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Zones of Earthquake occurrence: Examination of seismic source zone boundaries in the Ottawa Valley and south of the St. Lawrence Valley, including the northeastern United States

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ZONES OF EARTHQUAKE OCCURRENCE

Examination of seismic source zone boundaries in the Ottawa Valley and south of the St. Lawrence Valley, including the northeastern United States

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Abstract

This report documents present knowledge of earthquake patterns in and near two of the Canadian earthquake source zones (WQU and NAP) that had been previously defined in 1982 from data available to 1977. Earthquakes to the end of 1990 are analyzed using epicentre maps for various ranges of years and magnitudes. The monitoring ability of the seismograph network in eastern Canada is displayed on station maps for selected years. Data analysis for the 1980s was limited by incomplete databases of American earthquakes. The report demonstrates that caution should be exercised when interpreting seismicity patterns in eastern Canada, as some apparent patterns may be artifacts of uneven monitoring in space as well as in time. Modifications are suggested to the boundaries and related parameters of the Western Québec (WQU) and Northern Appalachian (NAP) source zones. However, no drastic changes are proposed, not because the 1982 values have proven to be "correct", but because their uncertainties are not significantly reduced by addition of more recent data (1978 to 1990).

The southern boundary of the WQU is moved about 100 km further south to 43°N latitude. The 1982 NAP boundaries are modified to insert a narrow sector of reduced activity between them and the WQU, and also to include those parts of New England arbitrarily excluded in 1982. The modified zone is renamed the New England–New Brunswick earthquake source zone (NE–NB). The database within the two zones is considered complete down to M 2.5 between 1981 and 1990 for the WQU, and between 1982 and 1990 for the Canadian sections of the NE–NB. Seismograph station closures would raise this magnitude level for subsequent years. The completeness level M 2.5 does not extend north of the WQU. Also, for most of the American portions of the NE–NB, the database in the computerized American catalogues examined is not complete below M 3.0. The parameter M_x remains at 7.0 for the modified WQU source zone but increases from 6.0 to 6.5 for the NE–NB source zone.

Earthquake source zone boundaries to be chosen in 1992 as a basis for revised seismic zoning maps for Canada may differ from those proposed in this report.

Résumé

Ce rapport présente une mise à jour des patrons de tremblements de terre à l'intérieur et à proximité de deux des zones-sources (WQU et NAP), définies en 1982 à partir des données disponibles jusqu'en 1977. Les tremblements de terre qui se sont produits jusqu'à la fin de 1990 sont traités au moyen de cartes d'épicentres dressées selon diverses plages d'années et de magnitudes. La capacité de surveillance du réseau séismographique dans l'Est canadien est démontrée au moyen de cartes de stations dressées pour certaines années. Le traitement de données pour les années 1980 fut limité par des lacunes dans les bases de données de séismes américains. Ce rapport démontre que la prudence s'impose quant à l'interprétation de patrons de séismicité dans l'Est canadien, car quelques groupements apparents pourraient découler d'une surveillance partielle, spatiale aussi bien que temporelle. Des modifications sont suggérées aux limites ainsi qu'aux paramètres associés des zones-sources WQU et NAP (Ouest du Québec et Appalaches du Nord). Toutefois, les changements apportés ne sont pas fondamentaux, non pas parce que les valeurs choisies en 1982 se sont avérées «correctes», mais parce que leurs incertitudes sont peu réduites par l'ajout des données subséquentes (1978 à 1990).

La limite sud de la zone WQU est déplacée d'environ 100 km plus au sud, vers 43°N de latitude. Les limites choisies en 1982 pour démarquer la zone NAP sont modifiées afin d'introduire un secteur étroit d'activité réduite entre cette zone et la zone WQU et afin d'inclure aussi les parties de la Nouvelle-Angleterre arbitrairement exclues en 1982. La zone-source ainsi modifiée est renommée la zone de la Nouvelle-Angleterre et du Nouveau-Brunswick (NE–NB). La base de données à l'intérieur des deux zones est jugée complète jusqu'à M 2,5 entre 1981 et 1990 pour la zone WQU, et entre 1982 et 1990 pour les secteurs canadiens de la zone NE–NB. En conséquence des fermetures de stations séismographiques, ce seuil de magnitude inférieure ne s'applique plus. Le degré de complétude M 2,5 n'est pas valide au nord de la zone WQU. Quant à la plupart des secteurs américains de la zone NE–NB, pour des catalogues informatisés américains qu'on a examinés, la base de données n'est pas complète pour les magnitudes inférieures à M 3,0. Le paramètre M_x demeure inchangé à 7,0 pour la zone-source WQU modifiée, quoique augmenté de 6,0 à 6,5 pour la zone-source NE–NB.

Les limites des zones-sources qui seront choisies en 1992, dans le cadre d'une mise à jour des cartes canadiennes de zonage séismique, pourraient être autres que celles proposées dans ce rapport.

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ZONES OF EARTHQUAKE OCCURRENCE

Examination of Seismic Source Zone Boundaries in the Ottawa Valley and south of the St. Lawrence Valley, including the northeastern United States

Anne E. Stevens, Geological Survey of Canada

Preamble

This report is intended to be an internal working report, written to document present knowledge of earthquake patterns in and near two of the Canadian earthquake source zones previously defined in 1982 from data to 1977. This report, prepared in mid-1991, uses earthquake data to the end of 1990. The report presupposes a knowledge of Canadian seismicity and the relevant technical vocabulary.

The two chief methods of analysis used in this report could be profitably applied to studies of earthquake patterns in other areas. It is common practice to plot earthquakes of different magnitudes on one map, with distinctive symbols for each magnitude range of interest. While this practice has been followed in the present report, additional maps are displayed with each magnitude range of interest plotted on a separate map to more clearly show where the choice of zone boundaries depends on a particular magnitude range.

The second method of analysis presents maps of Canadian seismograph stations for selected years, with a graphical indication of their average earthquake monitoring ability. Such maps demonstrate where the choices of zone boundaries and of magnitude–year completeness pairs are limited by seismograph station monitoring abilities.

While some modifications are proposed to the boundaries of the two source zones examined and to the magnitude–year completeness pairs, no drastic changes are proposed to the parameters chosen in 1982, not because the previous parameters have proven to be "correct", but because more recent data have not significantly reduced the uncertainties associated with their selection. Drastic changes to parameters of the two zones studied would have implied a sound observational basis for such changes.

For the two source zones studied, historical earthquakes are not critical for selection of source zone parameters. Historical earthquakes are those for which no instrumental data are available, which includes virtually all earthquakes prior to about 1925. In general, most historical earthquakes fail to satisfy magnitude–year completeness criteria.

For both source zones studied, the historical earthquakes lie within areas where more recent instrumentally-recorded earthquakes have occurred; furthermore, they have estimated magnitudes equal to or less than those of the instrumentally-recorded earthquakes. Historical earthquakes may be important for site-specific studies of earthquake hazard, but are not critical to the selection of parameters in the two source zones studied.

The main part of this report presents an overview of the data mapped in the three appendices and summarizes their conclusions. The reader will find the specific numerical results of this study in Figures 1 and 2 (pages 12 and 13) and in Tables 1 and 2 (pages 3 and 9) of the main

part of this report, where the old and proposed new source boundaries are defined and where magnitude–year completeness pairs are listed. The reader interested only in the overall method and results may not need to consult the appendices.

Introduction

The seismic zoning maps for the 1985 edition of the National Building Code of Canada (NBCC) were derived in part from a map of zones of earthquake occurrence. Details are found in the *Earth Physics Branch Open File 82–33*, dated December 1982 (Basham *et al.*, 1982). This Open File Report will be referred to below as the *1982 Open File*. The zone boundaries were based largely on the distribution of instrumentally-located earthquakes prior to 1978. The magnitude recurrence parameters for each zone were based on a subset of these earthquakes, a subset chosen according to a magnitude–year completeness table. The maximum magnitude for each zone, denoted M_x, was generally selected as one-half magnitude larger than the largest known earthquake in the zone.

The data set for the *1982 Open-File Report* was terminated in 1977. Hence the 1985 NBCC was based on data only to 1977. Due to advances in computing, both software and hardware, it is now possible to produce and analyze earthquake data sets using virtually current data. Studies in early 1991 can include data up to the end of 1990. Thus it is of interest to see to what extent earthquake data compiled for the years from 1978 to 1990 support the zones of earthquake occurrence published in 1982.

Figure 1 (page 12) shows a map of eastern North America on which are superimposed the seismic source zones as defined in *EPB Open File 82–33*. The Western Québec (WQU) and Northern Appalachian (NAP) zones are outlined in longer dashed lines, the remaining zones in shorter dashed lines. Note that the WQU and NAP zones abut in northeastern New York State, without an intervening area of reduced seismicity.

Figure 2 (page 13) shows a suggested modification of the boundaries of two of the zones, namely WQU and NAP. These modified zones may be used, in conjunction with modifications being proposed by others for the remaining zones, in the project to produce new seismic zoning maps for the 1995 NBCC. Modifications to the other zones are not shown; their 1982 boundaries are retained in Figure 2. The modified Western Québec zone continues to be denoted WQU, as only its southern boundary has been altered. The modified NAP zone is referred to as the New England–New Brunswick zone (NE–NB), as several of its boundaries have been altered.

The corners of the polygons defining the WQU, NAP and NE–NB zones in Figures 1 and 2 are presented in Table 1 (page 3) as latitude-longitude pairs.

The reasons for the presently known distribution of earthquakes in eastern North America are not at all well understood. That is, there is no particular justification for subdividing either the WQU or the NAP (or NE–NB) to create additional zones.

There is no general consensus on the relation between current earthquakes and either the geology or tectonics of eastern North America. In addition, tectonic hypotheses in vogue vary from year to year. [See, for example, Adams (1991): Proceedings, Geological Survey of Canada Workshop on Eastern Seismicity Source Zones for the 1995 Seismic Hazard Maps.] Therefore the WQU and NE–NB zones are defined in the present report only by the spatial distribution of earthquakes and the monitoring sensitivity of various groups of seismograph stations.

Table 1

Latitude (°N), longitude (°W) pairs defining polygon corners of zones WQU, NAP and NE–NB displayed in Figures 1 and 2

WQU 1982	*WQU modified*	*NAP 1982*	*NE–NB modified*
48.1, 75.6	48.1, 75.6	**47.6, 65.0**	**48.0, 65.0**
47.8, 78.6	47.8, 78.6	**45.0, 73.0**	**48.0, 68.0**
46.8, 79.4	46.8, 79.4	**44.4, 73.0**	**45.5, 71.5**
44.3, 75.0	44.3, 75.0	**44.3, 75.0**	**44.0, 72.5**
44.4, 73.0	**42.9, 75.0**	42.0, 75.0	**42.0, 72.5**
45.0, 73.0	**42.9, 73.0**	**42.0, 73.0**	42.0, 75.0
45.8, 73.5	45.0, 73.0	**43.5, 73.0**	**40.0, 75.0**
	45.8, 73.5	**43.5, 68.0**	**40.0, 73.0**
		44.5, 66.0	**41.0, 72.0**
		46.0, 64.0	**41.0, 69.5**
			43.0, 69.5
			44.0, 68.0
			44.0, 67.0
			44.5, 66.0
			46.0, 64.0

boldface shows differences between 1982 and modified zones

The southern boundary of the WQU and all boundaries of the NE–NB depend upon an analysis of databases containing American earthquakes. The CEEF (Canadian Earthquake Epicentre File) at present (mid-1991) does not contain all relevant American data and neither is there any single in-house database with these data. Accordingly, the following three American computer-based catalogues (GHD, 1990; EPRI, 1986) were analyzed for earthquakes relevant to revising zone boundaries.

- Global Hypocenter Data Base (GHD) on CD-ROM, version 1.0: catalogue HDS
- Global Hypocenter Data Base on CD-ROM, version 1.0: catalogue SRA
- (Electric Power Research Institute) EPRI 1986 catalogue

The various epicentre and seismograph station maps that follow in the three appendices include also the 1982 seismic source zones, depicted by dashed lines. The final set of epicentre maps at the end of the main text shows the two modified source zones. All maps are identified individually in the *Table of Contents*, page iv, facilitating reference to specific maps.

Magnitude–year completeness tables are presented for the WQU and NE–NB zones at 0.5 magnitude unit increments. Smaller increments are not considered appropriate for two main reasons. Individual magnitudes are rarely known to better than 0.3 magnitude unit due to measurements at an insufficient number of stations and to natural variability in radiation pattern and site response. Secondly, the most commonly used magnitude scale in eastern North America, m_N (i.e. $m_b L_g$), has not always been applied to data in exactly the same way by different agencies, leading to differing magnitude values for the same earthquake.

Note that estimates of magnitude–year completeness assume not only that an earthquake is

detectable, but also that its location and magnitude can be estimated with reasonable accuracy.

Zone Boundaries

Western Québec Zone (WQU)

Various subsets of the CEEF were plotted to examine the Canadian boundaries of the WQU. Various subsets of the three American catalogues were analyzed to study the southern WQU boundary. These maps are presented and discussed in Appendices A and B.

The eastern, northern and western boundaries, as defined in the *1982 Open File* from data up to 1977, are retained without modification. Improvements in the ECTN (Eastern Canada Telemetered Network) in the 1980s decreased the magnitude detection/location limits within the zone, but did little to improve monitoring north and northeast of the zone. Hence there is no basis for revising these boundaries. On the other hand, the western boundary remains sharply defined despite improved monitoring along the Ottawa Valley. Note that the eastern boundary is more diffuse; whether this is real or an effect of incomplete monitoring remains to be seen.

Based on CEEF data alone, the southern boundary of the WQU appears to be near 44°N, as the density of plotted epicentres decreases sharply further south. However, an examination of the three American databases puts this boundary about 100 km further south, near 43°N.

Maps: WQU – CEEF data only and seismograph stations

The following maps, showing earthquake and seismograph station distribution, appear in Appendix A.

- date ≤1977 (period covered by the *1982 Open File*)
- date ≤1929 (epicentres virtually all non-instrumental; these are seen not to be critical for defining WQU boundaries)
- 1930 ≤date ≤1977 (epicentres mostly instrumental)
- 1978 ≤date ≤1990 (data acquired since the *1982 Open File*); map of all magnitudes, then maps of four magnitude subsets, namely M≥4.0, M3, M2, M<2.0
- 1981 ≤date ≤1990 (period of best monitoring by the ECTN, although detection levels not uniform over the entire WQU zone)
- Canadian seismograph stations in and near the Western Québec zone for each of the following years: 1968, 1973, 1979, 1981 and 1990

On these station maps, circles proportional to the various magnitude detection limits were drawn about stations monitoring the WQU. Where stations were close together, only one circle was drawn to avoid cluttering the map. As it was impractical to examine individual station histories, the same detection limits were applied to all stations.

From these station maps, the magnitude–year completeness table, as defined for the WQU zone in the *1982 Open File*, can be augmented by one additional level, M 2.5 since 1981. But this level of completeness does not extend north of the zone. No

changes are proposed to the magnitude–year completeness table for magnitudes 3.0 and larger.

- date ≤1990 (complete CEEF to 1990 plotted on three maps – all magnitudes [1982 zone boundaries] and magnitude–year restriction [both 1982 and revised boundaries])
- date ≤1977 (CEEF to 1977 with magnitude–year restriction [1982 boundaries])

American data for the northeastern United States

southern boundary of the WQU zone and boundaries of an Appalachian zone

Epicentral data from two American databases (three catalogues) were plotted separately on small-scale maps of eastern North America. EPRI data were selected for the complete map area; GHD CD-ROM data were selected for a slightly smaller area, as defined below. Neither of these databases has an adequate coverage of the eastern United States in the 1980s. It is not known whether computed but unpublished American epicentral data exist for this period up to the end of 1990.

In Appendix B, data selected from these three catalogues are displayed on maps that include a geographic area large enough to encompass both the WQU zone, the NAP zone and adjacent areas. These maps were then used to study the southern boundary of the WQU (lying entirely in the United States) and all boundaries of the NAP. As a result, the southern boundary of the WQU zone was moved about 100 km further south and boundaries of the NAP redrawn to form a new New England–New Brunswick (NE–NB) zone.

— Global Hypocentre Database (CD-ROM version 1.0): The two catalogues relevant to eastern North America were examined: the HDS catalogue is the worldwide PDE catalogue spanning the years 1928 to 1988; the SRA catalogue contains only data within the geographic limits of the United States, spanning the period 1568 to 1984. Data within the rectangular area bounded by 35.0° to 50.0°N, 50.0° to 80.0°W were plotted on a map of eastern North America of somewhat larger geographic coverage. The map headings indicate the geographic limits of the extracted GHD data. Map headings also indicate subsets of these data, by time period, magnitude range, and data source agency.

Appendix B shows epicentre maps of eastern North America based on the HDS catalogue, as well as subsets for its various epicentre source agencies. Only the Lamont-Doherty and Weston subsets appeared likely to be able to supplement the American data for New York State and New England that are already available in the CEEF. It was noted that the coverage by these two agencies, as catalogued in the HDS catalogue, is incomplete, even within the final decade of the time period of the HDS catalogue. Other epicentre agencies referenced within the HDS catalogue had no relevant information not already found in the CEEF.

Appendix B also shows epicentre maps of non-instrumental and instrumental subsets of the SRA catalogue. The American epicentres in the SRA instrumental subset contained virtually all the American epicentres from the Lamont-Doherty and Weston subsets of the HDS catalogue, as well as many additional epicentres in New York State and New England.

Thus, instrumentally-determined American epicentres in the SRA catalogue in recent years

might be used to supplement American data already included in the CEEF. Data from the HDS catalogue contribute no information relative to zone boundaries that is not available either in the CEEF or in the SRA catalogue. This situation could change when the Global Hypocenter Data Base CD-ROM, version 1.0, is updated.

Maps: Global Hypocenter Data Base

The earthquake maps listed below are presented in Appendix B in order to examine relevant American data extracted from the Global Hypocenter Data Base.

- HDS, 1928 ≤date ≤1988, plus six subsets according to epicentre agency, as coded by the HDS catalogue.

  The HDS catalogue had 304 epicentres in the selected area, of which about one-third were located in Canada and more than one-third had been determined by the EPB/GSC. Coverage in time was uneven, even since 1970. Also the HDS catalogue has virtually no epicentres in western New York State, or in northern Maine.

- HDS, 1971 ≤date ≤1988, combination of data coded Lamont-Doherty and Weston (the epicentral agencies identified as the data source of most of the more recent events in New York State and New England)

- HDS, 1971 ≤date ≤1988, magnitude ≥3.0, combination of data coded Lamont-Doherty and Weston

- SRA, 1568 ≤date ≤1984

- SRA, 1568 ≤date ≤1977 (non-instrumental epicentres)

- SRA, 1925 ≤date ≤1984 (largely instrumental epicentres)

  The SRA catalogue has about twice as many events in the United States as does the HDS catalogue for a comparable time period and for the same geographic area. Some of the additional events occurred in areas such as western New York State and northern Maine.

- SRA, 1971 ≤date ≤1984 (instrumental data, period selected for comparison with HDS Lamont-Doherty and Weston data)

- SRA, 1971 ≤date ≤1984, magnitude ≥3.0

Data coverage on this last SRA map was similar to the corresponding HDS map.

— EPRI 1986 Database: The EPRI database includes epicentres in Canada and the United States compiled from various sources and issued as a computer file in 1986. All data within the total map area were plotted. The database spans the period 1627 to 15–02–1985, but has no events of interest after early 1984.

Several maps of EPRI data were plotted, as indicated below, and compared with similar maps plotted from the HDS and SRA catalogues.

The EPRI catalogue has more epicentres in New York State and New England than does

the HDS catalogue for similar time periods, whereas the EPRI and SRA maps show a similar epicentral distribution in the period since 1925. However, the EPRI catalogue has relatively few epicentres in New York State and New England since 1971 and contributes no information relevant to the determination of zone boundaries that is not also available from the SRA catalogue.

Maps: EPRI 1986 Database

The following earthquake maps of EPRI data are found in Appendix B.

- EPRI, date ≤15–02–1985
- EPRI, 1925 ≤date ≤15–02–1985 (largely instrumental epicentres)
- EPRI, 1925 ≤date ≤15–02–1985, magnitude ≥4.0
- EPRI, 1971 ≤date ≤15–02–1985 (period selected for comparison with HDS and SRA catalogues)

Two additional maps, not included in this report, were plotted using the two modified EPRI files sent by Armbruster to Adams on 29–01–1991. Both of these files consist only of American epicentres whose longitudes are east of 97.0°W. The distribution of epicentres in the United States appeared identical with that of the original EPRI file. The Armbruster files contain no additional information useful for determining zone boundaries.

It is clear from the various American maps that the southern boundary of the WQU zone should be moved further south. An area of much reduced seismicity appears to lie between about 41°N and 42°N. Whether this might be due in part to station distribution or a lack of data integration among various American agencies was not investigated.

Assuming that this area of reduced seismicity is real, the southern boundary of the Western Québec zone was moved from its 1982 position near 44.3°N southward to a new position at 42.9°N, remaining between longitudes 73.0°W and 75.0°W. One of the northern boundaries of the new New England–New Brunswick zone was then drawn at 42.0°N between these same two longitudes. The boundaries at 42.9° and 42.0° are not exact, but could be adjusted by a few tenths of a latitude degree north or south.

These American data plus data from the CEEF suggest that the remainder of the northern boundary of the NE–NB zone could be drawn to approximately follow the Vermont–New Hampshire border, the Maine–Québec border and the Québec–New Brunswick border. After passing just east and south of New Brunswick, the southern boundaries are drawn slightly offshore to parallel the Atlantic coastline. The suggested boundaries for the NE–NB zone are shown in Figure 2 (page 13). The new zone is similar to the 1982 NAP zone in New Brunswick, represents an enlargement of the NAP zone to include more of New England, and has been shifted further south in New York State. In addition, the revised WQU zone no longer abuts another zone.

New England–New Brunswick Zone (NE–NB)

Various subsets of the CEEF were plotted to examine the boundaries of the NAP zone and

of the new NE–NB zone that had been proposed after examining American data. Because of the size and shape of these two zones, and the need to include areas at least 100 km beyond their boundaries, the maps depicting the NAP and NE–NB zones also included the WQU zone, repeating some of the information displayed in Appendix A.

Maps: **NAP/NE–NB – CEEF data only and seismograph stations**

The following earthquake and seismograph station maps appear in Appendix C, with time and magnitude ranges corresponding to those selected in Appendix A for studying the WQU zone.

- date ≤1977 (period covered by the *1982 Open File*)
- date ≤1929 (epicentres virtually all non-instrumental; these are seen not to be critical for defining NAP/NE–NB boundaries)
- 1930 ≤date ≤1977 (epicentres mostly instrumental)
- 1978 ≤date ≤1990 (data acquired since the *1982 Open File*); map of all magnitudes, then maps of four magnitude subsets, namely M≥4.0, M3, M2, M<2.0
- 1982 ≤date ≤1990 (period of best monitoring in New Brunswick began in late 1981; detection levels not uniform over the entire NAP/NE–NB zones)
- Canadian seismograph stations monitoring New England and the Maritime provinces for each of the following years: 1968, 1975, 1982 and 1990

  On these station maps, circles proportional to the various magnitude detection limits were drawn about the stations, in the same manner as for the WQU, as described above and also in Appendix A. As it was impractical to examine individual station histories, the same detection limits were applied to all stations.

  From these station maps, the magnitude–year completeness table, as defined for the NAP zone in the *1982 Open File*, is retained for the new NE–NB zone and augmented by one additional level, M 2.5 since 1982. But this new level of completeness applies to the entire zone only if data from American stations in New England and New York State are assumed to have been regularly combined with Canadian data in preparing the CEEF.

- date ≤1990 (complete CEEF to 1990 plotted on three maps – all magnitudes [1982 zone boundaries] and magnitude–year restriction [both 1982 and revised boundaries])
- date ≤1977 (CEEF to 1977 with magnitude–year restriction [1982 boundaries])

Revised Zone Boundaries

The following eight summary maps (pages 14 to 21) are presented here with the revised WQU zone boundaries and those of the new NE–NB zone replacing the 1982 WQU and NAP zone boundaries. The 1982 boundaries are retained for the other zones, as these boundaries are being studied by other persons.

- CEEF, 1925 ≤date ≤1990
- CEEF, 1925 ≤date ≤1990, magnitude≥4.0

- CEEF, 1971 ≤date ≤1990
- CEEF, 1981 ≤date ≤1990
- EPRI, 1925 ≤date ≤15–02–1985, [effective date 02–02–1984]
- EPRI, 1971 ≤date ≤15–02–1985, [effective date 02–02–1984]
- SRA–i, 1925 ≤date ≤1984
- SRA–i, 1971 ≤date ≤1984

Earthquake data from 1925 onward are largely instrumental data, thus avoiding most of the epicentres located from felt reports alone. Data from 1971 to the end of each catalogue should represent the best continuous set of instrumental data in each catalogue, although the coverage is not uniform. For the CEEF, whose database extends to more recent years, an additional map is plotted representing the most recent decade of monitoring by the ECTN.

The SRA map has more epicentres in New England and New York State since 1971 than does the EPRI map. The CEEF maps suggest that the northeastern corner of the WQU zone is relatively inactive; however, this area is much less well monitored by the ECTN. Thus this boundary should not be altered. The CEEF maps show few data in the file since 1971 from New York State, south of 44°N. The maps also show scattered activity over New Brunswick, Maine and Vermont, but with a lack of recent data south of 43°N. The epicentral patterns seen on these eight maps are discussed in detail in the appendices.

Magnitude completeness and M_x

The magnitude–year completeness table for the 1982 WQU was retained with the addition of magnitude–year completeness pair M2.5 since 1981, but only within this zone, as explained in Appendix A. It would be difficult to adjust to a significantly earlier year any of the years that had been previously selected for the larger magnitudes. These depended largely on seismograph station distribution and sensitivity, plus population settlement patterns and levels of literacy. The magnitude–year completeness table for the 1982 NAP was transferred to the NE–NB zone with the addition of the pair M2.5 since 1982, as discussed in Appendix C.

Both tables are presented below in Table 2 for reference. Changes from values in the *1982 Open File* are noted in boldface.

Appendices A and C each terminate with maps of earthquakes restricted to those meeting the assumed magnitude–year completeness limits.

The largest magnitude event in the WQU zone remains the M6.2 Temiskaming earthquake of November 1935. The largest events in the New England–New Brunswick zone are the January 1982 Miramichi main shock (Wetmiller *et al.*, 1984), the March 1904 southern New Brunswick–Maine earthquake (Leblanc and Burke, 1985) and the November 1755 Cape Ann earthquake (Street and Lacroix, 1979; Coppersmith *et al.*, 1991), all three with magnitudes slightly less than M6. Thus the parameter M_x for the NE–NB zone should be increased to 6.5 from the value 6.0 that had been assigned to the 1982 NAP zone. For the WQU zone, an M_x of 7.0 is retained.

Table 2

Magnitude–year completeness pairs to 1990

WQU	*NE–NB*
2.5, 1981	**2.5, 1982**
3.0, 1968	3.0, 1975
3.5, 1963	3.5, 1963
4.0, 1937	4.0, 1937
4.5, 1928	4.5, 1937
5.0, 1928	5.0, 1937
5.5, 1900	5.5, 1900
6.0, 1900	
6.5, 1850	

For the WQU source zone only, magnitude recurrence curves presented in Appendix A show that the addition of data from 1978 to 1990 did not significantly alter the magnitude recurrence parameters presented in the *1982 Open File* based on data to 1977. Magnitude recurrence curves are not presented for the revised WQU source zone nor for the proposed NE–NB source zone, since all relevant American data were not available when this report was being prepared.

Concluding Remarks

The methods employed herein to analyze the two earthquake source zones of interest could be applied to other areas. The method consists in examining three types of maps: epicentre maps plotted for pertinent time periods; epicentre maps plotted for various unit magnitude ranges within a particular time period; and seismograph station maps plotted for pertinent time periods.

Modifications to source zone boundaries, magnitude–year completeness tables and parameter M_x have been proposed for two earthquake zones. The specific conclusions presented in the three appendices concerning these modifications as well as the uncertainties imposed by data limitations have been incorporated into the preceding text. The numerous maps presented here and in the three appendices enable the reader to further analyze earthquake patterns in these areas.

References

(this reference list includes all references in the three appendices)

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Figure 1

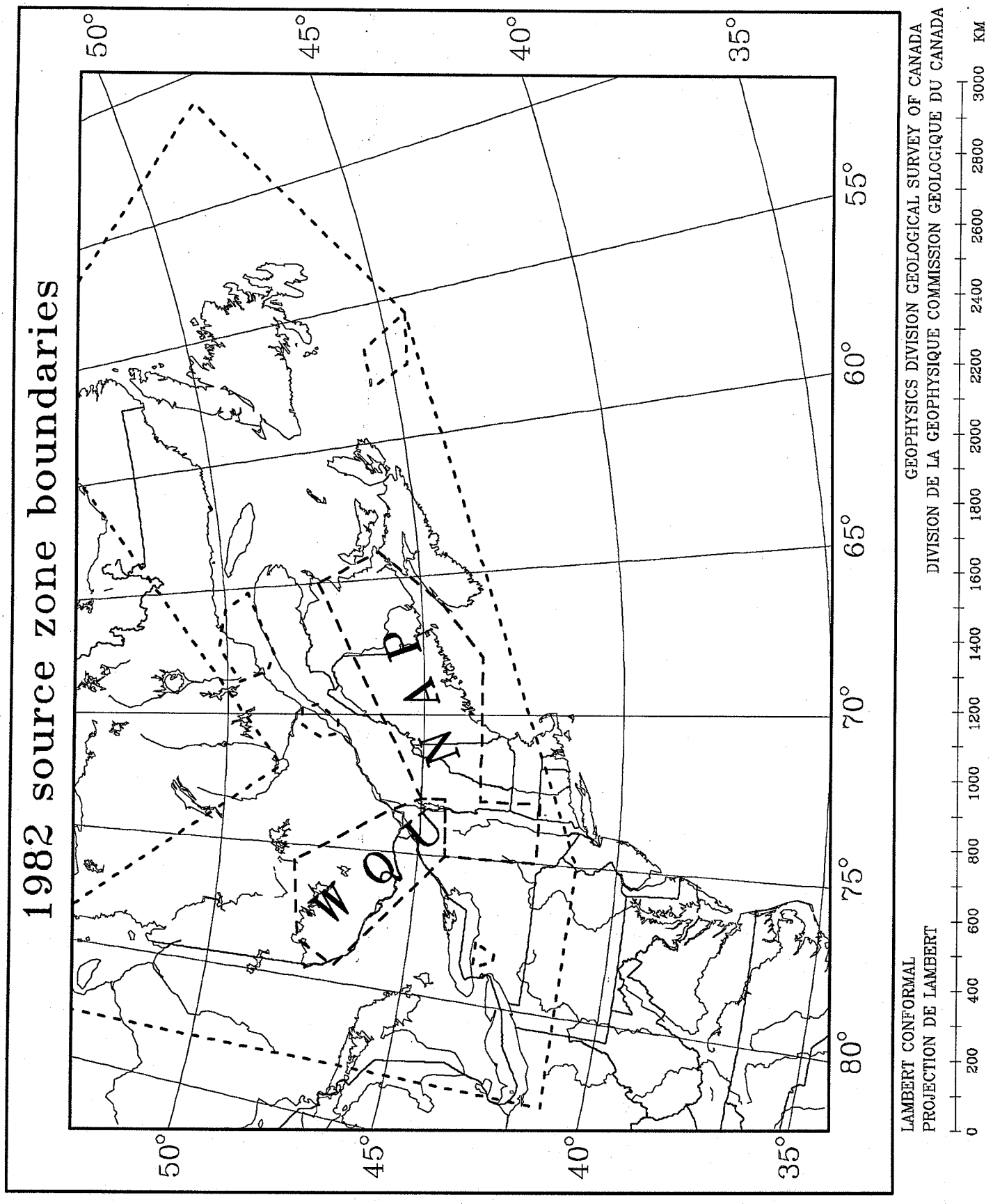
1982 source zone boundaries
50°
45°
40°
35°
55°
60°
65°
70°
75°
80°
WQZ
NAP
LAMBERT CONFORMAL
PROJECTION DE LAMBERT
GEOPHYSICS DIVISION GEOLOGICAL SURVEY OF CANADA
DIVISION DE LA GEOPHYSIQUE COMMISSION GEOLOGIQUE DU CANADA
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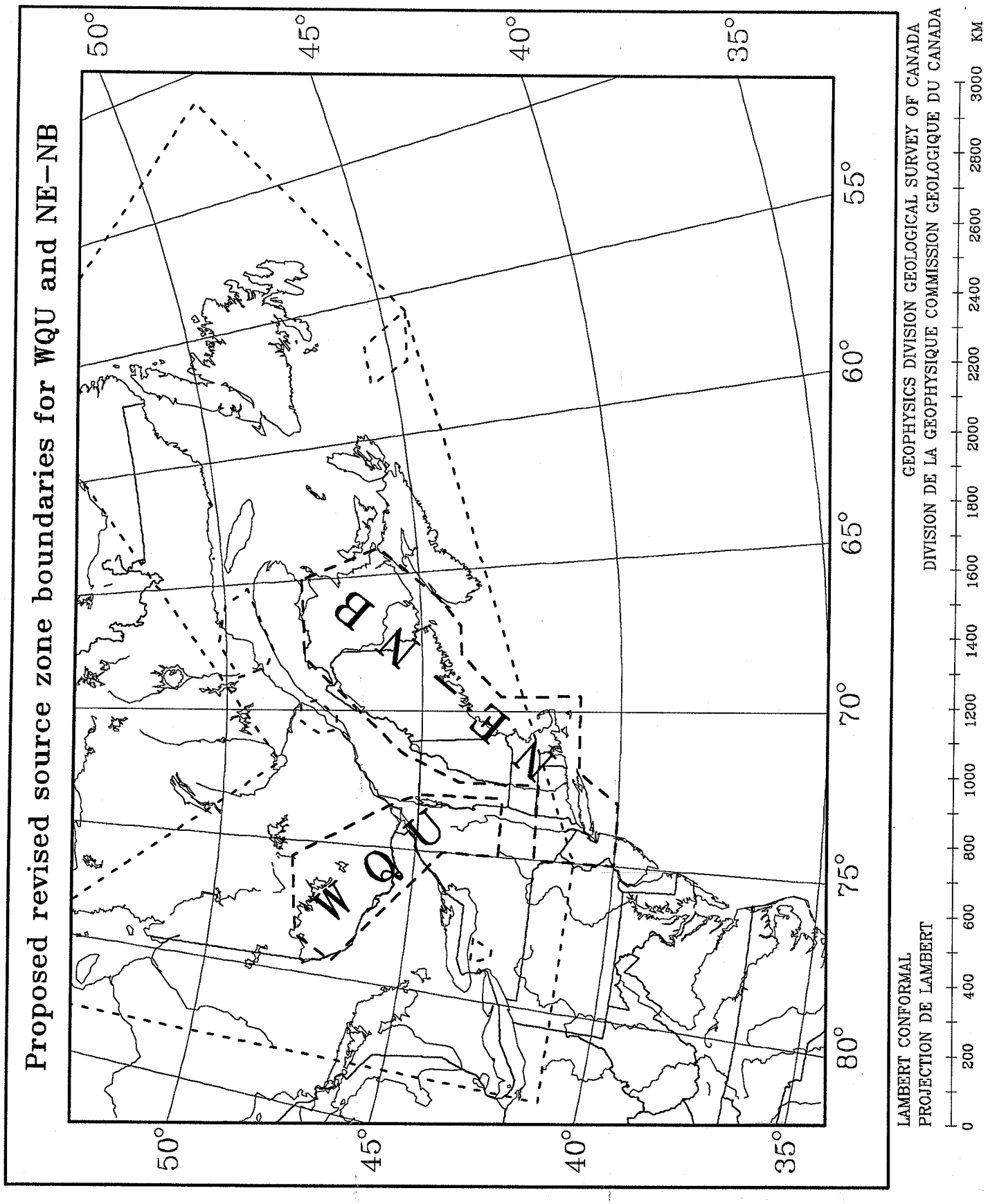
Figure 2


Proposed revised source zone boundaries for WQU and NE–NB
WQU
NB
50°
45°
40°
35°
55°
60°
65°
70°
75°
80°
LAMBERT CONFORMAL
PROJECTION DE LAMBERT
GEOPHYSICS DIVISION GEOLOGICAL SURVEY OF CANADA
DIVISION DE LA GEOPHYSIQUE COMMISSION GEOLOGIQUE DU CANADA
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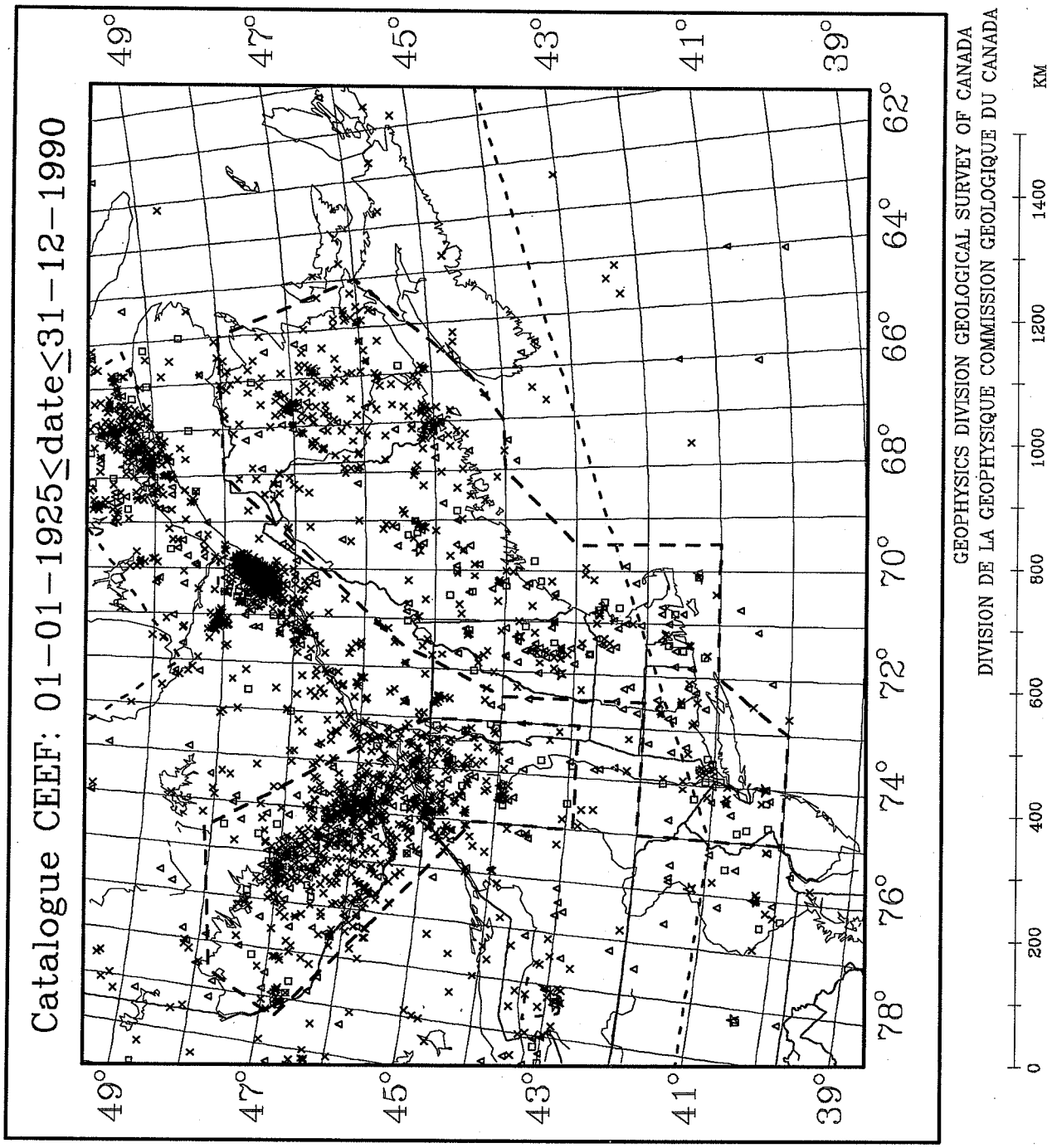
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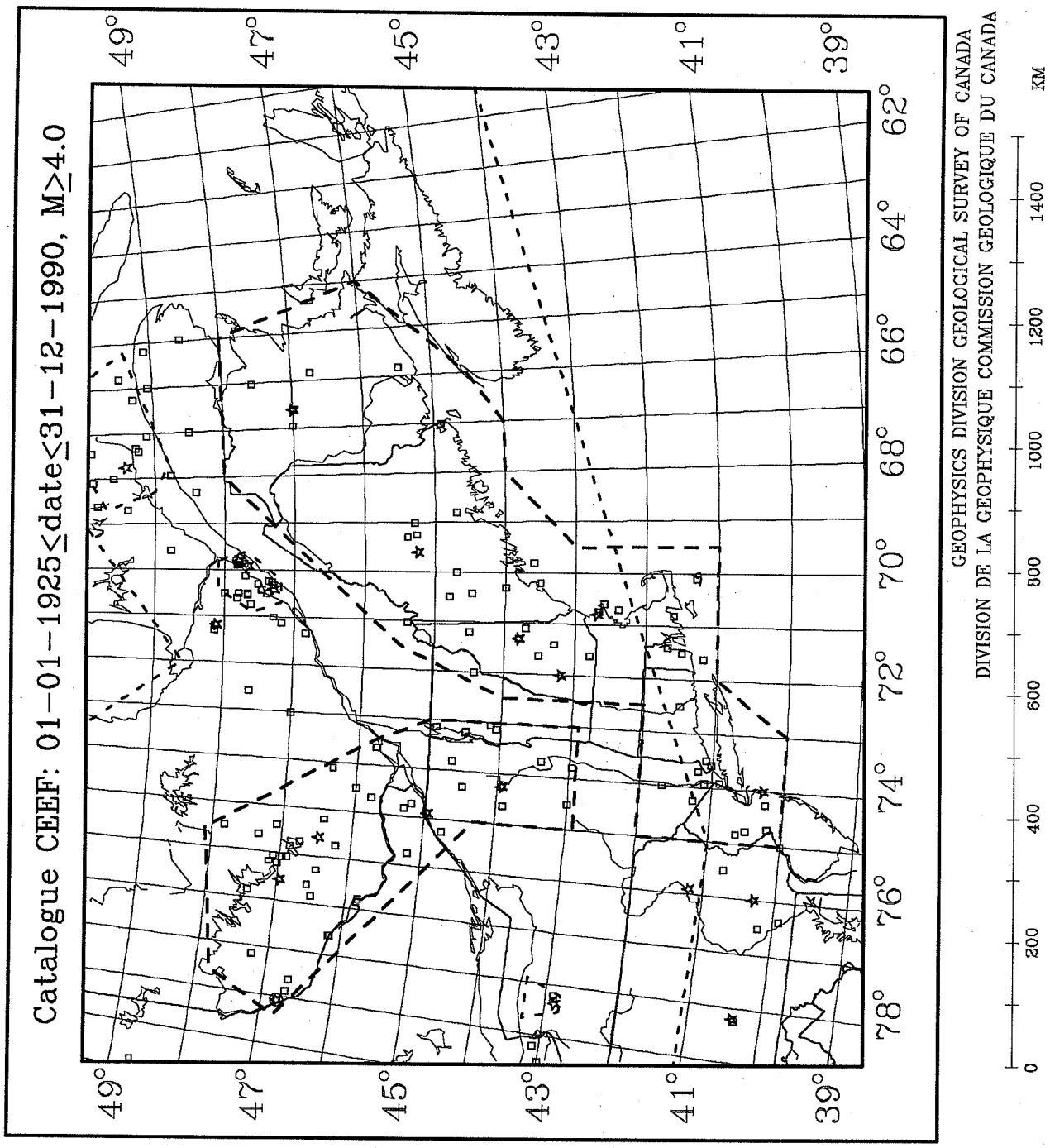
49°
47°
45°
43°
41°
39°
62°
64°
66°
68°
70°
72°
74°
76°
78°
GEOPHYSICS DIVISION GEOLOGICAL SURVEY OF CANADA
DIVISION DE LA GEOPHYSIQUE COMMISSION GEOLOGIQUE DU CANADA
0
200
400
600
800
1000
1200
1400
KM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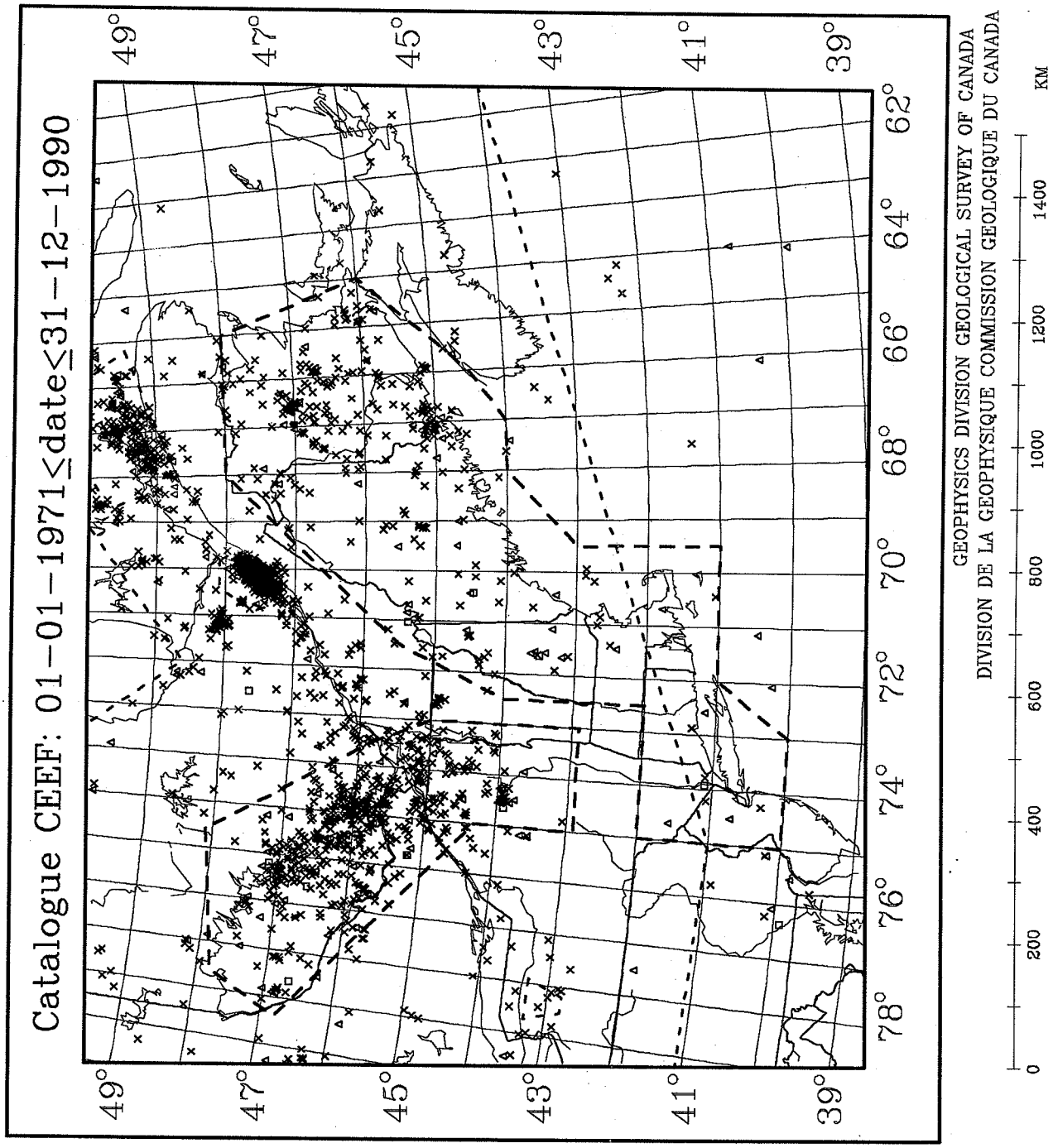
47°
45°
43°
41°
39°
62°
64°
66°
68°
70°
72°
74°
76°
78°
GEOPHYSICS DIVISION GEOLOGICAL SURVEY OF CANADA
DIVISION DE LA GEOPHYSIQUE COMMISSION GEOLOGIQUE DU CANADA
0
200
400
600
800
1000
1200
1400
KM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41°
39°
62°
64°
66°
68°
70°
72°
74°
76°
78°
GEOPHYSICS DIVISION GEOLOGICAL SURVEY OF CANADA
DIVISION DE LA GEOPHYSIQUE COMMISSION GEOLOGIQUE DU CANADA
0
200
400
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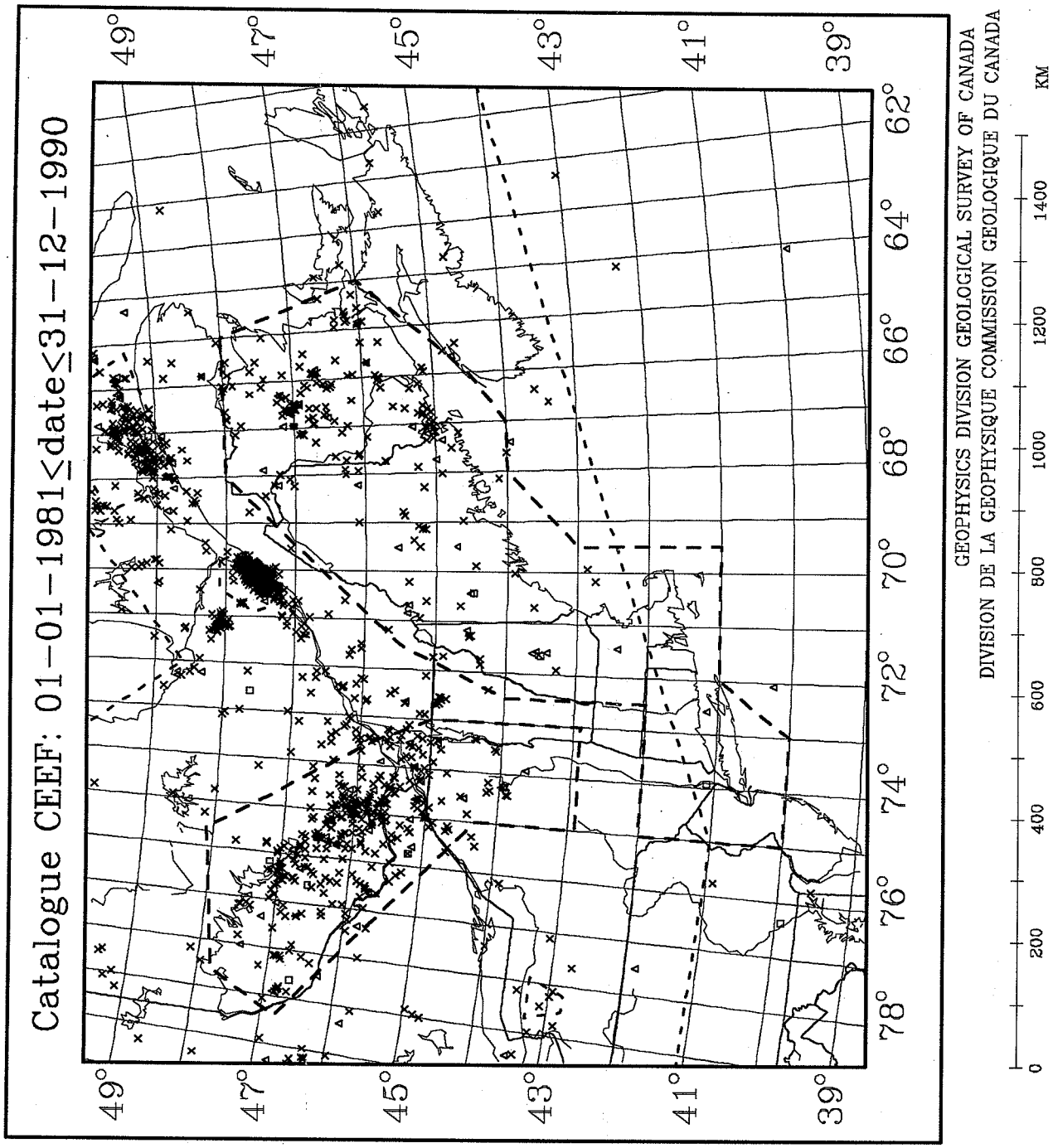
1000
1200
1400
KM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41°
39°
62°
64°
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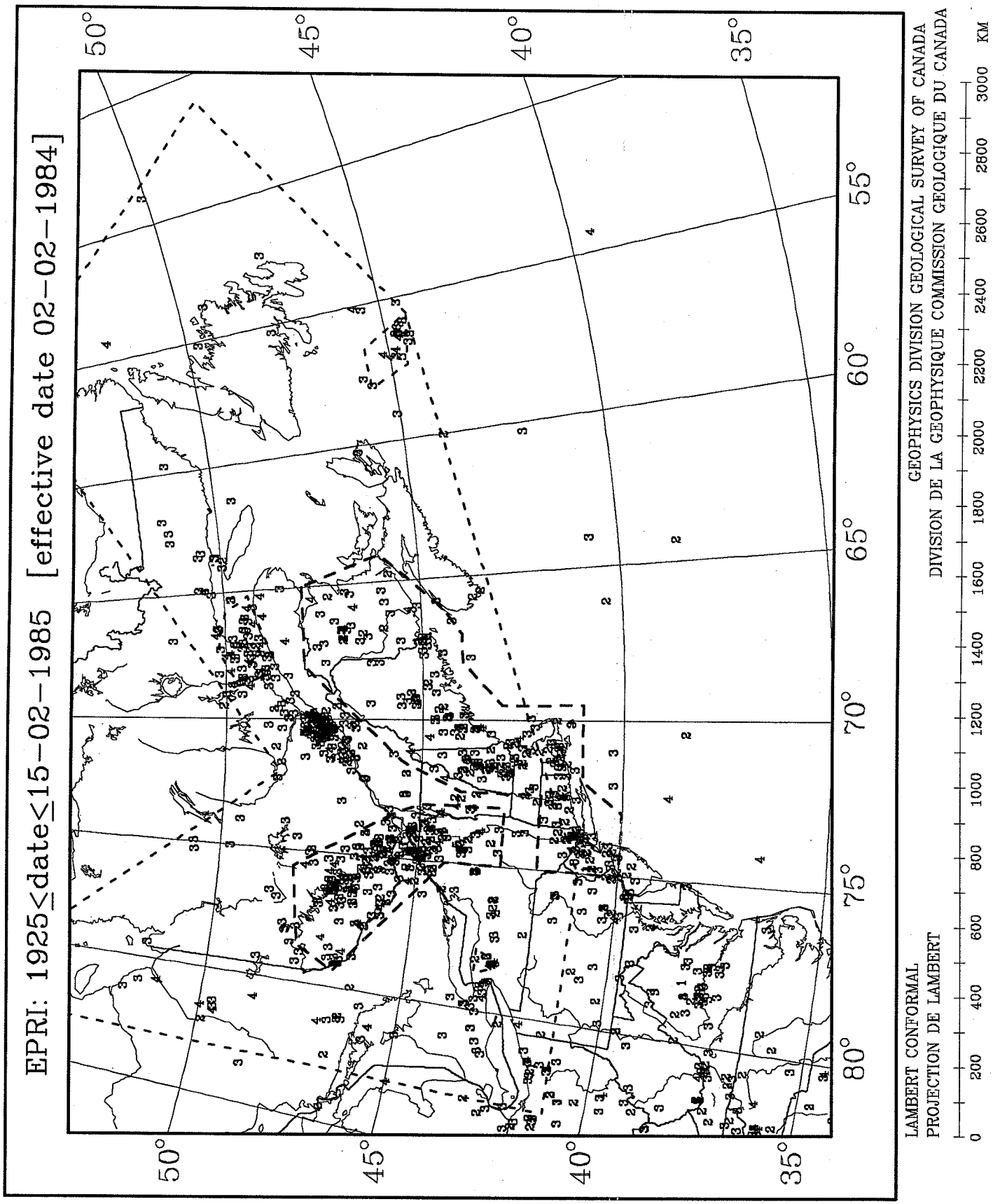
68°
70°
72°
74°
76°
78°
GEOPHYSICS DIVISION GEOLOGICAL SURVEY OF CANADA
DIVISION DE LA GEOPHYSIQUE COMMISSION GEOLOGIQUE DU CANADA
0
200
400
600
800
1000
1200
1400
KM


EPRI: 1925≤date≤15-02-1985 [effective date 02-02-1984]
50°
45°
40°
35°
55°
60°
65°
70°
75°
80°
LAMBERT CONFORMAL
PROJECTION DE LAMBERT
GEOPHYSICS DIVISION GEOLOGICAL SURVEY OF CANADA
DIVISION DE LA GEOPHYSIQUE COMMISSION GEOLOGIQUE DU CANADA
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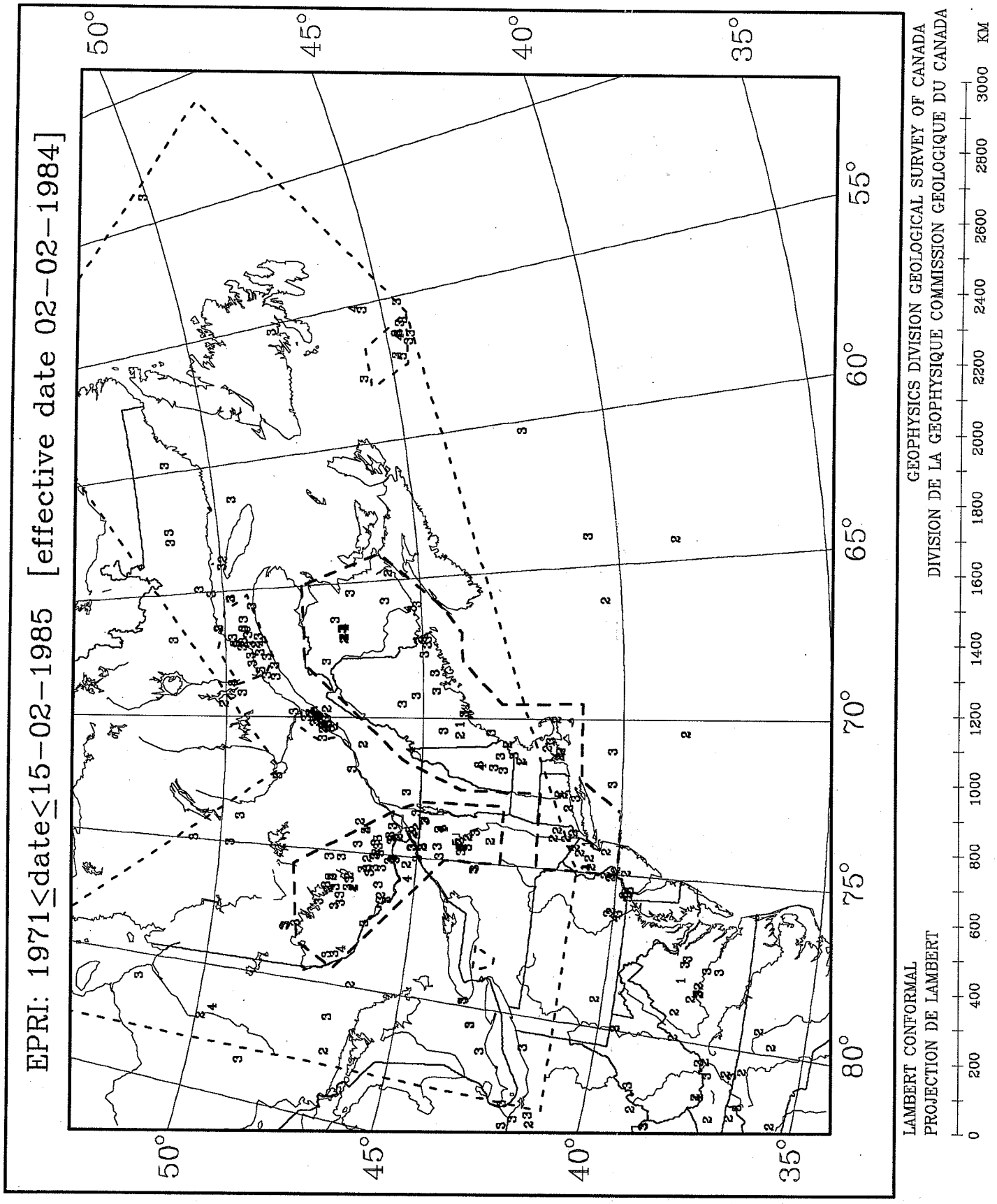
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50°
45°
40°
35°
55°
60°
65°
70°
75°
80°
LAMBERT CONFORMAL
PROJECTION DE LAMBERT
GEOPHYSICS DIVISION GEOLOGICAL SURVEY OF CANADA
DIVISION DE LA GEOPHYSIQUE COMMISSION GEOLOGIQUE DU CANADA
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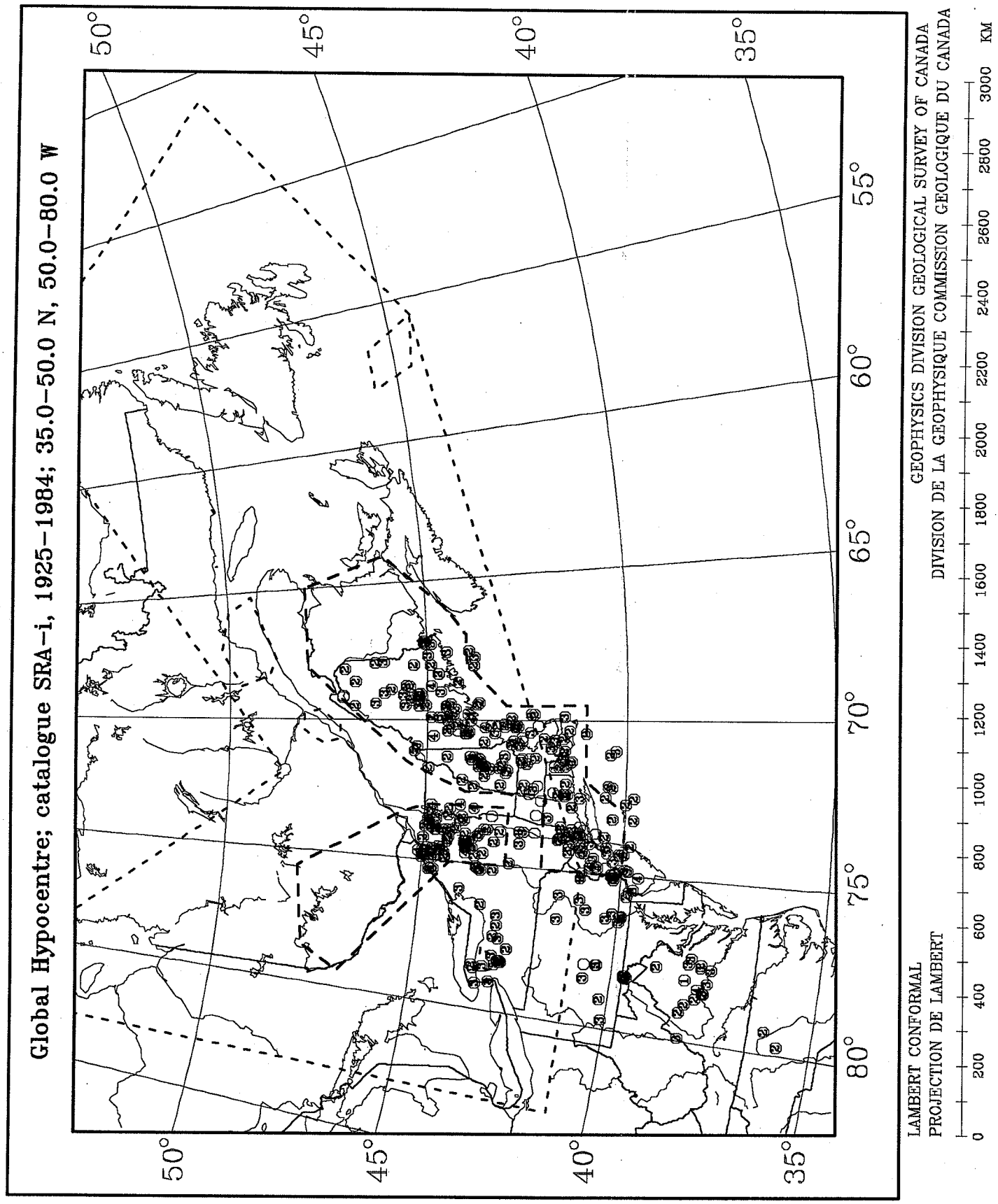
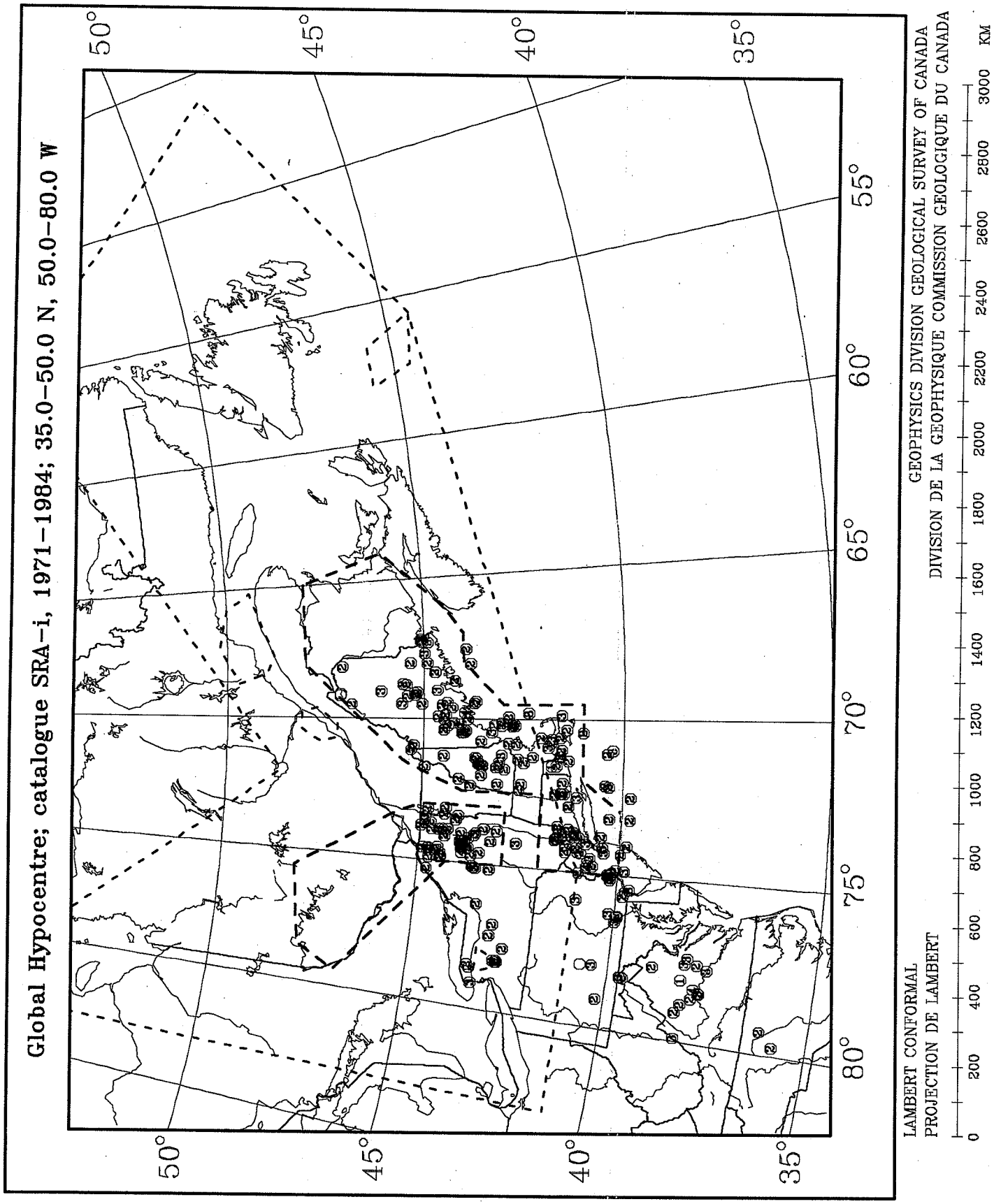

Global Hypocentre; catalogue SRA–i, 1925–1984; 35.0–50.0 N, 50.0–80.0 W
50°
45°
40°
35°
55°
60°
65°
70°
75°
80°
LAMBERT CONFORMAL
PROJECTION DE LAMBERT
GEOPHYSICS DIVISION GEOLOGICAL SURVEY OF CANADA
DIVISION DE LA GEOPHYSIQUE COMMISSION GEOLOGIQUE DU CANADA
0 200 400 600 800 1000 1200 1400 1600 1800 2000 2200 2400 2600 2800 3000 KM


Global Hypocentre; catalogue SRA-i, 1971-1984; 35.0-50.0 N, 50.0-80.0 W
50°
45°
40°
35°
55°
60°
65°
70°
75°
80°
LAMBERT CONFORMAL
PROJECTION DE LAMBERT
GEOPHYSICS DIVISION GEOLOGICAL SURVEY OF CANADA
DIVISION DE LA GEOPHYSIQUE COMMISSION GEOLOGIQUE DU CANADA
0 200 400 600 800 1000 1200 1400 1600 1800 2000 2200 2400 2600 2800 3000 KM

APPENDIX A

WESTERN QUÉBEC SEISMIC ZONE

This Appendix examines the Western Québec Seismic Zone (WQU), as defined in the *1982 Open-File Report* (Basham *et al.*, 1982), to see what modifications might be suggested on the basis of earthquake data alone.

The maps that follow display various subsets of data in the current version (mid-1991) of the *Canadian Earthquake Epicentre File (CEEF) [file MVAX3::SEIS:[MAPS]EPICENTRES.DAT].* Each map title indicates the year range and, if applicable, the magnitude range selected. The maps are not numbered but arranged in order of their presentation in the text below. Refer to the *Table of Contents*, page iv, for the page number of a specific map. Maps of Appendix A begin on page A–9, following the text.

On each of the maps below are superimposed the zone boundaries as published in the *1982 Open-File Report*, not only for the Western Québec zone, but for any other zone within the map area. The WQU (and NAP) boundaries are shown as longer dashed lines, the others as shorter dashed lines.

The boundaries of the maps in this appendix were selected to include all areas lying at least 100 km outside the WQU zone boundaries, as defined in 1982, in order to show clearly the change in epicentre distribution outside the boundaries. (See also the smaller-scale maps of eastern North America in Appendices B and C.)

References in this appendix will be found in the *Reference* section at the end of the main report (page 10).

Maps: CEEF data and seismograph stations

Earthquakes to the end of 1977, i.e. date ≤31–12–1977

This is essentially the data set available for the *1982 Open File.* The following three maps are plotted.

- *map: Earthquakes, date ≤31–12–1977*

The western boundary is sharply defined by these data, the eastern boundary is diffuse; note the M6 Temiskaming earthquake of 1935 near the northwestern corner.

- *map: Earthquakes, date ≤31–12–1929*

These are virtually all non-instrumental epicentres. Data are almost all in the southern third of the zone, in and near settled areas. These data are not necessary to define WQU zone boundaries, as earthquakes continued to occur in these same areas in more recent years.

- *map: Earthquakes, 01–01–1930 ≤ date ≤31–12–1977*

These are virtually all instrumental epicentres. Data distribution is similar to that shown on the map for the

entire period ≤1977; i.e. pre–1930 data are not needed to define WQU zone boundaries.

Earthquakes from 1978 to the end of 1990, i.e. 01–01–1978 ≤ date ≤31–12–1990

These are earthquake data obtained after the *1982 Open-File Report* was finalized. Maps are plotted for all magnitudes, then for four magnitude subsets.

A map of all earthquakes within the map area having magnitude≥4.0 is presented to show the location and number of the more significant earthquakes since 1977, the cutoff year for the *1982 Open-File Report*.

Maps for magnitudes 3.0 to 3.9, 2.0 to 2.9 and less than 2.0 are plotted to show to what extent the smaller events may have been preferentially located in areas of more dense seismograph station coverage. Maps of seismograph stations and their years of operation are presented later.

The magnitude–year completeness table was extended to 1990 based on the seismograph station distribution and on the results of these magnitude subset maps, by adding magnitude step 2.5 beginning in the year 1981.

- *map: Earthquakes, 01–01–1978 ≤ date ≤31–12–1990, all magnitudes*

American data are lacking south of 44°N. (Compare with the 1930–1977 map.) The western boundary continues to be sharply defined; the eastern boundary is diffuse; few events lie north of 47°; also very few lie in the northeastern corner, i.e. north of 46.7° and east of 76.0°, but this area has been not as well monitored during this time interval as other areas within the WQU zone.

- *map: Earthquakes, 01–01–1978 ≤ date ≤31–12–1990, magnitudes ≥ 4.0*

Only six events lie inside the zone; one M5 earthquake lies south of the zone at 43.9, 74.2, namely Goodnow, N.Y., 07 October 1983. The WQU boundary could be extended slightly southward to include this 1983 M5 event; this would imply that the adjacent NAP boundary must also shift southward.

- *map: Earthquakes, 01–01–1978 ≤ date ≤31–12–1990, magnitudes 3.0 to 3.9*

Most events lie along a northwest–southeast axis in mid-zone; the northeastern corner of the zone is blank; scattered events occurred within the WQU zone along western and southeastern boundaries.

- *map: Earthquakes, 01–01–1978 ≤ date ≤31–12–1990, magnitudes 2.0 to 2.9*

Events are scattered across the zone, with very few in the northeastern corner where magnitude detection levels are higher than in the rest of the zone. No particular pattern is seen, except that the western boundary is still sharply defined by the epicentres.

- *map: Earthquakes, 01–01–1978 ≤ date ≤31–12–1990, magnitudes less than 2.0*

No events are seen north of 47.1° within or adjacent to the zone; otherwise the map is similar to that for the M 2.0–2.9 subset.

Although magnitude 3 events seem to cluster along the northwest-southeast axis of the WQU zone, the larger earthquakes have occurred near some of the boundaries, making it imprudent to narrow the zone boundaries. As well, the events smaller than M 3.0 scatter randomly over

the zone, with fewer events in the northeastern corner where magnitude detection levels have always been higher.

- *map: Earthquakes, 01–01–1981 ≤ date ≤31–12–1990, all magnitudes*

This was the period of best monitoring by the ECTN; earthquakes occurred throughout the zone except in the northeastern corner where magnitude detection levels were higher. The western boundary is sharply defined, the eastern boundary diffuse. Lack of uniform monitoring over the zone precludes moving the northeastern boundary slightly westward. Note the virtual absence of data south of 44°N, indicating that the CEEF is not up-to-date for this region.

Maps of Canadian seismograph stations for selected years

Table A–1 (page A–4) and its related map (page A–18) show the Canadian seismograph stations that have monitored western Québec and adjacent areas from 1897 to 1990. Stations were not in simultaneous operation, as can been seen from the table. Stations operated at various sensitivities. In addition, some stations produced continuous analogue records; others produced only intermittent computer files of digital data of several minutes in length. These digital files were produced whenever an increase in the signal-to-noise ratio at one station triggered a file save procedure for all digital stations in the network.

The magnitude threshold for location of earthquakes within the WQU zone is shown on maps for the Canadian station network in and near the WQU zone for the years 1968, 1973, 1979, 1981 and 1990.

The detection limit for each station is plotted from the following assumptions: a station with an average magnification of 100K in the short-period range can detect both P and S onsets of *magnitude 3 at 300 km, magnitude 2.5 at 150 km* and *magnitude 2.3 at 100 km*. These limits are drawn on the station maps as circles corresponding to these radii. To detect an earthquake at a given point, that point must lie inside one of the station circles. To locate an earthquake, that point must lie within at least three station circles. To avoid cluttering the maps, only one circle was drawn whenever two stations were located close together.

Some station magnifications were much greater than the assumed average 100K. The assumed detection limits for the seismograph stations in eastern Canada might be considered somewhat conservative, as some stations were certainly more sensitive. This was offset, however, by the following three factors, which are relevant to the actual detection thresholds.

1. lack of continuous monitoring at some stations at certain times during which detection was entirely dependent on trigger mode.
2. disabling of trigger mode at some stations due to high noise levels.
3. lengthy downtimes while awaiting repair/replacement of components.

Note that without a continuous record, the absence of a triggering capability at a given station means that that station was dependent upon other stations to detect, trigger and save events near it.

While detection levels may have been better at some stations for some time intervals, the effective location levels can be probably closely estimated from the following maps.

Table A-1

CANADIAN STATIONS MONITORING THE WESTERN QUEBEC ZONE (1897 to 1990)
[Note: not in simultaneous operation, not comparable sensitivities]

Code	Lat(N) (deg)	Long(W) (deg)	Elevation (m)	Opening	Closure	* Station Type
TNT	43.6667	79.4000	0.1110	1897-09,	1942-05	
OTT	45.3938	75.7158	0.0830	1906-01,	--	; ectn 1974-02; benioff 1937-04
SHF	46.5517	72.7633	0.0600	1927-08,	1965-12	
SFA	47.1230	70.8260	0.2320	1927-09,	1975-07;	standard
KLC	48.1447	80.0292	0.3100	1939-12,	1945-11;	1947-08, 1957-06
MNT	45.5000	73.6230	0.1120	1956- ,	--	; ectn 1974-02
SCB	43.7160	79.2330	0.1530	1962-05,	197-	; 1973 intermittent, 1974 nil
SUD	46.4660	80.9660	0.2670	1967-11,	1986-07;	regional
QCQ	46.7790	71.2758	0.0910	1971-09,	--	; regional
CHQ	46.8900	71.3000	0.1450	1971-11,	1982-07;	regional
LPQ	47.3408	70.0094	0.1260	1972-01,	1990-10;	regional; ectn 1980-06
MIQ	46.3667	75.9667	0.1990	1974-02,	1981-04;	ectn
CFO	45.4692	76.2292	0.0700	1977-10,	1979-02;	regional
GNT	46.3630	72.3720	0.0100	1978-04,	1988-05;	ectn
FHO	45.4550	76.2170	0.0720	1979-01,	1982-01;	ectn
EFO	43.0917	79.3117	0.1680	1979-07,	--	; regional
GAC	45.7033	75.4783	0.0620	1979-10,	--	; sro
BUO	43.3617	79.7450	0.0880	1979-12,	1980-05;	regional
SBQ	45.3783	71.9264	0.2650	1980-08,	1991-3?;	ectn
VDQ	48.2300	77.9717	0.3050	1980-12,	1986-04;	ectn
WBO	45.0003	75.2750	0.0850	1980-12,	--	; ectn
CKO	45.9944	77.4500	0.1910	1981-01,	--	; ectn
GRQ	46.6067	75.8600	0.2900	1981-03,	--	; ectn
TRQ	46.2222	74.5555	0.8530	1981-03,	--	; ectn
WEO	44.0186	78.3744	0.1490	1982-04,	--	; ectn
EEO	46.6408	79.0727	0.3810	1984-03,	--	; ectn
SUO	46.4027	81.0068	0.2580	1984-12,	--	; sltn
DPQ	46.6804	72.7774	0.1670	1988-01,	--	; ectn
DAQ	47.9644	71.2425	0.9390	1988-12,	--	; ectn

ectn/sltn: eastern Canada/Sudbury telemetered network
* for other details see, for example, Munro *et al.* (1990), Stevens (1980).

- *map: 1968* (5 stations): 300-km radius circles drawn

Magnitude detection/location was complete down to magnitude 3.0 in 1968 for points within the WQU zone, but this limit was barely met in the northern third of the zone. Note that monitoring extended into the adjacent United States south to about 43°N.

- *map: 1973* (6 stations): 300-km radius circles drawn

There was no significant improvement in monitoring since 1968; magnitude detection/location was complete down to magnitude 3.0 within the WQU zone and immediately south of the zone to about 43°N.

- *two maps: 1979* (11 stations): 300-km and 150-km radius circles drawn

Monitoring was not complete in the northern third of the WQU zone at magnitude 2.5, nor immediately south of the zone. There was some improvement for magnitude 3.0 due to station MIQ, which extended monitoring about 100 km north of the zone.

- *map: 1981* (15 stations): 150-km radius circles drawn

Monitoring was complete at the M 2.5 level, but the northern third of the zone was much less well monitored. The increase in the number of smaller located events in the southern half of the zone during this period was probably due to the increased station density there. Note that the area northeast of the WQU zone was not well monitored for events of magnitude less than 3, which may account for its reduced seismicity, as seen on the seismicity map for the period 1981–1990. The area immediately south of the zone remained complete for magnitude 3.0 south to about 43°N, but complete to magnitude 2.5 only to 44°N, based on monitoring by Canadian stations alone.

- *two maps: 1990* (15 stations): 150-km and 100-km radius circles drawn

Monitoring within the zone was almost complete at the M 2.5 level, but not at the M 2.3 level. The northern third of the zone was still much less well monitored than the southern third. Monitoring south of the zone by Canadian stations alone was complete to magnitude 2.5 south to 44°N and to magnitude 3.0 south to 43°N.

Note that detailed monitoring of both eastern and western boundaries of the WQU began in 1981 with the opening of VDQ (just north of the zone) in December 1980, CKO (western boundary) in January 1981, and GRQ (mid-zone) and TRQ (eastern boundary) in March 1981. EEO (northwestern boundary) opened only in March 1984. VDQ was closed in April 1986, which eliminated monitoring at the M 2.5 level along the northern boundary and north of the WQU zone.

This series of station maps illustrates that the northern part of the WQU zone and the area north and northeast of the zone have always been much less well monitored than the southern part of the WQU and its immediately adjacent areas. Caution should thus be exercised when interpreting maps of earthquakes for patterns of seismicity. Some patterns may be an artifact of uneven monitoring of the zone in space as well as in time.

The station maps also show that magnitude completeness at M 3.0 since 1968, as presented in the *1982 Open-File Report*, cannot be reduced to M 2.5 until 1981. No further reduction is justified in subsequent years, as the closure of VDQ in April 1986 degraded the network monitoring ability north of 47.5°N, which has not been compensated for by the opening of other stations.

Earthquakes to the end of 1990, i.e. date ≤31–12–1990

This is the complete CEEF data set to the end of 1990. Three maps are presented, one with all magnitudes, then another with a magnitude–year restriction, which is plotted twice, with 1982 then with revised zone boundaries.

Analysis of detection limits of the Canadian seismograph stations monitoring the WQU zone has shown that magnitudes cannot be considered complete below M 2.5 over the entire WQU zone.

The magnitude–year completeness table for the period to the end of 1977 as used in the *1982 Open-File Report* is retained (see its Table 1, page 10), and an additional magnitude–year pair added, namely 2.5 since 1981.

Table A–2

WQU: Magnitude–year completeness pairs to 1990

M, year
2.5, 1981
3.0, 1968
3.5, 1963
4.0, 1937
4.5, 1928
5.0, 1928
5.5, 1900
6.0, 1900
6.5, 1850

For later calculation of zone parameters, data have been usually divided into 0.5 magnitude unit increments, combining data lying within ±0.2 magnitude unit. This explains why the map definitions legend differs from this table.

For simplicity, the magnitude–year completeness pairs of Table A–2 were applied to select data for plotting on the entire mapped area and not only to select earthquakes within the WQU zone. This means that the map for the period to the end of 1990, with magnitude–year limits applied, shows too many epicentres in some areas outside the WQU.

- *map: Earthquakes, date ≤31–12–1990, all magnitudes*

Few events are seen north of 47.0°N; the greatest density of events occurs in the lower half of the zone. The western and northern boundaries, as defined in 1982 with data to December 1977, are compatible with data up to December 1990. The eastern boundary remains diffuse, as it was in the 1982 Report. The southern boundary may need revision.

- *map: magnitude–year limits, to December 1990 (1982 zone boundaries plotted)*

Earthquakes of magnitude 4 and 6 are seen inside the zone near its eastern and western boundaries, suggesting that the zone should not be narrowed. The discussion of Canadian seismograph station monitoring ability had suggested that monitoring was complete to M3.0 since 1968 southward to about 43°N, but complete to M2.5 since 1981 only to about 44°N. In fact, very few events of magnitude less than 4.0 are plotted south of 43.5°N, suggesting that the CEEF may be lacking recent American data in this area. These American data are examined in Appendix B before selecting a new southern boundary for the WQU zone.

The table of plotted earthquakes generated from the magnitude–year completeness table showed that the earliest earthquake to meet these selection criteria occurred in 1914 and that the largest earthquake within the WQU zone remains the 1935 M6.2 Temiskaming earthquake. M≥5 earthquakes within the zone since 1935 number only three: September 1944 Cornwall–Massena, May 1958 Bark Lake and October 1990 Mont-Laurier. Also the October 1983 Goodnow, N.Y., earthquake occurred just south of the WQU zone, as defined in 1982, but lies within the revised WQU zone proposed in Appendix B.

- *map: magnitude–year limits, to December 1990 (revised zone boundaries plotted)*

To anticipate the results of Appendix B and to provide a complete set of WQU zone maps, this

map is replotted showing the modified WQU boundaries and adjacent modified NAP (NE–NB) boundaries.

A value of 7.0 had been assigned to the maximum magnitude, parameter M_x, in the *1982 Open File*. No data relevant to the WQU zone that have been acquired or interpreted since preparation of that Report demand any adjustment in that value nor, on the other hand, confirm it. An M_x of 7.0 remains as a reasonable but somewhat arbitrary choice.

- *map: magnitude–year limits, to December 1977 (1982 zone boundaries plotted)*

For comparison with the map to December 1990, a map of data to the end of 1977 with the same magnitude–year limits was also plotted. These are the data that had been used to calculate the WQU zone parameters that appeared in the *1982 Open-File Report*.

The earthquakes lying within the 1982 WQU zone, as shown on the preceding magnitude–year limits maps, have been used to produce conventional semi-log magnitude recurrence curves for the data sets to December 1977 and December 1990. M_x has been assumed to be 7.0 for both curves. Each magnitude recurrence graph is accompanied by a corresponding map and table that shows input variables, plus intermediate and final plotted variables. (See the *1982 Open File* and its references for methods of magnitude recurrence analysis.)

- *map: magnitude–year limits, to December 1977 (1982 boundaries, only data within zone plotted)*
- *map: magnitude–year limits, to December 1990 (1982 boundaries, only data within zone plotted)*

As seen by comparing the two epicentre maps (pages A–32 and A–35) and by comparing Table A–3 (page A–31) and Table A–4 (page A–34), the data set to 1990 is three times as large as the data set to 1977. Half of this increase came from adding earthquakes in the magnitude range 2.5±0.2 since 1981, and most of the remaining increase from earthquakes in magnitude classes 3.0 and 3.5.

- *graph: magnitude recurrence curve, 1982 WQU boundaries with data to 1977*
- *graph: magnitude recurrence curve, 1982 WQU boundaries with data to 1990*

The resulting magnitude recurrence curves (pages A–30 and A–33) were quite similar, as illustrated by the slope and intercept values printed in the upper right corner of each graph. Both graphs indicate that, if M_x 7.0 is a reasonable assumption and if the plotted data set is complete for magnitudes less than about 5 in the specified time periods, then the data set is incomplete for magnitudes above 5, since these points lie below the calculated curve.

As the purpose of the present study was only to examine zone boundaries, and not rates of activity, the magnitude recurrence curves are not further discussed. The two curves presented on pages A–30 and A–33 show that the parameters presented in the *1982 Open File* from data to 1977 are not significantly altered by the addition of data to 1990. As noted in the main part of the report (page 10), a similar graph was not plotted for earthquakes within the revised WQU zone boundaries, since all relevant American data were not available when this report was being prepared.

Conclusion: boundaries of the WQU in Canada

There is no compelling reason based on the distribution of located earthquakes to the end of

1990 to substantially modify the eastern, northern or western WQU boundaries as defined in the *1982 Open File*. While no changes in these boundaries are recommended, the boundaries as defined are not neccessarily "correct". Slightly different boundaries could be drawn.

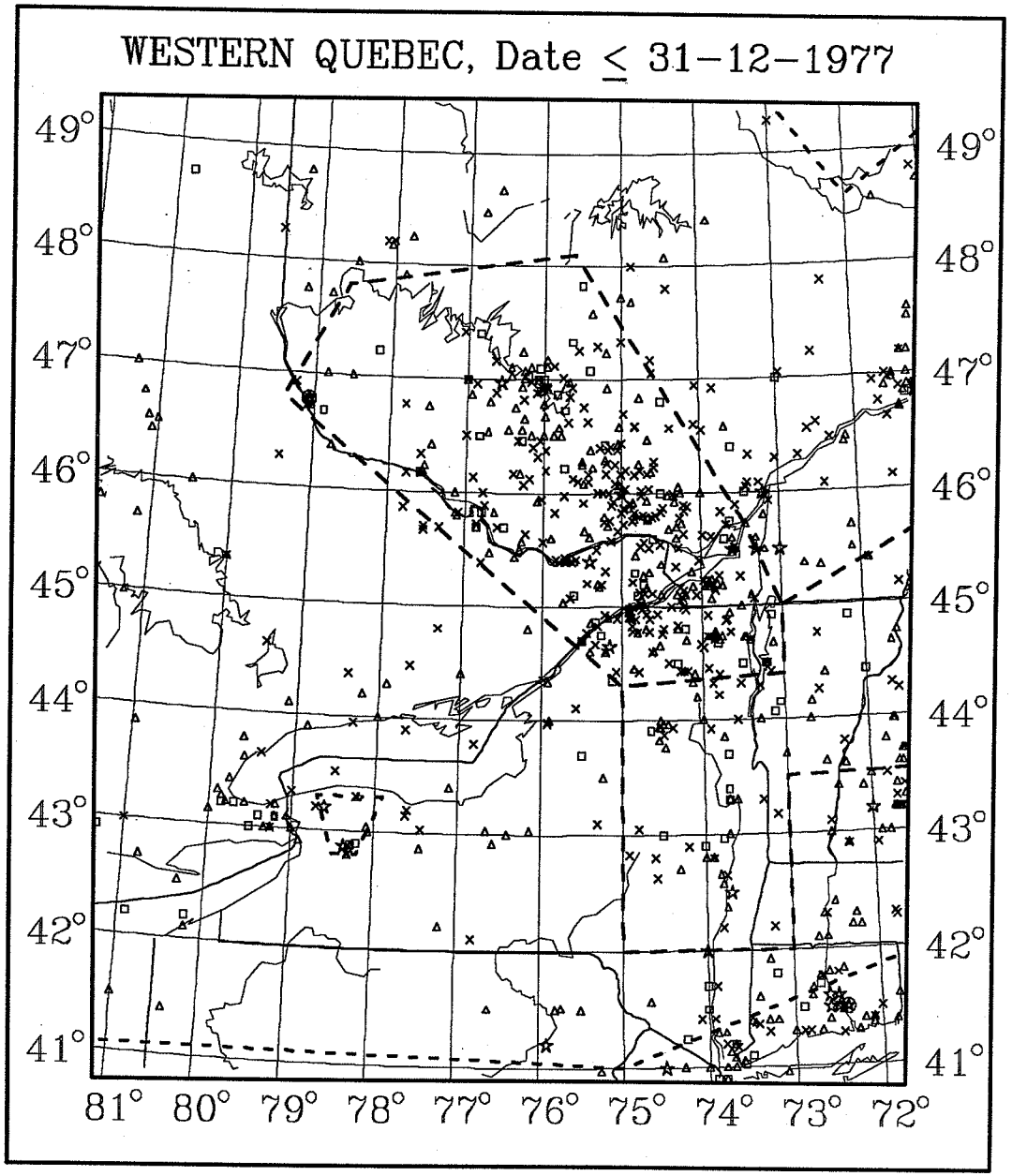
The western boundary of seismicity appears to be quite sharply defined, regardless which time interval is examined. The northern and eastern boundaries are more diffuse. Monitoring in recent years has shown low-level activity east of the eastern boundary. As monitoring of the northern third of the zone, even during the past decade, was much less intensive than monitoring of the southern part, the larger number of earthquakes in the southern part may be largely an artifact of the monitoring.

Thus, interpretation of epicentre patterns in western Québec is limited by the lack of uniform monitoring. Division into two or more smaller zones is not justified by the earthquake data.

Note that monitoring of northern Ontario in the 1980s has revealed scattered low-level activity with the occasional magnitude 3 or 4 earthquake. Thus, the "Eastern Background Zone" as defined in 1982 needs to be extended further west into northwestern Ontario; analysis of this activity is not included within this report as it is being studied by others.

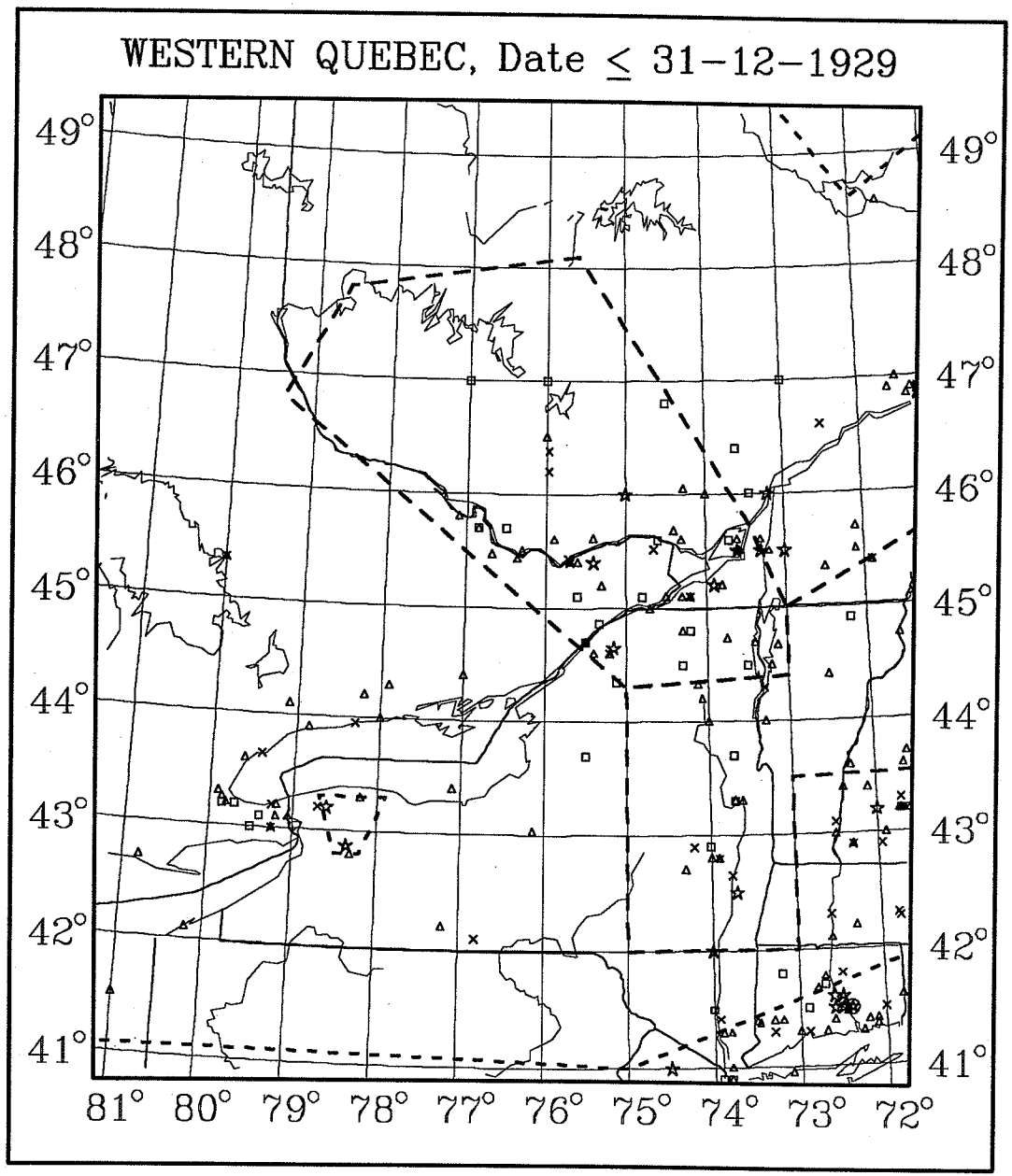
The various maps of CEEF data that have been presented show a sharp decrease in plotted epicentres south of the WQU zone and suggest that its southern boundary could be moved about 100 km further south.

Maps of American data are presented in Appendix B to examine where the southern boundary of the WQU zone should be drawn and whether the data support an area of reduced seismicity between the southeastern part of the WQU zone and the western part of a redefined Appalachian zone.



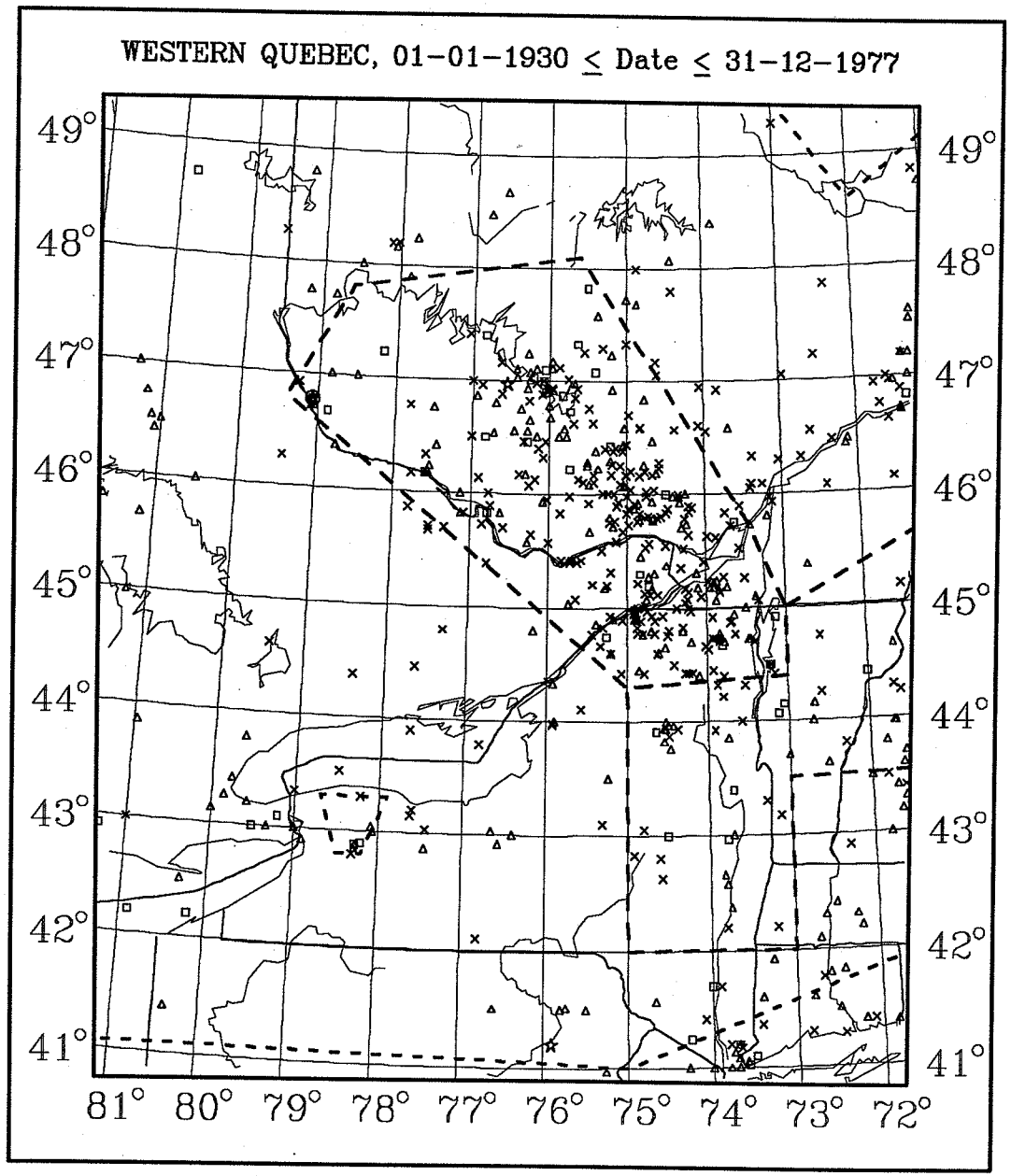
DEFINITIONS

M<3	×
M≧3	△
M≧4	□
M≧5	☆
M≧6	⊛



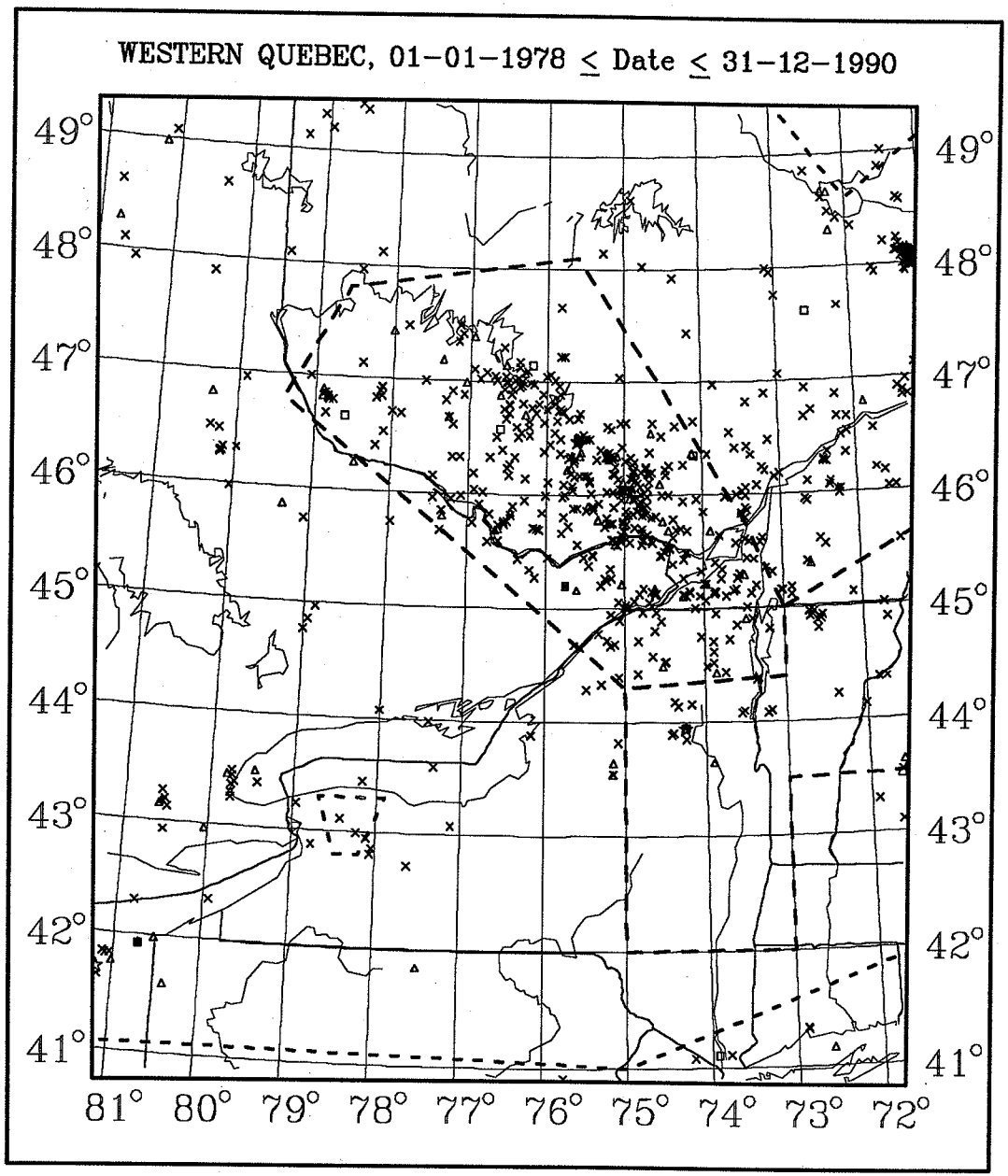
DEFINITIONS

M<3	×
M≧3	△
M≧4	□
M≧5	☆
M≧6	⊛



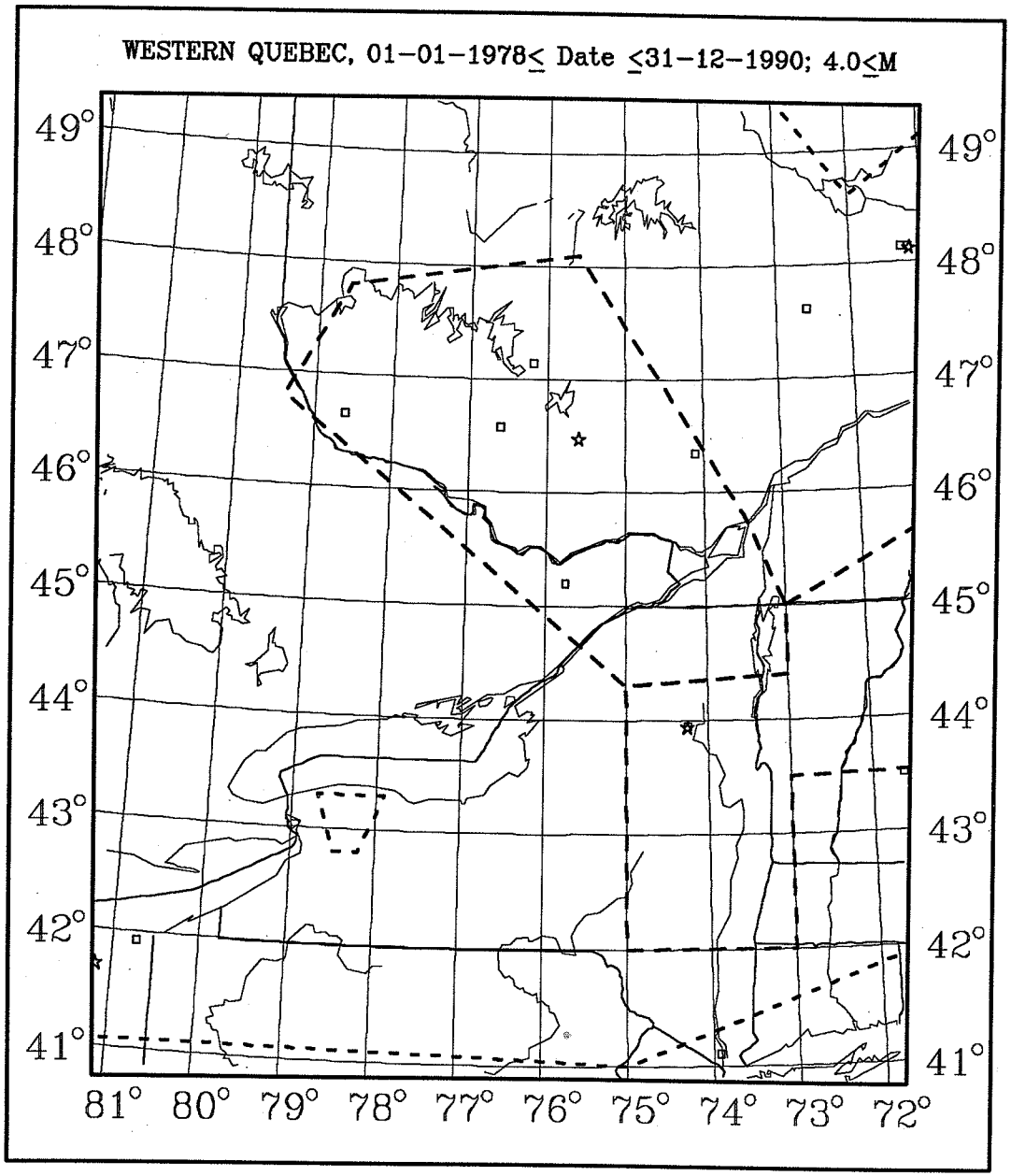
DEFINITIONS

M<3	×
M≧3	△
M≧4	□
M≧5	☆
M≧6	⊛



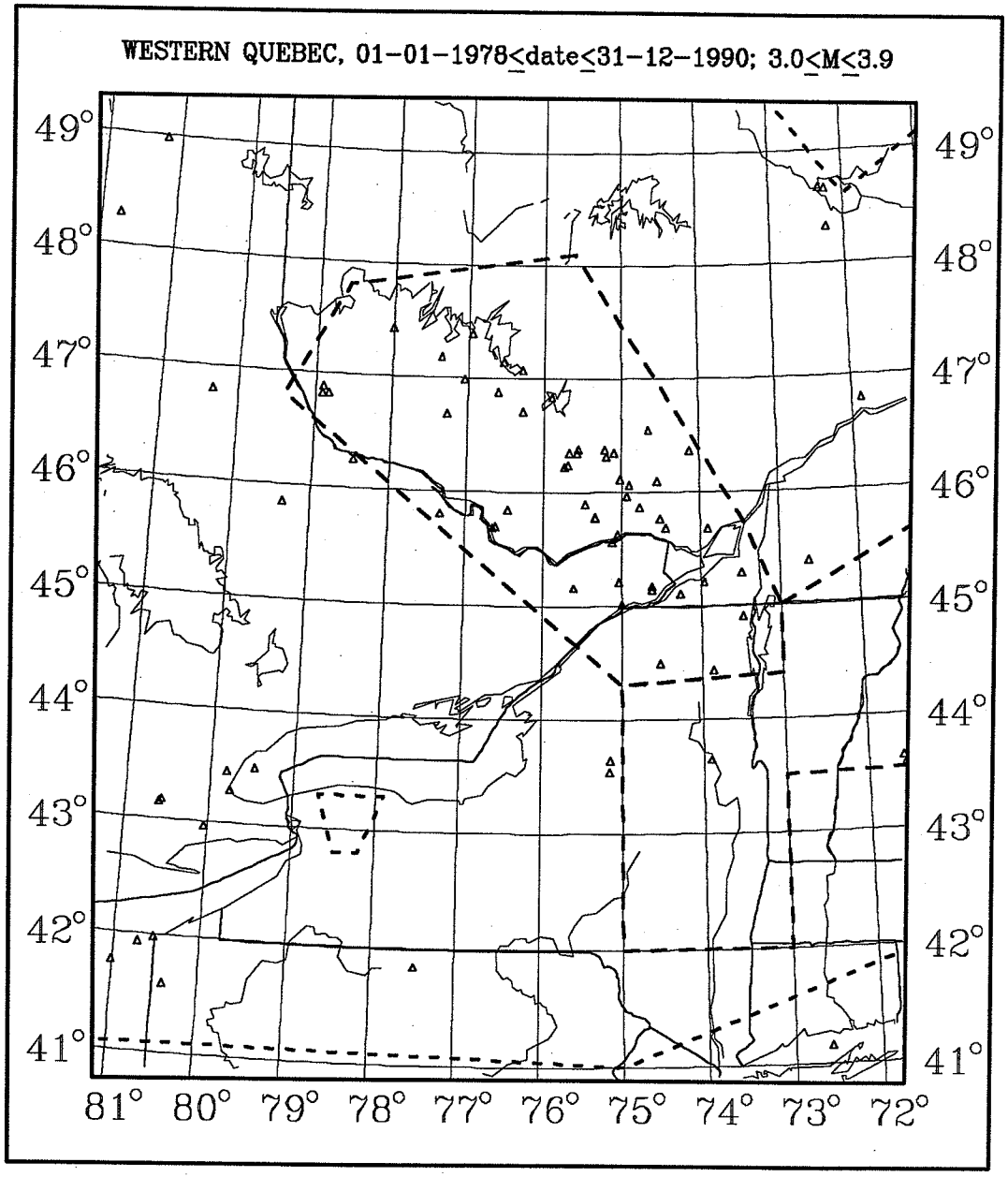
DEFINITIONS

M<3	×
M≧3	△
M≧4	□
M≧5	☆
M≧6	⊗



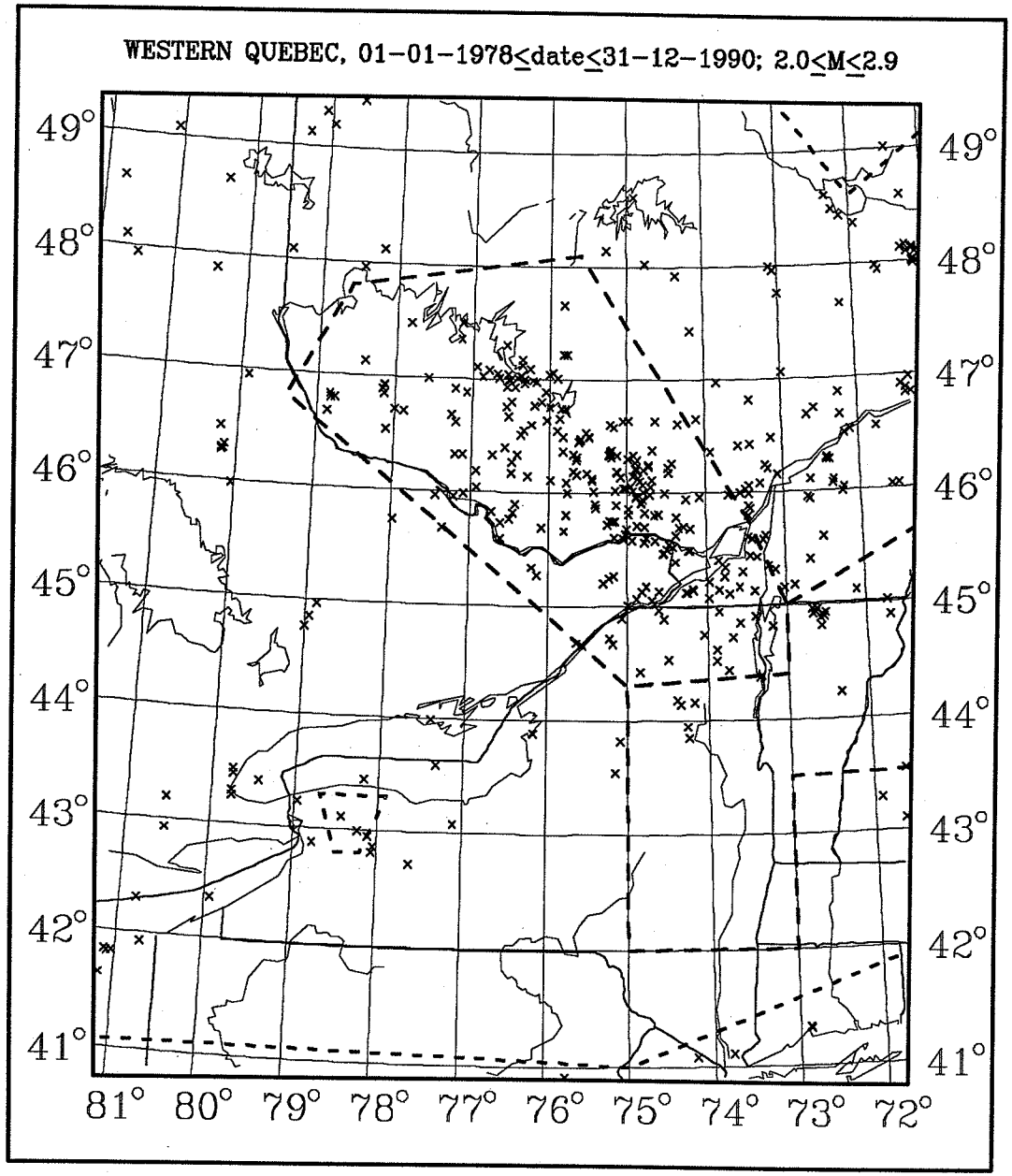
DEFINITIONS

M<3	×
M≧3	△
M≧4	□
M≧5	☆
M≧6	⊛



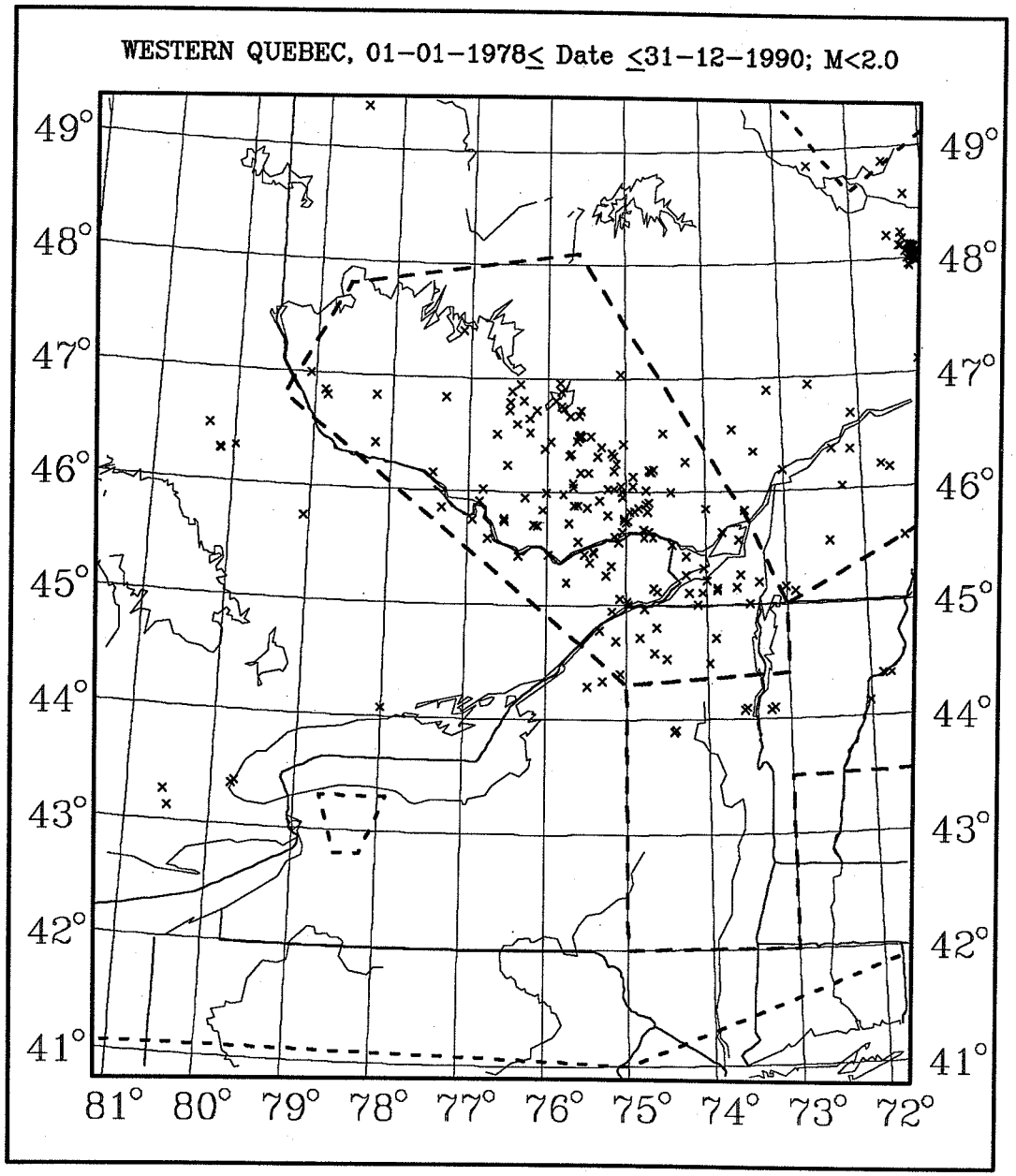
DEFINITIONS

M<3	×
M≧3	△
M≧4	□
M≧5	☆
M≧6	⊗



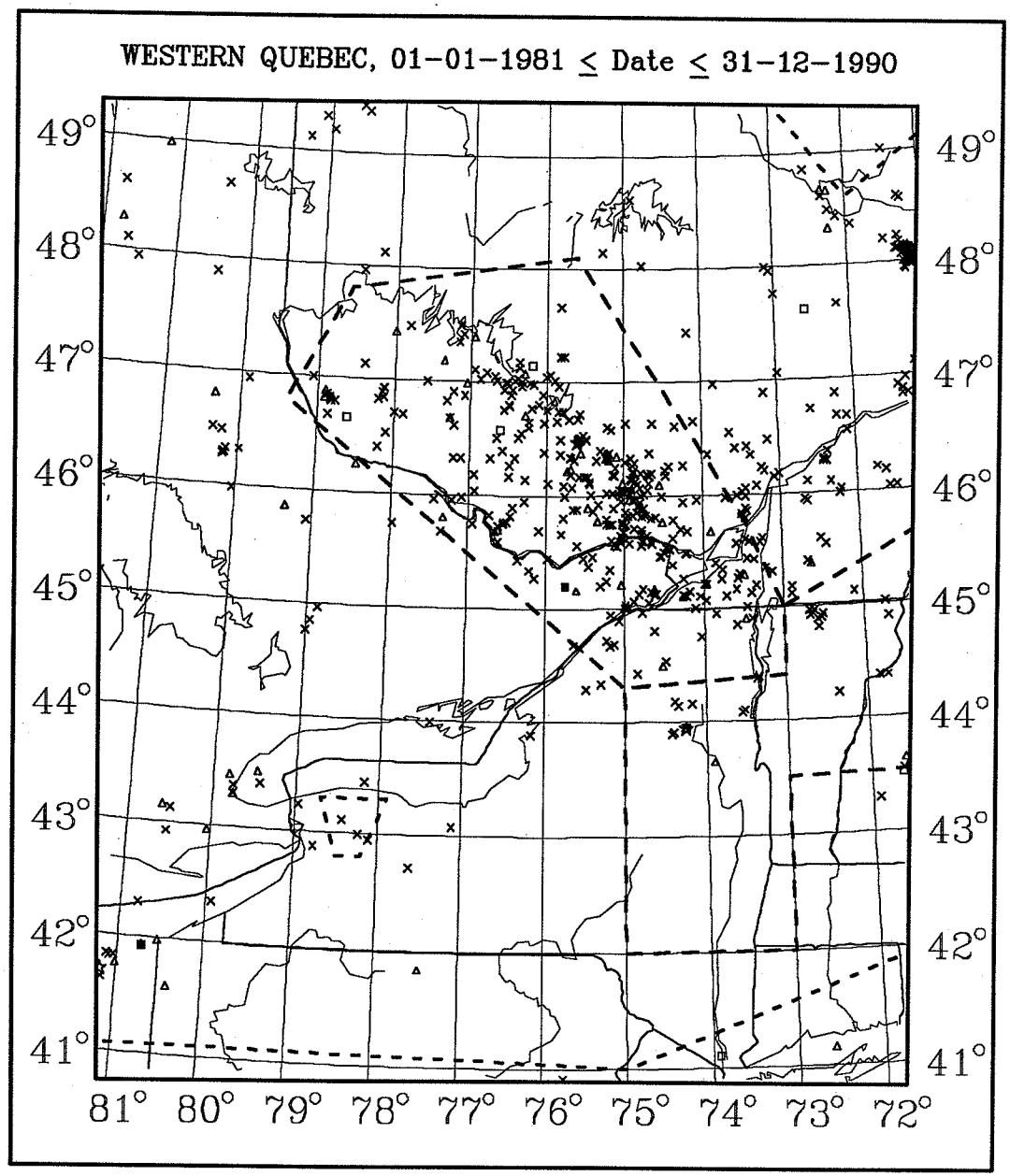
DEFINITIONS

M<3	×
M≧3	△
M≧4	□
M≧5	☆
M≧6	⊗



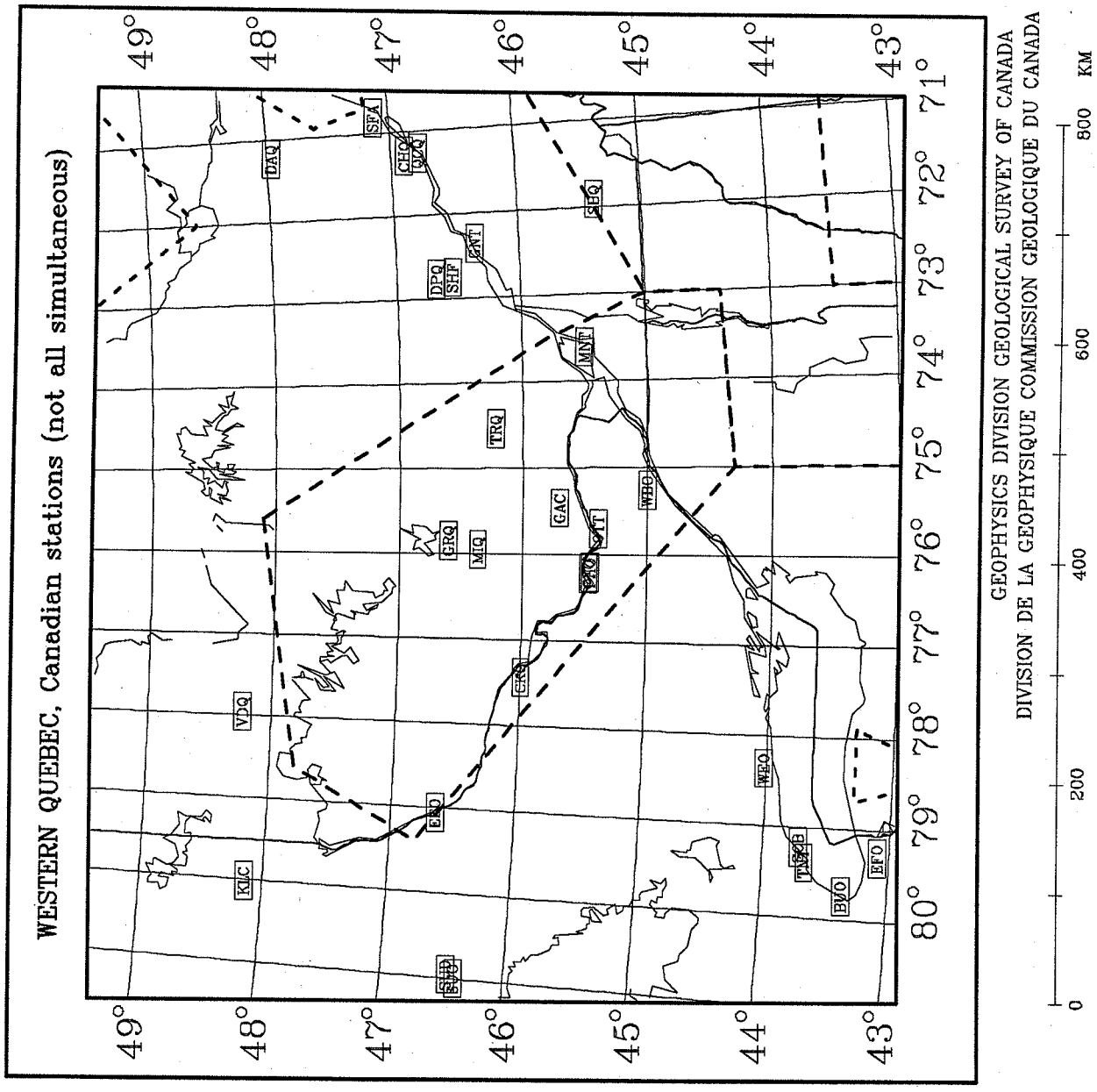
DEFINITIONS

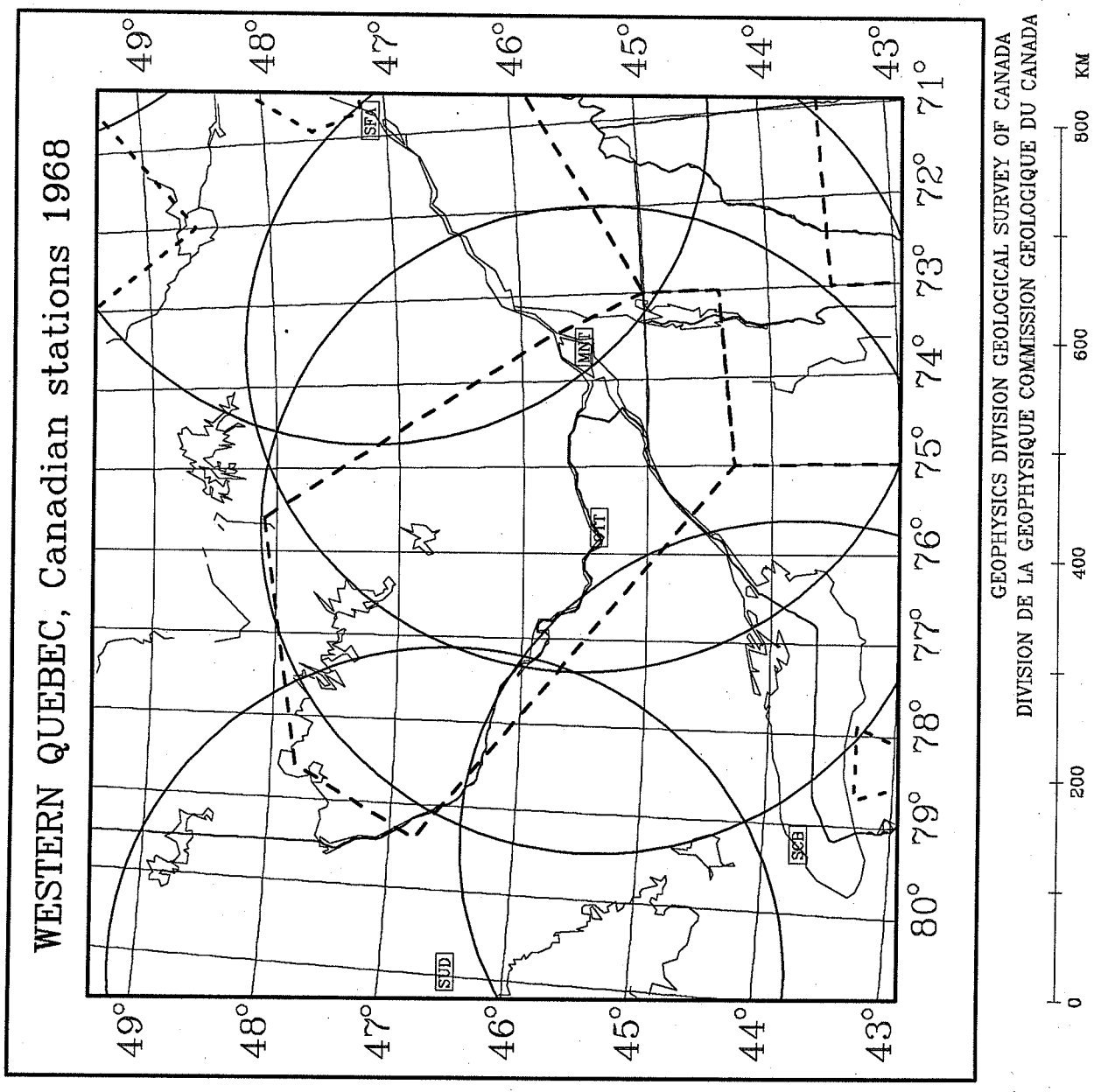
M<3	×
M≧3	△
M≧4	□
M≧5	☆
M≧6	⊗

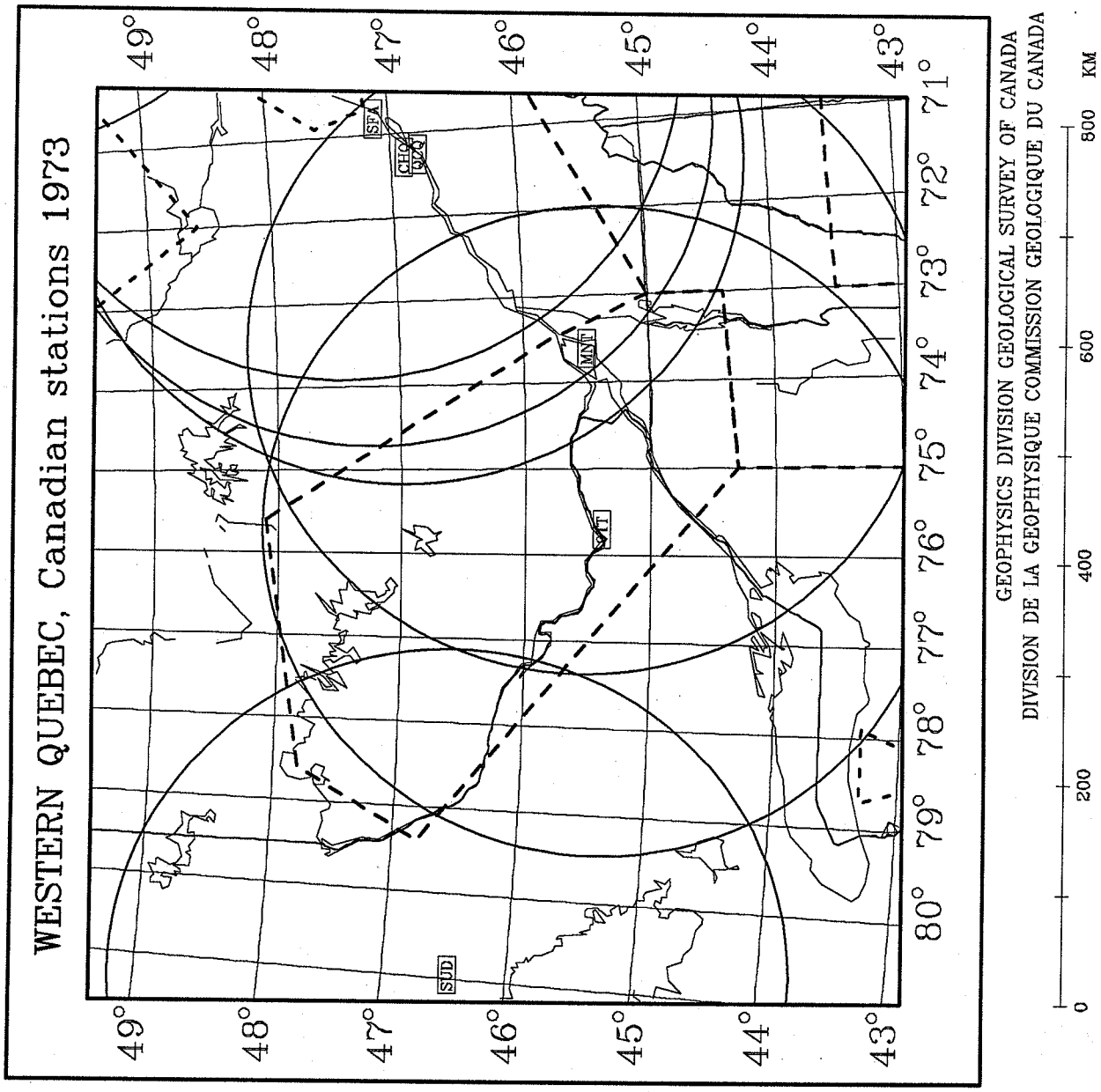


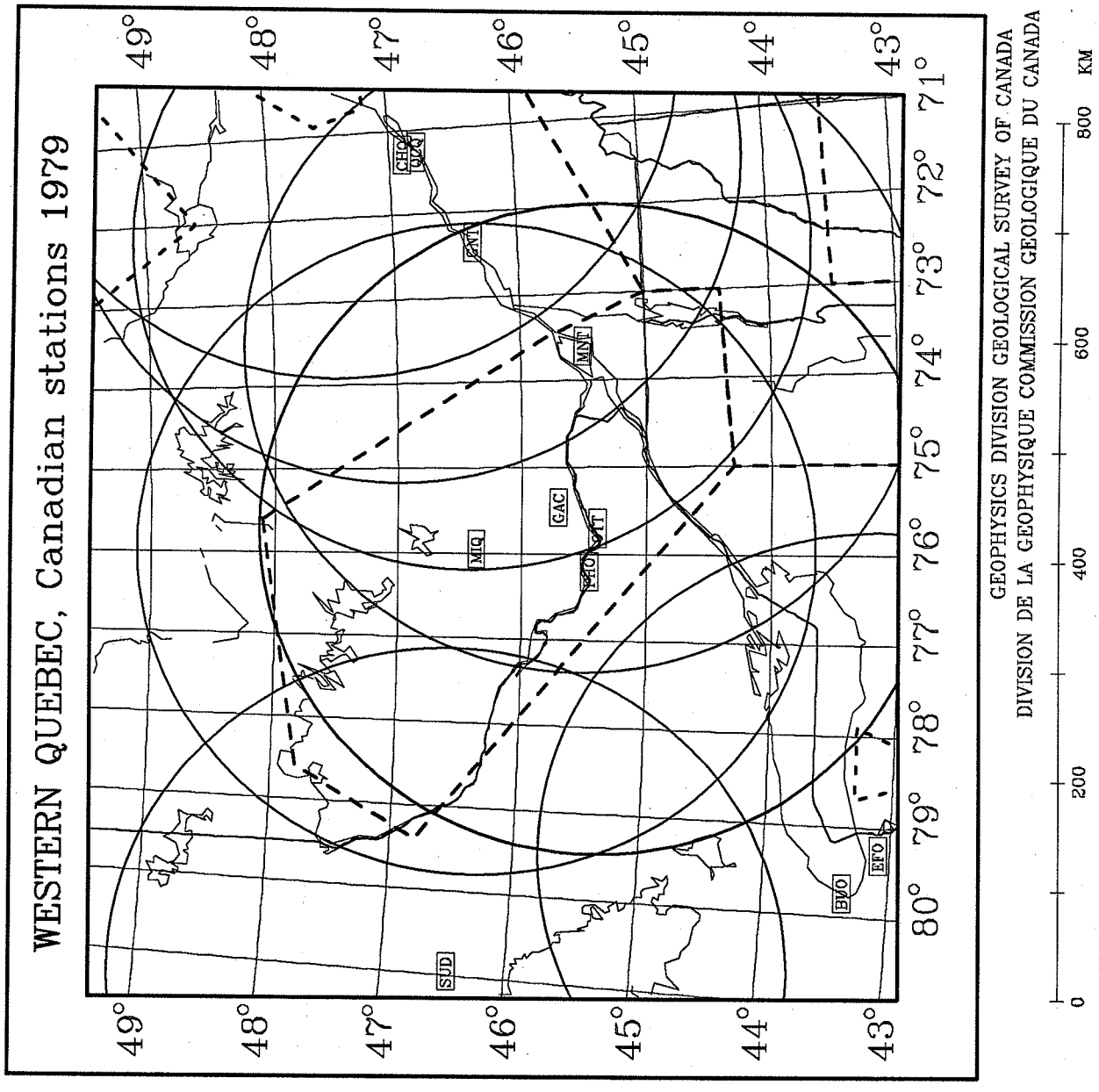
DEFINITIONS

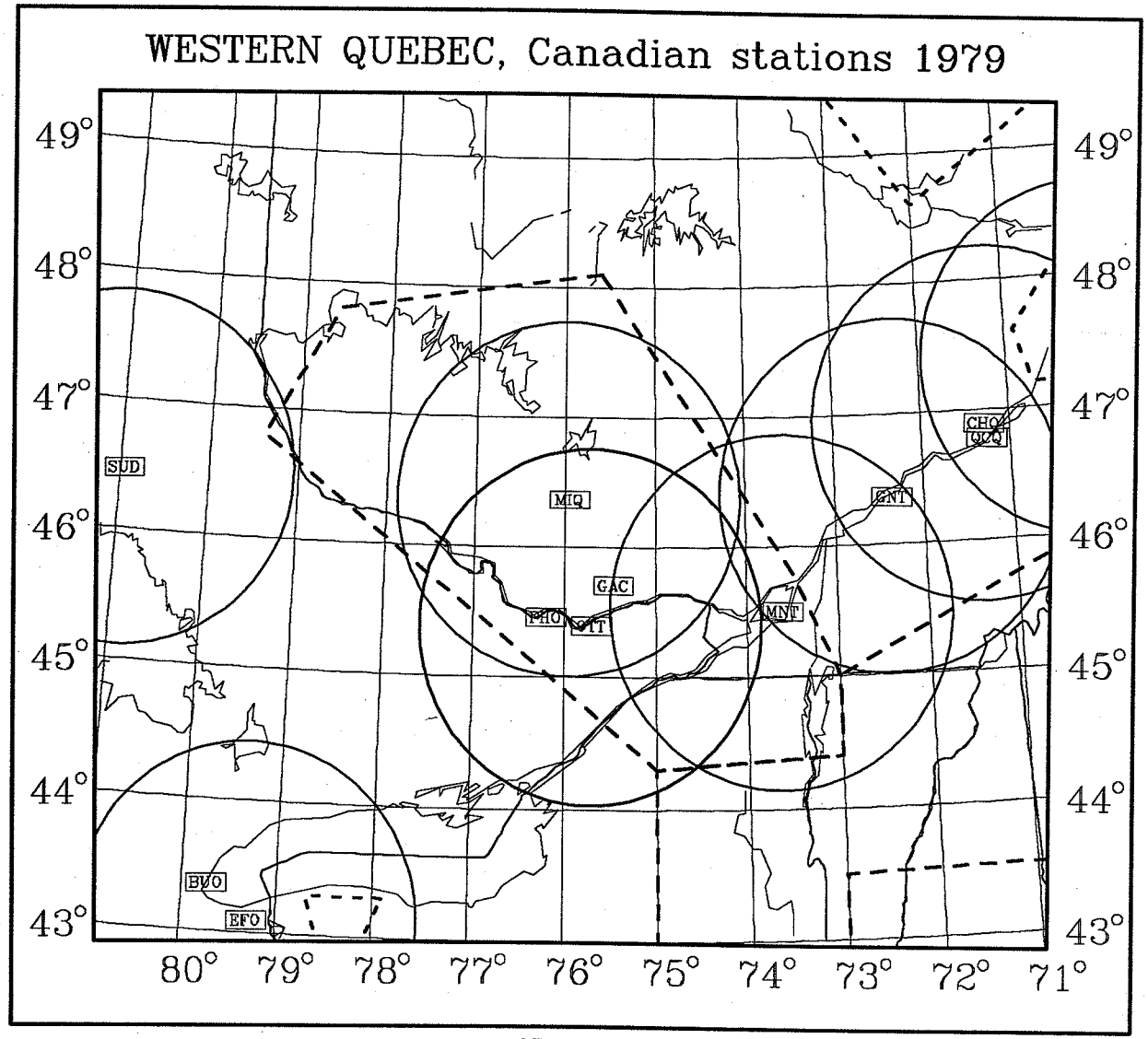
M<3	×
M≧3	△
M≧4	□
M≧5	☆
M≧6	⊗

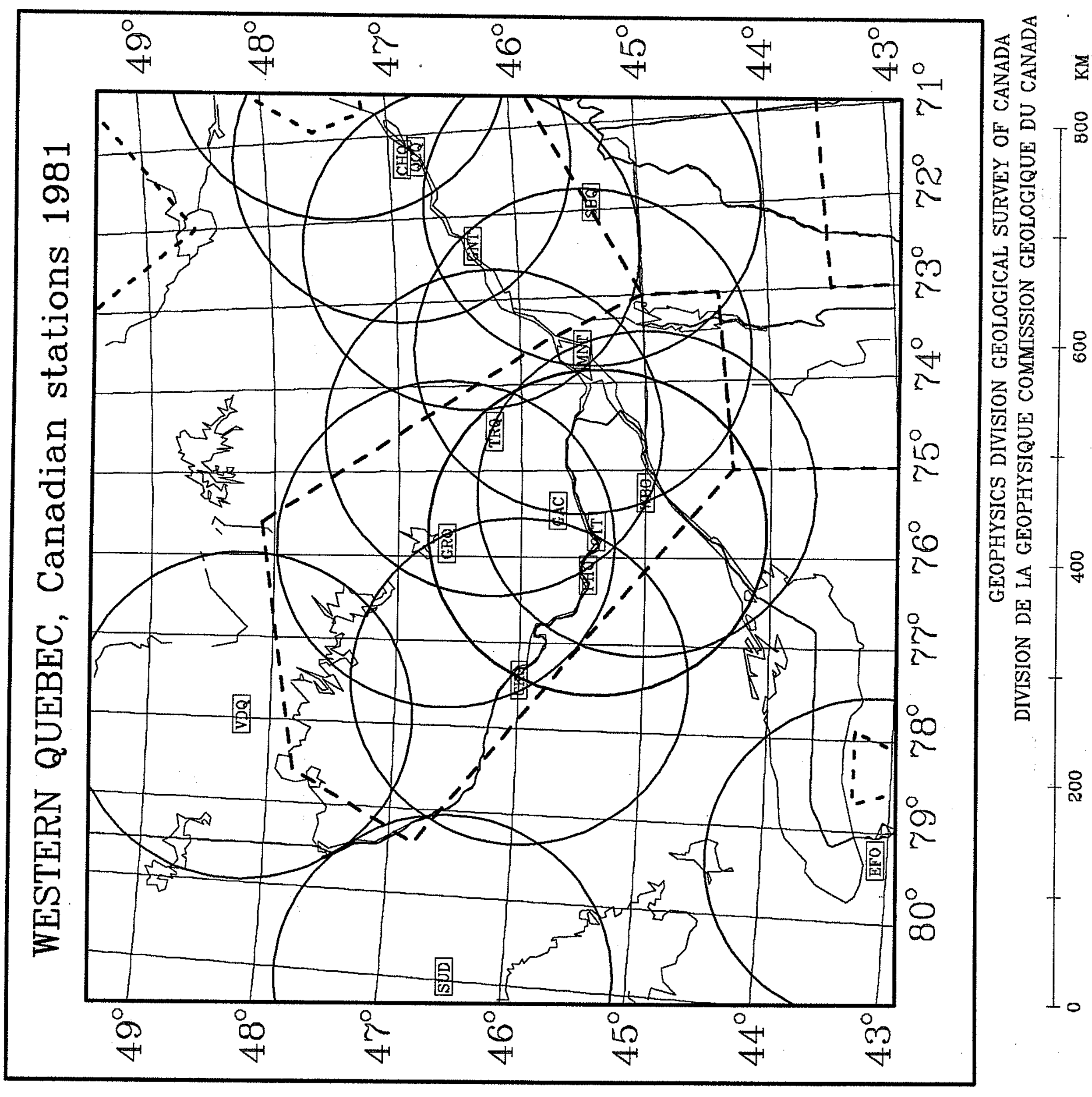

WESTERN QUEBEC, Canadian stations (not all simultaneous)
49°
48°
47°
46°
45°
44°
43°
80°
79°
78°
77°
76°
75°
74°
73°
72°
71°
DAQ
SFA
CHQ
QCQ
SHQ
DPQ
SHP
EXT
MNT
TRQ
GAC
OTT
WBQ
MEQ
ERQ
MLQ
VDQ
KLC
ESD
WEQ
BVO
EFO
0
200
400
600
800
KM
GEOPHYSICS DIVISION GEOLOGICAL SURVEY OF CANADA
DIVISION DE LA GEOPHYSIQUE COMMISSION GEOLOGIQUE DU CANADA

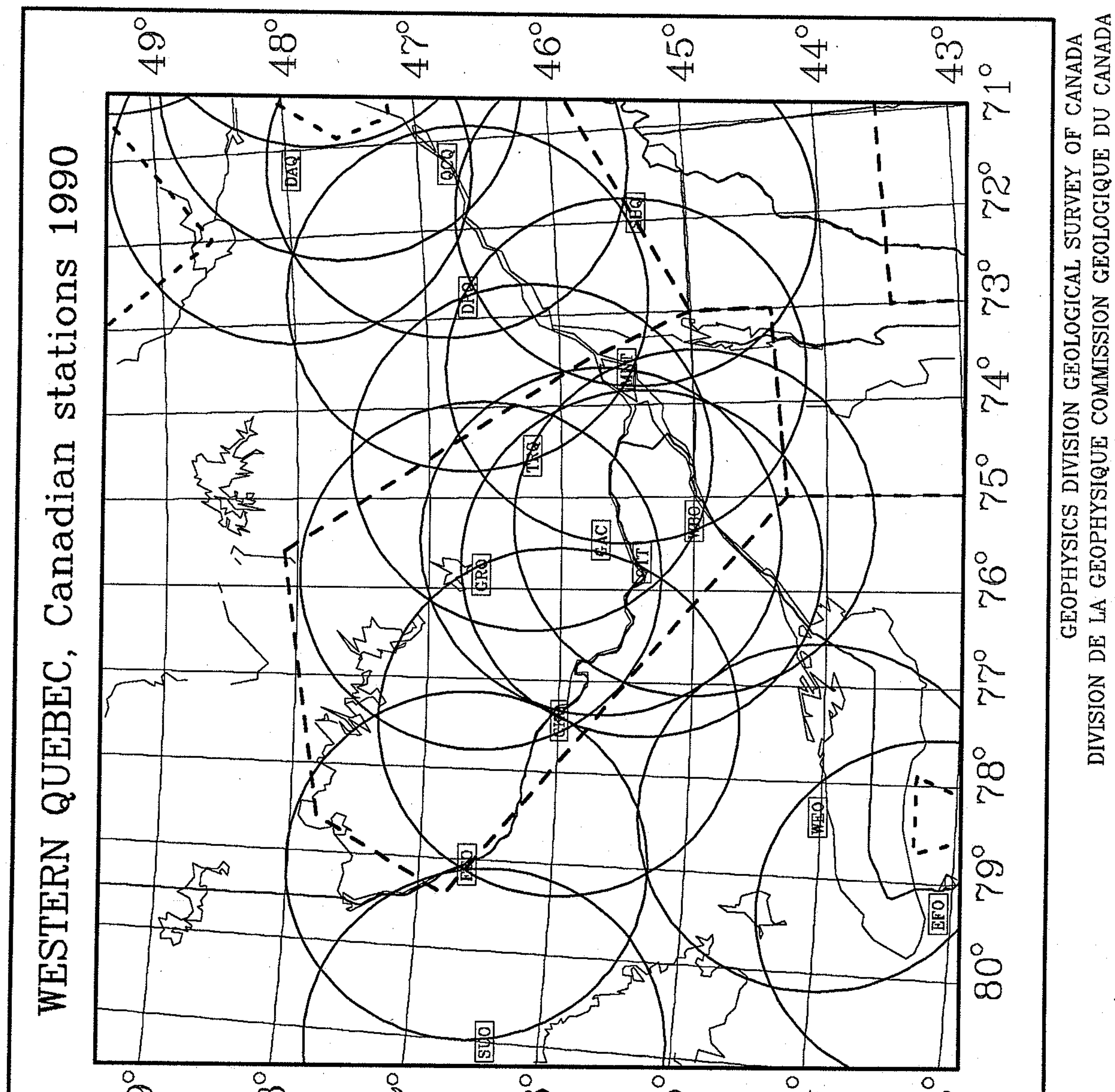

WESTERN QUEBEC, Canadian stations 1968
49°
48°
47°
46°
45°
44°
43°
80°
79°
78°
77°
76°
75°
74°
73°
72°
71°
SFX
MNF
OTT
SUD
SQB
GEOPHYSICS DIVISION GEOLOGICAL SURVEY OF CANADA
DIVISION DE LA GEOPHYSIQUE COMMISSION GEOLOGIQUE DU CANADA
0
200
400
600
800
KM

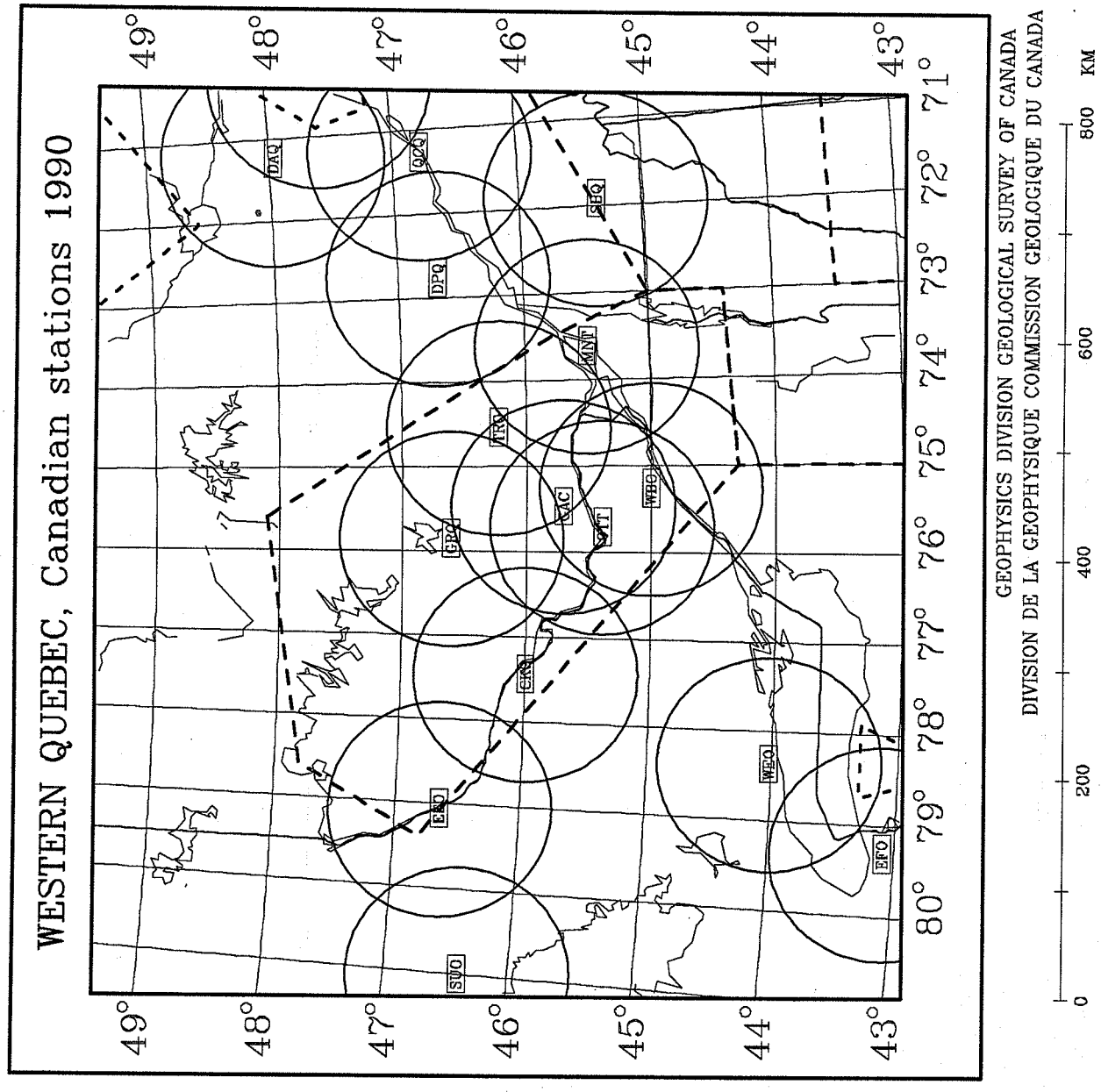

WESTERN QUEBEC, Canadian stations 1973
49°
48°
47°
46°
45°
44°
43°
71°
72°
73°
74°
75°
76°
77°
78°
79°
80°
SFA
CHQ
QZQ
MNT
LLT
SUD
GEOPHYSICS DIVISION GEOLOGICAL SURVEY OF CANADA
DIVISION DE LA GEOPHYSIQUE COMMISSION GEOLOGIQUE DU CANADA
0
200
400
600
800
KM

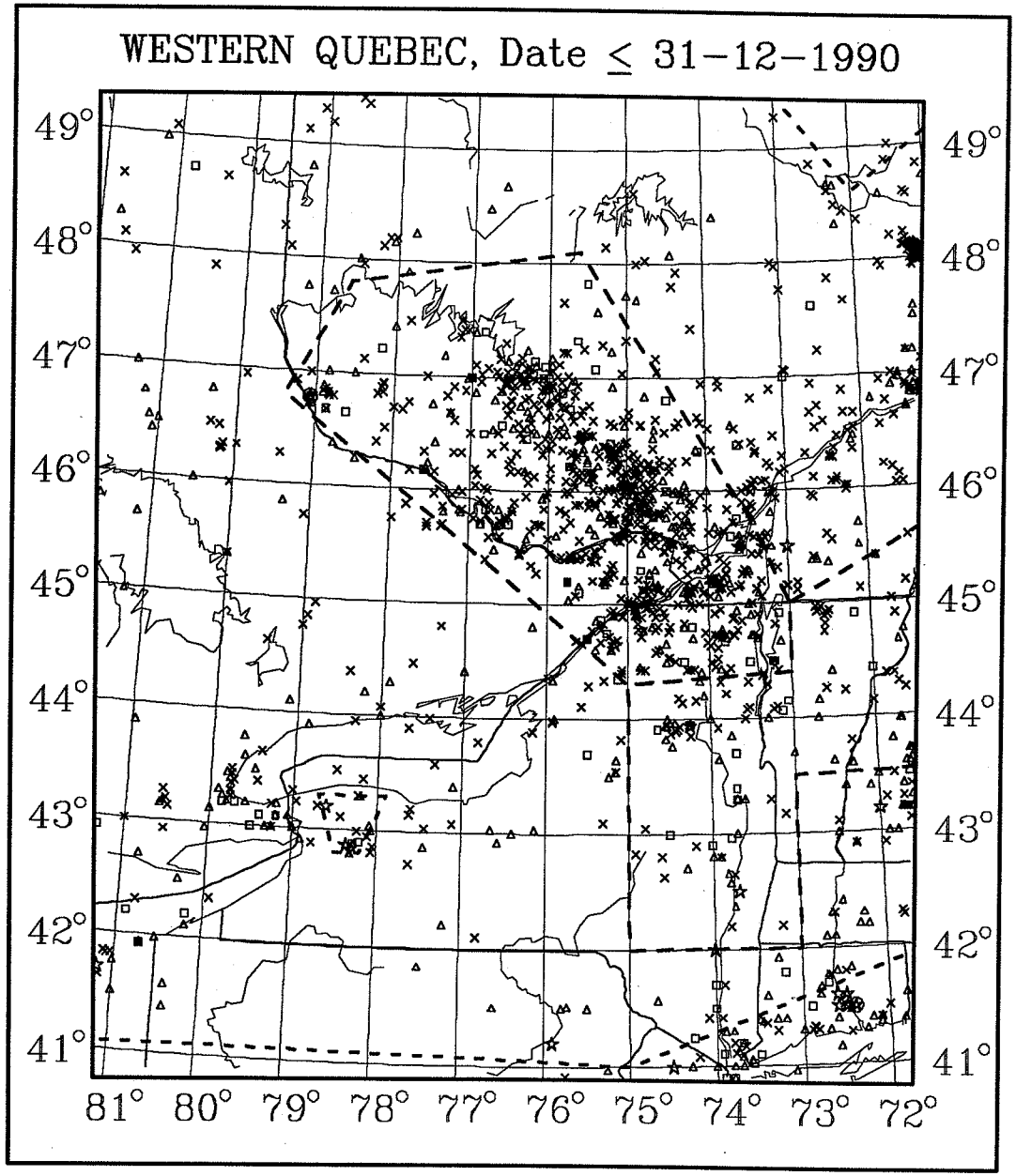

WESTERN QUEBEC, Canadian stations 1979
49°
48°
47°
46°
45°
44°
43°
80°
79°
78°
77°
76°
75°
74°
73°
72°
71°
CHQ
SUQ
EKT
MNT
GAC
OTT
MIQ
OHO
SUD
BVO
EFO
GEOPHYSICS DIVISION GEOLOGICAL SURVEY OF CANADA
DIVISION DE LA GEOPHYSIQUE COMMISSION GEOLOGIQUE DU CANADA
0
200
400
600
800
KM


WESTERN QUEBEC, Canadian stations 1979
49°
48°
47°
46°
45°
44°
43°
80° 79° 78° 77° 76° 75° 74° 73° 72° 71°
SUD
MIQ
GAC
PHO
OTT
MNT
CNT
CHQ
QCQ
BVO
EFO
GEOPHYSICS DIVISION GEOLOGICAL SURVEY OF CANADA
DIVISION DE LA GEOPHYSIQUE COMMISSION GEOLOGIQUE DU CANADA
0 200 400 600 800 KM


WESTERN QUEBEC, Canadian stations 1981
49° 48° 47° 46° 45° 44° 43°
80° 79° 78° 77° 76° 75° 74° 73° 72° 71°
SUD
VDQ
EFO
GRQ
TRQ
GAC
WBO
MNT
SBQ
CNT
CHC
SHQ
GEOPHYSICS DIVISION GEOLOGICAL SURVEY OF CANADA
DIVISION DE LA GEOPHYSIQUE COMMISSION GEOLOGIQUE DU CANADA
0 200 400 600 800 KM

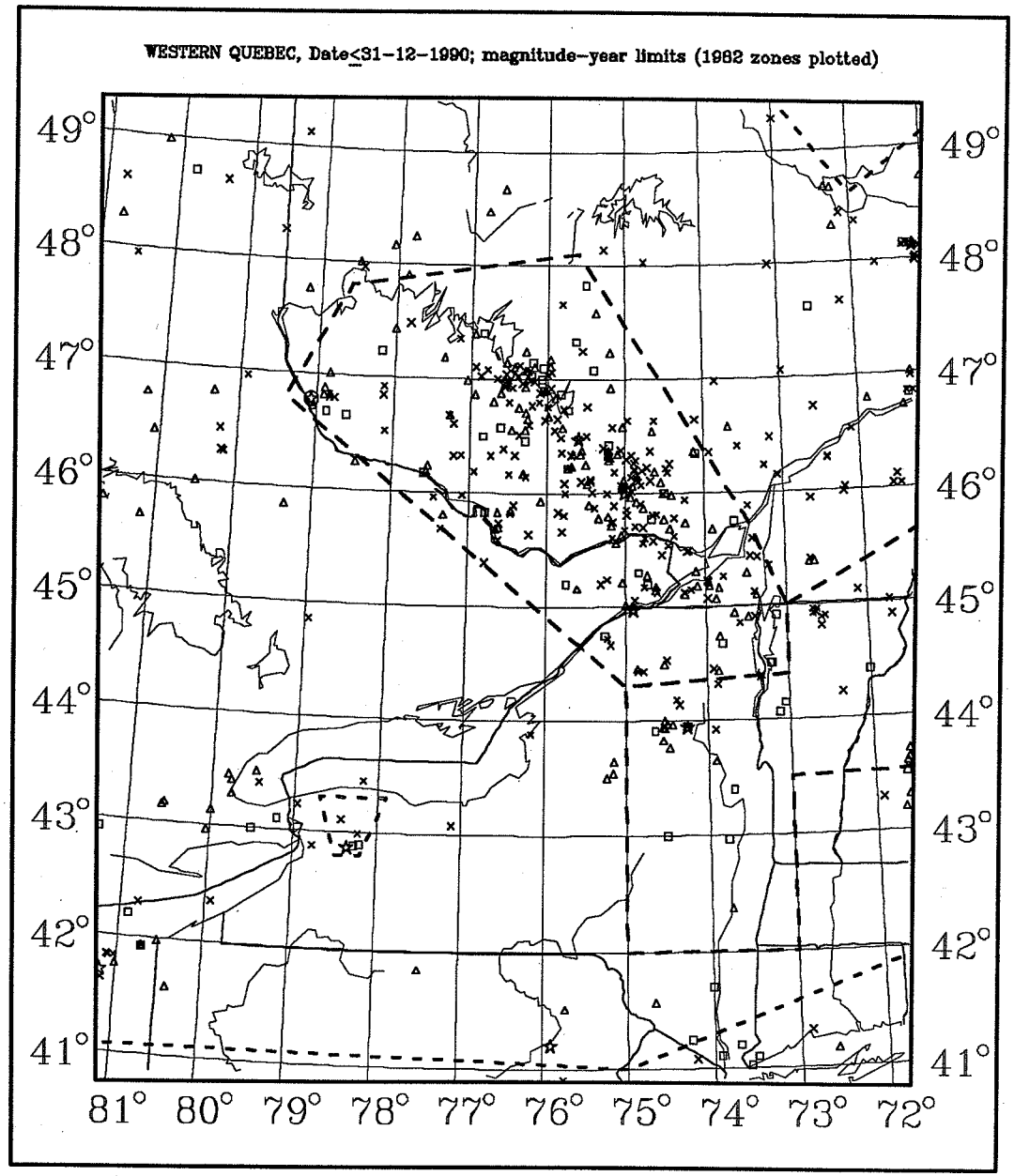

WESTERN QUEBEC, Canadian stations 1990
49° 48° 47° 46° 45° 44° 43°
80° 79° 78° 77° 76° 75° 74° 73° 72° 71°
SUO
EEO
EFO
WEO
OTT
GRQ
GAC
WBO
TRQ
MNT
DRQ
OCQ
DAQ
LBQ
GEOPHYSICS DIVISION GEOLOGICAL SURVEY OF CANADA
DIVISION DE LA GEOPHYSIQUE COMMISSION GEOLOGIQUE DU CANADA
0 200 400 600 800 KM


WESTERN QUEBEC, Canadian stations 1990
49°
48°
47°
46°
45°
44°
43°
80°
79°
78°
77°
76°
75°
74°
73°
72°
71°
DAQ
OGQ
DPQ
SBQ
MNT
TRQ
GBQ
CAC
OTT
WBQ
ERQ
WEQ
EDQ
SVO
EFO
GEOPHYSICS DIVISION GEOLOGICAL SURVEY OF CANADA
DIVISION DE LA GEOPHYSIQUE COMMISSION GEOLOGIQUE DU CANADA
0
200
400
600
800
KM



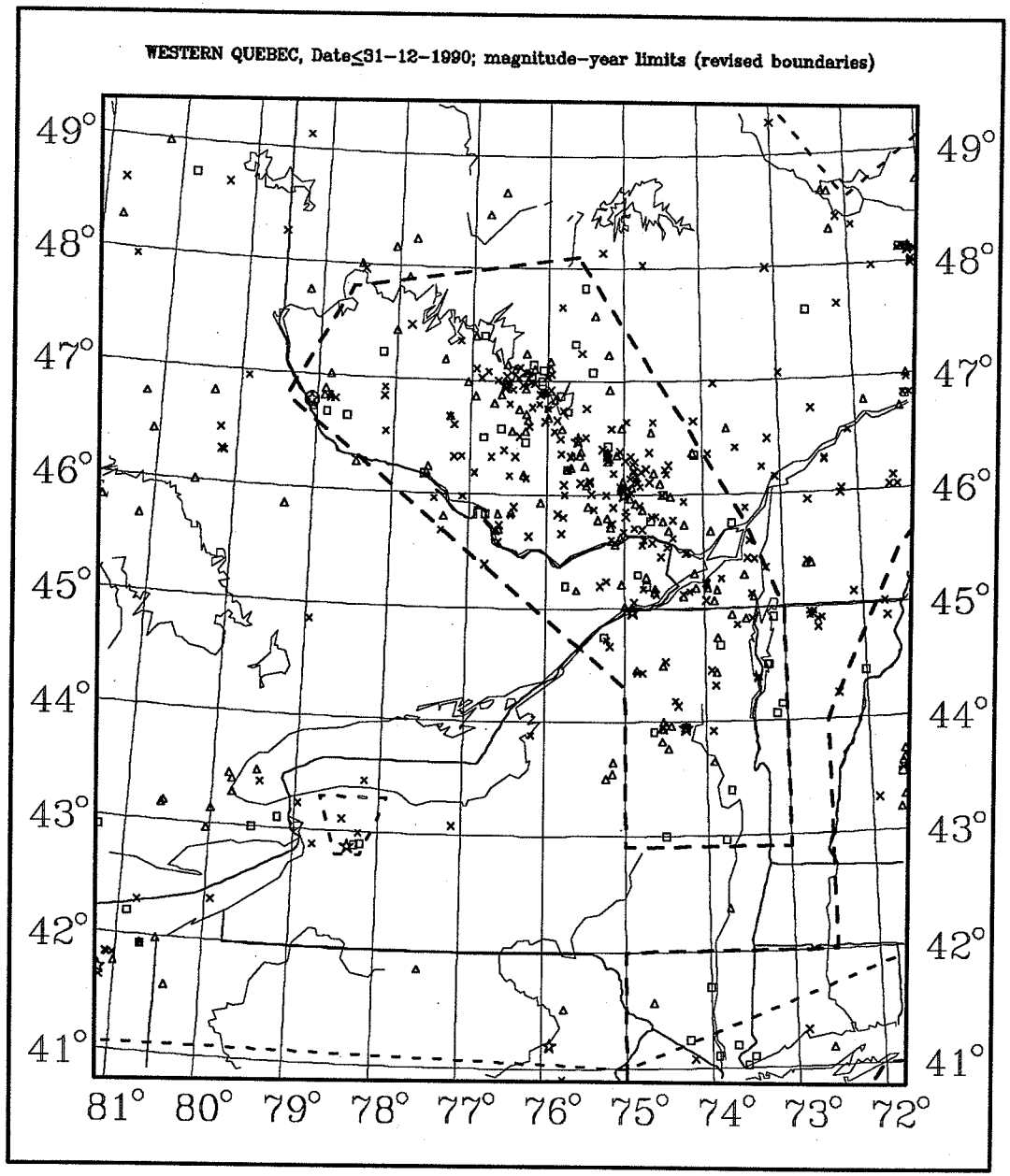
DEFINITIONS

M<3	×
M≧3	△
M≧4	□
M≧5	☆
M≧6	⊛



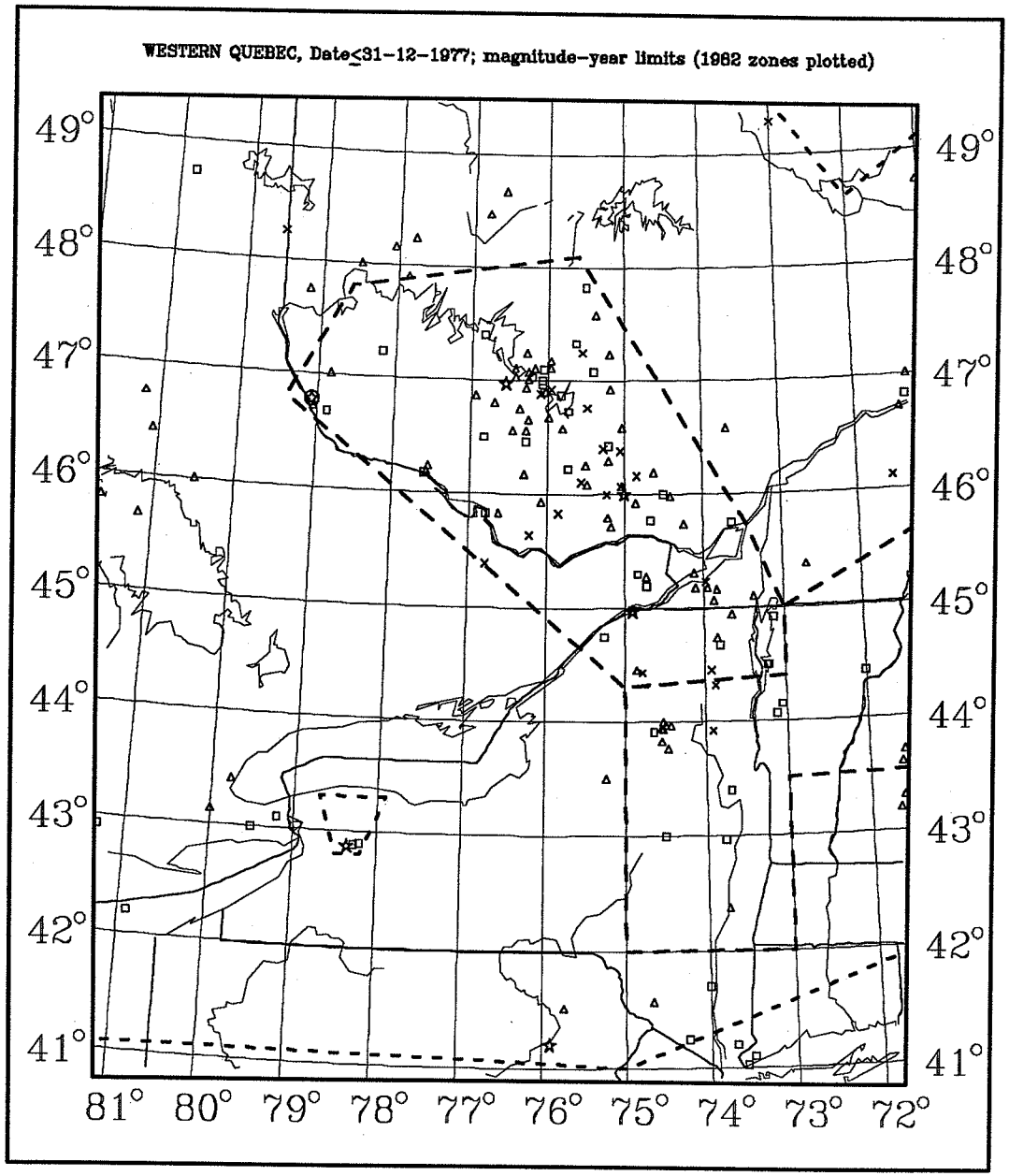
DEFINITIONS

M≧2.3	1981+	×
M≧2.8	1968+	×
M≧3.3	1963+	△
M≧3.8	1937+	△
M≧4.3	1928+	□
M≧5.3	1900+	☆
M≧6.3	1850+	⊛



DEFINITIONS

M≧2.3	1981+	×
M≧2.8	1968+	×
M≧3.3	1963+	△
M≧3.8	1937+	△
M≧4.3	1928+	□
M≧5.3	1900+	☆
M≧6.3	1850+	⊛



DEFINITIONS

M≧2.8	1968+	×
M≧3.3	1963+	△
M≧3.8	1937+	△
M≧4.3	1928+	□
M≧5.3	1900+	☆
M≧6.3	1850+	⊛

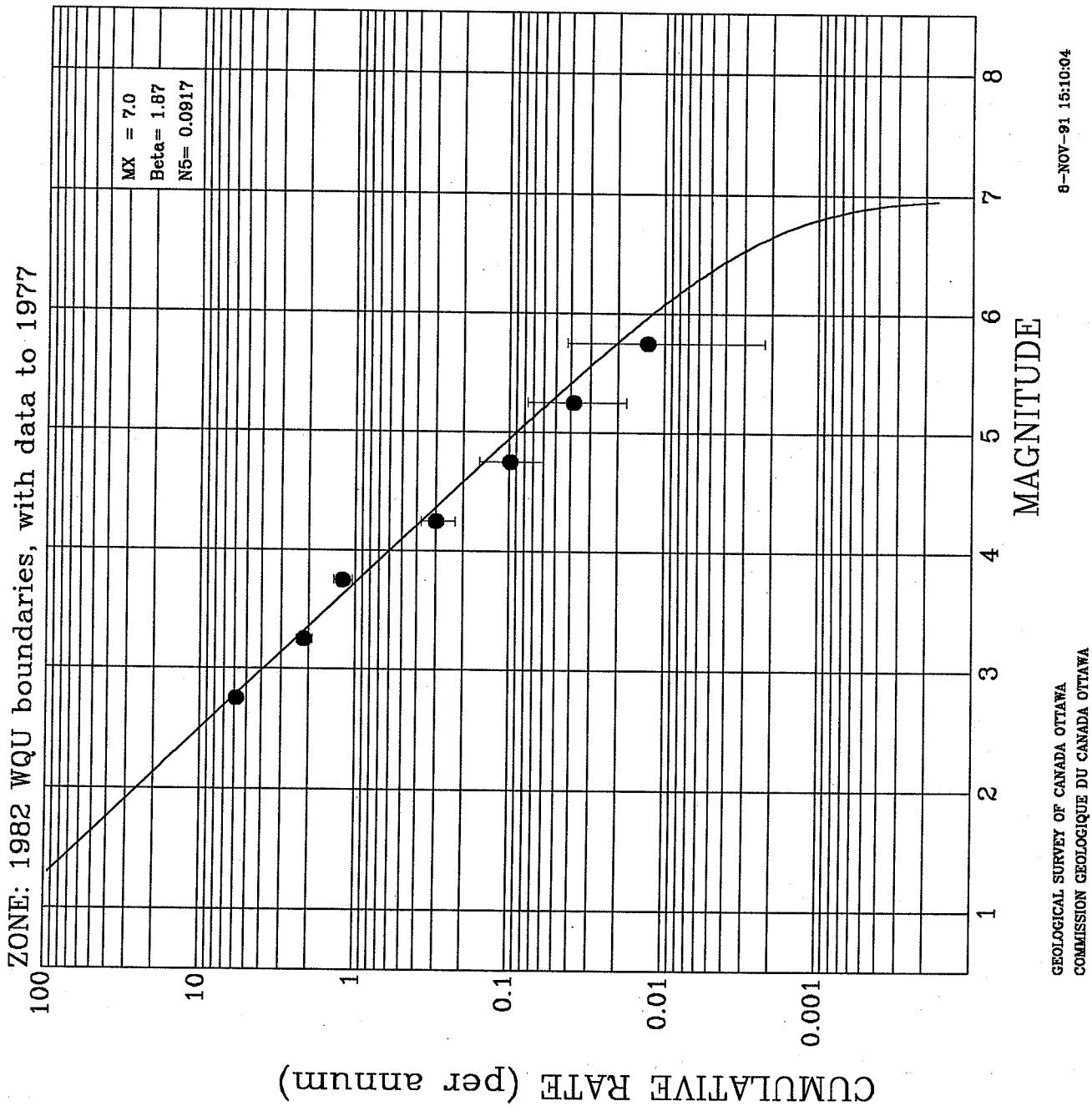

ZONE: 1982 WQU boundaries, with data to 1977
MX = 7.0
Beta= 1.87
N5= 0.0917
CUMULATIVE RATE (per annum)
100
10
1
0.1
0.01
0.001
1
2
3
4
5
6
7
8
MAGNITUDE
8-NOV-91 15:10:04
GEOLOGICAL SURVEY OF CANADA OTTAWA
COMMISSION GEOLOGIQUE DU CANADA OTTAWA

Table A-3

Input/output variables of magnitude recurrence programme, WQU data to 1977

Input

ZONE: 1982 WQU boundaries, with data to 1977

Minimum mag. 3.0 Maximum mag. 7.0 Magnitude increment 0.5

Plot= T Line wt1= 1 Line wt2= 2

1968 1963 1937 1928 1928 1900 1900 1850 1850 1900 1900 1900 1900 1900 1900 1900 1900 1900 1900 1900 1900 1900 1900 1900
1900 1900 1900 1900 1900 1900 1900 1900 1900 1900 1900 1900 1900 1900 1900 1900 1900 1900 1900 1900 1900 1900 1900 1900
1977

Last Year = 1977

Output

StartYr	1968	1963	1937	1928	1928	1900	1900	1900	Starting year
Mags.	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	Magnitude M
Number	37	14	37	10	3	2	1	0	Number in interval M +/- 0.2
Intvs.	10	15	41	50	50	78	78	78	Interval since Last Year
Incr.Rt	3.700	0.933	0.902	0.200	0.060	0.026	0.013		Number/Interval = Incremental rate per annum
ERR UP	1.164	1.267	1.164	1.430	1.973	2.320	3.300		Error bars
ERR DUN	0.836	0.733	0.836	0.689	0.457	0.354	0.173		
Cum Rt.	5.834	2.134	1.201	0.298	0.098	0.038	0.013		Cumulative rate per annum (see graph)
ERR UP	1.098	1.122	1.137	1.250	1.597	1.973	3.300		Error bars (see graph)
ERR DUN	0.902	0.878	0.863	0.750	0.603	0.457	0.173		

Low and High mags used: 3.00 6.00

For the a priori MX of 7.0,

Beta = 1.8737 +/-1 Stdv of 0.134 B = 0.8137 +/-1 Stdv of 0.058

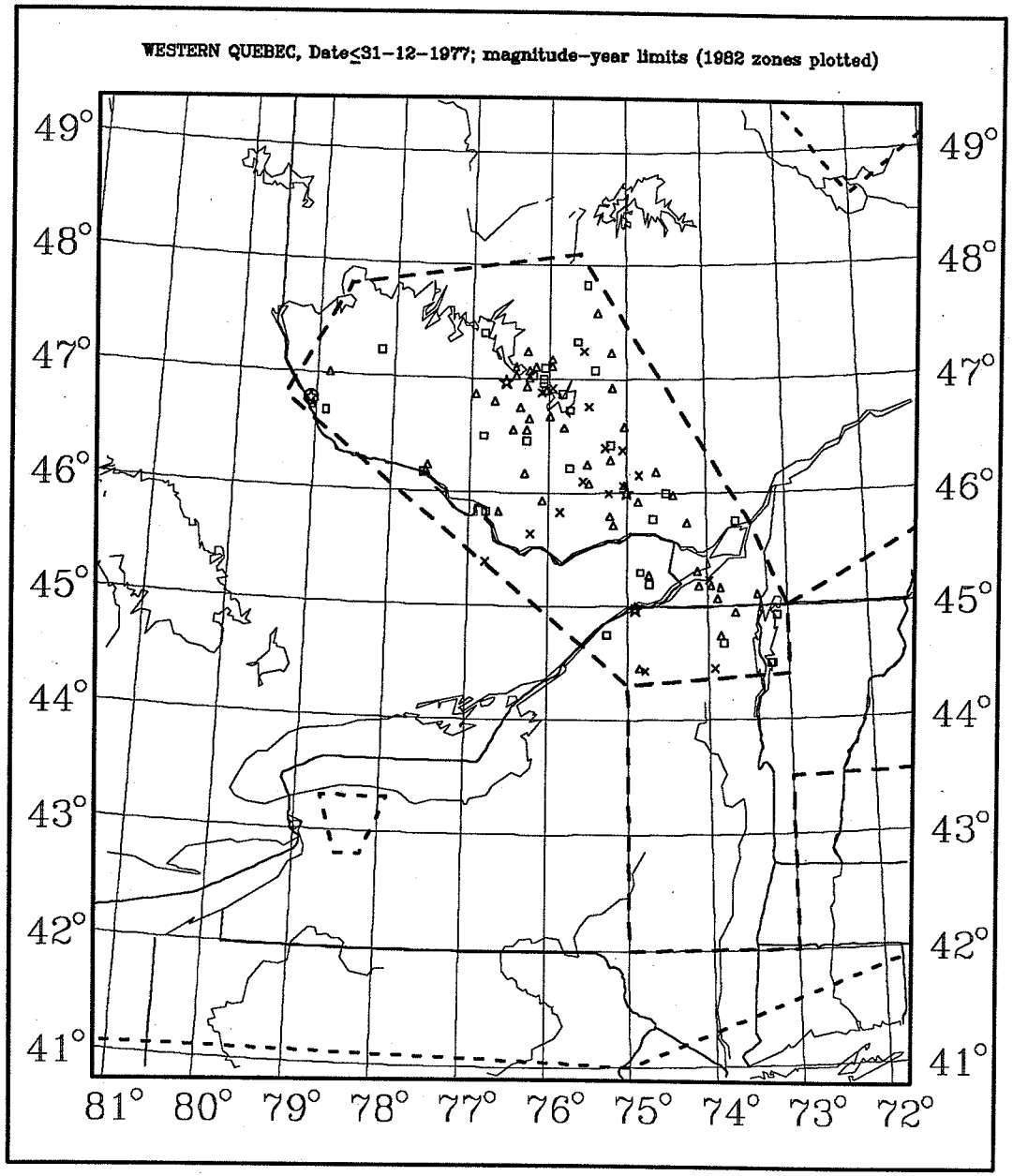
Number of events used 104

Events rejected 0

LOG(annual rate above M0) is 3.031

annual rate above M5 is 0.091713 +/-1 Stdv of 0.008993

Data are plotted on page A-30 (magnitude recurrence graph) and page A-32 (epicentre map)



DEFINITIONS

M≧2.8	1968+	×
M≧3.3	1963+	△
M≧3.8	1937+	△
M≧4.3	1928+	□
M≧5.3	1900+	☆
M≧6.3	1850+	⊛

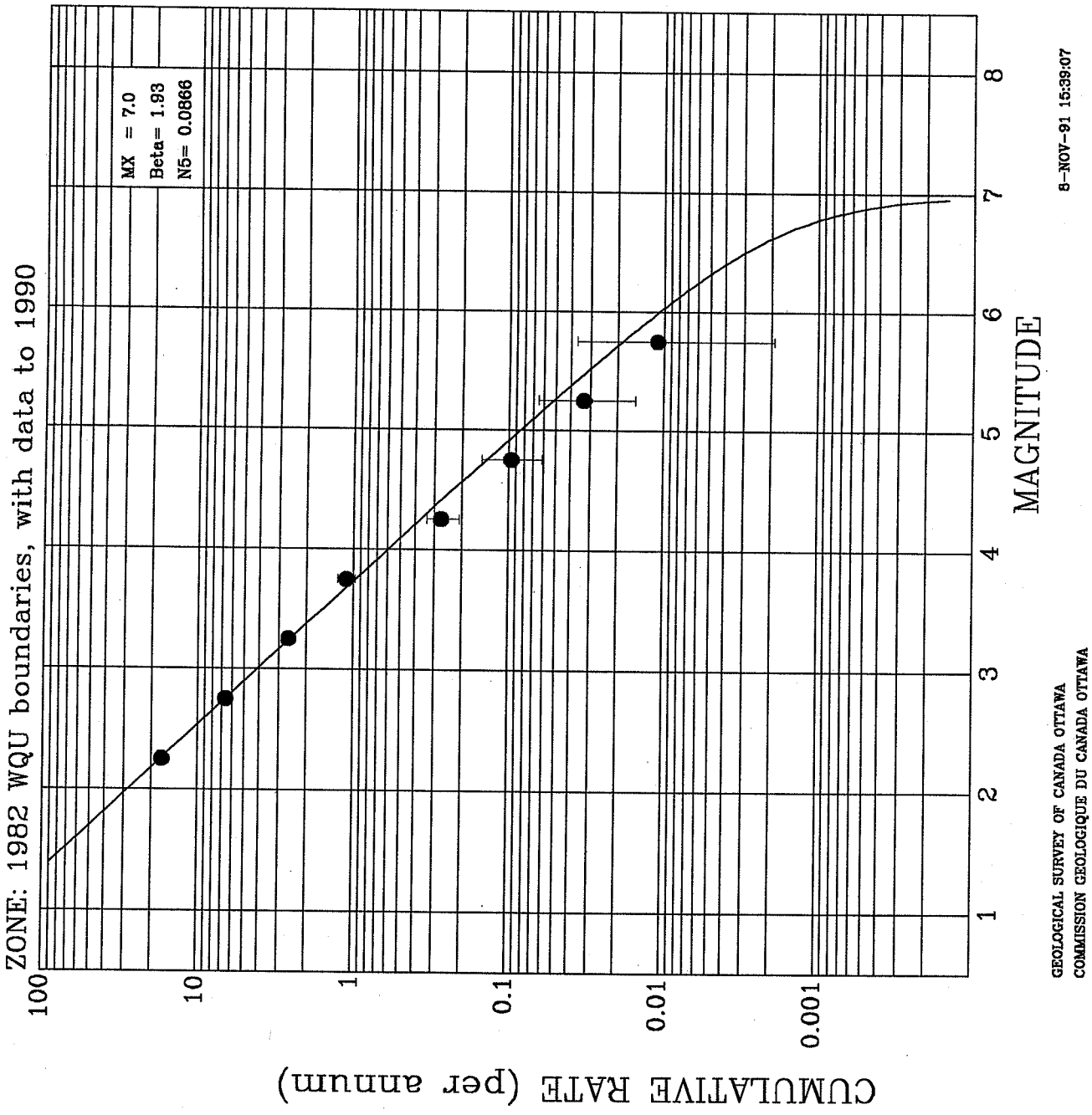

ZONE: 1982 WQU boundaries, with data to 1990
MX = 7.0
Beta= 1.93
N5= 0.0866
CUMULATIVE RATE (per annum)
100
10
1
0.1
0.01
0.001
1
2
3
4
5
6
7
8
MAGNITUDE
8-NOV-91 15:39:07
GEOLOGICAL SURVEY OF CANADA OTTAWA
COMMISSION GEOLOGIQUE DU CANADA OTTAWA

Table A-4

Input/output variables of magnitude recurrence programme, WQU data to 1990

Input

ZONE: 1982 WQU boundaries, with data to 1990

Minimum mag. 2.5 Maximum mag. 7.0 Magnitude increment 0.5

```
Plot= T Line wt1=            1 Line wt2=           2
1981 1968 1963 1937 1928 1928 1900 1900 1850 1850 1900 1900 1900 1900 1900 1900 1900 1900 1900 1900 1900 1900 1900 1900 1900
1900 1900 1900 1900 1900 1900 1900 1900 1900 1900 1900 1900 1900 1900 1900 1900 1900 1900 1900 1900 1900 1900 1900 1900 1900
1990
```

Last Year = 1990

Output

StartYr	1981	1968	1963	1937	1928	1928	1900	1900	1900	Starting year
Mags.	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	Magnitude M
Number	105	92	42	45	11	4	2	1	0	Number in interval M +/- 0.2
Intvs.	10	23	28	54	63	63	91	91	91	Interval since Last Year
Incr.Rt	10.500	4.000	1.500	0.833	0.175	0.063	0.022	0.011	Number/Interval = Incremental rate	
ERR UP	1.098	1.104	1.154	1.149	1.302	1.790	2.320	3.300	Error bars	
ERR DUN	0.902	0.896	0.846	0.851	0.698	0.522	0.354	0.173		
Cum Rt.	17.104	6.604	2.604	1.104	0.271	0.096	0.033	0.011	Cumulative rate per annum (see graph)	
ERR UP	1.058	1.071	1.098	1.126	1.236	1.543	1.973	3.300	Error bars	
ERR DUN	0.942	0.929	0.902	0.874	0.764	0.631	0.457	0.173		

Low and High mags used: 2.50 6.00

For the a priori MX of 7.0,

Beta = 1.9272 +/-1 Stdv of 0.081 B = 0.8370 +/-1 Stdv of 0.035

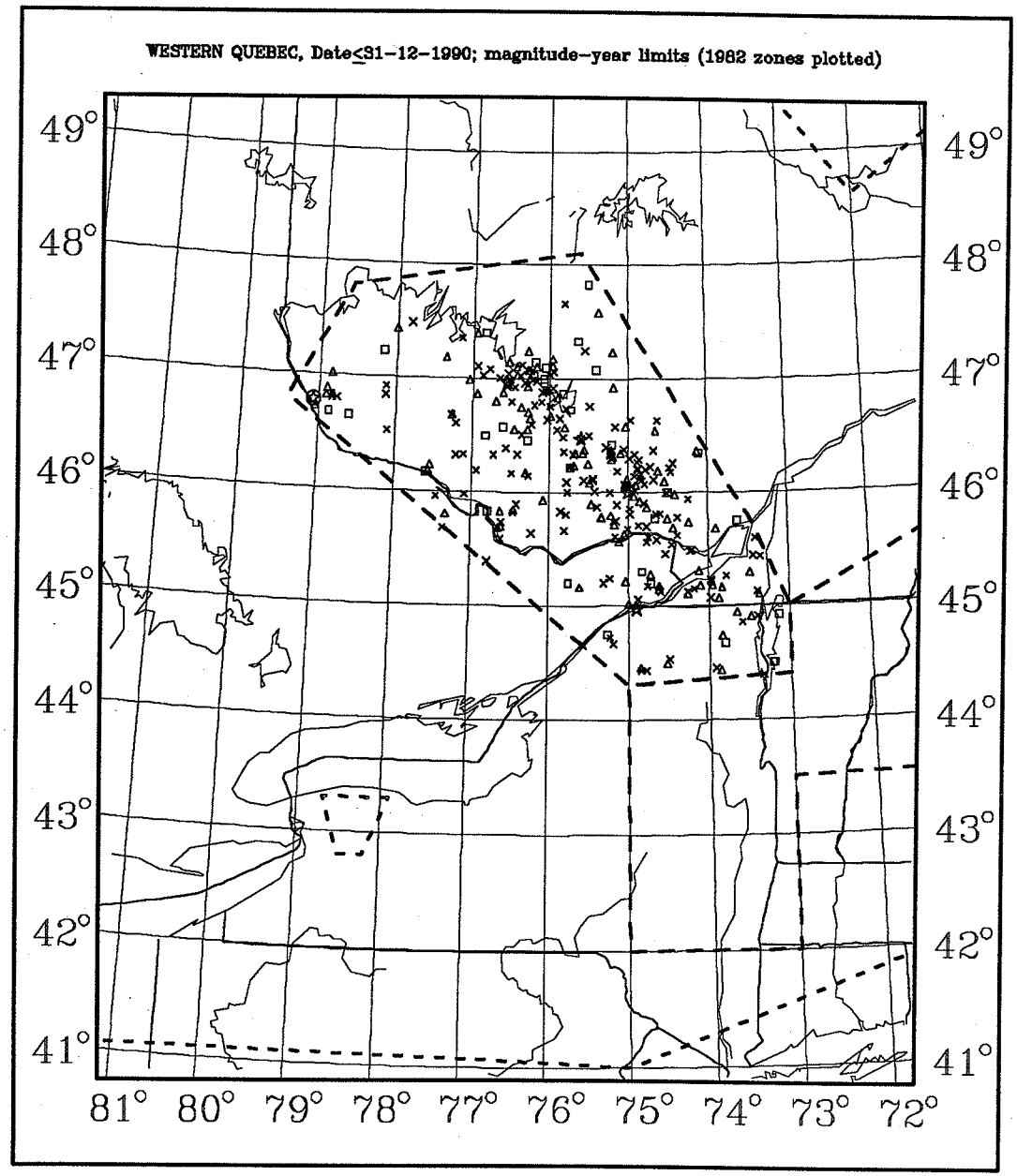
Number of events used 302

Events rejected 0

LOG(annual rate above M0) is 3.123

annual rate above M5 is 0.086646 +/-1 Stdv of 0.004986

Data are plotted on page A-33 (magnitude recurrence graph) and page A-35 (epicentre map)



DEFINITIONS

M≧2.3	1981+	×
M≧2.8	1968+	×
M≧3.3	1963+	△
M≧3.8	1937+	△
M≧4.3	1928+	□
M≧5.3	1900+	☆
M≧6.3	1850+	⊛

APPENDIX B

EPICENTRAL DATA FROM AMERICAN SOURCES

Examination of the Global Hypocenter database on CD-ROM and the EPRI 1986 database

Global Hypocenter Data Base (GHD), issued on CD-ROM, eastern United States events extracted from its catalogues HDS and SRA

The HDS catalogue is the worldwide PDE catalogue; the SRA catalogue contains only epicentres within the geographic boundaries of the United States. See the Users' Guide *EPIC, Retrieval Software for the Global Hypocenter Data Base CD-ROM* for further details (EPIC, 1990). Note that references in this appendix will be found in the *Reference* section at the end of the main report (page 10).

In the GHD database, the prime magnitude is found in columns 65 to 68 (format F4.2) for both HDS and SRA catalogues examined below. Most of the magnitudes are coded m_N, but amplitudes and periods selected for calculation of m_N were not selected in the same manner by all contributing agencies. Nevertheless, in the maps and discussion that follow, all prime magnitudes are considered of equivalent reliability.

Extracted with a rectangular search were all epicentres within the area defined by latitudes 35.0° to 50.0°N and longitudes 50.0° to 80.0°W. This area is more than adequate to include all American epicentres that might be relevant to an examination of the southern boundary of the Western Quebec Zone (WQU) and all boundaries of the Northern Appalachian Zone (NAP) or a new New England–New Brunswick zone (NE–NB). The area includes also eastern Canada south of 50.0°N and east of 80.0°W. The main purpose of this search was to study the data available from American sources, particularly for the years since 1977, the final year for data analyzed in the *1982 Open-File Report* (Basham *et al.*, 1982).

On the epicentre maps plotted below from HDS and SRA data sets, an open hexagon denotes each epicentre. Where the prime magnitude columns are not blank, the integer value of column 65 is plotted inside the hexagon. e.g. the epicentre of a magnitude 3.8 earthquake is plotted as the number 3 inside an open hexagon.

On each of the epicentre maps below are plotted also the zone boundaries for all the seismic source zones defined in the *1982 Open-File Report* and lying within the map area. To what extent the HDS and SRA data are compatible with these zones or would suggest revised boundaries can thus be readily seen.

The maps are not numbered but arranged in order of presentation in the text; they can be uniquely identified by their title. Refer to the *Table of Contents*, page iv, for the page number of a specific map. The map title also reminds the user that the geographic span of the data extracted from the Global Hypocenter Data Base is somewhat less than the geographic span of the map, particularly on the west where the data stop at 80°W, but the map continues several degrees further west. The maps of Appendix B begin on page B–10.

Catalogue HDS (i.e. PDE); spans years 1928 to 1988 only; epicentres in both Canada and the United States

This file of epicentres was sorted by epicentre agency (columns 25–26). Then the following nine maps (pages B–10 to B–18) were plotted in order to show which data might be considered to supplement the CEEF data for defining zone boundaries. A few comments are noted for each map, including the number of epicentres and the actual time period spanned by the data subset.

HDS Maps: 1928–1988, 35.0° to 50.0°N, 50.0° to 80.0°W;
The map title indicates epicentre agency X as HDS–X.

- HDS: all data; 304 epicentres, 1929–1988

The first event catalogued in this geographic area was dated August 1929. Only 20 events were catalogued prior to October 1963, none has a magnitude value; 64 events occurred between 1985 to 1988, but only four of these in 1987. Note a virtual absence of events in western New York State.

The following six maps are subsets of the events plotted on this first map. For each subset is noted the actual time period covered by the data subset. It will be seen that the geographic coverage in the HDS catalogue for events in eastern North America is non-uniform in time, even in the more recent years. Thus the HDS catalogue may not be a suitable general source of American epicentral data to supplement data in the CEEF.

- HDS–00: events without designated epicentre agency; 61 epicentres, including 6 explosions (south of 40.0°N); 1929 to 1988

45 of the 61 events occurred before 1976; 11 of remaining 16 were located either north of 44.0°N or south of 40.2°N. Hence this data subset is of no particular use in supplementing the CEEF in order to better analyze zone boundaries.

- HDS–C: events designated C, Pacific Geoscience Centre; 25 epicentres; 1974 to 1978

Six epicentres lie in southern New England (1974 and 1976, Connecticut, Rhode Island and southeastern Massachusetts); the remainder (1975–1978) lie in Canada, including one rockburst (1975, near Val-d'Or). "PGC" data were likely from "EPB". It is assumed that the 19 Canadian epicentres are in the CEEF.

The 6 epicentres in southern New England are NOT in the annual EPB catalogue (its Table 1B) nor in the current CEEF; one might assume that the agency was miscoded by the compilers of this HDS catalogue and that the epicentres were determined by an American agency. The 6 epicentres occurred near where other epicentres appear on the Weston (HDS–T) subset map below and hence add no new spatial information on epicentral patterns.

Hence the entire data subset coded C is of no interest in revising zone boundaries of the NAP zone or the southern part of the WQU zone.

- HDS–L: events designated L, Lamont-Doherty; 46 epicentres; 1971 to 1986

Lamont-Doherty began to develop its current network in 1971. All epicentres on this map lie between 73.0° and 74.9°W longitude, including several on the international border, but none in Canada. One group of epicentres lies in northeastern New York State north of 43.0°N, and the other group in extreme southeastern New York

State south of 42.0°N. Some of the Lamont-Doherty events may be already included in the CEEF. Note that the HDS catalogue has no events attributed to Lamont-Doherty in western New York State, although earthquakes are known to have occurred there in the period (1971–1986) covered by this data subset.

See paragraph HDS–L–T below (page B–4) for further analysis.

- HDS–OT: events designated O, Ottawa (i.e. EPB and GSC); 69 epicentres; 1979 to 1988

All epicentres lie within Canada or offshore; it is assumed that these are all in the CEEF. Then this subset has no new information and may be ignored.

Note that the events coded C (PGC) spanned 1974–1978 and the O-coded events spanned 1979–1988. Hence the HDS catalogue has specifically noted EPB/GSC as the epicentre source agency for events in Canada from 1974 to 1988, although some events in Canada in subsets HDS–00 (page B–2) and HDS–Z (page B–3) probably originated with the EPB/GSC.

- HDS–T: events designated T, Weston; 58 epicentres in New England (none in Vermont); 1976 to 1988

Only 2 events are catalogued in 1985, 2 in 1986, and one each in 1987 and 1988; this subset is obviously incomplete after 1984. There are 52 epicentres from 1976 to 1984, including one Canadian event at La Malbaie (1977); thus there are 51 epicentres in New England from 1976 to 1984; some of these Weston events may be in the CEEF.

See paragraph HDS–L–T below (page B–4) for further analysis.

- HDS–Z: remaining 45 of the 304 events selected from the HDS catalogue, 1970–1988

— 13 epicentres (1972 to 1986) are coded without designated epicentre agency and having large location uncertainty (11 coded * and 2 coded ?); 3 of these events are in Canada; 7 events south of 40.0°N are not likely in the CEEF; the remaining three American events (1979, 1980, 1982) are of possible interest, except that they are already in the CEEF. Thus, the subgroups coded * or ? may be ignored.

— The remaining 32 events (1970 to 1988) are designated either E (explosion – 4), F (Penn State – 1), G (USGS – 2), N (code not given – 4), P (Cal Tech – 2), S (NEIS special – 12), V (Virginia Polytech – 6) or W (U. of Washington –1).

Of this total of 32 epicentres, 4 were explosions (south of 40.7°N). Except for Woburn (1973) and three at Miramichi (1982), the remaining 28 of the 32 events are located in the United States; most of these are not likely in the CEEF since 16 of the 28 lie south of 41.0°N; 8 of the remaining 12 events lying north of 41.0 (and in the U.S.A.) are already listed in the CEEF. Hence there are only four events of possible interest (1974, 1975, 1979, 1981; magnitudes 2.4 to 3.0), only two of which occurred after 1977. These four small events are located within data clusters of subsets HDS–L and HDS–T and thus contribute no new spatial information on epicentre patterns.

Hence this subset of 45 events may be ignored, being of little use for supplementing American data in the CEEF in order to study zone boundaries.

Of the 304 epicentres extracted from the HDS catalogue (map, page B–10), only the Lamont-Doherty and Weston subsets (pages B–13 and B–15) have been shown to be of potential interest for redefining NBCC zone boundaries in the United States. A few events in New York State and

New England have been coded to other agencies as can be seen on the HDS subset maps, in particular, map HDS–Z (page B–16) for Woburn (1973) and Blue Mountain Lake (1971, 1973) earthquakes, and map HDS–00, (page B–11). Such events are not included in the following two maps and tables. Their inclusion would slightly increase the relative number of magnitude M≥3.0 events but would not significantly change the geographic pattern of epicentres.

Note that Lamont-Doherty data in the HDS catalogue span 16 years (1971–1986), with six of these years (1972, 1973, 1974, 1977, 1980, 1982) having either zero or only one catalogued event. In addition, no events were catalogued in western New York State. Thus, this Lamont-Doherty subset, extracted from the HDS catalogue, appears to be not complete in time during the period 1971 to 1986 for eastern New York State and does not cover western New York State at all.

Weston data spanned 13 years (1976–1988), with four years (1976, 1980, 1987, 1988) having either zero or one event catalogued. Again, this subset extracted from the HDS catalogue appears incomplete in time since 1976.

These two subsets are combined and replotted at a larger scale on two maps (pages B–17 and B–18).

- HDS–L–T, all magnitudes: 103 events, 1971–1988; all events in subset L plus subset T, minus the one Canadian (La Malbaie) event

These combined data show a clear separation in New York State with no events catalogued between latitudes 41.6° and 43.2° (a distance of about 150 km), from 1971 to 1986. In New England, no events are catalogued in Vermont, but the remaining epicentres in Maine, New Hampshire, Massachusetts, Rhode Island and Connecticut form a continuous band of activity and may merge with the activity in extreme southeastern New York State. It should be noted, however, that the Lamont-Doherty stations are concentrated in northeastern and southeastern New York State; the seismicity minimum may be due in part to decreased monitoring.

The magnitude completeness of these two subsets is examined in the following two tables, which show the number of earthquakes catalogued in each magnitude range; aftershocks have not been removed.

M≥	5.0	4.0	3.0	2.0	1.0	nil	*Total*
1971–1986 HDS–L	1	2	16	23	3	1	46
	(1983)	(1975, 1985)	(1971–1986)	(1975–1986)	(1978, 1986)	(1971)	
1976–1988 HDS–T	nil	3	17	35	2	nil	57
		(1979, 1982, 1983)	(1977–1988)	(1976–1987)	(1981, 1982)		

Assuming from these statistics that M≥3 is complete, which may not necessarily be true, then many more M2 earthquakes should have been located (factors of at least 2 to 5 more).

The events with M 2.0 to 2.9 were further subdivided in an attempt to refine the minimum magnitude completeness level.

M	2.0–2.4	2.5–2.9	*Total*	2.0–2.2	2.3–2.6	2.7–2.9	*Total*
L	9	14	23	5	7	11	23
T	20	15	35	9	15	11	35

The table shows that the M2 events are not well distributed and that the completeness cannot be extended to M2.5 or even to M2.7.

Thus, the magnitude completeness of these two subsets, based only on the HDS catalogue data, is not better than M 3.0±0.2, whether taken together or as individual subsets for their respective time periods.

- HDS–L–T, M≥3.0: 39 events, 1971–1988; all events with M≥3.0 in subset L plus subset T, minus the one Canadian (La Malbaie) event

This map of combined Lamont-Doherty and Weston data having M≥3.0 shows events scattered over the same area as the previous map. There is no concentration of larger events in only part of western New York State or in part of New England.

In summary, only data coded L or T in the HDS catalogue of the Global Hypocenter Data Base appear relevant to supplementing the CEEF in order to examine zone boundaries in the northeastern United States. These data span a limited time period (1971–1986, 1976–1988). However, within this time period there are years for which few or no data have been catalogued, which seems unrealistic. An examination of the magnitude distribution shows the data to be incomplete below M 3.0. With almost no data for some years within the time period covered, it is not certain that this data set (Lamont-Doherty plus Weston) is complete even at the M3.0 level.

Other catalogues of American data need to be examined to see whether the seismicity minimum in east-central New York State might be real and to estimate magnitude completeness, particularly in the period from 1970 to 1990.

As will be seen below, not all relevant Lamont-Doherty or Weston epicentral data in their respective time periods have been included in the HDS catalogue of the Global Hypocenter Data Base.

Catalogue SRA; spans years 1568 to 1984; all catalogued epicentres lie within the United States

This catalogue is said to have been partially revised and updated by the USGS (EPIC, 1990, page 22), but a cursory inspection suggests it is not yet a completely revised file. Its overall quality is probably similar to that of other American databases in current use.

Events in this catalogue are coded either Z (non-instrumental) or blank (instrumental) in column 25. The original source of hypocentral parameters is not indicated. Some Z-coded events are as late as 1977. While instrumental-coded events begin in 1925, an inspection of some of these early events shows them likely to have been non-instrumental, with events taken from Smith (1966).

SRA Maps: 1568–1984, 35.0° to 50.0°N, 50.0° to 80.0°W

Data extracted from the SRA catalogue are displayed on five maps (pages B–19 to B–23), following the same format as for the HDS map series.

- SRA: all data (1568–1984); 1628 events

The SRA map (page B–19) shows similar general epicentral trends to those seen on the HDS map (page B–10); the latter however has significantly fewer events in the United States.

- SRA–Z: 1568–1977; 1196 events

Although these are non-instrumental epicentres, a few have had numerical magnitudes assigned, as indicated by the number plotted inside a few of the open hexagons. The SRA–Z subset was not further analyzed on the reasonable assumption that its locations and magnitudes were not well determined. Furthermore, American data later than 1977 are the data of particular interest in this search for recent sources of American data to supplement the CEEF.

- SRA–i: 1925–1984: 432 events, only one event prior to 1928

This SRA map (page B–21) of largely instrumental data will be compared with maps of HDS data (which database began only in 1928) and will then be examined for data to supplement the CEEF.

This subset (all American events) can be compared with the HDS catalogue (page B–10), which had 304 epicentres (both American and Canadian events) in the period 1929–1988 and had 220 events from 1929–1984. The SRA catalogue has more than twice as many epicentres as does the HDS catalogue for the same time period (1928–1984). The SRA–i map shows events in western New York State, whereas the HDS map showed virtually none. The SRA–i subset also shows events more widely scattered throughout New England.

This SRA–i subset shows an area of reduced activity in east-central New York State, as did the HDS map, although the contrast between northeastern and southeastern New York State is not as marked as in the HDS data set. Similarly, there is an area of lesser activity in Vermont.

To compare with the Lamont-Doherty and Weston subsets extracted from the HDS catalogue, an SRA instrumental subset for the period 1971–1984 was also plotted, for all magnitudes (page B–22) and for M≥3.0 (page B–23). Note that the SRA catalogue ended in 1984 and thus did not extend as late as Lamont-Doherty (1986) and Weston (1988). The subset HDS–L had 12 epicentres in the period 1985–1986; the subset HDS–T had only 6 events in the period 1985–1988.

- SRA–i: 1971–1984: 275 events

All but 5 of the HDS–L subset to the end of 1984 are also included in this SRA subset, the five omitted events all being very near the international border and may have been omitted from the SRA catalogue for this reason. All but 3 of the HDS–T subset to the end of 1984 are also included in this SRA subset.

In the same geographic area as that covered by the data catalogued HDS–L, namely longitudes from 73.0° to 74.9°W, and latitudes north of 39.0°N, the SRA–i, 1971–1984 map has 103 epicenters, 67 of which are not listed in the HDS catalogue. Of these, 12 have magnitudes 3.0 to 3.4, 49 have magnitudes from 2.5 to 2.9 and the remaining 6 are smaller than M2.5. Similarly, in the area east of 73.0°W longitude, i.e. in the area

covered by data in the HDS–T subset, the SRA–i subset had 107 events in the period from 1976–1984, as compared to 51 in HDS–T for the same period.

It is not obvious why the SRA catalogue has twice as many events catalogued in New York State and New England as does the HDS catalogue; there is no dependence upon year or location; the HDS catalogue had no minimum magnitude for inclusion, as some events of M1 and M2 were included.

It would appear that the SRA catalogue for the period since 1971 is a better source of data for New York State and New England than is the HDS catalogue.

- SRA–i: 1971–1984, M≥3.0: 81 events

This map (page B–23) shows a similar epicentral distribution in eastern New York State and New England as did the HDS–L–T map for M≥3.0 (page B–18), although the SRA–i map still has more events. A few of the extra events might be explained by differences among American agencies in applying magnitude scales.

All events in the subset SRA–i, 1971–1984 were examined for magnitude completeness, with the following results.

M≥	5.0	4.0	3.0	2.0	1.0	nil	*Total*
1971–1984 SRA–i	2	6	73	182	7	5	275
	(1973, 1983)	(1971–1984)	(1971–1984)	(1972–1984)	(1971, 1975, 1976)		

If M≥3.0 is complete over the area studied in the period 1971–1984, which is by no means certain, then M2 is certainly not complete, having only twice as many events catalogued as for M3. An examination of the proportion of events in the M2 subgroups shows that magnitude completeness cannot be reduced to M2.7.

M	2.0–2.4	2.5–2.9	*Total*	2.0–2.2	2.3–2.6	2.7–2.9	*Total*
SRA–i	39	143	182	25	88	69	182

Map SRA–i, 1971–1984 indicates that the SRA catalogue, even for the period since 1970, has more events of interest for defining zone boundaries in the United States than does the HDS catalogue. The magnitude tables for either HDS or SRA catalogues of the Global Hypocenter Data Base suggest that the magnitude completeness is not lower than M 3.0 over New York State and New England from 1971 onwards, and may not even be complete at that level if one examined the recent history of seismograph networks in the northeastern United States.

Too few American data are catalogued since 1980 to look at a possibly lower magnitude completeness level since that date, to correspond with the M2.5, 1981 level added to the Western Quebec Zone due to improvements in the ECTN.

The various HDS and SRA catalogue maps plotted indicate that the 1982 southern WQU boundary does not separate areas of greater and lesser seismic activity and must be moved further south to do so. The American maps also show that the northern and southwestern

boundaries of the NAP need some revision to better correspond with the relative distribution of earthquakes. Revised boundaries are proposed following presentation of the EPRI database.

EPRI 1986 catalogue, issued on computer tape

This catalogue of earthquakes in eastern North America was issued by the Electric Power Research Institute (EPRI), based in Palo Alto, California, with data contributed by various agencies. The EPRI catalogue (EPRI, 1986) contains data of variable quality, probably comparable overall to the data quality in the HDS and SRA catalogues just examined. The catalogue is available on computer tape and on diskette; there appears to be no published hard-copy version and no accompanying published notes describing criteria for data selection and inclusion.

The catalogue was issued in 1986, and is thus commonly referred to as the *1986 EPRI catalogue*, although the catalogue terminates on 15 February 1985. Having only two entries in 1985, the catalogue effectively ends in December 1984. Furthermore, for studies of northeastern United States seismicity, the data end near the beginning of 1984, as after 02 February 1984 all events, with one exception, lie west of longitude 76.0°W and between latitudes 34.0° and 39.99°N. The exception is an event in New York State (23-10-1984), which is already included in the CEEF.

EPRI data were plotted on a map with the same geographic extent as the maps used for the HDS and SRA data, except that the EPRI data were allowed to fill the entire map, and not be restricted to the large rectangle, 35.0° to 50.0°N, 50.0° to 80.0°W. The preferred magnitudes in the EPRI catalogue are found in columns 98–101 (format F4.2); some had been derived from intensity data, others from instrumental data. The integer value of column 98 was used to denote epicentral location. The maps are not numbered but arranged in order of presentation in the text. (Refer to the *Table of Contents*, page iv, for the page number of a specific map.)

EPRI Maps

The following four maps of EPRI data are presented on pages B–24 to B–27.

- EPRI: date ≤15–02–1985, [effective date 02–02–1984]
- EPRI: 1925 ≤date ≤15–02–1985, [effective date 02–02–1984]
- EPRI: 1925 ≤date ≤15–02–1985, M≥4.0, [effective date 02–02–1984]
- EPRI: 1971 ≤date ≤15–02–1985, [effective date 02–02–1984]

The EPRI and SRA catalogues span almost the same time period. Comparison of the various SRA and EPRI maps shows that the two catalogues have similar coverage in New York State and New England, whereas the EPRI catalogue has better coverage than the HDS catalogue. However, in the period since 1971, EPRI (page B–27) has fewer American events than SRA (page B–22). Although both catalogues ended in 1984, it would appear that some M2 events were not included in the EPRI catalogue in this last decade.

The EPRI maps are consistent with a southward displacement of the WQU boundary and a modification of the NAP zone, as described below.

Revised zone boundaries

The American data from the two databases (three catalogues) examined suggest that the WQU zone could be extended about 100 km further south and that a background zone of about 100 km north-south width, between about 42°N and 41°N should be inserted before the beginning of the extreme southwestern end of a new New England–New Brunswick zone (NE–NB).

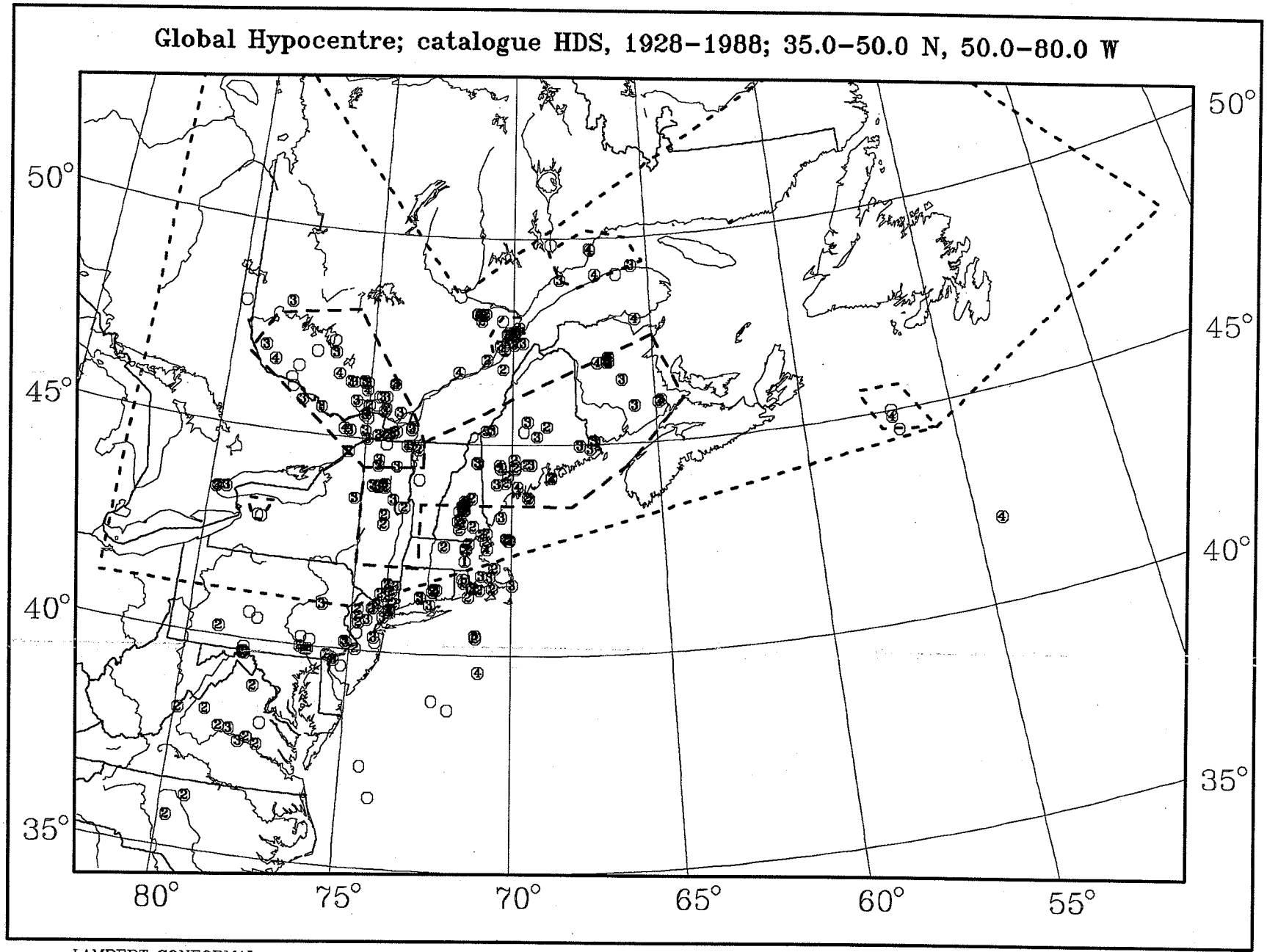
The northern boundary of the NE–NB zone lies just west of the Vermont–New Hampshire border and continues eastward along a line just north of the Québec–Maine border and then along the Québec–New Brunswick border to include the entire province of New Brunswick. The southeastern boundary of the NE–NB zone lies slightly offshore of the New England coast. (See Figure 2, page 13.) Exactly where this zone should terminate west and south of New York City is not critical for estimates of seismic hazard in Canada. The point 40.0°N, 75.0°W was selected somewhat arbitrarily.

Maps of CEEF and of American data appear in the main report showing these new boundaries. The latitude–longitude pairs defining the proposed NB–NE zone are presented in Table 1 (page 3) of the main report.

Magnitude completeness: New York State and New England

In this geographic area, magnitude completeness for American data in the three catalogues examined is not better than 3.0 since 1971, based upon an inspection of the number of epicentres per year in these catalogues in the northeastern United States. The catalogues terminate in the mid-1980s; where data continued to 1988, coverage was spotty from 1986–1988. The coverage in the three catalogues does not improve with time from 1971 to the mid-1980s, but seems somewhat random.

After presentation of CEEF data in Appendix C for the NAP zone and adjacent areas, estimates of magnitude–year completeness will be presented for the new NE–NB zone (page C–3).


Global Hypocentre; catalogue HDS, 1928–1988; 35.0–50.0 N, 50.0–80.0 W
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45°
40°
35°
80°
75°
70°
65°
60°
55°
LAMBERT CONFORMAL
PROJECTION DE LAMBERT
GEOPHYSICS DIVISION GEOLOGICAL SURVEY OF CANADA
DIVISION DE LA GEOPHYSIQUE COMMISSION GEOLOGIQUE DU CANADA
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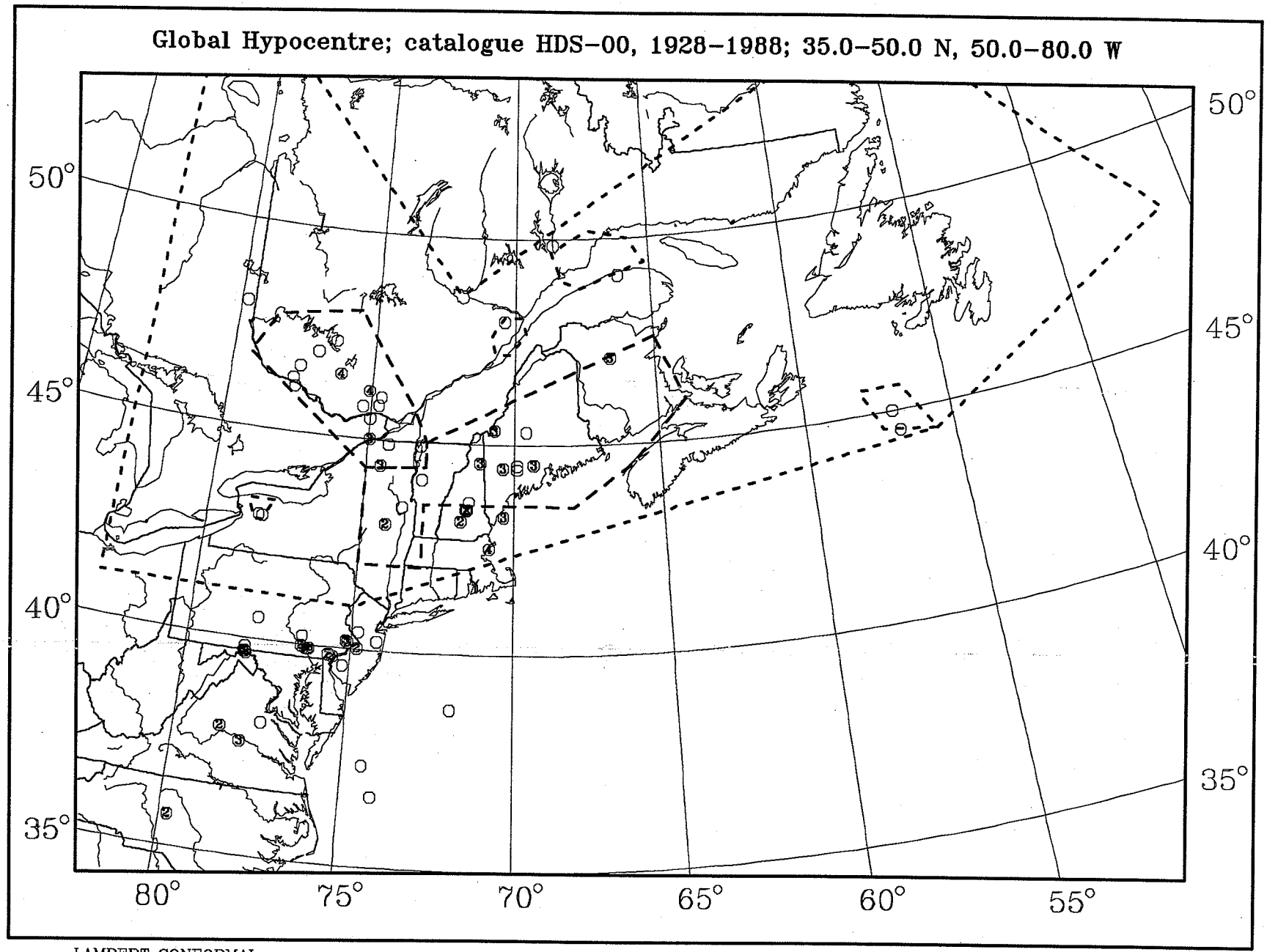
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50°
45°
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PROJECTION DE LAMBERT
GEOPHYSICS DIVISION GEOLOGICAL SURVEY OF CANADA
DIVISION DE LA GEOPHYSIQUE COMMISSION GEOLOGIQUE DU CANADA
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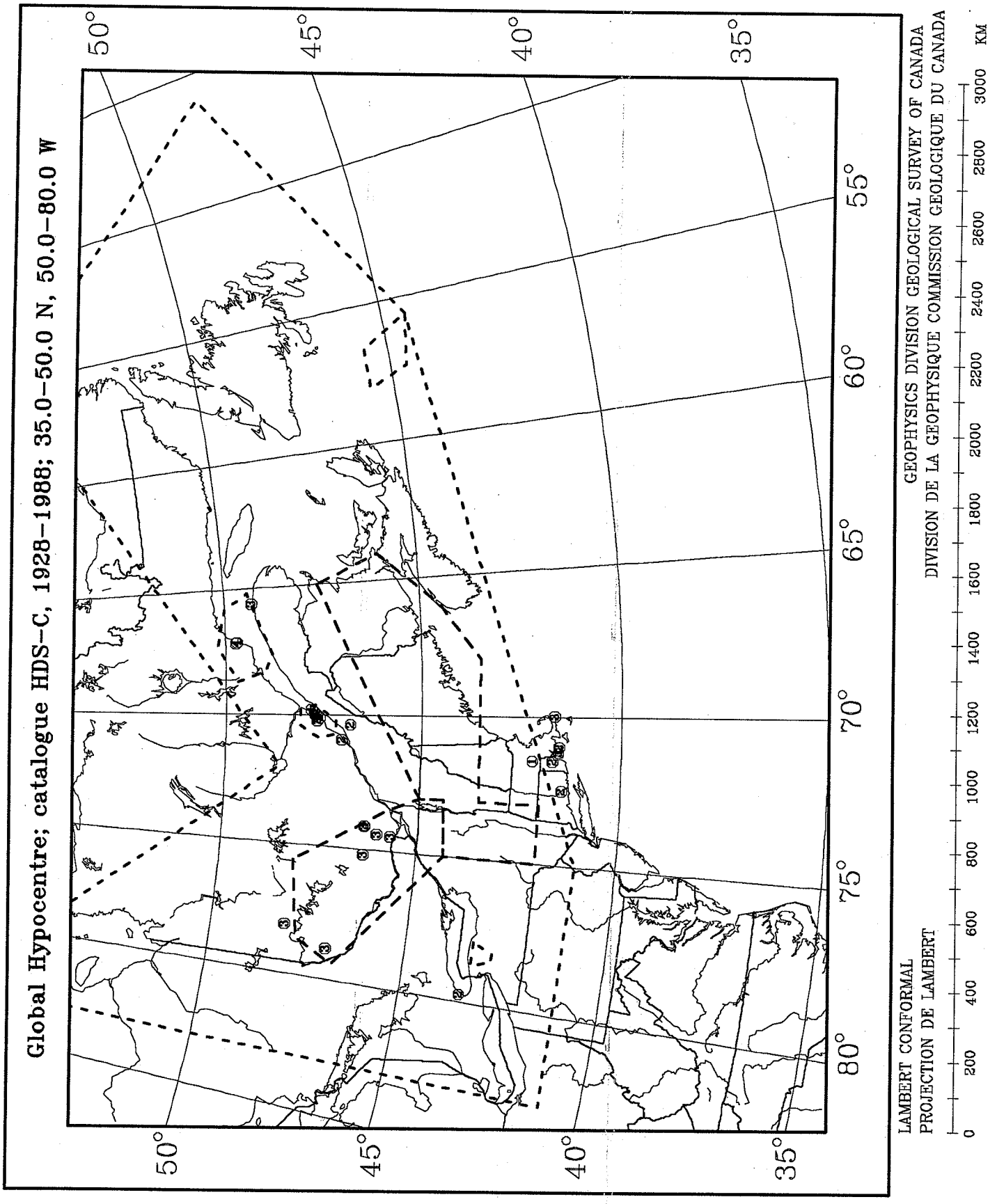
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45°
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PROJECTION DE LAMBERT
GEOPHYSICS DIVISION GEOLOGICAL SURVEY OF CANADA
DIVISION DE LA GEOPHYSIQUE COMMISSION GEOLOGIQUE DU CANADA
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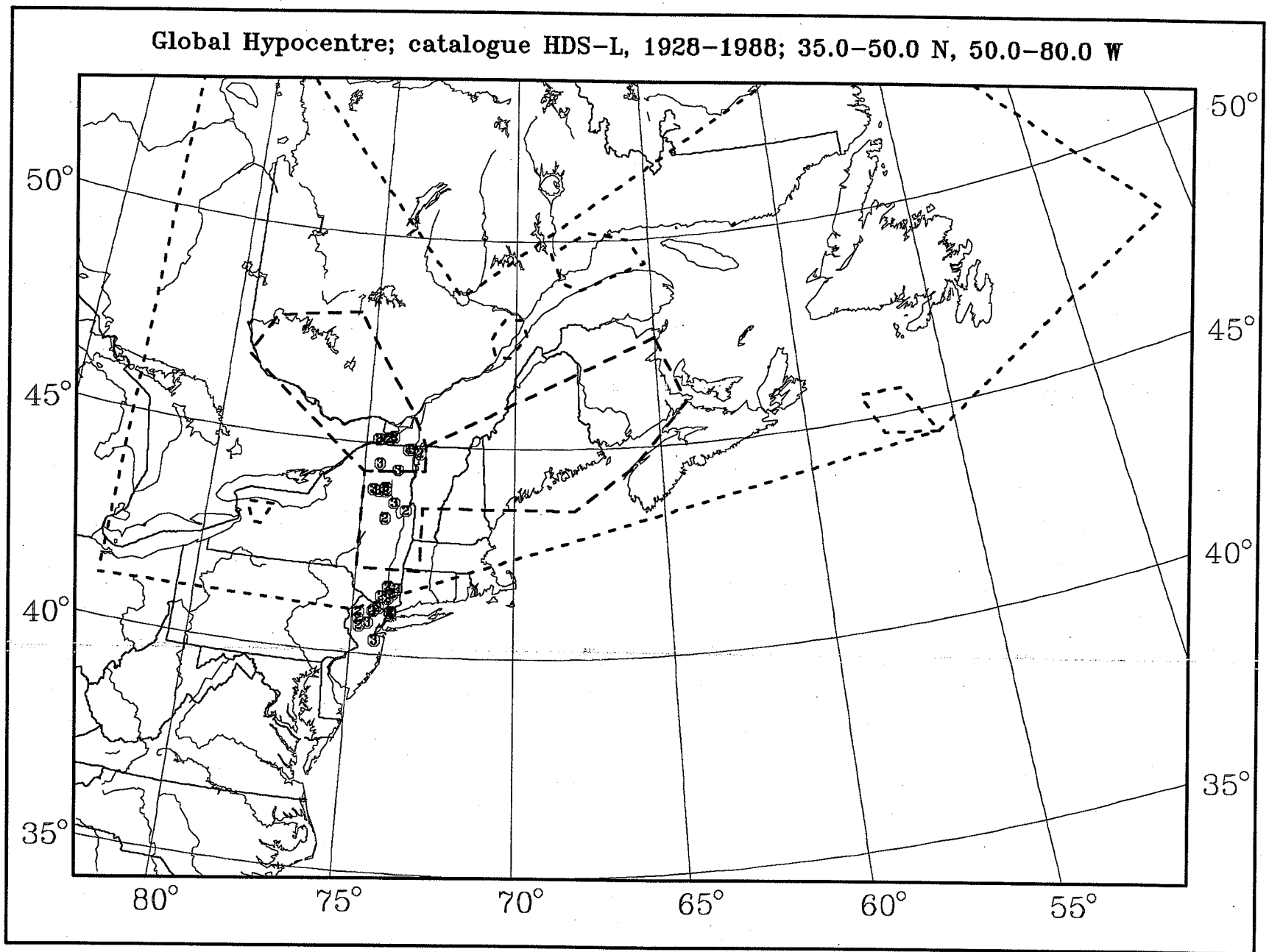
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45°
40°
35°
80°
75°
70°
65°
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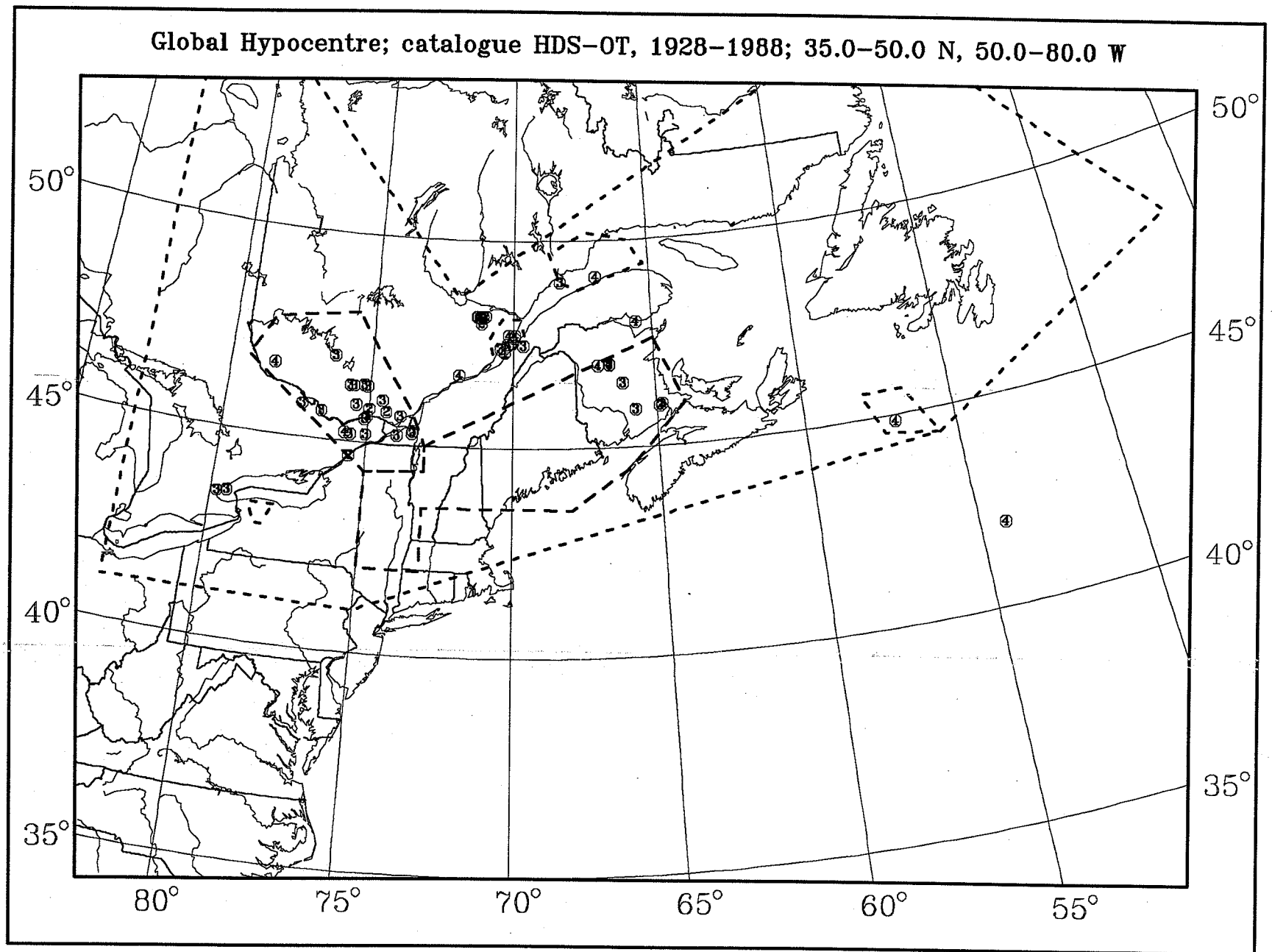
PROJECTION DE LAMBERT
GEOPHYSICS DIVISION GEOLOGICAL SURVEY OF CANADA
DIVISION DE LA GEOPHYSIQUE COMMISSION GEOLOGIQUE DU CANADA
0 200 400 600 800 1000 1200 1400 1600 1800 2000 2200 2400 2600 2800 3000 KM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45°
40°
35°
80°
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LAMBERT CONFORMAL
PROJECTION DE LAMBERT
GEOPHYSICS DIVISION GEOLOGICAL SURVEY OF CANADA
DIVISION DE LA GEOPHYSIQUE COMMISSION GEOLOGIQUE DU CANADA
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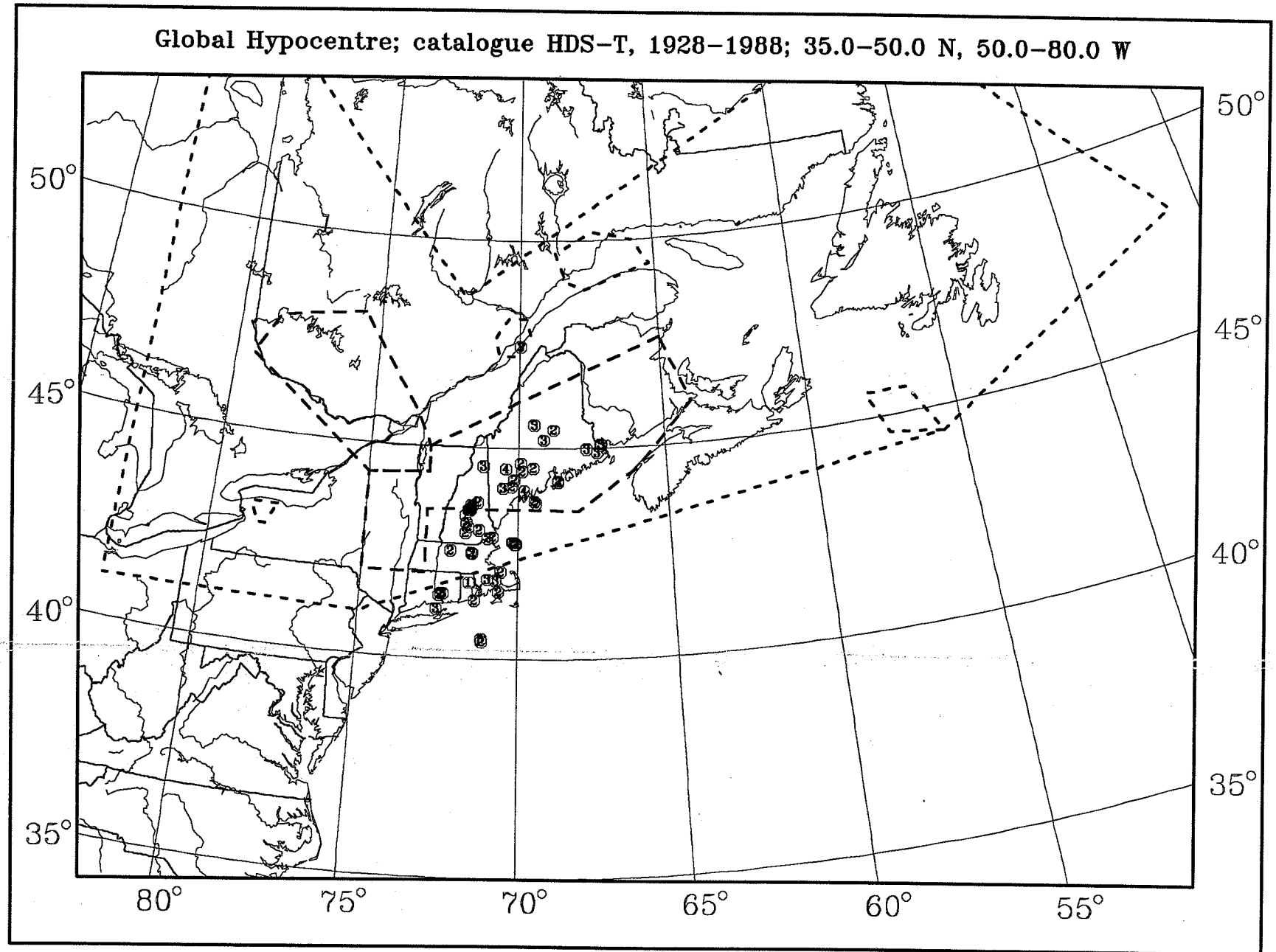
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45°
40°
35°
80°
75°
70°
65°
60°
55°
LAMBERT CONFORMAL
PROJECTION DE LAMBERT
GEOPHYSICS DIVISION GEOLOGICAL SURVEY OF CANADA
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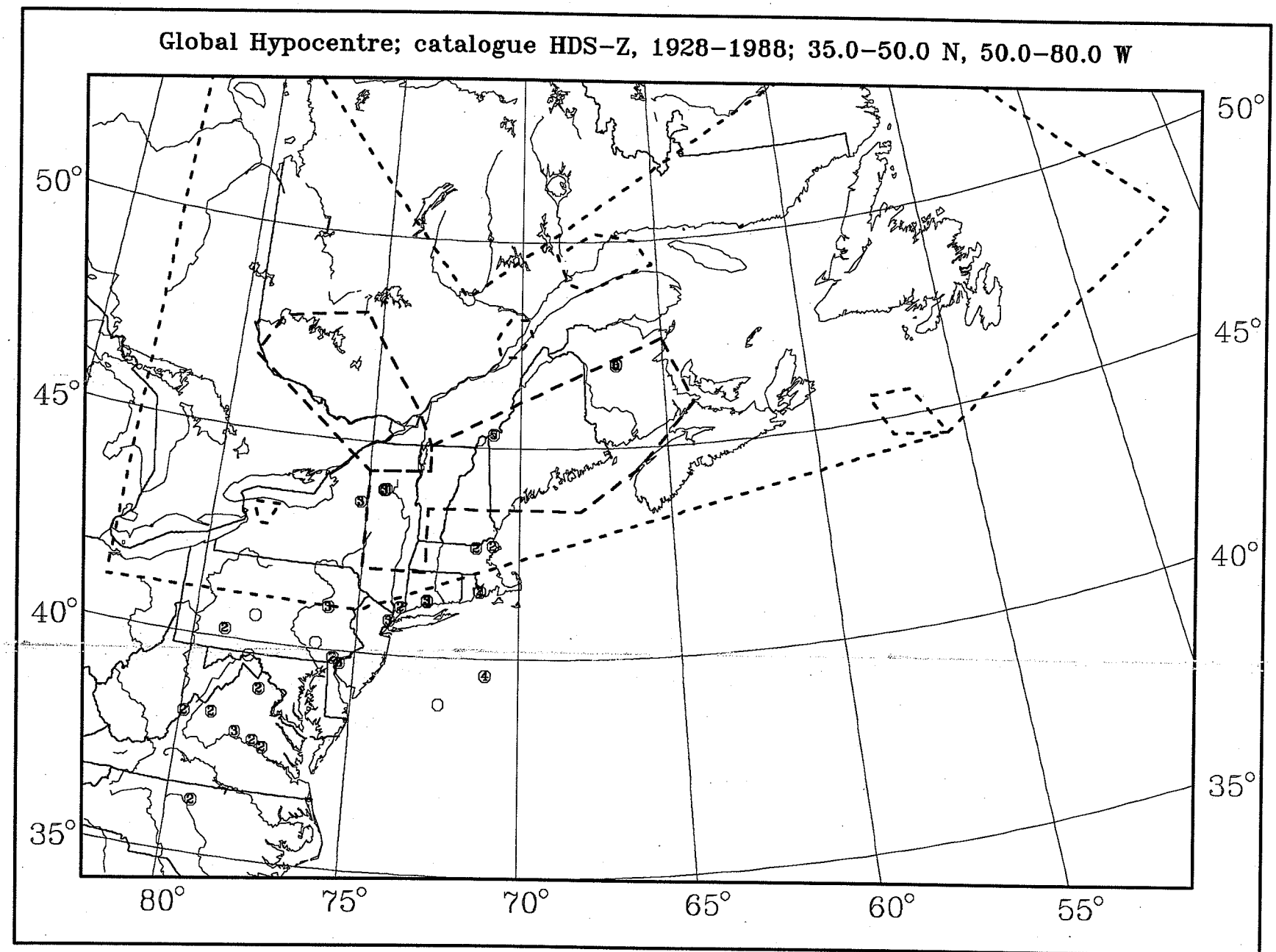
0 200 400 600 800 1000 1200 1400 1600 1800 2000 2200 2400 2600 2800 3000 KM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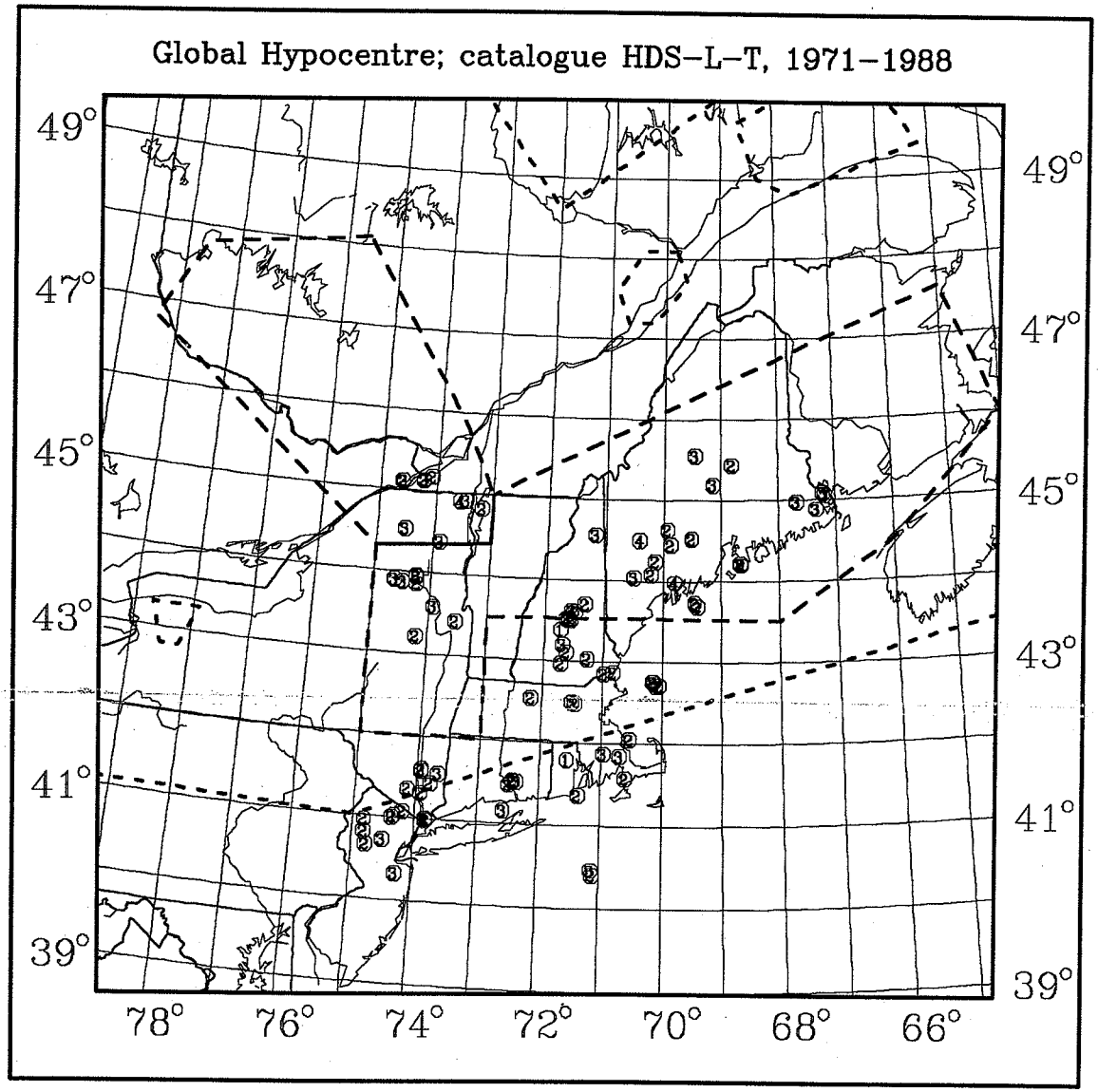
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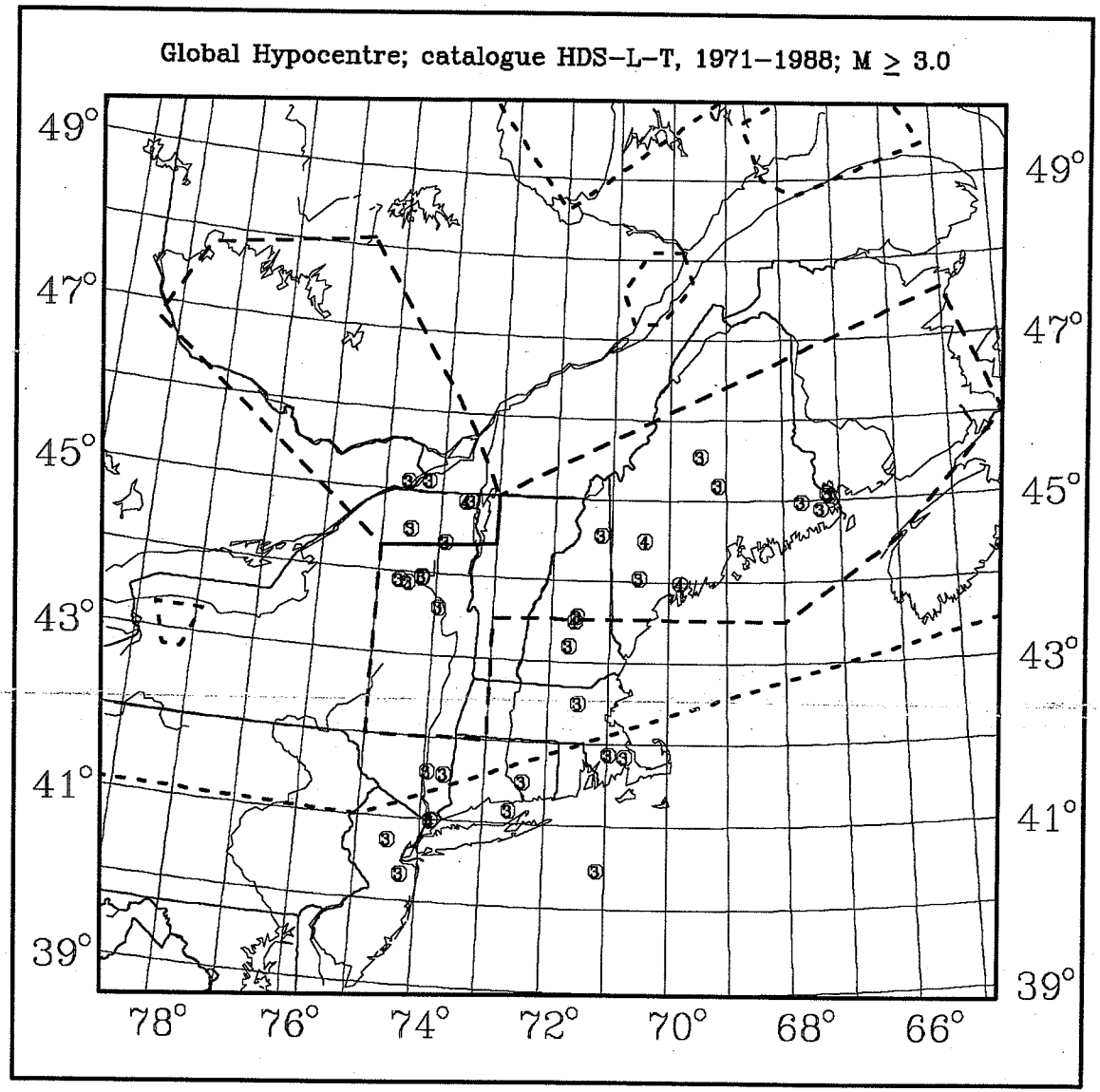
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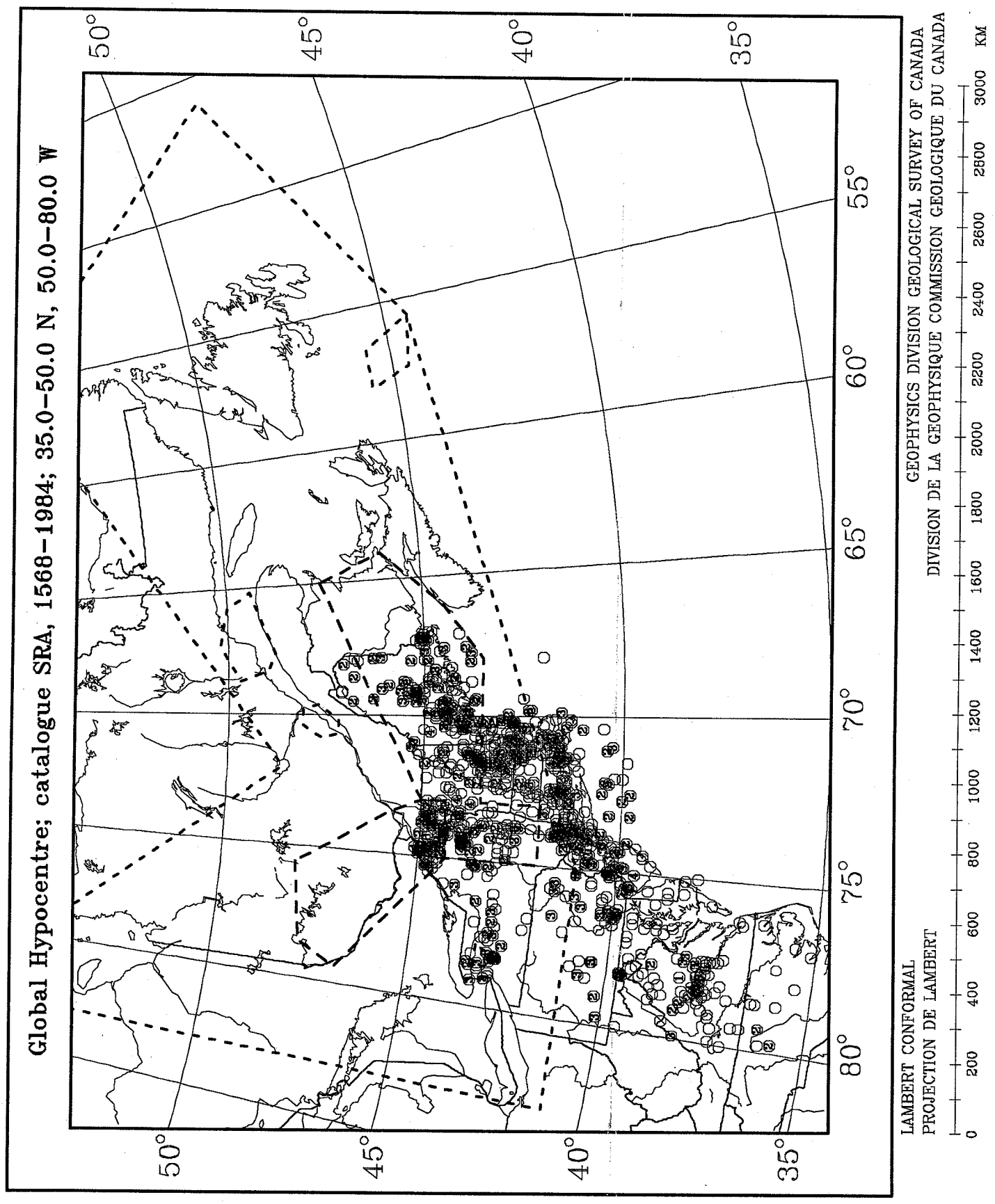
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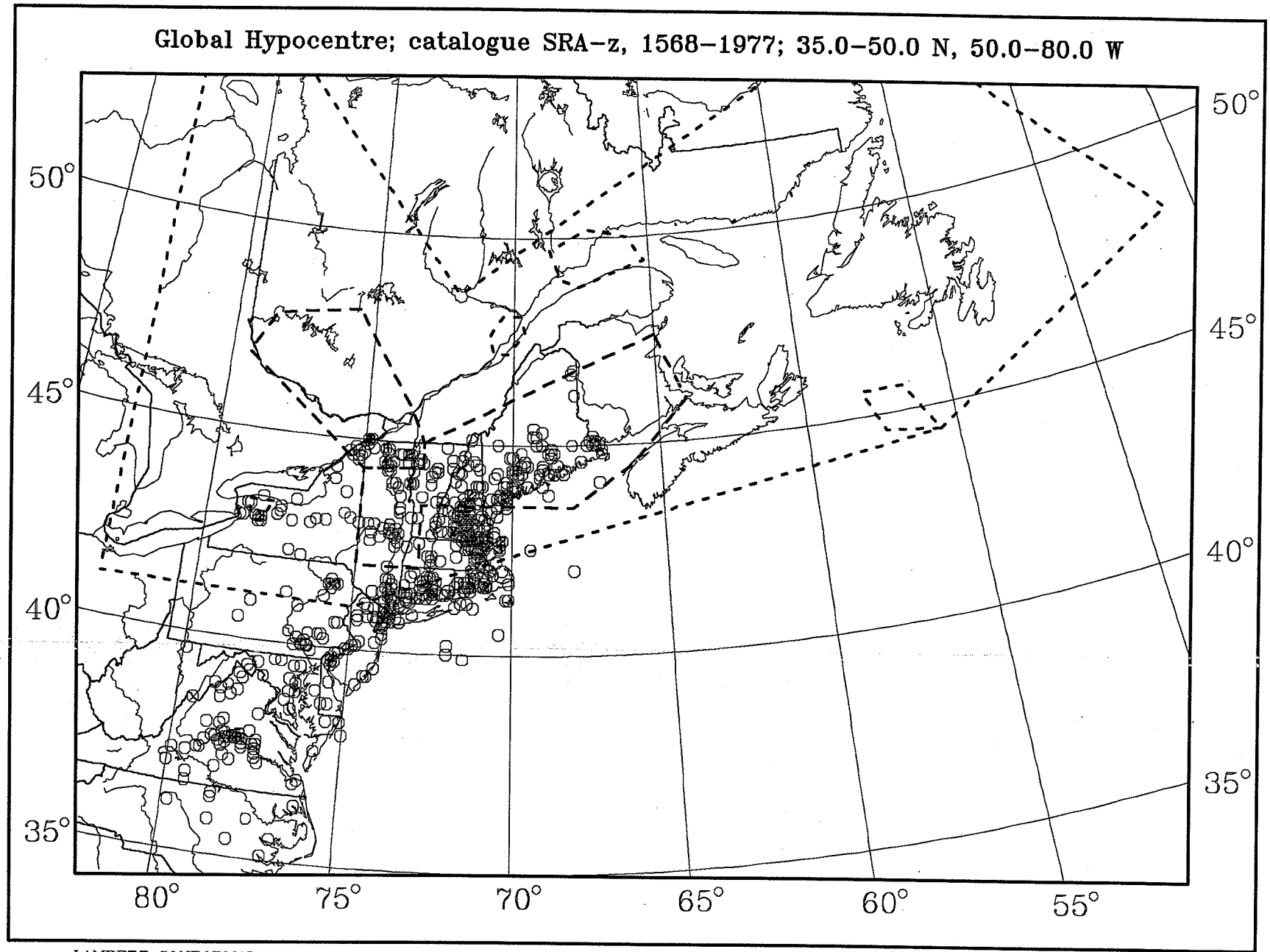
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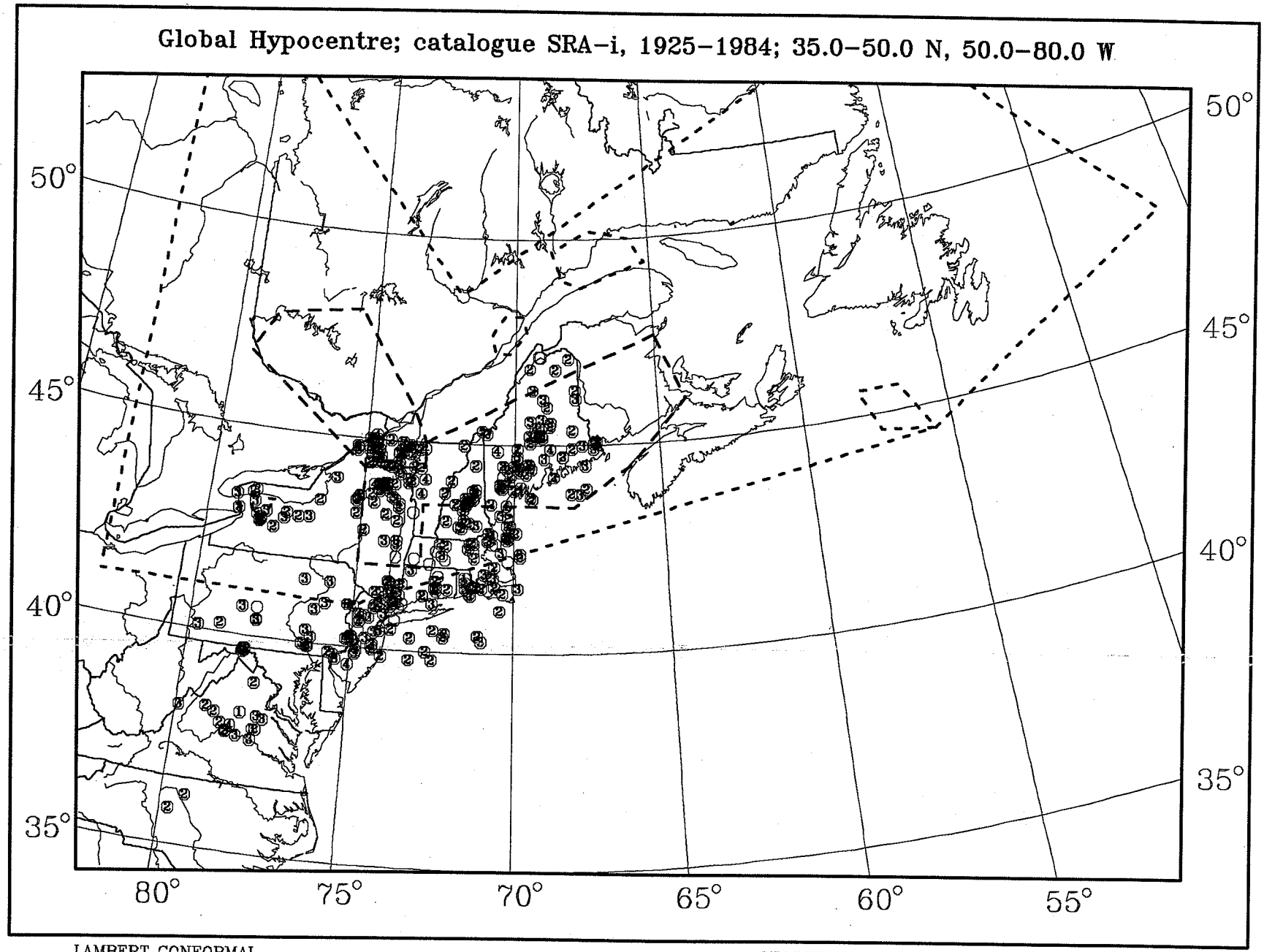
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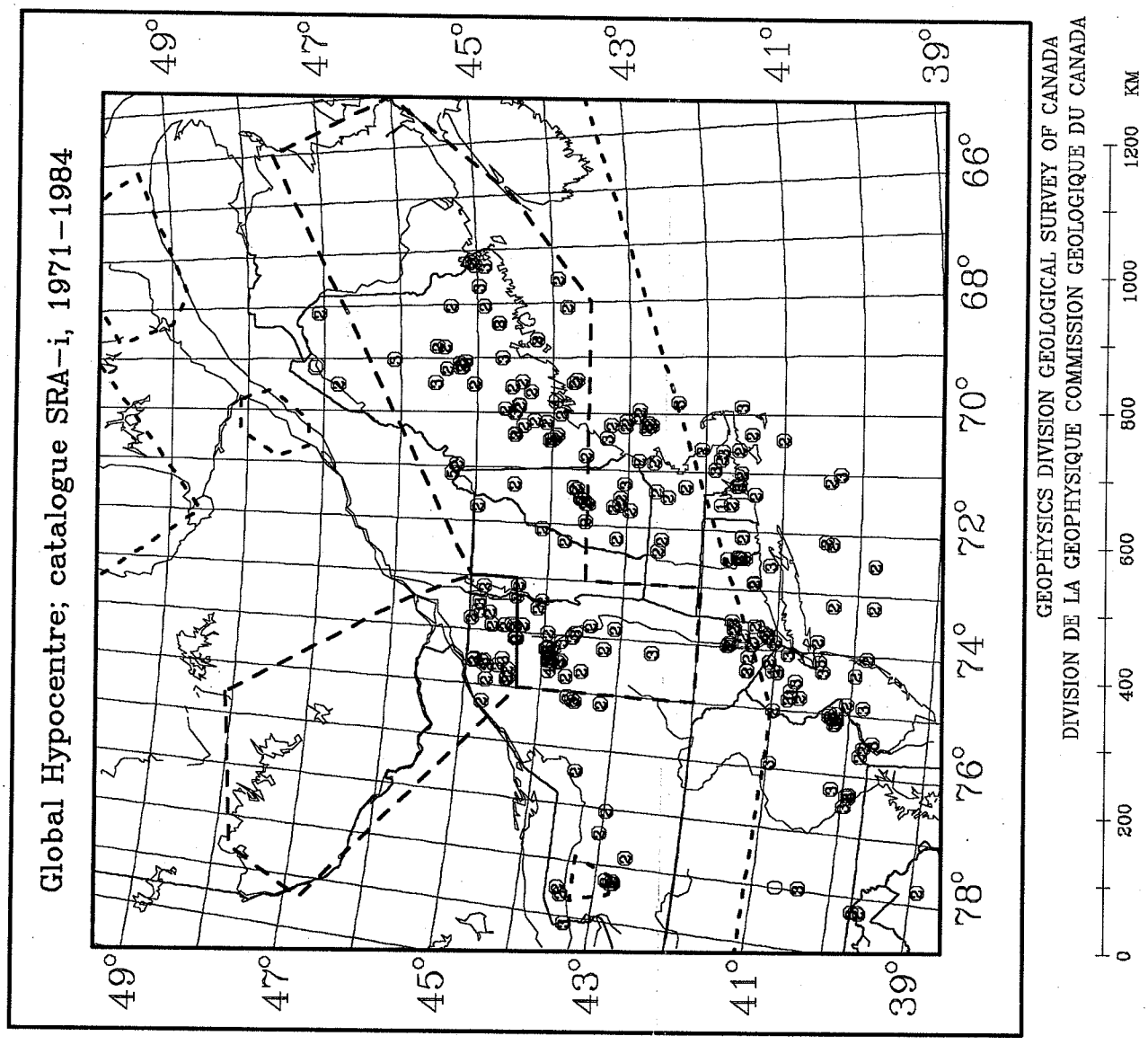
Global Hypocentre; catalogue SRA–i, 1971–1984
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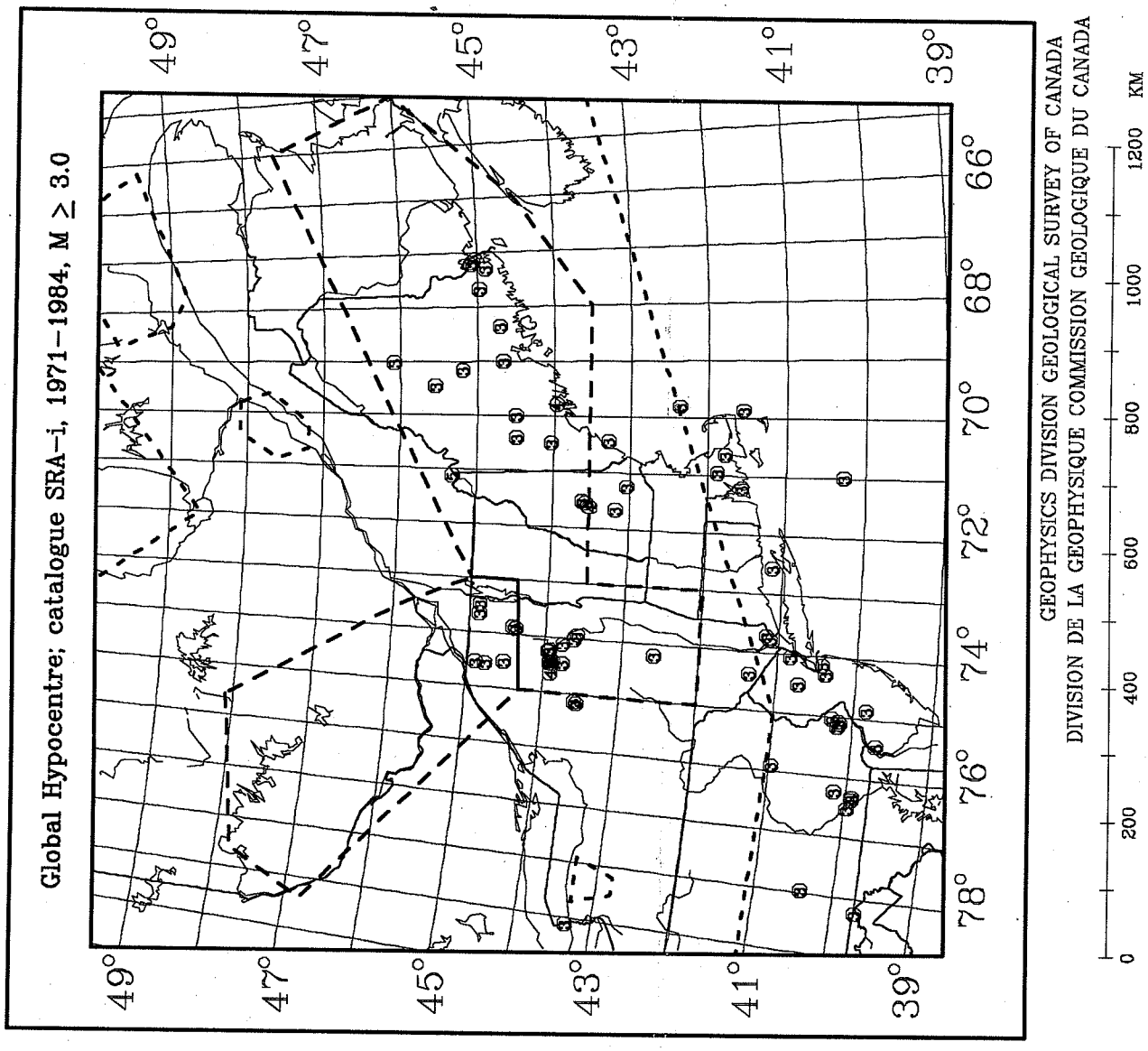
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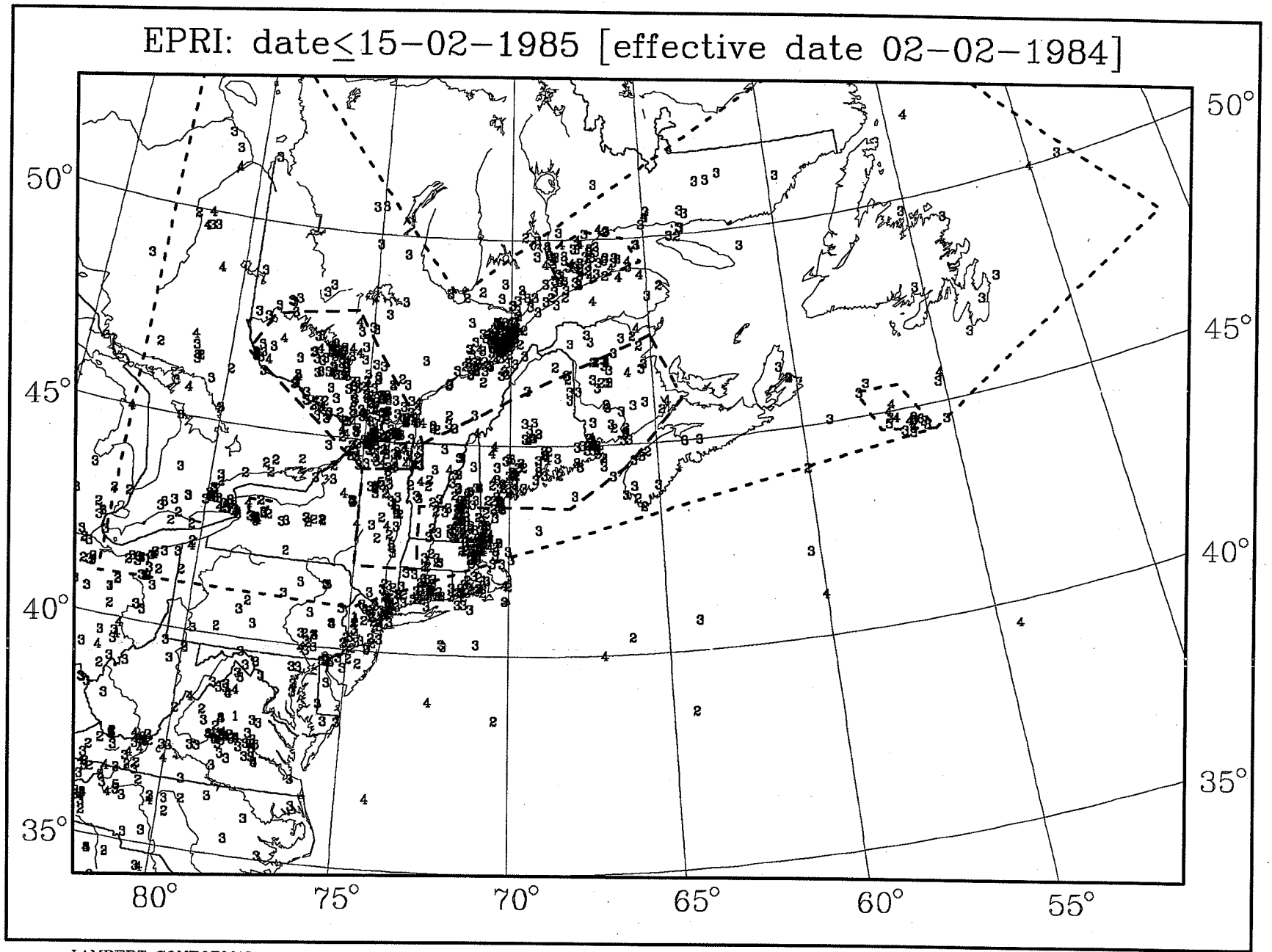
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PROJECTION DE LAMBERT
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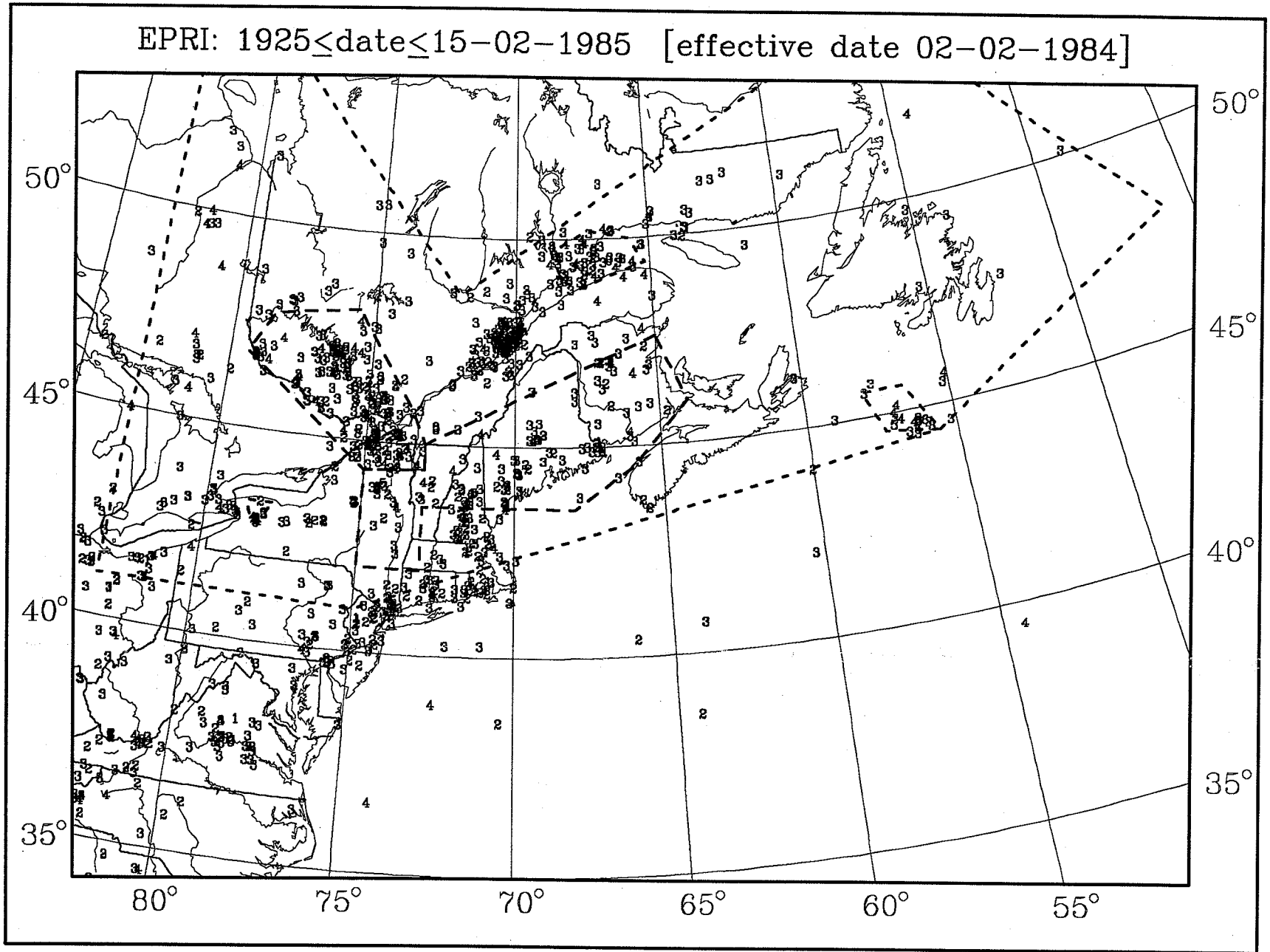

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PROJECTION DE LAMBERT

GEOPHYSICS DIVISION GEOLOGICAL SURVEY OF CANADA
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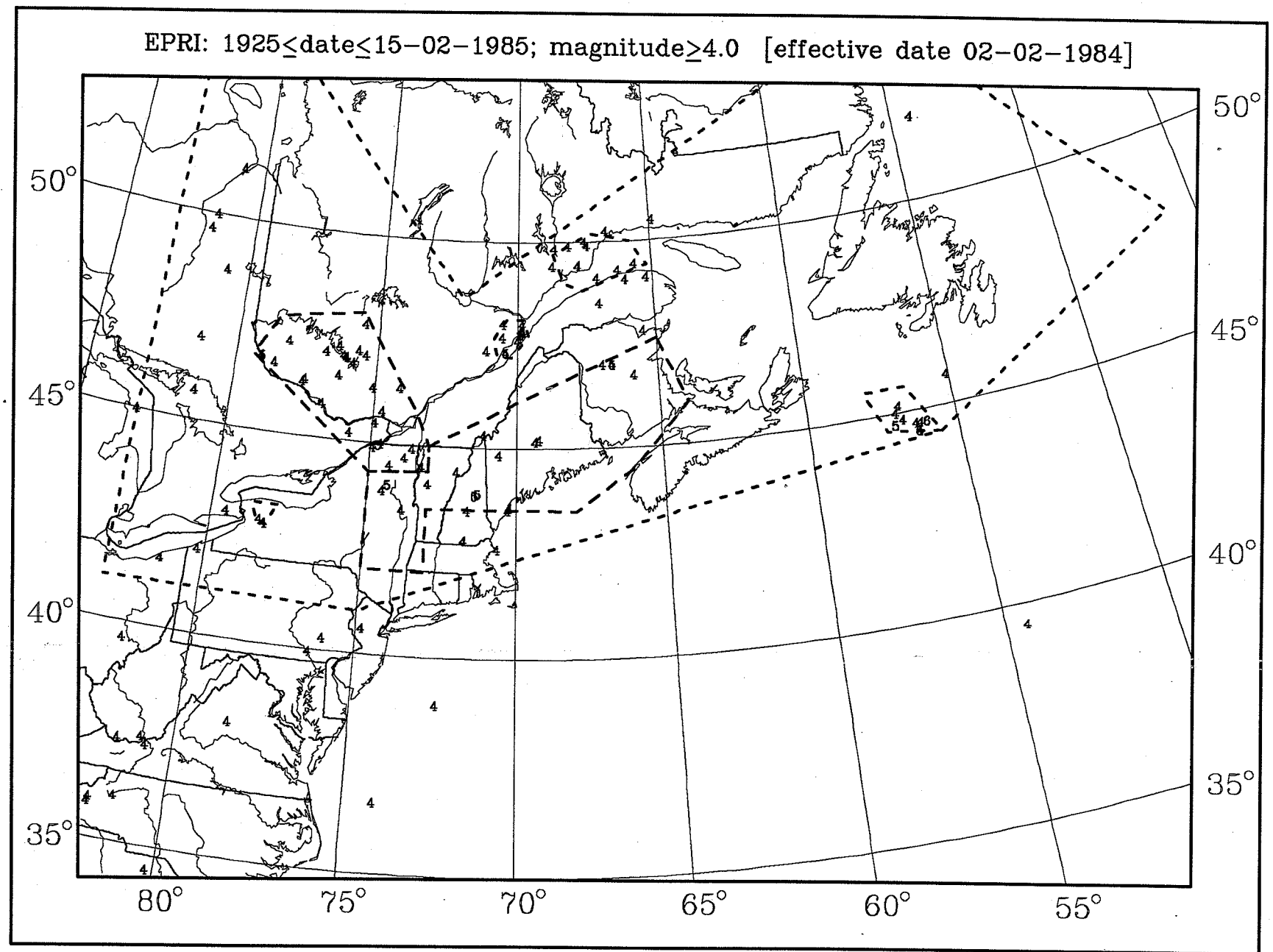

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PROJECTION DE LAMBERT

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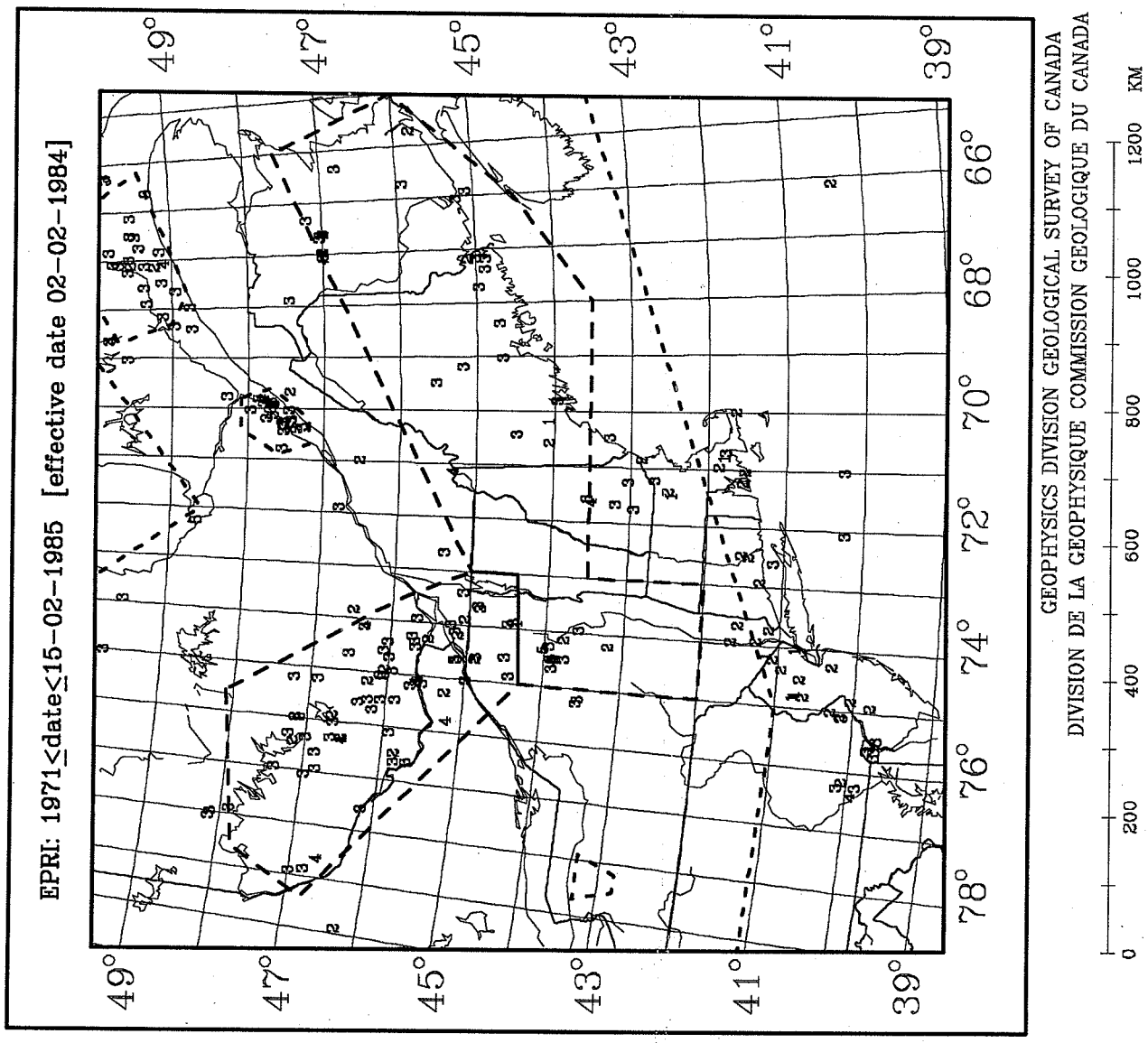
EPRI: 1971≤date≤15-02-1985 [effective date 02-02-1984]
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APPENDIX C

NEW ENGLAND AND NEW BRUNSWICK EARTHQUAKE DISTRIBUTION

The maps and analyses of Appendix C parallel those of Appendix A. General explanations are not repeated here. The geographic area selected includes the Maritimes, southern Québec and eastern Ontario, New England and New York State, an area large enough to show the 1982 NAP source zone and neighbouring source zones. References in this appendix will be found in the *Reference* section at the end of the main report (page 10). The maps are not numbered but arranged in order of their presentation in the text below. Refer to the *Table of Contents*, page iv, for the page number of a specific map.

Maps: NAP/NE–NB (CEEF data only) and seismograph stations

The following nine epicentre maps appear in this Appendix on pages C–5 to C–13.

- *map: Earthquakes, date ≤31–12–1977* (period covered by the *1982 Open File*)
- *map: Earthquakes, date ≤31–12–1929* (Epicentres are virtually all non-instrumental.)
- *map: Earthquakes, 01–01–1930 ≤date ≤31–12–1977* (Epicentres are mostly instrumental.)

Events prior to 1930 in New Brunswick and New England are seen to lie in similar areas to those in the 1930–1977 period. Hence pre-1930 events are not critical for drawing zone boundaries. These three maps illustrate that the boundaries of the NAP, as was admitted in the *1982 Open File* (pages 78 and 81), were drawn somewhat arbitrarily and not necessarily to separate areas of greater seismic activity from those of lesser activity.

- *five maps: Earthquakes, 01–01–1978 ≤date ≤31–12–1990,* all magnitudes, then four magnitude subsets, namely M≥4.0, M3, M2, M<2.0

The 1978–1990 map shows that the CEEF lacks data in New York State, as noted earlier in Appendix A.

M≥4.0 events since 1978 within the zone of interest (NAP/NE–NB) occurred as follows: Miramichi, N.B., January to May 1982, four M5 and five M4; Trousers Lake, N.B., June 1982, M4: New Hampshire, January 1982, M4; Maine, May 1983, M4; Goodnow, N.Y., October 1983, M5. [Note that Goodnow had been located in the NAP zone, but would now lie in the revised WQU zone.] Scattered activity occurred over Maine and New Brunswick, at both the M3 and M2 level, and in New Brunswick at M less than 2. Few events less than M2 were located in New England; a number of such small events were located in New Brunswick.

- *map: Earthquakes, 01–01–1982 ≤date ≤31–12–1990*

The best monitoring of New Brunswick began in October 1981, with the opening of four ECTN stations at GSQ, EBN, GGN and LMN; KLN was added in late January 1982. Prior to the extension of the ECTN to the Maritimes, these three provinces were monitored routinely at the magnitude 3 level, as illustrated on the station maps below (pages C–15 and C–16). Detection levels were not uniform over the entire area of the NAP/NE–NB zones in the 1982–1990 period.

Maps of Canadian seismograph stations for selected years

Table C–1 and its related map (page C–14) show the Canadian seismograph stations that have monitored New Brunswick, New England and adjacent areas from 1915 to 1990. [Refer also to the corresponding table and map in Appendix A (pages A–4 and A–17).] Stations were not in simultaneous operation, as can been seen from the table. Stations operated at various sensitivities. In addition, some produced continuous analogue records, others only digital event files for triggered events. Note that the Charlevoix–Kamouraska array has not been plotted on any of these maps nor included in Table C–1.

Table C-1

CANADIAN STATIONS MONITORING EASTERN CANADA (1915 to 1990) **
[Note: not in simultaneous operation, not comparable sensitivities]

Code	Lat(N) (deg)	Long(W) (deg)	Elevation (m)	Opening	Closure	* Station Type
HAL	44.6300	63.6000	0.0560	1915- ,	--	; regional 1971-04
SIC	50.1717	66.7383	0.2830	1963-01,	1989-04;	regional
UNB	45.9500	66.6300	0.0560	1971-10,	--	; regional
MNQ	50.5333	68.7744	0.5640	1974-11,	--	; ectn
LMQ	47.5483	70.3267	0.4190	1976- ,	--	; regional
GSQ	48.9142	67.1106	0.3980	1981-10,	--	; ectn
EBN	47.4620	68.2420	0.1950	1981-10,	1991-	; ectn
GGN	45.1170	66.8220	0.0300	1981-10,	1991-	; ectn
KLN	46.8433	66.3717	0.4110	1981-10,	1991-	; ectn
LMN	45.8520	64.8060	0.3630	1981-10,	--	; ectn
HTQ	49.1917	68.3939	0.1230	1982-04,	1991-	; ectn
GBN	45.4070	61.5130	0.0380	1983-05,	--	; regional
SLQ	47.6662	69.0103	0.3200	1984-06;	--	; regional

ectn: eastern Canada telemetered network
* for details see, for example, Munro *et al.* (1990), Stevens (1980).
** see also Table A-1 in Appendix A for the remaining Canadian stations monitoring eastern Canada during this period.

The magnitude threshold for location of earthquakes within the NAP/NE–NB zone is shown on maps for the station network in and near this area for the years 1968, 1975, 1982 and 1990 (pages C–15 to C–21).

The method and assumptions regarding magnitude detection limits were presented in Appendix A (page A–3). The assumed detection limits were as follows: *magnitude 3 at 300 km, magnitude 2.5 at 150 km* and *magnitude 2.3 at 100 km.*

- *map: 1968*: 300-km radius circles drawn

Magnitude detection/location was not complete down to magnitude 3.0 in 1968 for most of the Maritimes and Gaspé Peninsula nor for most of the adjacent United States.

- *two maps: 1975*: 300-km and 150-km radius circles drawn

Magnitude detection/location by Canadian stations had improved by 1975 to about magnitude 3.0 in much

of New England and New Brunswick. However, the minimum magnitude in New Brunswick rose whenever UNB or HAL was not operating. The second map for 1975 demonstrates that magnitudes were certainly not complete to M2.5 anywhere in New Brunswick or New England. The M3–1975 completeness level assumed for the 1982 NAP was somewhat optimistic for New Brunswick, as demonstrated by these two station maps for 1975.

- *two maps: 1982*: 150-km and 100-km radius circles drawn

A dramatic improvement in detection/location occurred in 1982, as these two maps illustrate. Coverage was complete in New Brunswick to M2.5, although coverage of eastern Nova Scotia and Cape Breton remained at M3. Much of New England was monitored to M2.5, particularly when American data were available and could be combined with Canadian data.

The second map for 1982 illustrates that coverage at M2.3 was restricted largely to central and southern New Brunswick. In assessing magnitude completeness for the ECTN stations, it must be remembered that continuous analogue records were not produced at all stations monitoring the New England–New Brunswick region. Complete detection depended upon maintaining the triggering capability of each station and on avoiding lengthy station downtimes due to communications problems (usually telephone links and supermodems).

- *two maps: 1990*: 150-km and 100-km radius circles drawn

Magnitude completeness for New England and New Brunswick remained similar to that in 1982, i.e. complete at M2.5, not complete at M2.3. There was, however, an improvement in eastern Nova Scotia, Cape Breton and Prince Edward Island with the addition of station GBN in mid-1983.

Note that detailed monitoring by Canadian stations of the eastern part of the NAP/NE–NB area did not begin until late 1981. Monitoring of Nova Scotia and Prince Edward Island has always been less intensive than that of New Brunswick.

These station maps show that magnitude–year completeness at M 3.0 since 1975, as presented in the *1982 Open-File Report*, cannot be reduced to M 2.5 until 1982. No further reduction is justified in subsequent years for the New England–New Brunswick area taken as a single zone. Table C–2 presents the updated set of magnitude–year completeness pairs.

Table C–2

NE–NB: Magnitude–year completeness pairs to 1990

M, year
2.5, 1982
3.0, 1975
3.5, 1963
4.0, 1937
4.5, 1937
5.0, 1937
5.5, 1900

The recent closure (1991) of three New Brunswick stations (EBN, KLN and GGN) has degraded the network monitoring ability in the Maritimes so that a magnitude completeness level of 2.5 is no longer assured.

As for the WQU zone, caution should be exercised when interpreting patterns of seismicity in New Brunswick, New England and adjacent areas. Such interpretation should not be done in isolation from a knowledge of network monitoring ability and actual performance. Some apparent seismicity patterns may be an artifact of uneven monitoring in space as well as in time.

Earthquakes to the end of 1990, i.e. date ≤31–12–1990

To complete the series of epicentre maps, three maps for the period to 1990 are presented for all magnitudes, plus a subset with magnitude–year limitations (pages C–22 to C–24). The 1990 magnitude–year completeness maps are presented twice to show both the 1982 zone boundaries and the proposed boundaries for the new New England–New Brunswick zone. The magnitude–year completeness map for data to 1977, with 1982 zone boundaries, concludes this series of maps. [Note that the map legends are missing the two lines M≥4.3 1937+ and M≥4.8 1937+, corresponding to the square symbols.]

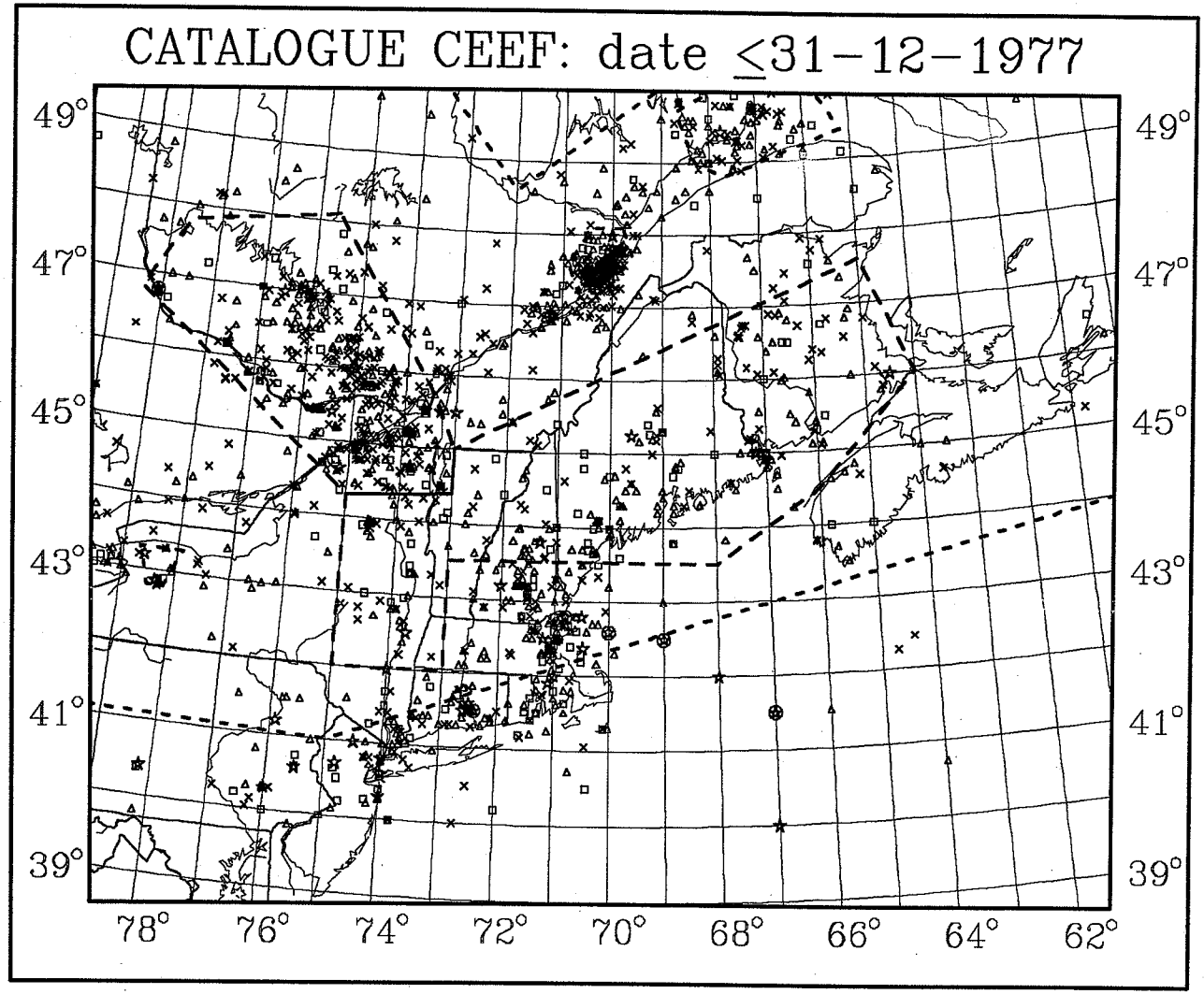
- *map: Earthquakes, date ≤31–12–1990, all magnitudes*
- *map: Earthquakes, date ≤31–12–1990, magnitude–year limits (1982 zone boundaries plotted)*
- *map: Earthquakes, date ≤31–12–1990, magnitude–year limits (revised zone boundaries plotted)*
- *map: Earthquakes, date ≤31–12–1977, magnitude–year limits (1982 zone boundaries plotted)*

This final map is similar to the corresponding map of the *1982 Open File* (page 79), with the notable addition of the March 1904 Maine–New Brunswick border earthquake, whose revised magnitude was published by Leblanc and Burke in 1985.

Conclusion: boundaries of the NE–NB zone

This series of earthquake and station maps for New Brunswick, New England and adjacent areas has confirmed the zone boundary changes proposed in Appendix B. The new boundaries of the NE–NB zone are defined in words near the end of Appendix B (page B–8) and by specific coordinates in Table 1 of the main report (page 3).

Final summary epicentre maps displaying the new boundaries are presented near the end of the main report (pages 14 to 17), as well as the magnitude–year completeness table (page 9) and remarks on the parameter M_x (page 9) for the NE–NB zone.



DEFINITIONS

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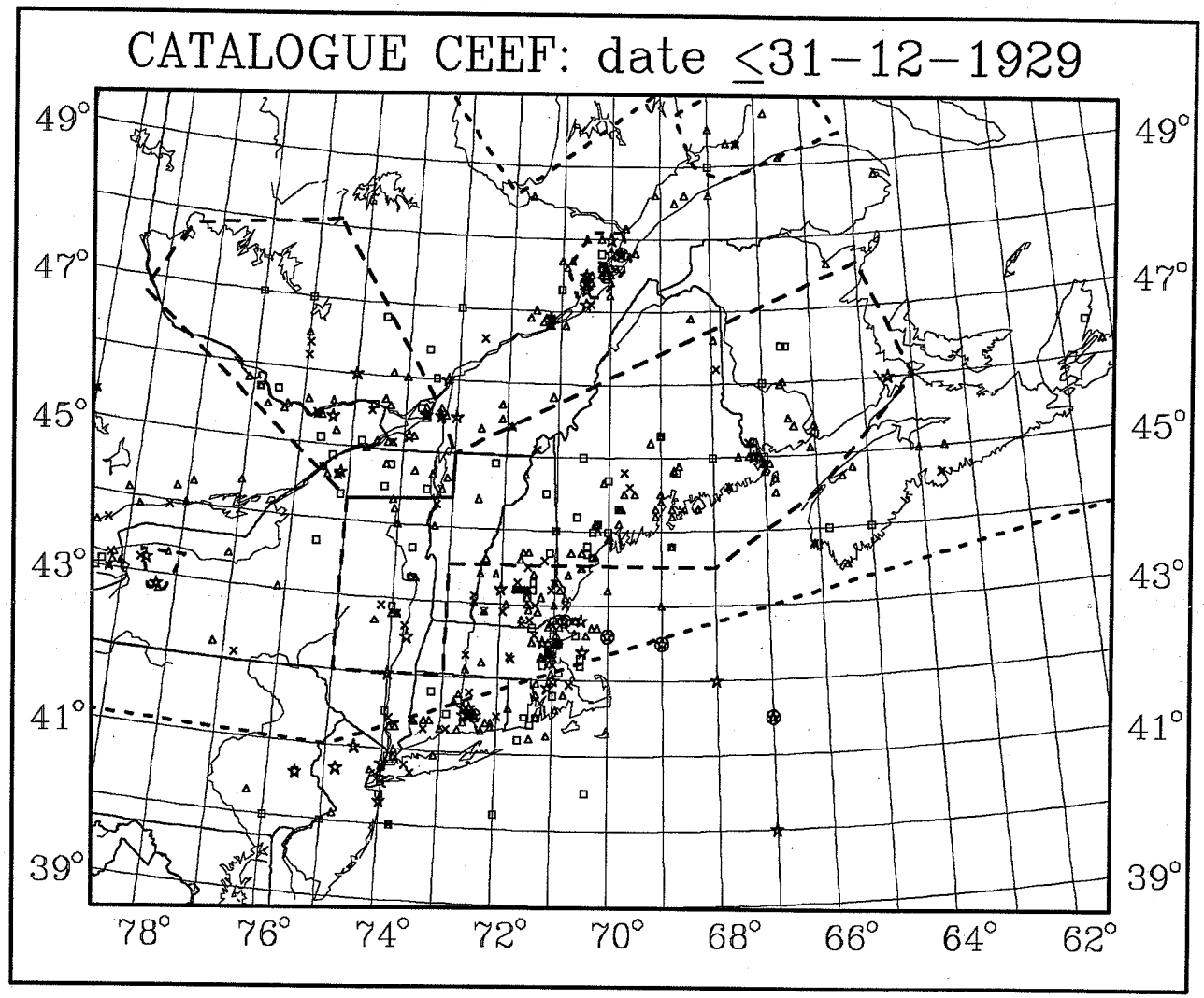
M≧3	△
M≧4	□
M≧5	☆
M≧6	⊛



DEFINITIONS

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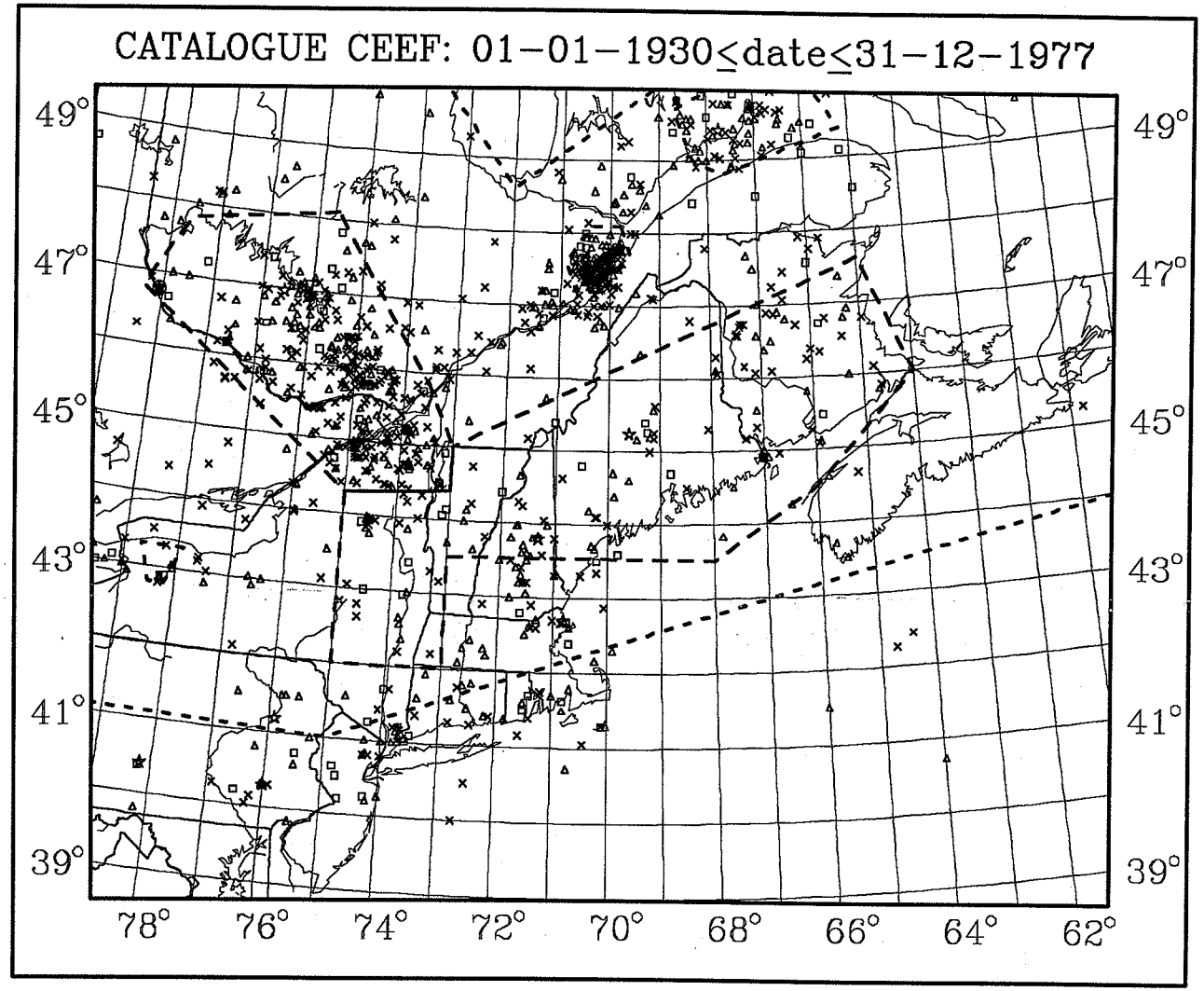
M≧3	△
M≧4	□
M≧5	☆
M≧6	⊛



DEFINITIONS

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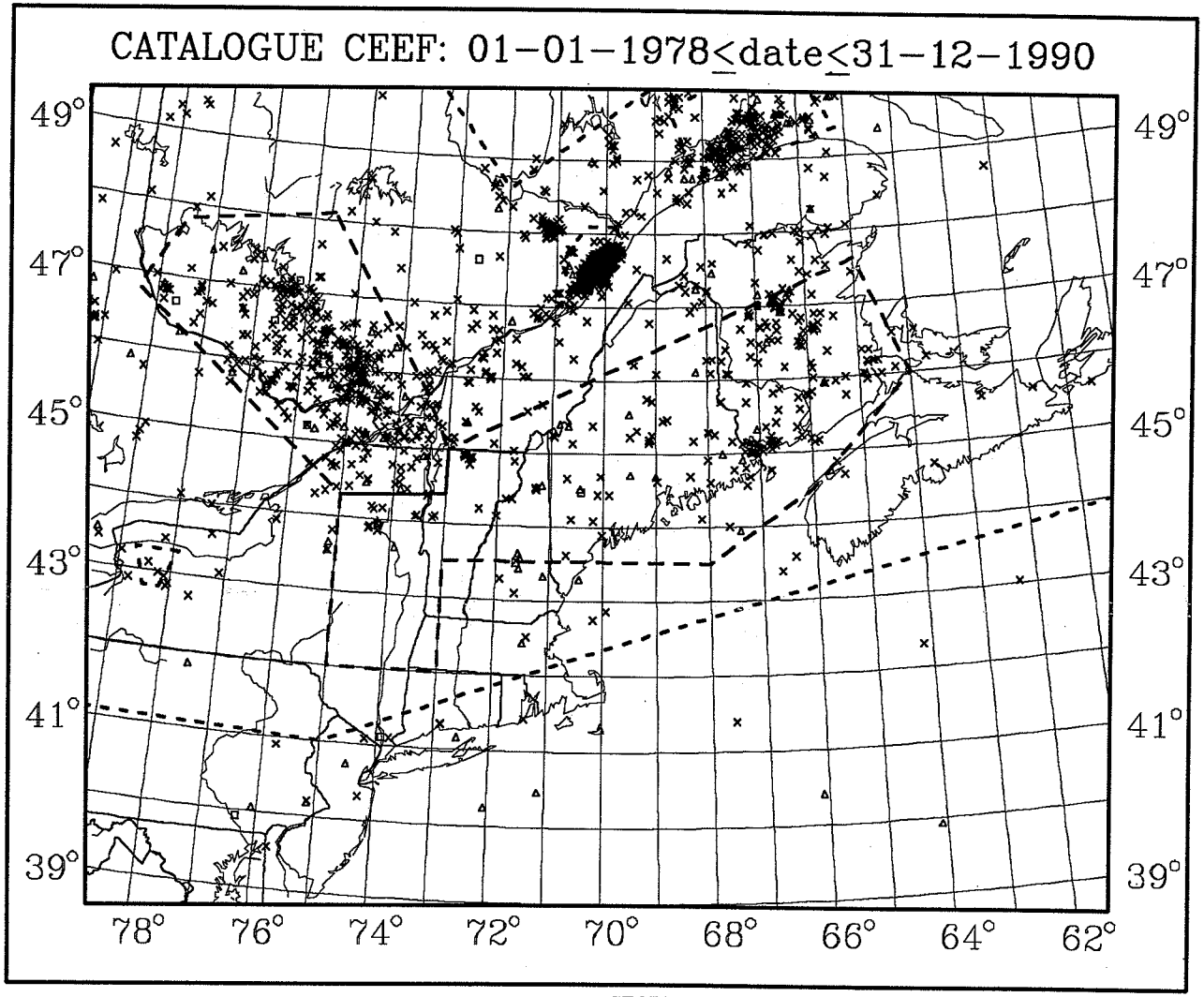

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M≧4	□
M≧5	☆
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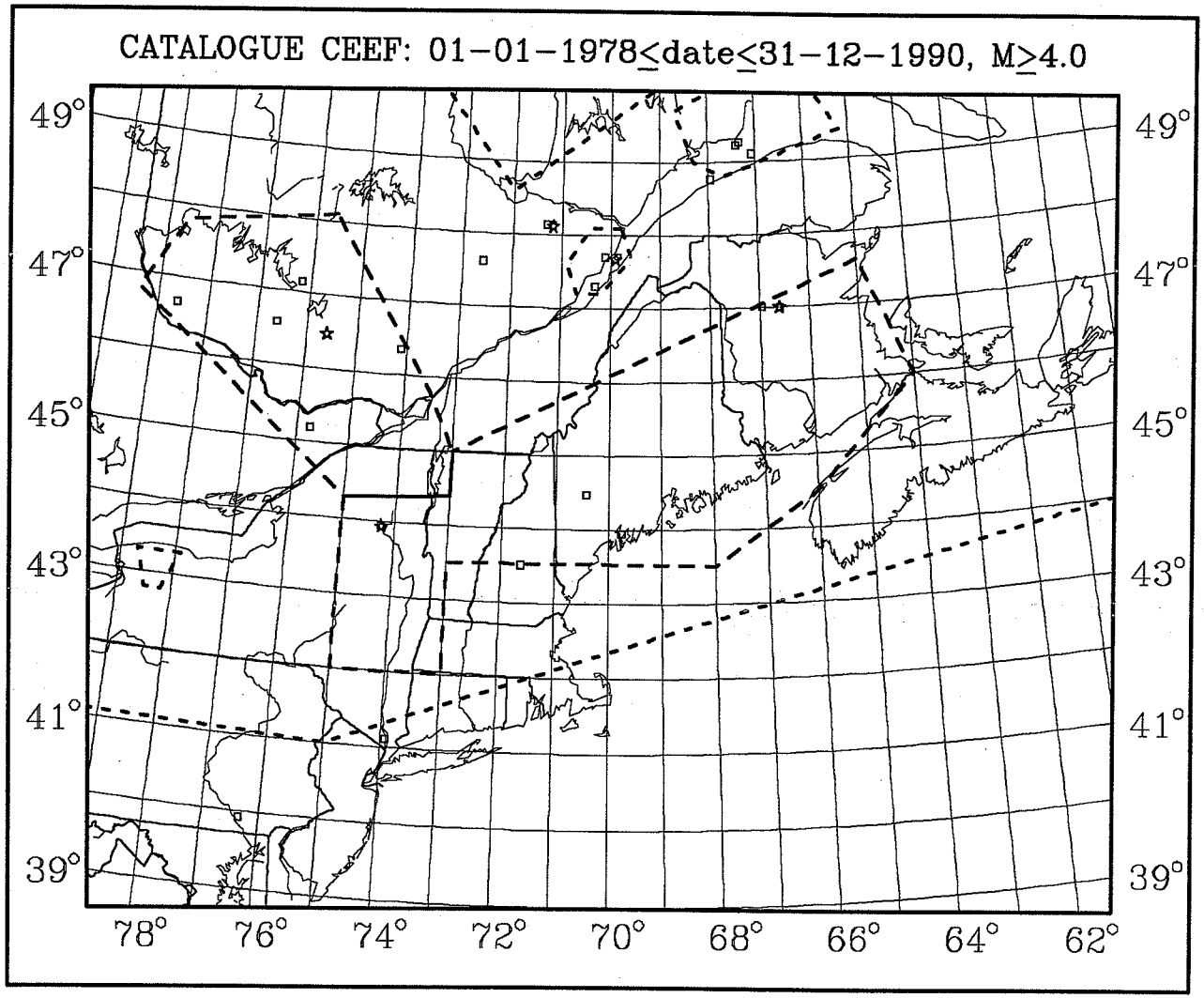

DEFINITIONS

M<3	×
M≧3	△
M≧4	□
M≧5	☆
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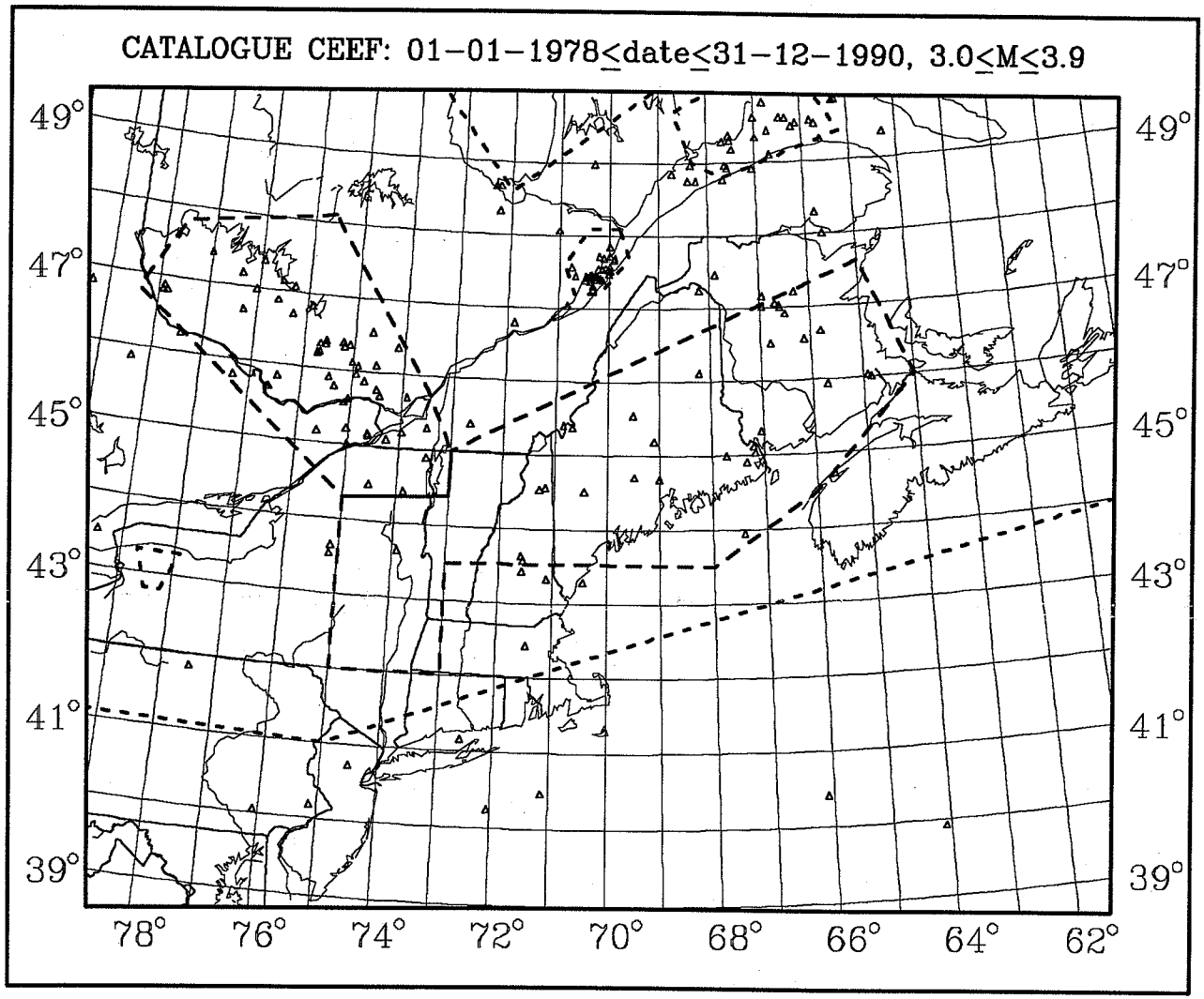

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M≧4	□
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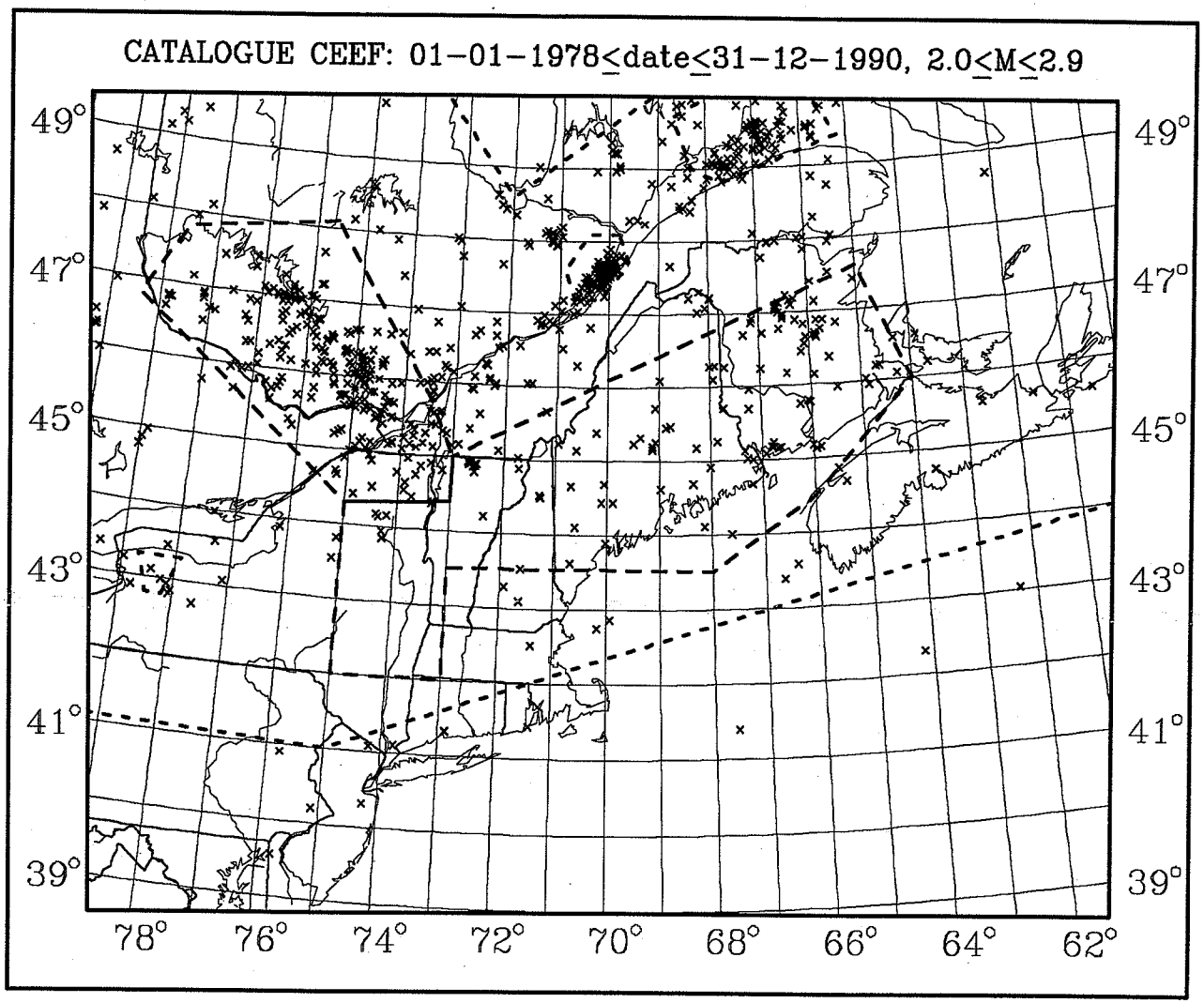

DEFINITIONS

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M≧3	△
M≧4	□
M≧5	☆
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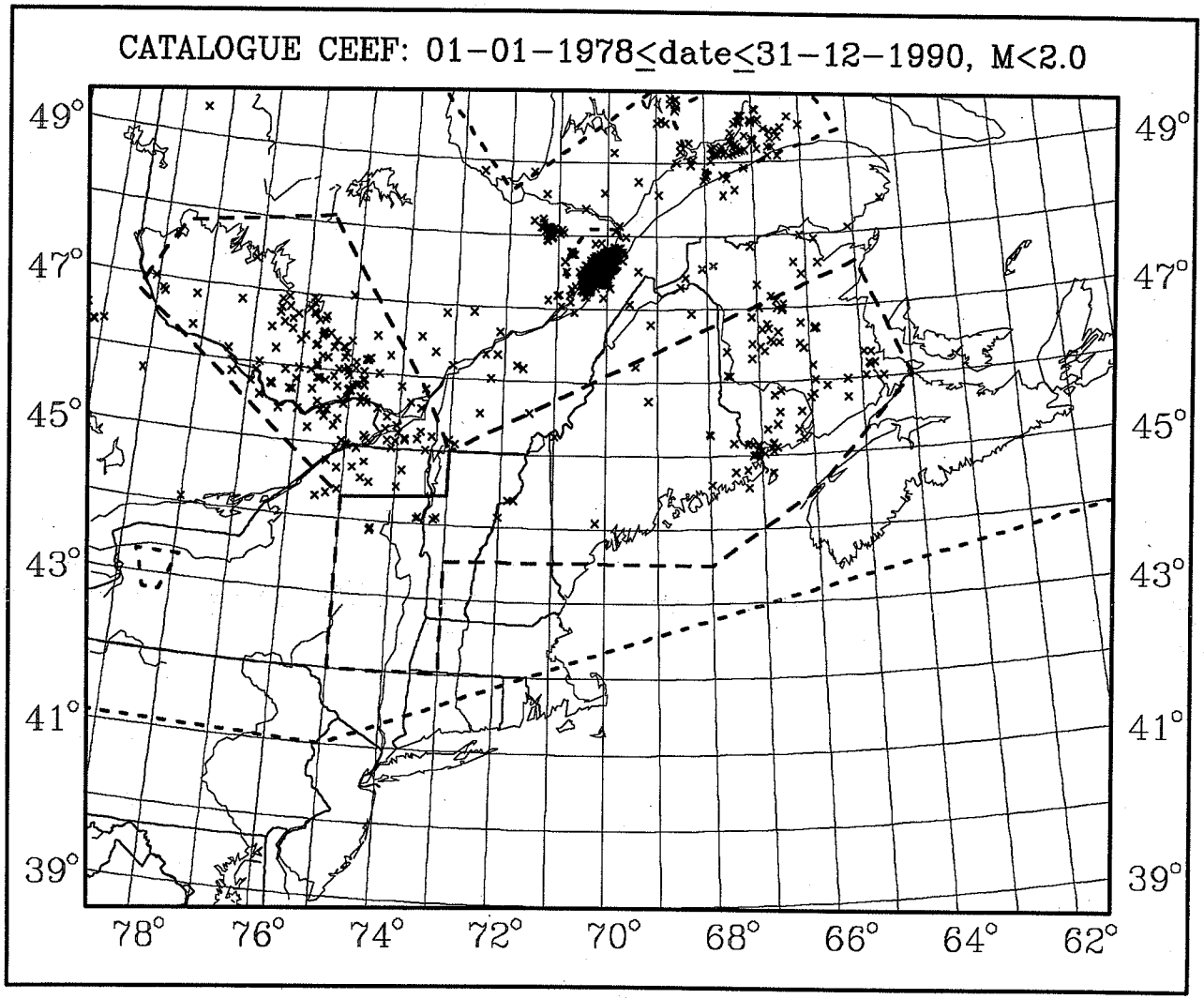

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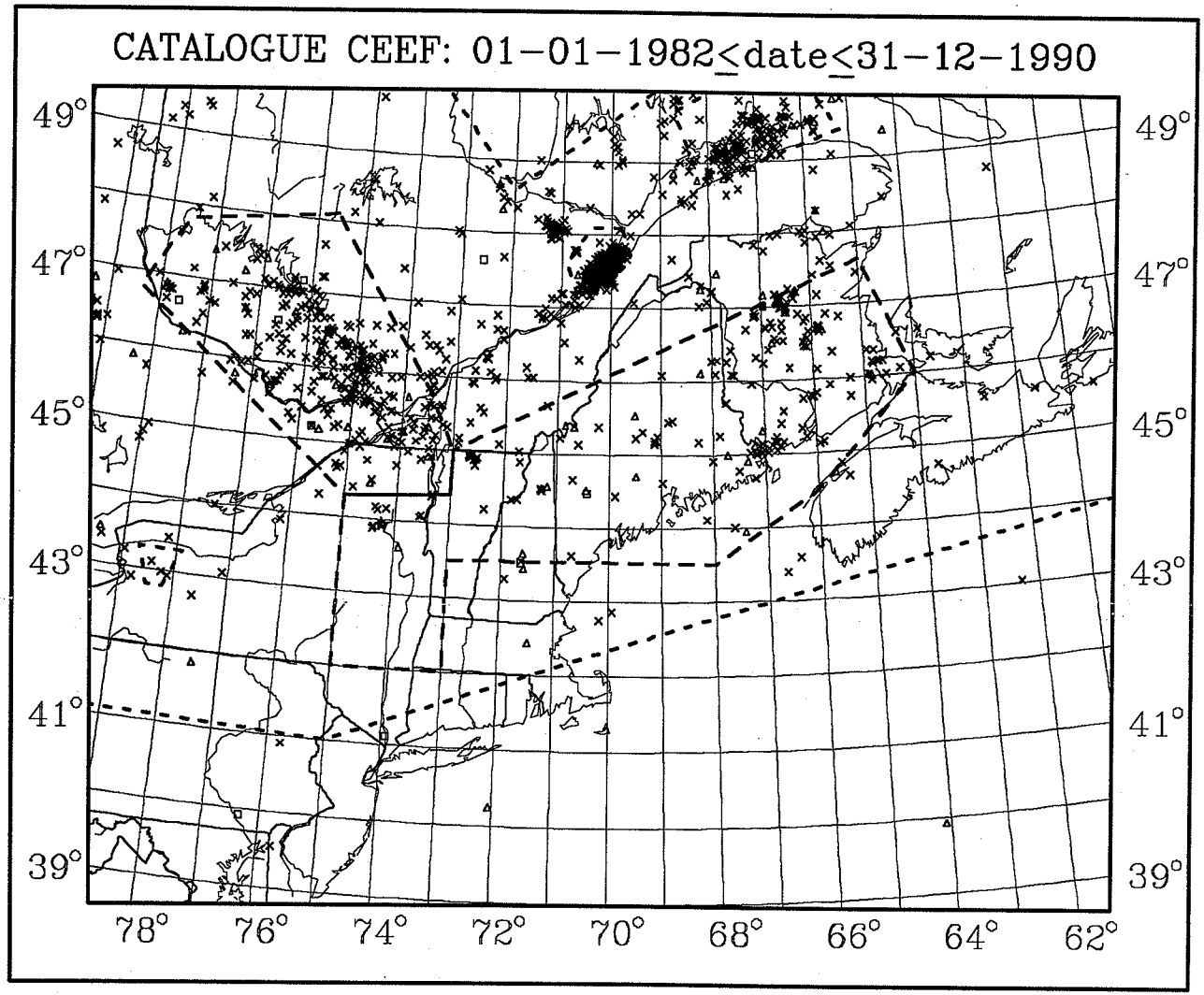

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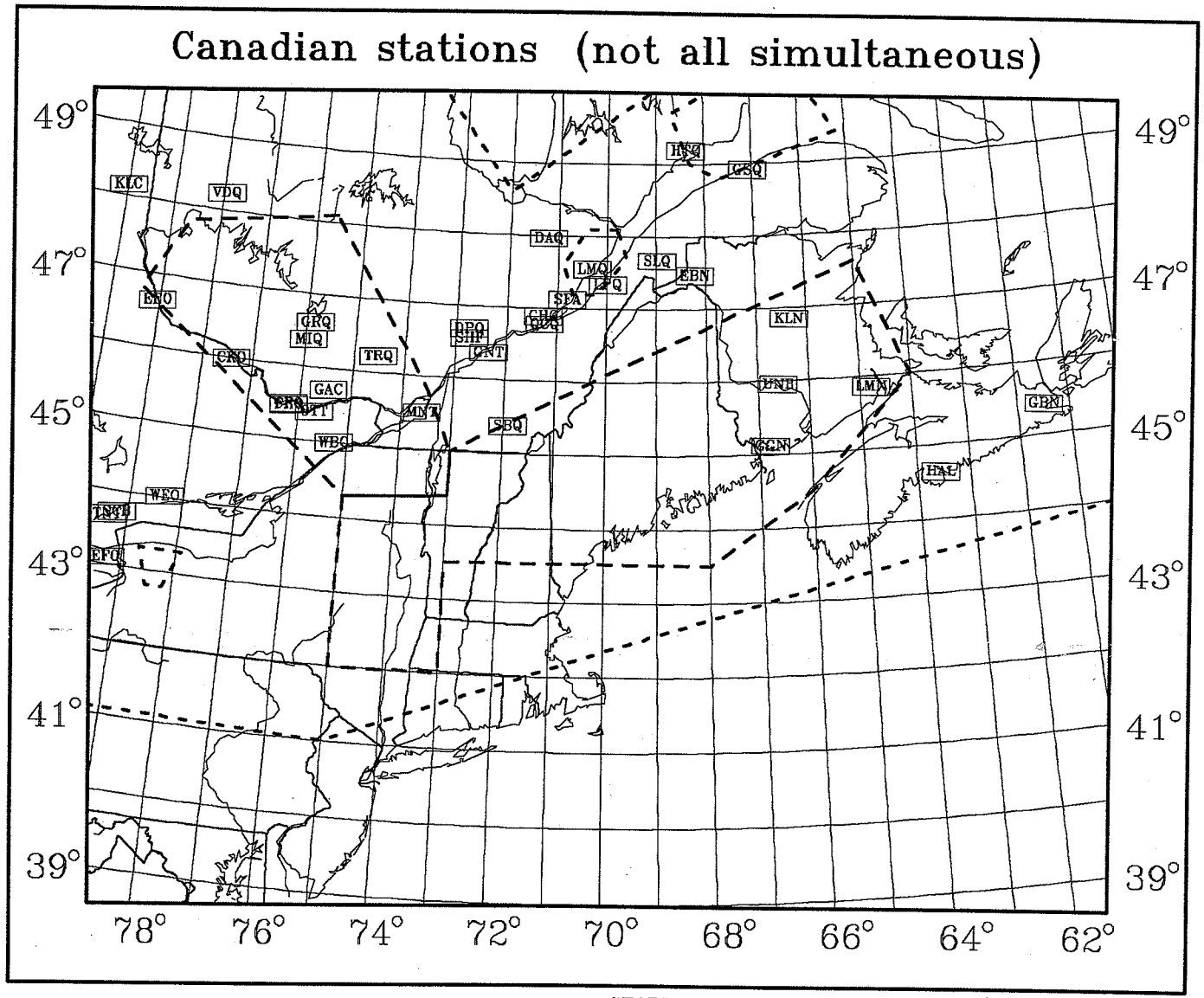

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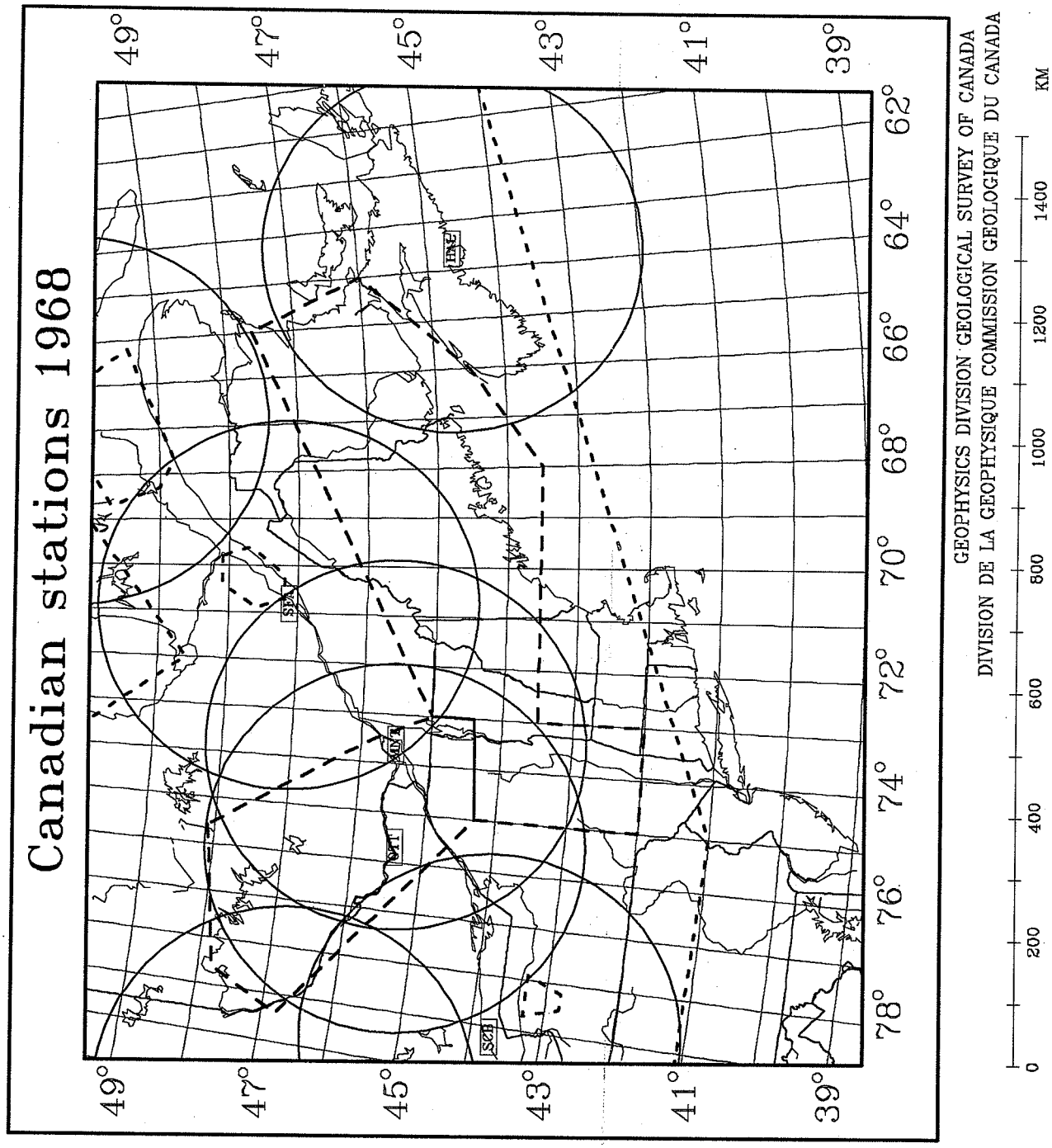
Canadian stations 1968
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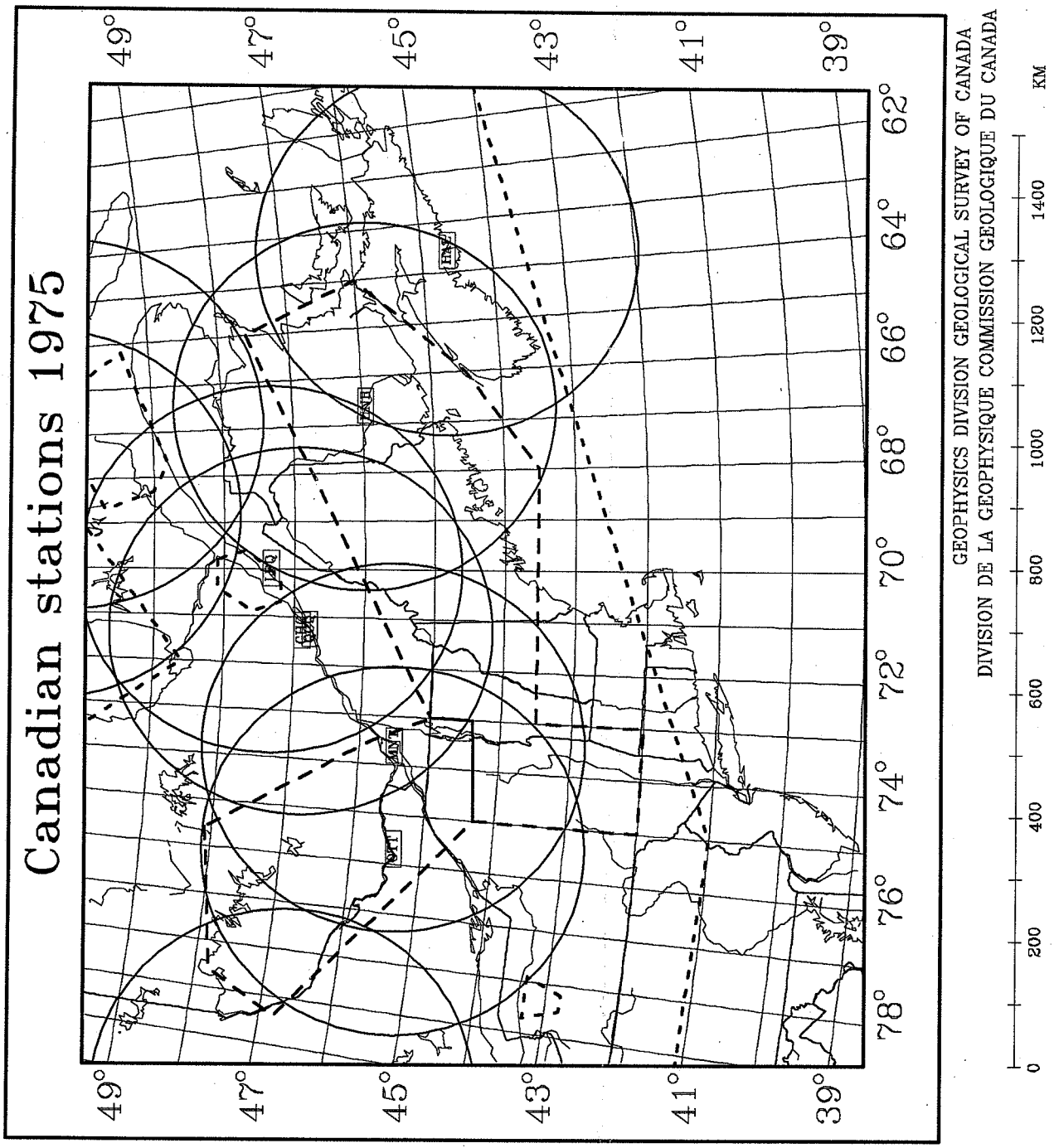
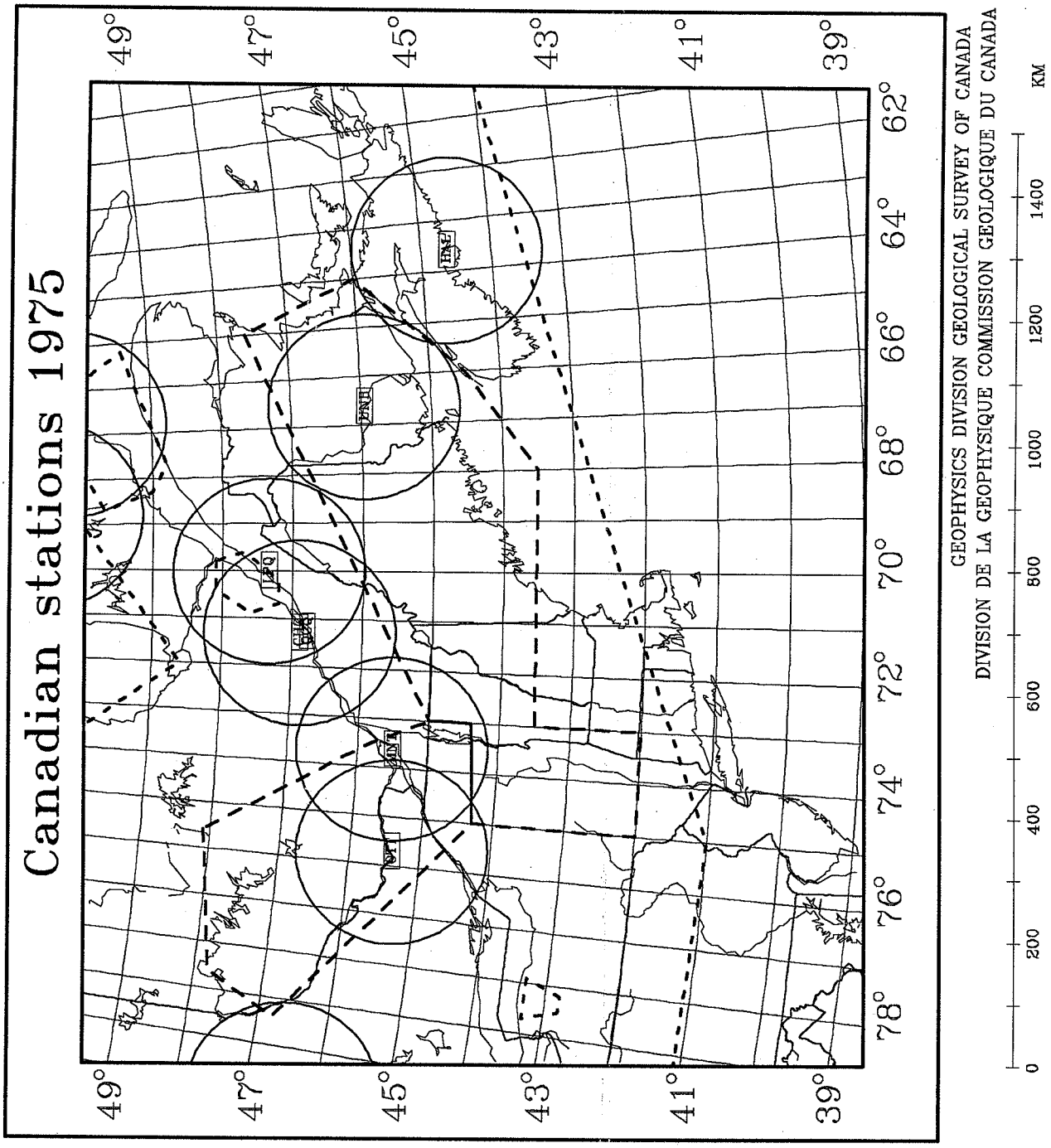
1400
KM


Canadian stations 1975
49°
47°
45°
43°
41°
39°
62°
64°
66°
68°
70°
72°
74°
76°
78°
GEOPHYSICS DIVISION GEOLOGICAL SURVEY OF CANADA
DIVISION DE LA GEOPHYSIQUE COMMISSION GEOLOGIQUE DU CANADA
0
200
400
600
800
1000
1200
1400
KM


Canadian stations 1975
49°
47°
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78°
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74°
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62°
GEOPHYSICS DIVISION GEOLOGICAL SURVEY OF CANADA
DIVISION DE LA GEOPHYSIQUE COMMISSION GEOLOGIQUE DU CANADA
0
200
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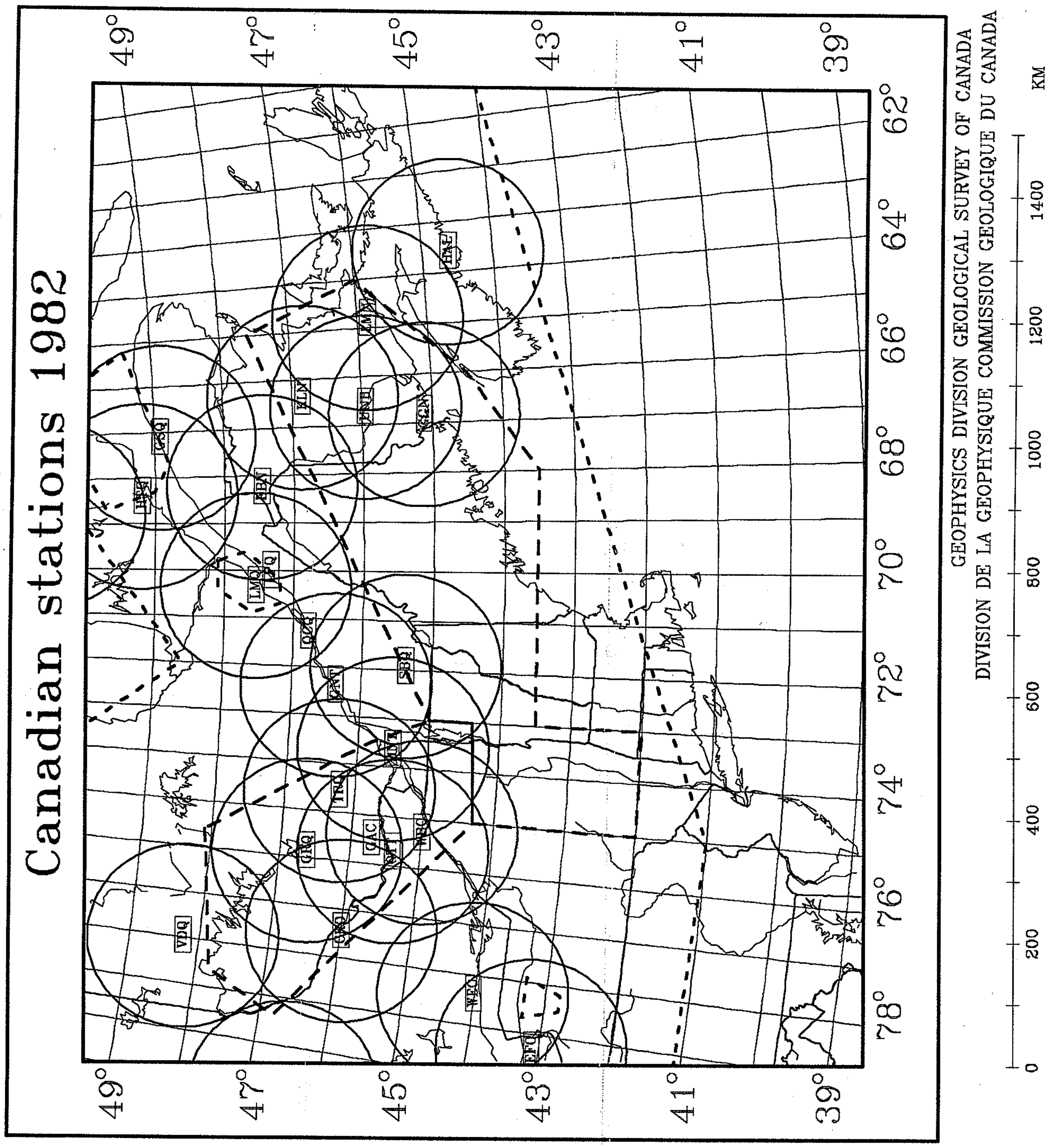
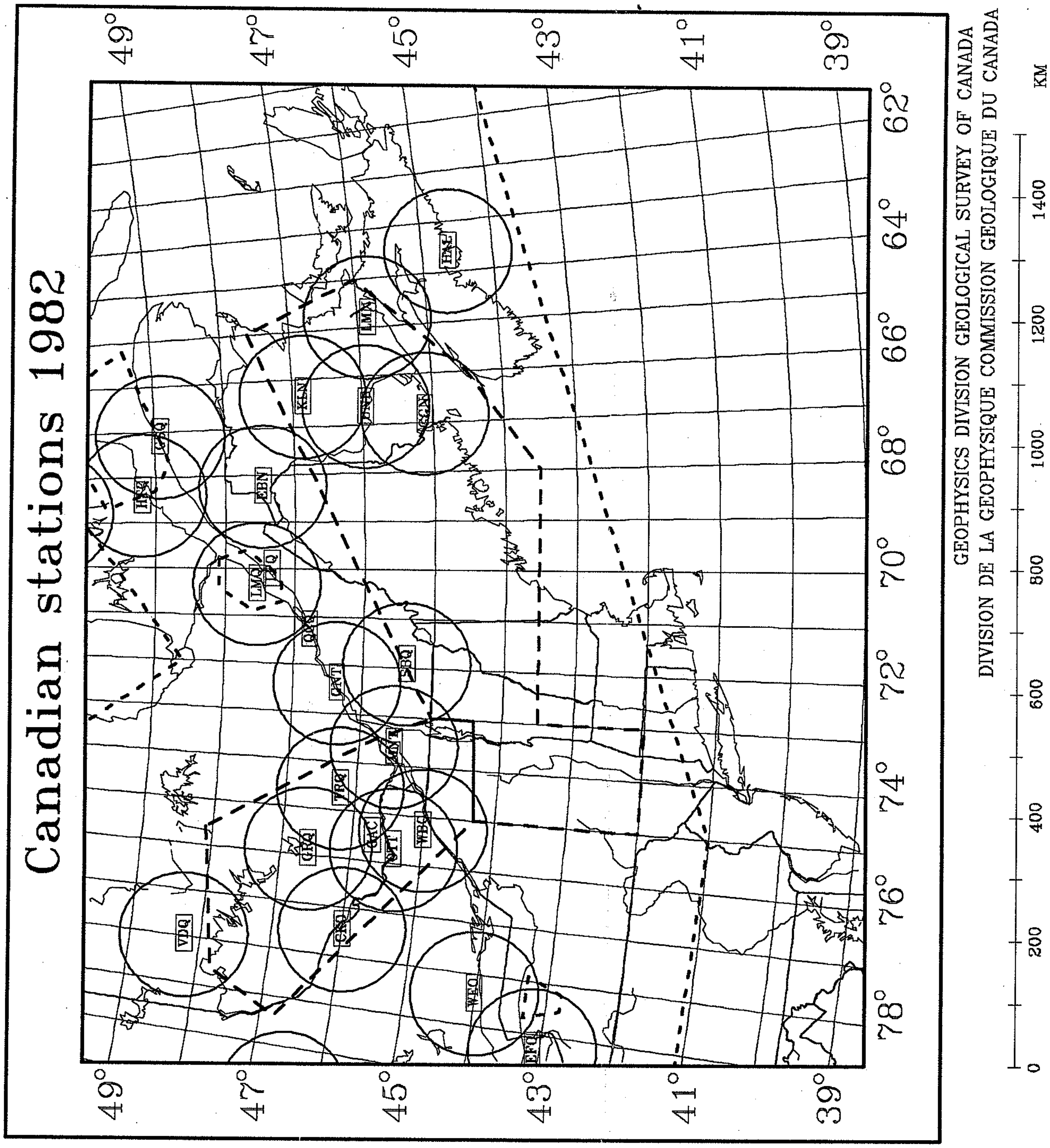
1400
KM


Canadian stations 1982
49° 47° 45° 43° 41° 39°
78° 76° 74° 72° 70° 68° 66° 64° 62°
VDQ
GRQ
CAC
TRQ
SBQ
QCQ
LMQ
GSQ
KLN
HAL
GEOPHYSICS DIVISION GEOLOGICAL SURVEY OF CANADA
DIVISION DE LA GEOPHYSIQUE COMMISSION GEOLOGIQUE DU CANADA
0 200 400 600 800 1000 1200 1400
KM


Canadian stations 1982
49°
47°
45°
43°
41°
39°
78°
76°
74°
72°
70°
68°
66°
64°
62°
VDQ
GRQ
GAC
OTT
SBQ
EBN
KLN
HAL
EFO
GEOPHYSICS DIVISION GEOLOGICAL SURVEY OF CANADA
DIVISION DE LA GEOPHYSIQUE COMMISSION GEOLOGIQUE DU CANADA
0
200
400
600
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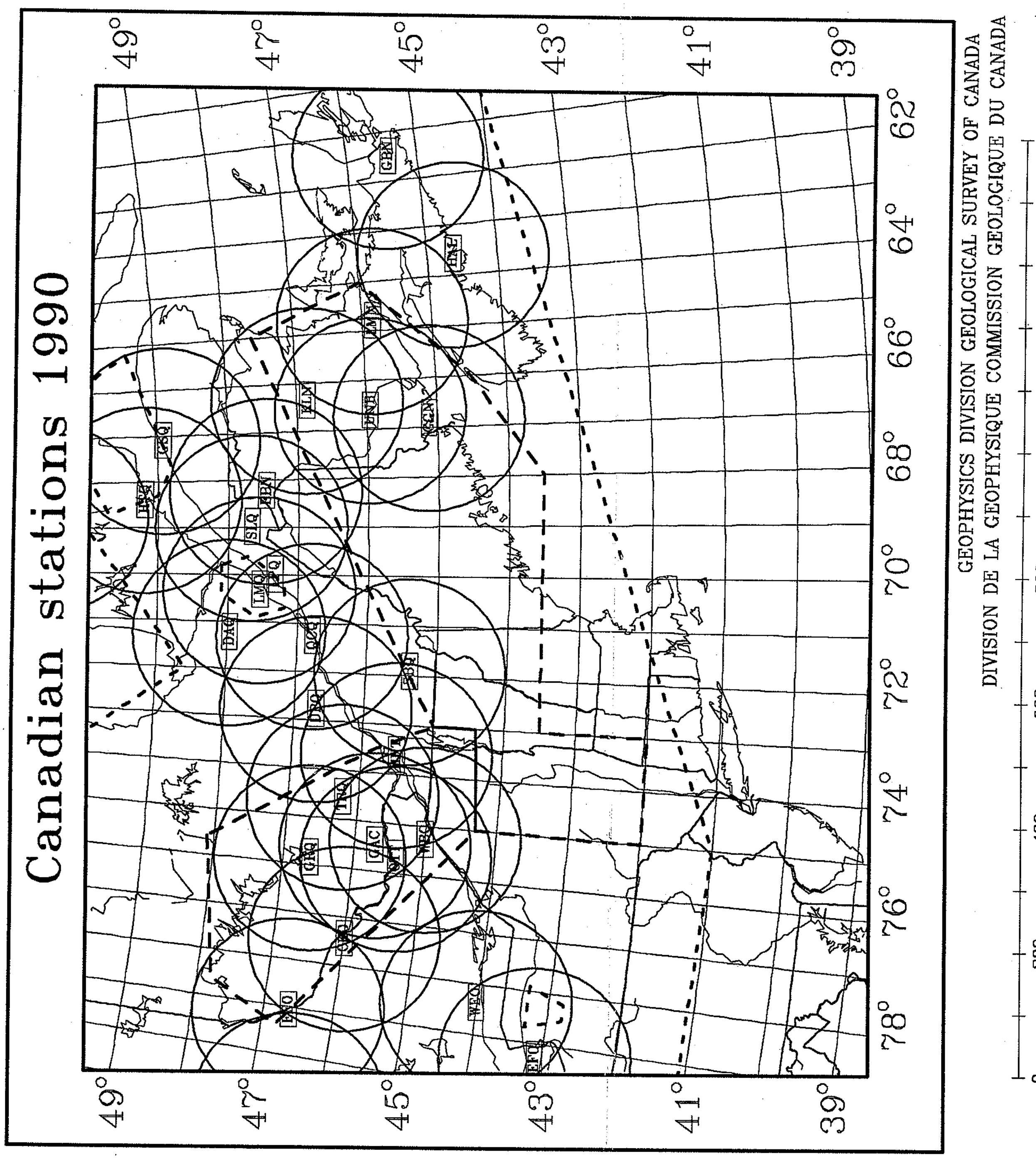
1000
1200
1400
KM


Canadian stations 1990
49°
47°
45°
43°
41°
39°
62°
64°
66°
68°
70°
72°
74°
76°
78°
GEOPHYSICS DIVISION GEOLOGICAL SURVEY OF CANADA
DIVISION DE LA GEOPHYSIQUE COMMISSION GEOLOGIQUE DU CANADA
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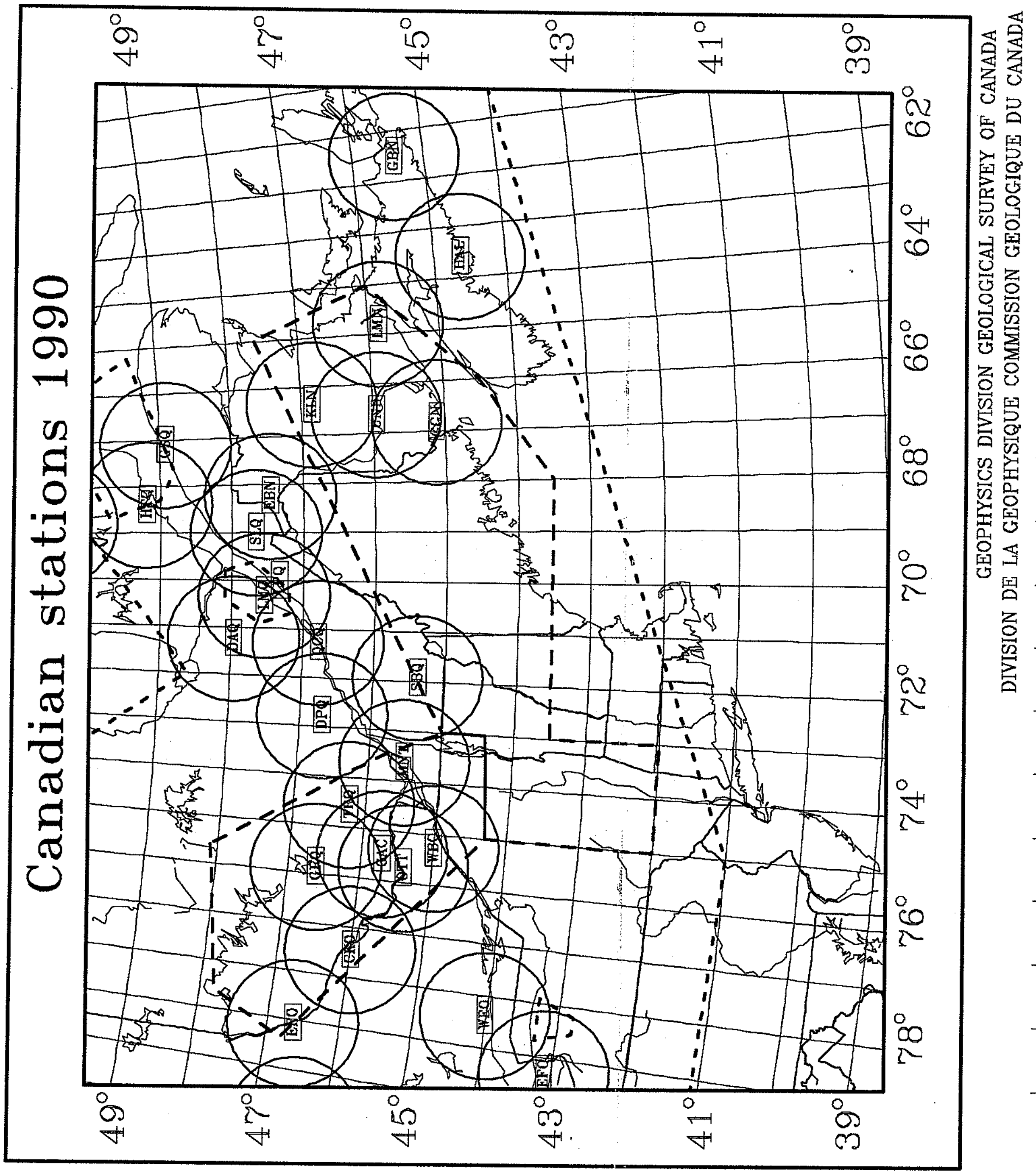
KM


Canadian stations 1990
49°
47°
45°
43°
41°
39°
62°
64°
66°
68°
70°
72°
74°
76°
78°
KLN
EBN
SLQ
DAQ
SBQ
DPQ
GAC
OTT
GEOPHYSICS DIVISION GEOLOGICAL SURVEY OF CANADA
DIVISION DE LA GEOPHYSIQUE COMMISSION GEOLOGIQUE DU CANADA
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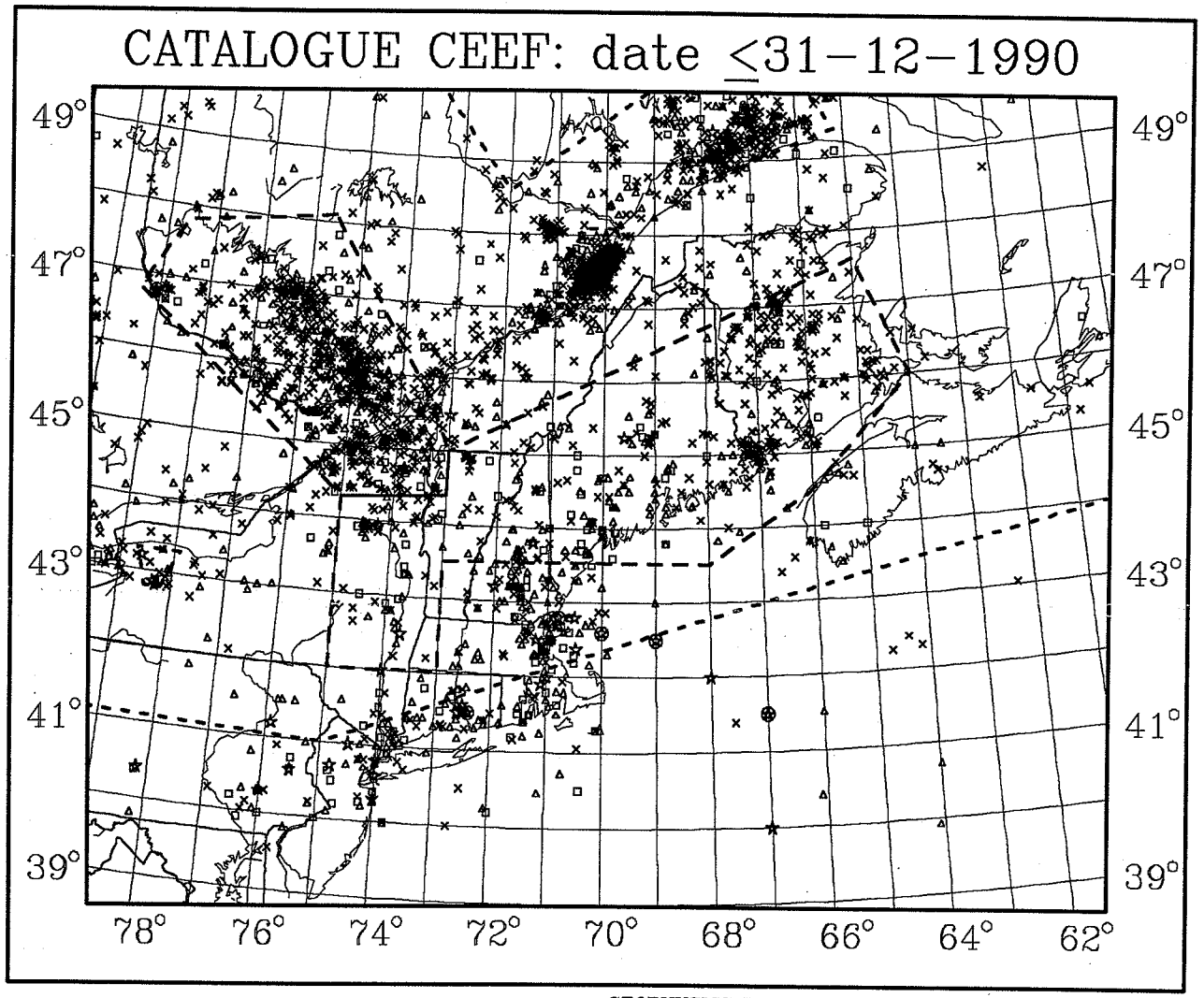
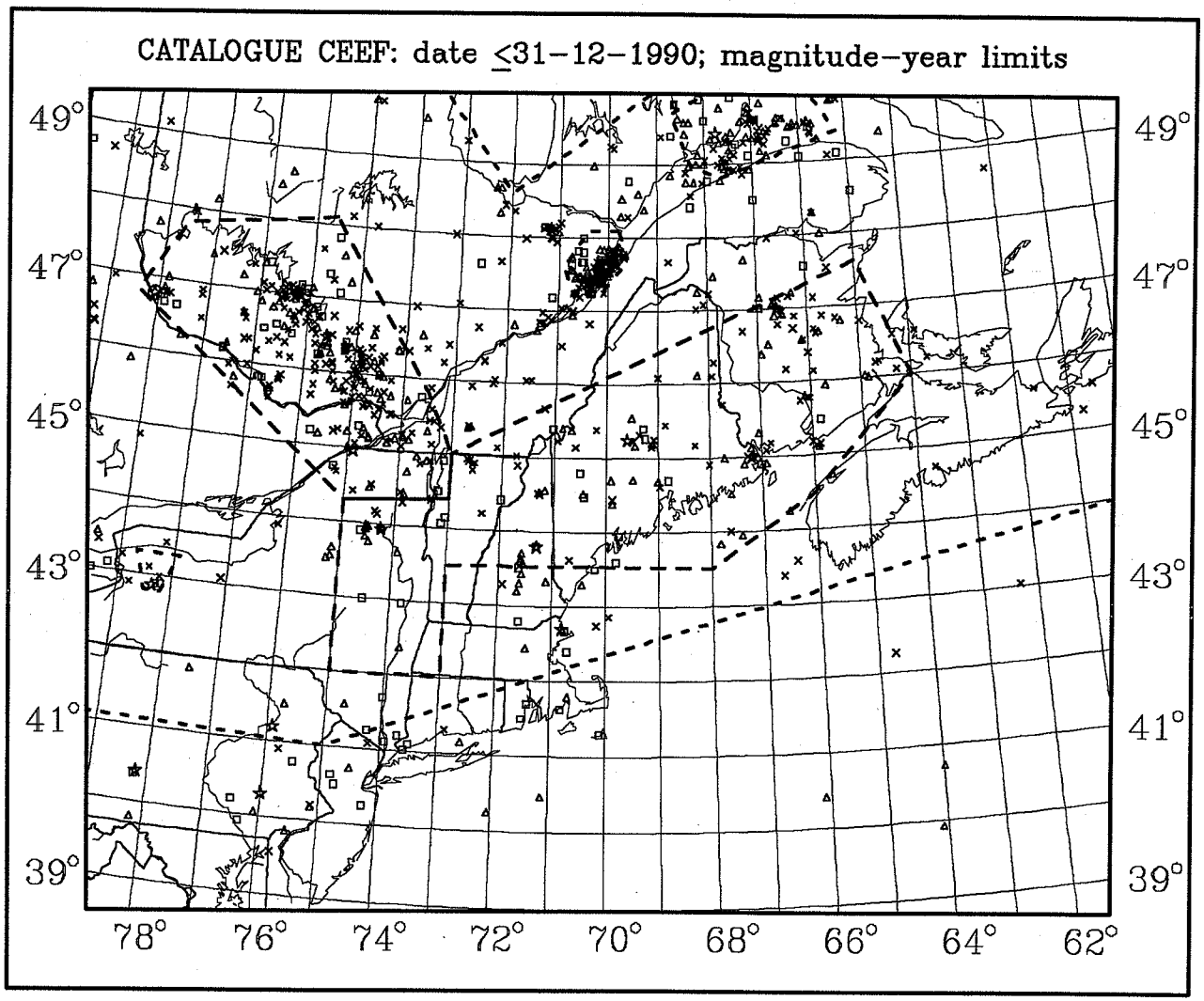
1200
1400
KM



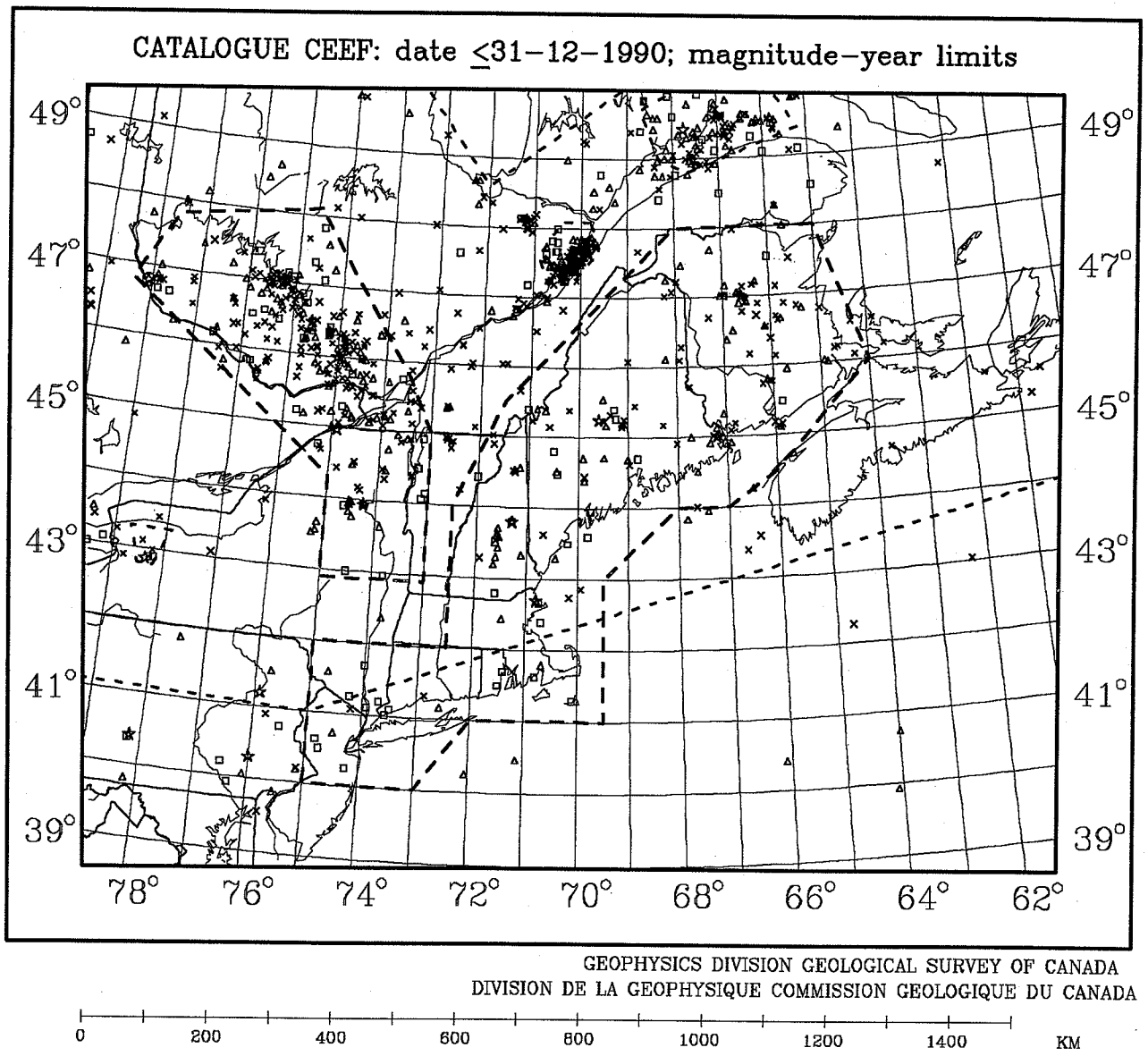
DEFINITIONS

M<3	×
M≧3	△
M≧4	□
M≧5	☆
M≧6	⊛



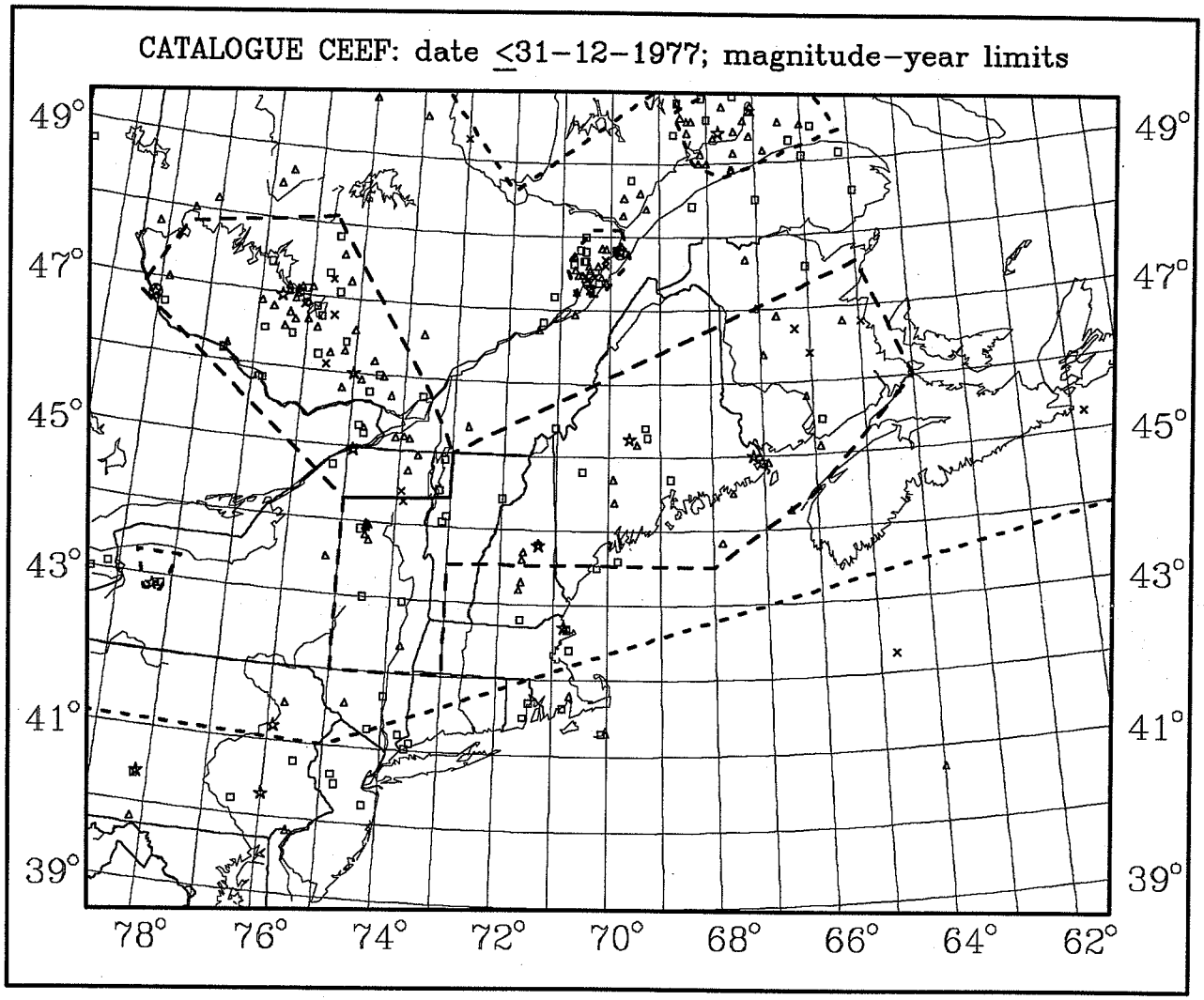
DEFINITIONS

M≧2.3	1982+	×
M≧2.8	1975+	×
M≧3.3	1963+	△
M≧3.8	1937+	△
M≧5.3	1900+	☆



DEFINITIONS

M≧2.3	1982+	×
M≧2.8	1975+	×
M≧3.3	1963+	△
M≧3.8	1937+	△
M≧5.3	1900+	☆



DEFINITIONS

M≧2.8	1975+	×
M≧3.3	1963+	△
M≧3.8	1937+	△
M≧5.3	1900+	☆