M	19400105	3414.0	46.72 N	79.08 W				I		4.0LI	4.2BI		
EP M	19400210	205717.3	46.50 N	76.83 W				I		4.0LI	3.8BI		
EP M	19400516	14 17.1	45.80 N	73.20 W				I					
EP M	19400804	162052.0	46.25 N	74.78 W				I		4.0LI	4.4BI		
EP M	19400807	235735.1	45.77 N	74.83 W				I		4.0LI	4.4BI		
EP M	19410305	072923.2	46.27 N	75.50 W				I		3.3LI	3.6BI		
EP M	19410404	081043.7	44.73 N	73.92 W				I					
EP M	19410626	040544.9	47.40 N	76.83 W				I	4.0XI		4.3BI		
EP M	19411021	061041.0	44.77 N	74.80 W				I					
EP M	19411024	141359.7	45.70 N	74.30 W				I					
EP M	19420218	075512.0	46.83 N	74.77 W				I	3.2XI	3.1LI	3.4BI		
EP M	19420520	121922.8	45.77 N	74.67 W				I		4.4LI	4.5BI		
EP M	19420524	1153	46.80 N	73.80 W				I	3.8XI	3.9LI	4.1BI		
EP M	19420826	1754	46.78 N	77.50 W				I		3.7NI	3.7BI		
EP M	19420915	223246.0	46.78 N	76.00 W				I		3.3LI	3.8BI		
EP M	19421116	1329.4	46.42 N	75.05 W				I		3.6LI	3.8BI		
EP M	19421205	211051.2	46.97 N	76.07 W				I	4.1XI	4.2?I	4.3BI		
EP M	19430215	165105.2	45.78 N	74.67 W				I	2.5XI	3.0II	3.0BI	3I	
EP M	19430228	164001.2	46.50 N	75.77 W				I		3.7LI	3.9BI		
EP M	19430509	110312.5	44.77 N	73.83 W				I		3.7LI	3.9BI		
EP M	19440122	215509.1	45.83 N	76.78 W				I		4.5LI	4.4BI		
EP M	19440308	1249	46.70 N	78.90 W				I	4.0XI	4.1LI	4.3BI		
EP M	19440624	234838.5	46.00 N	74.25 W				I		3.7LI	3.9BI		
EP M	19440905	043845.7	44.96 N	74.72 W	12.0			I	5.7XI	5.8NI	5.8BI	8I	567374.I
EP M	19450612	075815.1	47.08 N	75.40 W				I	4.2XI	4.3LI	4.4BI		
EP M	19460421	050555.5	45.73 N	73.43 W				I		3.6LI	3.8BI		
EP M	19460627	210622.0	44.65 N	74.53 W				I	3.1XI	3.0LI	3.4BI		
EP M	19470119	4501.7	46.80 N	76.70 W				I	3.8XI	5.9LI	4.1BI		
EP M	19480507	120227.3	45.86 N	73.69 W	3.0			I	3.9XI	4.0LI	4.2BI		
EP M	19480609	030412.2	45.23 N	75.87 W				I	3.7XI	3.7LI	3.9BI		
EP M	19480707	073801.4	45.18 N	73.90 W				I	3.5XI	3.5LI	3.8BI		
EP I	19490207	0617	44.90 N	74.90 W				I	2.5XI	3.0II	3.0BI	3I	
EP M	19491016	233345.4	45.49 N	74.90 W	14.0			I	4.1XI	4.2LI	4.3BI		
EP M	19500306	161411.8	46.00 N	74.50 W				I	3.9XI	4.0LI	4.2BI		
EP M	19500804	142928.7	45.20 N	74.72 W				I	3.9XI	4.0LI	4.2BI		
EP M	19501029	055926.0	45.82 N	77.12 W				I	3.1XI	3.0LI	3.4BI		
EP M	19510808	093624.1	45.93 N	74.67 W				I	3.5XI	3.3LI	3.6BI		
EP M	19510925	1545	46.22 N	75.37 W				I	3.7XI	3.7LI	3.9BI		
EP M	19511025	070752.8	45.27 N	74.73 W				I	3.5XI	3.8LI	4.0BI		
EP M	19511106	175445.9	44.92 N	73.55 W	31.0			I	4.0XI	4.1NI	4.1BI		7698.I
EP M	19520130	04	44.50 N	73.20 W				I	4.3XI	4.5XI	4.8BI	6I	
EP M	19520317	041441.0	47.10 N	76.17 W				I	3.7XI	3.8LI	4.0BI		
EP M	19520426	0459	47.00 N	78.50 W				I	3.7XI	3.7LI	3.9BI		
EP M	19520719	011617.2	46.87 N	75.84 W	1.0			I	4.2XI	4.3LI	4.4BI		
EP M	19530426	0117	44.70 N	73.50 W				I	3.7XI	3.7LI	3.9BI	4I	
EP M	19540412	212200.1	47.00 N	76.12 W	6.0			I	4.2XI	4.3LI	4.4BI	4I	
EP M	19540421	1545	44.70 N	73.50 W				I	3.1XI		3.4BI	4I	
EP M	19540520	22	45.00 N	74.20 W				I	3.2XI	2.7LI	3.4BI		
EP M	19540911	185555.6	47.18 N	75.66 W	28.0			I	4.4XI	4.6LI	4.7BI	4I	
EP M	19541215	0353	44.60 N	74.60 W				I	3.7XI	3.6LI	3.8BI	4I	
EP M	19550203	0230	44.50 N	73.22 W				I	4.1XI	4.0XI	4.3BI	5I	
EP M	19551007	180952.0	45.22 N	73.90 W				I	3.5XI	3.5LI	3.8BI		
EP M	19551101	074552.0	46.50 N	75.87 W				I	3.5XI	3.5LI	3.8BI		
EP M	19560110	120818.0	45.67 N	75.47 W				I	3.2XI	3.3LI	3.6BI		
EP M	19560202	192416.0	45.45 N	74.82 W				I	3.2XI	3.1LI	3.4BI		
EP M	19560306	233810.0	44.85 N	75.38 W				I	3.8XI	3.9LI	4.1BI		
EP M	19560615	5337.0	47.10 N	73.43 W				I	3.4XI	4.0LI	4.2BI		
EP M	19560727	013444.0	44.70 N	73.78 W				I	3.9XI	4.0LI	4.2BI		
EP M	19561104	115329.2	45.96 N	75.42 W	1.0			I				4I	
EP M	19570220	1545	44.90 N	74.90 W				I	3.1XI		3.6BI		
EP M	19570821	024033.0	44.80 N	76.17 W				I	3.2XI	3.0LI	3.4BI		
EP M	19571027	084827.0	46.38 N	78.75 W				I	3.2XI	3.2LI	3.5BI	4I	
EP M	19580111	1636	44.90 N	74.90 W				I	3.1XI		3.6BI		
EP M	19580301	174149.0	46.90 N	76.03 W				I	3.8XI	3.9LI	4.1BI		
EP M	19580319	063925.0	46.00 N	77.13 W				I	3.2XI	3.1LI	3.4BI		
EP M	19580514	174116.7	47.09 N	76.82 W	1.0			I	4.7XI	5.0XI	5.0BI		
EP M	19580725	034511.0	46.57 N	75.80 W				I	4.7XI	3.8LI	4.0BI		
EP M	19580930	1358.0	45.18 N	73.73 W				I	3.7XI	3.7LI	3.9BI		
EP M	19590521	093851.0	46.55 N	76.45 W				I	3.8XI	3.9LI	4.1BI		
EP M	19600120	200740.0	46.97 N	75.67 W				I	3.7XI	3.7LI	3.9BI		
EP M	19610313	105545.0	45.17 N	75.28 W				I	3.1XI	3.2LI	3.8BI		3130.I
EP I	19610420	1313	45.00 N	74.80 W				I	3.1XI	2.0LI	3.2BI	5I	
EP M	19610929	0630	44.90 N	74.90 W				I				4I	
EP M	19620127	121117.0	45.92 N	74.85 W				I	3.7XI	3.8NI	3.8BI		
EP I	19620621	020647.0	45.44 N	72.64 W	1.0			I	3.1XI	3.2NI	3.2BI	5I	
EP M	19621002	2345	44.80 N	74.30 W				I	3.1XI		3.6BI	4I	
EP M	19630519	1914	43.50 N	75.20 W				I	3.4XI		3.6BI	3I	
EP M	19630826	162935.0	45.18 N	73.95 W				I	3.5XI	3.5LI	3.8BI		
EP M	19631015	1229	46.31 N	77.55 W	5.0			I	4.0XI	4.1NI	4.1BI		
EP M	19640329	0916	44.90 N	74.90 W				I	4.2XI	4.3LI	4.4BI	5I	
EP M	19640616	14	45.00 N	74.20 W				I	3.3XI	2.7LI	3.4BI	4I	
EP M	19640724	103411.0	46.65 N	76.25 W				I	3.3XI	3.3LI	3.6BI		

There have been 200 events listed so far.

Lab	Date YearMoDy HrMnSec	OT (UCT)	Hypocenter Lat	Lon	Depth	Error (km) ERH ERZ	Hy LS	Magnitudes MagTS MagTS MagTS	Int S	Felt Area (mi2) S
EP M	19650915	175628.0	46.72 N	79.05 W				3.7?I 3.8LI 4.0BI		
EP M	19651107	205741.8	47.25 N	76.36 W	10.0			4.2?I 4.2NI 4.2BI		
EP M	19651124	212801.0	46.93 N	76.28 W						
EP M	19660320	234533.0	46.50 N	76.86 W						
EP M	19660625	0551.0	45.16 N	73.83 W						
EP M	19661113	1543	47.00 N	76.30 W						
EP M	19670611	014939.0	46.58 N	75.03 W						
EP M	19681019	1037	45.50 N	74.10 W						
EP I	19681103	205049.0	46.17 N	76.30 W	18.0				5I	
EP M	19691010	0704.9	46.31 N	75.06 W	2.0					23127.I
EP I	19701015	185611.0	47.07 N	76.25 W	18.0					
EP I	19710106	062208.0	47.17 N	75.96 W	18.0					
EP I	19710119	134425.0	46.92 N	75.18 W	18.0					
EP M	19710514	062009.0	45.10 N	73.37 W	18.0				4I	
EP M	19710523	062427.9	43.90 N	74.48 W	2.0					
EP M	19710706	174749.0	46.55 N	76.28 W	18.0					
EP I	19710927	084723.0	45.71 N	75.17 W	18.0					
EP I	19711115	103855.0	45.06 N	73.87 W	18.0					
EP M	19711122	052907.0	47.24 N	76.28 W	18.0					
EP M	19711123	163230.0	45.83 N	76.62 W	18.0					
EP I	19711218	153624.5	46.01 N	74.67 W	13.0				5I	
EP I	19720425	032425.0	46.67 N	75.99 W	18.0					
EP I	19720912	091538.0	46.18 N	77.56 W	18.0					
EP I	19721019	022259.0	45.52 N	74.28 W	18.0				3I	
EP M	19721216	190157.2	45.64 N	75.10 W	10.0					
EP M	19730715	082030.7	43.87 N	74.47 W	2.0					
EP M	19730715	103237.8	43.87 N	74.47 W	2.0					
EP M	19730716	084158.0	43.76 N	74.47 W	1.0					
EP M	19740318	1605	44.45 N	74.85 W						
EP M	19740609	1839	44.90 N	73.60 W						
EP M	19740808	115533.0	45.93 N	76.08 W	18.0					
EP M	19741023	225257.0	46.08 N	75.48 W	10.0					
EP M	19741102	134756.0	46.07 N	75.03 W	10.0					
EP I	19750115	1916	44.90 N	74.60 W					4I	
EP I	19750403	190317.0	45.73 N	74.24 W	5.0					
EP M	19750529	211916.0	47.23 N	75.19 W	18.0					
EP M	19750609	183922.7	44.87 N	73.65 W	11.0					5160.I
EP M	19750712	123713.8	46.54 N	76.31 W	17.0					34502.I
EP M	19751103	205455.3	43.91 N	74.65 W	5.0					
EP I	19751219	152500.1	47.01 N	78.89 W					3I	
EP I	19760713	035114.0	45.18 N	74.10 W	9.0				4I	
EP I	19761106	060929.0	47.11 N	75.96 W	18.0					
EP M	19770714	073929.8	46.04 N	74.38 W	4.0				4I	
EP I	19770928	172144.7	44.39 N	73.89 W	3.0				3I	
EP I	19771016	212919.1	46.52 N	73.82 W	1.0					
EP I	19771107	204852.7	46.27 N	75.15 W	5.0					
EP I	19771125	184724.4	46.69 N	75.86 W	1.0					
EP M	19771222	145701.3	46.84 N	76.91 W	11.0					
EP M	19780218	144825.0	46.35 N	74.11 W	7.0				5I	28248.I
EP M	19780730	105444.0	45.68 N	74.44 W	7.0					
EP I	19780821	0847	44.52 N	74.51 W						
EP I	19780826	035434.1	47.17 N	76.43 W	5.0				4I	
EP I	19781228	0924	44.50 N	73.90 W						
EP I	19790318	163112.0	45.84 N	76.46 W	18.0					
EP I	19790526	215832.8	46.18 N	75.68 W	1.0					
EP M	19790529	204849.1	45.00 N	74.99 W	2.0					
EP M	19790607	134553.3	44.43 N	73.86 W						
EP M	19790708	012918.0	46.87 N	76.60 W	18.0					
EP I	19790709	081626.0	46.54 N	74.65 W	18.0				5I	
EP I	19800519	234050.0	45.26 N	75.25 W	19.0					
EP M	19800523	083944.0	44.89 N	74.55 W						
EP I	19800606	131551.9	43.56 N	75.23 W	1.0				5I	1406.I
EP I	19800725	062234.0	45.14 N	74.17 W	5.0					
EP I	19800811	145446.1	43.54 N	75.16 W						
EP I	19800921	040731.0	45.69 N	74.34 W	4.0					
EP I	19800928	221905.4	43.77 N	74.12 W						
EP M	19810219	070710.0	45.96 N	74.93 W	18.0					
EP M	19810705	214723.0	45.17 N	74.62 W	13.0					
EP M	19810918	071607.0	46.11 N	75.02 W					4I	
EP M	19810930	234139.0	46.37 N	75.56 W						
EP M	19811112	184014.0	46.98 N	77.04 W	18.0					
EP I	19811206	161127.0	45.38 N	72.64 W	3.0					
EP M	19820623	22	47.58 N	76.95 W	18.0				4I	
EP M	19820713	021849.0	46.09 N	74.55 W	17.0				4I	
EP M	19820806	062910.0	45.89 N	75.46 W	19.0				4I	
EP M	19820813	010642.0	46.67 N	78.61 W	18.0					
EP M	19820903	231403.0	45.67 N	76.61 W	12.0					
EP I	19830110	213127.0	46.82 N	78.83 W	18.0					
EP I	19830717	224745.0	46.06 N	74.91 W	18.0				6I	114551.I
EP M	19831007	101847.0	44.03 N	74.31 W	7.0					
EP I	19831011	041055.0	45.21 N	75.77 W	15.0					
EP I	19831016	03 47.0	45.62 N	75.05 W	11.0					
EP I	19831101	101652.0	45.68 N	73.90 W	18.0					
EP I	19831214	015203.0	46.69 N	76.29 W	18.0					
EP I	19831221	150444.0	45.24 N	73.97 W	18.0					
EP M	19831228	122421.0	47.01 N	76.33 W	18.0					
EP I	19840117	190446.0	45.56 N	75.12 W	19.0					
EP M	19841023	062621.9	43.59 N	73.93 W						

There are 288 events in this listing.

SOURCE CODES FOR HYPOCENTERS AND MAGNITUDES
    B - Bollinger, 1975, Southeastern U. S. Catalog 1754-1974,
    E - Earth Physics Branch, Canadian catalog,
    G - USGS - State Seismicity Maps (Stover/Reagor et al.),
    I - EPRI Catalog (8 July 1986),
    M - Sibol, Bollinger, and Birch, BSSA, 77, pp. 1635-1654,
    N - Neilsen, 1982 (Stanford Data Base,...),
    O - Nuttli, 1974, BSSA, 64, pp. 1189-1207,
    R - Barstow et al., 1981 (Rondout Asso.), NUREG/CR-1577,
    S - Street and Turcotte, 1977, BSSA, 67, pp. 599-614,
    T - Reinbold and Johnston (TEIC), 1986, USGS Final Rept.,
    U - Earthquake History of the U.S./U.S. Earthquakes,
    V - SEUSSN Bulletins (Va. Tech Publication),
    W - Nuttli, et al., 1979, BSSA, 69, pp. 893-909,
    Y - Felt area only, value is the average of those found in G and R above,
    Z - Felt area only, value is the average of those found in U and R above,
    ? - Some discrepancy exists for the event (Follows State),

LOCATION CODES
    H - Historical Location (from intensity/felt area data),
    I - Instrumental Location,

MAGNITUDE TYPE CODES (FOLLOWS MAGNITUDE VALUE, THAT IS, THE T IN MAGTS)
    B - mb from Baysian estimate (Veneziano & VanDyck, 1984),
    C - mb from intensity and felt area (Sibol et al.; 1987)'
    D - Md from duration or coda length,
    F - mb from felt area or attenuation data,
    I - mb from intensity data
    L - ML (Richter, 1958),
    M - mb determined from modified instruments/formuli,
    N - mb from Lg wave data (Nuttli, 1973),
    O - m3Hz (Lawson, et al., 1979 - Oklahoma earthquakes),
    P - mb from P wave data (Gutenberg and Richter, 1956),
    S - MS (Bath, 1966, Gutenberg, 1945),
    X - Magnitude of unknown type.
Remember to change :"s to : in output file.

22-SEP-90 18:11:20 for the program RMGEN
       Input data from file......: CHARLEVOIX MI.EPRI

Lab	I- Date -|OT (UCT)|I---- Hypocenter ----|Error (km) |Hy|-- Magnitudes ---|Int	Felt Area	
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	YearMoDv HrMnSec	Lat	Lon	Depth	ERH	ERZ	LS MagTS MagTS MagTS	S	(mi2)	S

EP	M	16630205 1730	47.60 N	70.10 W			I 6.1XI 7.0II 6.5BI	9I	
EP	M	16680413 13	47.10 N	70.50 W			I 4.3CI 5.0II 4.8BI	6T	
EP	M	167202	48.15 N	69.70 W			I 3.3CI 5.0II 3.6BI	4T	
EP	M	16731208	48.15 N	69.70 W			I 3.5CI 5.0II 3.0BI	3I	
EP	M	17911206 20	47.40 N	70.50 W			I 5.9XI 6.0XI 5.9BI	8I	
EP	M	18310508	47.30 N	70.50 W			I 4.9CI 5.7II 5.4BI	7C	
EP	M	18310714	47.60 N	70.10 W			I 4.3CI 5.0XI 4.8BI	6C	
EP	T	183303	47.65 N	70.17 W			I 3.5CI 3.7II 3.6BI	4C	
EP	T	185307	47.50 N	70.00 W			I 3.5CI 3.7II 3.0BI	3I	
EP	M	18580915 2130	47.60 N	69.90 W			I 3.5CI 5.0II 3.0BI	3I	
EP	M	18601017 1115	47.50 N	70.10 W			I 5.9CI 5.0XI 6.1BI	8I	692992.I
EP	M	186912	47.50 N	70.50 W			I 4.3CI 4.0XI 3.9BI	5I	1033823.I
EP	M	18701020 1630	47.40 N	70.50 W			I 6.3CI 6.5XI 6.5BI	9I	
EP	T	18710217	47.40 N	70.40 W			I 2.5CI 5.0II 3.0BI	3I	
EP	T	18770717	47.80 N	69.50 W			I 3.5CI 3.7II 3.0BI	3C	
EP	M	18790407 05	47.45 N	70.50 W			I 4.3CI 5.0II 3.0BI	3C	
EP	M	18801128 1330	47.45 N	70.50 W			I 3.7II 3.6BI	4I	
EP	M	18811001 0640	47.60 N	70.20 W			I 3.5CI 3.7II 3.6BI	4I	
EP	M	18850416 14	47.50 N	70.20 W			I 2.5CI 3.0II 3.0BI	3C	
EP	M	18870311	47.50 N	70.50 W			I 3.0II 3.0BI	4I	
EP	M	18870527 0615	47.45 N	70.50 W			I 4.0XI 3.9BI	5I	
EP	M	18880419 0530	47.45 N	70.50 W			I 4.0XI 3.9BI	5I	
EP	T	18880419 0540	47.80 N	69.50 W			I 3.5CI 3.7II 3.6BI	4I	
EP	T	18920726	47.80 N	69.50 W			I 3.5CI 5.0II 3.0BI	3I	
EP	T	189411 12	47.40 N	70.00 W			I 2.5CI 5.0II 3.0BI	3I	
EP	T	189811 12	47.22 N	70.02 W			I 3.5CI 5.0II 3.0BI	3I	
EP	M	19061221	47.70 N	70.80 W			I 2.5CI 3.7II 3.0BI	5I	
EP	M	19070805 1243	47.65 N	70.16 W			I 3.5CI 3.7II 3.6BI	4I	
EP	M	19080310	47.45 N	70.50 W			I 3.5CI 3.7II 3.6BI	4I	
EP	M	191002	48.00 N	70.00 W			I 4.3XI 5.0II 4.8BI	6I	
EP	M	19101025 0930	47.60 N	69.80 W			I 4.3CI 4.0XI 3.9BI	5I	
EP	M	19191026 1028	47.60 N	70.00 W			I 3.5CI 3.7II 3.6BI	4C	
EP	M	19200206	48.15 N	69.71 W			I 3.7II 3.6BI	4I	
EP	M	19240304 1915	47.80 N	70.20 W			I 3.7CI 4.3II 4.2BI	5I	
EP	M	19240930 085230.0	47.80 N	69.80 W			I 5.0XI 5.5LI 5.1BI	7I	31219.I
EP	M	19250301 021914.7	47.76 N	69.84 W	9.0		I 6.4XI 6.6NI 6.5BI	9I	1262714.I
EP	I	19250410 0930	47.80 N	69.80 W			I 2.5CI 3.0II 3.0BI	3C	
EP	I	19250411 1130	47.80 N	69.80 W			I 2.5CI 5.0II 3.0BI	3C	
EP	T	19250531 0357	47.80 N	69.80 W			I 2.5CI 5.0II 3.0BI	3C	
EP	T	19250727 09	47.80 N	69.80 W			I 2.5CI 5.0II 3.0BI	3C	
EP	M	19260219 2020	47.70 N	71.00 W			I 3.1XI 3.7II 3.6BI	4I	
EP	M	19260921 1130	48.00 N	70.50 W			I 3.5CI 3.7II 3.6BI	4I	
EP	I	19270209 2330	47.65 N	70.17 W			I 2.5CI 3.0II 3.0BI	3I	
EP	I	19270320	47.65 N	70.16 W			I 2.5XI 3.0II 3.0BI	3I	
EP	M	19270725 56	47.30 N	71.00 W			I 3.4XI 4.0XI 3.9BI	5I	
EP	M	19280127	48.00 N	70.20 W			I 3.1XI 3.6BI	4I	
EP	M	19300713 045239.3	47.50 N	69.83 W			I 3.2XI 3.1LI 3.4BI	
EP	M	19301213 231823.7	47.65 N	70.17 W			I 3.5XI 3.5LI 3.8BI	
EP	M	19301225 220734.0	47.30 N	70.40 W			I 4.4XI 4.6LI 4.7BI	*
EP	M	19310108 1300.3	47.30 N	70.40 W			I 5.0XI 5.4LI 5.3BI	
EP	I	19320802 073749.6	47.45 N	70.50 W			I 2.5XI 3.0II 3.0BI	3I
EP	M	19330111 2332	47.45 N	70.50 W			I 2.5XI 3.2LI 3.5BI	
EP	M	19330225 094302.7	47.43 N	69.93 W			I 3.4XI 3.4LI 3.7BI	
EP	M	19360329 4923.4	47.33 N	70.25 W			I 3.8XI 4.0NI 3.9BI	
EP	M	19390624 172018.3	47.59 N	69.98 W	14.0		I 4.3XI 4.5NI 4.4BI	
EP	M	19391019 115358.0	47.80 N	69.80 W	15.0		I 5.5XI 5.6XI 5.6BI	6I	380322.I
EP	M	19400413 081334.0	47.73 N	70.73 W			I 3.7XI 3.8LI 4.0BI	
EP	M	19410622 095931.0	47.39 N	70.34 W			I 3.1XI 3.0LI 3.4BI	
EP	M	19410906 170456.5	47.43 N	70.52 W			I 3.7XI 3.8LI 4.0BI	
EP	M	19430925 055236.1	47.55 N	70.65 W			I 3.5XI 3.3LI 3.6BI	
EP	M	19430928 163025.2	47.27 N	70.40 W			I 3.7XI 3.8LI 4.0BI	
EP	M	19450618 152004.7	47.34 N	71.09 W	5.0		I 4.5XI 4.7LI 4.7BI	
EP	M	19451009 131842.0	47.99 N	69.81 W	5.0		I 4.5XI 4.7LI 4.7BI	
EP	M	19470202 165032.3	47.67 N	70.53 W			I 4.1XI 4.2LI 4.3BI	
EP	M	19470329 122852.4	47.37 N	70.23 W			I 3.9XI 4.0LI 4.2BI	
EP	M	19480101 183345.3	47.30 N	70.40 W			I 4.3XI 4.5XI 4.6BI	
EP	M	19500804 064521.0	47.33 N	70.25 W			I 3.3XI 3.2LI 3.5BI	
EP	M	19520330 131107.0	47.83 N	69.88 W			I 4.0XI 4.1NI 4.1BI	
EP	M	19520419 025052.8	47.47 N	70.58 W			I 3.7XI 3.8LI 4.0BI	
EP	M	19521014 220344.8	47.80 N	69.80 W			I 4.8XI 4.9NI 4.9BI	5I	139913.I
EP	M	19540207 202416.0	47.60 N	70.25 W			I 3.7XI 3.8LI 4.0BI	
EP	M	19540221 09 37.0	47.67 N	70.62 W			I 3.5XI 3.5LI 3.8BI	
EP	M	19550201 124027.0	47.67 N	70.50 W			I 3.9XI 4.0LI 4.2BI	
EP	M	19570219 051833.0	48.40 N	69.93 W			I 3.5XI 3.5LI 3.8BI	
EP	M	19570806 235038.0	47.48 N	70.42 W			I 3.9XI 4.0LI 4.2BI	
EP	M	19571009 141658.0	48.42 N	69.90 W			I 3.2XI 3.1LI 3.4BI	
EP	M	19580727 0858	47.32 N	70.30 W			I 3.1XI 3.0LI 3.4BI	
EP	M	19590416 163625.0	47.12 N	70.33 W			I 3.5XI 3.5LI 3.8BI	
EP	M	19600206 4402.0	47.80 N	70.38 W			I 3.5XI 3.3LI 3.6BI	
EP	M	19600423 114747.1	47.88 N	70.34 W	5.0		I 3.9XI 4.0LI 4.2BI	
EP	M	19610822 185551.0	47.33 N	70.50 W			I 3.4XI 3.4LI 3.7BI	
EP	M	19620727 175657.0	47.25 N	70.67 W			I 3.8XI 3.9NI 3.9BI	
EP	M	19620811 030516.0	47.53 N	70.05 W			I 3.5XI 3.6NI 3.6BI	
EP	M	19650301 022208.0	47.50 N	71.25 W			I 4.0XI 4.1LI 4.3BI	
EP	M	19651216 135319.0	47.83 N	70.60 W			I 3.3XI 3.2LI 3.5BI	
EP	M	19660720 200829.0	47.75 N	70.00 W			I 3.1XI 3.0LI 3.4BI	
EP	M	19661001 172355.0	47.66 N	70.33 W			I 3.1XI 3.0LI 3.4BI	
EP	I	19680330 152859.0	47.94 N	70.49 W	18.0		I 3.1XI 3.1NI 3.1BI	
EP	M	19680411 0918	47.60 N	70.40 W			I 3.5XI 3.5LI 3.8BI	
EP	M	19690714 030659.0	47.83 N	70.09 W	18.0		I 3.8XI 3.8NI 3.8BI	
EP	M	19690831 072027.0	47.49 N	70.07 W	18.0		I 3.3XI 3.2LI 3.5BI	
EP	I	19700907 213927.0	47.92 N	70.30 W	18.0		I 3.2XI 3.2NI 3.2BI	
EP	I	19710912 083143.0	47.56 N	70.24 W	18.0		I 3.1XI 3.1NI 3.1BI	
EP	T	19730128 130750.0	47.98 N	70.00 W	10.0		I 3.1XI 3.1NI 3.1BI	
EP	T	19731116 013634.0	47.55 N	70.29 W	10.0		I 3.1XI 3.1NI 3.1BI	
EP	I	19740630 165500.1	47.71 N	69.84 W	15.0		I 3.2XI 3.1LI 3.4BI	
EP	M	19750821 042937.0	47.44 N	70.18 W	5.0		I 3.2XI 3.3NI 3.3BI	4I	
EP	I	19750902 062117.0	48.29 N	69.74 W	2.0		I 4.2XI 4.2NI 4.2BI		20927.I
EP	M	19761023 205818.0	47.82 N	69.78 W	18.0		I 3.1XI 3.1NI 3.1BI	
EP	I	19761023 212306.0	47.88 N	69.78 W	18.0			

       There have been 100 events listed so far.

I- Date -	OT (UCT)		---- Hypocenter ----			Error (km)		Hy		-- Magnitudes ---			Int	Felt Area	
Lab	YearMoDy	HrMnSec	Lat	Lon	Depth	ERH	ERZ	LS	MagTS	MagTS	MagTS	S	(mi2)	S
EP I	19770214	3504.1	47.54 N	70.42	H	8.0		I	3.1XI	3.1NI	3.1BI			
EP I	19770620	050554.7	47.77 N	70.16	H	8.0		I	3.1XI	3.1NI	3.1BI			
EP f	19780526	023100.4	47.72 N	69.99	H	5.0		I	3.2XI	3.2NI	3.2BI			
EP A	19790323	225305.0	47.69 N	70.10	H	10.0		I	3.5XI	3.2NI	3.2BI			
EP M	19790819	224930.4	47.67 N	69.90	H	10.0		I	4.6XI	5.0NI	4.6BI		5I	23127.I
EP T	19790820	231110.0	47.67 N	69.90	H	7.0		I	3.0XI	3.0NI	3.0BI			
EP H	19800701	030658.0	47.56 N	70.75	H	10.0		I	3.4XI	3.4NI	3.4BI		4I	
EP I	19800702	075033.0	47.30 N	70.33	H	10.0		I	3.1XI	3.1NI	3.1BI			
EP I	19800930	182601.0	47.50 N	69.90	H	6.0		I	3.0XI	3.0NI	3.0BI			
EP M	19810616	175504.0	47.47 N	70.00	H	8.0		I	3.7XI	3.7NI	3.7BI			
EP I	19820127	013556.0	47.45 N	70.38	H	6.0		I	3.3XI	3.3NI	3.3BI			
EP M	19820829	020711.0	47.37 N	70.38	H	20.0		I	3.4XI	3.4NI	3.4BI			
EP H	19830516	020157.0	47.70 N	69.89	H	11.0		I	3.8XI	3.8NI	3.8BI			
EP I	19830604	05 23.0	47.46 N	69.65	H	10.0		I	5.0XI	5.0NI	5.0BI			

There are   114 events in this listing.

SOURCE CODES FOR HYPOCENTERS AND MAGNITUDES
```
B - Bollinger, 1975, Southeastern U. S. Catalog 1754-1974,
E - Earth Physics Branch, Canadian catalog,
G - USGS - State Seismicity Maps (Stover/Reagor et al.),
I - EPRI Catalog (8 July 1986),
M - Sibol, Bollinger, and Birch, BSSA, 77, pp. 1635-1654,
N - Neilsen, 1982 (Stanford Data Base,   ),
O - Nuttli, 1974, BSSA, 64, pp. 1189-1207,
R - Barstow et al., 1981 (Rondout Asso.), NUREG/CR-1577,
S - Street and Turcotte, 1977, BSSA, 67, pp. 599-614,
T - Reinbold and Johnston (TEIC), 1986, USGS Final Rept.,
U - Earthquake History of the U.S./U.S. Earthquakes,
V - SEUSSN Bulletins (Va. Tech Publication),
W - Nuttli, et al., 1979, BSSA, 69, pp. 893-909,
Y - Felt area only, value is the average of those found in G and R above,
Z - Felt area only, value is the average of those found in U and R above,
? - Some discrepancy exists for the event (Follows State),
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LOCATION CODES
```
H - Historical Location (from intensity/felt area data),
I - Instrumental Location,
```

MAGNITUDE TYPE CODES (FOLLOWS MAGNITUDE VALUE, THAT IS, THE T IN MAGTS)
```
B - mb from Baysian estimate (Veneziano & VanDyck, 1984),
C - mb from intensity and felt area (Sibol et al., 1987)
D - Md from duration or coda length,
F - mb from felt area or attenuation data,
I - mb from intensity data
L - ML (Richter, 1958),
H - mb determined from modified instruments/formuli,
N - mb from Lg wave data (Nuttli, 1973),
O - m3Hz (Lawson, et al., 1979 - Oklahoma earthquakes),
P - mb from P wave data (Gutenberg and Richter, 1956),
S - MS (Bath, 1966, Gutenberg, 1945),
X - Magnitude of unknown type.
```
Remember to change :"s to : in output file.

22-SEP-90 18:13:02 for the program RWGEN

Input data from file......: ST LAWRENCE RIFT MI.EPRI

Lab	- Date - YearMoDy	OT (UCT) HrMnSec	---- Hypocenter ---- Lat	Lon	Depth	Error (km) ERH	ERZ	Hy LS	-- Magnitudes --- MagTS	MagTS	MagTS	Int S	Felt Area (mi2) S
EP M	16651015	2130	46.82 N	71.22	M			I	3.1XI	3.7II	3.6BI	4I	
EP M	17440527		46.80 N	71.20	M			I	5.1OI	5.7II	5.6BI	4I	
EP M	17840102	10	46.80 N	71.20	M			I	5.1OI	5.7II	5.6BI	4I	
EP M	18181011		46.90 N	71.20	M			I	5.1OI	5.7II	5.6BI	4I	
EP I	182102		46.80 N	71.30	M			I	3.5OI	5.4II	5.6BI	1O	
EP I	18580510		45.70 N	72.10	M			I	2.5OI	3.0II	3.0BI	3O	
EP A	18640420	1815	46.90 N	71.20	M			I	4.3OI	5.0II	4.8BI	6I	
EP M	18661109	1610	46.80 N	71.20	M			I	5.1OI	5.7II	5.6BI	4I	
EP M	18710520	07	46.80 N	71.20	M			I	5.1OI	5.7II	5.6BI	4I	
EP I	18710520	0820	46.80 N	71.20	M			I	2.5OI	3.0II	3.0BI	4O	
EP I	18801124		46.80 N	71.20	M			I	2.5OI	3.0II	3.0BI	5O	
EP I	19150806		46.82 N	71.22	M			I	2.5OI	3.0II	3.0BI	4I	
EP M	19160229	0515	46.80 N	70.90	M			I	5.1OI	5.7II	5.6BI	4I	
EP I	19180723	12	46.85 N	71.35	M			I	2.5OI	3.0II	3.6BI	4I	
EP I	19250506	0914	46.90 N	71.60	M			I	2.5OI	3.0II	3.0BI	3I	
EP I	19250720		46.90 N	71.30	M			I	2.5OI	3.0II	3.0BI	5I	
EP A	19251009	05	46.82 N	71.55	M			I	2.5OI	3.7II	5.6BI	4O	
EP I	19260301		46.82 N	71.22	M			I	2.5OI	3.0II	3.0BI	3O	
EP I	19260315		46.82 N	71.22	M			I	2.5OI	3.0II	3.0BI	3I	
EP M	19260718	06	47.00 N	71.50	M			I	2.5OI	5.7II	5.6BI	4I	
EP I	19261228		46.82 N	71.22	M			I	2.5OI	3.0II	3.0BI	4I	
EP I	19270617		46.82 N	71.55	M			I	2.5OI	3.0II	3.0BI	3I	
EP M	19400911	010655.4	47.00 N	71.13	M			I	2.5OI	3.5LI	3.8BI		
EP M	19420905	143024.1	46.97 N	71.50	M			I	3.4OI	3.1LI	3.4BI		
EP M	19460901	043941.0	47.33 N	71.47	M			I	3.4OI	3.2LI	3.6BI		
EP M	19460926	211908.2	46.43 N	72.15	M			I	2.5OI	3.4LI	3.7BI		
EP I	19470102	1815	47.03 N	70.93	M			I	2.5OI	3.0II	5.0BI	3I	
EP M	19491030	205113.7	46.47 N	72.12	M			I	3.4OI	3.4LI	3.7BI		
EP M	19510725	2251.5	47.20 N	71.57	M			I	3.3OI	3.0LI	3.6BI		
EP M	19560130	094313.0	47.05 N	71.17	M			I	3.7OI	3.7LI	3.9BI		
EP M	19580718	235627.0	46.70 N	71.40	M			I	3.3XI	3.2LI	3.5BI		
EP M	19590822	035230.0	46.95 N	70.78	M			I	3.3XI	3.2LI	3.5BI		
EP I	19640120	185745.3	46.92 N	70.70	M 27.0			I	3.1XI	3.1NI	3.1BI		
EP M	19640712	41.0	46.72 N	71.41	M			I	3.4XI	3.4LI	3.7BI		
EP M	19670923	162755.0	46.93 N	70.70	M			I	3.4XI	3.4LI	3.7BI		
EP M	19680724	231637.0	47.01 N	71.30	M 18.0			I	3.2XI	3.1LI	3.4BI		
EP M	19800311	041555.0	46.79 N	71.87	M 18.0			I	3.7XI	3.7NI	3.7BI		1406.I
EP I	19830723	032538.0	46.53 N	70.95	M 10.0			I	3.0XI	3.0NI	3.0BI		

There are   38 events in this listing.

SOURCE CODES FOR HYPOCENTERS AND MAGNITUDES
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    R - Barstow et al., 1981 (Rondout Asso.), NUREG/CR-1577,
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    Y - Felt area only; value is the average of those found in G and R above,
    Z - Felt area only; value is the average of those found in U and R above,
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LOCATION CODES
    H - Historical Location (from intensity/felt area data),
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MAGNITUDE TYPE CODES (FOLLOWS MAGNITUDE VALUE, THAT IS, THE T IN MAGTS)
    B - mb from Baysian estimate (Veneziano & VanDyck; 1984),
    C - mb from intensity and felt area (Sibol et al.; 1987)
    D - Md from duration or coda length,
    F - mb from felt area or attenuation data,
    I - mb from intensity data
    L - ML (Richter, 1958),
    M - mb determined from modified instruments/formuli,
    N - mb from Lg wave data (Nuttli, 1973),
    O - m3Hz (Lawson, et al., 1979 - Oklahoma earthquakes),
    P - mb from P wave data (Gutenberg and Richter, 1956),
    S - MS (Bath, 1966, Gutenberg, 1945),
    X - Magnitude of unknown type.

22-SEP-90 18:12:08 for the program RMGEN

Input data from file......: LOWER ST LAWRENCE MI.EPRI

Lab		Date YearMoDy	OT (UCT) HrMnSec	Hypocenter Lat	Lon	Depth	Error (km) ERH	ERZ	Hy LS	Magnitudes MagTS	MagTS	MagTS	Int S	Felt Area (mi2) S
EP	I	1859		48.60 N	68.00 W				I	2.5XI	3.0II	3.0BI	3I	
EP	M	18740201	19	48.60 N	68.50 W				I	2.5XI	3.0II	3.0BI	3I	
EP	M	18740731	09	48.60 N	69.10 W				I	3.1XI	3.2II	3.6BI	4I	
EP	I	18801230		49.30 N	67.40 W				I	2.5XI	3.0II	3.0BI	3I	
EP	I	18820801	23	49.30 N	67.40 W				I	2.5XI	3.0II	3.0BI	3I	
EP	M	18820815	1530	49.30 N	67.40 W				I	3.1XI	3.7II	3.6BI	4I	
EP	I	18820920	17	49.30 N	67.40 W				I	2.5XI	3.0II	3.0BI	3I	
EP	I	18831015		49.30 N	67.40 W				I	2.5XI	3.0II	3.0BI	3I	
EP	I	18831105		49.30 N	67.40 W				I	2.5XI	3.0II	3.0BI	3I	
EP	I	18831122	16	49.30 N	67.40 W				I	2.5XI	3.0II	3.0BI	3I	
EP	I	18831222		49.30 N	67.40 W				I	2.5XI	3.0II	3.0BI	3I	
EP	I	18841121	2330	49.30 N	67.40 W				I	2.5XI	3.0II	3.0BI	3I	
EP	M	18850426	1030	49.30 N	67.40 W				I	3.1XI	3.7II	3.6BI	4I	
EP	M	18860518	1930	49.30 N	67.40 W				I	3.1XI	3.7II	3.6BI	4I	
EP	M	18870215	1830	49.10 N	66.50 W				I	3.1XI	3.7II	3.6BI	4I	
EP	M	18870222	2259	49.30 N	67.40 W				I	3.1XI	3.7II	3.6BI	4I	
EP	M	18881207	1425	48.50 N	68.70 W				I	3.1XI	3.7II	3.6BI	4I	
EP	I	18900517		49.30 N	67.40 W				I	2.5XI	3.0II	3.0BI	3I	
EP	M	18940111	09	49.70 N	66.80 W				I	3.1XI	3.7II	3.6BI	4I	
EP	M	19121023		49.50 N	68.00 W				I	3.1XI	3.7II	3.6BI	4I	
EP	M	19140412		49.31 N	67.61 W				I	3.1XI	3.7II	3.6BI	4I	
EP	M	19170612	02	49.00 N	68.00 W				I	3.4XI	4.0XI	3.9BI	5I	
EP	M	19301008	010841.0	48.93 N	68.70 W				I	3.8XI	3.9LI	4.1BI		
EP	M	19380517	1832	49.00 N	68.00 W				I	3.7XI	3.9NI	3.8BI		
EP	M	19380928	043316.0	48.78 N	69.58 W				I	4.0XI	4.1LI	4.3BI		
EP	M	19420911	110513.0	49.22 N	67.40 W				I	3.6XI	3.7NI	3.7BI		
EP	M	19440409	1244	49.90 N	67.40 W				I	4.8XI	4.9NI	4.9BI		
EP	M	19440623	063753.0	49.42 N	67.75 W				I	4.8XI	5.1LI	5.1BI		
EP	M	19460117	080452.0	49.40 N	68.70 W				I	4.2XI	4.3LI	4.4BI		
EP	M	19500629	091333.0	49.90 N	68.10 W				I	4.2XI	4.3NI	4.3BI		
EP	M	19510628	010357.0	50.00 N	67.50 W				I	4.1XI	4.2NI	4.2BI		
EP	M	19510919	081938.0	49.30 N	66.25 W				I	4.2XI	4.3NI	4.3BI		
EP	M	19530124	095837.0	49.07 N	66.00 W				I	4.5XI	4.6NI	4.6BI		
EP	M	19530914	225257.0	49.10 N	65.20 W				I	4.2XI	4.4NI	4.4BI		
EP	I	19540110	210430.0	49.17 N	68.23 W				I	3.0XI	3.1NI	3.1BI		
EP	M	19540908	012953.0	49.03 N	68.37 W				I	3.5XI	3.6NI	3.6BI		
EP	M	19560803	125139.0	49.42 N	66.17 W				I	3.4XI	3.5NI	3.5BI		
EP	M	19561027	144006.0	48.25 N	69.00 W				I	3.4XI	3.4LI	3.7BI		
EP	M	19571113	204538.0	48.67 N	69.55 W				I	3.3XI	3.3LI	3.6BI		
EP	M	19581021	093251.0	49.60 N	68.00 W				I	4.0XI	4.1LI	4.3BI		
EP	M	19590801	135249.0	48.42 N	68.32 W				I	4.0XI	4.1LI	4.3BI		
EP	M	19610705	224344.0	50.25 N	66.68 W				I	4.2XI	4.3NI	4.3BI		
EP	M	19621215	5832.0	50.20 N	66.38 W				I	3.9XI	4.0NI	4.0BI		
EP	M	19640701	214130.0	49.43 N	67.42 W				I	3.7XI	3.8LI	4.0BI		
EP	M	19650318	120905.0	49.77 N	67.53 W				I	3.2XI	3.1LI	3.4BI		
EP	M	19651005	143655.0	49.78 N	67.66 W				I	3.9XI	3.9NI	3.9BI		
EP	M	19660114	152925.0	48.90 N	67.47 W				I	3.9XI	3.9NI	3.9BI		
EP	M	19660712	010638.0	49.50 N	66.00 W				I	3.3XI	3.3LI	3.6BI		
EP	M	19660724	221946.0	49.63 N	68.55 W				I	3.7XI	3.7LI	3.9BI		
EP	I	19661212	210412.0	49.00 N	68.17 W				I	3.4XI	3.3NI	3.7BI		
EP	M	19670930	223948.0	49.44 N	65.63 W	15.0			I	4.7XI	4.7NI	4.7BI		
EP	M	19680929	100448.0	50.14 N	67.22 W	18.0			I	3.6XI	3.6NI	3.6BI		
EP	I	19711027	071324.0	49.23 N	67.13 W	18.0			I	3.0XI	3.0NI	3.0BI		
EP	I	19711103	055349.0	50.17 N	66.42 W	18.0			I	3.2XI	3.2NI	3.2BI	4I	
EP	M	19720822	191748.0	49.54 N	66.47 W	18.0			I	3.9XI	3.9NI	3.9BI		
EP	I	19730614	150955.0	49.48 N	66.50 W	18.0			I	3.1XI	3.1NI	3.1BI		
EP	I	19730720	170639.0	49.56 N	66.96 W	18.0			I	3.1XI	3.1NI	3.1BI		
EP	I	19740217	125728.0	49.54 N	67.09 W	18.0			I	3.0XI	3.0NI	3.0BI		
EP	M	19740702	044651.0	49.58 N	67.22 W	10.0			I	3.4XI	3.4NI	3.4BI		
EP	M	19741227	5012.0	49.14 N	67.44 W	18.0			I	3.5XI	3.5NI	3.5BI		
EP	I	19750718	042106.0	49.16 N	66.81 W	18.0			I	3.2XI	3.1LI	3.4BI		
EP	I	19751021	205002.0	49.13 N	68.13 W	18.0			I	3.1XI	3.1NI	3.1BI		
EP	I	19760329	212327.0	49.34 N	67.86 W	18.0			I	3.3XI	3.5NI	3.3BI		
EP	M	19760918	4032.0	49.36 N	67.10 W	18.0			I	3.4XI	3.4NI	3.4BI		
EP	M	19770808	230612.0	49.70 N	67.08 W	18.0			I	3.8XI	3.8NI	3.8BI	4I	
EP	I	19780630	17	48.75 N	68.39 W	18.0			I	3.2XI	3.2NI	3.2BI	4I	
EP	M	19780729	135643.0	49.30 N	65.61 W	18.0			I	3.4XI	3.4NI	3.4BI	4I	
EP	I	19781202	083644.0	48.96 N	67.62 W	18.0			I	3.3XI	3.3NI	3.3BI	4I	
EP	M	19790605	085820.0	49.37 N	67.54 W	18.0			I	3.3XI	3.3NI	3.3BI	3I	
EP	M	19791219	185810.0	49.43 N	66.72 W	18.0			I	3.8XI	3.8NI	3.8BI	4I	
EP	M	19800403	165724.0	48.77 N	67.95 W	18.0			I	4.0XI	4.0NI	4.0BI	4I	
EP	I	19810713	044804.0	49.82 N	66.80 W	18.0			I	3.7XI	3.7NI	3.7BI		
EP	I	19810918	022411.0	49.53 N	66.11 W	18.0			I	3.1XI	3.1NI	3.1BI		
EP	M	19811028	195614.0	49.83 N	65.25 W	18.0			I	3.9XI	3.9NI	3.9BI		
EP	I	19821029	215057.0	49.82 N	65.30 W	18.0			I	3.3XI	3.3NI	3.3BI		
EP	M	19830117	193552.0	49.11 N	67.06 W	18.0			I	4.1XI	4.1NI	4.1BI		
EP	M	19830211	154656.0	48.98 N	68.33 W	18.0			I	3.5XI	3.5NI	3.5BI		

There are   77 events in this listing.

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    I - EPRI Catalog (8 July 1986),
    M - Sibol, Bollinger, and Birch, BSSA, 77, pp. 1635-1654,
    N - Neilsen, 1982 (Stanford Data Base),
    O - Nuttli, 1974, BSSA, 64, pp. 1189-1207,
    R - Barstow et al., 1981 (Rondout Asso.), NUREG/CR-1577,
    S - Street and Turcotte, 1977, BSSA, 67, pp. 599-614,
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    Y - Felt area only; value is the average of those found in G and R above,
    Z - Felt area only; value is the average of those found in U and R above,
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LOCATION CODES
    H - Historical Location (from intensity/felt area data),
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MAGNITUDE TYPE CODES (FOLLOWS MAGNITUDE VALUE, THAT IS, THE T IN MAGTS)
    B - mb from Baysian estimate (Veneziano & VanDyck; 1984),
    C - mb from intensity and felt area (Sibol et al., 1987)
    D - Md from duration or coda length,
    F - mb from felt area or attenuation data,
    I - mb from intensity data
    L - ML (Richter, 1958),
    M - mb determined from modified instruments/formuli,
    N - mb from Lg wave data (Nuttli, 1973),
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    P - mb from P wave data (Gutenberg and Richter, 1956),
    S - MS (Bath, 1966, Gutenberg, 1945),
    X - Magnitude of unknown type.
Remember to change :"s to : in output file.

22-SEP-90 18:10:51 for the program RWGEN

Input data from file......: APPALACHIAN FORELAND GASPE MI.EPRI

Lab	Date YearMoDy	OT (UCT) HrMnSec	Lat	Lon	Depth	ERH	ERZ	LS	MagTS	MagTS	MagTS	Int S	Felt Area (mi2) S
EP M	18430314		44.40 N	72.50 N				I	3.1XI		3.6BI	4I	
EP M	18580517	20	45.50 N	72.10 N				I	3.1XI		3.6BI	4I	
EP M	18630609	2130	44.50 N	73.00 N				I	3.1XI	3.7II	3.6BI	4I	
EP T	18640420		46.90 N	68.40 N				I	2.5XT	3.0II	3.0BI	3I	
EP I	18830311	16	45.35 N	72.50 N				I	2.5EXT	3.0II	3.0BI	3I	
EP E	18841122		48.80 N	64.50 N				I	2.5XI	3.0II	3.0BI	3I	
EP M	18850311	1557	45.35 N	72.50 N				I	2.5XI	3.0II	3.0BI	3I	
EP M	19051022		44.90 N	72.20 N				I			3.6BI	4I	
EP I	19260704		45.40 N	71.90 N				I	3.5XI	3.0II	3.0BI	3I	
EP M	19290511	0930	45.40 N	71.90 N				I	3.1XI		3.6BI	4I	
EP M	19300619	120656.0	45.73 N	71.22 N				I	3.6XI	3.6LI	3.8BI		
EP I	19340411	03	44.00 N	72.70 N				I	2.5XI	3.0II	3.0BI	3I	
EP I	19340411	0324	44.00 N	72.70 N				I	2.5XI	3.0II	3.0BI	3I	
EP M	19430706	221016.0	44.84 N	73.03 N	22.0			I	4.0XI	4.1LI	4.3BI		
EP T	19440604	020830.0	44.15 N	72.67 N				I	2.5XI	3.0II	3.0BI	3I	
EP M	19441014	132617.0	48.50 N	67.00 N				I	4.1XI	4.2LI	4.3BI		
EP M	19481113	164956.6	46.70 N	70.30 N				I	4.5XI	4.5LI	4.8BI		
EP M	19520218	205607.0	46.33 N	69.38 N				I	3.5XI	3.5LI	3.6BI		
EP M	19520226	56	46.80 N	70.20 N				I	3.7XI	3.7LI	3.9BI		
EP M	19530331	125833.4	43.76 N	73.08 N	1.0			I	3.9XI	4.0NI	4.0BI	5I	
EP M	19540630	074107.0	47.00 N	70.12 N				I	3.7XI	3.7LI	3.9BI		
EP M	19570817	013007.0	46.73 N	70.12 N				I	3.5XI	3.5LI	3.6BI		
EP M	19581223	231416.0	46.98 N	69.82 N				I	3.5XI	3.7LI	3.9BI		
EP M	19620131	143238.0	47.50 N	67.13 N				I	3.5XI	3.5LI	3.8BI		
EP M	19620323	020221.0	47.18 N	69.47 N				I	3.5XI	3.5LI	3.6BI		
EP M	19620410	143045.2	44.11 N	72.97 N	5.0			I	4.1XI	4.2XI	4.2BI	5I	18935.I
EP M	19641017	141307.0	47.67 N	67.25 N				I	3.8XI	3.9LI	4.1BI		
EP M	19670805	080832.0	48.57 N	64.97 N				I	4.9XI	4.0LI	4.2BI		
EP M	19730615	010905.1	45.51 N	71.12 N	12.0			I	4.8XI	5.0NI	4.8BI	5I	93786.I
EP I	19830120	141721.0	47.46 N	67.86 N	15.0			I	3.1XI	3.1NI	3.1BI		

There are   30 events in this listing.

SOURCE CODES FOR HYPOCENTERS AND MAGNITUDES
    B - Bollinger, 1975, Southeastern U. S. Catalog 1754-1974,
    E - Earth Physics Branch, Canadian catalog,
    G - USGS - State Seismicity Maps (Stover/Reagor et al.),
    I - EPRI Catalog (8 July 1986),
    M - Sibol, Bollinger, and Birch, BSSA, 77, pp. 1635-1654,
    N - Neilsen, 1982 (Stanford Data Base,),
    O - Nuttli, 1974, BSSA, 64, pp. 1189-1207,
    R - Barstow et al., 1981 (Rondout Asso.), NUREG/CR-1577,
    S - Street and Turcotte, 1977, BSSA, 67, pp. 599-614,
    T - Reinbold and Johnston (TEIC), 1986, USGS Final Rept.,
    U - Earthquake History of the U.S./U.S. Earthquakes,
    V - SEUSSN Bulletins (Va. Tech Publication),
    M - Nuttli, et al., 1979, BSSA, 69, pp. 893-909,
    Y - Felt area only, value is the average of those found in G and R above,
    Z - Felt area only, value is the average of those found in U and R above,
    ? - Some discrepancy exists for the event (Follows State),

LOCATION CODES
    H - Historical Location (from intensity/felt area data),
    I - Instrumental Location,

MAGNITUDE TYPE CODES (FOLLOWS MAGNITUDE VALUE, THAT IS, THE T IN MAGTS)
    B - mb from Baysian estimate (Veneziano & VanDyck, 1984),
    C - mb from intensity and felt area (Sibol et al.; 1987)
    D - Md from duration or coda length,
    F - mb from felt area or attenuation data,
    I - mb from intensity data
    L - ML (Richter, 1958),
    H - mb determined from modified instruments/formuli,
    N - mb from La wave data (Nuttli, 1973),
    O - m3Hz (Lawson, et al., 1979 - Oklahoma earthquakes),
    P - mb from P wave data (Gutenberg and Richter, 1956),
    S - MS (Bath, 1966, Gutenberg, 1945),
    X - Magnitude of unknown type.
Remember to change :"s to : in output file.

22-SEP-90 18:10:07 for the program RHGEN
    Input data from file......: APPALACHIANS MI.EPRI

Lab	Date YearMoDv	OT (UCT) HrMnSec	Hypocenter Lat	Lon	Depth	Error (km) ERH	ERZ	Hvl LS	Magnitudes MagTS	MagTS	MagTS	Int S	Felt Area (mi2) S
EP M	1627		42.60 N	70.80	H			4.3XI		4.8BI	6I		
EP I	16380701		42.50 N	70.90				2.5XI	3.0II	3.0BI	3I		
EP I	16390125		42.50 N	70.95				2.5OI	3.0II	3.0BI	3I		
EP M	16430315	12	42.80 N	70.80				3.5XI		3.6BI	4I		
EP A	16551108		42.60 N	70.90				2.5XI		3.0BI	3I		
EP M	16580414		42.50 N	70.90				3.5XI		4.2BI	5I		
EP M	16680403	09	42.35 N	71.10				4.5XI	3.7II	3.6BI	4I		
EP M	16771213		41.10 N	73.50				3.5XI		3.6BI	4I		
EP M	16850218		42.70 N	70.80				3.5XI		3.6BI	4I		
EP M	1698		41.38 N	73.47				3.5XI		3.6BI	4I		
EP I	17010210		42.60 N	70.95				2.5XI	3.0II	3.0BI	3I		
EP M	17010308		42.60 N	70.95				2.5XI	3.0II	3.0BI	3I		
EP M	1702		41.40 N	73.50				3.5XI		3.6BI	4I		
EP I	17050627		42.40 N	71.10				2.5XI		3.6BI	4I		
EP I	17111221		41.40 N	73.50				3.5XI		3.6BI	4I		
EP M	17271110	0340	42.80 N	70.60				4.5OI	5.0FI	5.0BI	7I	114551.I
EP I	17280112		42.60 N	71.65				2.5OI	3.0II	3.0BI	3I	
EP M	17290806		41.40 N	73.50				3.5XI		3.6BI	4I	
EP M	17301222	2345	42.80 N	70.60				3.5XI		3.6BI	4I	
EP M	17341123	05	42.80 N	70.60				4.5XI		4.8BI	5I	1406.I
EP M	17360215	2245	42.80 N	70.60				3.5XI		3.6BI	4I	
EP M	17361012	0630	42.80 N	70.60				3.5XI		3.6BI	4I	
EP M	17370217	2130	42.40 N	71.00				3.5XI		3.6BI	4I	
EP M	17590815	0730	42.80 N	70.60				4.5OI		3.7BI	4I	1718.I
EP M	17410205	2050	42.80 N	70.60				3.5XI		3.0BI	3I	
EP I	17410614	1535	42.20 N	71.20				2.5XI		3.0BI	3I	
EP I	17411217	13	42.50 N	71.20				2.5XI		3.0BI	3I	
EP M	17440614	1515	42.50 N	70.90				4.6XI	4.7FI	4.7BI	6I	62867.I
EP I	17440709		42.50 N	70.90				2.5XI	3.0II	3.0BI	3I	
EP I	17450103	17	42.80 N	70.90				2.5XI	3.0II	3.0BI	3I	
EP I	17470825		43.20 N	70.90				2.5XI	3.0II	3.0BI	3I	
EP I	17510721		42.50 N	70.90				2.5XI	3.0II	3.0BI	3I	
EP M	17551118	0912	42.70 N	70.30				5.7XI	6.0XI	5.8BI	8I	380322.I
EP I	17560102		42.35 N	71.10				2.5XI	3.0II	3.0BI	3I	
EP I	17561116	09	42.35 N	71.10				2.5XI	3.0II	3.0BI	3I	
EP I	17561204		42.35 N	71.10				2.5XI	3.0II	3.0BI	3I	
EP M	17570708	1915	42.30 N	71.10				3.5XI		3.0BI	3I	
EP M	17590202	07	42.35 N	71.00				3.5XI		3.6BI	4I	
EP M	17600203		42.52 N	71.10				3.5XI		3.6BI	4I	
EP I	17610312	0715	42.50 N	71.00				2.5XI	2.4II	3.0BI	3I	46573.I
EP M	17611102	01	43.10 N	71.50				4.5XI	4.6FI	4.6BI	5I	
EP M	17640930		45.30 N	66.00				4.5XI		4.6BI	4I	
EP M	17660123	10	43.70 N	70.30				3.7XI	4.4II	4.2BI	5I	
EP M	17660302	08	43.07 N	70.77				3.5XI		3.6BI	4I	
EP I	17660614		42.70 N	70.90				2.5XI	3.0II	3.0BI	3I	
EP M	17661217	1148	43.10 N	70.80				3.5XI		3.6BI	4I	
EP M	17691019		43.70 N	70.30				3.5XI		3.6BI	4I	
EP M	17801129		42.50 N	70.90				3.5XI		3.6BI	4I	
EP M	17831130	0350	41.00 N	74.50				4.3XI		4.8BI	6I	
EP I	17861129	22	42.40 N	71.10				2.5XI	3.0II	3.0BI	3I	
EP I	17870225	06	42.40 N	71.10				2.5XI	3.0II	3.0BI	3I	
EP M	17910516	1322	41.50 N	72.40				4.3XI	4.4XI	4.4BI	7I	23127.I
EP I	17921024	06	41.50 N	72.50				2.5XI		3.0BI	3I	
EP I	17930111	13	41.50 N	72.50				2.5XI		3.0BI	3I	
EP I	17930706	11	41.50 N	72.50				2.5XI		3.0BI	5I	
EP M	17940306	19	41.50 N	72.50				3.5XI		3.6BI	4I	
EP M	18001220		43.70 N	72.30				3.5XI		3.6BI	4I	
EP M	18001225		41.90 N	71.10				4.5XI		3.6BI	4I	
EP M	18010301	2030	43.10 N	70.80				2.5XI		3.0BI	3I	
EP M	18030118	1450	42.50 N	70.90				2.5XI		3.0BI	3I	
EP A	18050406	1915	42.50 N	70.90				2.5XI		3.0BI	3I	
EP M	18050425		42.50 N	70.90				3.5XI		3.6BI	4I	
EP M	18050612	1230	44.50 N	69.00				3.5OI		3.6BI	4I	
EP A	18050803		41.50 N	72.50				2.5XI		3.6BI	4I	
EP M	18051230	11	41.50 N	72.50				2.5XI		3.6BI	4I	
EP M	18070114	04	43.00 N	71.10				2.5XI	3.0II	3.0BI	3I	
EP I	18070222	19	43.70 N	70.50				2.5XI		3.6BI	4I	=
EP M	18070506	18	43.50 N	70.50				3.5XI		4.2BI	5I	
EP M	18080626	0250	44.40 N	69.00				3.9XI	4.0FI	4.0BI	5I	8508.I
EP M	18101110	0215	43.00 N	70.90				3.5XI		3.0BI	3I	
EP I	181107		41.50 N	72.50				2.5XI		3.0BI	3I	
EP I	18120209	14	41.50 N	72.50				2.5XI		3.0BI	3I	
EP I	18120705	13	41.50 N	72.50				2.5XI		3.0BI	3I	
EP A	18131228	21	41.50 N	72.50				4.2XI	4.3FI	4.3BI	5I	18935.I
EP M	18141129	14	43.70 N	70.30				4.0XI	4.7XI	4.5BI	6I	
EP M	18170522	20	45.00 N	67.20				2.5XI	3.0II	3.0BI	3I	20927.I
EP I	18170907		42.50 N	70.95				4.2XI	4.3FI	4.3BI	6I	7698.I
EP M	18171005	1645	42.50 N	71.20				4.9XI	4.0FI	4.0BI	5I	
EP M	18210505	1230	44.80 N	68.80				3.5XI		4.2BI	5I	11485.I
EP M	18230307	15	43.90 N	70.00				3.7XI		4.2BI	5I	
EP M	18230610	17	44.80 N	68.80				4.0XI	4.1FI	4.1BI	5I	
EP M	18230723	1155	42.90 N	70.60				4.0XI	4.3II	4.2BI	5I	
EP M	18240709		46.50 N	66.50				3.7XI		3.6BI	4I	
EP M	18270823		41.40 N	72.10				3.5XI		3.6BI	4I	
EP M	18280725	11	43.90 N	70.00				2.5XI	3.0II	3.0BI	3I	
EP I	18290101		43.10 N	70.80				2.5XI		3.0BI	3I	
EP I	18290826		43.90 N	70.00				2.5XI	3.0II	3.0BI	3I	
EP M	18290827	2145	44.20 N	69.80				2.5XI		3.6BI	4I	
EP I	18301201		42.50 N	70.95				3.7XI		4.2BI	5I	
EP M	18370115	07	42.50 N	70.90				3.7XI	3.8FI	3.8BI	5I	4225.I
EP M	18370412		41.70 N	72.70				2.5XI		3.6BI	4I	
EP M	18400809	2030	41.70 N	72.90				2.5XI		3.0BI	3I	
EP M	18431024		41.10 N	71.20				2.5XI		3.0BI	3I	
EP I	184406	01	41.50 N	72.40				3.8XI	3.9XI	3.9BI	5I	5160.I
EP M	18450101		41.50 N	72.40				3.1XI		3.6BI	4I	
EP M	18451026	2315	41.20 N	73.30				2.5XI	3.0II	3.0BI	3I	
EP M	18460530	1830	42.70 N	70.30				4.2XI	4.3FI	4.3BI	5I	20927.I
EP I	18460710		43.10 N	71.25				2.5XI	3.0II	3.0BI	3I	
EP M	18460825	0945	42.50 N	70.80								
EP I	18460912		43.10 N	71.25								

Lab	Date YearMoDy	OT (UCT) HrMnSec	Lat	Lon	Felt Area (mi2) S
EP	18461029		43.10 N	71.25	
EP	18461031		43.10 N	71.25	
EP	18461112		43.10 N	71.25	
EP	18461202		43.10 N	71.25	
EP	18470120		44.30 N	68.50	
EP	18470202		43.10 N	71.25	
EP	18470202		44.20 N	69.10	
EP	18470214		43.10 N	71.25	
EP	18470219		44.40 N	69.00	
EP	18470221		43.10 N	71.25	
EP	18470401		43.70 N	70.70	
EP	18470808	15	41.70 N	70.10	12693.I
EP	18490204		41.50 N	71.60	
EP	18490215		42.10 N	72.60	
EP	18491008		42.50 N	71.40	
EP	18500720		43.65 N	70.30	
EP	18510103		44.50 N	69.70	
EP	18510104	0430	44.60 N	69.60	
EP	18511011		43.10 N	71.25	
EP	18520110	1140	41.20 N	71.40	
EP	18520630		41.40 N	72.40	
EP	18520801		41.40 N	72.10	
EP	18520802		47.60 N	65.60	
EP	18520811		43.10 N	71.25	
EP	18521128	0445	43.00 N	70.90	3823.I
EP	18530603		44.80 N	65.50	
EP	18530617		43.65 N	70.30	
EP	18530620		43.65 N	70.30	
EP	18530717	1030	43.50 N	70.20	
EP	18530720		43.65 N	70.30	
EP	18530817		41.60 N	70.95	
EP	18530908	0410	41.60 N	70.95	
EP	18531121		43.00 N	71.90	
EP	18531127		43.00 N	69.00	
EP	18531128		43.00 N	71.90	
EP	18540124		42.20 N	72.30	
EP	18540127		42.20 N	72.30	
EP	18540222		42.50 N	71.10	
EP	18541024		42.90 N	72.30	
EP	18541211	0530	43.00 N	70.80	1554.I
EP	18550116	23	44.00 N	71.00	12693.I
EP	18550119		43.65 N	70.30	
EP	18550120	01	43.65 N	70.30	
EP	18550123		42.60 N	70.40	
EP	18550208	1130	46.00 N	64.50	84861.I
EP	18550219		44.60 N	69.60	
EP	18550223		44.40 N	69.00	
EP	18550529	10	44.70 N	71.60	
EP	185506		44.70 N	65.50	
EP	18560313	03	41.40 N	72.60	
EP	18571208	20	46.70 N	68.00	
EP	18571223	1830	44.10 N	70.20	4225.I
EP	18580627		41.40 N	72.80	853.I
EP	18600312		41.50 N	72.50	
EP	18600317	0230	42.20 N	70.50	
EP	18610301		42.40 N	71.10	
EP	18620203	01	41.50 N	72.50	
EP	18620204		42.50 N	71.20	
EP	18680301		44.30 N	69.75	
EP	18691022	11	45.00 N	67.20	
EP	18700208		44.10 N	69.80	
EP	18700317	11	45.50 N	66.50	
EP	18701023		42.10 N	72.60	
EP	18710720		43.20 N	71.50	
EP	18721118	19	43.20 N	71.60	2319.I
EP	18730111		43.90 N	70.00	
EP	18730222		44.90 N	67.00	
EP	18730417		44.50 N	69.70	
EP	18731005		42.90 N	71.30	
EP	18731113		44.80 N	68.75	
EP	18740106		43.60 N	71.20	
EP	18740125	17	42.60 N	71.40	
EP	18740126		43.00 N	71.50	
EP	18740126	07	43.00 N	71.50	
EP	18740228	0340	45.18 N	67.28	5703.I
EP	18741124		42.70 N	70.90	
EP	18750728	0910	41.90 N	73.00	1406.I
EP	18751201	09	42.90 N	72.30	
EP	18760115		44.50 N	69.50	
EP	18760922	0430	41.50 N	71.30	2563.I
EP	18770218		43.65 N	70.30	
EP	18770910		42.40 N	71.10	
EP	18781004	0730	41.50 N	74.00	632.I
EP	18791026	0230	43.00 N	71.50	
EP	18800329		43.40 N	70.75	
EP	18800403		46.60 N	67.95	
EP	18800512	1245	42.70 N	71.00	1718.I
EP	18800720		43.00 N	71.50	
EP	18810121	0240	44.00 N	70.00	1898.I
EP	18810226		44.30 N	69.80	
EP	18810403		43.00 N	71.90	
EP	18810518		43.20 N	71.70	
EP	18810619		42.80 N	70.90	
EP	18810731		44.80 N	68.75	
EP	18810813		43.20 N	71.75	
EP	18811006	0503	43.20 N	71.60	
EP	18811216	21	42.30 N	71.10	
EP	18820508	09	43.20 N	71.55	
EP	18821219	2224	43.20 N	71.40	2832.I
EP	18830101	0255	45.00 N	67.00	

There have been 200 events listed so far.

Lab	Date YearMoDv	OT (UCT) HrMnSec	Hypocenter Lat	Lon	Depth	Error (km) ERH	ERZ	Hv LS	Magnitudes MagTS	MagTS	MagTS	Int S	Felt Area (mi2) S
EP M	18830101	0758	44.60 N	67.70	H			I 3.1XI			3.6BI	4I	
EP M	18830204	2005	43.60 N	71.20				I 3.9XI			3.6BI	4I	
EP M	18830228	0330	41.50 N	71.30				I 3.9XI			4.1BI	5I	
EP M	18840118	07	43.20 N	71.70				I 3.9XI			3.6BI	4I	3459.I
EP I	18840126		45.40 N	66.00				I 2.5XI	3.0II	5.0BI	3.6BI	5I	
EP M	18841123	0530	45.20 N	71.70				I 4.0XI		4.1BI		5I	4225.I
EP U	18841117	07	43.70 N	71.50				I 4.0XI			3.6BI	4I	
EP T	18850104	1106	41.30 N	73.90				I 3.5XI			3.0BI	3I	
EP T	18850131	1005	41.30 N	73.80				I 3.5XI			3.0BI	5I	
EP A	18850428	2010	42.70 N	72.70				I 3.9XI				3I	
EP M	188506	15	45.10 N	66.10				I 4.0XI	3.7II	3.6BI		4I	
EP M	18860106	10	42.90 N	71.50				I 4.0XI			3.6BI	4I	
EP M	18860125	04	41.60 N	73.80				I 3.5XI			3.6BI	4I	
EP M	18860905		41.50 N	72.50				I 3.9XI			3.6BI	4I	
EP M	18870630	22	43.20 N	71.50				I 3.9XI			3.6BI	4I	
EP M	18880201		44.65 N	70.10				I 4.0XI	3.7II	3.6BI		4I	
EP M	18880815	0115	44.30 N	70.00				I 3.9XI			3.6BI	4I	
EP M	18890308		43.50 N	71.60				I 3.9XI			3.6BI	4I	
EP M	18910502	10	43.20 N	71.60				I 4.0XI	3.8FI	5.8BI		5I	4225.I
EP M	18921211	1630	44.30 N	71.70				I 4.0XI			3.6BI	4I	
EP M	18930314		42.30 N	72.70				I 3.9XI			3.6BI	4I	
EP M	18940410		41.60 N	72.50				I 3.9XI			3.6BI	4I	
EP T	18941123	1330	41.40 N	72.20				I 2.5XI	3.0II	3.0BI		3I	
EP M	18950528		43.00 N	72.50				I 2.5XI			3.0BI	5I	
EP M	18960323	56	45.20 N	67.20				I 4.1XI	4.0II	4.3BI		5I	7698.I
EP M	18960516	04	45.90 N	66.60				I 4.0XI			3.6BI	5I	
EP M	18961022	1030	44.30 N	71.80				I 4.0XI			3.6BI	4I	
EP I	18970126		44.90 N	66.90				I 2.5XI	3.0II	5.0BI		3I	
EP M	18970128		44.50 N	66.80				I 3.9XI	3.0II		3.6BI	4I	
EP I	18970214		44.70 N	66.80				I 4.0XI	3.0II		3.0BI	3I	
EP M	18970701	0920	43.70 N	71.60				I 4.0XI			3.6BI	4I	
EP M	18970905		41.50 N	72.50				I 3.9XI			3.6BI	4I	
EP M	18970925	1805	44.70 N	68.70				I 4.2XI	4.3FI	4.3BI		5I	18935.I
EP M	18971012		44.70 N	66.80				I 4.0XI	3.0II	4.0BI		3I	
EP M	18980111	09	44.70 N	66.80				I 4.1XI	3.7II		3.6BI	4I	
EP M	18980611	0645	42.80 N	72.60				I 4.0XI			3.6BI	4I	
EP M	18990517	0115	41.60 N	72.60				I 4.0XI			4.1BI	5I	3459.I
EP M	18991005	1150	44.00 N	69.50				I 3.9XI			3.6BI	4I	
EP M	19030424	1230	42.70 N	71.00				I 3.9XI			3.6BI	4I	
EP M	19040321	0604	45.00 N	67.20				I 5.7XI	5.8FI	5.8BI		7I	139913.I
EP M	19050715	1010	44.20 N	70.00				I 4.4XI	4.5FI	4.5BI		6I	38131.I
EP M	19050830	2240	43.10 N	70.70				I 3.7XI			3.9BI	5I	1406.I
EP M	19051126	30	41.50 N	71.30				I 3.1XI			3.6BI	4I	
EP M	19060508	1330	41.50 N	72.50				I 3.9XI			3.6BI	4I	
EP I	19061019		43.50 N	70.50				I 2.5XI			3.0BI	3I	
EP M	19061020	14	43.50 N	70.50				I 3.5XI	4.0OXI		5.0BI	3I	
EP M	19061020	16	43.50 N	70.50				I 3.4XI	3.0II		5.9BI	5I	
EP I	19061021		43.65 N	70.30				I 2.5XI			3.0BI	3I	
EP M	19070629		43.50 N	70.50				I 3.9XI			3.6BI	4I	
EP M	19071016	10	42.80 N	71.00				I 3.8XI			4.0BI	5I	2098.I
EP I	19080205	07	42.30 N	71.20				I 2.5XI	3.0II		3.0BI	3I	
EP M	19080808	12	46.50 N	67.60				I 3.7XI	4.3II	4.2BI		5I	
EP M	19081123	13	43.50 N	71.70				I 4.0XI			3.6BI	4I	
EP I	19090414		45.40 N	66.40				I 2.5XI	3.0II		3.0BI	3I	
EP I	19090816	0130	42.30 N	71.23				I 2.5XI	3.0II		3.0BI	3I	
EP M	19100123	0130	43.80 N	70.40				I 3.4XI	4.0OXI		3.9BI	5I	
EP M	19100821	1845	42.70 N	71.10				I 3.1XI			3.6BI	4I	
EP M	19100830	1430	43.40 N	72.10				I 3.9XI			3.6BI	4I	
EP M	19101020	2150	44.30 N	68.80				I 3.9XI			3.6BI	4I	
EP M	19110302	2130	43.20 N	71.50				I 3.9XI	3.0II		3.6BI	4I	
EP I	19120320	12	45.17 N	67.28				I 2.5XI			3.0BI	3I	
EP M	19131103	1430	41.50 N	71.50				I 3.9XI			3.0BI	3I	
EP I	19151115		41.50 N	72.50				I 2.5XI			3.0BI	3I	
EP M	19140113	08	45.10 N	67.20				I 3.5XI	3.0II	5.0BI		4I	
EP I	19140114	46.0	42.28 N	71.23				I 4.1XI	4.0OXI	4.3BI		5I	7698.I
EP M	19140222	1915	45.00 N	70.50	H			I 4.1XI	4.4II	4.2BI		5I	
EP M	19150221	0120	42.70 N	71.40	H			I 3.7XI			3.6BI	4I	
EP I	19160608	2115	41.00 N	73.80	H			I 2.5XI			3.0BI	3I	.
EP M	19161202	09	41.50 N	72.50	H			I 3.5XI			3.0BI	4I	
EP I	19170216	09	41.50 N	72.50	H			I 2.5XI			3.0BI	3I	
EP U	19170311		41.50 N	72.50	H			I 2.5XI			3.0BI	5I	
EP M	19180114	0720	45.00 N	67.30	H			I 4.4XI	4.5XI	4.2BI		6I	3459.I
EP M	19180821	0515	44.20 N	70.50	H			I 3.5XI			3.0BI	3I	
EP M	19181212	0330	44.80 N	68.80	H			I 3.9XI			3.6BI	4I	
EP M	19190711	0140	43.90 N	70.00	H			I 3.5XI			3.6BI	4I	
EP M	19190723	1150	43.70 N	70.30	H			I 3.5XI			3.0BI	3I	
EP I	19190811		41.50 N	72.50	H			I 2.5XI			3.0BI	4I	
EP M	19200523	08	43.10 N	71.50	H			I 3.5XI			3.6BI	4I	
EP M	19200607	08	43.50 N	70.50	H			I 3.5XI			3.6BI	4I	
EP M	19201109	40	45.00 N	67.10	H			I 3.5XI	3.7II	3.6BI		4I	
EP M	19210729	2114	42.50 N	70.40	H			I 3.7XI	3.7II		3.6BI	4I	
EP M	19211010	13	44.80 N	67.00	H			I 3.7XI	3.7II		3.6BI	4I	
EP M	19220507	2240	43.40 N	71.40	H			I 3.7XI	4.3II	4.2BI		5I	
EP M	19220702	222535.0	46.50 N	66.60	H			I 2.5XI	3.0II		3.0BI	3I	
EP I	19220909	06	45.01 N	67.12	H			I 4.0XI	4.1FI	4.1BI		5I	11485.I
EP M	19250107	1307	42.60 N	70.60	H			I 3.1XI			3.6BI	4I	
EP M	19250309		42.90 N	71.50	H			I 2.5XI	3.0II		3.6BI	4I	
EP I	19250416	0930	45.97 N	66.65	H			I 3.9XI			3.6BI	3I	3459.I
EP M	19250424	0756	41.70 N	70.80	H			I 3.9XI	4.0FI	4.1BI	4.0BI	5I	6966.I
EP M	19251009	1355	43.70 N	71.10	H			I 3.9XI			3.6BI	6I	
EP M	19251018	2130	44.10 N	70.20	H			I 2.5XI			3.0BI	3I	
EP M	19251024	0130	41.40 N	73.20	H			I 3.1XI			3.6BI	4I	
EP M	19251030		41.50 N	72.50	H			I 3.5XI			3.6BI	4I	
EP I	19251122	05	41.80 N	71.30	H			I 2.5XI	3.0II		3.0BI	3I	
EP I	19260121	1957	42.40 N	71.10	H			I 3.8XI			3.9BI	5I	1898.I
EP M	19260318	2109	42.80 N	71.80	H			I 2.5XI	3.0II	3.0BI		3I	
EP I	19260515	11	43.65 N	70.25	H			I 2.5XI	3.0II		3.0BI	3I	
EP I	19260525		44.88 N	68.65	H			I 3.7XI	4.0II		3.9BI	4I	3130.I
EP M	19260828	21	44.70 N	70.00	H		I	2.5XI	3.0II	3.0BI		3I	
EP I	19261025	0152	42.08 N	71.03	H								

There have been 300 events listed so far.

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         I- Date -IOT (UCT)I---- Hypocenter ----IError (km) IHyI-- Magnitudes ---IInt Felt Area
Lab  YearMoDy HrMnSec    Lat       Lon   Depth  ERH    ERZ  ILS MagTS MagTS MagTS  S  (mi2)  S
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Lab	YearMoDy	HrMnSec	Lat	Lon	Depth	Mag1	Mag2	Mag3	Int S	Felt Area (mi2)
EP M	19261124	1930	45.00 N	67.50		3.1XI		3.6BI	4I	
EP	19270309	0408	43.30 N	71.40		3.7XI		3.8BI	5I	1898.I
EP	19270330		41.70 N	72.80				3.6BI	4I	
EP	19270820		42.50 N	71.00				3.6BI	4I	
EP	19280113	1950	41.30 N	71.60				3.6BI	4I	
EP	19280121	0530	45.30 N	69.00				3.6BI	4I	
EP	19280217	0529	45.30 N	69.00		3.0II	3.0BI		5I	
EP	19280329		45.50 N	69.00		3.0II	3.0BI			
EP	19280425	2338	44.50 N	71.20		3.9FI	3.9BI		5I	5703.I
EP	19280428	2207	43.20 N	71.50					5I	
EP	19281017	30	42.80 N	71.60		3.0II	3.0BI		3I	
EP	19281120	0250	45.00 N	67.20		3.6II	3.6BI		3I	
EP	19290115	0245	43.30 N	71.00		3.0II	3.0BI			
EP	19290205	1909	44.00 N	70.30					4I	
EP	19291008	1220	44.00 N	70.20		3.0II	3.0BI			
EP	19291009	30	44.50 N	69.50		3.0II	3.0BI		3I	
EP	19300104	143038.0	46.73 N	65.83		4.6LI	4.7BI			
EP	19300214	0615	43.40 N	71.70				3.3BI	4I	
EP	19300327	1930	42.10 N	72.70				3.0BI		
EP	19300801	02	41.50 N	70.80				3.0BI	3I	
EP	19310409		45.00 N	67.00		3.0II	3.0BI		3I	
EP	19310504	1017	42.40 N	72.50		3.0II	3.0BI		3I	
EP	19310701	0245	41.60 N	73.40				3.6BI	4I	
EP	19310809		44.62 N	65.77		3.6II	3.6BI		4I	
EP	19321015	0310	43.60 N	71.50		3.0II	3.0BI		4I	
EP	19330117	0530	41.60 N	70.90				3.0BI	3I	
EP	19330626	1410	41.00 N	73.80				3.0BI		
EP	19340130	1030	41.80 N	72.60				3.6BI	4I	
EP	19340802	1459	43.70 N	70.30				3.6BI		
EP	19340802	1750	43.70 N	70.30		3.0II	3.0BI		4I	
EP	19340826	1136	44.90 N	67.00				3.0BI		
EP	19350424	0124	42.20 N	70.20		3.0II	3.0BI		4I	
EP	19360614	0540	43.50 N	71.50				3.0BI		
EP	19360615		45.80 N	71.40		3.0II	3.0BI			
EP	19361110	0246	43.60 N	71.40				4.2BI	5I	
EP	19361110	0402	44.70 N	71.70				3.6BI	4I	
EP	19370727	0910	41.80 N	72.40				3.0BI	3I	
EP	19570930	075803.4	47.80 N	65.43	5.0	4.5LI	4.6BI			
EP	19380401	2215	43.30 N	70.98		3.0II	3.0BI		3I	
EP	19380615	050743.0	46.50 N	66.80		3.3II	3.3BI		4I	
EP	19380623	0357	42.60 N	71.40				3.6BI	3I	
EP I	19380729	074407.0	41.00 N	73.70				3.0BI	4I	
EP	19380802	090230.0	41.08 N	73.70				3.3BI		
EP M	19380822	124809.4	44.89 N	68.79	5.0	4.0XI	4.0BI			5160.I
EP	19380823	051823.0	41.20 N	73.70				3.0BI	3I	
EP	19380823	071146.0	41.20 N	73.70				3.0BI	3I	
EP	19380920		41.50 N	72.20				3.0BI	3I	
EP	19400102	020544.0	42.50 N	71.50		3.0II	3.0BI		3I	
EP	19400128	2312	41.60 N	70.80		2.7NI	2.6BI		4I	2319.I
EP I	19400302	041536.0	41.50 N	72.50				3.0BI	3I	
EP	19400313	0129	41.50 N	72.50				3.0BI		
EP M	19400328	1142	44.70 N	69.90		3.8LI	4.0BI			
EP M	19401220	072726.2	43.87 N	71.37	10.0	3.5NI	5.4BI		7I	311381.I
EP M	19401225	050300.4	43.91 N	71.30		3.7XI	3.7BI			
EP	19410728	192410.0	41.13 N	73.75				3.0BI	3I	
EP	19410830	1021	46.10 N	67.90		3.7LI	3.9BI			
EP M	19411011	0815	42.50 N	72.30		3.0LI	3.5BI		4I	
EP M	19420308	2337	44.20 N	70.40				3.6BI	4I	
EP M	19430114	213238.0	45.16 N	69.33		4.3NI	4.3BI		5I	51471.I
EP	19430210	0945	43.67 N	70.25		3.0II	3.0BI		4I	
EP M	19431219	09 44.0	44.60 N	69.60		3.3II	3.3BI		4I	
EP	19440411	2025	43.97 N	71.70		3.0II	3.0BI		3I	
EP	19440606	06	47.36 N	65.39		3.0II	3.0BI		4I	
EP M	19441214	0315	41.60 N	72.80				3.6BI	4I	
EP	19450322	080305.0	43.20 N	71.55		3.0II	3.0BI		3I	
EP	19450715	1044	44.90 N	67.00				3.6BI	3I	
EP	19450805	1720	43.62 N	72.52		3.0II	3.0BI		3I	
EP	19470104	1851	41.00 N	73.60				3.6BI	4I	
EP	19470401	132554.0	41.00 N	74.28				3.0BI	3I	
EP M	19471228	1958	45.20 N	69.20		4.3XI	4.3BI		5I	62867.I
EP	19480504	0223	41.40 N	71.80				3.6BI	4I	
EP	19481121	1541	44.90 N	67.00		3.0II	3.0BI		3I	
EP	19490417	15	41.60 N	71.50				3.6BI	3I	
EP	19490902	054810.0	43.80 N	71.80		3.0II	3.0BI		3I	
EP M	19491005	023347.8	44.84 N	70.58	20.0	4.4XI	4.4BI		5I	139913.I
EP	19500224	130405.2	43.05 N	71.50		3.0II	3.0BI		4I	
EP	19500329	1443	41.00 N	73.60				3.6BI	4I	
EP	19510126	0327	41.50 N	72.50				3.6BI	4I	
EP	19510331	0350	42.20 N	72.20				3.6BI	4I	
EP M	19510610	172037.7	41.52 N	71.53	5.0	3.9FI	3.9BI		5I	3823.I
EP M	19510903	212624.8	41.35 N	73.86	18.0	3.8NI	3.8BI		4I	5703.I
EP M	19530327	0850	41.10 N	73.50			4.2BI		5I	
EP	19530511	0613	44.00 N	71.10			3.6BI		4I	
EP	19530817	042250.0	41.00 N	74.00			3.6BI		5I	
EP M	19540729	195656.0	42.81 N	70.70	1.0	3.9NI	3.9BI		5I	1554.I
EP I	19541007		42.70 N	71.30		3.0II	3.0BI		5I	
EP M	19570424	4159.0	44.42 N	72.00		3.0II	3.0BI		5I	
EP M	19570426	114008.6	43.53 N	70.25	5.0	4.7XI	4.8BI		6I	31219.I
EP M	19570804	124058.0	46.58 N	67.08		3.7LI	3.9BI			
EP M	19580323	220417.0	45.55 N	67.12		3.4LI	3.7BI			
EP M	19580919	1745	43.60 N	70.20		4.0LI	4.3BI		5I	
EP M	19581121	2330	44.00 N	71.70			3.6BI		4I	
EP M	19590413	212019.0	41.92 N	73.27		3.4LI	3.7BI			
EP M	19610129	4939.0	46.38 N	66.93		3.8LI	4.0BI			
EP M	19611214	0149	43.80 N	67.80		3.9LI	4.1BI			
EP M	19620325	051505.0	47.57 N	66.02		4.0LI	4.2BI			
EP M	19621201	212923.0	45.57 N	69.13		3.0LI	3.4BI			
EP M	19621229	0619	42.80 N	71.70		4.3LI	4.4BI		5I	
EP M	19630801	063416.0	46.80 N	66.50		3.0LI	3.4BI			
EP M	19631016	153059.7	42.40 N	70.42	14.0	3.8XI	3.8BI		5I	6966.I

There have been   400 events listed so far.

Lab		Date YearMoDy	OT (UCT) HrMnSec	Hypocenter Lat	Lon	Depth	Error (km) ERH	ERZ	Hy LS	Magnitudes MagTS	MagTS	MagTS	Int S	Felt Area (mi2) S
EP	I	19631030	223657.9	42.70 N	70.80 W					2.3XI	2.4NI	2.4BI	5I	2319.I
EP	T	19631204	215254.8	45.60 N	71.60 W	9.0				2.2XI	2.3NI	2.3BI	5I	853.I
EP	C	19640401	112134.0	45.60 N	71.50 W					1.8XI	1.8PI	1.8BI	4I	
EP	M	19640626	110449.0	43.40 N	71.68 W	1.0				5.2NI	5.2BI		5I	5703.I
EP	M	19641117	1708	41.20 N	73.70 W						4.2BI		5I	
EP	M	19650103	170501.0	45.50 N	72.00 W					3.0LI	3.4BI			
EP	M	19650831	083844.0	46.00 N	65.28 W					3.2LI	3.5BI			
EP	M	19650929	2057	41.40 N	74.40 W						3.6BI		4I	
EP	M	19651024	1745	41.30 N	70.10 W						4.2BI		4I	
EP	M	19651208	0302	41.70 N	71.40 W						3.6BI		5I	
EP	M	19660428	1202	44.10 N	71.90 W						3.6BI		4I	383.I
EP	M	19660520	0542.0	44.25 N	66.50 W									
EP	M	19660724	0159	44.50 N	67.60 W					3.8LI	4.0BI		5I	
EP	M	19660928	201135.0	46.92 N	65.25 W					3.6LI	4.0BI			
EP	M	19661023	2305	43.00 N	71.80 W					3.1LI	3.5BI		5I	632.I
EP	T	19670202	134009.0	41.40 N	71.40 W					2.4PI	2.4BI		5I	632.I
EP	M	19670428	1223	46.30 N	67.90 W					2.5LI	3.3BI		4I	
EP	M	19670515	224712.0	42.50 N	69.90 W					2.5LI	2.5BI			
EP	T	19670701	141007.0	44.40 N	69.90 W					2.9NI	2.9BI		4I	
EP	T	19670701	155558.2	44.38 N	69.87 W					3.3PI	3.3BI		5I	
EP	M	19670701	160539.6	44.55 N	69.81 W	7.0				2.4XI	2.4BI		5I	383.I
EP	M	19671122	2210	41.20 N	73.80 W					2.6XI	2.4BI		5I	
EP	M	19680527	192156.0	46.90 N	66.66 W	18.0				3.1LI	3.6BI			
EP	I	19680923	153850.0	45.17 N	69.45 W	18.0				3.3NI	3.3BI			
EP	M	19681103	0833	41.40 N	72.50 W					3.3NI	3.3BI		5I	698.I
EP	M	19690806	160200.5	43.80 N	71.40 W						4.2BI		5I	
EP	M	19691006		41.10 N	74.60 W						3.6BI		4I	
EP	T	19700808	1030.0	45.80 N	66.12 W	18.0				3.3NI	3.3BI			
EP	M	19700919	1335	42.90 N	71.90 W						3.6BI		4I	
EP	M	19711021	54	42.70 N	71.20 W						3.8BI		5I	943.I
EP	T	19721019	022200.1	45.80 N	64.70 W					3.0XI	3.0BI		5I	
EP	T	19740607	194535.7	41.63 N	73.94 W	1.0				3.0NI	2.9BI		5I	
EP	M	19750827	222822.0	46.80 N	65.34 W	18.0				3.0LI	2.4BI			
EP	I	19751010	045427.3	44.08 N	70.17 W					1.9NI	1.9BI		4I	
EP	I	19751015	032617.0	45.11 N	65.89 W	18.0				3.1NI	3.1BI			
EP	T	19760311	082932.2	41.56 N	71.21 W					2.2NI	2.2BI		5I	4225.I
EP	T	19760314	231224.6	41.66 N	69.97 W					3.0NI	3.0BI		5I	
EP	T	19760424	102222.1	41.46 N	72.49 W					2.2NI	2.2BI		4I	
EP	T	19760510	013420.5	41.54 N	71.01 W					2.7NI	2.7BI		5I	
EP	T	19770310	162225.2	41.18 N	74.15 W	9.0				1.9NI	1.9BI		4I	
EP	T	19771024	180912.0	47.00 N	67.05 W	18.0				3.0NI	3.0BI			
EP	T	19771220	174423.8	41.79 N	70.68 W					3.1NI	3.1BI		5I	772.I
EP	T	19771220	224444.5	41.81 N	70.78 W					2.0NI	2.0BI		3I	
EP	T	19771225	153553.5	43.20 N	71.64 W					2.2NI	2.2BI		4I	1042.I
EP	T	19780104	192810.8	44.07 N	70.55 W	9.0				3.0NI	3.0BI		4I	
EP	T	19780630	201343.6	41.08 N	74.20 W	5.0				2.4NI	2.4BI		5I	
EP	T	19780825	200130.5	42.87 N	70.83 W					2.3NI	2.3BI		3I	
EP	T	19780901	033343.6	42.48 N	71.46 W					2.0NI	2.0BI		3I	
EP	M	19790418	023415.3	43.97 N	69.79 W	17.0				4.0NI	4.0BI			20927.I
EP	T	19790420	103249.2	45.24 N	66.03 W	18.0				3.2NI	3.2BI			
EP	T	19790423	0545.7	43.04 N	71.24 W					3.1DI	3.3BI		4I	
EP	M	19790728	232912.0	43.29 N	70.44 W	11.0				3.5NI	3.5BI		4I	
EP	T	19791230	141512.3	41.15 N	73.71 W	13.0				2.2NI	2.2BI		4I	
EP	I	19800117	101316.2	41.31 N	73.92 W	2.0				2.7NI	2.7BI		5I	35.I
EP	T	19800410	153643.8	44.71 N	68.36 W					2.2NI	2.2BI			
EP	I	19800908	055955.2	44.67 N	69.00 W	8.0				2.2NI	2.2BI			
EP	I	19801024	172738.2	41.30 N	72.90 W					2.8NI	2.8BI		4I	
EP	I	19801025	4128.3	41.30 N	72.90 W					2.7NI	2.7BI		3I	
EP	I	19801123	3932.0	42.52 N	71.39 W					2.5NI	2.5BI		5I	
EP	M	19810413	173158.0	45.93 N	65.70 W	18.0				3.7NI	3.7BI			
EP	I	19810628	224235.0	43.57 N	71.55 W	0.0				3.1NI	3.1BI		4I	5703.I
EP	M	19811021	164906.9	41.14 N	72.57 W	5.0				5.8NI	5.7BI		5I	254938.I
EP	M	19820109	125352.0	47.00 N	66.60 W	5.0				3.0NI	3.0BI			
EP	T	19820109	133833.0	47.00 N	66.60 W	5.0				3.3NI	3.3BI			
EP	C	19820109	134817.0	47.00 N	66.60 W	5.0				3.3NI	3.3BI			
EP	T	19820109	134936.0	47.00 N	66.60 W	5.0				3.0NI	3.0BI			
EP	T	19820109	143614.0	47.00 N	66.60 W	5.0				2.7NI	2.7BI			
EP	T	19820109	150249.0	47.00 N	66.60 W	5.0				3.2NI	3.2BI			
EP	T	19820109	173736.0	47.00 N	66.60 W	5.0				3.0NI	3.0BI			
EP	T	19820109	221318.0	47.00 N	66.60 W	5.0				3.0NI	3.0BI			
EP	T	19820110	211222.0	47.00 N	66.60 W	5.0				3.1NI	3.1BI			
EP	T	19820111	215315.0	47.00 N	66.60 W	5.0				3.3NI	3.3BI			
EP	T	19820111	215351.0	47.00 N	66.60 W	5.0				3.1NI	3.1BI			
EP	C	19820111	220244.0	47.00 N	66.60 W	5.0				3.2NI	3.2BI			
EP	T	19820112	020139.0	47.00 N	66.60 W	5.0				3.1NI	3.1BI			
EP	T	19820112	020945.0	47.00 N	66.60 W	5.0				3.1NI	3.1BI			
EP	T	19820112	052901.0	47.00 N	66.60 W	5.0				3.3NI	3.3BI			
EP	T	19820112	133833.0	47.00 N	66.60 W	5.0				3.0NI	3.0BI			
EP	T	19820113	020544.0	47.00 N	66.60 W	5.0				3.0NI	3.0BI			
EP	T	19820113	072405.0	47.00 N	66.60 W	5.0				3.1NI	3.1BI			
EP	T	19820113	170619.0	47.00 N	66.60 W	5.0				3.0NI	3.0BI			
EP	T	19820115	191623.0	47.00 N	66.60 W	5.0				3.0NI	3.0BI			
EP	T	19820115	082855.0	47.00 N	66.60 W	5.0				3.2NI	3.2BI			
EP	T	19820115	143637.0	47.00 N	66.60 W	5.0				3.0NI	3.0BI			
EP	T	19820118	193451.0	47.00 N	66.60 W	5.0				4.0NI	4.0BI		5I	51471.I
EP	M	19820119	1442.6	43.51 N	71.62 W	7.0				4.6PI	4.6BI			
EP	I	19820123	085647.0	47.00 N	66.60 W	5.0				3.2NI	3.2BI			
EP	T	19820126	05 30.0	47.00 N	66.60 W	5.0				3.3NI	3.3BI		3I	
EP	T	19820127	185004.6	41.87 N	70.94 W					3.0NI	3.0BI			
EP	I	19820318	032720.0	47.00 N	66.60 W	5.0				3.0NI	3.0BI			
EP	I	19820320	030811.0	47.00 N	66.60 W	5.0				3.1NI	3.1BI			
EP	I	19820402	194945.0	47.00 N	66.60 W	5.0				3.2NI	3.2BI			
EP	I	19820411	182719.0	47.00 N	66.60 W	5.0				3.1NI	3.1BI			
EP	I	19820502	014244.0	47.00 N	66.60 W	5.0				3.1NI	3.1BI			
EP	C	19820502	233137.0	47.00 N	66.60 W	5.0				3.0NI	3.0BI			
EP	C	19820616	154151.0	47.01 N	66.95 W	8.0				3.3NI	3.3BI		3I	
EP	I	19820617	141436.0	41.55 N	72.45 W	4.0				3.0NI	3.0BI			
EP	T	19820618	112436.0	47.00 N	66.60 W	5.0				3.3NI	3.3BI			
EP	T	19820812	204318.0	47.00 N	66.60 W	5.0				3.1NI	3.1BI			
EP	I	19820919	013717.0	47.00 N	66.60 W	5.0				3.1NI	3.1BI			

There have been 500 events listed so far.

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     I- Date -IOT (UCT)I---- Hypocenter ----IError (Km) IHvI-- Magnitudes ---IInt Felt Area
Lab  YearMoDy HrMnSec   Lat     Lon  Depth  ERH    ERZ  LS MagTS MagTS MagTS   S  (mi2)  S
---------------------------------------------------------------------------------
EP T 19821018 043749.0 47.00 N 66.60 M   5.0                     3.0XI 3.0NI 3.0BI
EP T 19821222 125326.0 47.00 N 66.60 M   5.0                     3.0XI 3.0NI 3.0BI
EP T 19830226 195935.4 41.55 N 73.66 M   7.0                     3.00I 3.0DI 3.1BI
EP M 19830324 142720.2 43.96 N 71.72 M   7.0                     3.40E 3.4LE 3.7BE
EP T 19830515 204215.0 47.00 N 66.60 M   5.0                     3.10I 3.1NI 3.1BI
EP T 19830527 230435.2 45.54 N 69.46 M  10.0                     3.20I 3.2NI 3.2BI
EP M 19830529 054549.9 44.49 N 70.40 M   5.0                     3.50N 3.5NI 3.9BI
EP T 19830610 042239.0 47.00 N 66.60 M   5.0                     3.30N 3.3NI 3.3BI
EP M 19830812 140847.6 44.27 N 67.68 M  12.0                     3.60I 3.6NI 3.6BI
EP T 19831017 225856.0 47.21 N 66.31 M   5.0                     3.20I 3.2NI 3.2BI
EP T 19831116 121356.0 47.00 N 66.60 M   5.0                     3.10I 3.1NI 3.1BI
EP T 19831118 102840.0 47.00 N 66.60 M   5.0                     3.10I 3.1NI 3.1BI
EP T 19831204 104833.6 45.49 N 69.49 M   7.0                     3.30I 3.3NI 3.3BI
EP T 19831208 122345.0 45.11 N 67.17 M   7.0                     3.00I 3.0NI 3.0BI
EP M 19840114 090835.0 45.01 N 67.15 M  18.0                     3.30I 3.3NI 3.3BI
EP M 19840114 090932.0 44.88 N 67.16 M  18.0                     3.5XI 3.5NI 3.5BI
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There are 516 events in this listing.

SOURCE CODES FOR HYPOCENTERS AND MAGNITUDES
- B - Bollinger, 1975, Southeastern U. S. Catalog 1754-1974,
- E - Earth Physics Branch, Canadian catalog,
- G - USGS - State Seismicity Maps (Stover/Reagor et al.),
- A - EPRI Catalog (8 July 1986),
- H - Sibol, Bollinger, and Birch, BSSA, 77, pp. 1635-1654,
- N - Neilsen, 1982 (Stanford Data Base ...),
- O - Nuttli, 1974, BSSA, 64, pp. 1189-1207,
- R - Barstow et al., 1981 (Rondout Asso.), NUREG/CR-1577,
- S - Street and Turcotte, 1977, BSSA, 67, pp. 599-614,
- T - Reinbold and Johnston (TEIC), 1986, USGS Final Rept.,
- U - Earthquake History of the U.S./U.S. Earthquakes,
- V - SEUSSN Bulletins (Va. Tech Publication),
- M - Nuttli, et al., 1979, BSSA, 69, pp. 893-909,
- Y - Felt area only, value is the average of those found in G and R above,
- Z - Felt area only, value is the average of those found in U and R above,
- ? - Some discrepancy exists for the event (Follows State),

LOCATION CODES
- H - Historical Location (from intensity/felt area data),
- I - Instrumental Location,

MAGNITUDE TYPE CODES (FOLLOWS MAGNITUDE VALUE, THAT IS, THE T IN MAGTS)
- B - mb from Baysian estimate (Veneziano & VanDyck, 1984),
- C - mb from intensity and felt area (Sibol et al., 1987),
- D - Md from duration or coda length,
- F - mb from felt area or attenuation data,
- I - mb from intensity data
- L - ML (Richter, 1958),
- M - mb determined from modified instruments/formuli,
- N - mb from Lg wave data (Nuttli, 1973),
- O - m3Hz (Lawson, et al., 1979 - Oklahoma earthquakes),
- P - mb from P wave data (Gutenberg and Richter, 1956),
- S - MS (Bath, 1966, Gutenberg, 1945),
- X - Magnitude of unknown type.

Remember to change :"s to : in output file.

22-SEP-90   18:12:27 for the program RMGEN

Input data from file......: NEW YORK MI.EPRI

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        I- Date -IOT (UCT)I---- Hypocenter ----IError (Km) IHyI-- Magnitudes ---IInt Felt Area
Lab     YearMoDy HrMnSec   Lat      Lon  Depth   ERH    ERZ  LS MagTS MagTS MagTS  S  (mi2) S
-------------------------------------------------------------------------------------------
EP M  17961226  11       42.90 N 79.00 N                    I 4.3XI        4.8BI 6I
EP M  18181207           44.00 N 76.50 N                    I 3.1XI        3.6BI 4I
EP I  18230530           42.50 N 81.00 N                    I 2.2XI 3.2II 2.7BI 3I
EP M  18400116  20       45.00 N 75.00 N                    I 4.0XI        4.5BI 6I
EP M  18400910           43.20 N 79.85 N                    I 3.4XI 4.0XI 3.9BI 5I
EP I  18470108  20       44.00 N 78.00 N                    I 2.5XI        3.0BI 3I
EP I  18470114           44.20 N 78.20 N                    I 2.5XI        3.0BI 3I
EP I  18470709  14       43.50 N 73.60 N                    I 2.5XI 3.0II 3.0BI 5I
EP M  18521215           43.30 N 78.20 N                    I 2.5XI        3.0BI 3I
EP M  18530312  07       43.70 N 75.50 N                    I 4.0XI 4.5XI 4.5BI 6I
EP M  18530313  10       45.10 N 79.40 N                    I 3.4XI        3.9BI 5I
EP M  18551217  19       45.30 N 73.70 N                    I 3.1XI        3.6BI 4I
EP M  18570301  0140     41.80 N 80.60 N                    I 3.4XI 4.0II 3.9BI 5I
EP M  18571023  2015     43.20 N 78.60 N                    I 4.5XI        4.6BI 6I   17133.I
EP I  18580101  07       42.90 N 78.50 N                    I 2.5XI        3.0BI 3I
EP I  18670115  22       42.70 N 77.90 N                    I 2.5XI 3.4II 3.0BI 3I
EP I  18690409  13       42.70 N 80.80 N                    I 2.5XI 3.4II 3.0BI 3I
EP M  18730430           45.30 N 79.90 N                    I 3.1XI        3.6BI 4I
EP M  18730706  1430     45.00 N 79.50 N                    I 4.6XI 4.5XI 4.7BI 6I   31219.I
EP I  18770503  0320     43.90 N 78.85 N                    I 2.5XI        3.0BI 3I
EP I  18781229  0232     42.70 N 74.30 N                    I 2.5XI        3.0BI 3I
EP M  18790821  08       43.20 N 79.20 N                    I 2.5XI        3.7BI 4I    1273.I
EP I  18810319  0230     42.80 N 75.90 N                    I 2.5XI        3.0BI 3I
EP M  18821127  2330     43.00 N 79.25 N                    I 3.1XI        3.6BI 4I
EP I  18830401  06       43.25 N 79.85 N                    I 2.5XI        3.6BI 3I
EP I  18850904  1440     44.30 N 77.90 N                    I 2.5XI        3.0BI 3I
EP I  18860819  08       43.60 N 79.60 N                    I 2.5XI        3.0BI 3I
EP I  18880711  04       44.40 N 77.00 N                    I 2.5XI        3.0BI 3I
EP M  18890810           43.40 N 73.70 N                    I 3.1XI        3.6BI 4I
EP M  18941217           42.50 N 73.80 N                    I 3.1XI        3.6BI 4I
EP M  18970307           43.10 N 79.20 N                    I 3.1XI        3.6BI 4I
EP M  19070110  0945     41.20 N 77.10 N                    I 3.1XI        3.6BI 4I
EP M  19100225           43.20 N 79.80 N                    I 3.1XI        3.6BI 4I
EP M  19120527  1252     43.20 N 79.70 N                    I 3.7XI        4.2BI 5I
EP M  19160105  1356     43.70 N 73.70 N                    I 4.0XI 4.0II 4.2BI 5I    7698.I
EP M  19160203  0426     43.00 N 74.00 N                    I 4.1XI        4.3BI 5I
EP M  19161102  0232     43.30 N 73.70 N                    I 3.7XI        4.2BI 5I
EP I  19171002  0214     43.30 N 73.60 N                    I 2.5XI 3.0II 3.0BI 4I
EP I  19210927  0432     42.10 N 80.20 N                    I 2.5XI        3.0BI 3I
EP I  19250407  2018     43.03 N 76.13 N                    I 2.5XI        3.0BI 3I
EP I  19270329  2030     43.00 N 76.10 N                    I 2.5XI        3.0BI 3I
EP I  19270331  21       43.00 N 76.10 N                    I 2.5XI        3.0BI 3I
EP I  19270331  2130     43.00 N 76.10 N                    I 2.5XI        3.0BI 3I
EP M  19271113  50       43.10 N 79.06 N                    I 3.1XI        3.6BI 4I
EP I  19290812  06       42.20 N 77.20 N                    I 2.5XI        3.0BI 3I
EP I  19290812  0845     42.87 N 78.35 N                    I 2.5XI        3.0BI 3I
EP M  19290812  112448.7 42.91 N 78.40 N   9.0              I 5.0XI 5.2NI 5.1BI 8I  208725.I
EP I  19300216  1217     42.50 N 80.31 N                    I 2.5XI 3.0II 3.0BI 3I
EP M  19310420  195430.6 43.47 N 73.78 N   5.0              I 4.8XI 4.7XI 5.0BI 7I   34502.I
EP M  19310422           42.90 N 78.90 N                    I 3.1XI        3.6BI 4I
EP M  19331029           43.00 N 73.70 N                    I 3.1XI        3.6BI 4I
EP M  19341029  2007     42.00 N 80.20 N                    I 4.1XI 4.0LI 4.3BI 5I
EP I  19360826  0855     41.40 N 80.40 N                    I 2.5XI        3.0BI 3I
EP M  19390114  081016.0 43.25 N 79.85 N                    I 3.3XI 3.3LI 3.6BI 3I
EP I  19390224  20       42.90 N 78.30 N                    I 2.5XI        3.0BI 3I
EP M  19421002  222950.5 42.57 N 73.80 N                    I 3.1XI 3.0LI 3.4BI 3I
EP I  19450415  1315     43.00 N 76.40 N                    I 2.5XI        3.0BI 3I
EP I  19460320  0201     44.33 N 75.92 N                    I 2.5XI        3.0BI 3I
EP M  19461028  2036     41.50 N 76.60 N                    I 3.6XI 3.6LI 3.8BI
EP M  19461110  114123.1 42.87 N 77.45 N                    I 3.2XI 3.1LI 3.4BI
EP M  19500320  225511.5 41.50 N 75.80 N                    I 3.3XI 3.3LI 3.6BI 5I    383.I
EP I  19520825  07       43.00 N 74.50 N                    I 3.4XI        3.6BI 3I
EP I  19521120           42.92 N 76.57 N                    I 2.5XI        3.0BI 4I
EP M  19540131  1230     42.90 N 77.30 N                    I 3.1XI        3.6BI
EP M  19540201  3750.0   43.03 N 76.65 N                    I 3.3XI 3.3LI 3.6BI
EP M  19540427  021408.0 43.10 N 79.20 N                    I 4.0XI 4.1LI 4.3BI
EP M  19550629  011740.0 43.77 N 79.63 N                    I 4.4XI 3.0LI 3.5BI 4I
EP M  19550816  0735     42.90 N 78.30 N                    I 3.7XI        4.2BI 5I
EP M  19580722  014640.0 43.00 N 79.50 N                    I 4.2XI 4.4XI 4.5BI 4I
EP M  19580804  202558.0 43.13 N 80.00 N                    I 3.8XI 3.8PI 4.0BI
EP M  19580822  142505.0 43.00 N 79.00 N                    I 3.6XI 3.6LI 3.8BI 4I
EP M  19590209           43.00 N 81.00 N                    I 3.1XI 3.8II 3.6BI 4I
EP M  19620327  0635     43.00 N 79.30 N                    I 3.6XI 3.0LI 3.7BI 5I
EP M  19630130  1450     44.00 N 75.90 N                    I 4.4XI 3.0LI 3.5BI 4I
EP M  19630227  06       43.20 N 79.57 N                    I 3.1XI 3.0LI 3.4BI
EP M  19630302  202432.0 41.51 N 75.73 N                    I 3.4XI 3.4LI 3.7BI
EP M  19630701  195912.0 42.37 N 73.75 N                    I 3.3XI 3.3LI 3.6BI
EP M  19650716  110657.0 43.04 N 78.08 N  18.0              I 3.6XI 3.5LI 3.8BI 4I
EP I  19650827  015556.0 43.00 N 78.07 N  18.0              I 3.1XI 3.1NI 3.1BI 4I
EP M  19660101  132339.0 42.84 N 78.25 N   2.0              I 4.6XI 4.6NI 4.6BI 6I   3459.I
EP M  19670613  190855.5 42.84 N 78.22 N   1.0              I 4.4XI 4.4NI 4.4BI 6I   3130.I
EP I  19690813  024224.0 43.30 N 78.22 N                    I 2.5XI 2.5NI 2.5BI 4I
EP M  19750630  201523.0 43.40 N 79.77 N  10.0              I 3.4XI 3.4LI 3.7BI 3I
EP M  19801014  5856.4   43.15 N 80.57 N   5.0              I 3.3XI 3.3NI 3.3BI 3I
EP I  19810828  105133.0 43.15 N 80.59 N   1.0              I 2.6XI 2.6NI 2.6BI
EP I  19820831  101628.4 43.20 N 74.19 N   5.0              I 3.1XI 3.1NI 3.1BI
EP I  19831004  171840.0 43.44 N 79.79 N   2.0
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There are   87 events in this listing.

SOURCE CODES FOR HYPOCENTERS AND MAGNITUDES
    B - Bollinger, 1975, Southeastern U. S. Catalog 1754-1974,
    E - Earth Physics Branch, Canadian catalog,
    G - USGS - State Seismicity Maps (Stover/Reagor et al.),
    I - EPRI Catalog (8 July 1986),
    M - Sibol, Bollinger, and Birch, BSSA, 77, pp. 1635-1654,
    N - Neilsen, 1982 (Stanford Data Base...),
    O - Nuttli, 1974, BSSA, 64, pp. 1189-1207,
    R - Barstow et al., 1981 (Rondout Asso.), NUREG/CR-1577,
    S - Street and Turcotte, 1977, BSSA, 67, pp. 599-614,
    T - Reinbold and Johnston (TEIC), 1986, USGS Final Rept.,
    U - Earthquake History of the U.S./U.S. Earthquakes,
    V - SEUSSN Bulletins (Va. Tech Publication),
    W - Nuttli, et al., 1979, BSSA, 69, pp. 893-909,
    Y - Felt area only; value is the average of those found in G and R above,
    Z - Felt area only; value is the average of those found in U and R above,
    ? - Some discrepancy exists for the event (Follows State),

LOCATION CODES
    H - Historical Location (from intensity/felt area data),
    I - Instrumental Location,

MAGNITUDE TYPE CODES (FOLLOWS MAGNITUDE VALUE, THAT IS, THE T IN MAGTS)
    B - mb from Baysian estimate (Veneziano & VanDyck; 1984),
    C - mb from intensity and felt area (Sibol et al., 1987)
    D - Md from duration or coda length,
    E - mb from felt area or attenuation data,
    I - mb from intensity data
    L - ML (Richter, 1958),
    M - mb determined from modified instruments/formuli,
    N - mb from Lg wave data (Nuttli, 1973),
    O - m3Hz (Lawson, et al., 1979 - Oklahoma earthquakes),
    P - mb from P wave data (Gutenberg and Richter, 1956),
    S - MS (Bath, 1966, Gutenberg, 1945),
    X - Magnitude of unknown type.
Remember to change :"s to : in output file.

22-SEP-90   18:11:38 for the program RHGEN
        Input data from file......: CRATON MI.EPRI

Lab	Date YearMoDy	OT (UCT) HrMnSec	Hypocenter Lat	Lon	Depth	Error (Km) ERH	ERZ	Hy LS	Magnitudes MagTS	MagTS	MagTS	Int S	Felt Area (mi2) S
EP M	18870219		45.35 N	80.00	M			I	3.1XI	3.7II	3.6BI	4I	
EP M	19251019	120517.0	47.00 N	73.00	M			I	3.7XI	4.3II	4.2BI	5I	
EP I	19251027		48.57 N	71.63	M			I	2.5XI	3.0II	3.0BI	3I	
EP M	19381225	0746	47.60 N	75.40	M			I	4.8XI	3.9LI	4.1BI		
EP I	19390206	052145.0	46.50 N	61.00	M			I	4.5XI	3.0II	3.0BI	3I	
EP M	19391208	011747.0	47.97 N	71.40	M			I	3.7XI	3.6LI	3.8BI	4I	
EP M	19431206	071940.0	47.68 N	74.87	M			I	3.3XI	3.2LI	3.5BI		
EP M	19441105	1907	48.70 N	80.80	M			I	4.3XI	4.4NI	4.4BI		
EP M	19450702	132952.1	48.47 N	76.80	M			I	3.8XI	3.9LI	4.1BI		
EP M	19460919	5328.8	47.72 N	75.00	M			I	3.3XI	3.2LI	3.5BI		
EP M	19480116	060256.0	50.00 N	69.00	M			I	3.6XI	3.7NI	3.7BI		
EP M	19500414	182048.5	47.83 N	75.50	M			I	4.6XI	4.9LI	4.9BI		
EP I	19521225		43.80 N	61.00	M			I	4.1XI	3.8II	3.6BI	4I	
EP M	19530228	062402.5	48.07 N	74.43	M			I	3.5XI	3.5LI	3.8BI		
EP M	19551020	205832.0	48.93 N	70.20	M			I	3.5XI	3.2LI	3.5BI		
EP M	19580506	160249.0	48.57 N	70.12	M			I	3.6XI	3.7LI	3.9BI		
EP M	19590524	1052	48.80 N	79.20	M			I	3.5XI	3.7LI	3.8BI		
EP M	19590925	013630.0	50.18 N	68.20	M			I	3.8XI	3.9LI	4.1BI		
EP M	19611007	223651.0	48.67 N	76.58	M			I	3.7XI	3.8LI	4.0BI		
EP M	19640627	1917	47.80 N	79.20	M			I	3.6XI	3.7LI	3.9BI		
EP M	19640909	061626.0	48.40 N	73.87	M			I	3.5XI	3.5LI	3.4BI		
EP M	19650108	122945.0	48.00 N	78.50	M			I	3.5XI	3.5LI	3.8BI		
EP M	19650305	121101.0	47.72 N	78.83	M			I	3.5XI	3.2LI	3.5BI		
EP M	19650401	063020.0	46.00 N	80.50	M			I	3.5XI	3.4LI	3.7BI		
EP M	19670914	011938.0	50.67 N	75.25	M			I	4.0XI	4.0NI	4.0BI		
EP T	19700227	080836.0	48.24 N	77.78	M	18.0		I	3.1XI	3.1NI	3.1BI		
EP T	19701009	163501.0	48.72 N	71.03	M	18.0		I	3.0XI	3.0NI	3.0BI		
EP M	19720717	015846.0	47.90 N	77.86	M	18.0		I	3.0XI	3.0LI	3.4BI		
EP I	19731115	173135.0	49.60 N	69.01	M	18.0		I	3.1XI	3.1NI	3.1BI		
EP M	19751023	211748.7	49.83 N	68.62	M	2.0		I	4.1XI	4.1NI	4.1BI		
EP T	19760505	030104.0	49.56 N	73.90	M	18.0		I	3.1XI	3.1NI	3.1BI		
EP T	19760515	210652.0	49.84 N	68.62	M	3.0		I	3.5XI	3.5NI	3.5BI		
EP T	19760807	075011.0	49.77 N	74.98	M	18.0		I	3.1XI	3.1NI	3.1BI		
EP M	19761022	185056.0	48.16 N	78.05	M	18.0		I	3.1XI	3.0LI	3.4BI		
EP T	19810123	025750.0	50.07 N	69.46	M	5.0		I	3.0XI	3.0NI	3.0BI		
EP T	19810823	231720.0	48.66 N	72.24	M	5.0		I	3.3XI	3.3NI	3.3BI		
EP I	19820319	164813.0	46.30 N	79.88	M	18.0		I	3.0XI	3.0NI	3.0BI		
EP M	19830314	091121.0	50.70 N	74.89	M	18.0		I	3.7XI	3.7NI	3.7BI		
EP I	19831024	01 06.0	48.14 N	77.97	M	1.0		I	3.1XI	3.1NI	3.1BI		

There are   39 events in this listing.

SOURCE CODES FOR HYPOCENTERS AND MAGNITUDES
 B - Bollinger, 1975, Southeastern U. S. Catalog 1754-1974,
 E - Earth Physics Branch, Canadian catalog,
 G - USGS - State Seismicity Maps (Stover/Reagor et al.),
 I - EPRI Catalog (8 July 1986),
 M - Sibol, Bollinger, and Birch, BSSA, 77, pp. 1635-1654,
 N - Neilsen, 1982 (Stanford Data Base,),
 O - Nuttli, 1974, BSSA, 64, pp. 1189-1207,
 R - Barstow et al., 1981 (Rondout Asso.), NUREG/CR-1577,
 S - Street and Turcotte, 1977, BSSA, 67, pp. 599-614,
 T - Reinbold and Johnston (TEIC), 1986, USGS Final Rept.,
 U - Earthquake History of the U.S./U.S. Earthquakes,
 V - SEUSSN Bulletins (Va. Tech Publication),
 W - Nuttli, et al., 1979, BSSA, 69, pp. 893-909,
 Y - Felt area only; value is the average of those found in G and R above,
 Z - Felt area only; value is the average of those found in U and R above;
 ? - Some discrepancy exists for the event (Follows State),

LOCATION CODES
 H - Historical Location (from intensity/felt area data),
 I - Instrumental Location,

MAGNITUDE TYPE CODES (FOLLOWS MAGNITUDE VALUE, THAT IS, THE T IN MAGTS)
 B - mb from Baysian estimate (Veneziano & VanDyck; 1984),
 C - mb from intensity and felt area (Sibol et al.; 1987)
 D - Md from duration or coda length,
 F - mb from felt area or attenuation data,
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 S - MS (Bath, 1966, Gutenberg, 1945),
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Remember to change :"s to : in output file.

APPENDIX C: GLOSSARY OF EARTHQUAKE TERMS

GLOSSARY

Accelerogram. The record from an accelerometer presenting acceleration as a function of time.

Attenuation. Characteristic decrease in amplitude of the seismic waves with distance from source. Attenuation results from geometric spreading of propagating waves, energy absorption and scattering of waves.

B-line. The slope of a straight line indicating frequency of occurrence of earthquakes versus earthquake magnitude.

Bedrock. A general term for any hard rock where it is not underlain by unconsolidated materials.

Design Spectrum. A set of curves used for design that shows acceleration velocity, or displacement (usually absolute acceleration, relative velocity, and relative displacement of the vibrating mass) as a function of period of vibration and damping.

Duration of Strong Ground Motion. The length of time during which ground motion at a site has certain characteristics. Bracketed duration is commonly the time interval between the first and last acceleration peaks that are equal to or greater than 0.05 g. Bracketing may also be done at other levels. Alternatively, duration can be a window in which cycles of shaking are summed by their individual time intervals between a specified level of acceleration that marks the beginning and end.

Earthquake. A vibration in the earth produced by rupture in the earth's crust.

    1. Maximum Credible Earthquake. The largest earthquake that can be reasonably expected to occur.

    2. Maximum Probable Earthquake. The worst historic earthquake. Alternatively it is (a) the 100-year earthquake or (b) the earthquake that by probabilistic determination of recurrence will occur during the life of the structure.

    3. Floating Earthquake. An earthquake of a given size that can be moved anywhere within a specified area (seismotectonic zone).

    4. Safe Shutdown Earthquake. The earthquake which is based upon an evaluation of the maximum earthquake potential considering the regional and local geology and seismology and specific characteristics of local subsurface material. It is that earthquake which produces the maximum vibratory ground

motion for which certain structures, systems, and components are designed to remain functional. These structures, systems, and components are those necessary to assure: (a) the integrity of the reactor coolant pressure boundary; (b) the capability to shut down the reactor and maintain it in a safe shutdown condition; or (c) the capability to prevent or mitigate the consequences of accidents which could result in potential offsite exposures comparable to the guideline exposures of this part. (Nuclear Regulatory Commission: Title 10, Chapter 1, Part 100, 30 April 1975. Same as Maximum Credible Earthquake.)

5. Operating Basis Earthquake. The earthquake for which the structure is designed to remain operational. It should be an earthquake that is expected to happen during the life of the structure. The motions assigned can be an engineering decision.

Effective Peak Acceleration. A time history after the acceleration has been filtered to take out high frequency peaks that are considered unimportant for structural response.

Epicenter. The point on the earth's surface vertically above the point where the first earthquake ground motion originates.

Fault. A fracture or fracture zone in the earth along which there has been displacement of the two sides relative to one another.

1. Active Fault. A fault, which has moved during the recent geologic past (Quaternary) and, thus, may move again. It may or may not generate earthquakes. (US Army Corps of Engineers 1983).

2. Capable Fault. An active fault that is judged capable of generating felt earthquakes.

Focal Depth. The vertical distance between the hypocenter or focus at which an earthquake is initiated and the ground surfafce.

Focus. The location in the earth where the slip responsible for an earthquake was initiated. Also, the hypocenter of an earthquake.

Free Field. A ground area in which earthquake motions are not influenced by topography, man-made structures or other local effects.

Ground Motion. Numerical values representing vibratory ground motion, such as particle acceleration, velocity, and displacement, frequency content, predominant period, spectral values, intensity, and duration.

Hard Site. A site in which shear wave velocities are greater than 400 m/sec and overlying soft layers are less than or equal to 15 m.

Hotspot. A localized area where the seismicity is anomalously high compared with a surrounding region.

Intensity. A numerical index describing the effects of an earthquake on man, on structures built by him and on the earth's surface. The number is rated on the basis on an earthquake intensity scale. The scale in common use in the U.S. today is the Modified Mercalli (MM) Intensity Scale of 1931 with grades indicated by Roman numerals from I to XII. An abridgement of the scale is as follows:

I. Not felt except by a very few under especially favorable circumstances.

II. Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing.

III. Felt quite noticeable indoors, especially on upper floors of buildings, but many people may not recognize it as an earthquake. Standing motor cars may rock slightly. Vibration like passing of truck. Duration can be estimated.

IV. During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.

V. Felt by nearly everyone; many awakened. Some dishes, windows, etc., broken; a few instances of cracked plaster; unstable objects overturned. Disturbance of trees, poles and other tall objects sometimes noticed. Pendulum clocks may stop.

VI. Felt by all; many frightened and run outdoors. Some heavy furniture moved, a few instances of fallen plaster or damaged chimneys. Damage slight.

VII. Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving motor cars.

VIII. Damage slight in specially designed structures; considerable in ordinary substantial buildings with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand

and mud ejected in small amounts. Changes in well water. Persons driving motor cars disturbed.

IX. Damage considerable in specially designed structures; well designed frame structures thrown out of plumb; damage great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken.

X. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed over banks.

XI. Few structures remain standing. Unreinforced masonry structures are nearly totally destroyed. Bridges destroyed. Broad fissures in ground. Underground pipe lines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.

XII. Damage total. Waves seen on ground surfaces. Lines of sight and level distorted. Objects thrown upward into the air.

Liquefaction. The sudden, total loss of shear strength in a soil as the result of excess pore water pressure. The result is a temporary transformation of unconsolidated materials into a fluid.

Magnitude. A measure of the size of an earthquake related to the strain energy. It is based upon the displacement amplitude and period of the seismic waves and the distance from the earthquake epicenter.

1. Body Wave Magnitude (m_b). The m_b magnitude is measured as the common logarithm of the maximum displacement amplitude (microns) of the P-wave with period near 1 sec. Developed to measure the magnitude of deep focus earthquakes, which do not ordinarily set up detetable surface waves with long periods. Magnitudes can be assigned from any suitable instrument whose constants are known. The body waves can be measured from either the first few cycles of the compression waves (m_b) or the 1 sec period shear waves (m_{b1s}).

2. Local Magnitude (M_L). The magnitude of an earthquake measured as the common logarithm of the displacement amplitude, in microns, of a standard Wood-Anderson seismograph located on firm ground 62 miles (100 km) from the epicenter and having a magnification of 2,800, a natural period 0.8 sec, and a damping coefficient of 80 percent. Empirical charts and tables are available to correct to an epicentral distance of 62 miles (100 km), for other types of seismographs and for various conditions of the ground. The correction charts

are suitable up to epicentral distances of 373 miles (600 km) in southern California and the definition itself applies strictly only to earthquakes having focal depths smaller than about 19 miles (30 km). The correction charts are suitable up to epicentral distances of about 373 miles (600 km). These correction charts are site dependent and have to be developed for each recording site.

3. <u>Surface Wave Magnitude (M_S)</u>. This magnitude is measured as the common logarithm of the resultant of the maximum mutually perpendicular horizontal displacement amplitudes, in microns, of the 20-sec period surface waves. The scale was developed to measure the magnitude of shallow focus earthquakes at relatively long distances. Magnitudes can be assigned from any suitable instrument whose constants are known.

4. <u>Richter Magnitude (M)</u>. Richter magnitude is nonspecified but is usually M_L up to 6.5 and M_S for greater than 6.5.

5. <u>Seismic Movement (M_o)</u>. Seismic moment is an indirect measure of earthquake energy.

$$M_o = G A D$$

where

        G - rigidity modulus

        A - area of fault movement

        D - average static displacement

The values are in dyne centimeters.

6. <u>Seismic Moment Scale (M_w)</u>. Expresses magnitude based on the concept of seismic moment:

$$M_w = 2/3 \log M_o - 10.7$$

7. <u>Comparison of Magnitude Scales.</u> Table C1 presents a comparison of values for m_b, M_L, M, $\log M_o$, M_w and M_S.

<u>Particle Acceleration.</u> The time rate of change of particle velocity.

<u>Particle Displacement.</u> The difference between the initial position of a particle and any later temporary position during shaking.

Table C1
Comparison Between m_b, M_L, M, $\log M_o$, M_w and M_S Scales

m_b Body-Wave	M_L Local	M Richter	$\log M_o$ (dyne-cm) Seismic Moment	M Moment	M_S Surface-Wave
5.0	5.4	5.4	24.2	5.4	5.0
5.5	5.9	5.9	25.0	6.0	5.8
6.0	6.4	6.7	26.1	6.7	6.7
6.5	6.9	7.5	27.3	7.5	7.5
7.0	7.5	8.3	28.6	8.4	8.3

Particle Velocity. The time rate of change of particle displacement.

Response Spectrum. The maximum values of acceleration, velocity, and/or displacement of an infinite series of single-degree-of-freedom systems, each characterized by its natural period, subjected to a time history of earthquake ground motion. The spectrum of maximum response values is expressed as a function of natural period for a given damping. The response spectrum acceleration, velocity, and displacement values may be calculated from each other by assuming that the motions are harmonic. When calculated in this manner these are sometimes referred to as pseudo-acceleration, pseudo-velocity, or pseudo-displacement response spectrum values.

Saturation. Where those measures of earthquake motions (acceleration, velocity, magnitude, etc.) do not increase though the earthquakes generating them may become larger.

Scaling. An adjustment to an earthquake time history or response spectrum where the amplitude of acceleration, velocity, and/or displacement is increased or decreased, usually without change to the frequency content of the ground motion.

Seismic Hazard. The physical effects of an earthquake.

Seismic Risk. The probability that an earthquake of or exceeding a given size will occur during a given time interval in a selected area.

Seismic Zone. A geographic area characterized by a combination of geology and seismic history in which a given earthquake may occur anywhere.

Soft Site. A site in which shear wave velocities are less than 400 m/sec in a surface layer 16 m or more thick.