REVISED SEISMICITY OF THE GRAND BANKS AND OFFSHORE NEWFOUNDLAND

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ABSTRACT

A comprehensive review of the catalogued seismicity of the Grand Banks of Newfoundland (1922–1994) has revised or added earthquakes in four time periods: 1922–1970, the two largest earthquakes (M≈5) relocated to Baffin Island (1922) and the northern Labrador Sea (1962); 1977–1982, added four new earthquakes; 1969–1984, revised the locations and magnitudes for five earthquakes; 1984–1994, added 15 earthquakes. Many earthquakes appear to be spatially associated with Mesozoic extensional structures that trend northeastwards across the Grand Banks. A cluster of six post-1970 earthquakes lies 40-80 km northwest of the Hibernia oilfield and represents the most seismically active region of the Grand Banks.

RÉSUMÉ

Un examen approfondi de la séismicité catalogué antérieurement à la région des Grands Bancs de Terre-Neuve (1922–1994) a révélé quelques révisions et quelques séismes nouveaux dans les quatre périodes suivantes: 1922–1970, relocalisation des deux séismes les plus importants (M≈5) à l'île Baffin (1922) et dans le nord de la mer du Labrador (1962); 1977–1982, quatre séismes nouveaux; 1969–1984, révisions aux localisations et aux magnitudes de cinq séismes; 1984–1994, ajout de 15 séismes. Plusieurs séismes semblent associés spatialement à des structures extensionelles du Mésozoïque qui tendent vers le nord-est à travers les Grands Bancs. Une grappe de six séismes postérieurs à 1970 se trouve de 40 à 80 km au nord-ouest du champ pétrolifère Hibernia et constitue la région la plus active des Grands Bancs.

INTRODUCTION

This open-file is the third of a series documenting our current knowledge of earthquakes off the southeastern Canadian continental margin (Fig. 1). The other reports in the series include: Adams and Staveley (1985) for the island of Newfoundland, and Adams and Simmons (1991) for the Labrador Sea, and are expected to include: Adams (in prep.) for the Laurentian Slope seismic zone, Adams (in prep.) for the Laurentian Channel and Fan, and Wahlström and Adams (in prep.) for the Scotian Margin. The current report covers a part of the region defined by the Grand Banks Basin Atlas sheet (a Frontier Geoscience project of the Geological Survey of Canada), and revises the epicentres and magnitudes of earthquakes on the Grand Banks and adjacent parts of the offshore.

As a side note, it should be noted that the "Grand Banks" earthquake of 1929, at magnitude 7.2 the largest on the southeastern Canadian continental margin, occurred in the Laurentian Channel (44.5°N 56°W), south of Newfoundland, and not on the Grand Banks proper. Thus it is not discussed in the present report.

Besides the more long-term scientific aspects, a recent interest in the seismicity of the Atlantic Margin has arisen from the need to produce seismic design levels (e.g. Foo and Crouse, 1986) for the Hibernia platform, near 46.7°N 48.9°W, east of St. John's, and to refine estimates of seismic hazard to future offshore hydrocarbon production platforms such as may be emplaced off Sable Island, east of Halifax, or on the Grand Banks (Keen et al., 1990). Earlier hazard estimates (Basham et al., 1983; Adams, 1986) recognized the poorly determined nature of the offshore seismicity and the need to improve seismograph coverage to detect more of the smaller offshore earthquakes and to relocate the older earthquakes.

The current project was begun in 1982 by Adams, and many of the original earthquake phase arrivals were re-read during R. Wahlström's study period in Ottawa in October 1984 - October 1985. Preliminary epicentres and magnitudes for the older earthquakes were determined at that time. Although only informal, these results have been available for use in seismic hazard analyses and have appeared in various reviews (e.g., Basham and Adams, 1983; Adams, 1986; Adams and Basham, 1989); it is our intention here to finally report them in a formal manner, and to update the results to take account of more recent earthquakes, 1985-1994.

HISTORY OF EARTHQUAKE MONITORING

A brief, and probably still incomplete, history of earthquakes in Newfoundland is given by Adams and Staveley (1985). Prior to the advent of instrumental monitoring of earthquakes in Atlantic Canada, all earthquakes were detected by their felt effects. All of the earthquakes felt on the island of Newfoundland documented by Adams and Staveley (1985) appear to pertain to small, onshore earthquakes and not to large offshore earthquakes. By contrast, some earthquakes felt in coastal Labrador are likely to have been large offshore events (Basham and Adams, 1983; Adams and Staveley, 1985), though A. Stevens (pers. comm., 1991) considers they might have been local earthquakes along the coast. For example, an event felt widely (but not strongly in any one place) in Nova Scotia and New Brunswick in 1882 might have been an offshore earthquake (Ruffman and Peterson, 1988, p. 284). Another feature that might signify an offshore earthquake is the occurrence of a tsunami (e.g., Adams and Staveley, 1985; Ruffman et al., 1991); however no earthquake has yet been convincingly confirmed from the numerous reports of tsunami-like waves.

Seismograph monitoring of the Grand Banks has improved with time, so that small earthquakes that can currently be detected would have passed unnoticed in previous years. The following brief history is adapted in part from Stevens (1980). A seismograph was operational in Halifax (HAL) from 1915, but it operated at a low magnification (first a Bosch and then a Mainka instrument, with magnifications of 100 - 150x) and was able to detect only the largest earthquakes. The installation of the Wood-Anderson seismographs (peak magnification at 1 second = 2700x) at Seven Falls (SFA) and Shawinigan Falls (SHF) in 1927 improved the monitoring, as did the Benioff seismograph (≈8,000x for 1937-1939 and ≈80,000x subsequently) at Ottawa in 1937 and the Willmore seismograph (≈30,000x) at Halifax in 1952.

All of these seismographs lay distant from and southwest of the Grand Banks, and it was not until 6-component Canadian Standard Seismographs were opened at at Schefferville (SCH) in July 1962 and St. John's (STJ) in June 1964 that coverage improved significantly. STJ, while it was well-located with respect to Grand Banks earthquakes, operated at a magnification of only 35,000x for the short-period instruments because of the high microseismic and cultural noise of the site.

A further improvement in monitoring occurred when Memorial University of Newfoundland started to operate short-period vertical component seismographs in St. John's (in the same vault as STJ, but herein named 'MUNF' to distinguish it for the period when the STJ standard station was also in operation) in February 1975 and Corner Brook (CBK) in October 1976. These instruments operated at a higher gain (≈100,000x) than STJ because of their restricted low frequency response and proved very successful at detecting smaller offshore earthquakes. However, they were not always operated to modern standards with respect to timing, calibration, or record annotation, and the records were not routinely read with the other Canadian seismograms. In June 1983, Adams retroactively read the earlier seismograms, and the subsequent seismograms have been forwarded to Ottawa and have been systematically read by Adams as part of the national seismograph network.

The most recent changes affecting the earthquakes in this report are as follows. STJ was closed in March 1989, and the MUNF seismometer was relocated from a vault on the main campus to nearby Mount Scio and was renamed to STJN in September 1991. STJN has been operated under contract from Memorial University to the Geological Survey of Canada since April 1989, and CBK was operated under contract from April 1989 to March 1994. GSC's new digital seismograph at Deer Lake (DRLN) opened in December 1993 and replaced the function of CBK.

Although coverage has improved with time, it is still poor with respect to the rest of Canada. As will be seen (e.g., Fig. 4), very few earthquakes of magnitude less than 4 are detected more than 300 km distant from St. John's. The few larger earthquakes that are located (or only detected, see Table 2) must therefore be indicative of many smaller earthquakes that pass unnoticed in the same active areas. The last earthquakes mapped in this report occurred in 1992. There were no earthquakes located in the study area in 1993; the three that occurred in 1994 and one in early 1995 are added only to the Appendix and the "Results" section as a "note in proof", since the report was substantially completed in July 1992, even though its issue was delayed until March 1995.

PROCEDURES

Choice of events studied

Figure 1 delimits the area of the southeastern offshore covered by the Basin Atlas map-sheets and the sub-region treated in this report. The earthquakes studied in this paper represent: all known earthquakes thought to lie in the Grand Banks region according to the Canadian Earthquake Epicentre File (CEEF) in October 1985 (being the previous state of knowledge, see Fig. 2 and Table 1); all subsequent earthquakes located by current methods; and some older earthquakes (not in the CEEF) found by searching the older Memorial University seismograms.

In all, 23 pre-1993 earthquakes are studied in this paper: the two earliest are moved away from the area (having been grossly mislocated), 4 are new events added from the Memorial seismograms, and 17 are earthquakes which have either been relocated (pre-1985 events) or new events located during this project. In addition a number of unlocatable events were detected, usually only on STJ or MUNF, but occasionally on CBK alone if the high-gain MUN station in St. John's was not operating (Table 2). These earthquakes were too small to register on other seismographs and are thus probably offshore.

Determination of Epicentres

For all the earthquakes studied here the epicentres and focal depths have been determined with the standard crustal model and location program used by the Geophysics Division. This model is a good average for the Canadian Shield and is used for offshore earthquakes in the absence of sufficient information to refine the average velocity structure. The crustal model has a 36-km-thick crust of P-velocity 6.2 km/s overlying a mantle of P-velocity 8.2 km/s. S-wave velocities are 3.62 km/s (revised from the previous crustal 'Lg' velocity of 3.57 km/s by Connors and Adams, 1988) and 4.70 km/s, respectively. It would not be surprising if the use of this simple structure leads to some systematic bias in the epicentres (likely up to a few tens of kilometres, but possibly even larger), because with the distribution of land-based seismographs (all to the east of the earthquakes) the epicentres move to minimize the residuals created by an inappropriate crustal model. However, it is impossible to be sure because there have been no earthquakes large enough to give a reliable teleseismic epicentre for comparison, and no earthquakes located both by ocean-bottom seismometers and the seismograph network (contrast the situation on the west coast of Canada, e.g. Wahlström and Rogers, 1993; Wahlström et al., 1990). For these reasons the reader should be warned that the apparent precision of the results (e.g. the errors on Table 3 or in the the Appendix "pikfile" solution lines) is misleading. Furthermore, because of the distribution of stations, the true epicentres are often more uncertain in latitude than longitude, even where this is not indicated by the errors in Table 3.

For each earthquake, all existing Canadian seismograms were read for phase identification, phase onset times (Pn, Pg, Sn, Lg), maximum amplitudes and corresponding periods (Sn or Lg), and P-wave polarity (Pn or Pg). Many of the records for the earlier earthquakes were read by Wahlström at Lamont-Doherty Geological Observatory, New York, where the older Canadian seismograms were stored until the mid-80's. Adams subsequently re-read selected phases in Ottawa. Phases from the Greenland stations were added from Danish bulletins when available. Timing was uncertain on the Memorial seismogram until about 1983; notes in the Appendix indicate where an arbitrary time correction was applied in order to use the S-P information.

The routine determination of epicentres by the Geophysics Division uses all available phases except those that obviously misfit. Hypocentral depths are often assigned to 18 km, being simply the mid-crustal depth according to the model. Epicentres in the present paper were recalculated from the earthquake phase arrival times according to the following guidelines:

1) STJ and MUNF were co-located in the same vault. Therefore where individual phases were read on both instruments, only one was used in the location, the other being zero-weighted ('X-ed' out). Usually it was the Pn from MUNF (its higher gain gave a sharper arrival) and the Sn from STJ (the Sn could be read best from the horizontal component; MUNF was vertical component only) that were used.

2) Pg and Sg arrivals for stations within about 100 km were fit well, even at the expense of larger residuals on the many distant stations (affects only events #69, #94b, #94c, and #95).

3) Pn and some Sn arrivals for the closest stations were fit well, at the expense the fit of arrivals at more distant stations.

4) Lg phases at distances beyond about 1000 km were given lesser weight because of their less sharp onsets and uncertainty in the Lg velocity.

5) In a few cases, a single station was chosen to replace a cluster of stations at a similar azimuth and distance to avoid undue bias.

The results of this data selection can be seen by examining the residuals for the earthquake solutions in the Appendix. While such recomputations of standard epicentres – which occasionally revise the routinely-determined epicentres by many kilometres – do not guarantee that an **accurate** epicentre has been found, we believe that they represent an improvement on the routinely determined epicentres. The epicentres are listed in Table 3 and plotted in Figure 3.

Focal depth

It is in general difficult to compute focal depth for small local earthquakes in the absence of a very dense local seismic network and a good knowledge of the crustal velocities. For large (M>5) earthquakes that are recorded at teleseismic distances (>2000 km) it is possible to compare arrivals of different waves to determine the depth of the earthquake, e.g. the delay between the direct, downward P-wave and the wave that propagates upwards before being reflected down at the earth's surface as P (pP and sP). All the earthquakes studied here are too small for this method.

At close epicentral distances (conventionally, within twice the focal depth of the earthquake being studied), the depth can be computed by minimizing the combined residuals on the upward- and downward-propagating rays; however, the earthquakes in this report lie offshore and have poor seismograph coverage at small distances. Consequently all but one earthquake in this report are placed at the mid-crustal depth (18 km) of the standard model.

Determination of magnitudes

Magnitudes are determined according to current GSC practice, namely: a m_b or M_S from teleseismic P amplitudes is preferred for the larger events (say M>5) if it is available from USGS or ISS; a m_{bLg} (also described as a m_N) determined from the Lg-wave amplitude is preferred where the Lg has propagated normally and not been severely attenuated; and finally a M_L determined from the Sn amplitude is used as a last resort. Supplementary magnitudes (e.g. m_b where a m_{bLg} is preferred) are retained in the CEEF. The M_L calculation with Sn amplitudes uses California attenuation and overestimates magnitudes from stations involving long paths across the high-Q Canadian Shield. Results reported by Adams and Simmons (1991), who compared teleseismic m_b with M_L for nine Labrador Sea earthquakes, suggest that the M_L's for the magnitude range 4.5 to 5.4 might be higher than m_b by 0.4 magnitude units. However, their results are too poorly based to suggest that the M_L magnitudes reported here should be uniformly reduced by that estimate of bias.

Determination of polarities

Where possible, polarities were read from the first P (Pg or Pn) on all available records. These produced a sparse set of data, often only the polarity on the closest station being readable. Polarities were assigned either full or half weight. The polarities were read by both authors and readings on which we differed were either not used or a consensus was reached and the polarity was used at half-weight. Full weight polarities are impulsive and unambiguous. Half weight polarities are emergent, less strong, or may occur on noisy records.

RESULTS

The results of the relocations are summarized in Tables 3 and 4, and as a map of the revised seismicity in Figure 3. Details of the relocated solutions are in the Appendix, which also contains detailed comments on the phases and solutions. Figure 4 shows a map of the relocation vectors. The earthquakes are mapped at their revised locations and the tails point back to their old epicentre. Figure 5 shows the new epicentres with diamonds showing the computed precision of the epicentre (large diamonds represent poorly determined epicentres), Figure 6 shows the detail of the area east of St John's, and Figure 7 shows the detail of the cluster of earthquakes near Hibernia.

In the following discussion, and in Tables 3 and 4 and the Appendix, earthquakes are denoted by their date, e.g., #89b, which is the second earthquake in 1989.

#22 was originally located by the International Seismological Summary (ISS) at 50°N, 50°W based on six stations, only OTT being in Canada. Although SAS was operating, the records were apparently not saved, and the records for VIC have still not been located. The OTT records were not found, and the microfilm of the Bosch and Milne-Shaw records show no clear signal. However, we did find the HAL Mainka record (one horizontal component). This had a time correction of -45 seconds, and gave clear phases P=06h34m33s, amplitude 0.10mm at a period of 2.6 s; S=06h39m05s; and surface wave maximum at 06h42m amplitude 0.15mm at a period of 4.0 s. This indicates a distance of 26.5° (irrespective of the exact time correction; that P and S are the recorded phases is confirmed by later arriving surface waves), which is more than twice the distance of HAL from the assigned ISS epicentre (the HAL readings were not included in the ISS solution).

The distance from HAL is also consistent with the recorded surface wave maximum at 06h42m. Using the arrival times given by ISS and a revised phase interpretation we find origin time 062855, OTTAWA distance=25° (S and RM; the P misfits by about 1 min, which may be a 1 minute reading or reporting blunder because accurate timing was not a problem at the Dominion Observatory), CHICAGO distance=28.5° (RM), WASHINGTON distance=32° (RM), and ESKDALEMUIR distance=32° (RM). 'RM' denotes the Rayleigh wave maximum, the time of which can be used for crude locations in the absence of phase onset arrival times (At Uppsala a set of RM travel time tables prepared by Bäth are used). These readings give an approximate epicentre at 70°N, 75°W (Baffin Island). For this solution, the two other ISS readings give distances about 4° too long if the recorded phase is interpreted as RM for this solution (BIDSTON distance=38.5° and DE BILT distance=41°). The

Uppsala Weichert records were checked, but there was absolutely no trace of the earthquake. Thus, that two of the three European stations with data in the ISS are off by a few minutes should not be discouraging: the signals must be very weak.

Dr. Anne Stevens has suggested that the HAL, OTT, and WAS phases would fit neatly as Pn, Lg; Pn, Sn; and Lg respectively and give an epicentre near 59N 53W, off southwestern Greenland. We can not agree with this location, for: 1) if the epicentre is in eastern Labrador Sea, then the second phase at HAL is not Lg, because Lg does not propagate across this oceanic region (the same goes for the WAS reading); and 2) the clear 3rd phase at HAL is not explained. The "reasonable fit" of these three stations is worth little compared with our new solution which satisfies practically all stations.

Our solution, with identified and accurately timed phases at HAL, giving a reliable distance, and several fitting LR maximum arrivals for a Baffin Island location, is no doubt the best from the documented data. The greatest "obstacle" is the misfitting OTT P arrival and that this cannot be checked since the records are lost. Our solution is both the best and is very rough (see Discussion below).

Smith (1962), gave a fictitious intensity of MM VI-VII to this earthquake, which was not reported felt, and from this intensity the current M_L 5.3 in the CEEF was derived. From the horizontal component at HAL (orientation unknown) we read a trace amplitude of 0.15 mm at a period of 4.0 s. Assuming i) a magnification of 150 (the maximum magnification was 100-150 according to Stevens, 1980) for the found record, and ii) zero amplitude for the missing orthogonal component, we compute M_s(Prague-Moscow)=5.1. Due to the two assumptions this is the minimum value.

In conclusion #22 is a magnitude 5 earthquake in Baffin Island (about 2850 km from its ISS epicentre) and not a Grand Banks earthquake.

#62 was originally located east of the Strait of Belle Isle, and prior to revision was a single large earthquake in an otherwise aseismic area. Both the original and revised locations are based on only three phases from two stations, a P and an S on SCH and one phase on HAL, which Smith (annotations on Dominion Observatory epicentre cards) took to be Sn. A inland epicentre west of Schefferville was ruled out by Smith because the earthquake was not detected on southern stations such as SFA or

MNT, so he located it on the southern Labrador Shelf. After re-examining the HAL seismogram and confirming that only one phase was recorded, we have re-interpreted Smith's Sn reading as the Pn phase. This, together with the absence of Lg energy at Schefferville, is consistent with an earthquake in the oceanic crust of the Labrador Ridge. A slightly larger Labrador Ridge event, 621202, close to the revised #62 epicentre, is well-located, and is also found to lack a Sn reading for HAL (Adams and Simmons, 1991). HAL and SCH were at similar distances from the old #62 epicentre, but the SCH record had a 30 mm amplitude, while HAL signal was "very small"; this suggests the earthquake was much further from HAL, as we now locate it. The epicentre of #62 has thus been revised by over 1000 km.

#69 occurred very close to St. John's, but was not reported in the newspapers as being felt (Adams and Staveley, 1985). The epicentre is revised 17 km to the SE.

#70 is a relatively large earthquake, M_L 4.3, north of the Grand Banks. It is located using only stations STJ and SCH, but the absence of phases on HAL excludes the southern alternative epicentre.

#71 is now the largest earthquake on the Grand Banks at m_b 4.8. It lies within 65 km of the Hibernia Oilfield, and has been moved 32 km SE of the CEEF epicentre. The maximum amplitude readings on Canadian seismographs for this earthquake represent Lg energy, and the m_N 4.8 so calculated is similar to the teleseismic m_b from the ISC. However, m_N is the preferred magnitude scale since it best represents the frequencies of engineering interest when this earthquake is used in eastern Canadian seismic hazard calculations.

#76 is confirmed as being located north of the Grand Banks, the revised epicentre being essentially the same as that in the CEEF.

#77 is a new earthquake found by searching the Memorial University seismograms, but was too small to be confirmed by GSC seismograph records. From the absence of phases at Halifax, the earthquake lies to the northeast of St. John's on the northern Grand Banks, rather than south of St. John's.

#78 is a new earthquake found by searching the Memorial University seismograms, and confirmed by GSC seismograph records. It lies far to the north of the Grand Banks, close to the similar-sized #70.

#81 is a new earthquake found by searching the Memorial University seismograms, and confirmed by GSC seismograph records. It is one of the most easterly of the Grand Banks earthquakes, but some Lg energy did propagate to STJ.

#82 is a new earthquake found by searching the Memorial University seismograms, and confirmed by GSC seismograph records. It is the first known earthquake from the Newfoundland Ridge – Tail of the Bank area. It is magnitude M_L4.0, a relatively large earthquake to have been missed during the routine compilation of seismicity (it occurred during the Miramichi aftershock sequence and may simply have been overlooked). However, it is probably close to the detection threshold for this remote area, and should be taken as indicative of seismic activity along the southeastern margin of the Grand Banks that is currently undetectable.

#84a is a moderate earthquake on the northern Grand Banks, notable for having a M_L 2.6
#84b aftershock two and a half hours later. The mainshock epicentre is relocated 17 km to the SE of the CEEF epicentre. The aftershock was entered into the CEEF as a note, but here is proposed to have its own entry (#84b). The STJ seismograms for both mainshock and aftershock show significant Lg energy, indicating a source in continental rather than thinned continental or oceanic crust.

#85 is an earthquake found first by searching the Memorial University seismograms, and then confirmed by GSC seismograph records. By contrast to #84a and #84b, the Lg wave did not propagate efficiently to STJ, suggesting the earthquake occurred in oceanic or thinned continental crust. #85 lies farther offshore from St. John's than #84, and may reflect crustal thinning towards the edge of the Grand Banks.

#88a is similar to #85, occurs in the same general area, and also lacks Lg energy at STJ. The current epicentre is 10 km to the SW of the CEEF epicentre.

#88b occurred close (within 20 km) to another large earthquake (#71) in the vicinity of the Hibernia Oilfield. Lg-wave energy was not recorded at STJ, even though the STJ seismogram of #71 showed an Lg-wave.

#89a is a large, M>5, earthquake near the Mid-Atlantic Ridge, which is included for completeness. Many earthquakes occur on the ridge to the east of the map area, and some of the larger ones give Pn and sometimes Sn energy on Atlantic Canada seismographs. These earthquakes are best located using world-wide data (we choose the ISC solution instead of computing a GSC solution), and have no seismic hazard implications for Canada, because they are too distant to cause significant ground shaking and these mid-Atlantic Ridge earthquakes are not known to trigger tsunamis.

#89b is an earthquake on the Grand Banks. It appears to be close to the Hibernia Oilfield and is the largest earthquake in the vicinity since 1971.

#90 is only the second known earthquake from the southernmost Grand Banks. It is considerably larger (M_L 4.7) than #82, which is nearby. The m_b determined by the ISC from 8 stations is 4.3, consistent with the anticipated overestimation of magnitude by M_L.

#91 is an earthquake on the shelf east of St. John's. It is clearly closer to St. John's than the cluster of events (#71, #88b, #89b, #92a,b,d), that lie about 80 km farther east.

#92a is the third magnitude 4 earthquake to occur in a cluster about 270 km east of St. John's. This earthquake was well-recorded throughout eastern Canada, with Lg-wave energy being seen as far as Alberta. Relative arrivals at St. John's and Halifax suggest a similar location to the much larger 1971 earthquake (see Discussion).

#92b is a further earthquake in the cluster about 270 km east of St. John, the second of three in 1992.

#92c is the first earthquake known from the eastern margin of the Grand Banks, at the southern end of Flemish Pass. It is located 200 km southeast of the nearest cluster of earthquakes and has a distinctly different location from the other Grand Banks earthquakes in 1992. It lies under the continental slope, where the crustal thickness is about 10-15 km (see Discussion). Despite this, strong Lg-energy was observed on STJN.

#92d is a further earthquake in the cluster about 270 km east of St. John, the last of three in 1992.

"Note added in proof" The following four earthquakes occurred after the preparation of the figures, tables, and text of this report were completed in 1992. They are referenced only here and in the Appendix.

#94a is a M_L 3.2 earthquake on 940108 near the northeast trend of earthquakes discussed below under "Northeast Newfoundland Shelf and Basin".

#94b is a m_{bLg} 3.1 earthquake 35 km north of St. John's on 940811. It occurred during daylight hours, but despite numerous enquiries, no blasting source was identified. #69 was a similar-sized earthquake at a similar epicentral distance, but the unclear Sg arrival at STJN and the poor distribution of seismograph stations prevents a decision whether or not both occurred in the effectively same place. A subsequent event occurred on 950122 (#95).

#94c is a m_{bLg} 2.6 earthquake on 941201, about 80 km east of St. John's, distinctly farther east of St. John's than #69 or #94b.

#95 is a small, m_{bLg} 2.4, event on 950122, 35 km from St. John's, and likely in the same place as #69 and #94b. It occurred at night, so blasting can probably be ruled out.

DISCUSSION

Revision of epicentres

Both of the two earliest earthquakes originally placed on the Grand Banks have proved to be mislocated northern events. #22 gives a poorly constrained location in central Baffin Island, but likely occurred in the northern of the two seismically-active regions along the coast of Baffin Island (and not actually in the interior where the crude epicentre places it). In that region, its magnitude is not exceptional. #62 is confirmed as a Labrador Ridge event, and is one of several magnitude 5 events on the ridge. It would likely not have been mislocated if it had occurred a year later, when FBC had begun operating.

Of the other five earthquakes in the pre-1985 CEEF (Table 1; Fig. 2), one (#71) moves 32 km, two move about 17 km, and two less than 6 km (Table 4). Fifteen new events have been added to the CEEF since 1984 (11 given in Table 3, plus 4 in 94/95). Their CEEF epicentres reflect the incorporation of our enhanced research effort into the ongoing compilation of seismicity. Past experience suggests that without this enhanced effort some of these earthquakes would have been missed, and the routinely-determined epicentres for others would have needed revision.

Four earthquakes between 1975 and 1982 are reported for the first time, having been found from examination of the Memorial seismograms. During the same period only one earthquake (#76) had been located in the study area during the routine analysis. It is disturbing that three of the new earthquakes are larger than M_L 4 (4.0 to 4.2) and the closest (#81) is only 380 km from STJ (but 1280 km from the next closest seismograph of the Canadian Network, HAL). Although the amplitude on STJ was easily detectable, #81 gave less than 0.8 mm amplitude on all the other GSC seismograms.

Detection and location thresholds, and rates of activity

Now that the re-examination of the Memorial seismograms is complete it seems likely that since 1977 almost all earthquakes on the Grand Banks have been **detected** if they exceed the magnitude thresholds for the following radial distances east of St. John's:

350 km	3.0	m_N
550 km	3.5	M_L
900 km	4.0	M_L

However, for a **location** requiring, say, HAL or SCH, the threshold has been considerably higher:

350 km	4.0	m_N
550 km	4.2	M_L
900 km	4.6	M_L

Note that these thresholds are subjective estimates of a 90% confidence ability, based on the appearance of past earthquakes on the seismograms together with the attenuation rate implied by the M_L formula. A more rigorous analysis is intended in the context of a Canada-wide assessment of detection capability.

The location capability improved in 1983 with the opening of station GBN in Nova Scotia, and improved slightly for the period 1981–1991 because of the operation of four ECTN stations in New Brunswick. However, it is clear that smaller earthquakes on the inner Grand Banks, and larger earthquakes along the outer continental margin are not all being detected, and it is difficult to estimate how many are being missed, since the known annual rate of earthquakes in a particular magnitude range and in any given region is highly variable.

In addition, for the Grand Banks, it is difficult to calculate the annual probability of earthquakes larger than a given size because the location capability varies so dramatically in space and has varied also with time. If, however most of the magnitude 4 and greater earthquakes that occurred within 400 km of St. John's since 1977 are assumed to have been located, then Table 4 shows four earthquakes in this category between 1977 and 1994, i.e. four earthquakes in 18 years, or an average rate of 0.2 earthquakes of magnitude 4 and greater per annum on the inner Grand Banks. Since the located number is so small, then the annual rate is only a very rough estimate. If even two earthquakes in this category had been missed, then the annual rate would be 50% higher. Since there are even fewer earthquakes located with magnitudes greater than 4.5, they provide no direct basis for an annual rate of higher magnitude earthquakes east of St. John's. To make such estimates requires assumptions about the relative rates of big and small earthquakes; such assuptions are commonly made for input to seismic hazard calculations.

Lg Attenuation and propagation

There are numerous references in the brief earthquake descriptions above regarding the extent to which Lg-wave energy has propagated from the earthquake to St. John's. Lg-wave energy is known to be very sensitive to crustal structure, propagating very efficiently in normal continental crust but very poorly in oceanic or thinned-continental crust.

Figure 8 uses thick, moderate, and thin lines to show the paths with excellent, weakened, and zero Lg-wave propagation to St. John's. There are still too few paths to fully delimit the region of normal crust, though the 20-km contour of crustal thickness (see Fig. 10) appears to divide the earthquakes correctly. The difference in Lg propagation between #88b and that from the nearby earthquakes could be due to local crustal variations or to earthquake depth, but must be considered unexplained at this time.

Earthquakes with significant Lg-wave energy at St. John's commonly also show Lg-wave energy at Schefferville, but almost never in Nova Scotia or southern New Brunswick. The later path contains oceanic-thickness crust south of Newfoundland that attenuates the Lg-wave.

Focal Mechanisms (J. Adams has sole responsibility for the contents of this section)

None of the earthquakes discussed in this report is large enough to determine a reliable focal mechanism at present. This is mostly due to the extremely poor station distribution for these offshore earthquakes, as #71 would have been easily large enough for a reliable mechanism, had it occurred onshore.

At m_{bLg} 4.8, #71 was large enough to be recorded by 84 seismographs reporting to the International Seismological Centre. Thirteen (3 being Canadian) reported polarities. Both Adams and Wahlström independently read all Canadian seismograms, confirmed the 3 Canadian readings reported to the ISC, and added 10 more (Table 4). Figure 9A shows the distribution of polarities. Of particular note is that STJ and HAL have opposite polarities, despite having similar azimuths from the epicentre. Figure 9B shows a range of mechanisms that fit the polarity data acceptably well (each misfits the equivalent of 4 full-weight polarities) without misfitting either STJ or HAL. These mechanisms, which represent almost pure strike-slip faulting on north-south or east-west planes, misfit our Canadian compressional readings at OTT, GWC, BLC, SES, and FFC and the ISC-reported polarity at ELT. Of these only the misfit of the clear polarity at FFC is of concern, but as the reported phase arrives 5 s late for GSC's solution, it may well be a depth phase rather than the direct P-wave arrival.

Two points to note about this poor mechanism are:

- pure strike-slip faulting is very uncommon in onshore southeastern Canada.
- the P-axis is oriented NW-SE, at a high angle to the "regional" stress field orientation which is NE-SW (Adams and Bell, 1991, Figure 3). However, local stress orientations estimated from oil-well breakouts in the Hibernia oilfield (70 km to the southeast) include anomalous east-west and north-south compression directions (Adams and Bell, 1991, Figure 16).

I suggest that future modelling (for example, of the Pnl wave on STJ and the teleseismic P-waves at Canadian Arctic stations) should be carried out to test my tentative mechanism and also to establish the depth of the 1971 earthquake.

Polarities from other earthquakes in this report are given in the PIK files (Appendix). Worthy of note is that STJ and MUNF are dilatational for Pn arrivals and HAL and GBN are usually compressional, and that both compressional arrivals at STJ are for upward-directed arrivals from the close events #69 and #94b.

Seismotectonics

Figure 10 shows the relocated earthquakes together with bathymetry and crustal thickness contours taken from Shih et al. (1988). We discuss the earthquakes in five groups.

Mid-Atlantic Ridge. Event #89a lies in the extreme northeast of the study area, near the Mid-Atlantic Ridge. These earthquakes have no seismic hazard implications for Canada.

Newfoundland Ridge. Two earthquakes (#82 and #90) lie south of the Tail of the Bank, on the Newfoundland Ridge. Little is known of the seismotectonics of this region, though the pair of earthquakes might be associated with the rifted continental margin (Adams and Basham, 1989) and might represent reactivation of the extensional faults formed during the opening of the Atlantic Ocean.

Newfoundland Rifted Margin. A single earthquake (#92c) is known to have occurred under the continental slope that marks the southeastern edge of the Grand Banks. However, few earthquakes smaller than M4 can be located in this area. It occurred in a region of continental crust somewhat thinned by the rifting that formed the Atlantic Ocean. Although this is the first known earthquake from the 1000-km-long rifted margin that bounds the Grand Banks to the southeast and southwest, seismicity of the margin was predicted by the 'ESX' seismicity model of Basham and Adams (1983) and Basham et al. (1983). Their model suggested that the entire rifted margin would be capable of generating large (M≈7) earthquakes. By implication, either the entire margin would need to be seismically-active at a low level (below the detection threshold) or earthquakes were occurring at long intervals, so that contemporary seismicity (which at the time was absent) might not reveal all active structures. Therefore #92c is important supporting evidence for the ESX model, which itself is important because of the seismic hazard large earthquakes on the margin would pose to facilities producing hydrocarbons from the Jeanne D'Arc Basin.

Grand Banks Proper. Seven earthquakes (#71, #88b, #89b, #91, #92a, #92b, and #92d) lie on the Grand Banks in the vicinity of the Hibernia Oil Field. #91 lies about 70 km to the west of the other six, but the azimuthal precision is such that the remaining six earthquakes (except, perhaps #89b) could well have occurred in the same place (Fig. 7). Although not conclusive, an analysis of relative arrival times for Nova Scotia and Quebec stations (representing the maximum azimuthal spread of the data) suggests a NNE-SSW to N-S alignment of the epicentres. This possible alignment roughly parallels the structural trends on the central Grand Banks.

The epicentres lie on the Bonavista Platform, about 20 km west of, but parallel to, the Mercury Fault (Adams and Bell, 1991, Figure 16). In view of the potential location bias (due to the unknown crustal velocity structure), it is not impossible that they actually occurred on the Mercury Fault. Alternatively, they may have occurred on a less-significant or an unknown fault within the Bonavista Platform. The Mercury Fault is an east-dipping listric detachment which bounds the northwest side of the Jeanne D'Arc Basin, the largest of a number of northeast-trending basins that cut across the Grand Banks. These basins were formed by normal faulting of the basement consequent on crustal stretching during the opening of the Atlantic Ocean (Ziegler, 1988).

This cluster of activity represents the most active region on the Grand Banks, having generated three M4, and four M3 earthquakes. Allowing for different periods of completeness, the recorded earthquakes suggest an annual rate for $M \geq 4.0$ earthquakes of about 0.1, which makes the cluster about a third as active as the Laurentian Slope zone south of Newfoundland (Keen et al., 1990; Adams, unpub.).

East Newfoundland Basin and Shelf. One earthquake (#81) lies south of Orphan Knoll and 200 km northeast of the cluster of earthquakes near Hibernia. The remaining nine earthquakes lie along a northeast trend extending from just off St. John's (#69) to 52°N, 47°W. The earthquakes in this trend lie in a band about 70-100 km wide, and might extend southwest to include earthquakes off Bonavista in 1965 and on the northern Avalon Peninsula in 1884 and 1956 (Adams and Staveley, 1985).

The earthquakes near the middle of the trend (#76, #77, #84a,b, #85, #88a) lie in a region where the basement surface has a local relief of 2-4 km and is formed into linear, northeast-trending ridges (Grant, 1988). These are interpreted as the result of strong block faulting of the Paleozoic basement in Jurassic times (Proctor et al., 1984, p. 39).

The two most northeasterly earthquakes (#70 and #78) occurred on oceanic crust close to the inshore extension of the Charlie-Gibbs Fracture Zone. Smaller earthquakes could seldom be located in this area. In this region the fracture zone trends east-northeast. In the Labrador Sea to the north, Adams and Simmons (1991) have found that many of the earthquakes on the oceanic crust occur in the vicinity of the major fracture zones.

In summary, the seismicity discussed in this report may be due to fracture zones weakening the oceanic crust around the Grand Banks, or to northeast-trending normal faults and rift features that broke the integrity of the basement in the Mesozoic during the opening of the Atlantic Ocean. At this point in our understanding there are no correlations with individual faults, only spatial associations with broad zones of weakness. These conclusions are not very different from those of Adams and Basham (1989).

Seismic Hazard Implications

Earthquakes on the Grand Banks have significant seismic hazard implications for offshore hydrocarbon production platforms such as will be emplaced at Hibernia or elsewhere on the Grand Banks. Some earlier hazard estimates included the two largest earthquakes (1922 and 1962) in the hazard calculations, but these earthquakes have now been relocated away from the Grand Banks. The largest earthquake is now m_{bLg} 4.8, but more importantly it is now seen to lie within an active cluster, revealed chiefly because of activity in the past five years.

The problems with detection and location thresholds (discussed above) make it difficult to assess the rates of earthquakes and hence the hazard for the offshore. Previous hazard estimates (Basham et al., 1983; Adams, 1986) recognized the poorly determined nature of the offshore seismicity and the need to relocate the older earthquakes and to improve seismograph coverage to detect more of the small offshore earthquakes. Some relatively inexpensive additions to the onland seismograph network – for example a station near Bonavista, Cape Freels, or St. Anthony – would certainly improve the detection and location of offshore earthquakes. Although expensive, and technically difficult to install and operate, a tethered ocean bottom seismometer in the vicinity of the Hibernia platform would present the best near-term opportunity to improve seismic monitoring on the outer Grand Banks. One further conclusion of the present report is that effort needs to be made to assess the earthquake location threshold in both time and space so that the seismicity record can be interpreted in terms of recurrence rates for the entire Grand Banks.

CONCLUSIONS

1. The two largest earthquakes once considered on the Grand Banks have been relocated out of the area. The largest earthquake is now m_{bLg} 4.8.

2. Four new earthquakes between 1977 and 1985 have been found, the epicentres of five previously-known earthquakes prior to 1985 have been revised slightly, and post-1984 records have been searched for earthquakes with more care, resulting in a further 15 earthquakes being added.

3. Most earthquakes appear to be spatially associated with Mesozoic extensional structures that trend northeastwards across the Grand Banks, although another decade of monitoring may be needed to test this conclusion.

4. A cluster of activity northwest of the Hibernia site represents the most active region on the Grand Banks in recent years.

5. The earthquakes catalogued in this report form the most reliable basis for seismic hazard calculations for the Grand Banks.

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TABLE CAPTIONS

Table 1. 1922 to 1984 earthquake epicentres, as known in 1985.

Table 2. Probable earthquakes recorded on Memorial seismographs, but unlocatable. (possible Grand Banks earthquakes)

Table 3. A. New solutions for earthquakes no longer in the study area. B. Revised, new, & added solutions for earthquakes in the study area.

Table 4. Summary of revisions to Grand Banks earthquakes.

Table 5. Polarity data for the 1971 Grand Banks earthquake.

FIGURE CAPTIONS

Figure 1. Map of the Eastern Margin showing the geographic scope of the two published reports and the region of the present study.

Figure 2. Seismicity of the Grand Banks as known in 1985, taken from the then-current Canadian Earthquake Epicentre File. Only earthquakes within the study area (east of the heavy line) are shown. Symbols in this and subsequent figures are:– star, magnitude (M) $\geq$ 5.0; square, 4.0$\leq$M$\leq$4.9; triangle, 3.0$\leq$M$\leq$3.9; and cross, M$\leq$3.0.

Figure 3. Relocated Grand Banks earthquakes. The label next to each earthquake symbol identifies the earthquake by year (76, 81, etc) and sequence in the year (84a, 84b, etc) and reference to Table 3.

Figure 4. Relocation vectors for the studied earthquakes. The heavy lines extend back from the revised epicentre (also marked by a symbol) to the pre-revision epicentre. For most earthquakes the revisions are small, less than the symbol size, but two events have moved north, off the map area (see text).

Figure 5. Computed uncertainty for the revised epicentres, as represented by precision diamond (the axes represent the standard errors in latitude and longitude). For almost all the earthquakes, the computed precision is less than the space occupied on the map by the earthquake symbol (see also Fig. 6 and 7), though the plotted epicentres may be inaccurate by an amount at least as large as the symbol size.

Figure 6. Detail of Figure 5, showing the seismicity of the Grand Banks proper, together with the precision diamonds.

Figure 7. Detail of Figure 5, showing the epicentres in the cluster of earthquakes near Hibernia, together with their precision diamonds.

Figure 8. Propagation of Lg-wave energy to St. John's from offshore earthquakes. Thick lines represent paths with efficient propagation, single moderate-thickness line represents partial attenuation of Lg, and thin lines represent paths that completely attenuate Lg.

Figure 9. Focal mechanism information for event #71. A) Data (see Table 5). C and D represent full-weight data, c and d represent half-weight data. B) Possible nodal planes, representing strike-slip faulting on a N-S or an E-W plane. P, B, and T represent the axes of the solution.

Figure 10. Relocated offshore earthquakes, crustal thickness (taken from Shih et al., 1988), and 500-m isobath. Compare with Figure 3 to determine the identity of the events. As in previous maps, earthquakes west of the heavy line are not plotted.

TABLE 1

1922 TO 1984 EARTHQUAKE EPICENTRES AS KNOWN IN 1985

REF	DATE	TIME (UT)	LAT		LONG		DEPTH (km)	MAGNITUDE	TYPE
ISC	19220726	062855	50.0	N	50.0	W		5.3	ML
GSC	19620803	013102	52.	N	54.2	W		4.8	ML
GSC	19690805	215324	47.74	N	52.31	W	18	3.3	MN
GSC	19701031	174445	52.17	N	46.37	W	18	4.3	ML
ISC	19710815	061715	47.46	N	49.53	W		4.8	MB
GSC	19760828	192330	50.10	N	48.85	W	18	4.0	ML
GSC	19840526	192549	48.89	N	51.06	W	18	3.5	MN

REF: GSC - solution from GSC, ISC - solution from ISC

TABLE 2

PROBABLE EARTHQUAKES RECORDED ON MEMORIAL SEISMOGRAPHS, BUT UNLOCATABLE. (POSSIBLE GRAND BANKS EARTHQUAKES)

DATE	TIME UT	STATION	S-P (s)	DIST (km)	AMP (mm)	MAGNITUDE[1] ML
750403	0941	MUNF	47	470	2.0	3.4
760217	0658	MUNF	45	450	3.0	2.9
760327	1101	MUNF	63	645	2.5	3.8
761124	2154	MUNF	160	1710	7.0	-
770811	1048	MUNF	42	420	2.5	3.5
780618	1316	CBK	69	710	-	-
780228	0756	MUNF	75	780	2.0	3.7
790408	2132	MUNF	43	425	1.5	3.4
790712	0314	MUNF	67	690	1.5	3.6
790725	0444	MUNF	62	635		
791014	1407	MUNF	24	220	4.0	2.9
791112	1429	MUNF	32	305	6.0	3.0
800731	1609	MUNF	82	850	-	-
810121	0426	CBK	61	625	-	-
821215	0654	MUNF	23	205	-	-
920218	0346	STJN	54	550	0.8	3.0
920925	1818	STJN	63	645	0.3	2.9

[1]Magnitude assuming Sn amplitudes; '-' not determined

TABLE 3

A. NEW SOLUTIONS FOR EARTHQUAKES NO LONGER IN THE STUDY AREA.

ID[1]	ST	LAT	LONG	MAG	TIME	DATE	ERRORS	STN	PH	M	RMS	DEPTH
22	M	+70.000- (Baffin Island)	75.000	MS=5.1	0628550	26071922	00.0000.000 0.0	2	3	0	0.00N	18.00
62	M	+61.027- (Labrador Ridge)	58.225	ML=4.8	0131042	03081962	00.0000.000 0.0	2	3	1	0.00	18.00

B. REVISED, NEW, & ADDED SOLUTIONS FOR EARTHQUAKES IN THE STUDY AREA.

ID[1]	ST	LAT	LONG	MAG	TIME	DATE	ERRORS	STN	PH	M	RMS	DEPTH
69	R	+47.632-	52.156	MN=3.4	2153207	05081969	00.0860.110 0.2	5	9	4	0.94	18.00
70	R	+52.189-	46.333	ML=4.3	1744440	31101970	00.0310.110 0.3	2	4	2	0.29	18.00
71	R	+47.308-	49.160	MN=4.8	0617095	15081971	00.1310.215 0.2	10	17	6	2.50	18.00
76	R	+50.133-	48.910	ML=4.1	1923304	28081976	00.0260.108 0.3	5	8	3	0.54	18.00
77	N	+49.337-	49.586	ML=3.4	0805261	25031977	00.1230.155 0.0	2	4	1	0.12	18.00
78	N	+52.573-	46.752	ML=4.1	1435140	03011978	00.0280.073 0.1	3	6	3	0.36	18.00
81	N	+48.643-	47.820	ML=4.2	1306126	26091981	00.0670.170 0.2	5	10	6	1.16	18.00
82	N	+41.367-	47.282	ML=4.0	0407239	22071982	00.1040.124 0.1	6	8	4	1.05	18.00
84a	R	+48.852-	50.837	MN=3.6	1925475	26051984	00.0190.037 0.3	8	18	6	0.48	18.00
84b	A	+48.852-	50.837	MN=2.6	2204198	26051984	00.0000.000 0.0	1	1	0	0.00H	18.00
85	A	+49.787-	50.480	ML=2.8	1806035	03081985	00.0150.053 0.3	4	6	2	0.14	18.00
88a	A	+49.834-	49.982	ML=3.5	0715448	09011988	00.0180.058 0.2	8	11	6	0.34	18.00
88b	A	+47.463-	49.246	ML=3.1	0016451	09081988	00.1950.120 0.0	5	8	2	0.76	18.00
89a	A	+52.730-	35.200	MS=5.4	2253371	14051989	00.0390.030 0.0	-	-	25	0.00H	10.00
89b	A	+46.960-	49.247	ML=4.2	0515398	03121989	00.0500.088 0.4	6	9	4	0.71	18.00
90	A	+41.918-	48.341	ML=4.7	2140041	24041990	00.0270.062 0.1	14	23	13	0.67	18.00
91	A	+47.364-	50.167	MN=3.2	1123013	23071991	00.0820.146 0.2	6	10	3	0.79	18.00
92a	A	+47.245-	49.236	MN=4.0	0607283	13011992	00.0570.100 0.2	17	25	14	0.93	18.00
92b	A	+47.326-	49.346	ML=3.0	1658161	06071992	00.3710.268 0.2	3	6	3	0.74	18.00
92c	A	+46.118-	47.438	MN=3.9	0420227	17071992	00.1120.087 0.1	9	17	2	0.77	18.00
92d	A	+47.353-	49.114	MN=3.4	1131520	10081992	00.0830.070 0.0	5	9	1	0.39	18.00

[1]This table is modified from GSC's CEEF format. A brief description is given by the column heads as follows: ID, see text; ST, status - M moved, R revised, N new, A added; LAT, LONG latitude and longitude in decimal degrees; MAG, magnitude; TIME, hour minute seconds in Universal Time; DATE; ERRORS, standard errors on latitude, longitude, and magnitude; STN, number of stations used for location; PH, number of phases used; M, number of stations used for average magnitude; RMS, root mean square residual (seconds); DEPTH, assigned depth (km).

TABLE 4

SUMMARY OF REVISIONS TO GRAND BANKS EARTHQUAKES

ID	SEQ	DATE TIME	ΔLAT	ΔLONG	ΔMAG	ΔZ	STATUS	ΔKM
22	1	19220726.0628	20.000	-25.000	-0.2	18.00	moved	2852.8
62	2	19620803.0131	9.027	-4.025	0.0	18.00	moved	1040.9
69	3	19690805.2153	-0.108	0.154	0.1	0.00	revised	16.6
70	4	19701031.1744	0.019	0.037	0.0	0.00	revised	3.3
71	5	19710815.0617	-0.152	0.370	-0.1	18.00	revised	32.5
76	6	19760828.1923	0.033	-0.060	0.1	0.00	revised	5.6
77	7	19770325.0805	0.000	0.000	3.4	0.00	new	0.0
78	8	19780103.1435	0.000	0.000	4.1	0.00	new	0.0
81	9	19810926.1306	0.000	0.000	4.2	0.00	new	0.0
82	10	19820722.0407	0.000	0.000	4.0	0.00	new	0.0
84a	11	19840526.1925	-0.038	0.223	0.1	0.00	revised	16.8
84b	12	19840526.2204	0.000	0.000	2.6	0.00	added	0.0
85	13	19850803.1806	0.000	0.000	2.8	0.00	added	0.0
88a	14	19880109.0715	0.000	0.000	3.5	0.00	added	0.0
88b	15	19880809.0016	0.000	0.000	3.1	0.00	added	0.0
89a	16	19890514.2353	0.000	0.000	5.4	0.00	added	0.0
89b	17	19891203.0515	0.000	0.000	4.2	0.00	added	0.0
90	18	19900424.2140	0.000	0.000	4.7	0.00	added	0.0
91	19	19910723.1123	0.000	0.000	3.2	0.00	added	0.0
92a	20	19920113.0607	0.000	0.000	4.0	0.00	added	0.0
92b	21	19920706.1658	0.000	0.000	3.0	0.00	added	0.0
92c	22	19920717.0420	0.000	0.000	3.9	0.00	added	0.0
92d	23	19920810.1131	0.000	0.000	3.4	0.00	added	0.0

ID and SEQ represent the earthquake identification number and a simple counting sequence, respectively; ΔLAT, ΔLONG, ΔMAG and ΔZ represent the changes to these parameters established in this Open File; STATUS describes the reason for the change: moved - moved out of the area; revised - existing solution improved; new - event found on old MUN seismograms; added - event added from enhanced reading of MUN and GSC seismograms; ΔKM represents the distance moved in kilometres.

TABLE 5

POLARITY DATA FOR THE 1971 GRAND BANKS EARTHQUAKE

ID	AZ	TO	POL	SOURCE
STJ	274.000	49.000	D	ISC and Wahlstrom
SCH	311.000	49.000	-	Adams -, ISC D, Wahlstrom C
MNT	272.000	46.000	-	ISC and Adams
CLE	267.000	33.000	D	ISC
FAV	267.000	29.000	C	ISC
DOU	65.000	29.000	C	ISC
NOR	8.000	28.000	C	ISC
GOL	280.000	28.000	D	ISC
ILT	340.000	23.000	D	ISC
BNG	103.000	19.600	D	ISC
ELT	26.000	19.200	D	ISC
AAB	37.000	18.000	C	ISC
GAR	44.000	18.000	C	ISC
HAL	261.000	49.000	C	Wahlstrom and Adams good quality, not strong
SIC	290.000	49.000	-	Wahlstrom C, Adams -
OTT	274.000	42.000	+	very weak, noisy record
UNB	270.000	49.000	-	clear, not strong, Wahlstrom D
SFA	277.000	49.000	D	good
GWC	305.000	39.000	+	v weak on noisy record
SUD	280.000	35.000	E	low signal stength, emergent
BLC	321.000	33.000	+	Adams 900925
FFC	303.000	32.000	C	Adams 900925 good polarity but 5 sec late
SES	298.000	30.000	+	Adams 900925
INK	329.000	29.000	D	Adams 900925
MCE	303.000	29.000	-	ISC

ID, Station providing the reading; AZ azimuth from earthquake to station; TO take-off angle from earthquake to station; POL P-wave first motion:- C and D are compression and dilatation; + and - are half-weight C and D.

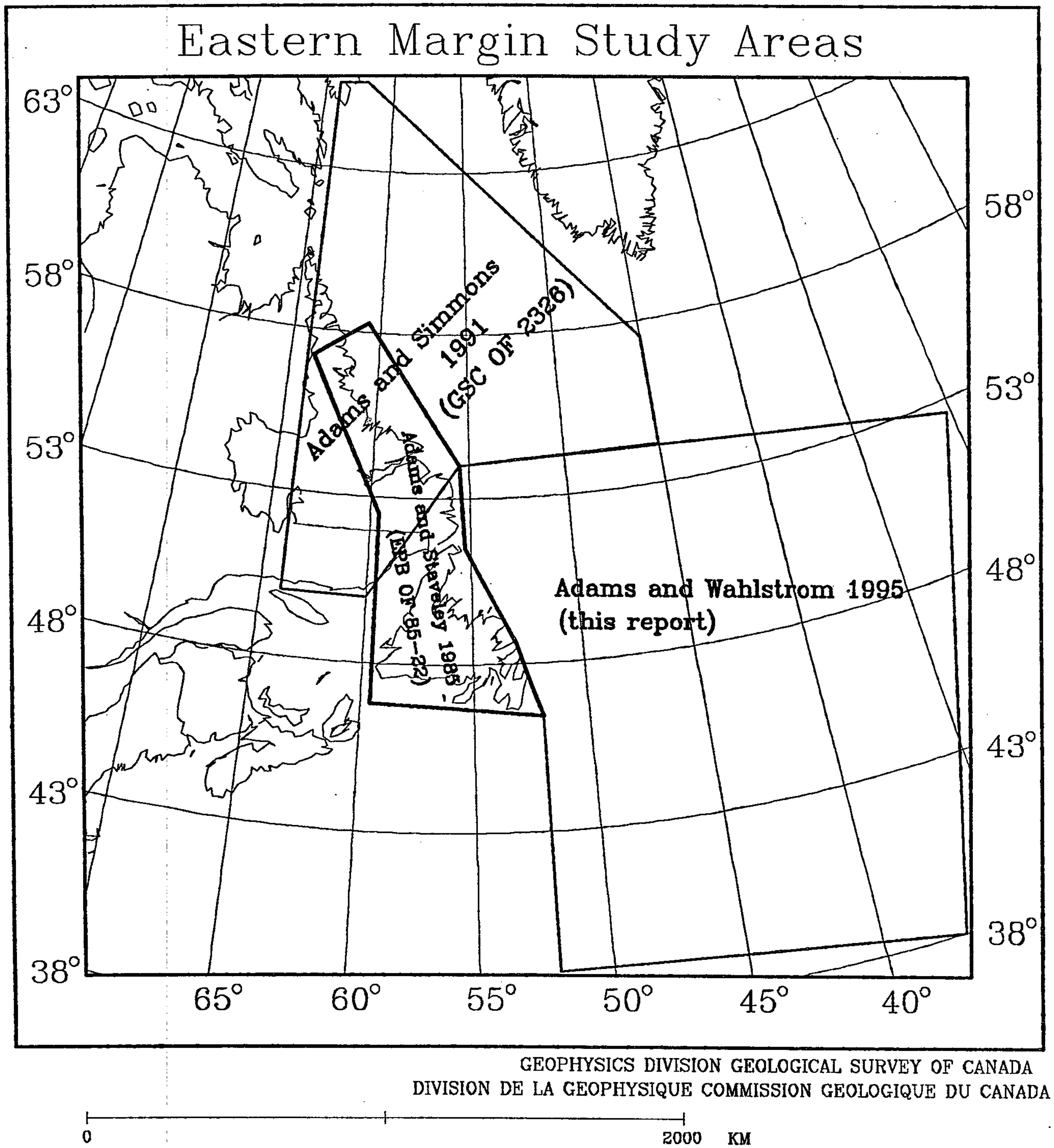
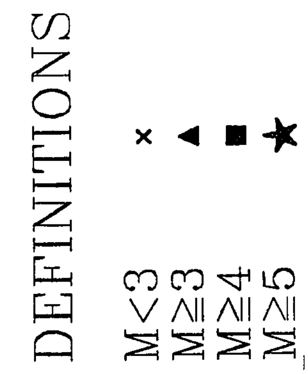


Figure 1. Map of the Eastern Margin showing the geographic scope of the two published reports and the region of the present study.

Figure 2. Seismicity of the Grand Banks as known in 1985, taken from the then-current Canadian Earthquake Epicentre File. Only earthquakes within the study area (east of the heavy line) are shown. Symbols in this and subsequent figures are:– star, magnitude (M) ≥ 5.0; square, $4.0 \leq M \leq 4.9$; triangle, $3.0 \leq M \leq 3.9$; and cross, $M \leq 3.0$.



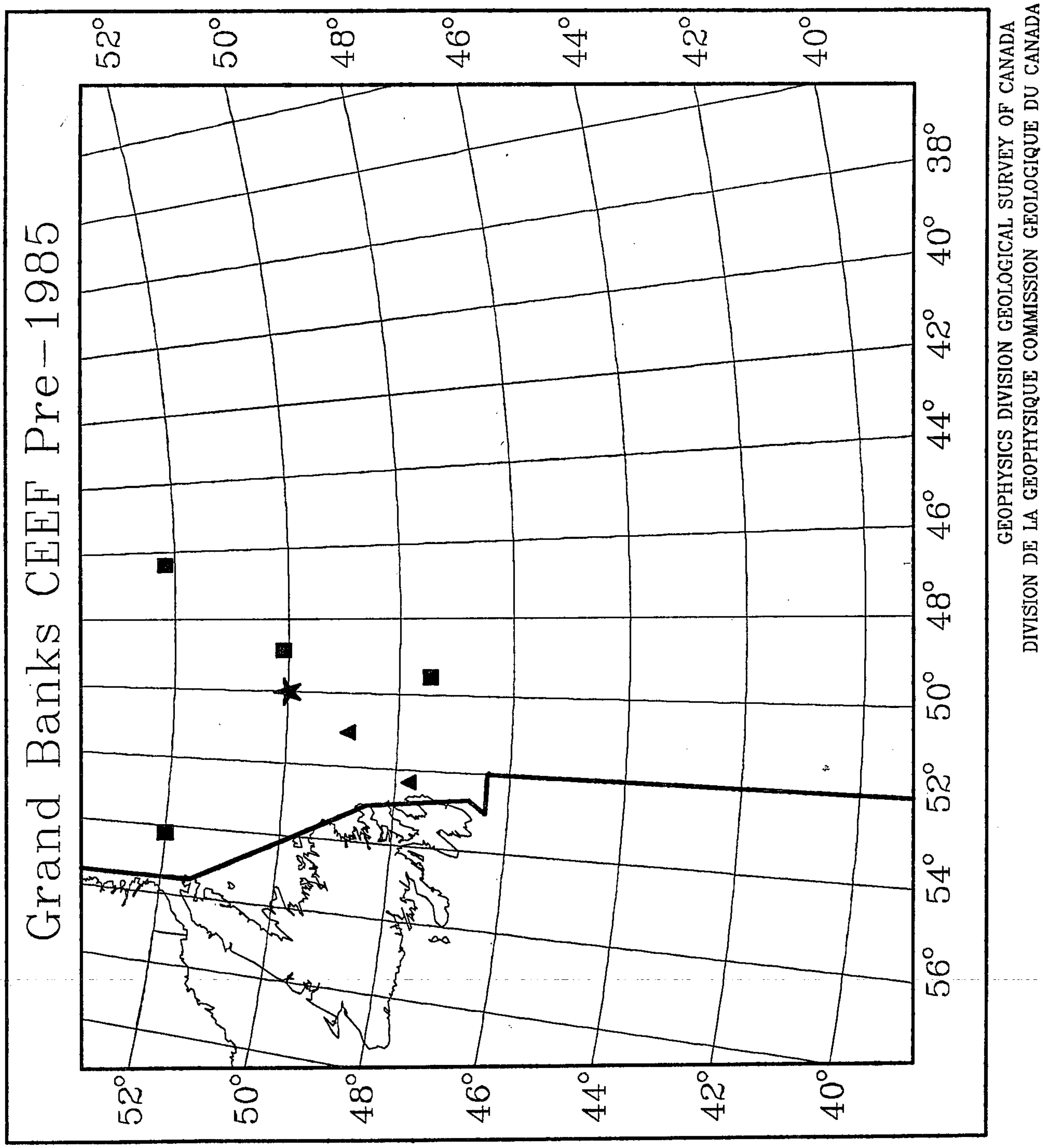


Figure 3. Relocated Grand Banks earthquakes. The label next to each earthquake symbol identifies the earthquake by year (76, 81, etc) and sequence in the year (84a, 84b, etc) and reference to Table 3.

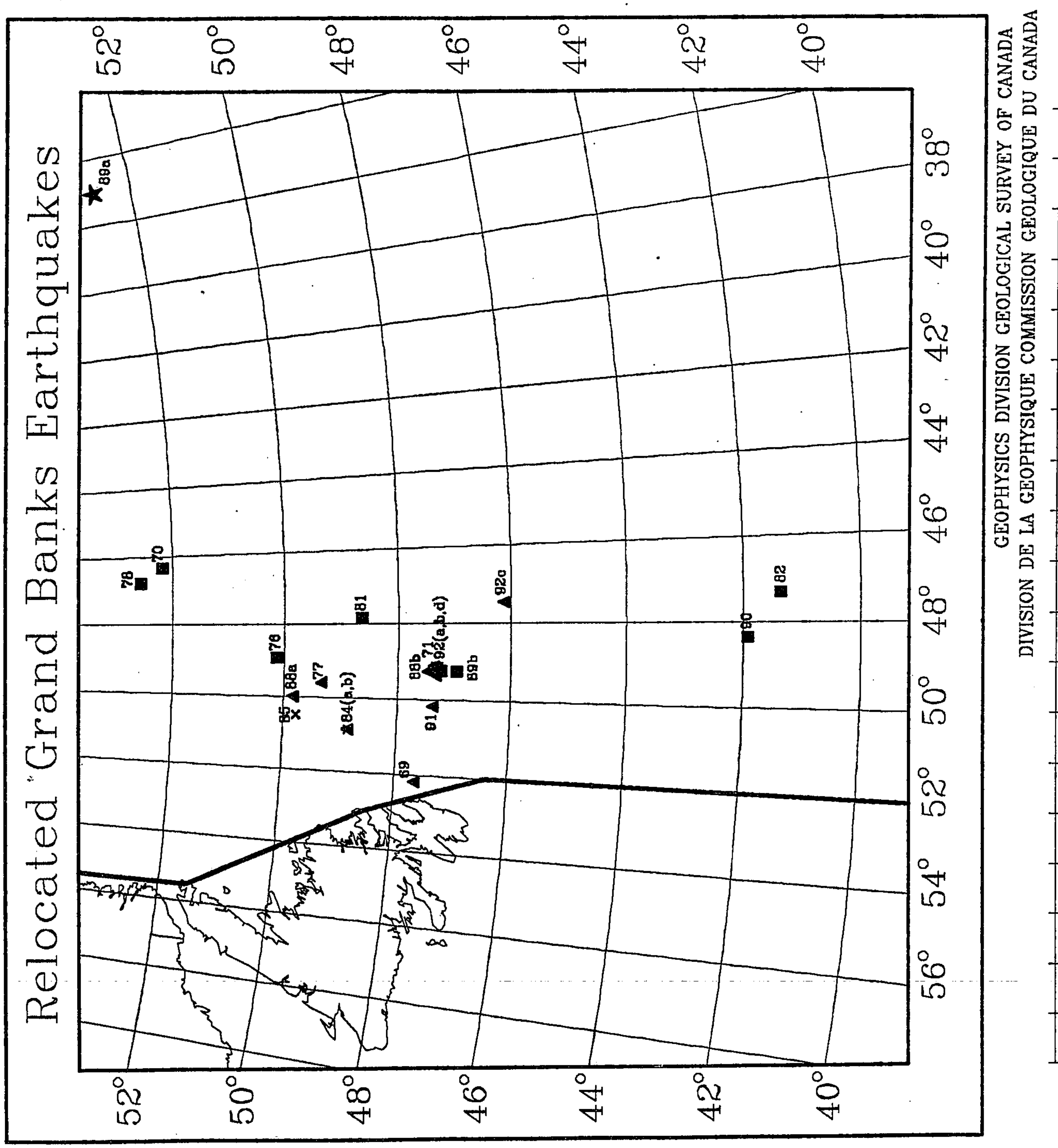


Figure 4. Relocation vectors for the studied earthquakes. The heavy lines extend back from the revised epicentre (also marked by a symbol) to the pre-revision epicentre. For most earthquakes the revisions are small, less than the symbol size, but two events have moved north, off the map area (see text).

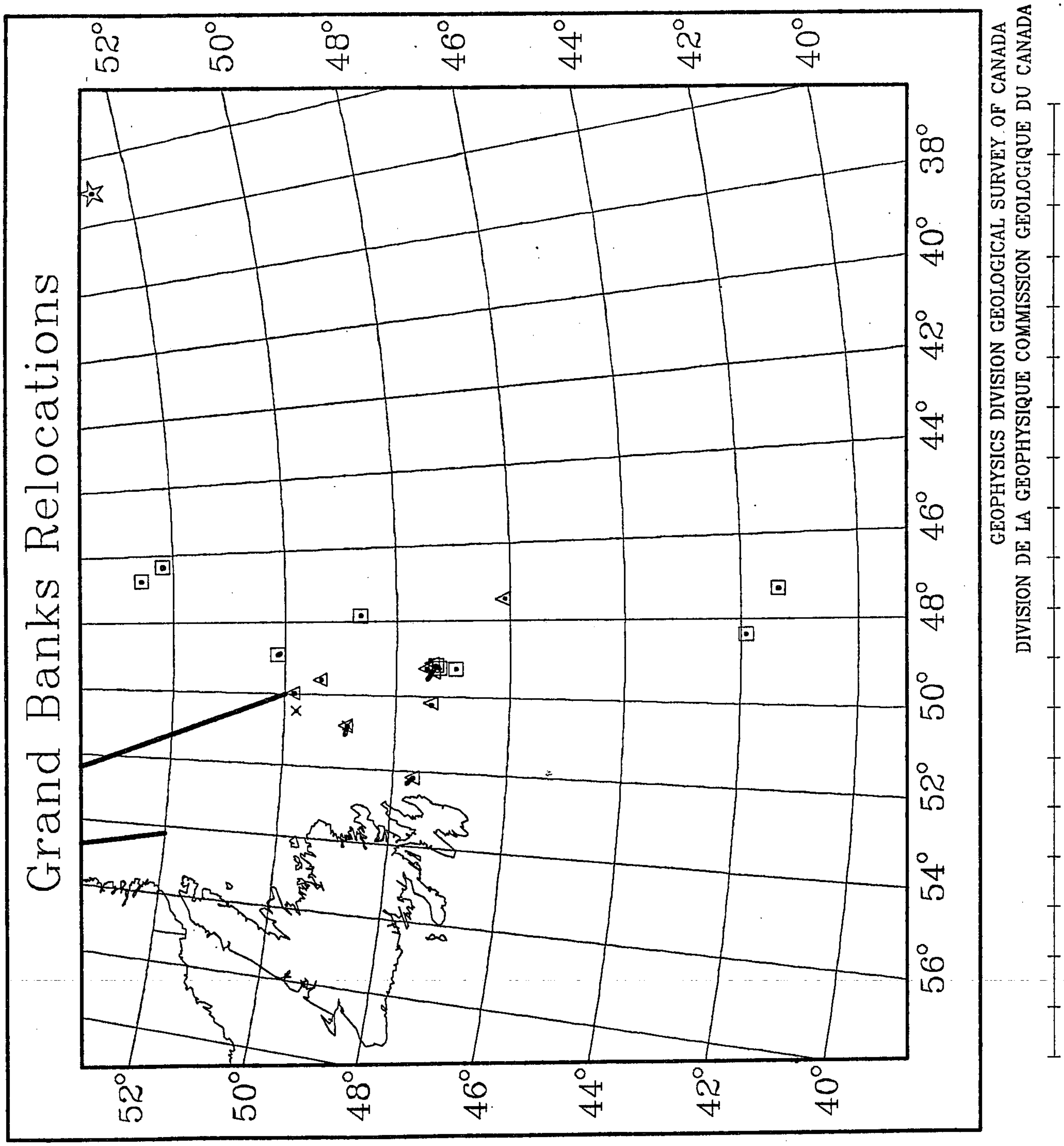
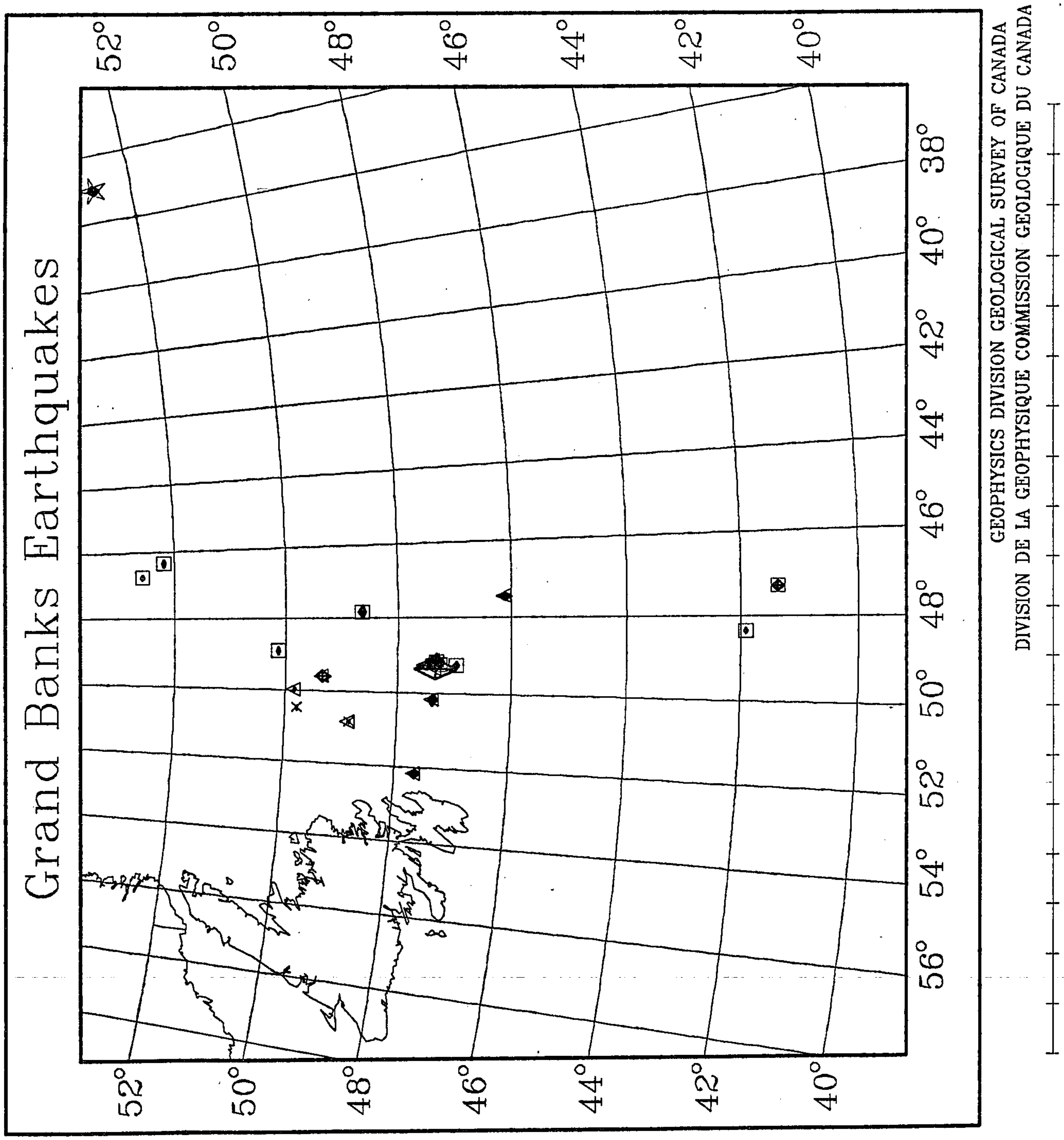


Figure 5. Computed uncertainty for the revised epicentres, as represented by precision diamond (the axes represent the standard errors in latitude and longitude). For almost all the earthquakes, the computed precision is less than the space occupied on the map by the earthquake symbol (see also Fig. 6 and 7), though the plotted epicentres may be inaccurate by an amount at least as large as the symbol size.



010406
48.75N
51.69W
3.1MN

Figure 6. Detail of Figure 5, showing the seismicity of the Grand Banks proper, together with the precision diamonds.

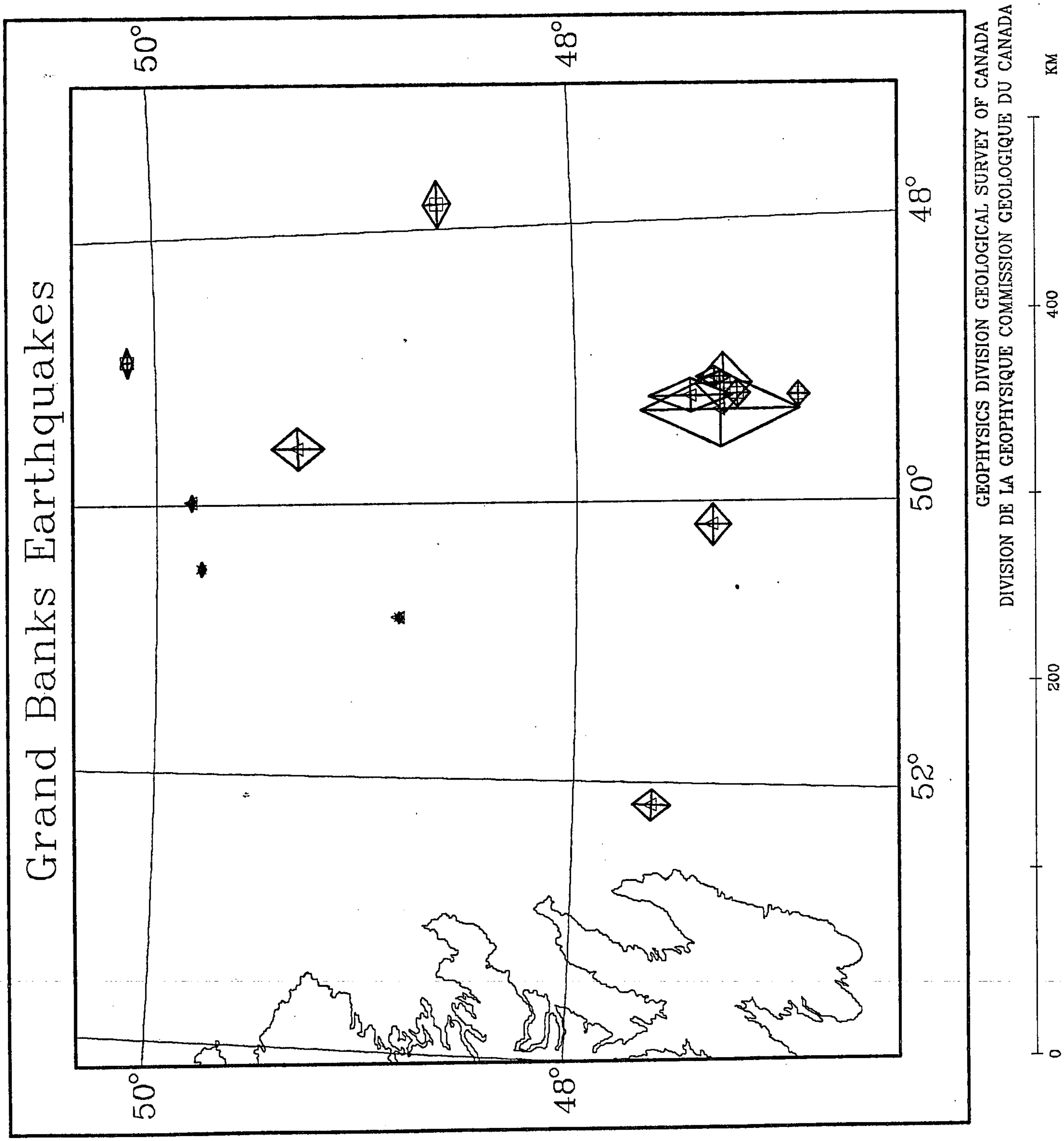


Figure 7. Detail of Figure 5, showing the epicentres in the cluster of earthquakes near Hibernia, together with their precision diamonds.

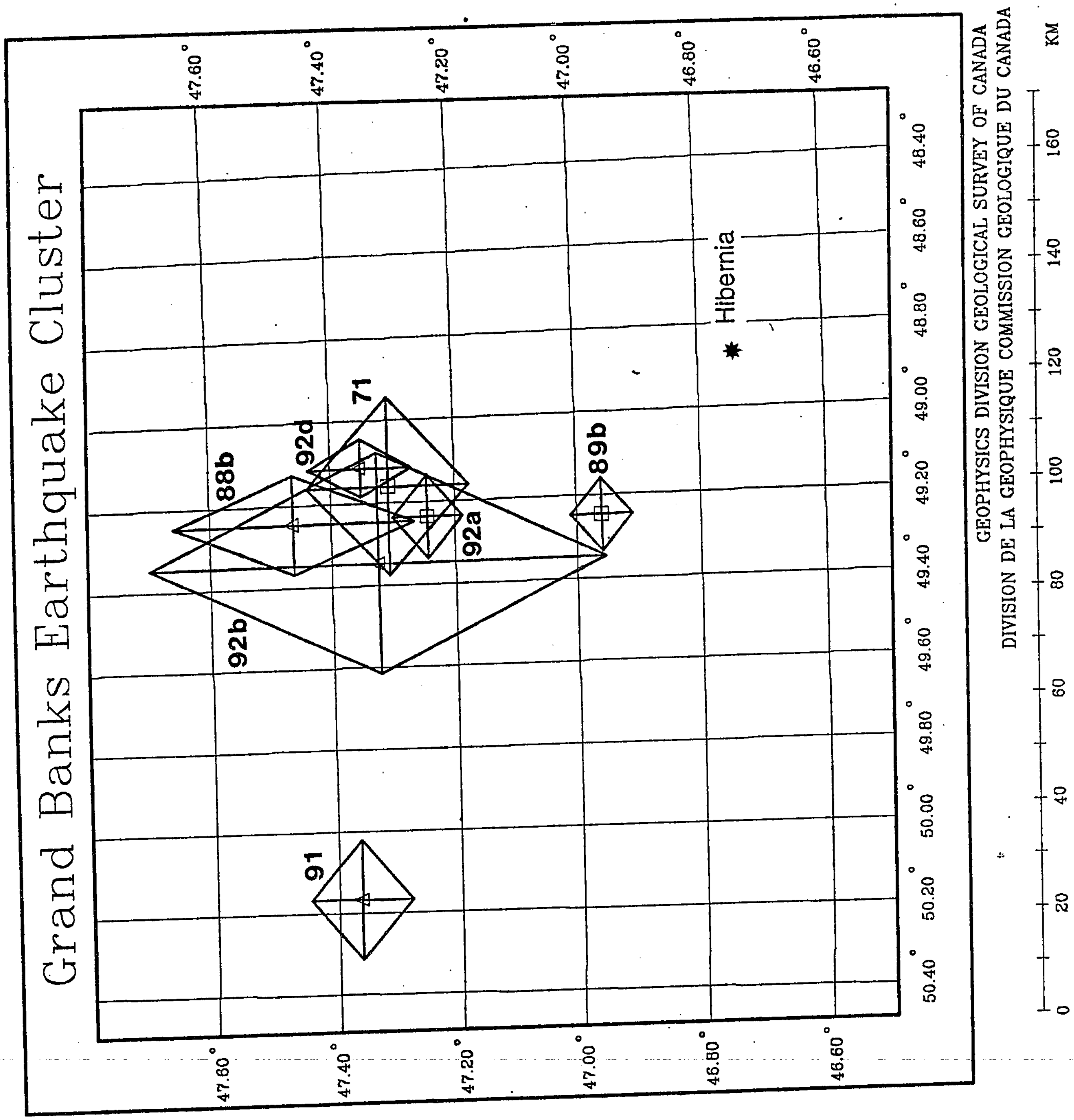
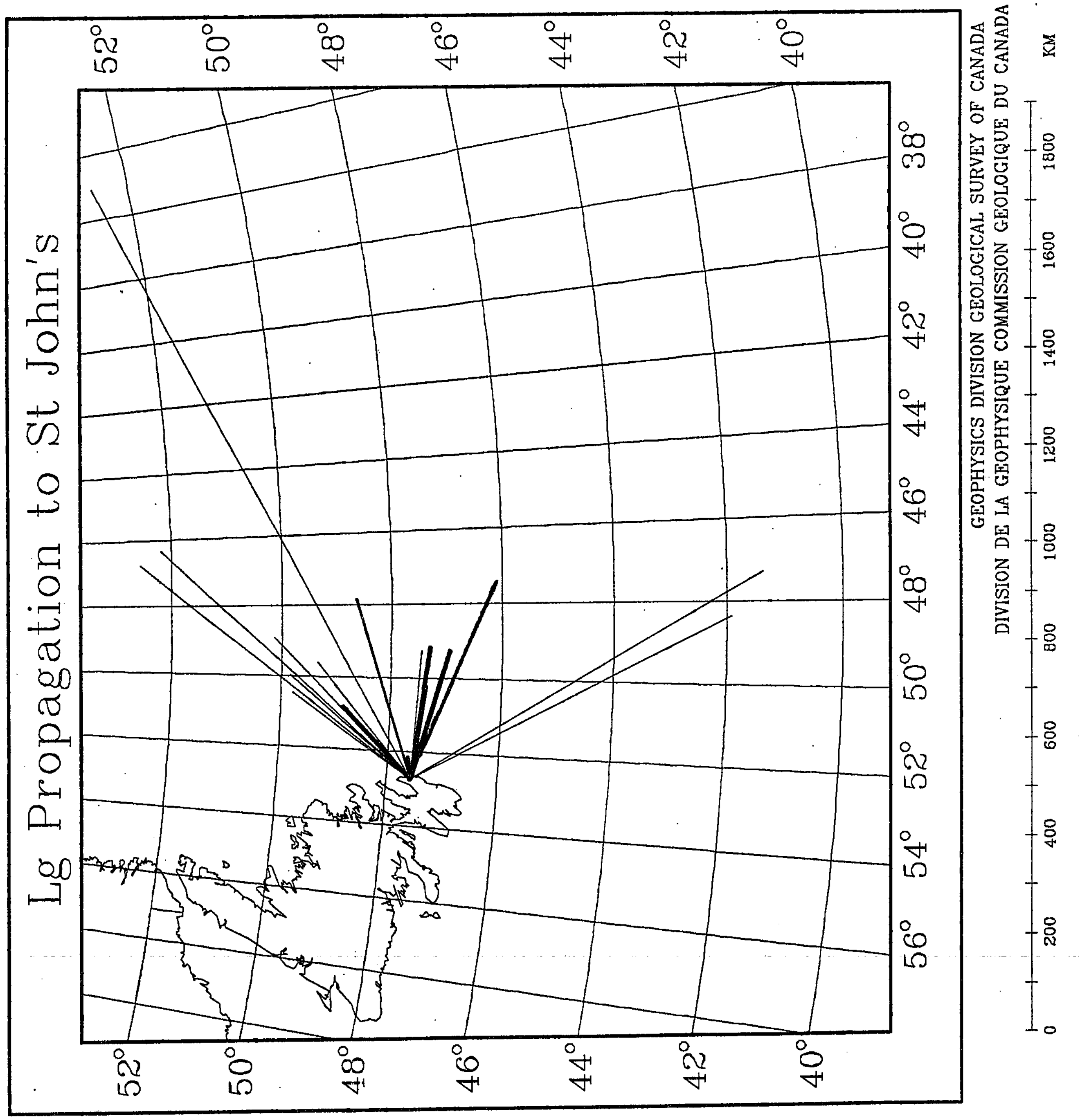


Figure 8. Propagation of Lg-wave energy to St. John's from offshore earthquakes. Thick lines represent paths with efficient propagation, single moderate-thickness line represents partial attenuation of Lg, and thin lines represent paths that completely attenuate Lg.



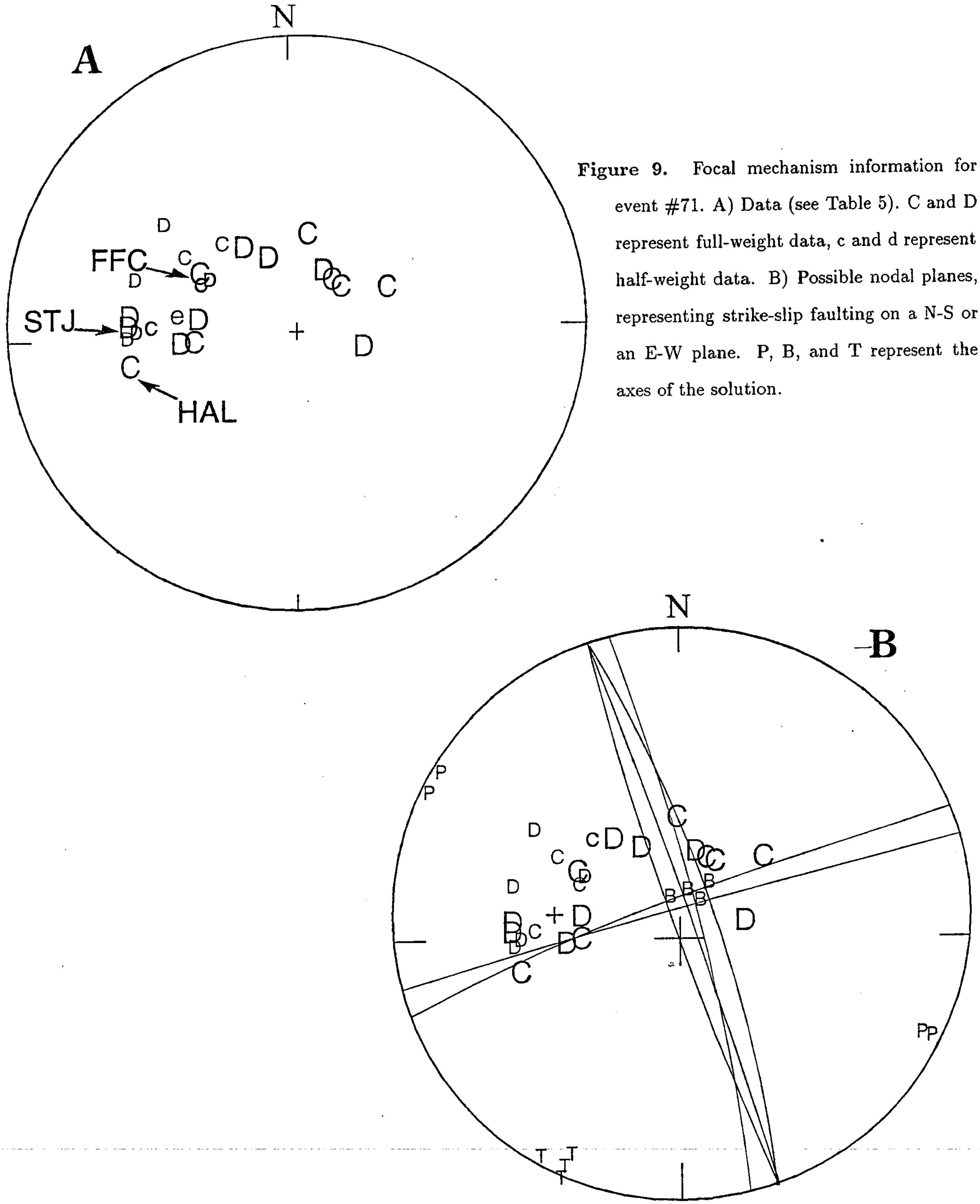
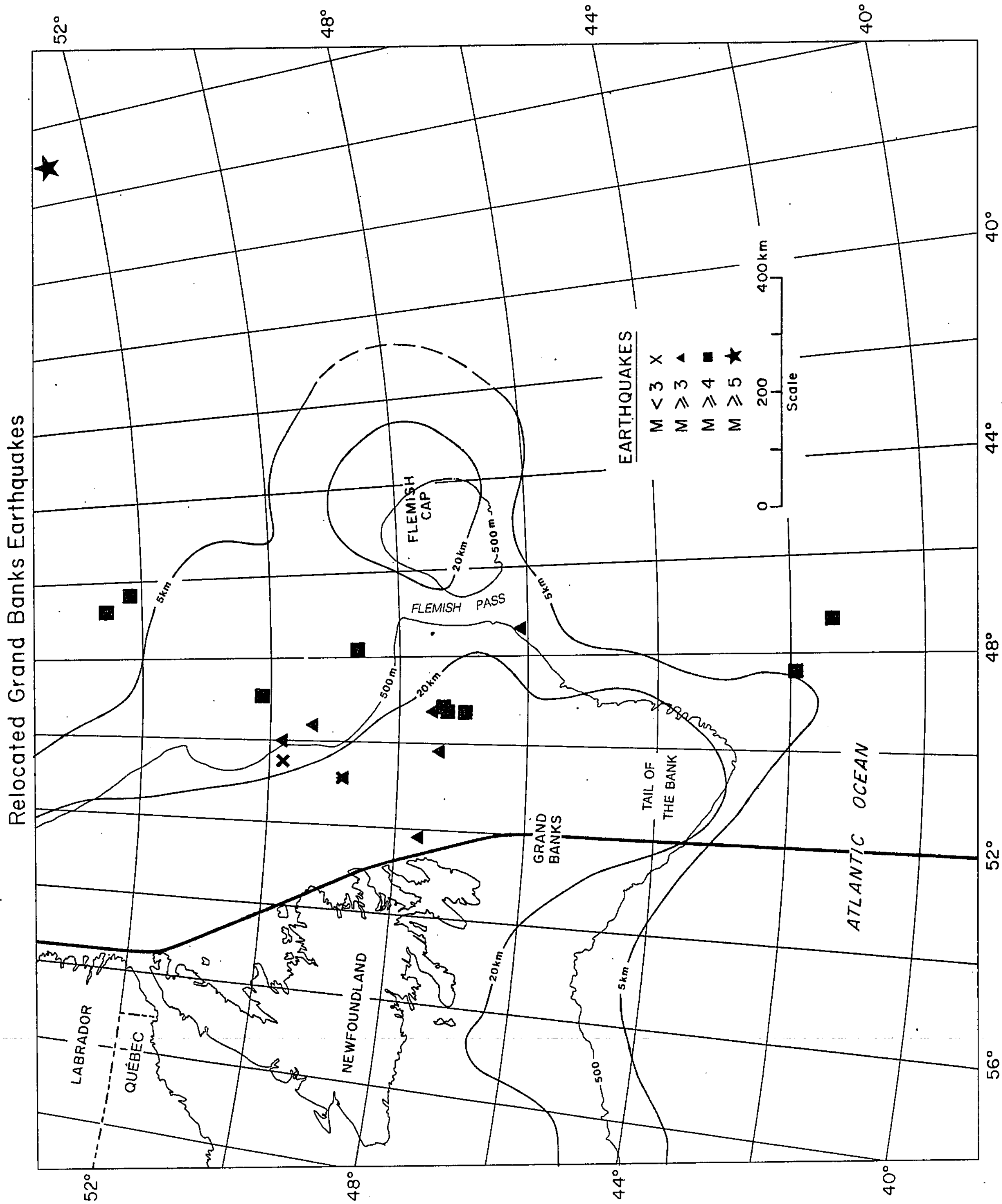


Figure 9. Focal mechanism information for event #71. A) Data (see Table 5). C and D represent full-weight data, c and d represent half-weight data. B) Possible nodal planes, representing strike-slip faulting on a N-S or an E-W plane. P, B, and T represent the axes of the solution.

Figure 10. Relocated offshore earthquakes, crustal thickness (taken from Shih et al., 1988), and 500-m isobath. Compare with Figure 3 to determine the identity of the events. As in previous maps, earthquakes west of the heavy line are not plotted.



APPENDIX

Event files in this Appendix are arranged chronologically. We have tried to provide a full documentation of our data and results, so for each earthquake there is a ''PIK" listing of the earthquake phase data used to compute the epicentre (a description of the format is given on the final pages), together with comments on the data and epicentre.

22

```
+70.000- 75.00001MS=5.1 0628550 26071922 00.0000.000 0.0  2  3  00.00N218.00   0 1ML=0.0  00  0L3.60
$50.0  - 50.0    ML=5.3 063108  CEEF
BAFFIN ISLAND REGION
$ ORIGINALLY PLACED BY ISS AT 50N 50W
$ EPICENTRE PEGGED AT LOCATION FOUND ROUGHLY BY WAHLSTROM
$ SEE GSC OPEN FILE 3043 BY ADAMS AND WAHLSTROM
$  DOUBTFUL THAT ANY BETTER CAN BE DONE WITHOUT THE ORIGINAL RECORDS
$ SAS OPERATING BUT RECORD NOT KEPT
$ HAL READINGS BY WAHLSTROM FORCES EPICENTRE TO NORTH
$ CHI, WAS, ESK READINGS FROM ISS, REPRESENT RAYLEIGH WAVE MAXIMUM
$     SEE TEXT OF GSC OPEN FILE 3043 FOR DISCUSSION
$  OTT P TAKEN WITH ASSUMED 1 MIN READING OR REPORTING BLUNDER FITS HAL S IF PHASE IS FIRST S
$ LOCATION FROM HAL P AND SN, OTT SN AND (P-1MIN) IS:
$68.837- 73.76301MS=5.1 0629094 26071922 00.3742.100 0.0  3  4  02.52 218.00   0 1ML=0.0  00  0 3.62
$ GSC DOES NOT CURRENTLY HAVE A TELESEISMIC LOCATION PROGRAM TO ALLOW
$  FITTING THE DISTANT PHASES
$
OTT  2207260631P  X3514                         3837  X4006
OTT   S  2744KM 00 6012$181 35                 00-1148$00-9123$  0000000 00ML00MN
HAL  2207260631P   3433                         3905  X3905
HAL   S  2899KM 00  622 161 34                 00-1646$00-9999$  0000000 00ML00MN
CHI  2207260631P                                      X4215
CHI   S  3215KM         200 33                        00-9307$  0000000 00ML00MN
WAS  2207260631P                                      X4400
WAS   S  3468KM         183 33                        00-5841$  0000000 00ML00MN
ESK  2207260631P                                      X4400
ESK   E  3748KM         078 32                        00-9999$  0000000 00ML00MN
            Z
```

62

```
+61.027- 58.2250 ML=4.8 0131042 03081962 00.0000.000 0:0  2  3  10.00 218.00   0 1MN=0.0  00  0 3.65
$+52    -54.2     ML=4.8 CEEF AFTER SMITH
$ LABRADOR RIDGE (PROBABLY)
$ NEEDS GREENLAND STATIONS AND RES, MBC, ALE, PNT.
$
$ SMITH'S COMMENTS
$  SCH CLEAR PN AND SN; NO LG - OCEANIC EVENT
$  HAL (SN) TRACE "VERY SMALL AND MAY NOT BE ASSOCIATED".
$  WESTERN EPICENTRE NOT POSSIBLE BECAUSE OF LACK OF RECORDS ON SOUTHERN STATIONS.
$
$ WAHLSTROM COMMENTS:
$  HAL: RE-READ AT LAMONT, LARGE T.C. USED TO REPORT PHASE IN BULLETIN
$       CONFIRMED WITH TELESEISM, CHECK AGAIN FOR S.
$  SCH: ARR. TIMES AND AMP/PER FROM SMITH CONFIRMED (ROUGHLY) BY MICROFILM,
$       RECORD NOT FOUND? (CHECK)
$  SFA: MICROFILM NOT FOUND, RECORD NOT FOUND, INTERMITTENT OPERATION
$  SHF: NO SIGNAL FROM MICROFILM, RECORD NOT FOUND? (CHECK)
$  OTT: STATION DISCONNECTED.
$  MNT: POSSIBLE S PHASE AT 3904 ON EW, NOT ON NS. 44 SEC TOO LATE FOR SN
$
$ ADAMS COMMENTS
$  NO TRACE OF SECOND (EARLIER OR LATER) PHASE ON HAL
$  HAL PHASE RE-INTERPRETED AS PN, PLACES EPICENTRE ON LABRADOR RIDGE.
$  CURRENT EXPERIENCE SUGGESTS SMITH EPICENTRE JUST N OF NEWFOUNDLAND
$    SHOULD HAVE GENERATED LG ON SCH
```

```
$  RIDGE LOCATION IS CONSISTANT WITH OCEANIC PATH FOR SCH.
$  RIDGE IS LOCUS OF MANY EARTHQUAKES; SMITH'S LOCATION IS HIGHLY UNUSUAL.
$  ABSENCE OF SN ON HAL IS STILL PUZZLING.
$  COMPARE WITH ML=5.0 EVENT ON 621202.
$  COMPARE WITH ML=5.1 EVENT ON 621026. THIS EVENT ALSO LACKS HAL SN READING
$    THOUGH AS IT WAS LARGER HAD PN ON SHF AND RES TO CONFIRM NORTHERN EPICENTRE.
$
$
SCH  6208030132P   32545                        3416              30 175 150       8 1
SCH   SW 0857KM 10  000 220 49                 10  000             0001795 48ML42MN
HAL  6208030132P   3456                                                              1
HAL   S  1860KM 10  000 193 50                                     0000000 00ML00MN
           Z

69

+47.632- 52.156F1MN=3.4 2153207 05081969 00.0860.110 0.2  5  9  40.94 218.00   0 1ML=0.0  00  0 3.62
$47.74 - 52.31   MN=3.3 215324  CEEF
$ OFF ST JOHN'S
$ ST JOHN'S NEWSPAPERS DO NOT REPORT IT AS FELT, DESPITE CLOSENESS
$ COMMENT FROM COMPUTER CARDS:  FM IS CNW - EVENT FROM ALMOST DUE EAST
$ HAL: LG USED FOR MAGNITUDE, MAY BE ATTENUATED
$
STJ  6908052153P                      A53288 C            A53333                     1
STJ   W  0044KM         261-68        03  036             08 -059   0000000 00ML00MN
HAL  6908052153P  B5523                         B5652    X5746    040  66   6        1
HAL   W  0944KM 03  142 254 49                  01  089 00  446    0000143 40ML32MN
SIC  6908052153P  A55421                                  B58275  050 106  10        1
SIC   W  1105KM 18  088 290 49                            03  154   0000119 42ML32MN
SCH  6908052153P  A56032                                  B5922   050  72  11        1
SCH   NW 1294KM 32 -117 314 49                            20  365   0000192 46ML36MN
SFA  6908052153P  B56190                                                             1
SFA   W  1409KM 01  071 275 49                                      0000000 00ML00MN
GWC  6908052153P                                         XB6224   090  35   4        1
GWC   NW 1959KM         305 47                            00  195   0000080 47ML35MN
           Z

70

+52.189- 46.33301ML=4.3 1744440 31101970 00.0310.110 0.3  2  4  20.29 218.00   0 1MN=0.0  00  0 3.62
$ 52.17    46.37  ML=4.3 174445  CEEF
$ GRAND BANKS
$ ORIGINAL COMMENTS: NO RECORDS FOR SIC; NOT AT HAL, FBC, SFA, GWC
$ WAHLSTROM COMMENTS: NOT ON HAL,OTT,GWC,FBC,SFA,SUD
$      SIC CLOCK WRONG
$      NO SIGNAL ON HAL EXCLUDES THE OTHER POSSIBLE SOLUTION: 43.3N 59.3W
$ ML ASSUMED - EARTHQUAKES CLOSE BY DO NOT HAVE LG
$
STJ  7010311744P   46135                        47205             30  34   9       8 1
STJ   SW 0689KM 15 -036 224 49                  05  021            0000554 41ML36MN
SCH  7010311744P   4739                         4948              40  94   9       8 1
SCH   W  1384KM 15  036 290 49                  05 -021            0000150 45ML35MN
           Z

71

+47.308- 49.160F1MN=4.8 0617095 15081971 00.1310.215 0.2 10 17  62.50 218.00   0 1ML=0.0  00  0L3.62
$ 47.46- 49.53   MB=4.8 061715   CEEF  (FROM ISC)
$ 47.46- 49.53   MB=4.8 0617152  ISC
$ GRAND BANKS
$ READING BY WAHLSTROM IN 1985 ADDED BY ADAMS OCT 1988
$ POLARITIES CHECKED BY ADAMS OCT 1988
$ WAHLSTROM COMMENTS: STJ ONLY GIVES DIST=255KM, BACKAZ=084DEG, H=18KM ASSUMED
$                     I.E. 47.8N 49.4W OT=061713
$ STJ: FM IS D-E. EVENT FROM SLIGHTLY NORTH OF EAST
$     WELL-RECORDED ON LPS
$ HAL: FM IS C. LG SLIGHTLY LARGER THAN SN
$ SCH READ BY WAHLSTROM AS C; BY ADAMS AS -
$ SIC READ BY WAHLSTROM AS C; BY ADAMS AS +
$ OTT READ BY WAHLSTROM AS  ; BY ADAMS AS +
$
$
$ CHECK ISC
$ CHECK REST OF CSN
$ WAHLSTROM HAS TRIED A FM
$
STJ  7108150617P  A17498 D       X17508      B18172  X18192                          1
STJ   W  0271KM 05  147 278 49   00 -259     00  042 00 -544    0000000 00ML00MN
```

```
HAL  7108150617P  A19371 C                     A21278          100  18 155       3 1
HAL   W  1156KM 02  087 260 49                 17  277           0005411 60ML49MN
SIC  7108150617P  A19560 C
SIC   W  1329KM 04 -137 290 49                                   0000000 00ML00MN
UNB  7108150617P  A19533 -                           XA23336  100  35 166
UNB   W  1346KM 81 -604 270 49                         00 1232$  0002980 59ML48MN
SCH  7108150617P  A20167 C                     A22344           80  62 405
SCH   NW 1486KM 00  015 311 49                 02 -098           0005130 63ML51MN
SFA  7108150617P  A20330 D                     A23069  X25001   90  27  45
SFA   W  1637KM 08 -193 277 49                 01 -054 00 1826$  0001164 57ML45MN
OTT  7108150617P  A21213                       B24410          110  17  28
OTT   W  2047KM 01 -074 274 47                 06  650           0000941 58ML46MN
GWC  7108150617P  A21376 +                     B24578          100  26 115
GWC   NW 2165KM 21  305 305 45                 01 -194           0002779 63ML51MN
FBC  7108150617P  B21389                       B25114           90  39  18       3
FBC   NW 2181KM 01  269 334 43                 09  827           0000322 54ML42MN
SUD  7108150617P  A22011 +                                     110  20  49
SUD   W  2411KM 12  229 280 39                                   0001399 61ML49MN
           Z
```

76

```
+50.133- 48.910F1ML=4.1 1923304 28081976 00.0260.108 0.3   5   8   30.54 218.00    0 1MN=0.0   00   0 3.62
$50.10 - 48.85    ML=4.0 192330   CEEF
$ GRAND BANKS
$ MUNF IS MEMORIAL SEISMOGRAPH IN STJ VAULT
$ WAHLSTROM COMMENTS:
$ ISC: AS OTT SOLUTION, I.E., 50.10 N 48.85 W OT=192330 ML=4.0 "POOR SOLUTION"
$ MIQ, SUD, FRB, OTT, QCQ, LGQ: NOT RECORDED, CBK, HAL: RECORD NOT FOUND
$ PBQ: VISIBLE 1932 BUT NO CLEAR ONSET
$ UNB, SIC: PROB DISTURBANCES AT APPR 2940
$
MUNF 7608281925P                                                40  73 156       8 1
MUNF  SW 0400KM          226 49                                  0003357 42ML39MN
STJ  7608281925P  A24258 D                     A25048           40  32  20       8 1
STJ   SW 0400KM 34  086 226 49                 04 -028           0000982 37ML34MN
SCH  7608281925P  A26168                       A28209           30 100   8       8 1
SCH   NW 1318KM 01 -017 300 49                 06  037           0000168 43ML35MN
MNQ  7608281925P  A26281                       B28427           50       5       3 1
MNQ   W  1412KM 04 -031 279 49                 14  219           0000000 00ML00MN
POC  7608281925P  A26483                                                           1
POC   W  1580KM 12 -052 267 49                                   0000000 00ML00MN
CHQ  7608281925P  B27006                                                           1
CHQ   W  1688KM 05 -137 266 49                                   0000000 00ML00MN
           Z
```

77

```
+49.337- 49.58601ML=3.4 0805261 25031977 00.1230.155 0.0   2   4   10.12 218.00    0 1MN=0.0   00   0 3.62
$ NEW EVENT FOUND BY SEARCHING MEMORIAL UNIVERSITY SEISMOGRAMS
$ GRAND BANKS
$ ALTERNATIVE LOCATION (LESS LIKELY BECAUSE HAL SHOWS NO TRACE) FOLLOWS:
$44.88 - 52.59 01ML=3.4 080527. 25031977 1 0.06 0.54 0.0   2   5   1 0.5 218MUN 300
$ CBK PEN AND INK RECORD
$ MUNF NO LG
$
MUNF 7703250806P  A0609           XB06175      A06405          030 108  85       8 1
MUNF  SW 0305KM 00 -001 231 49     00  213     00  001           0001648 34ML34MN
CBK  7703250806P  C0649                        C0745                               1
CBK   W  0614KM 30  227 269 49                 10 -130           0000000 00ML00MN
HAL  7703250806P                                                                   1
HAL   W  1185KM          249 49                                  0000000 00ML00MN
           Z
```

78

```
+52.573- 46.752F1ML=4.1 1435140 03011978 00.0280.073 0.1   3   6   30.36 218.00    0 1MN=0.0   00   0 3.62
$ NEW EVENT FOUND BY SEARCHING MEMORIAL UNIVERSITY SEISMOGRAMS
$ GRAND BANKS
$ ADAMS RE-READ RECORDS OCT 1988
$ MUNF, STJ NO LG
$
MUNF 7801031436P XA36458 -                     X37542          030 108  30       8 1
MUNF  SW 0702KM 00  038 220 49                 00  120           0000582 41ML36MN
STJ  7801031436P  A36455 -                     A37530          040  29   6       8 1
STJ   SW 0702KM 01  008 220 49                 00  000           0000325 40ML33MN
CBK  7801031436P  A3710      -2.0              A38350                              1
CBK   SW 0889KM 08 -029 247 49                 01  010           0000000 00ML00MN
```

```
SCH  7801031436P  B38066                        A40094          050 120    7        8 1
SCH   W  1343KM 50  295 289 49                  01 -008           0000073 42ML32MN
FRB  7801031436P                                                                     1
FRB   NW 1773KM          323 49                                   0000000 00ML00MN
             Z
```

81

```
+48.643- 47.820F1ML=4.2 1306126 26091981 00.0670.170 0.2  5 10  61.16 218.00   0 1MN=0.0  00  0 3.62
$ NEW EVENT FOUND BY SEARCHING MEMORIAL UNIVERSITY SEISMOGRAMS
$ GRAND BANKS
$ READ BY WAHLSTROM AND ADAMS
$MUNF: TC UNKNOWN, APPEARS TO BE 0.0 AS TIMES AGREE
$MUNF: LG=0.5SN, NO AFTERSHOCKS
$CBK: T.C. UNKNOWN, T.C. -2 SEC APPLIED
$     LG WEAK OR ABSENT
$HAL: V QUIET TRACE
$SIC: QUIET, NO PHASES READABLE
$UNB: BOTH READING SIMILAR TO NOISE
$LPQ,LMQ: HIGH FREQUENCY ON LOW FREQUENCY NOISE
$FRB: NOT RECORDED
$
STJ  8109261307P  A07068           A07155       A07431          50  36  65          8 1
STJ   W  0385KM 24  153 254 49     05  073      09 -095           0002269 41ML37MN
MUNF 8109261307P                                                30 108 250          8 1
MUNF  W  0385KM          254 49                                   0004848 42ML41MN
CBK  8109261307P  X07523                        X09031          50      89          3 1
CBK   W  0746KM 00  291 276 49                  00  208           0000000 00ML00MN
HAL  8109261307P  X09046                        B10566          50  83   6          8 1
HAL   W  1285KM 00  957 256 49                  01  106           0000091 43ML32MN
UNB  8109261307P XB09168                                                              1
UNB   W  1452KM 00  139 265 49                                    0000000 00ML00MN
SCH  8109261307P  A09180                        A11369          40  95   6          8 1
SCH   NW 1474KM 00 -016 305 49                  10  100           0000099 44ML34MN
MNQ  8109261307P  A09224                        B11437          40 220   8          8 1
MNQ   W  1526KM 43 -204 286 49                  06 -315           0000057 42ML31MN
LPQ  8109261307P XA09410                                                              1
LPQ   W  1658KM 00  050 273 49                                    0000000 00ML00MN
LMQ  8109261307P  A09427                        B12200          30 190   3          8 1
LMQ   W  1676KM 00 -006 274 49                  01  119           0000033 39ML30MN
             Z
```

82

```
+41.367- 47.282F1ML=4.0 0407239 22071982 00.1040.124 0.1  6  8  41.05 218.00   0 1MN=0.0  00  0 3.62
$ NEW EVENT FOUND BY SEARCHING MEMORIAL UNIVERSITY SEISMOGRAMS
$ SOUTHEAST OF TAIL OF THE BANK, GRAND BANKS
$ FIRST EARTHQUAKE KNOWN IN THIS AREA
$ GOOD ON MUNF, STJ AND CBK, KLN
$ HAL: VERY WEAK
$ CBK TC SEVERAL HOURS AND ABOUT 26 SECONDS
$ SCH, UNB: PRESENT, BUT UNCLEAR
$ SIC, GSQ, LMN, GGN, LMQ: RECORDS NOT CHECKED
$
STJ  8207220409P  X09114                        A10267          50  36   4          8 1
STJ   NW 0815KM 00  239 330 49                  00 -009           0000140 39ML31MN
MUNF 8207220409P  A09087                        X10277          20 173  19          8 1
MUNF  NW 0815KM 01 -031 330 49                  00  090           0000345 39ML35MN
CBK  8207220409P  X1021      -26.4              X12123          50      11          3 1
CBK   NW 1186KM 00  022 319 49                  00 -006           0000000 00ML00MN
HAL  8207220409P XB10284                        B12265                                1
HAL   W  1377KM 00 1084$291 49                  00  011           0000000 00ML00MN
KLN  8207220409P  A10491                        A13210          20 628  18          8 1
KLN   NW 1641KM 05 -070 298 49                  28 -164           0000090 41ML34MN
EBN  8207220409P  A11082                        A13573                                1
EBN   NW 1795KM 00 -018 299 52                  32  177           0000000 00ML00MN
MNQ  8207220409P  A11264                       XC14327          50 161   2          8 1
MNQ   NW 1944KM 14  115 309 50                  00  557           0000016 39ML28MN
             Z
```

84a

```
+48.852- 50.8370lMN=3.6 1925475 26051984 00.0190.037 0.3  8 18  60.48 218.00   0 1ML=4.1  30  0 3.62
$48.89 - 51.06    MN=3.5 192540   CEEF
$ GRAND BANKS
$ KLN,SIC NOISY.
$ LG>SN FOR THIS OFFSHORE EVENT
$ AFTERSHOCK ONLY ON MUNF AT 2204:50, SAME S-P, MAGNITUDE = 2.6
```

```
$
STJ  8405261926P  A26181                          A26395  C26405  040  29 167         1
STJ    SW 0200KM 18  038 225 49                   07 -024 04 -266   0009046 37ML39MN
CBK  8405261926P  A26566                          A27490          030 184 125         1
CBK    W  0523KM 35 -053 274 49                   34  051           0001423 41ML38MN
GBN  8405261926P  A27427                          A29075          040 211  35         1
GBN    W  0896KM 05  021 249 49                   03 -014           0000261 42ML34MN
HAL  8405261926P  C2805                           X3002   C3049                       1
HAL    W  1080KM 00 -003 249 49                   00 1504$04  295   0000000 00ML00MN
SCH  8405261926P  B2829                           C3027   C3138   05  102  15         1
SCH    NW 1281KM 02 -054 307 49                   04 -273 06 -347   0000185 46ML35MN
GGN  8405261926P  C2830                           B3029           04  132  14       8 1
GGN    W  1283KM 00  026 257 49                   09 -107           0000167 44ML35MN
MNQ  8405261926P  C2831                           C3030   C31415  04  163  20         1
MNQ    W  1305KM 01 -154 285 49                   12 -495 23 -674   0000193 45ML36MN
JAQ  8405261926P                                          C3403   05  163  06         1
JAQ    NW 1811KM         297 52                           11 -479   0000046 43ML32MN
             Z
```

84b

```
+48.852- 50.837O1MN=2.6 2204198 26051984 00.0000.000 0.0  1  1  00.00H218.00   0 1ML=0.0  00  0 3.62
$ NEW EVENT NOT IN CEEF
$ GRAND BANKS
$ AFTERSHOCK OF EARTHQUAKE AT 192547
$ ONLY ON MUNF (STJ) AT 2204:50, SAME S-P, MAGNITUDE = 2.6 BY PROPORTION TO MAINSHOCK
$ PEGGED AT MAINSHOCK EPICENTRE
$
STJ  8405262204P  A0450
STJ    SW 0200KM 00  000 225 49                                     0000000 00ML00MN
             Z
```

85

```
+49.787- 50.480F1ML=2.8 1806035 03081985 00.0150.053 0.3  4  6  20.14 218.00   0 1MN=2.8  10  0 3.62
$ NEW EVENT FOUND BY SEARCHING MEMORIAL UNIVERSITY SEISMOGRAMS
$ WELL RECORDED ONLY ON STJ AND MUNF
$ HAL,SCH,MNQ,SIC,KLN,LPQ,LMQ, NOTHING
$ SLQ AT PAPER CHANGE
$ POOR RECORDING ON GBN CONFIRMS THIS EVENT IS NE OF STJ, AND NOT A LSP EQ
$ MUNF PN NEAR PAPER EDGE
$ HINT OF LG ON MUNF
$ GBN GOOD PHASE MUST BE PN TO FIT STJ ORIGIN TIME
$ CBK READINGS VERY POOR, MAY BE FOLLOWED BY LG AT 0841
$ SN ABSENT ON GGN, TINY ON GBN (TYPICAL FOR THESE EQ)
$ NOT A WELL-LOCATED EARTHQUAKE, BUT CLEARLY ON NORTHERN GRAND BANKS
$
MUNF 8508031806P XB06455                         XA07155          020 173  22
MUNF  SW 0297KM 00  001 215 49                    00 -080           0000400 26ML28MN
STJ  8508031806P  A06455                          A07163          040  29  11       8
STJ    SW 0297KM 00  001 215 49                   00 -001           0000596 30ML30MN
CBK  8508031806P  C0713                           C0812
CBK    W  0553KM 53 -369 263 49                   06  128           0000000 00ML00MN
GBN  8508031806P  A08065                         XC09435
GBN    SW 0961KM 00  001 244 49                   00  588           0000000 00ML00MN
GGN  8508031806P  C0852
GGN    W  1335KM 00 -002 253 49                                     0000000 00ML00MN
             Z
```

88a

```
+49.834- 49.982F1ML=3.5 0715448 09011988 00.0180.058 0.2  8 11  60.34 218.00   0 1MN=0.0  00  0 3.62
$49.880- 49.883  ML=3.5 0715438 CEEF
$ ON NORTHERN SIDE OF GRAND BANKS; AN AREA OF FEW EARTHQUAKES
$ SOLUTION BY ADAMS, WITH A GREAT DEAL OF EFFORT
$ HAL: NO SN VISIBLE
$ KLN MAX AMPLITUDE TINY
$
MUNF 8801090715P  A16297                         XA17045           30  91  70       8
MUNF  SW 0323KM 11 -022 220 49                    00  142          0001611 35ML35MN
STJ  8801090715P                                  A17030           40  29  15       8
STJ    SW 0323KM             220 49               02 -008          0000812 33ML32MN
CBK  8801090715P  A17023                          B17595           40 135  21       8
CBK    W  0589KM 01 -008 263 49                   01 -020           0000244 35ML31MN
GBN  8801090715P  A17525                          B1926            20 563  13       8
GBN    SW 0996KM 59  052 245 49                   01 -024           0000073 35ML29MN
HAL  8801090715P  C1817
HAL    SW 1180KM 06  261 246 49                                     0000000 00ML00MN
```

```
KLN  8801090715P XC1827                               C2022                           8
KLN    W  1258KM 00   305 261 49                      00 -002             0000000 00ML00MN
SCH  8801090715P  B1824                               B2024              30 137    4      8
SCH    NW 1270KM 27 -141  302 49                      04 -056             0000061 39ML30MN
MNQ  8801090715P                                      B2040              20 628    3      8
MNQ    W  1342KM          281 49                      00  003             0000015 31ML25MN
              Z
```

88b

```
+47.463- 49.24601ML=3.1 0016451 09081988 00.1950.120 0.0  5  8  20.76 218.00   0 1MN=3.2  20  0 3.62
$47.463- 49.293  ML=3.1 0016455 CEEF
$ ON THE GRAND BANKS, EAST OF ST JOHN'S
$ STJ HAS GOOD SHARP ONSETS
$ THIS EARTHQUAKE WOULD NOT HAVE BEEN MISSED ON MUNF! (& PERHAPS NOT ON STJ)
$ MUNF LG NOT EVIDENT
$ NOTHING ON HAL, SIC, LMQ, SLQ, GGN
$ SCH MEAREST WIGGLE AT 2218
$ MNQ SN MAY BE LOST NEAR PAPER EDGE
$ CBK HAS LARGER AMPLITUDE PHASE 20 TO 40 SEC AFTER SN
$ KLN NO SN; GBN SN AMP TOO SMALL FOR MAGNITUDE
$ POOR AZIMUTHAL DISTRIBUTION OF STATIONS
$ FITS ALMOST AS WELL AT 48.96N 49.98W (THIS MISFITS THE VERY POOR MNQ PHASE)
$ STJ P ONSET AND CODA IS STRONGER ON EW COMPONENT THAN ON NS, SUPPORTING
$   THE CHOSEN EPICENTRE OVER THE  ALTERNATIVE EPICENTRE TO THE NW OF STJ
$
STJ  8808090018P  A17235                              A17509             40  30  21       8
STJ    W  0263KM 15  059 274 49                       03  029             0001100 31ML32MN
MUNF 8808090018P XA17225                             XA17512             30  91  70       8
MUNF   W  0263KM 00 -041 274 49                       00  058             0001611 32ML33MN
CBK  8808090018P  B18105                              B19132
CBK    W  0668KM 09 -188 287 49                       37 -373             0000000 00ML00MN
GBN  8808090018P  A18487 C                            B20195
GBN    W  0970KM 06 -037 261 49                       05 -144             0000000 00ML00MN
KLN  8808090018P  B1928
KLN    W  1299KM 04 -126 273 49                                           0000000 00ML00MN
MNQ  8808090018P  C1951
MNQ    W  1466KM 00  137 291 49                                           0000000 00ML00MN
              Z
```

89a

```
+52.730- 35.200F1MS=5.4 2253371 14051989 00.0390.030 0.0 00 00 250.00H610.00   0 1MB=4.9  60  0L0.00
052.671- 35.037F1MB=5.0 2253387 14051989 00.1010.155 0.0 13 19  00.00H510.00   0 1ML=5.9  60  0L0.00
052.618- 34.687F1ML=5.9 2253369 14051989 00.0820.126 0.2 14 20  60.96 218.00
MID-ATLANTIC RIDGE                               RIDE MEDIO-ATLANTIQUE
MAG (NEIS) 5.0 MB (50 OBS)
$  ADOPTING THE NEIS ORIGIN TIME AND EPICENTRE LEADS TO A 5-6 S ERROR
$    ON ALL CANADIAN PHASES.  THIS IS LIKELY NOT DUE TO AN ERROR IN
$    THE TIME SERIES FILE TRIGGER ERROR, SINCE ALSO ON STD STATIONS
$    RATHER IT IS LIKELY DUE TO INAPPROPRIATE VELOCITY MODEL
$
SCH  8905142257P  A57565 -   0.00                     B0120              060  86 117    0  8
SCH    W  2092KM 00 -072 289 45                       00  468             0001425 60ML48MN
LMN  8905142257P  B581489   -0.29                     C615482            053 100  61    0  8
LMN    W  2278KM 00 -167 262 43                       00 -034             0000723 57ML45MN
GSQ  8905142257P  B581647   -0.22                     C615538            077 100 239    0  8
GSQ    W  2282KM 00 -042 272 41                       00 -056             0001950 62ML50MN
FRB  8905142257P  A58163 +   0.00                                        000   0   0    0  0
FRB    NW 2287KM 00 -083 316 41                                           0000000 00ML00MN
MNQ  8905142257P  B582045   -0.10                     C620766            080 100 173    0  8
MNQ    W  2330KM 00 -112 278 41                       00  158             0001359 61ML48MN
KLN  8905142257P  B582036   -0.29                     B620663            053 100  74    0  8
KLN    W  2330KM 00 -139 266 41                       00  037             0000877 58ML46MN
HTQ  8905142257P  B582390   -0.07                     C620999            060 100  50    0  8
HTQ    W  2357KM 00 -013 274 41                       00 -170             0000524 56ML44MN
EBN  8905142257P  B583069   -0.22                                        000   0   0    0  0
EBN    W  2426KM 00 -003 270 39                                           0000000 00ML00MN
LPQ  8905142257P  B584521   -0.22                                        000   0   0    0  0
LPQ    W  2551KM 00  296 271 37                                           0000000 00ML00MN
DPQ  8905142257P  C590130   -0.06                                        000   0   0    0  0
DPQ    W  2772KM 00  006 271 35                                           0000000 00ML00MN
TRQ  8905142257P  B591363   -0.09                                        000   0   0    0  0
TRQ    W  2917KM 00  029 272 34                                           0000000 00ML00MN
GRQ  8905142257P  B591813   -0.09                                        000   0   0    0  0
GRQ    W  2985KM 00 -067 273 33                                           0000000 00ML00MN
WBO  8905142257P XC593216   -0.06                                        000   0   0    0  0
WBO    W  3033KM 00  950 270 33                                           0000000 00ML00MN
```

```
EEO  8905142257P  B593575   -0.06                                   000   0   0     0  0
EEO   W  3200KM 00 -035 276 33                                        0000000 00ML00MN
             Z
```

89b

```
+46.960- 49.247F1ML=4.2 0515398 03121989 00.0500.088 0.4   6   9  40.71 218.00    0 1MN=0.0   00   0L3.62
OFFSHORE NEWFOUNDLAND                       AU LARGE DE TERRE-NEUVE
MAG (GSC) 3.9 MB (1 OBS)
$ MB 3.9 FROM YELLOWKNIFE ARRAY
$ MNQ DOWN,  TOO WEAK FOR OTHERS
$ LOCATION FROM YELLOWKNIFE ARRAY: 49.7 51.4 O.T. 05:15:58
$ SCH LG>=SN AMP; SN PRECEEDED BY NOISE
$ STJ UNABLE TO DECIDE IF LG>SN
$ FRB NOT VISIBLE
$ CBK NOT OPERATING
$ ADAMS ADDED STJ AND REVISED SCH
$ ADAMS DID NOT USE KLN, GGN, EBN BECAUSE TOO MANY STATIONS ON THIS AZIMUTH
$
STJ  8912030515P  B16197         XB16215      C1647
STJ   W  0273KM 19  092 286 49    00 -239     00 -035             0000000 00ML00MN
GBN  8912030515P  B17435 -                    B19145            040 216  20      8
GBN   W  0962KM 09  062 264 49                04  043               0000145 40ML32MN
HAL  8912030515P  B1804
HAL   W  1144KM 22 -100 262 49                                      0000000 00ML00MN
LMN  8912030515P  B181142   -0.29            XC2005             000   0   0     0  0
LMN   W  1201KM 20 -096 270 49                00 -034               0000000 00ML00MN
KLN  8912030515P XB182287   -0.29            XC2031             050 204   4     0  8
KLN   W  1303KM 00 -192 276 49                00  402               0000025 37ML27MN
GGN  8912030515P XB183188   -0.29            XC2043             050 102   7     0  8
GGN   W  1374KM 00 -147 268 49                00  109               0000086 43ML32MN
EBN  8912030515P XB1838      0.00                               000   0   0     0  0
EBN   W  1437KM 00 -285 279 49                                      0000000 00ML00MN
SCH  8912030515P  B18500 -                    B21095            050 102  11        8
SCH   NW 1507KM 09  065 312 49                06 -054               0000136 46ML35MN
YKA  8912030515P  B2304      0.00                               000   0   0     0  0
YKA   NW 4329KM 00 -010 318 31                                      0000000 00ML00MN
             Z
```

90

```
+41.918- 48.341O1ML=4.7 2140041 24041990 00.0270.062 0.1 14 23 130.67 218.00    0 1MN=0.0   00   0L3.62
042.000- 48.480O1MB=4.3 2140030 24041990 00.1800.072 0.1 00 00  81.31 618.00    0 1MN=0.0   00   0L3.62
SOUTHERNMOST PART OF THE GRAND BANKS    LA PARTIE LA PLUS AU SUD DU GRAND BANC
                                        DE TERRE NEUVE
MAG (GSC) 3.9 MB (1 OBS)
MAG (ISC) 4.3 MB (8 OBS)
$ DETECTED ON THE YELLOWKNIFE ARRAY
$ MAGNITUDE MB=3.9 AT 1 HZ ON YK
$ STJ: NO LG; POLARITY POSSIBLE +
$ SCH: STRONG P, WEAK SN; PN READING IS VERY SHARP
$ GBN: EMERGENT BEGINNING, POLARITY NOT READABLE
$ CBK: PRECURSOR TO SN MAKES ONSET UNCERTAIN
$
STJ  9004242140P  A41379                      A42465            020 173 145        8
STJ   NW 0718KM 27  049 333 49                00  005               0002633 46ML43MN
CBK  9004242140P  B4221                      XB4405             040 132  46        8
CBK   NW 1082KM 05 -082 319 49                00  106               0000547 48ML39MN
GBN  9004242140P  B42295 E                    B4412             020 563 200        8
GBN   NW 1130KM 25  190 295 49                28 -203               0001116 48ML42MN
HAL  9004242140P  B42455                     XC44405            030 207  60        8
HAL   W  1273KM 01  047 289 49                00 -394               0000607 49ML40MN
LMN  9004242140P  A425987D  -0.29             B451097           013 100  13     0  8
LMN   NW 1391KM 01  008 294 49                07  100               0000628 46ML41MN
GGN  9004242140P  C432033   -0.29             C453877           017 100  13     0  8
GGN   W  1533KM 05  328 290 49                01 -131               0000480 47ML41MN
UNB  9004242140P  C43175                      X4532             050  74  12        8
UNB   NW 1533KM 00  072 293 49                00 -783               0000204 48ML37MN
KLN  9004242140P  B431925   -0.29             C454049           0131000  88     0  8
KLN   NW 1534KM 28  202 297 49                00  010               0000425 46ML40MN
GSQ  9004242140P  B433283   -0.22             C460650           040 100  14     0  8
GSQ   NW 1657KM 03  069 304 49                00  004               0000220 48ML38MN
EBN  9004242140P  B433497   -0.22             C461354           0201000  77     0  8
EBN   NW 1689KM 07 -101 298 49                00  038               0000242 46ML38MN
LPQ  9004242140P XB435397   -0.22                               000   0   0     0
LPQ   NW 1816KM 00  289 297 52                                      0000000 00ML00MN
DAQ  9004242140P  B440216   -0.06             C470492           0271000  83     0  8
DAQ   NW 1921KM 04 -077 298 50                02  241               0000193 48ML38MN
```

```
SCH  9004242140P  A44076 C                          C4713           060  94  12         8
SCH    NW 1971KM 74 -082 323 47                     00 -003           0000134 49ML37MN
DPQ  9004242140P  C441495    -0.06                  X472281         0331000  46    0  8
DPQ    NW 2013KM 02  194 294 47                     00  089           0000088 45ML35MN
YKB9 9004242140P XB480459C
YKB9   NW 4803KM 00  117 322 30                                       0000000 00ML00MN
YKA  9004242140P  X4804          0.00                               000   0    0    0  0
YKA    NW 4804KM 00  053 322 30                                       0000000 00ML00MN
YKR3 9004242140P XB480555C
YKR3   NW 4816KM 00  118 322 30                                       0000000 00ML00MN
YKR2 9004242140P  B480575C
YKR2   NW 4819KM 10  119 322 30                                       0000000 00ML00MN
             Z
```

91

```
+47.364- 50.167F1MN=3.2 1123013 23071991 00.0820.146 0.2  6 10  30.79 218.00   0 1ML=3.8  20  0L3.62
GRAND BANKS
$ EAST OF ST JOHN'S
$ LG ON STJ, CBK, SMQ, SCH, NOT ON GBN OR LMN
$ NOT ON LMQ, CIQ, DAQ
$ MNQ DEAD
$ NO ECTN TRIGGER (?)
$ STJ: ONLY FIRST MOTION VISIBLE; NO AFTERSHOCKS EVIDENT
$ CBK: P PRECEEDED BY ?NOISE AT 24122
$ CBK: NO CLEAR S PHASES
$ HAL: NOISY RECORD, READING IS PROBABLY JUST NOISE
$ SMQ: NOISY RECORD
$ SCH: LG SEEMS OK
$ KUQ: ?PHASE AT 26455 IS 10 SEC TOO LATE FOR P
$
$ SOLUTION BY ADAMS 910814
$ POOR STATION DISTRIBUTION; THIS LOCATION FITS PN'S AT STJ, CBK, GBN, AND SCH
$        ACCEPTABLY, ALSO SN'S AT GBN AND SCH (BUT NOT CBK S PHASES)
$
STJ  9107231123P  A23308 D
STJ    W  0195KM 00 -005 278 49                                       0000000 00ML00MN
CBK  9107231123P  B2420                             C2515  XC2535   030 193  27
CBK    W  0606KM 07 -100 289 49                     10 -486 00-1382$  0000293 37ML32MN
GBN  9107231123P  B24575                            B26205          020 563  25         8
GBN    W  0899KM 04  077 260 49                     20 -171           0000140 36ML31MN
HAL  9107231123P                                    X2715
HAL    W  1082KM           259 49                   00 1383$          0000000 00ML00MN
LMN  9107231123P  B2525                             B27145          040 300  13         8
LMN    W  1133KM 01 -028 267 49                     43  248           0000068 39ML30MN
SMQ  9107231123P XB25325                            C2734    X2832  040 300  13
SMQ    W  1254KM 00 -752 291 49                     06 -373 00-1579$  0000068 40ML31MN
SCH  9107231123P  B2602                             B2814  XB29155  060  94  10
SCH    NW 1425KM 09  112 312 49                     00 -013 00-1950$  0000111 45ML34MN
             Z
```

92a

```
+47.237- 49.226F1MN=4.0 0607280 13011992 00.0560.097 0.2 16 24 140.98 218.00   0 1ML=4.5  20  0L3.62
SOUTHERN GRAND BANKS
OFFSHORE NEWFOUNDLAND                      AU LARGE DE TERRE-NEUVE
$ EXACT EPICENTRE RATHER UNCERTAIN BECAUSE OF EXTREMELY POOR STATION
$    DISTRIBUTION
$ ISC 47.2N 49.2W OT=060727.2; added 3 stations to GSC's 15;
$   "EXACT EPICENTRE RATHER UNCERTAIN BECAUSE OF EXTREMELY POOR STATION DISTRIBUTION"
$ ADAMS SOLUTION
$ VLG OF 3.62 USED FOR THIS SOLUTION
$ LG GREATER THAN SN ON MOST ECTN EXCEPT LMN AND DAQ WHERE AMPLITUDE SN = LG
$ LG ON PWM AND FCC, NOT IN TRIGGER WINDOW
$ SCH, FRB CLOSED
$ CBK ASSYMETRIC TRACE; MAX DOWNSWING USED
$ HAL LONG CODA, PROBABLY REPRESENTS ATTENUATED LG
$ GBN NO LG
$ KUQ, IGL, FFC AMP FROM LG
$ FFC EARLIER PHASE AT 2141, STONGEST ON SPZ MAY BE  BE TELESEISMIC S OR
$     UNRELATED TELESEISM
$ CLOSE TO LARGE EARTHQUAKE IN 1971
$ RELATIVE ARRIVALS ON STJ AND HAL (ONLY COMMON STATIONS) SUGGEST
$     SIMILAR LOCATION TO 1971 EARTHQUAKE
$
STJN 9201130610P  A08074 D                          X0833
STJN  W  0268KM 22  063 279 49                      00 -197           0000000 00ML00MN
CBK  9201130610P  A08575                                    B1033   040 135 170
```

```
CBK   W  0678KM 65  103 289 49                 21 -237   0001978 47ML41MN
GBN  9201130610P  A0932                B1104           050 206  73        8
GBN   W  0967KM 04  025 262 49         01  057           0000445 46ML37MN
HAL  9201130610P  B09540 +             B1142           040 154  24        8
HAL   W  1150KM 00  000 261 49         00 -024           0000245 45ML36MN
LMN  9201130610P  B100072   -1.20      B115564 X130895 043 100  47        3
LMN   W  1204KM 04 -107 268 49         02  070 00  715   0000687 50ML41MN
SMQ  9201130610P  B101454   -0.10     XB122983 X132960 080 100  86              134033
SMQ   W  1326KM 04 -101 291 49         00 1006$00 -477   0000675 52ML41MN
GSQ  9201130610P  B101761   -0.10      B122527XC133599 057 100  47              134814
GSQ   W  1344KM 00 -014 285 49         11  166 00 -335   0000518 51ML40MN
ICQ  9201130610P  B101905   -0.10     XB123123XC134195 080 100  89              135470
ICQ   W  1358KM 01 -047 287 49         00  453 00 -148   0000699 53ML41MN
CNQ  9201130610P  B102654   -0.10      C124235XC135862 063 100  39              141300
CNQ   W  1415KM 00  006 286 49         03  352 00 -052   0000389 51ML39MN
MNQ  9201130610P  A103291   -0.10      C125679XB141412 057 100  45              143145
MNQ   W  1476KM 67 -105 292 49         06  492 00 -188   0000496 52ML41MN
A21  9201130610P XB104029
A21   W  1540KM 00 -131 279 49                           0000000 00ML00MN
A64  9201130610P XB104154
A64   W  1554KM 00 -176 280 49                           0000000 00ML00MN
A16  9201130610P XB104604
A16   W  1567KM 00  121 279 49                           0000000 00ML00MN
A61  9201130610P XB104380
A61   W  1570KM 00 -150 280 49                           0000000 00ML00MN
A11  9201130610P XB104562
A11   W  1584KM 00 -135 278 49                           0000000 00ML00MN
A54  9201130610P XB104691
A54   W  1597KM 00 -169 279 49                           0000000 00ML00MN
DAQ  9201130610P  B105447+  -0.10
DAQ   W  1653KM 05 -111 281 49                           0000000 00ML00MN
KUQ  9201130610P  B11098               B1355           070 101  24
KUQ   NW 1765KM 02  076 320 49         13  184           0000213 51ML38MN
MOQ  9201130610P  B111003   -0.10             XC1604   070  48  17
MOQ   W  1782KM 05 -113 272 52                 00 2342$  0000318 52ML40MN
DPQ  9201130610P  B110914   -0.06
DPQ   W  1788KM 25 -256 277 52                           0000000 00ML00MN
TRQ  9201130610P XC112762   -0.09
TRQ   W  1932KM 00 -058 276 50                           0000000 00ML00MN
JAQ  9201130610P  B113602   -0.07             XC1642   090  48  33
JAQ   NW 2003KM 00  003 301 47                 00  046   0000480 55ML43MN
WBO  9201130610P  C113960   -0.05
WBO   W  2021KM 01  178 273 47                           0000000 00ML00MN
GRQ  9201130610P XC113716   -0.09
GRQ   W  2021KM 00 -081 278 47                           0000000 00ML00MN
EEO  9201130610P  C120603   -1.12     XB15235 XC1814   090  48  20
EEO   W  2261KM 01  204 279 43         00-1641$00 2011$  0000291 54ML41MN
IGL  9201130610P XC1316                                100  65   5
IGL   NW 3046KM 00  417 336 33                           0000048 48ML36MN
FCC  9201130610P                              XC2220   100  48   7
FCC   NW 3202KM         310 33                 00  746   0000092 51ML39MN
ULM  9201130610P                              XC2317   100  96  11
ULM   NW 3394KM         293 33                 00 1144$  0000072 50ML38MN
FFC  9201130610P                              XC2437   110  82   8
FFC   NW 3707KM         303 32                 00  477   0000056 49ML38MN
YKR8 9201130610P
YKR8  NW 4307KM         318 31                           0000000 00ML00MN
             Z
```

92b

```
+47.326- 49.346F1ML=3.0 1658161 06071992 00.3710.268 0.2  3  6  30.74 218.00   0 1MN=0.0  00  0L3.62
GRAND BANKS
$ CLOSE TO CLUSTER OF EARTHQUAKES IN 1971, 1988, 1989, AND 1992, BUT SLIGHTLY
$    FARTHER TO THE WEST
$ HAL TOO NOISY
$ NOT ON LMN,ICQ,MNQ,KUQ,DAQ
$ STJN GOOD SIGNAL BUT POOR LG, HALF AMP OF SN
$ CBK AMPLITUDE OF SN WAS READ
$ CBK PROMINENT PHASE FITS AS LG WITH AMP 1.1 MM Z-P AT 030;. TWICE AMP OF SN
$ GBN POOR PHASES, NOISY RECORD.
$ GBN POSSIBLE OTHER ARRIVALS AT 6028 AND 6228
$       ARE NOT CONSISTANT WITH CBK AND STJN
$
STJN 9207061658P  A58533               B59222  X5928   020 146  54        8
STJN  W  0259KM 02 -014 277 49         12  143 00  017   0001162 28ML32MN
CBK  9207061658P  B59455               B6046   X6118   040 135  05        8
CBK   W  0666KM 33  238 289 49         12 -145 00 -221   0000058 32ML26MN
```

```
GBN  9207061658P  C6017                          C6150           030 317  02        8
GBN   W  0960KM 01 -192 262 49                   00  010           0000013 29ML22MN
             Z
```

92c

```
+46.118- 47.438F1MN=3.9 0420227 17071992 00.1120.087 0.1  9 17  20.77 218.00   0 1ML=4.2  30  0L3.62
EASTERN MARGIN OF GRAND BANKS
$ FIRST EARTHQUAKE KNOWN FROM HERE; APPROX 200 KM SE OF NEAREST CLUSTER
$    OF EARTHQUAKES
$ STJN VERY CLEAR,  GOOD PHASES; LG SEEMS OK
$ CBK GOOD LG
$ LG FROM THIS SITE TO NEWFOUNDLAND STATIONS IS UNEXPECTED
$ ALSO THE LG HAS QUITE LONG PERIODS
$ GBN VERY WEAK LG;  LG AT ALL ECTN SITES APPEARS ATTENUATED
$
$ ECTN TRIGGER CONTAINS ONLY PN FOR STATIONS BEYOND LMN
$ KURILE AFTERSHOCK AT THIS TIME INTERFERS: MNQ, MOQ, DAQ READINGS WERE OF THIS EVENT
$ JAQ DEAD
$ KUQ  LG ARRIVAL NOT READABLE, BUT AMPLITUDE READ AT TIME CORRESPONDING TO LG
$
STJN 9207170421P  A21223 -                       A22052  C22185  040  62 127
STJN  NW 0437KM 31  060 294 49                   00  002 08 -497   0003218 43ML40MN
CBK  9207170421P  A22122 D                       B2332   C2418   070  43  36
CBK   NW 0852KM 01 -013 295 49                   12 -152 00 -006   0000751 47ML38MN
GBN  9207170421P  B22407 +                       C2424
GBN   W  1097KM 12 -151 271 49                   01 -165           0000000 00ML00MN
HAL  9207170421P  C23045                         B25055          050 116   8        8
HAL   W  1274KM 00  066 268 49                   24  210           0000087 42ML32MN
LMN  9207170421P  B231104    -1.52               C251825         0571000  51        8     25243
LMN   W  1344KM 44 -287 275 49                   01 -157           0000056 41ML30MN
SMQ  9207I70421P  B232985    -0.10
SMQ   NW 1500KM 14 -163 295 49                                     0000000 00ML00MN
GSQ  9207170423P  B233080    -0.10
GSQ   W  1511KM 21 -197 289 49                                     0000000 00ML00MN
ICQ  9207170423P XB233268    -0.10             XC2604
ICQ   W  1529KM 00 -229 292 49                   00  636           0000000 00ML00MN
CNQ  9207170423P XB233972    -0.10
CNQ   W  1584KM 00 -203 290 49                                     0000000 00ML00MN
SLQ  9207170421P  C23505                         C2624   X2810   100  68   4        3
SLQ   W  1649KM 00  099 284 49                   00  092 00 1181$  0000037 42ML30MN
MNQ  9207170421P             -0.10               C26225          100  96   8        3
MNQ   NW 1651KM         295 49                   01 -125           0000052 44ML32MN
DPQ  9207170421P                                 X2723  XC2938   050 140   2        3
DPQ   W  1943KM         281 50                   00 -258 00 1863$  0000018 40ML28MN
KUQ  9207170421P                                                 090  44   1        3
KUQ   NW 1948KM         321 47                                     0000016 40ML28MN
             Z
```

92d

```
+47.353- 49.114F1MN=3.4 1131520 10081992 00.0830.070 0.0  5  9  10.39 218.00   0 1ML=3.6  30  0L3.62
GRAND BANKS
$ IN CLUSTER OF EARTHQUAKES (4 PREVIOUS) NW OF HIBERNIA
$ VERY  POOR AZIMUTHAL COVERAGE FOR THESE EARTHQUAKES
$ NOT ON DAQ, ICQ
$ STJ SN>LG
$ CBK SG=3*SN
$ GBN AMP READ FROM SN, THERE IS WEAK LG FOLLOWING THE SN
$ CBK LG MIGHT BE 4 SEC EARLIER
$
STJ  9208101132P  A32312                         B33012 XC3308   040  73 165        8
STJ   W  0274KM 00  000 276 49                   44  129 00  006   0003550 37ML37MN
CBK  9208101132P  B33211                         B34260 XC3458   040 135  32
CBK   W  0682KM 01  017 288 49                   12 -068 00 -244   0000372 40ML34MN
GBN  9208101132P  B33572                         B3529   X3627   030 370  12        8
GBN   W  0978KM 01  021 262 49                   09 -059 00  483   0000068 36ML29MN
HAL  9208101132P
HAL   W  1160KM         260 49                                     0000000 00ML00MN
LMN  9208101132P  B34255                         C3618           030 428   5        8
LMN   W  1213KM 01 -017 268 49                   04 -162           0000024 34ML26MN
MNQ  9208101132P  C3455                                 XC3933
MNQ   W  1479KM 17 -324 291 49                          00 5223$  0000000 00ML00MN
             Z
```

94a

```
+52.127- 48.523F1ML=3.2 1052279 08011994 00.0380.065 0.2  6 10  40.56 218.00    0 1MN=0.0  00  0L0.00
NORTHEAST NEWFOUNDLAND SLOPE
$ LIES WITHIN LINEAR TREND OF EPICENTRES ALONG EXTENSION OF CARTWRIGHT FRACTURE ZONE
$ SEEN FIRST ON DRLN, PICKED UP WITH DIFFICULTLY ON LMN
$ ANALOG ECTN READ - TRACES ARE MERE WRIGGLES
$ NOT ON HAL, CBK
$ KUQ  IS WRIGGLE
$
STJN 9401081055P  B53455                        B5444           040  62   9       8
STJN  SW 0591KM 07 -030 213 49                  08  033           0000228 35ML31MN
DRLN 9401081054P  B540047    +0.00              B550865         0152240  46 0000  8    559.62
DRLN  SW 0710KM 02  016 247 49                  08 -033           0000086 30ML28MN
GBN  9401081055P                                C56564          030 317   2       8
GBN   SW 1210KM          237 49                 05  105           0000013 31ML23MN
ICQ  9401081055P                                C5726
ICQ   W  1350KM          265 49                 05  104           0000000 00ML00MN
LMN  9401081055P  C552005    +0.00              C572900         0452560  11 0000  8   5736.35
LMN   SW 1378KM 12 -163 246 49                  18 -195           0000006 31ML21MN
MNQ  9401081055P  C5529                         C57415
MNQ   W  1419KM 23  222 271 49                  13  165           0000000 00ML00MN
KUQ  9401081055P                                X5738
KUQ   NW 1428KM          306 49                 00 -362           0000000 00ML00MN
FRB  9401081055P
FRB   NW 1743KM          326 49                                   0000000 00ML00MN
             Z
```

94b

```
+47.827- 52.673O1MN=3.1 1813492 11081994 00.0270.064 0.2  6 11  30.50 2 0.00    0 1ML=3.3  10  0L3.62
ST JOHN'S NFLD                            ST JOHN'S T.-N.
$ LOCATION PERHAPS 15-30 KM N OF ST JOHN'S, BUT N-S RESOLUTION
$      IS POOR BECAUSE OF STATION DISTRIBUTION
$ BECAUSE OF TIME OF DAY AND PROXIMITY TO CITY A BLAST WAS SUSPECTED
$ ENQUIRIES BY PAUL BARNES (MEMORIAL UNIV., PAUL@CONVEX.ESD.MUN.CA)
$    TO A LOCAL EXPLOSIVES SUPPLIER INDICATED:
$ 1. APPROXIMATELY 20 KM WEST OF ST. JOHN'S (LONG POND), THERE IS A
$    PYROPHYLITE MINE THAT USES CHARGES ON THE ORDER OF 25 KG.
$ 2. ON 24 OCTOBER, APPROX 12-15 KM WEST OF ST. JOHN'S, 300X25KG WERE
$    DETONATED OVER A 2 SECOND INTERVAL TO BLAST AWAY A ROCK FORMATION TO
$    GENERATE ROADBED GRAVEL. THE MAXIMUM CHARGE SIZE IN ANY ONE HOLE WAS
$    250KG.  THIS WAS THE LARGEST BLAST EXPLODED. THE DATE MAY BE IN ERROR.
$    THE EVENT WAS NOT LOCATED ON THE STJN RECORD.
$ 3. ABOUT  5-8 KM N OF THAT SITE, CONSTRUCTION OF A BYPASS ROAD IS BEING
$    UNDERTAKEN. ACCORDING TO THE EXPLOSIVES SUPPLIER, THEY ARE DETONATING
$    CHARGES ON THE ORDER OF 50 KG.
$ 4. THERE IS ALSO BLASTING FOR ROAD CONSTRUCTION OCCURING ALONG THE TCH
$    APPROXIMATELY 50 KM WEST OF ST. JOHN'S.
$ 5. UNAWARE OF ANY OTHER CONSTRUCTION.
$
$ ADAMS CHECKED ALL THE STJN RECORDS HERE FOR AUG 10 TO EARLY OCT AND
$ IDENTIFIED 10 EVENTS, 3 WITH A S-P OF 5.5 SEC AND AROUND 2030-2230 UT
$ (PROBABLY SINGLE SOURCE, POSSIBLY YOUR TCH BLASTING?), AND THE REST
$ WITH S-P AROUND 2 SEC AT 1200-2045 UT (DAYLIGHT HOURS, LIKELY MULTIPLE
$ SOURCES WITHIN 20 KM).  NOT A SINGLE ONE WOULD BE CLASSED AS A LARGE
$ BLAST, AND THE LARGEST EVENT IS AT LEAST 1 MAGNITUDE BELOW THE AUG 11TH
$ EVENT. IF THE AUG 11 EVENT WAS A BLAST, WE SEEM FORCED TO CONCLUDE THAT
$ IT WOULD HAVE NEEDED TO INVOLVE C. 10* THE 300X25 KG = 87 TONNES, AND
$ THEREFORE WOULD HAVE BEEN REMEMBERED!
$  ---> CONCLUSION CLASSIFY AS AN EARTHQUAKE
$
$ MISSED DURING REGULAR DAILY PROCESSING OF CSN
$ STJN CODA LASTS 2.5 MIN
$ STJN: SUSPECT S-P IS ABOUT 2.8 SEC, BUT UNREADABLE
$ HAL NOT EVIDENT ON NOISY RECORD
$ SCH NOISY RECORD
$ LMN DEAD
$ MNQ FROM ANALOG
$ DONE BY ADAMS
$ LAST COMPARABLE EVENT WAS IN 1969:
$ +47.632- 52.156F1MN=3.4 2153207 05081969 00.0860.110 0.2  5  9  40.94 218.00
$ THIS WAS FROM ALMOST DUE EAST OF STJ ACCORDING TO 3 COMPONENT MOTIONS
$
STJN 9408111814P                   A13542 C
STJN  S  0029KM          192-90    06  024                        0000000 00ML00MN
DRLN 9408111814P  A144492C  -1.00             A152635 B153947 0252303 672 0000  0    1544.58
DRLN  NW 0391KM 32 -055 296 49                11  033 11  129   0000733 33ML33MN
```

```
GBN  9408111814P  A15257                      B16355  B1709   040 216  20       3
GBN   W  0729KM 00  001 252 49                14 -144 15 -151   0000145 37ML30MN
MNQ  9408111818P                                      C1920   060 164  10
MNQ   W  1210KM         290 49                        05 -356   0000064 41ML30MN
SCH  9408111818P            -1.00             B183037 C193952 0452560  87 0000  0    1942.17
SCH   NW 1251KM         314 49                11  130 05  362   0000047 39ML29MN
LMQ  9408111818P            -1.00             C184462                           0
LMQ   W  1324KM         275 49                00  010           0000000 00ML00MN
             Z
```

94c

```
+47.315- 51.72501MN=2.6 0932259 01121994 00.1150.138 0.4  5 10  30.94 218.00   0 1ML=2.5  30  0L3.62
OFFSHORE NEWFOUNDLAND                    AU LARGE DE TERRE-NEUVE
$ VERY CLEAR ON ANALOG STJN RECORD; ALMOST IGNORED ON DRLN ANALOG
$ LOCATION USING DAN IMPOSSIBLE, KEPT CRASHING; READINGS WERE TYPED IN MANUALLY
$ POOR LOCATION RESOLUTION IN N-S DIRECTION
$ RESIDUALS ARE LOWER FOR A SHALLOW DEPTH
$ NO LG ON GBN OR LMN
$ NOT ON HAL
$ NOT REPORTED FELT
$ PREVIOUS CLOSE EVENTS ARE
$ +47.632- 52.156F1MN=3.4 2153207 05081969 00.0860.110 0.2  5  9  40.94 218.00
$ +47.827- 52.67301MN=3.1 1813492 11081994 00.0270.064 0.2  6 11  30.50 2 0.00
$ DONE BY ADAMS
$
STJN 9412010932P                A32387 D              B3250   025 120 23
STJN  W  0083KM         290-78   37 -087              01  068   0004817 26ML30MN
DRLN 9412010932P  A33307                     B34204  C34386  0357138 428 0000       3448.58
DRLN  NW 0480KM 15  055 299 49                24  283 00 -008   0000108 29ML26MN
GBN  9412010932P  B34070                     B35245          020 563   1       8
GBN   W  0782KM 00 -002 258 49                20  261           0000006 20ML17MN
LMN  9412010932P  B34344                     B36113
LMN   W  1015KM 03 -095 266 49                00 -003           0000000 00ML00MN
SCH  9412010932P  C35161                     XC37283  X38414  0354999  25 0000  0   3854.75
SCH   NW 1342KM 00  087 314 49                00  740 00  469   0000009 32ML22MN
             Z
```

95

```
+47.840- 52.517F1MN=2.4 0646205 22011995 00.0180.049 0.0  3  7  10.29 218.00   0 1ML=2.2  20  0L3.62
 33 KM NE OF ST JOHN'S, NFLD               33 KM NE DE ST JOHN'S, T.-N.
$ STJN VERY CLEAR, WRONG TIME OF DAY FOR BLAST
$ LMN DEAD
$ GBN TINY SIGNAL, SN STRONGER THAN PN
$ DRLN CLEAR WHEN FILTERED
$ DRLN READINGS FROM VERTICAL COMPONENT ONLY, ONE HORIZONTAL HAD C. 30 SEC TIMING ERROR
$     TIMING DUBIOUS ON THE RECORDS AS TRANSFORMED USING RDSEED AND READ
$ SCHQ TRIED BUT NOT VISIBLE THERE
$ NOT ON HAL
$ LAST NEARBY EVENT 940811 M3.1, MIGHT BE IN SAME PLACE
$  DONE BY ADAMS
$
STJN 9501220647P                A46269 D              A46315  020 146 195
STJN  SW 0035KM         211-63   01 -005              00  002   0004196 19ML31MN
DRLN 9501220647P  C47196    -1.00            B47569  B48117  0207211 237 0000  0    4813.5
DRLN  NW 0401KM 18  347 295 49                08  058 11 -069   0000103 24ML24MN
GBN  9501220647P  C48012                     B49077
GBN   W  0740KM 32  465 252 49                00  013           0000000 00ML00MN
SCHQ 9501220654P            +0.00            XX545490                    0
SCHQ  NW 1262KM         313 49                00 9999$          0000000 00ML00MN
             Z
```

[SAMDEV.LOC]PICKF
C. WONG MAY 1

PIK FILE

>>>>>>>> NEW FORMAT VERSION AUGUST 1987
>>>>>>>> 5 CHARACTER STATION ID

The PIK file is the input file to and also the output file (o version newer) from the CANSESS MULTILAYER epicenter location prog (LOC). SAM PIK (or PK4) command generates a PIK file automatically the event. These PIK files can be modified/created by the EPK progr or by the DEC text editor EDT.

It contains four types of records:

1. ESR - earthquake solution record.
2. ECR - earthquake comment record.
3. ODR - observed data record.
4. CDR - calculated data record.

The ESR (if it exists) has to be the first record in the file. It is an output record from the previous LOC. Some of its fields can b to modify the LOC parameters for the next run. The ECR records come the ESR, they have to be before the first ODR. There is one ODR for station with picked information. This is an input record, LOC progr not modified any field on this record. The CDR contains only the ca results for this station. If it exists, it is always right after it corresponding ODR. You can have as many ECR, ODR or sets of ODR & C you want. However, the current EPK program can handle total of 100 at most, and the LOC program is dimensioned only 100 for all the ph picked. If you have any deficulties with the above limitations, ple me know. The detail layout of these records starts on the next pag

EARTHQUAKE SOLUTION RECORD (ESR)

(solution record is defined as having "+" or "-" on col.1 and "M" ON

CLOUNS		ENTRY	FORMAT DEFINITION
1-1	+	A1	PRIME SOLUTION BY EPB
	-		PRIME SOLUTION BY OTHER AGENCY
	0		SUPPLEMENTARY SOLUTION
2-7	45.233	F6.3	NORTH LATITIDE, DEGREES
8-15	-123.300	F8.3	LONGITUDE, DEGREES
16-16		A1	HYPOCENTRE QUALITY INDICATOR.
	O		POOR QUALITY SOLUTION
	F		GOOD QUALITY SOLUTION
17-17		I1(A1)	OBSERVED DATA FORMAT INDICATOR,
	BLANK		PRE-1979 DATA FORMAT USED
	1		1979 DATA FORMAT USED.
18-19		A2	PRIME MAGNITUDE TYPE
	ML		RICHTER
	MLE		EBEL
	MN		NUTTLI (DEFAULT)
	MLG		H. & K.
	MB		BODY-WAVE
	MS		SURFACE WAVE
	MC		CODA LENGTH
20-20	BLANK		
21-23	3.1	F3.1	AVERAGE MAGNITUDE VALUE (MN)
24-24	BLANK		
25-26	18	I2	ORIGIN TIME HOUR, U.T.
27-28	23	I2	ORIGIN TIME MINUTE
29-31	323	I3	ORIGIN TIME SECOND*10 (OR F3.1 IN SECOND)
32-32	BLANK		
33-34	12	I2	DAY
35-36	03	I2	MONTH
37-40	1979	I4	YEAR
41-41	BLANK		
42-42	2	I1	STANDARD DEVIATION ORIGIN TIME, SECONDS

```
43-47 0.122   F5.3   STD IN LATITUDE, DEGREES

48-52 0.333   F5.3   STD IN LOGITUDE, DEGREES

53-53   BLANK

54-56 0.3     F3.1   STD IN MAGNITUDE FOR EPB
      XXX     A3     AGENCY CODE FOR EXTERNAL MAG, DEPENDS ON COL.

57-59 34      I3     NUMBER OF STAIONS USED FOR HYPOCENTER

60-62 14      I3     NUMBER OF PHASES USED FOR THIS HOPOCENTER.

63-65 14      I3     NUMBER OF AMPLITUDE USED FOR MAGNITUDE.

66-69 0.33    F4.2   RMS OF HYPOCENTER SOLUTION, SECONDS.

70-70         A1     SUOLUTION TYPE INDICATOR
      BLANK          FIXED DEPTH.
      Z              FREE DEPTH
      X              NO ACTION FOR THE WHOLE FILE
      N              ASSIGNED HYPOCENTER AND TIME
      H              ASSIGNED HYPOCENTER,
                       BUT CALCULATED ORIGIN TIME.

71-71         I1     AGENCY CODE
      1              USGS
      2              EPB
      3              PGC
      4              SEA    UNIVERSITY OF WASHINGTON
      5              NEIS   NATIONAL EARTHQUAKE INFORMATION CENTER
      6              ISC    INTERNATIONAL SEISMOLOGICAL CENTER
      7              LDGO   LAMONT-DOHERTY GEOLOGICAL OBSERVATORY
      8              WES    WESTON GEOPHYSICAL OBSERVATORY
      9              UAGI   UNIV. OF ALASKA, GEOPHYSICAL INSTITUTE

72-76 18.33   F5.2   FOCAL DEPTH, KM
                     IF AND ONLY IF COL.=Z, FREE DEPTH SOLUTION

77-80 3.0     F4.1   STD IN DEPTH, KM ( OR I4 FORMAT IN 100-METERS)

81-82   03      I2     MODEL NUMBER

83-85   ML=          AVERAGE ML

86-88   1.3   F3.1   RICHTER MAGNITUDE

89-91   008   I3     NUMBER OF STATIONS USED TO CALCULATE AVERAGE M

92-92   1     I1     MULTILAYER HYPO SIMULATION FLAG, 0-OFF, 1-ON.

93-93           A1                                   ! FL001
        F              FELT                          ! FL001
        N," "          NOT FELT                      ! FL001

94-95   10      I2     NB. OF ASSOCIATED EVENTS      ! FL001

96-96           A1                                   ! FL001
        E," "          EARTHQUAKE
        B              BLAST
        R              ROCKBURST
        P              POSSIBLE ROCKBURST

97-100  3.56    F4.2   S VELOCITY USED BY SINGLE LAYER MODEL   ! FL00

<     FORMAT(A1,F6.3,F8.3,2A1,A2,1X,F3.1,1X,I2.2,I2.2,I3.3,1X,2I2.2,
<     &                '19',I2.2,1X,I1,2F5.3,1X,A3,            ! FOR AG
<     &                '19',I2.2,1X,I1,2F5.3,1X,F3.1,          ! FOR ST
<     &                3I3.3,F4.2,A1,I1,F5.2,I4,T81,I2,'MC=',F3.1,I3,I1
<     &           A1,I2,A1,F4.2)
```

EARTHQUAKE COMMENT CARDS (ECR)

COLUMNS	ENTRY	FORMAT	DEFINITION
1-40		40A1	EARTHQUAKE DESCRIPTION IN ENGLISH
41-80		40A1	EARTHQUAKE DESCRIPTION IN FRANCH

OBSERVED DATA RECORD (ODR)

COLUMNS		ENTRY	FORMAT	DEFINITION	
1-5	OTT	A5	STATION CODE	! FL001	
6-7	79	I2	YEAR	! FL001	
8-9	12	I2	MONTH	! FL001	
10-11	23	I2	DAY	! FL001	
12-13	12	I2	HOUR, U. T.	! FL001	
14-15	14	I2	MINUTE OF 1ST RECORDED P PHASE,NOT NECESSARY @		
16-16		A1	INSTRUMENT CODE	! FL001	
	P		SHORT PERIOD INSTRUMENT READ		
	L		LONG PERIOD INSTRUMENT READ,AMP. & 1ST MOTION		
17-17	BLANK				! FL0
18-18		A1	PN WEIGHT		! FL0
	" "		USED IN CALCULATION		
	X		NOT USED IN CALCULATION		
19-19		A1	PN QUALITY DESIGNATOR		! FL0
	A		SHARP CLEAR BEGINNING	(+- 0.25 SEC.)	
	B," "		GOOD BEGINNING	(+- 1.0 SEC.)	
	C		WEAK POOR BEGINNING	(+- 4.0 SEC. OR MORE)	
	X		PHASE NOT USED IN SOLUTION, LARGE RESIDUAL.		
	O		PHASE NOT READ		
20-21	14	I2	MUNITE OF PN ARRIVAL		! FL0
22-25	2341	F4.2	SECOND OF PN ARRIVAL		! FL0
26-28	CNM ??	3A1	FIRST MOTION OF PN ARRIVAL		! FL0
29-33	+0.03	F5.0??	TIME CORRECTION		! FL0
34-34		A1	PG WEIGHT		! FL0
	" "		USED IN CALCULATION		
	X		NOT USED IN CALCULATION		
35-35	A,B..	A1	PG QUALITY DESIGNATOR, SEE 16		! FL0
36-37	14	I2	MINUTE OF PG ARRIVAL		! FL0
38-41	264	F4.2	SECOND OF PG ARRIVAL		! FL0
42-44	DSE	3A1	FIST MOTION OF PG ARRIVAL		! FL0
45-45		A1	SN WEIGHT		! FL0

```
      " "              USED IN CALCULATION
      X                NOT USED IN CALCULATION

46-46 A,B...  A1      SN QUALITY DESIGNATOR, SEE 16          ! FL0

47-48 14      I2      MINUTE OF SN ARRIVAL                   ! FL0

49-52 52      F4.2    SECOND OF SN ARRIVAL                   ! FL0

53-53            A1     LG WEIGHT                               ! FL0
      " "               USED IN CALCULATION
      X                 NOT USED IN CALCULATION

54-54 A,B...  A1      LG QUALITY DESIGNATOR, SEE 16          ! FL0

55-56 14      I2      MINUTE OF LG ARRIVAL                   ! FL0

57-60 589     F4.2    SECOND OF LG ARRIVAL                   ! FL0

61-61  BLANK                                                    ! FL0

62-64 031     F3.2    PERIOD OF MAX. TRACE AMPLITUDE, SECOND ! FL0

65-68 150     F4.0    MAGNIFICATION OF INSTRUMENT AT GIVEN PERIOD, I

69-72 125     F4.1    TRACE AMPLITUDE( ONE-HALF MAX. PEAK-TO-PEAK) I

73-73  BLANK                                                    ! FL0

74-77         I4      DURATION IN SECONDS.                   ! FL0

78-79  BLANK                                                    ! FL0

80-80                 I1      MAGNITUDE CODE
   BLANK              AMPLITUDE SUITABLE FOR NUTTLI OR RICHTER SCALE
   1                  AMPLITUDE SUITABLE FOR RICHTER ONLY, CORDILLER
   2                  AMPLITUDE SUITABLE FOR EBEL
   3                  AMPLITUDE UNRELIABLE, NOT USED FOR MAGNITUDE
   4                  AMPLITUDE SUITABLE FOR HUEM & KISCO
   5                  AMPLITUDE SUITABLE FOR MS SCALE ONLY
   8                  SN AMPLITUDE READ,
                      USE RICHTER SCALE ONLY BEYOND 600 KM IF REQUIR

81-83  BLANK                                                    ! FL0

84-85  15     I2      MINUTE OF THE MAX. AMPLITUDE           ! FL0

86-89 155     F4.2    SECONDS OF THE MAX. AMPLITUDE          ! FL0

<     FORMAT(A5,5I2,A1,1X,2A1,I2,F4.2,A3,F5.0,2A1,I2,F4.2,A3,2A1
<     &                  I2,F4.2,2A1,I2,F4.2,1X,F3.2,F4.0,F4.1,1X,I4,2X,I
<     &                  3X,I2,F4,2)
```

CALCULATED DATA RECORD (CDR)

```
COLUMNS         ENTRY  FORMAT  DEFINITION

1-5   OTT       A3     STATION CODE                           ! FL001

6-6   BLANK

7-8   NW        A2     QUADRANT OF STATION

9-9   BLANK

10-13 1305      I4     EPICENTRAL DISTANCE, KM

14-15 KM        A2     RECORD FLAG

16-16 BLANK

17-18 28        F2.1   PN WEIGHT USED FOR CALCULATIONS        ! FL001

19-19 BLANK

20-23 0107      F4.2   PN RESIDUAL, SECOND                    ! FL001

24-24 BLANK,#   A1     LARGE RESIDUAL FLAG                    ! FL001

25-27 235       I3     AZIMUTH TO STATION, DEGREES

28-30 049       I3     EMERGENT ANGLE
                       PN POSITIVE
                       PG NEGATIVE

31-34 BLANKS

35-36 14        F2.1   PG WEIGHT                              ! FL001

37-37 BLANK

38-41 -091      F4.2   PG RESIDUAL, SECOND                    ! FL001

42-42 BLANK,#   A1     LARGE RESIDUAL FLAG                    ! FL001

43-45 BLANKS

46-47 07        F2.1   SN WEIGHT                              ! FL001

48-48 BLANK

49-52 0024      F4.2   SN RESIDUAL, SECOND                    ! FL001

53-53 BLANK,#   A1     LARGE RESIDUAL FLAG                    ! FL001
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54-55	07	F2.1	SG WEIGHT	! FL001
56-56	BLANK			
57-60	-434	F4.2	SG RESIDUAL, SECOND	! FL001
61-61	BLANK,#	A1	LARGE RESIDUAL FLAG	! FL001
62-63	BLANKS			
64-70	0001356	I7	GROUND VELOCITY, NM/SEC	
71-71	BLANK			
72-73	35	F2.1	RICHTER OR SURFACE WAVE MAGNITUDE	
74-75	ML,MS	A2	MAGNITUDE DESIGNATOR	
76-77	34	F2.1	NUTTLI MAGNITUDE	
78-79	MN	A2	MAGNITUDE DESIGNATOR	

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<     FORMAT(A5,1X,A2,1X,I4.4,'KM',1X,F2.1,1X,F4.2,A1,2I3.3,  >
<     &             4X,F2.1,1X,F4.2,A1,3X,F2.1,1X,F4.2,A1,F2.1,1X,
<     &        F4.2,A1,2X,I7.7,1X,2(F2.1,A2)) >
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