# NEW PROBABILISTIC STRONG SEISMIC GROUND MOTION MAPS OF CANADA: A COMPILATION OF EARTHQUAKE SOURCE ZONES, METHODS AND RESULTS

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## ABSTRACT

New probabilistic seismic ground motion maps of Canada, displaying peak horizontal acceleration and peak horizontal velocity at a probability of exceedence of 10 percent in 50 years, have been recommended as the replacement for the 1970 Seismic Zoning Map in National Building Code applications. This report presents a comprehensive description of the basic earthquake data and the methods employed in deriving the new maps.

## RESUME

Les nouvelles cartes de probabilité des mouvements séismiques du sol pour le Canada ont été recommandées pour remplacer la carte de zonage séismique de 1970 dans les applications du Code national du bâtiment. Ces cartes présentent l'accélération horizontale maximum et la vitesse horizontale maximum à la probabilité de dépassement de 10 pourcent en 50 ans. Ce rapport donne une description détaillée des données séismiques de base ainsi que les méthodes utilisées dans l'élaboration de ces nouvelles cartes.

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# 1. INTRODUCTION

In Canada, the primary application of seismic zoning information is made within the context of seismic loading provisions of the National Building Code (Associate Committee on the National Building Code, 1980). In the first edition of the code (1941) the seismic provisions appeared in an appendix and were based on concepts presented in the 1937 United States Uniform Building Code. In the 1953 edition, the earthquake loading requirements were updated and placed in the main text, and referenced the first seismic zoning map of Canada, which was subsequently described by Hodgson (1956). The Hodgson zoning map was a qualitative "seismic probability map" based on knowledge of the larger earthquakes and general considerations of the regional extent of earthquake zones.

The Hodgson zoning map was replaced in the 1970 edition of the code by the 1970 Seismic Zoning Map (Figure 1). This, the first strictly probabilistic map, was developed from the work of Milne and Davenport (1969) (see also Whitham et al., 1970), and displayed contours of peak horizontal acceleration at a probability of exceedence of 0.01 per annum that were used as boundaries for the four seismic risk zones. Although some of the seismic loading provisions have changed (Uzumeri et al., 1978), the 1970 zoning map has been referenced by subsequent editions of the code up to 1980.

The 1970 zoning map shown in Figure 1 was developed using extreme-value statistics applied to the catalog of known Canadian earthquakes (to 1963) to compute probabilities of peak acceleration exceedence at a grid of sites throughout the country (Milne and Davenport, 1969). Reviews and recent applications of seismic risk estimation in Canada (Weichert and Milne, 1979;

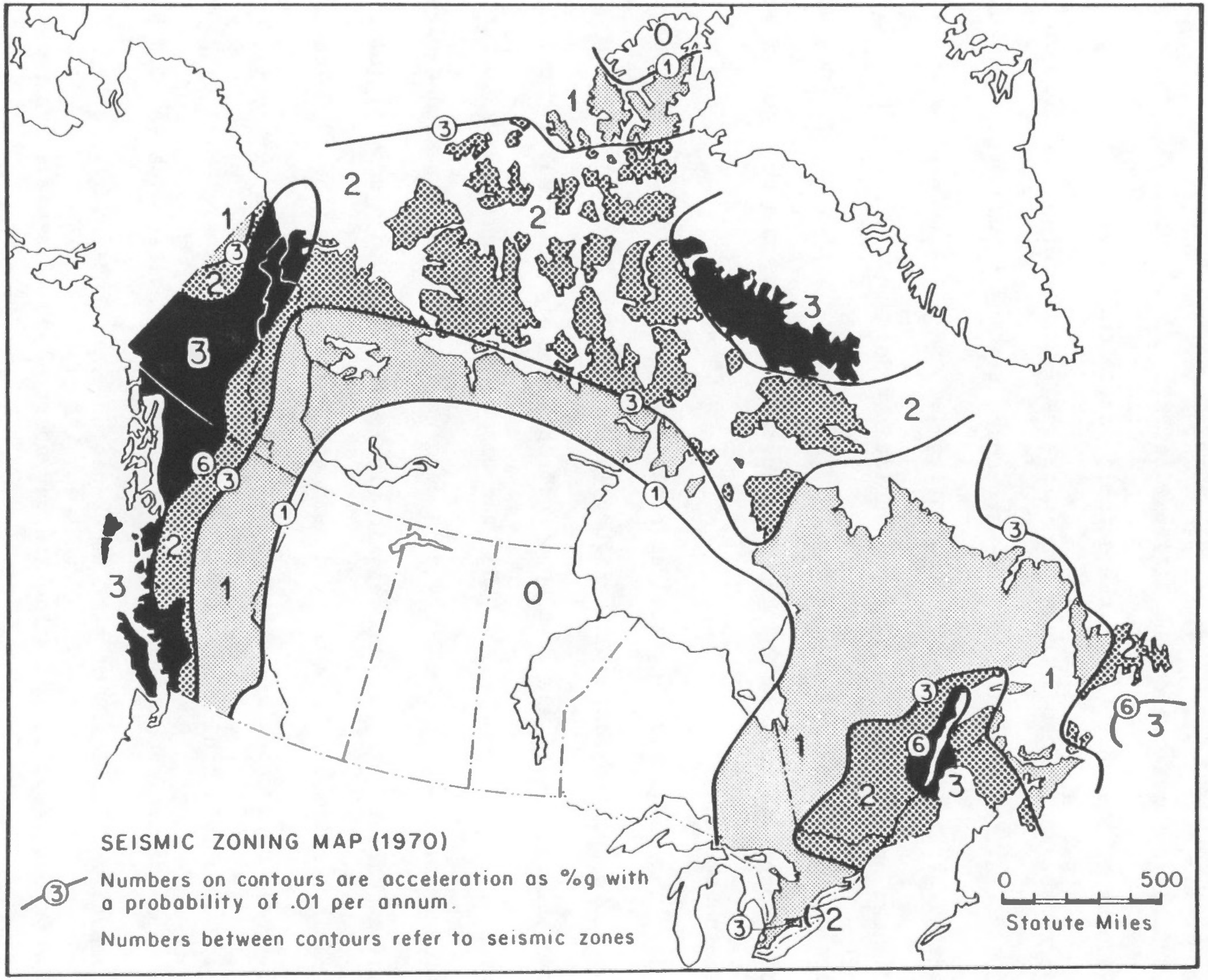

SEISMIC ZONING MAP (1970)
3
Numbers on contours are acceleration as %g with a probability of .01 per annum.
Numbers between contours refer to seismic zones
0
500
Statute Miles
0
1
2
3
6

Figure 1

Basham and Weichert, 1979; Basham et al., 1979) have shown that the method developed by Cornell (1968) is the most appropriate for derivation of new probabilistic seismic ground motion maps of Canada. For computational purposes we have adapted the computer program of McGuire (1976) and will therefore refer to the method as "Cornell-McGuire".

The new probabilistic seismic ground motion maps are described in the publication by Basham et al. (1983), which includes a discussion and illustration of the influences of: (a) the expanded catalog of Canadian seismicity since the preparation of the 1970 map which was based on seismicity to 1963; (b) the change in method from extreme-value to Cornell-McGuire; (c) the change in strong ground motion attenuation relations from those of Milne and Davenport (1969) to the new relations developed by Hasegawa et al. (1981); and (d) a change in probability of exceedence from the value of 0.01 per annum used for the 1970 zoning map to the value of 10% in 50 years recommended for the next version of the National Building Code. The adaptation of probabilistic peak horizontal acceleration and velocity maps to seismic zoning maps and the concomitant changes to the seismic loading provisions that would be required in the National Building Code are described by Heidebrecht et al. (1983). The contour maps of acceleration and velocity at a probability of exceedence of 10% in 50 years that will be employed as new seismic zoning maps are shown in Figures 2 and 3.

It is the purpose of this report to present a comprehensive description of the basic earthquake data and the methods employed in deriving the new maps. The contents and format of the report are described in the following section with reference to the basic requirements of the Cornell-McGuire method.

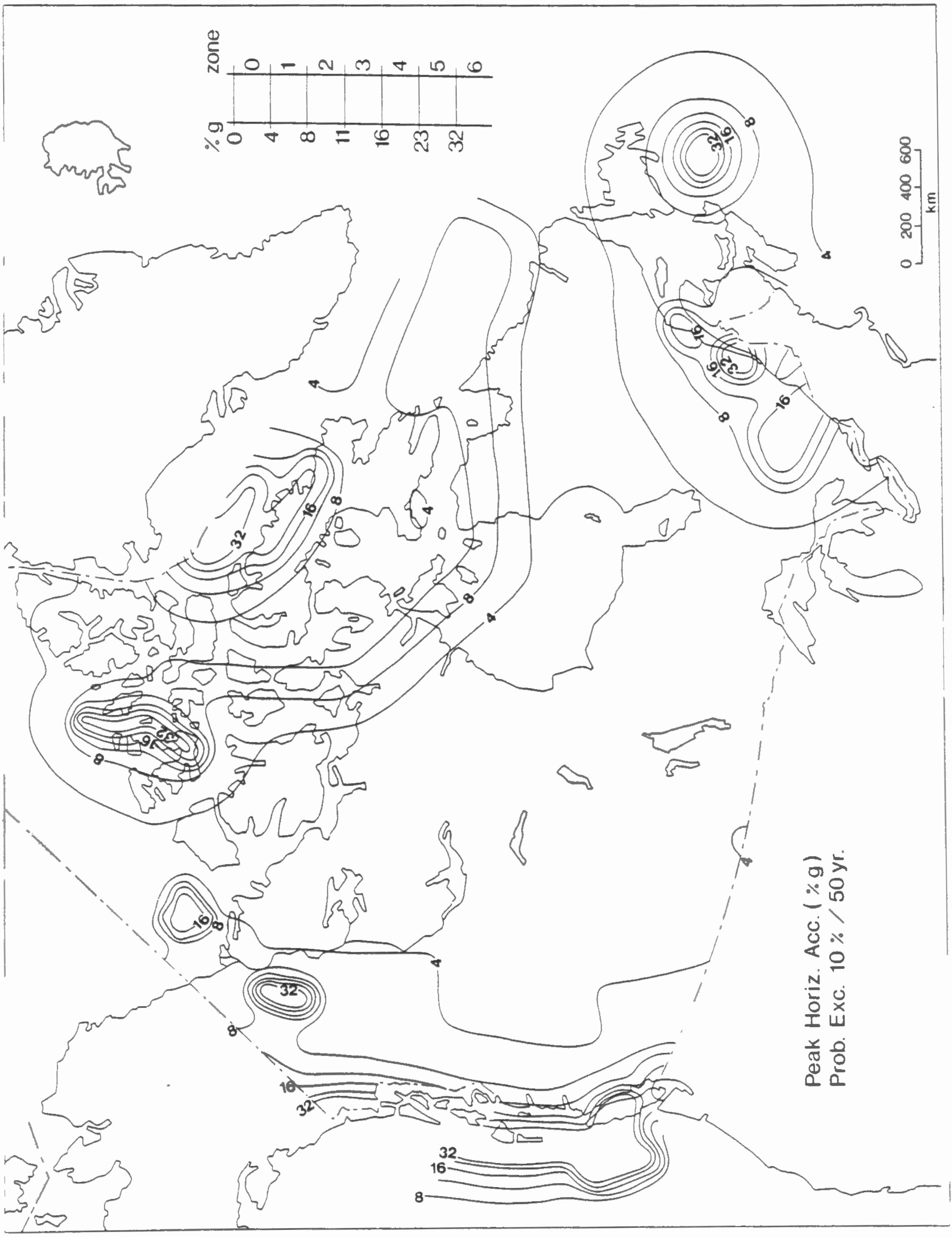

%g
0
4
8
11
16
23
32
zone
0
1
2
3
4
5
6
0 200 400 600
km
Peak Horiz. Acc. ( %g )
Prob. Exc. 10 % / 50 yr.
4
8
16
32

Figure 2

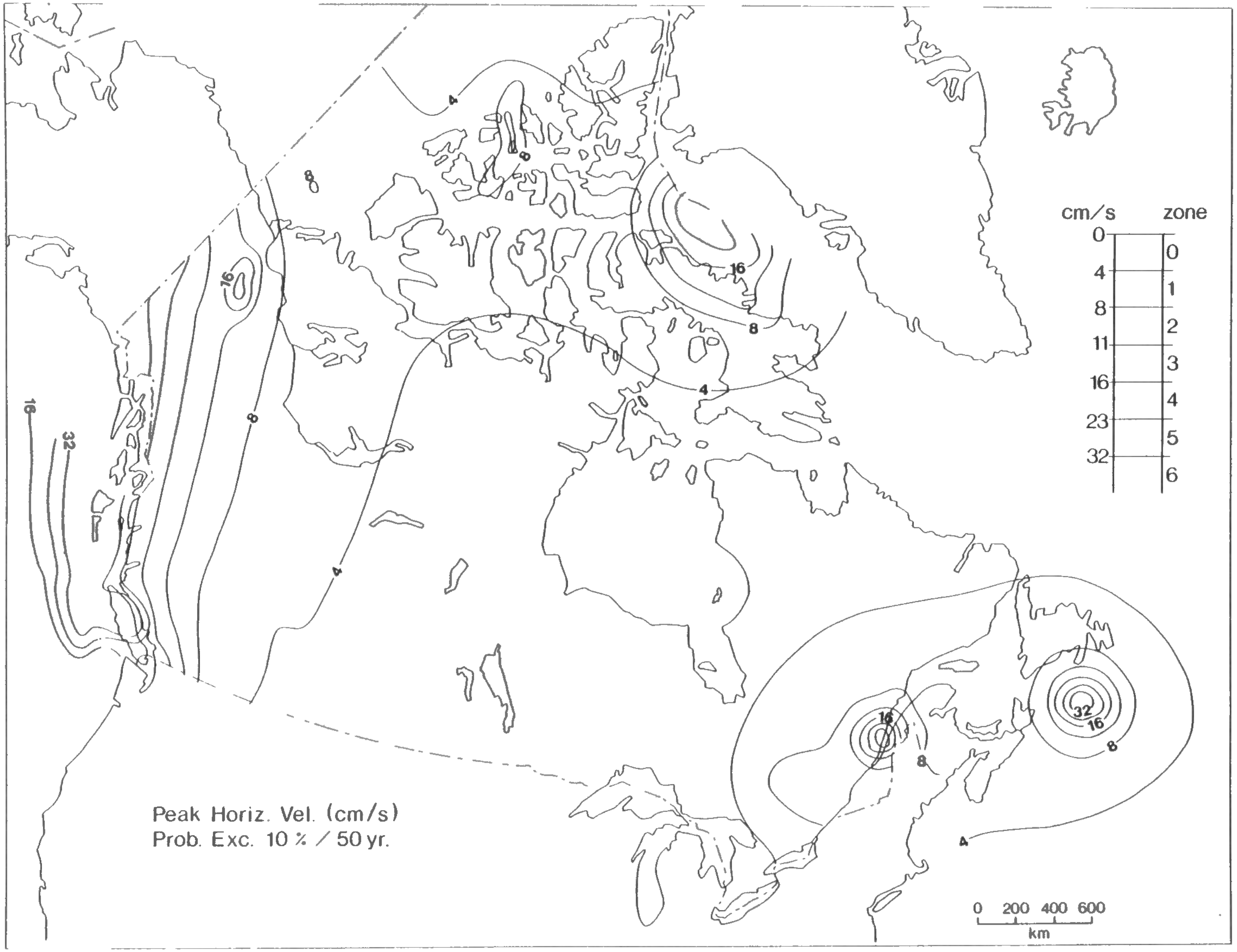

Peak Horiz. Vel. (cm/s)
Prob. Exc. 10 % / 50 yr.
cm/s
zone
0
4
8
11
16
23
32
0
1
2
3
4
5
6
4
8
16
32
0 200 400 600
km

Figure 3

## 2. CORNELL-MCGUIRE SEISMIC RISK ESTIMATION

The four basic components of the Cornell-McGuire seismic risk estimation method are illustrated schematically in Figure 4.

### 2.1 Earthquake Source Zones

The method requires that the seismicity be defined in finite source zones (Figure 4a) with uniform activity. The seismicity of Canada and adjacent active regions has been modelled with a total of 32 source zones (Figure 5) based on the distribution of historic and recent earthquakes and any geologic or tectonic evidence that can be employed to delineate the extent of future earthquake activity. A description of the rationale used for the selection of zone boundaries and a small scale map of each of the source zones, with its associated seismicity, is given in Section 3. The source zone boundaries on Figure 5 and on the individual source zone maps are straight lines in the Lambert Conformal projection used for these maps. Each of these zones is modelled as a horizontal, uniformly active source of earthquakes. In the absence of a reliable depth distribution, the seismicity in all zones, with one exception, is assigned a focal depth of 20 km. This is slightly deeper than the average depths of Canadian earthquakes, but the choice partially compensates for the unrestricted near-field attenuation (see Section 2.3). The exception is the Puget Sound subduction zone (see Section 3). The Alaskan seismicity is also modelled in simplified zones at a depth of 20 km, even though many of the earthquakes do occur in deeper subduction zones.

### 2.2 Magnitude Recurrence Relations

Each of the zones is assigned a cumulative magnitude recurrence relation

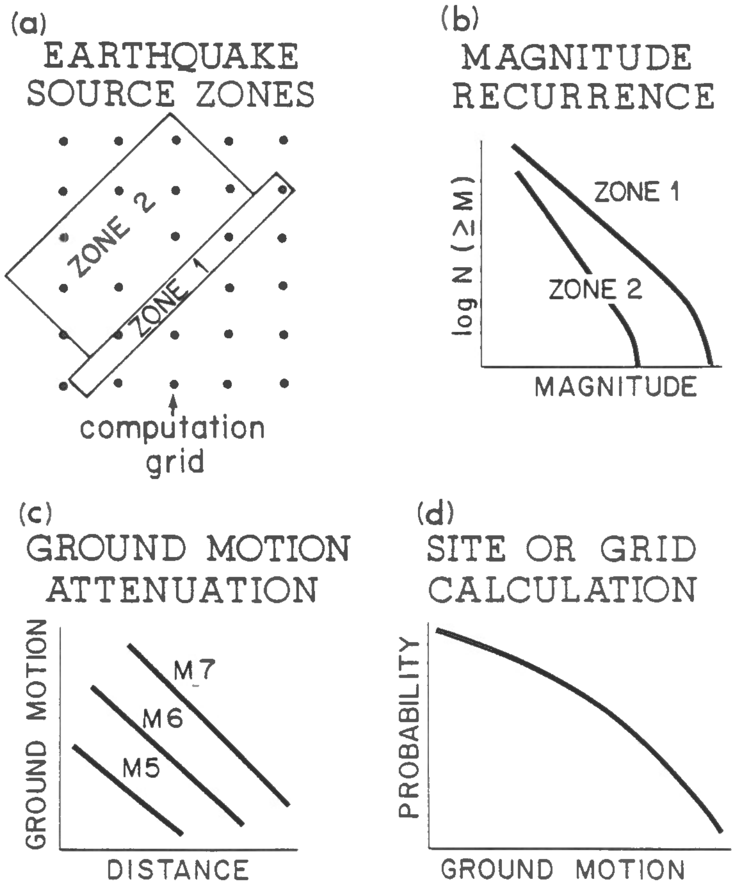

(a)
EARTHQUAKE SOURCE ZONES
ZONE 2
ZONE 1
computation grid
(b)
MAGNITUDE RECURRENCE
log N (≥ M)
ZONE 1
ZONE 2
MAGNITUDE
(c)
GROUND MOTION ATTENUATION
GROUND MOTION
M7
M6
M5
DISTANCE
(d)
SITE OR GRID CALCULATION
PROBABILITY
GROUND MOTION

Figure 4

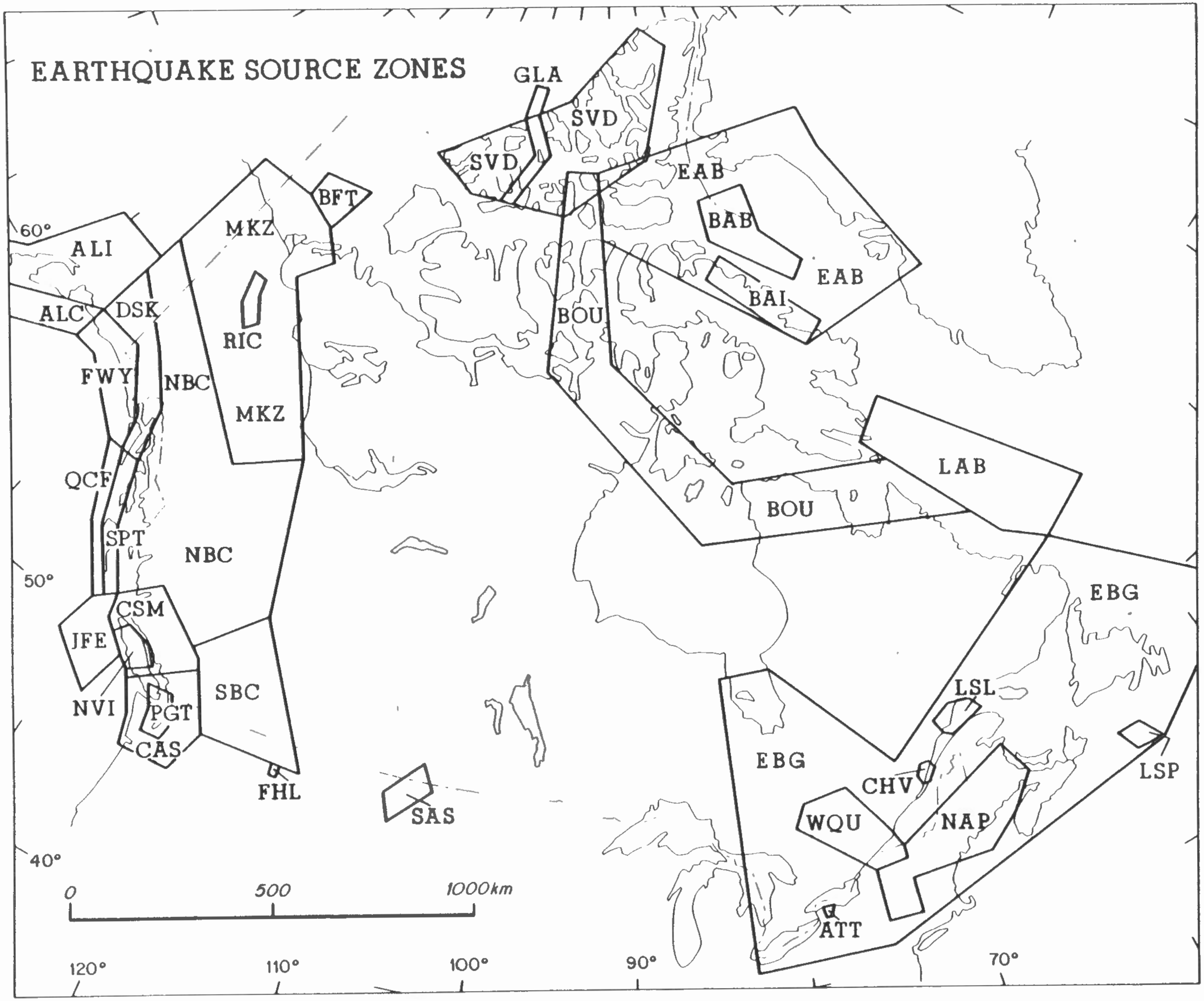

EARTHQUAKE SOURCE ZONES
GLA
SVD
SVD
EAB
BAB
EAB
BAI
BOU
BOU
LAB
BFT
MKZ
RIC
MKZ
ALI
ALC
DSK
FWY
NBC
QCF
SPT
NBC
CSM
JFE
NVI
PGT
CAS
SBC
FHL
SAS
EBG
EBG
LSL
CHV
WQU
NAP
LSP
ATT
60°
50°
40°
0
500
1000km
120°
110°
100°
90°
70°

Figure 5

terminated at an upper-bound magnitude (Figure 4b). The recurrence relations have been computed using the method of Weichert (1980), a maximum likelihood method extended to the case of earthquakes with an assigned maximum magnitude and grouped in magnitude with each group observed over its individual time period. This requires an estimate of the first year of complete reporting of different magnitude category earthquakes in each of the zones. The estimated years for half-magnitude categories are given in Table 1. These are estimates based on our experience and on discussions with Branch colleagues familiar with historical Canadian seismicity, and are determined by the historical patterns of population distribution and reporting of earthquake occurrences in the pre-instrumental era, and by the capabilities of global and Canadian seismograph networks and methods of routinely reporting earthquakes that have developed since the turn of the century. Milne et al. (1978) and Rogers (1983) describe these considerations for a part of the west coast region (see also Basham and Whitham (1966)). For a number of zones a starting year is imposed rather arbitrarily on a larger magnitude category. These cases are noted in the individual zone descriptions in Section 3. The earthquakes that postdate these completeness years were used to derive the magnitude recurrence relations and are listed in Appendix A. The final year of earthquakes included for these computations is 1977, with two exceptions noted in Section 3 for which 1978 data were used. For only the Northern Appalachian zone would the inclusion of more recent earthquakes be expected to influence the derived magnitude recurrence relation; the implications for this zone are discussed in Section 3.21.

In the compilation of earthquakes for each of the source zones, aftershocks <u>are</u> included if they pass the completeness test described in Table 1. It is a debatable question whether aftershocks should be included in

## Table 1

## Estimated First Year of Complete Reporting of Magnitude Categories

| Zone | Magnitude Category* | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 3.0 | 3.5 | 4.0 | 4.5 | 5.0 | 5.5 | 6.0 | 6.5 | 7.0 | 7.5 | 8.0 |
| | Western Canada | | | | | | | | | | |
| PGT | - | - | 1965 | 1956 | 1940 | 1917 | 1899 | 1899 | 1860 | 1860 | |
| CAS | - | - | 1965 | 1956 | 1940 | 1917 | 1899 | 1899 | 1860 | 1860 | |
| NVI | - | 1965 | 1956 | 1956 | 1940 | 1917 | 1917 | 1917 | 1860 | 1860 | |
| CSM | - | 1965 | 1956 | 1956 | 1940 | 1917 | 1917 | 1917 | | | |
| JFE | - | - | 1965 | 1965 | 1965 | 1917 | 1917 | 1917 | 1899 | | |
| QCF | - | - | 1965 | 1965 | 1965 | 1940 | 1917 | 1917 | 1899 | 1899 | 1899 |
| SPT | - | - | 1965 | 1965 | 1965 | 1940 | 1917 | 1917 | 1899 | | |
| SBC | - | 1965 | 1960 | 1960 | 1940 | 1917 | 1899 | 1899 | | | |
| NBC | - | 1971 | 1965 | 1965 | 1965 | | | | | | |
| SAS | 1968 | 1965 | 1940 | 1940 | 1940 | 1900 | | | | | |
| | Northwestern | | | | | | | | | | |
| FWY | - | - | 1972 | 1968 | 1964 | 1950 | 1950 | 1930 | 1920 | 1850 | 1850 |
| DSK | - | - | 1972 | 1968 | 1964 | 1950 | 1950 | 1930 | 1920 | | |
| RIC | - | - | 1968 | 1968 | 1964 | 1950 | 1950 | 1930 | 1920 | | |
| BFT | - | - | 1968 | 1968 | 1964 | 1950 | 1950 | 1930 | | | |
| MKZ | - | - | 1968 | 1968 | 1964 | 1950 | 1950 | | | | |
| | Eastern Canada | | | | | | | | | | |
| CHV | 1968 | 1963 | 1937 | 1928 | 1920 | 1900 | 1800 | 1660 | 1660 | | |
| WQU | 1968 | 1963 | 1937 | 1928 | 1928 | 1900 | 1900 | 1850 | | | |
| LSL | 1975 | 1963 | 1963 | 1937 | 1937 | 1937 | 1900 | | | | |
| NAP | 1975 | 1963 | 1937 | 1937 | 1937 | 1900 | | | | | |
| LSP | - | - | 1956 | 1956 | 1937 | 1937 | 1930 | 1930 | 1800 | | |
| ATT | - | 1963 | 1937 | 1937 | 1937 | 1850 | | | | | |
| EBG | - | 1963 | 1963 | 1956 | 1937 | | | | | | |
| | Northeastern | | | | | | | | | | |
| BAB | - | - | 1968 | 1968 | 1964 | 1950 | 1950 | 1930 | 1920 | 1850 | |
| BAI | - | - | 1968 | 1968 | 1964 | 1950 | 1950 | | | | |
| LAB | - | - | 1968 | 1968 | 1964 | 1950 | | | | | |
| EAB | - | - | 1968 | 1968 | 1964 | 1950 | | | | | |
| GLA | - | - | 1968 | 1968 | 1964 | 1950 | | | | | |
| SVD | - | - | 1968 | 1968 | 1964 | 1950 | | | | | |
| BOU | - | - | 1968 | 1968 | 1964 | 1950 | 1950 | | | | |

*With magnitudes defined to one-tenth unit, each category includes earthquakes in a half-magnitude range; e.g., M 5.5 includes M 5.3 to 5.7.

defining magnitude recurrence relations for the purpose, here, of deriving earthquake source models for seismic risk estimates. On the one hand, the inclusion of aftershocks violates the assumption of Poissonian distribution often used to model earthquake occurrence; on the other, large aftershocks can contribute risk in their own right. Further, it is often difficult to decide if earthquakes have occurred as mainshock-aftershock sequences, or as swarms with many events of similar magnitude. Examples of swarm-like activity described in Section 3 are the earthquakes of Byam Martin Channel, Baffin Island and Miramichi, New Brunswick. In general, the effect on magnitude recurrence of including aftershocks is a small change in the recurrence slope. This may be a small increase if many small aftershocks pass the completeness test, or a small descrease if only large aftershocks of the larger historical earthquakes pass the completeness test.

Each of the magnitude recurrence relations is terminated by an adopted upper-bound magnitude. The upper bound magnitude truncates the incremental magnitude distribution which produces a smooth curve approach to zero rate in the plotted cumulative distribution.

The maximum magnitude earthquake that can occur in a source zone can be a critical parameter in probabilistic estimates of seismic risk. For zones with high rates of seismicity, significant risk contributions at moderate probabilities are coming from earthquakes near the maximum; therefore, the choice is important. However, for zones of low seismicity the probability of occurrence of earthquakes near the maximum can be much less than the probability being considered in the risk estimate, and the choice is less important.

There are a number of ways of estimating maximum magnitude: by a magnitude truncation in observed seismicity for source zones in which the return period for maximum magnitude is shorter than the observation period; by consideration of the maximum fault area that can break in a single event; by estimates of the average fault slip rate, from plate tectonic models or geological data. Where this type of evidence is available, these methods are considered for choosing upper bound magnitudes. For many zones, however, this type of evidence is not available, and a rather arbitrary value has been adopted. In many cases this is approximately one-half a magnitude unit larger than the largest known historical event. A discussion is given in Section 3 if the choice is considered important to the resulting estimate of earthquake risk.

The magnitude recurrence relations have the form

$$N(\geq M) = N_o \exp(-\beta M)(1 - \exp(-\beta(M_x - M))).$$

A summary of the recurrence parameters and the total area of each source zone is given in Table 2. Figures showing graphical illustrations of the recurrence curves accompany the zone descriptions in Section 3. In a number of cases the seismicity data are too sparse to derive an independent relation and recurrence parameters are imposed (parameters in parentheses in Table 2). For those source zones exclusively in United States territory we have not estimated the magnitude recurrence parameters but have adopted them from equivalent work by the U.S. Geological Survey.

## 2.3 Strong Ground Motion Attenuation

Attenuation relations that predict ground motion as a function of magnitude and distance (Figure 4c) are required for the ground motion parameters being mapped, and Hasegawa et al. (1981) have developed the

## Table 2

## Source Zone Magnitude Recurrence Parameters

| Zone | $\beta$ | $N_o$ | $M_x$ | Area ($km^2$) |
|---|---|---|---|---|
| | Western Canada | | | |
| PGT | 1.58 | 436. | 7.5 | 28400 |
| CAS | 1.87 | 1060. | 7.5 | 145000 |
| NVI | 1.04 | 21. | 7.5 | 27000 |
| CSM | 1.77 | 272. | 6.5 | 139000 |
| JFE | 1.72 | 7360. | 7.0 | 84800 |
| QCF | 1.50 | 1610. | 8.5 | 46400 |
| SPT | 1.87 | 1240. | 7.0 | 53700 |
| SBC | 2.28 | 3230. | 6.5 | 255000 |
| NBC | (2.28) | (1830.) | 5.0 | 875000 |
| FHL | 2.58 | 38000. | 6.5 | 2100 |
| SAS | 2.07 | 188. | 6.0 | |
| | Northwestern | | | |
| FWY | 1.66 | 4590. | 8.5 | 111000 |
| DSK | 1.96 | 2820. | 7.0 | 110000 |
| RIC | 1.76 | 1560. | 7.0 | 20000 |
| BFT | 1.76 | 681. | 6.5 | 39000 |
| MKZ | 2.67 | 92000. | 6.0 | 698000 |
| ALC | 1.43 | 3820. | 8.5 | 132000 |
| ALI | 1.73 | 57100. | 8.5 | 321000 |
| | Eastern Canada | | | |
| CHV | 1.66 | 310. | 7.5 | 6880 |
| WQU | 1.85 | 1030. | 7.0 | 121000 |
| LSL | 1.85 | 533. | 6.0 | 24500 |
| NAP | 1.87 | 638. | 6.0 | 241000 |
| LSP | 1.30 | 41. | 7.5 | 15200 |
| ATT | 1.32 | 11. | 6.0 | 2620 |
| EBG | 2.78 | 16200. | 5.0 | 2670000 |
| | Northeastern | | | |
| BAB | 1.64 | 611. | 7.5 | 100000 |
| BAI | 2.54 | 52100. | 7.0 | 85000 |
| LAB | 1.95 | 1970. | 6.5 | 352000 |
| EAB | 1.81 | 847. | 6.0 | 1067000 |
| GLA | 2.19 | 18900. | 6.5 | 42000 |
| SVD | (2.19) | (2280.) | 6.0 | 480000 |
| BOU | 2.02 | 3780. | 6.5 | 830000 |

relations for this purpose in Canada. These authors, and Heidebrecht et al. (1983) and Basham et al. (1983), have discussed the need to estimate probabilistic ground motion in the two dominant frequency ranges represented by the parameters of peak horizontal acceleration (near 5 Hz) and peak horizontal velocity (near 1 Hz).

The analytical form of the attenuation relations of Hasegawa et al. (1981) are unrestricted at high magnitudes and in the near distances ranges. Although there are no strong motion data available for large earthquakes ($M \geq 7.5$) to provide good evidence, it is generally agreed that the excitation of seismic ground motion in the frequency range of engineering interest reaches an upper limit as magnitude increases to large values, much as the magnitude scales that measure ground motion in the frequency range near 1 Hz tend to saturate near M 7.5. To impose this condition on the Hasegawa et al. (1981) attenuation relations, the ground motion contributions from earthquakes with magnitudes greater than 7.5 are computed as if the earthquakes were magnitude 7.5; i.e., the recurrence relations for magnitudes greater than 7.5 are collapsed onto the relation for 7.5. The manner in which this is implemented in the computations is described in Section 4.4.

Although there is good evidence (e.g., Joyner and Boore, 1981; Campbell, 1981) that an extrapolation of attenuation relations applicable at greater distances to the near field will produce an over-estimate of peak ground motion parameters, particularly for the larger magnitudes, the Hasegawa et al. relations have not been explicitly restricted in the near field for purposes of these computations. There is, however, a de facto limitation on near field ground motion by the adoption of a minimum focal depth of 20 km for the earthquake source models. Hasegawa et al. (1982) have argued that this is adequate for regional probabilistic ground motion mapping at moderate probabilities, but would not be adequate for estimating low-probability, near-field effects of large earthquakes that may be required for design of critical facilities (see also Basham et al. (1982) and Heidebrecht et al. (1983)).

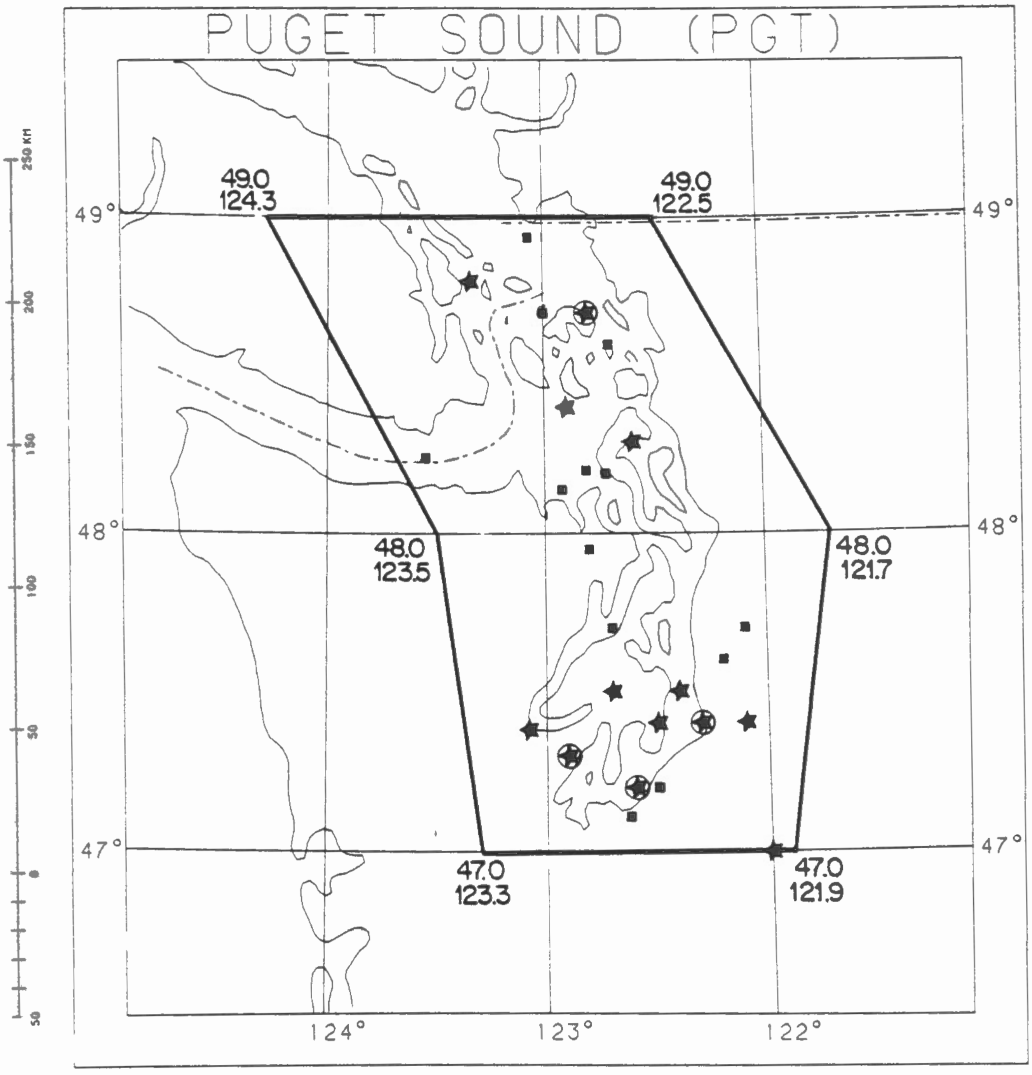
### 2.4 Ground Motion Exceedence Computations

The final component in the Cornell-McGuire seismic risk analysis is the computation of a distribution function of probability of exceedence of the ground motion parameters (Figure 4d), by numerical integration of contributions from all relevant source zones. We have employed a modified version of the McGuire (1976) computer program; a program listing is given in Appendix B. A description of a variety of important matters related to the implementation of the program and the stability of the calculations is given in Section 4.

## 3. DESCRIPTION OF EARTHQUAKE SOURCE ZONES

### 3.1 Puget Sound (PGT) (Figures 6, 7)

The large Benioff zone of relatively deep earthquakes in this area is the most important factor differentiating this zone from the surrounding zones. The events appear to be in the subducted oceanic lithosphere, and may arise from the bend in the sinking oceanic lithosphere from a dip of 10-20° under the coast, to a dip of about 50° east of Puget Sound. Crosson (1982) has shown that diffuse shallow seismicity extends throughout this zone to depth of 20 - 25 km. A quiet zone separates this low-magnitude seismicity from deeper activity at 40 - 70 km, which dips towards the northwest. The



EARTH PHYSICS BRANCH EMR OTTAWA CANADA

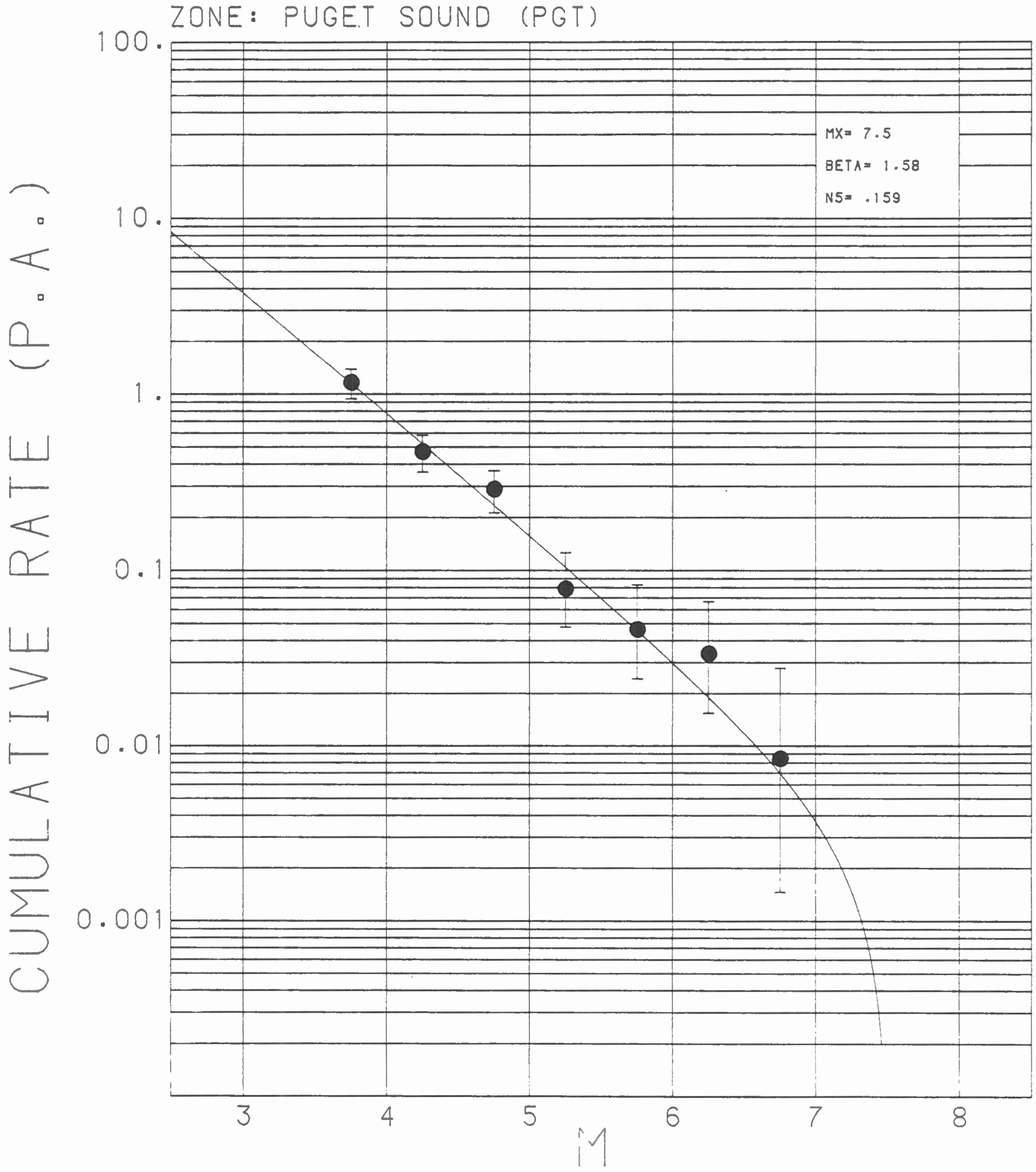
**M**

■ 4·0, 4·5

★ 5·0, 5·5

⊛ ≥ 6·0

Figure 6



EARTH PHYSICS BRANCH EMR OTTAWA CANADA 28/10/81 12.33.02.

DIRECTION DE LA PHYSIQUE DU GLOBE OTTAWA CANADA

Figure 7

observed seismicity, when interpreted as seismic shortening, reflects only 10% of the convergence rate between the Juan de Fuca and North American plates in this area (Weichert and Hyndman, 1982a), but corresponds approximately to a north-south component of convergence, i.e., parallel to the margin. The corner of the continental margin (buried trench or axis of start of subduction) requires N-S compression or overlap in the subducted lithosphere in this area. Towards the north, subduction has slowed and is northward oblique to the margin (Hyndman et al. 1979a), but a detailed picture of the transition beneath the margin has not yet emerged.

A number of choices can be made in modelling the Puget Sound Zone. We have chosen to model the zone by a horizontal uniform distribution, at a depth of 40 km, of all events that occur within the zone boundaries. Although the more significant events may be deeper (40 - 60 km; Crosson (1982)), there is evidence (Hasegawa et al. 1981) that these events produce larger than average peak ground motion at epicentral distances smaller than their focal depths, which is partially accounted for by modelling them at the shallower depth. Crosson (1982) has shown that the Puget Sound seismicity rates are greater at smaller magnitudes in the shallow zone (0 - 30 km) and greater at larger magnitudes in the deep zone. Our model places all of the events at a depth of 40 km. This is an adequate simplification, but not strictly correct since the shallow seismicity described by Crosson has a higher activity than our Cascades zone (Section 3.2). Alternative models have been tested which include more of the Puget Sound activity in the overlapping and surrounding Cascases zone, but the risk estimates differ by only a few percent throughout the region.

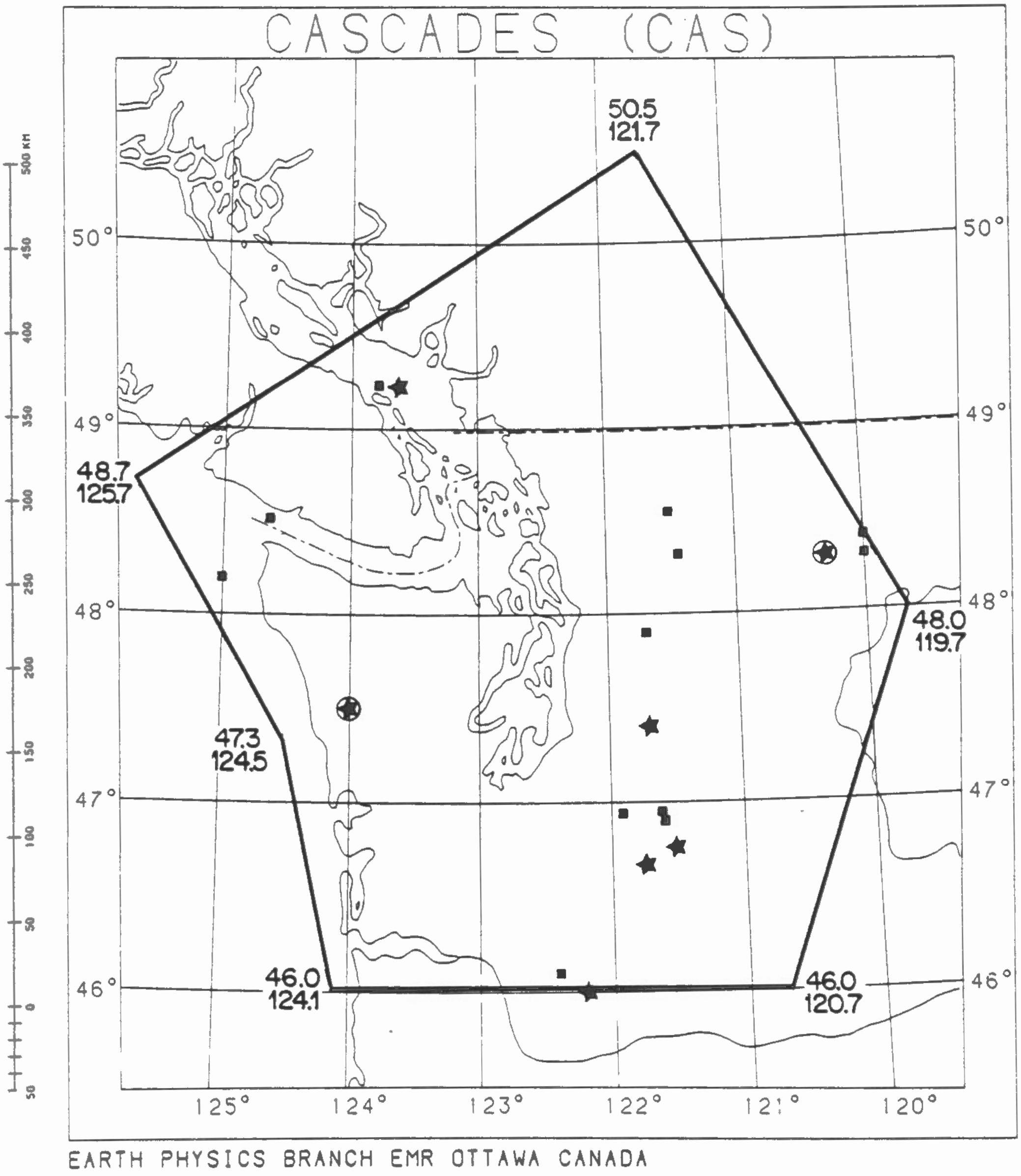
The width of the Puget Sound zone is taken as about 50 km east and west of the estimated position of the change in dip of the subducted slab. The eastern boundary of the zone is also set by calculations on the maximum possible landward persistence of Benioff-type events on thermal grounds. The landward persistence of oceanic lithosphere below the critical temperature for earthquakes depends on the rate of subduction and the age of the oceanic lithosphere being underthrust, both of which vary along the margin. The resulting model may be somewhat too wide in the east-west direction as the significant earthquakes tend to cluster near the centre of the zone (see Figure 6).

The northern boundary of the zone has been chosen along 49°N in agreement with the pattern of the larger historical events. Since a few smaller deep earthquakes have been observed a further 50 km north, under Georgia Strait, an alternate model would have to extend the zone that far. A third, more sophisticated model could include a gradual diminishing of activity and perhaps also of maximum magnitude from the south end of the Puget Sound to the north; our chosen model is thus intermediate in terms of the estimated risk to the densely populated Lower Mainland of British Columbia.

A maximum magnitude of 7.5 is selected for the zone as about half a magnitude unit larger than the largest in the data file, 7.1, in 1949. Magnitude 7.5 is approximately the earthquake size expected for a normal fault breaking completely through the subducted oceanic lithosphere (perhaps 20 km thick) over a horizontal dimension of 100 - 200 km, using the fault area - magnitude relation of Kanamori and Anderson (1975).

### 3.2 Cascades (CAS) (Figures 8, 9)

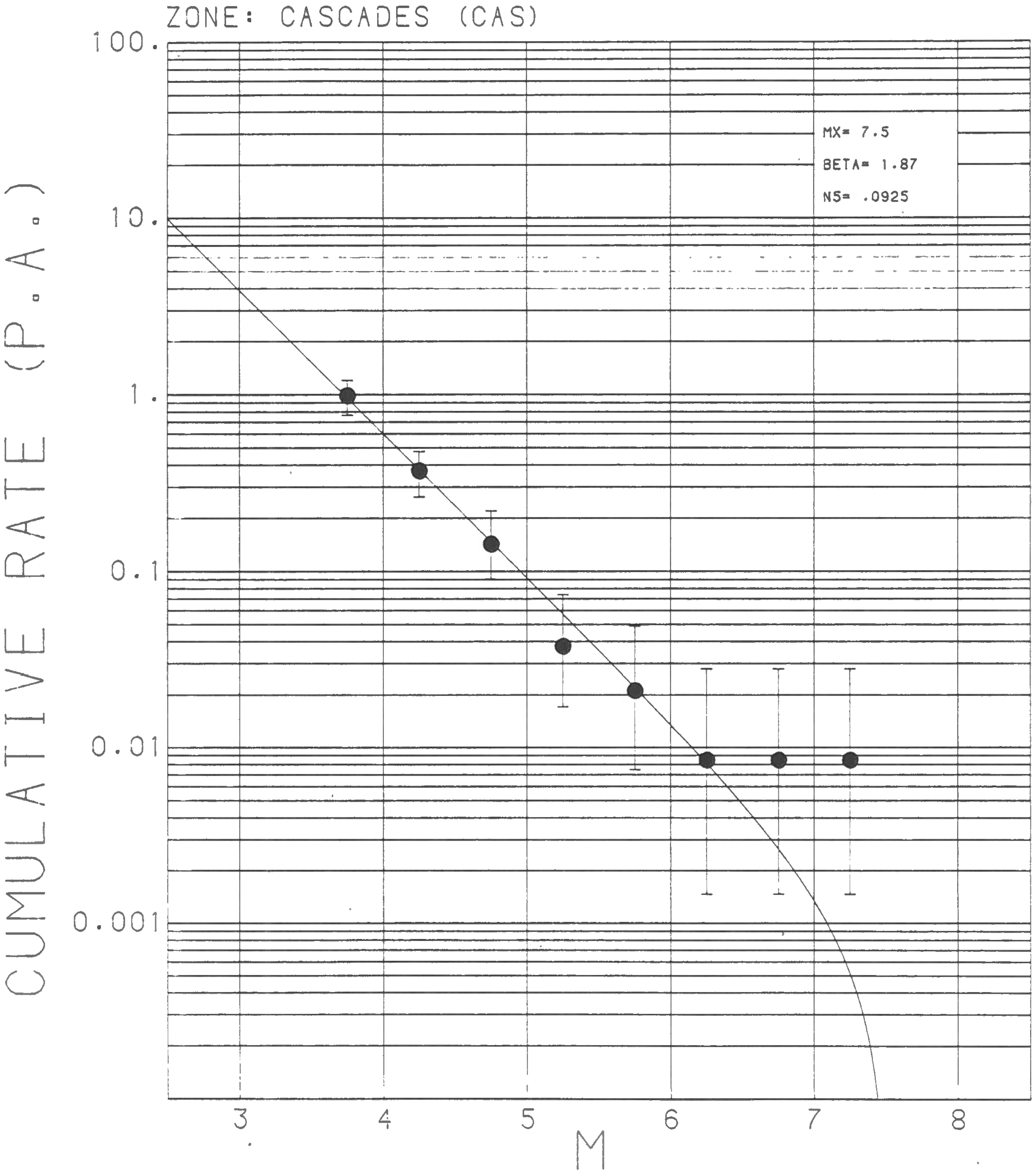
The shallower stress regime in this region probably arises from the Juan de Fuca - America plate convergence at a rate of several centimetres per



EARTH PHYSICS BRANCH EMR OTTAWA CANADA

**M**
■ 4·0, 4·5
★ 5·0, 5·5
⊛ ≥ 6·0

Figure 8



EARTH PHYSICS BRANCH EMR OTTAWA CANADA
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Figure 9

year. The eastern boundary of the zone is taken to the east side of the high Cascades on the assumption that their presence indicates a significant underlying change in stress regime. The eastern limit of the zone may also be taken from a probable eastward decrease in shear coupling between the continental lithosphere and the underthrusting oceanic lithosphere. The coupling and thus stress in the continental lithosphere may decrease as the temperature in the subducted oceanic lithosphere increases and the shear zone approaches the melting temperature under the volcanic zone.

Scattered seismicity extends from the coast to several hundred kilometres inland, and from southern Washington State to a quiet area in south-central Vancouver Island. The most significant earthquake in the historic record is the event of 1872 with an estimated magnitude somewhat greater than 7 (Coombs et al., 1976; Malone and Bor, 1979). The only obvious geologically-recent fault of a length that might generate such a large event seems to be the Fraser-Yalakom fault system although there is no evidence that the 1872 event occured on this fault system. A maximum magnitude of 7.5 is selected to accommodate such an event anywhere in the zone, albeit at a rather low rate as shown by the magnitude recurrence curve (Figure 9).

In the Cascades zone model, and in all other zones described in the following, the earthquakes are assumed to occur at a focal depth of 20 km; i.e., the Puget Sound zone discussed above is the only one for which deeper focal depths are assumed. The Cascades zone is modelled to include the region above the Puget Sound Zone by assuming uniform shallow seismicity to extend throughout the area.

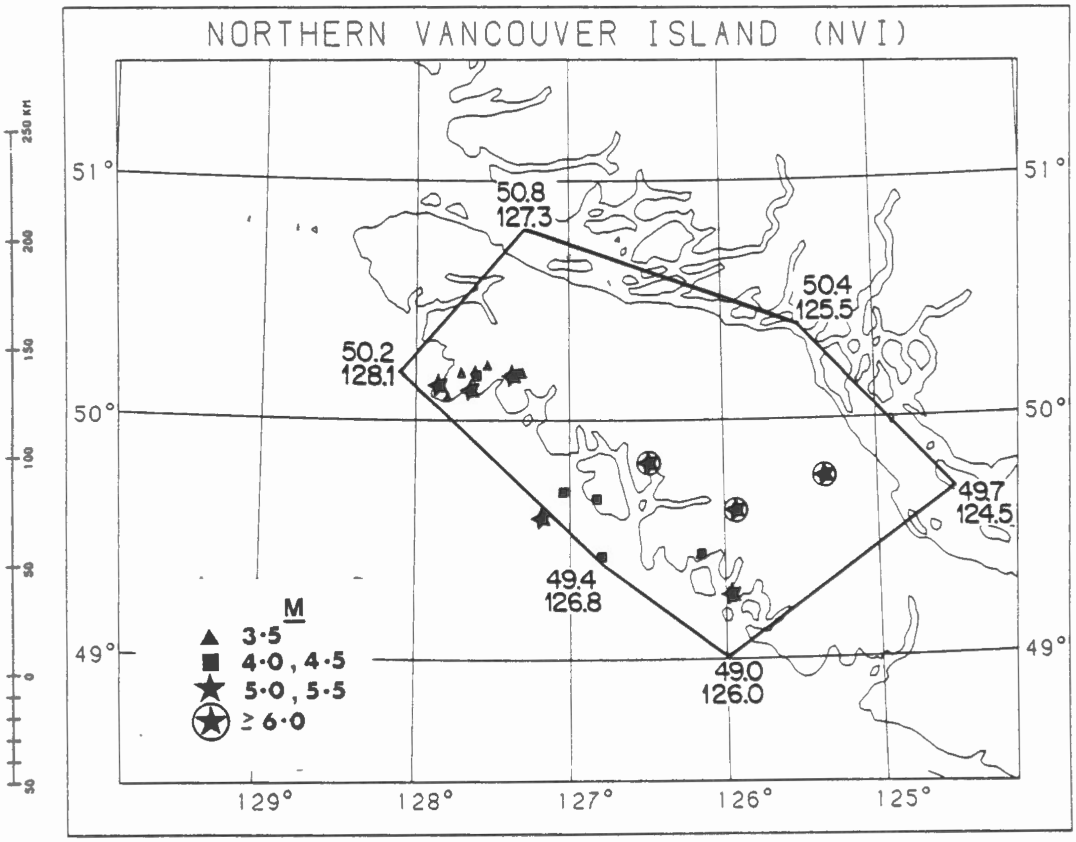
This overlapping of lower and higher seismicity zones occurs in a number of additional cases in the following. Although it is not the most representative modelling of the seismicity that is possible, it is done to avoid the excessive calculations that would be required for these overlapping zones if they were modelled with a "cut-out" of the more active zones, which would require a more detailed pattern of sub-zones for the risk analysis.

### 3.3 Northern Vancouver Island (NVI) (Figures 10, 11)

The stress field in this area is related to the Explorer -Juan de Fuca-America plate interaction (Hyndman et al., 1979): varying rates of convergence along the margin and strike-slip across the offshore Nootka fault perpendicular to the margin. There may be stress coupling between the Nootka fault which is being subducted beneath the margin and the overlying continental lithosphere. The northern and southern limits of the zone are parallel to and roughly equidistant from the landward projection of the Nootka fault zone. Also included near the north end of the zone are the geologically recent plutons across Vancouver Island that probably arise from the northern edge of the subducted Explorer plate. The narrowing of the zone to the north is suggested by decreasing ocean-continent interaction as the oceanic plate becomes younger, thinner and weaker and the convergence rate becomes slower. The eastern boundary of the zone is taken as the edge of the Insular Belt.

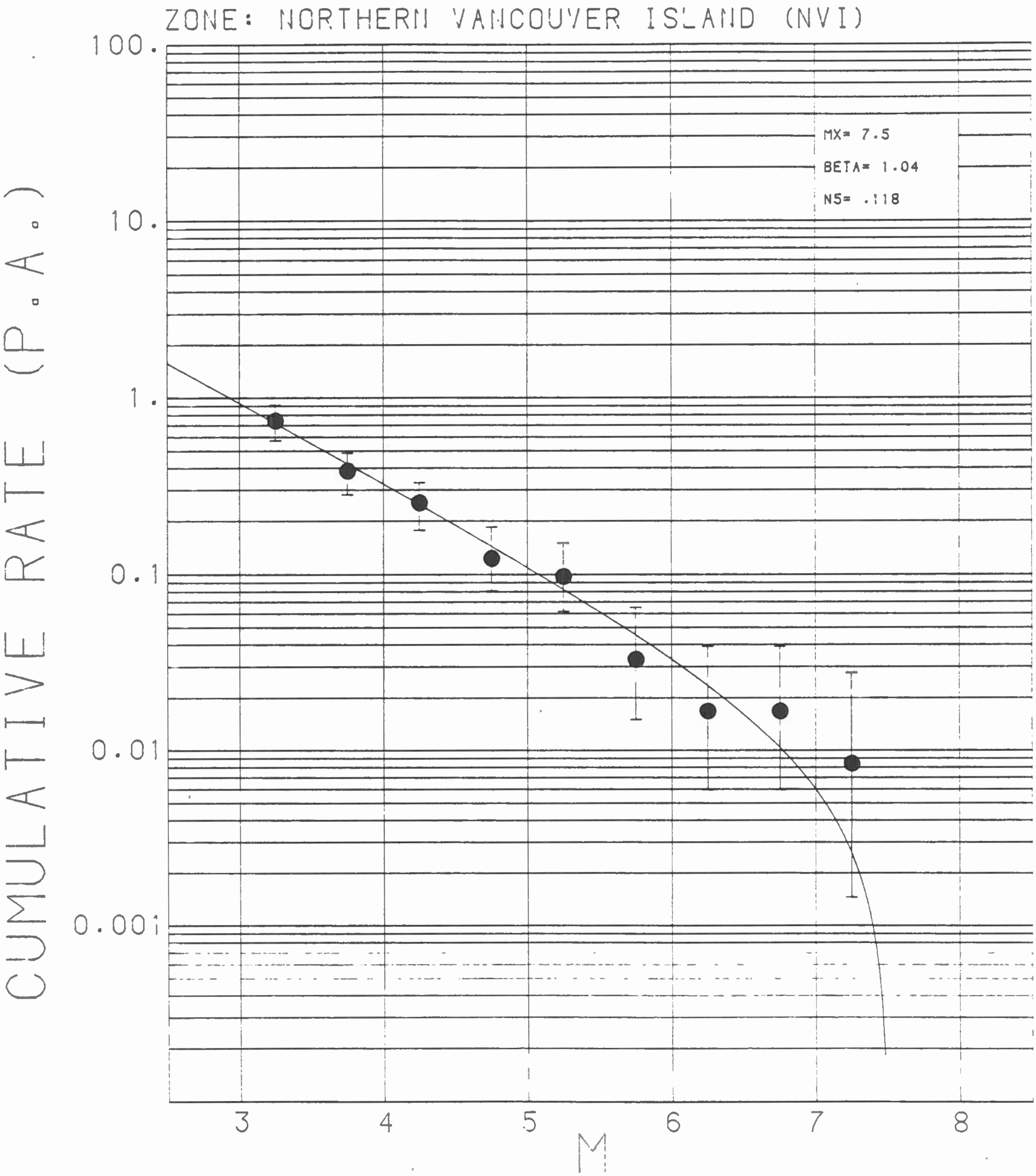
As seen in air photos and satellite images, the zone exhibits some evidence of recent faulting in several areas. The most significant morphological feature, and the longest linear feature on the island, is the Beaufort Range scarp on which the magnitude 7.3, 1946 earthquake probably occurred (Rogers and Hasegawa, 1978; Slawson and Savage, 1979).

The seismicity includes a number of large shallow events, including the 1946 earthquake, in a roughly east-west line across north-central Vancouver



EARTH PHYSICS BRANCH EMR OTTAWA CANADA

Figure 10



EARTH PHYSICS BRANCH EMR OTTAWA CANADA 28/10/81 12.33.02.

DIRECTION DE LA PHYSIQUE DU GLOBE OTTAWA CANADA Figure 11

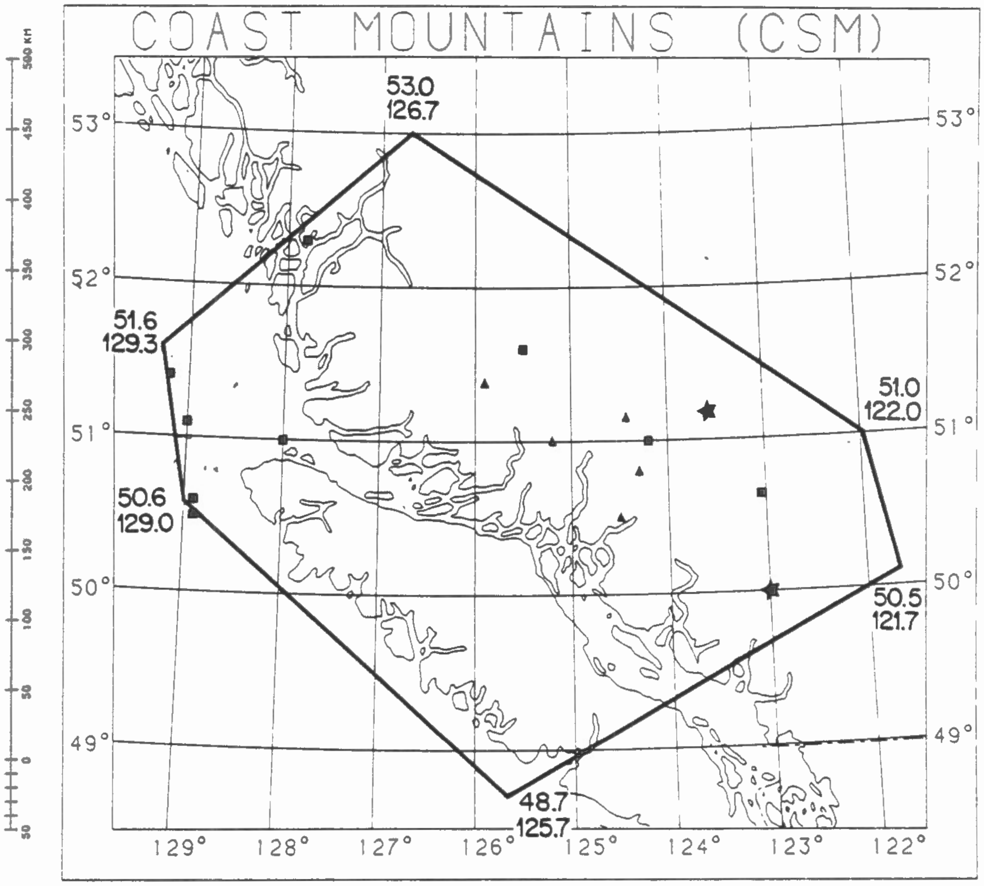
Island. There are, however, relatively few small events, which results in a low slope for the magnitude recurrence curve. In a somewhat arbitrary attempt to increase the slope, assuming the low value is in part due to a temporary lull in a numbers of small earthquakes in recent decades, we have included for this zone the 1978 earthquakes, most of which occurred near Cape Cook at the northwest corner of the zone. The inclusion of 1978 data increases the slope slightly but does not affect the estimated rates of the more significant higher magnitude events.

The maximum magnitude of 7.5 is selected as representative of a 100-km fault break with a depth of 20 km, i.e., a fault break with a length approximately half the largest dimension of the zone.

### 3.4 Coast Mountains (CSM) (Figures 12, 13)

A shallow stress regime can be postulated for this region primarily from the Explorer-America plate interaction along the margin, although the tectonic regime of the margin is complex. The eastern boundary is taken approximately at the eastern side of the Coast Mountains on the assumption that they reflect the limit of the major stress regime. The Coast Mountains zone can be considered as a lower level aureole around the Northern Vancouver zone, much like the Cascades zone around the Puget Sound zone, although the zone is modelled to overlap the Northern Vancouver Island zone.

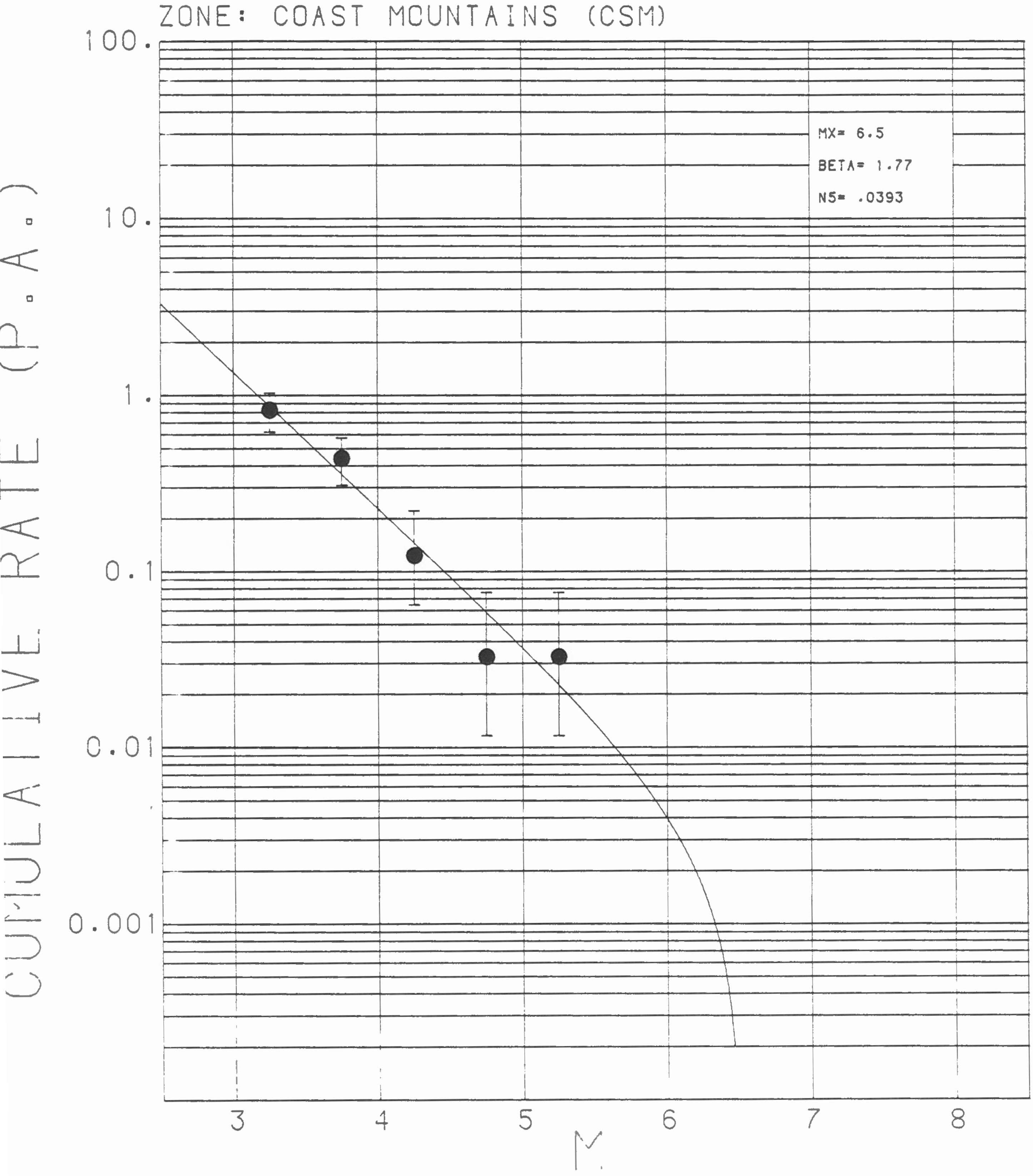
The level of seismicity is quite low but is judged to be slightly higher than the adjacent Southeastern B.C. zone to the southeast (see Section 3.8). The northeast corner of the zone is chosen to include the historical events near Bella Coola that do not pass the completeness test; the western boundary terminates against the Juan de Fuca - Explorer zone. The maximum magnitude



EARTH PHYSICS BRANCH EMR OTTAWA CANADA

**M**
- ▲ 3·5
- ■ 4·0, 4·5
- ★ 5·0, 5·5
- ⍟ ≥ 6·0

Figure 12



EARTH PHYSICS BRANCH EMR OTTAWA CANADA
DIRECTION DE LA PHYSIQUE DU GLOBE OTTAWA CANADA

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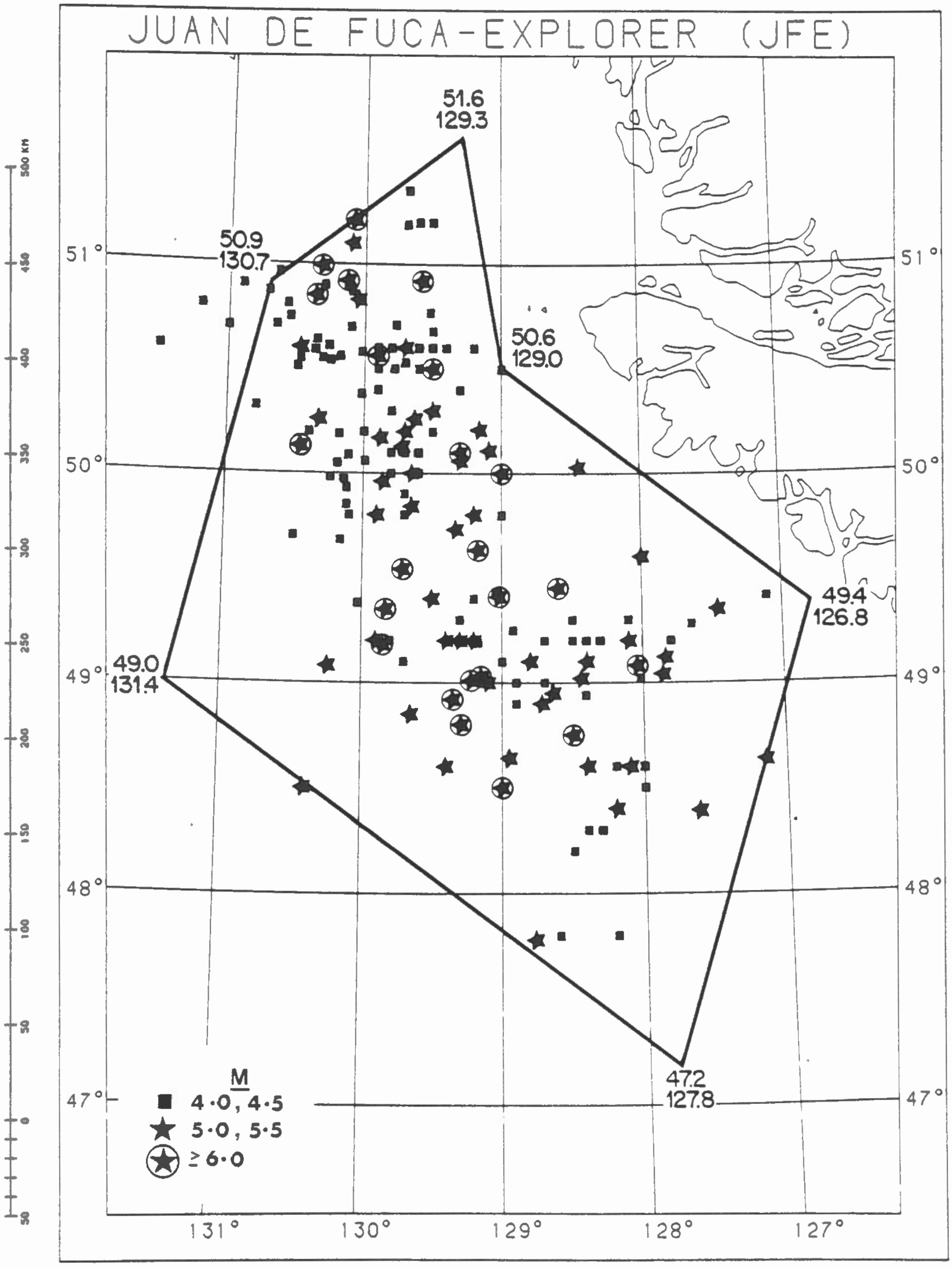
Figure 13

of 6.5 is more than half a magnitude unit larger than the largest historic event, but is selected on the basis of assumed similarity with the Southeastern B.C. zone. However, neither the Cascades nor the Southeastern B.C. zones has known geologic or tectonic features that could be used to estimate maximum magnitude.

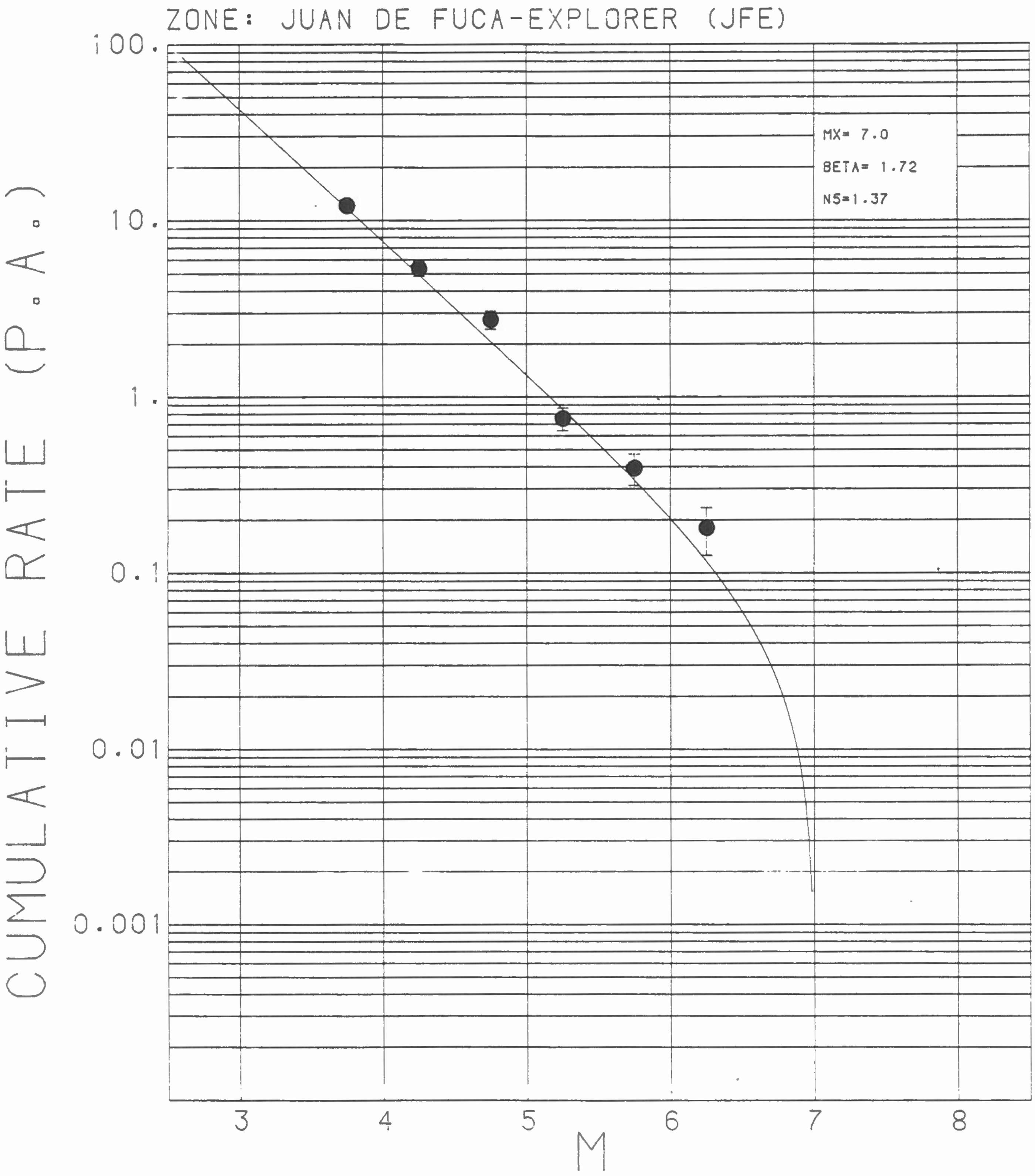
### 3.5 Juan de Fuca-Explorer (JFE) (Figures 14, 15)

The seismicity of this zone appears to follow the en-echelon ridge-transform boundary of the Pacific - Juan de Fuca plate boundary. (Riddihough, 1977; Hyndman et al. 1978; Riddihough et al., 1980; Davis and Riddihough, 1982). The Juan de Fuca ridge system consists of a series of spreading centres (Tuzo Wilson, Dellwood, Explorer, Juan de Fuca and Gorda), offset by transform fault segments (Dellwood-Wilson, Revere-Dellwood, Sovanco). The oceanic lithosphere landward of the Dellwood Wilson and Revere-Dellwood transform faults and Dellwood and Tuzo Wilson spreading centres appears to be coupled or nearly coupled to the America plate (Riddihough et al. 1980). Most of the seismicity is probably associated with transform faults rather than the ridge segments of the boundary. There is Plio-Pleistocene deformation and faulting in seismic profiles off the main plate boundaries nearer to the margin, such as the Winona ridge, but no clear evidence of more recent faulting. The zone is taken to extend from about 50 km west of the Pacific - Juan de Fuca plate boundary to the edge of the shelf, although the area of Winona Basin to the north of the Nootka fault zone appears to be less active. The width of the seismicity pattern probably comes from epicentral location uncertainties and biases. An ocean-bottom seismograph survey (Hyndman and Rogers, 1981) indicates that most of the active features are no more than 25 km wide.



EARTH PHYSICS BRANCH EMR OTTAWA CANADA

Figure 14



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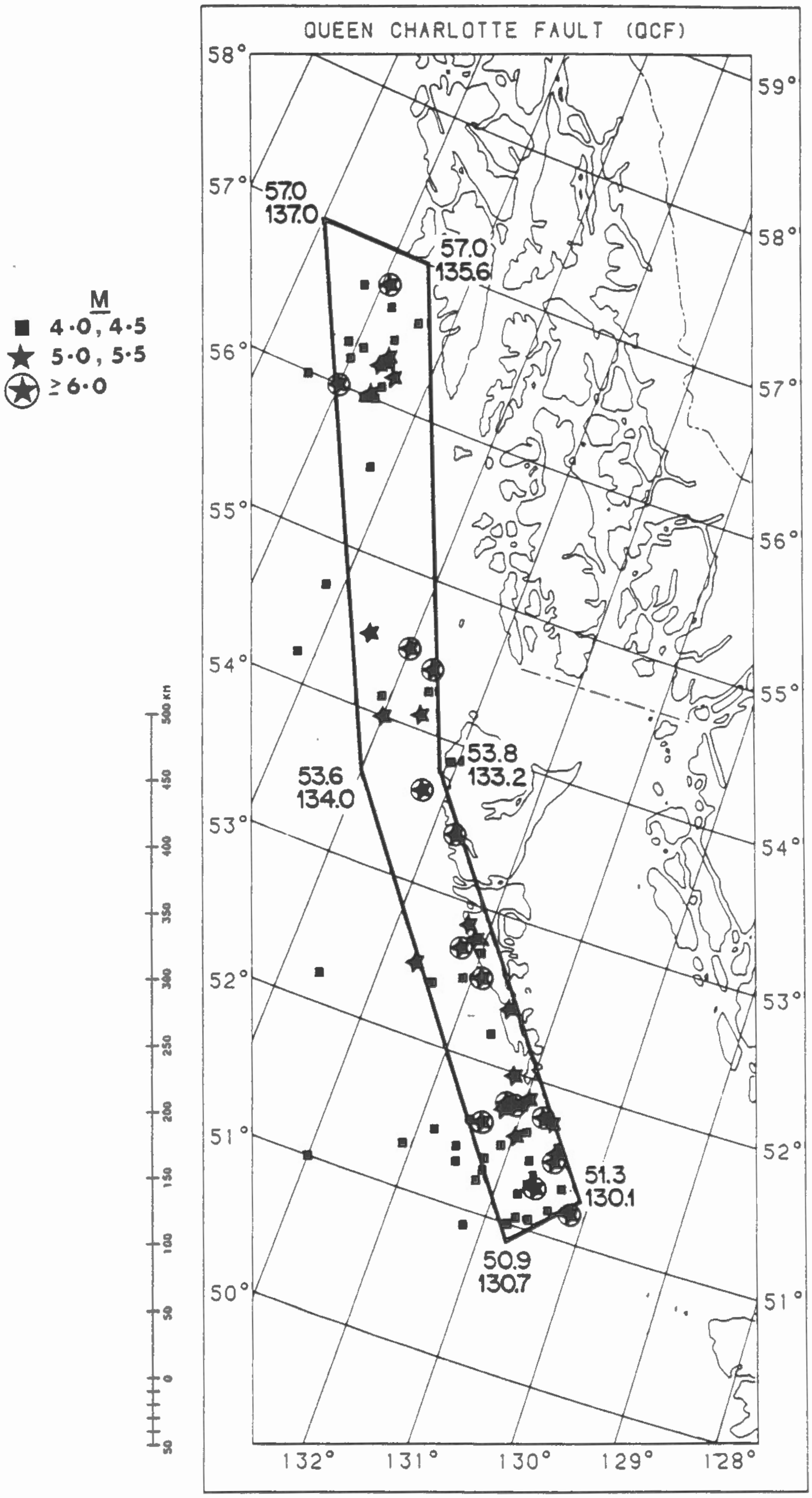
DIRECTION DE LA PHYSIQUE DU GLOBE OTTAWA CANADA

Figure 15

The largest event in the data file is magnitude 6.7; there are many near this magnitude but none larger (Figure 15). There is good evidence for a geological limit on maximum magnitude. The faults on and near the plate boundary have a maximum length of about 100 km and could have a vertical extent of about 10 km; therefore the maximum fault area is about 1000 $km^2$. Using relations between magnitude and fault area (Kanamori and Andersen, 1975; Singh et al., 1980), the maximum plausible earthquake is magnitude 7.0. This is in good agreement with the historic data and is selected as the maximum magnitude (see also Hyndman and Weichert (1983)).

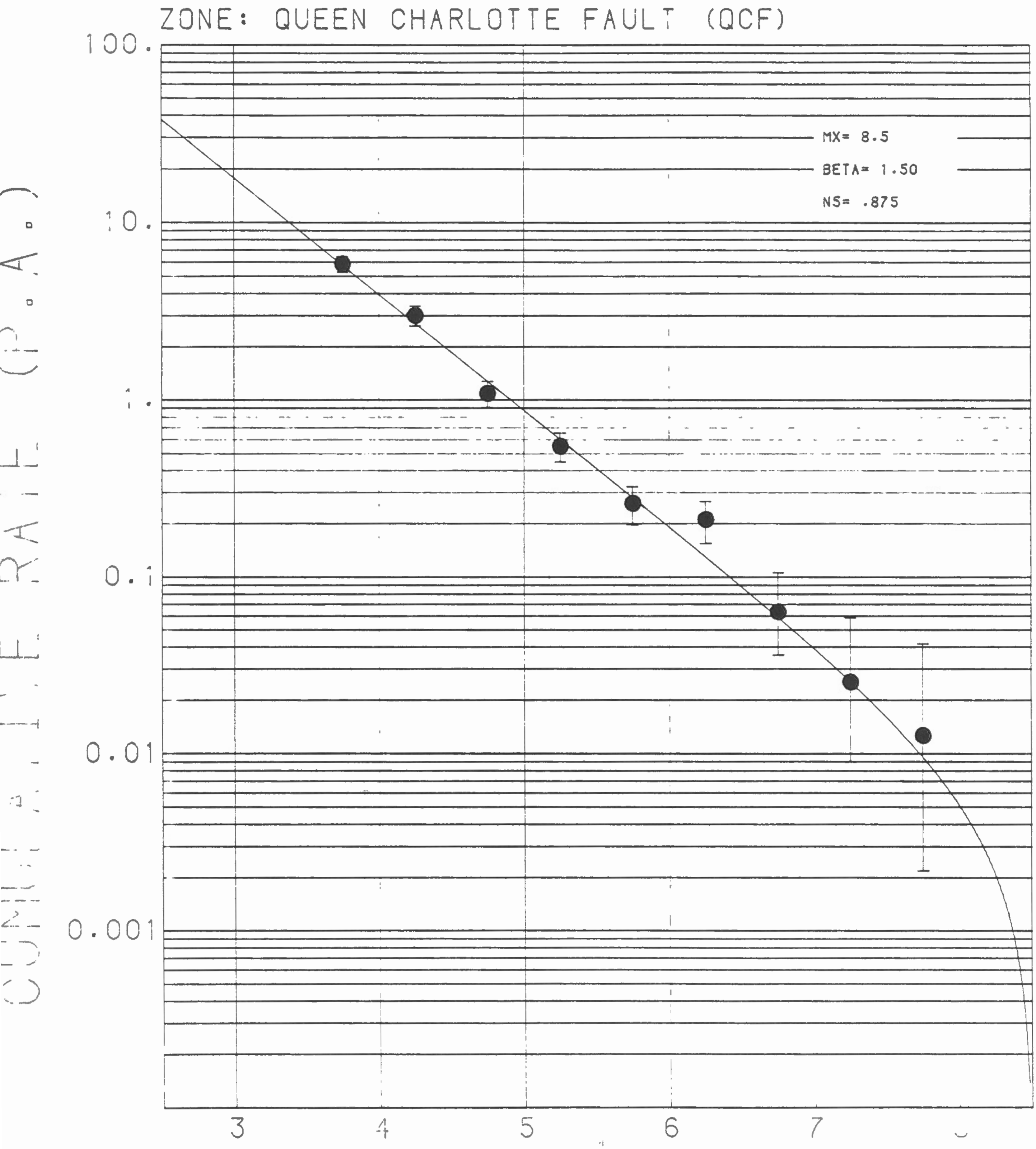
### 3.6 Queen Charlotte Fault (QCF) (Figures 16, 17)

The Queen Charlotte fault is the present transform boundary between the Pacific and North America lithospheric plates off western Canada between 52°N and 55°N. Off Queen Charlotte sound, there is a triple point with a convergence zone to the southeast and the Juan de Fuca ridge system to the southwest (Keen and Hyndman, 1979; Davis and Riddihough, 1982). The Queen Charlotte fault plate boundary has primarily right lateral, strike-slip motion with an average rate of about 55 mm per year (Atwater, 1970; Riddihough, 1977). Some convergence and underthrusting is predicted from global plate models (e.g., Minster and Jordan, 1978) and is also suggested by the shallow depression or trench and associated gravity low along the margin and by uplift over the Queen Charlotte Islands (e.g. Currie et al., 1980; Bird, 1981; Hyndman and Weichert, 1982b; Hyndman et al., 1982). The morphology and seismic profiles indicate two parallel fault scarps on the continental slope separated by a 30 km wide irregular terrace at a water depth of 2 km. The present seismic activity is concentrated on a probably vertical fault beneath the landward of the two slopes (Hyndman and Ellis, 1981).



EARTH PHYSICS BRANCH EMR OTTAWA CANADA

Figure 16



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DIRECTION DE LA PHYSIQUE DU GLOBE OTTAWA CANADA

Figure 17

The southern limit of the zone is taken as the triple point. The northern limit at 57°N, is a somewhat arbitrary division between the Queen Charlotte fault and the northern extension, the Fairweather fault system. The epicentres that fall west of the zone in Figure 16 may be mislocations of events that occurred along the fault; they are included in the zone for purposes of magnitude recurrence calculation.

The maximum magnitude selected for the Queen Charlotte Fault zone is 8.5. By integration of the magnitude recurrence relation (Figure 17), to provide an estimate of total seismic moment, Hyndman and Weichert (1983) estimate a slip rate of 52 mm per year on the Queen Charlotte fault system using a maximum magnitude of 8.5, i.e., in good agreement with the plate model estimate. From fault area considerations, this would represent a break along most of the length of the fault zone as defined in Figure 16.

### 3.7 Sandspit (SPT) (Figures 18, 19)

A number of recently active splinter faults trend generally northward to the east of the main Queen Charlotte fault zone, e.g., the Sandspit fault (Yorath and Chase, 1981; Yorath and Hyndman, 1983). Seismic profiling has revealed active grabens northeast of the Queen Charlotte Islands. The Rennell Sound-Louscoone Inlet fault is also a major fault trace. These faults could be a response to the small difference between the estimated direction of the Pacific-North America relative plate motion and the strike of the Queen Charlotte fault along the margin and the postulated very oblique underthrusting. The Sandspit zone covers these faults but does not extend as far east as the mainland coast. Its length and width are arbitrarily chosen to be the same as the Queen Charlotte Fault zone.

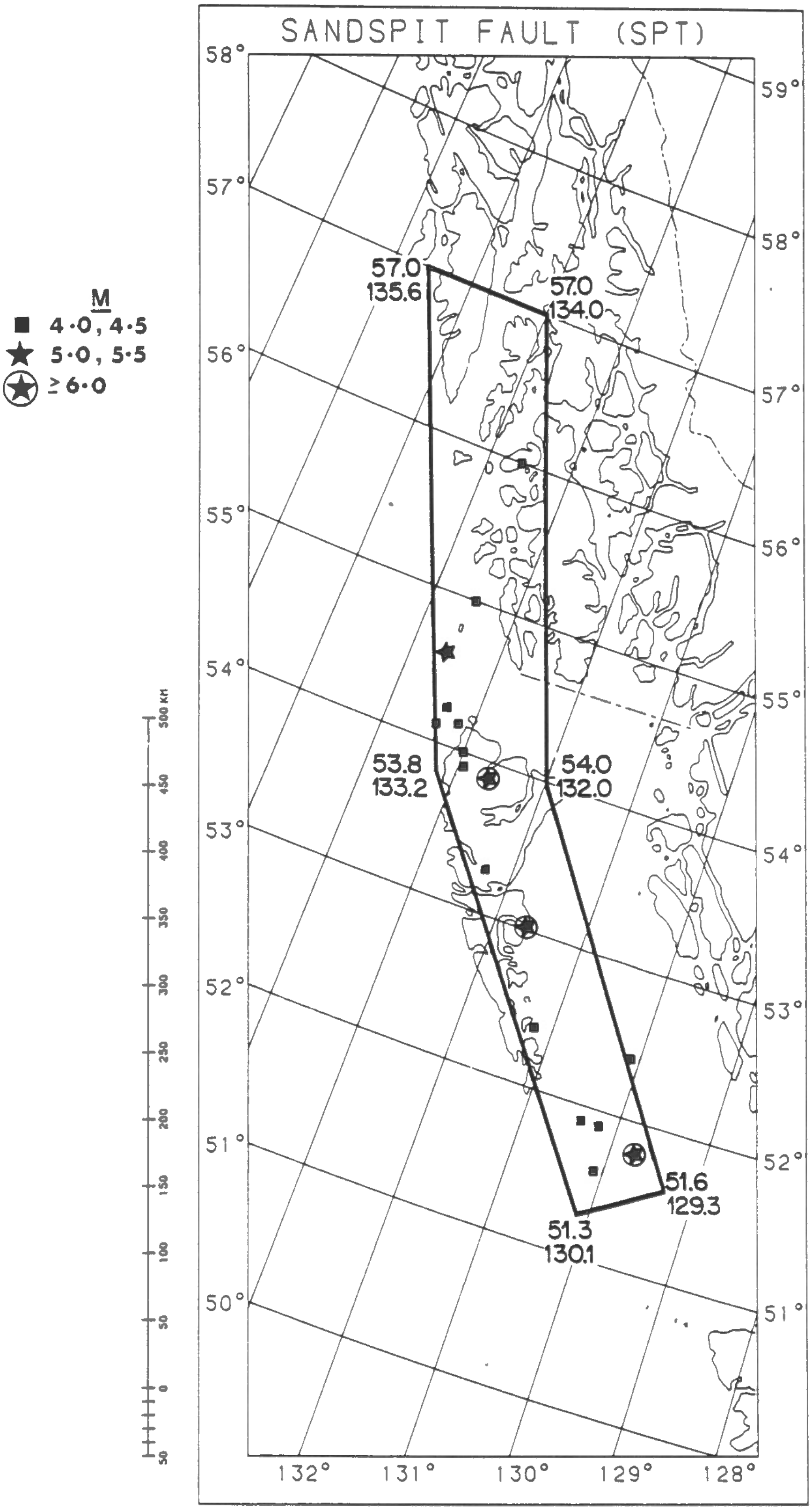

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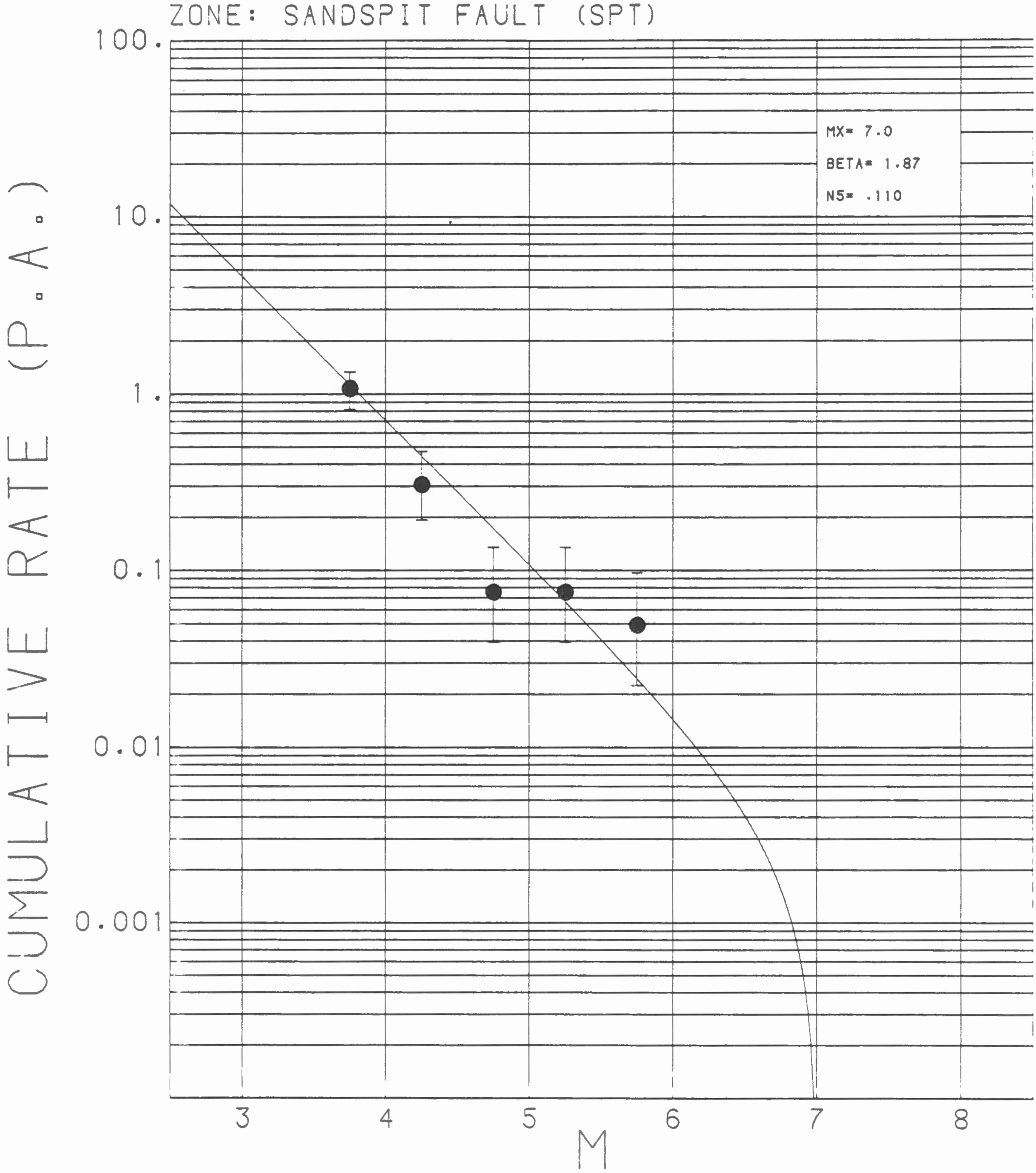
Figure 18



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DIRECTION DE LA PHYSIQUE DU GLOBE OTTAWA CANADA

Figure 19

The seismicity of the Sandspit zone proper is difficult to distinguish from apparent seismicity that may be caused by mis-location of Queen Charlotte fault earthquakes. We included only those events that are not obvious mis-locations; however, there is no certainty that all of the events actually occurred in this zone, or that there are not some mis-located Sandspit zone events included with the Queen Charlotte Fault zone seismicity.

Rogers (1982) has subsequently reviewed the older events and concluded that most of the seismicity that we have included in this zone occurred on the Queen Charlotte fault. Our source zone models were finalized prior to Rogers' work and, therefore, his revisions have not been included. The effect on the probabilistic ground motion maps are, however, negligible because the overwhelmingly dominant source zone in this region is the Queen Charlotte fault. There have also been recent (1982) earthquakes located in the Sandspit zone and east of it in Hecate Strait, so the Sandspit zone has been retained.

### 3.8 Southeastern B.C. (SBC) (Figures 20, 21)

All of the interior of B.C. could be considered a typical background zone. However, the differences in detection completeness between north and south and an apparent higher seismicity in the south are reasons for considering a separate southeastern zone. In the Rocky Mountain part of the zone the high topography may reflect higher than average stress, but tectonically the Rocky Mountain area is probably not related to the Intermountain seismic belt to the south. A hot spot trace similar to, but weaker than the Yellowstone hot spot, may traverse British Columbia west to east with the youngest rock ages lying near the 1918 magnitude 6 earthquake north of Revelstoke (Rogers and Ellis, 1979; Rogers et al., 1980; Rogers, 1981). We consider this centre of activity not yet sufficiently well defined

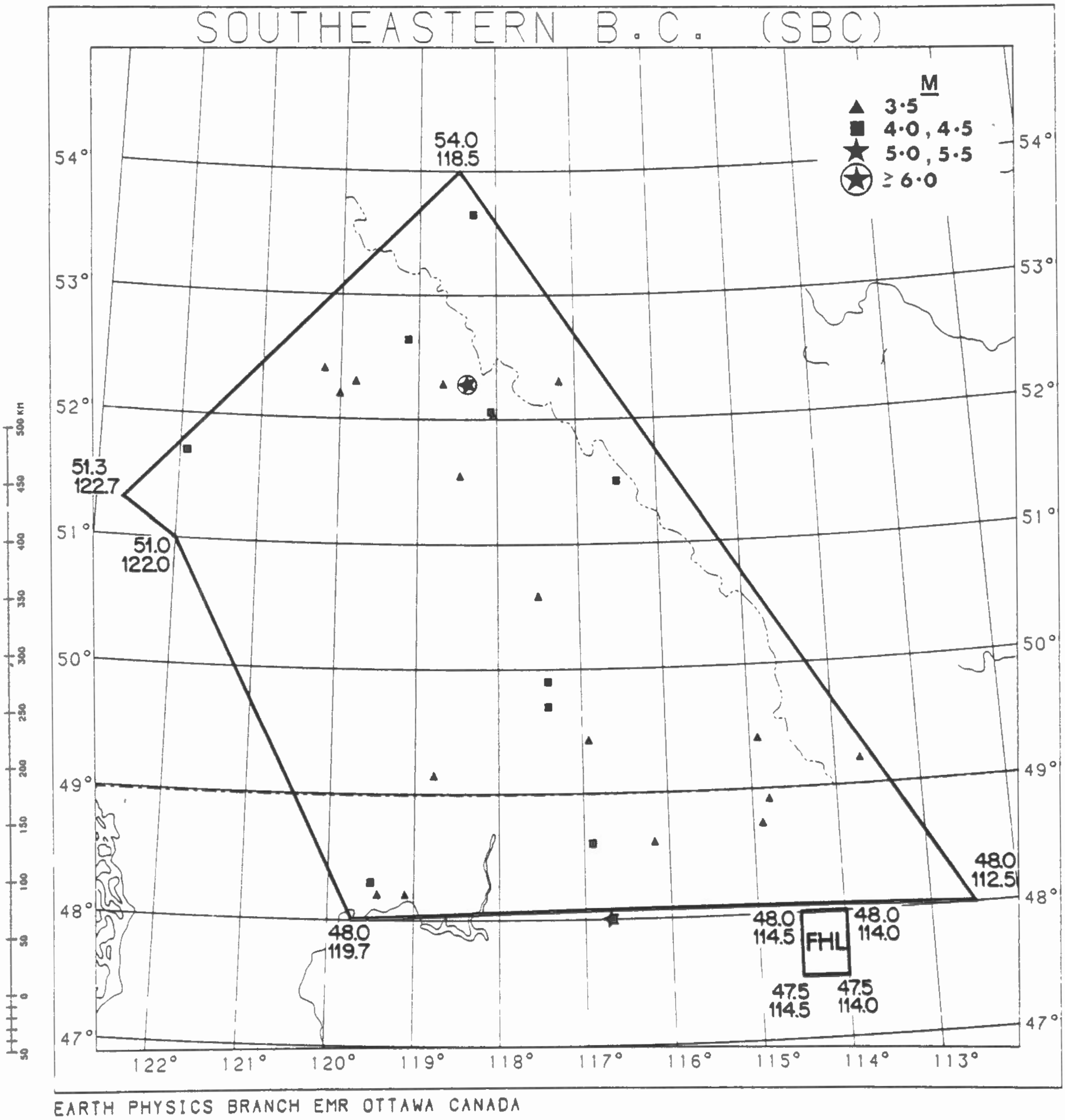

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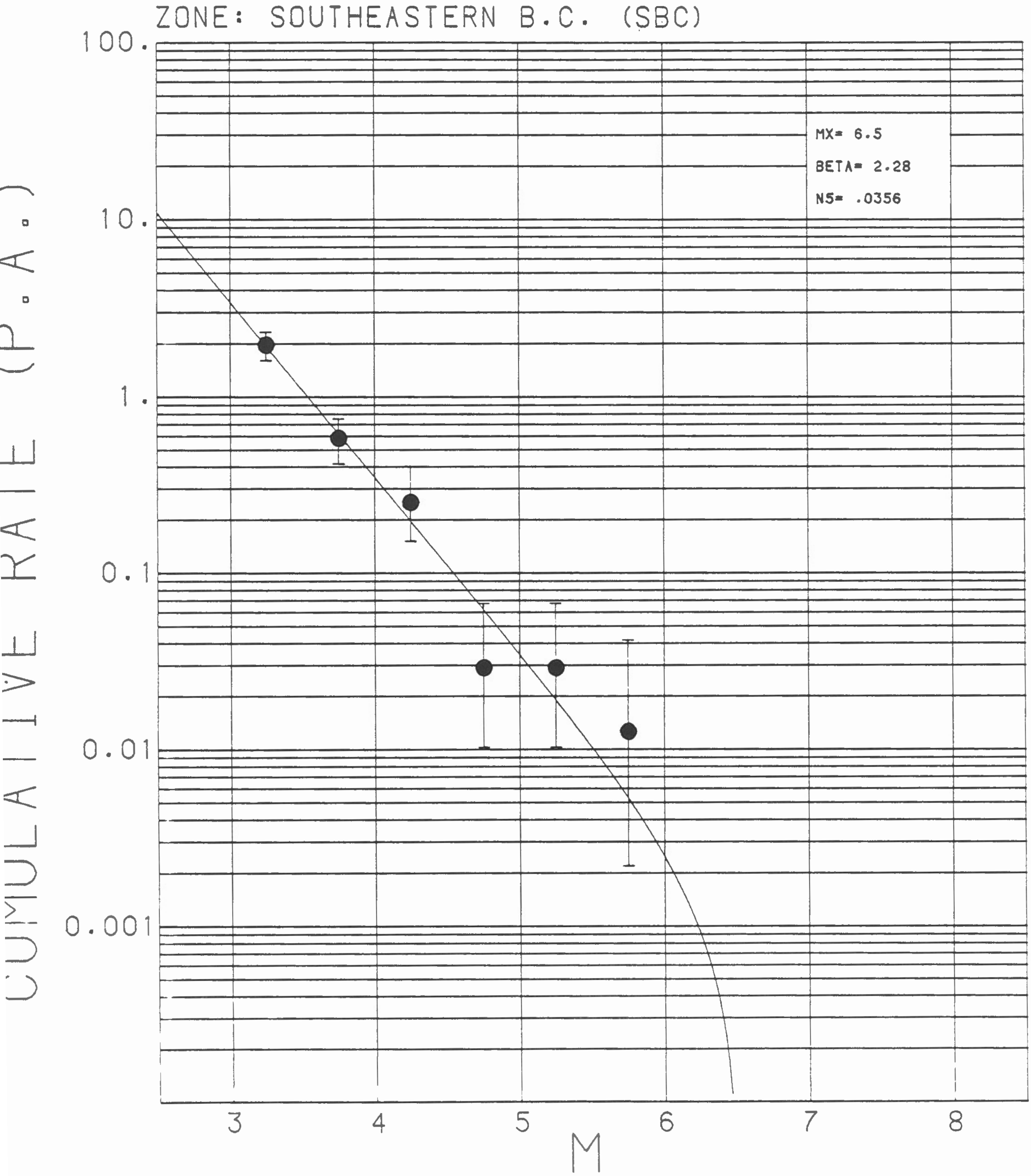
Figure 20



EARTH PHYSICS BRANCH EMR OTTAWA CANADA
DIRECTION DE LA PHYSIQUE DU GLOBE OTTAWA CANADA

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Figure 21

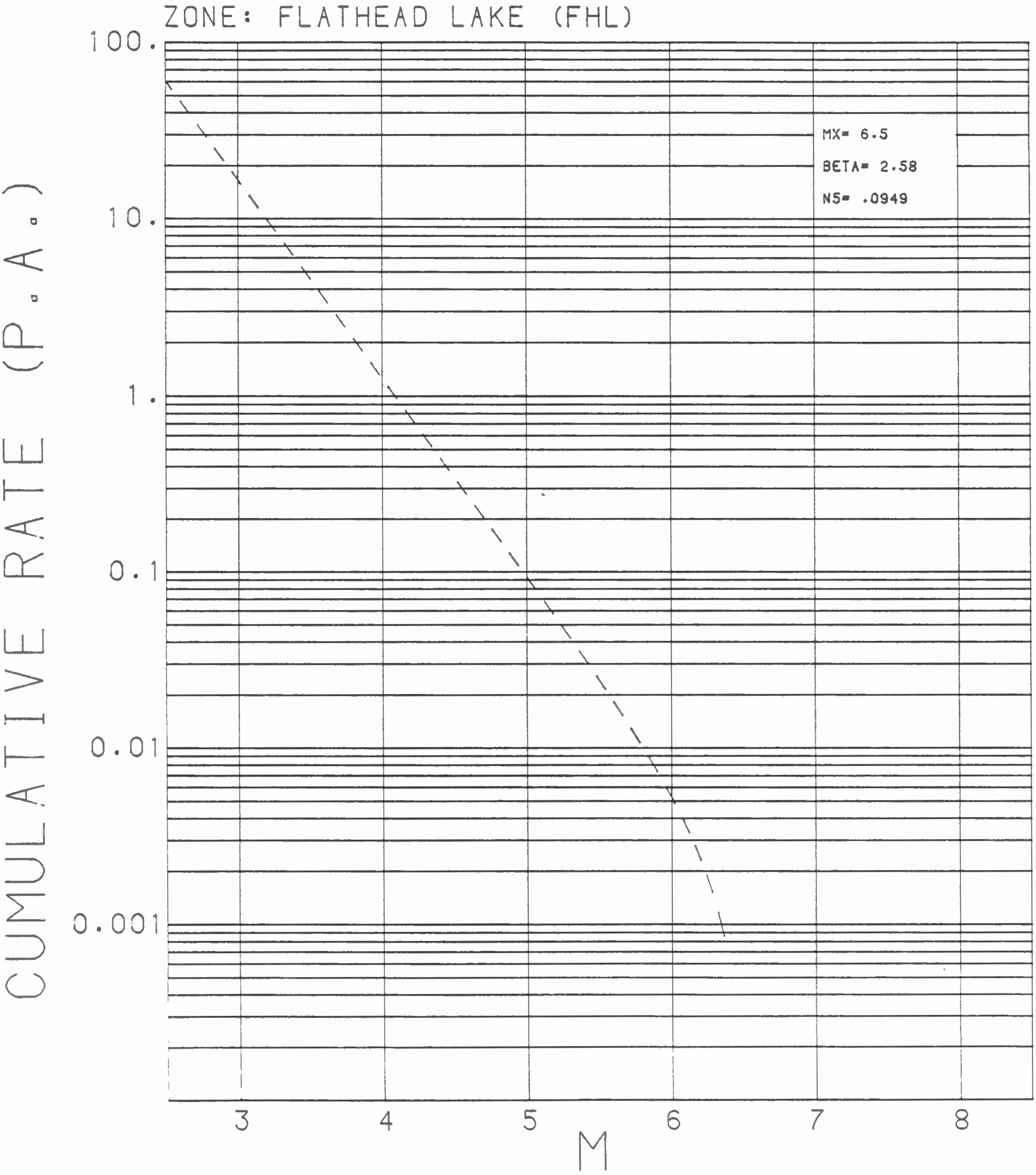
to justify a separate zone. The changing epicentral pattern in the 1960s and 1970s is evidence against the notion of a quiet zone between the Rockies and the Cascades zone. The west-central portion of the zone as displayed in Figure 20 is devoid of earthquakes, but this region has experienced earthquakes as large as M 4 that do not pass the completeness criterion for inclusion here.

### 3.9 Flat Head Lake (FHL) (Figures 20, 22)

This zone is part of the Intermontane Seismic Belt, extending north-south in west-central United States as far north as Flathead Lake, Montana. The belt has been interpreted as a boundary within the main North America lithospheric plate. Two subplates are moving apart producing rift faulting (e.g. Smith and Sbar, 1974). The seismic activity is characterized by shallow focal depths and swarm activity. The nearest concentration to Canada is near 48°N at Flathead Lake, and we consider this to be the only significant contribution to Canadian seismic risk. We have modelled the source with a small area (shown on Figure 20 with the Southeastern B.C. zone) with activity scaled to match source 27 of Algermissen and Perkins (1976). Instead of their maximum magnitude of 5.5, we have adopted 6.5, which is still about 1/2 unit smaller than the maximum observed in the Intermontane seismic belt (i.e. Hebgen Lake, 1959). The resulting magnitude recurrence curve is shown in Figure 22.

### 3.10 Northern B.C. (NBC) (Figures 23, 24)

This is a zone of very low seismicity that includes the northern B.C. Cordillera. It has been extended into the Yukon to include the region between



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DIRECTION DE LA PHYSIQUE DU GLOBE OTTAWA CANADA

Figure 22

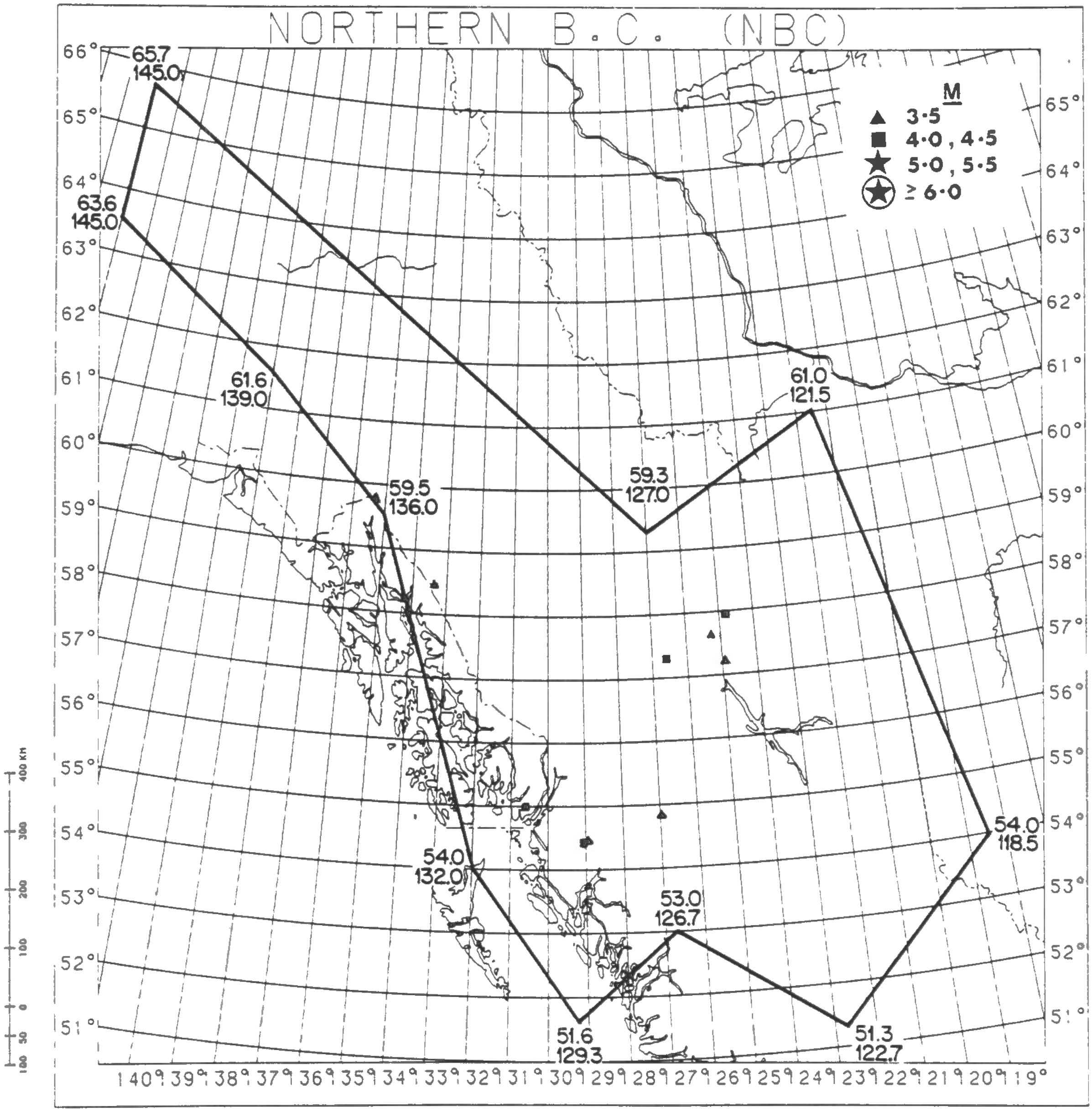

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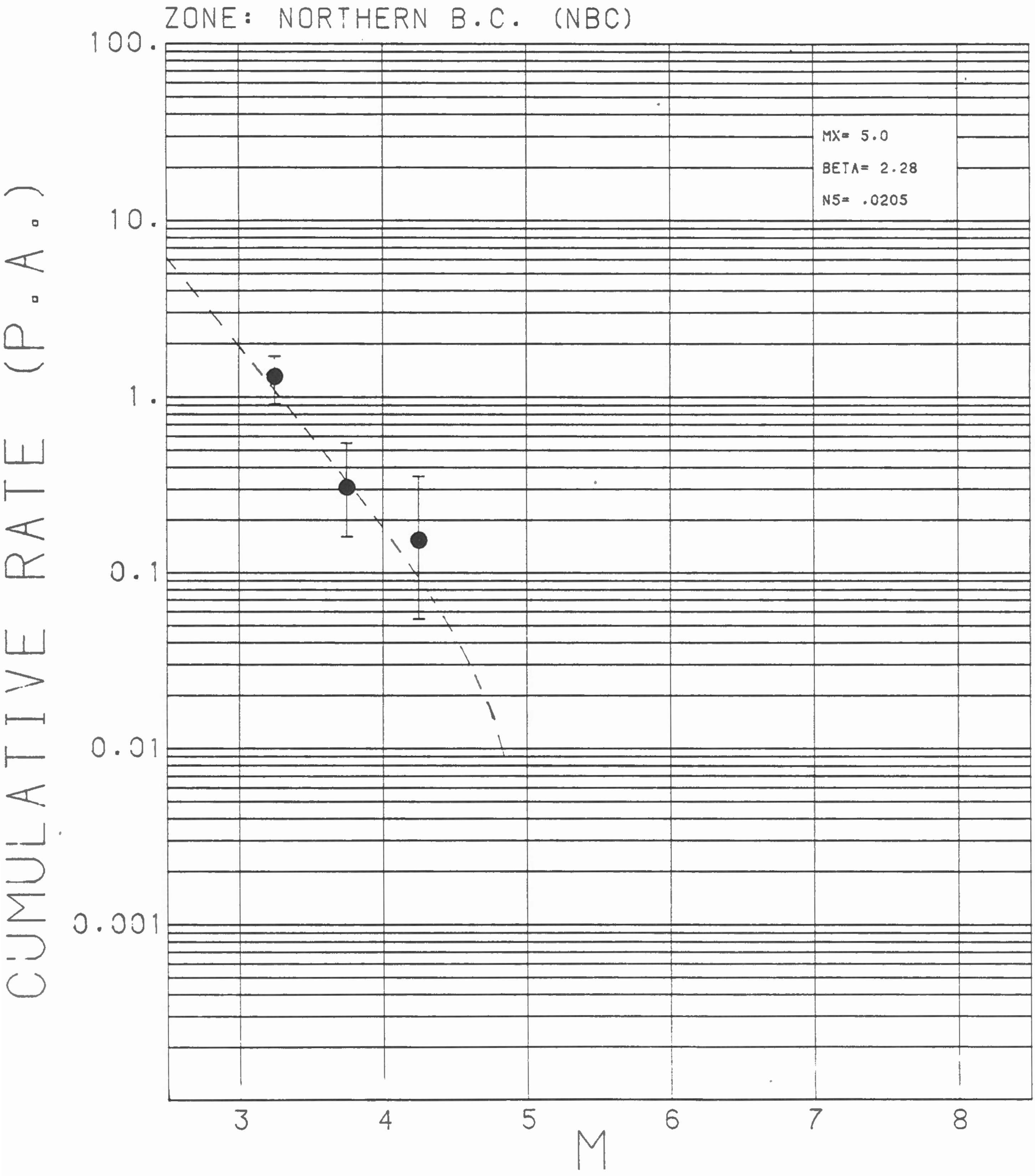
Figure 23



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DIRECTION DE LA PHYSIQUE DU GLOBE OTTAWA CANADA

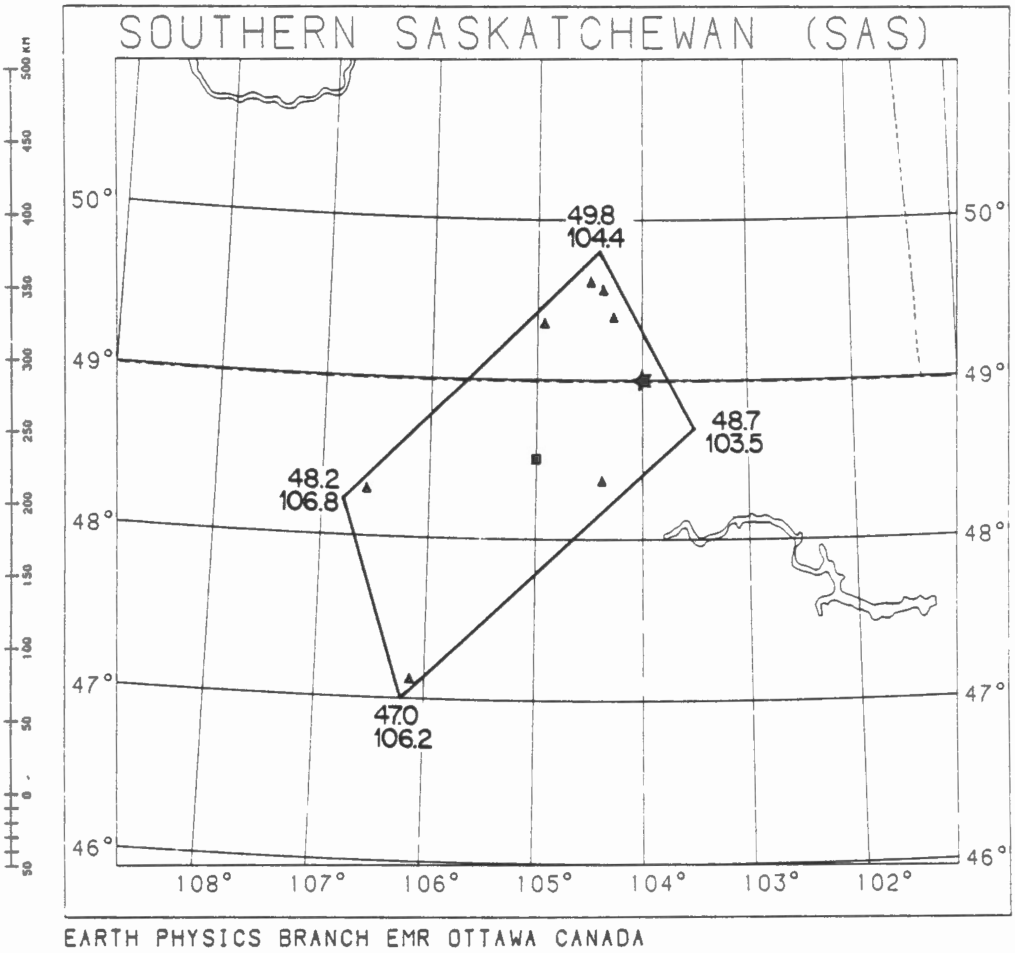
Figure 24

the Shakwak Valley and the Tintina Trench (see Section 3.3). The detection threshold at low magnitudes in this zone has been poor until very recently. (Three new regional stations were installed in 1981.) However there are no known events as large as magnitude 5, which would have been detected since at least the early 1960's. Tectonically, this zone cannot be considered to be much different from southeastern B.C., and the magnitude recurrence slope for the later zone has been imposed on the meagre data base to produce the recurrence relation shown in Figure 24. The maximum magnitude has been set at 5.0, one-half unit above the observed maximum. However, with the low earthquake rates in a relatively large zone its contribution to the probabilistic ground motion will be small.

### 3.11 Southern Saskatchewan (SAS) Figures 25, 26)

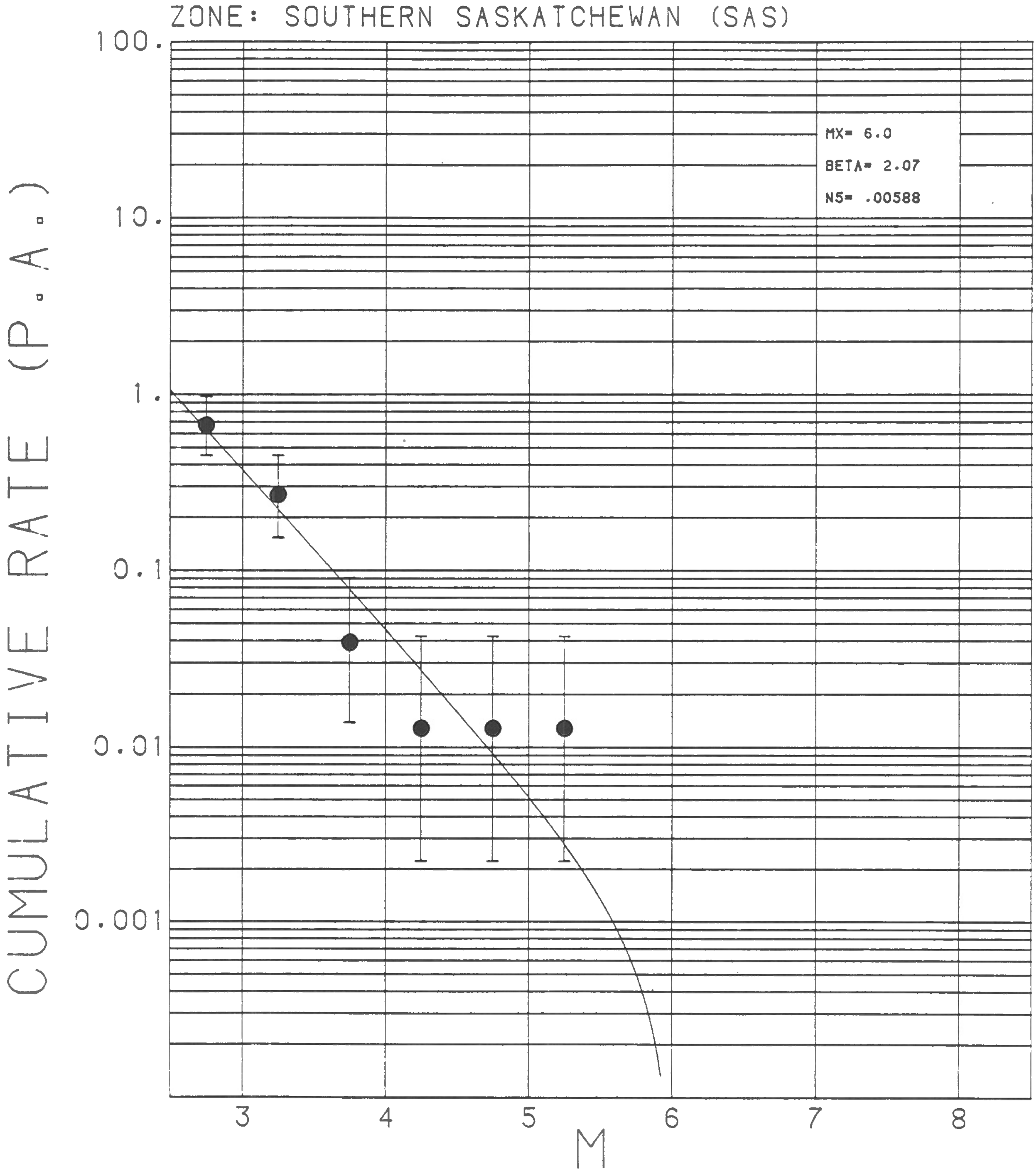
This source zone has been drawn to encompass the cluster of seismicity in southern Saskatchewan and adjacent Montana and North Dakota (Horner and Hasegawa, 1978). The main cluster of earthquakes, including the M 5.5 event in 1909, is spatially associated with the Williston Basin, but the zone is extended to the southwest in Montana to include magnitude 3-4 earthquakes that occurred in the 1969-1973 time period. The location of the 1909 earthquake is not well known, but the location of 49°N, 104°W was selected by Horner and Hasegawa (1978) as the centre of the area of maximum intensity.

There is good evidence (Horner et al., 1973; McLennan et al., 1983) that the earthquakes included in the Southern Saskatchewan source zone are tectonic events in the Precambrian basement. There is also evidence (Gendzwill et al., 1982) of earthquakes as large as M 3.5 as far north as central Saskatchewan being induced by potash mining activity. These induced events have produced



**M**
▲ 3·0 , 3·5
■ 4·0 , 4·5
★ 5·0 , 5·5
⍟ ≥ 6·0

Figure 25



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DIRECTION DE LA PHYSIQUE DU GLOBE OTTAWA CANADA

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Figure 26

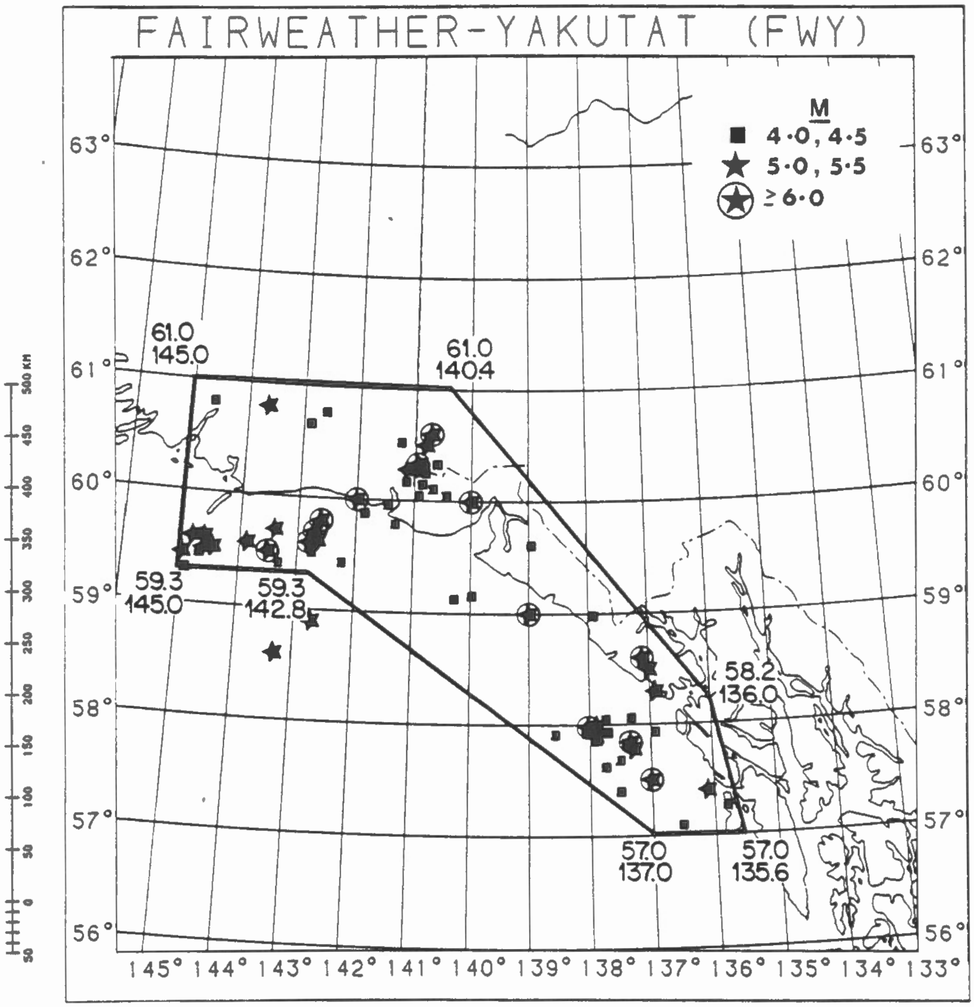
moderate seismic shaking, but they cannot be included in a general model of earthquake sources because regions of similar potash mining in future are not known.

The maximum magnitude chosen is 6.0, half a unit larger than the 1909 earthquake, but the adopted recurrence relation is poorly defined (Figure 26). This source zone contributes a small region of peak acceleration greater than the minimum level contoured (Figure 2), but does not contribute significantly to peak velocity (Figure 3).

### 3.12 Fairweather-Yakutat (FWY) (Figures 27, 28).

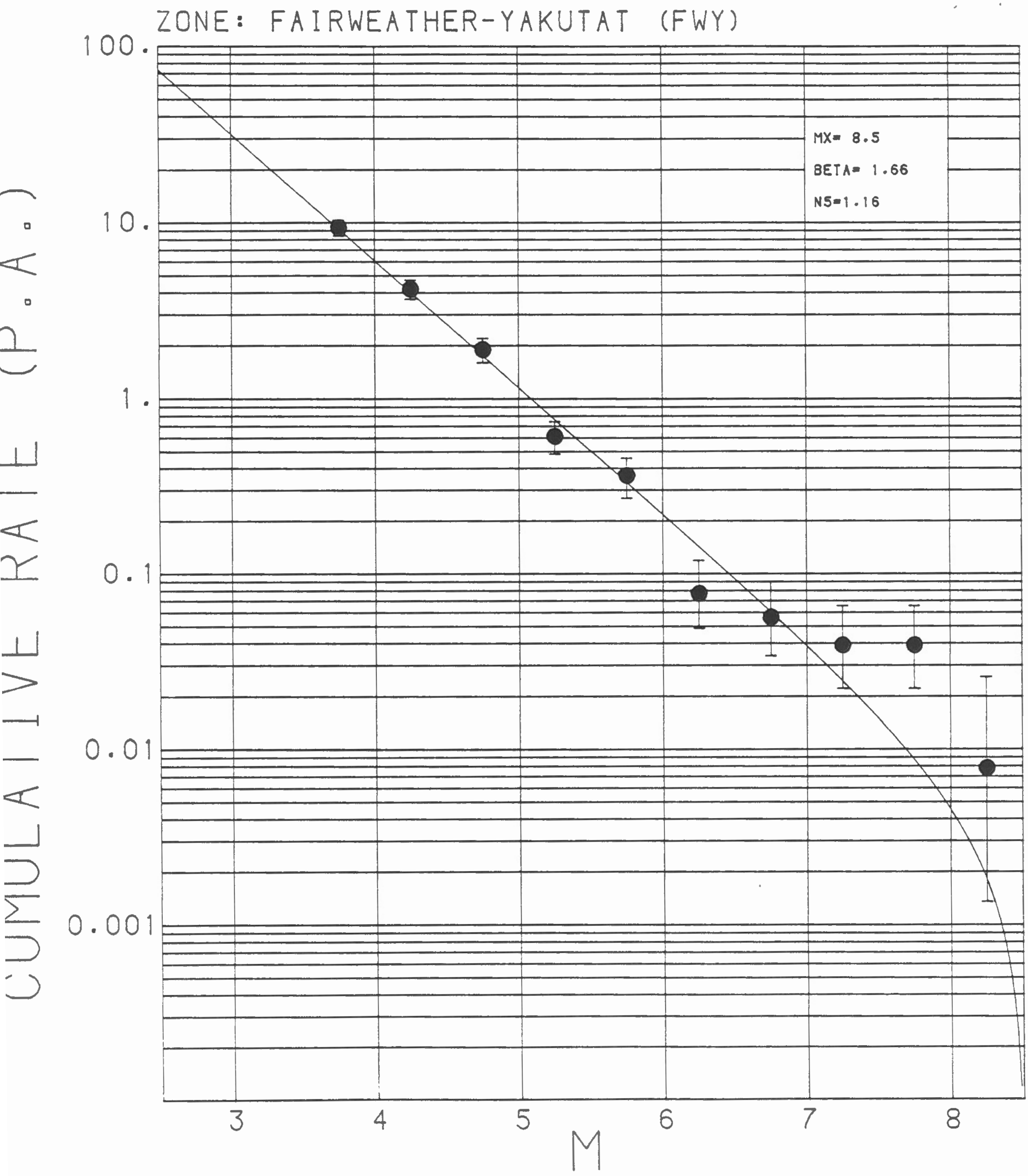
The region of transitional tectonics, from transcurrent faulting along the coast of British Columbia and southeastern Alaska to subduction along the Aleutian Island arc (e.g., Perez and Jacob, 1980; von Heune et al., 1979) is modelled here as one continuous, simplified zone (Figure 27). The southern boundary at 57°N is the approximate location of the transition from the Queen Charlotte Fault offshore to the Fairweather Fault onshore in southeastern Alaska. The northeastern and northern boundaries are drawn to include in the zone the large earthquakes of the strike-slip Fairweather and underthrusting Chugach - St. Elias Faults, respectively. The western boundary is somewhat arbitrary, but it is drawn at 145°W which is the easternmost extent of the rupture zone of the great Alaska earthquake of 1964 and, in the offshore, is the approximate location of the beginning of the Aleutian Trench. (The seismicity to the west is modelled as separate zones described below.) The southern boundary is drawn along the shelf edge structure to include in the zone the seismicity of the Yakutat Block.

This source zone includes the series of large (magnitude 8) earthquakes



EARTH PHYSICS BRANCH EMR OTTAWA CANADA

Figure 27



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DIRECTION DE LA PHYSIQUE DU GLOBE OTTAWA CANADA

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Figure 28

which ruptured the coast between Yakutat Bay and Kayak Island at the turn of the century, and the magnitude 7.9 on the Fairweather fault in 1958. The inclusion of the turn-of-the-century earthquakes for the magnitude recurrence estimates seems to produce too high a rate for the larger earthquakes compared to a well defined relation for events less than magnitude 7 (Figure 28). To partially reduce this effect the completeness date for earthquakes of magnitude 7.5 and greater has been extended back to 1850 (Table 1), even though we don't believe there has been complete reporting of even these larger events since that date. The reduction of the starting year to 1850 simply imposes an assumption that no large earthquakes occurred in the zone between 1850 and 1899.

On the other hand, this region has been identified as a seismic gap. Sykes (1971) identified a gap between the aftershock zone of the 1964 Prince William Sound and the 1958 Fairweather Fault earthquakes. Lahr et al. (1980) demonstrated that this gap was only partially filled by the 1979 St. Elias earthquake. If the Pacific and North American plates have been converging at the rate of 5 cm/yr since the turn of the century, enough elastic strain has accumulated to produce a potential slip of 4 m. If this amount of slip occurred in one earthquake, it would generate an event as large as magnitude 8 that would likely fill the remainder of the gap (Lahr and Plafker, 1980).

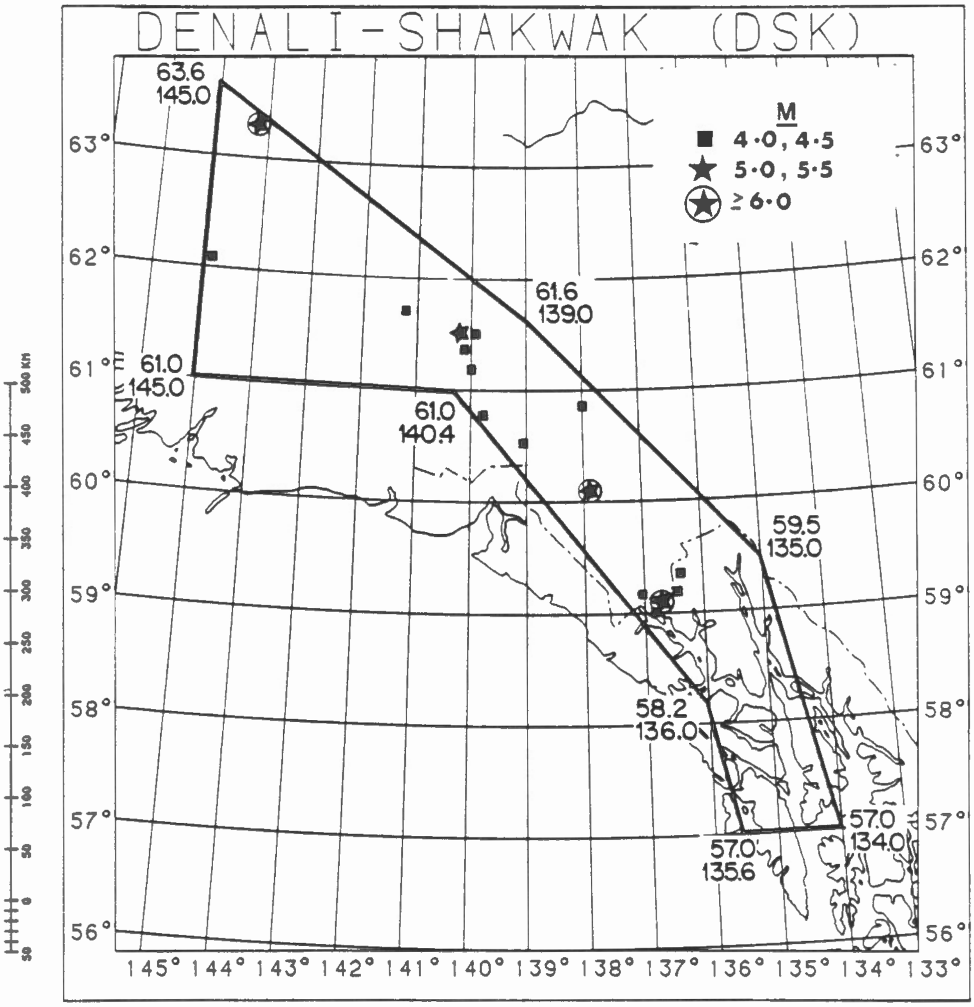
The influence of potential seismic gaps is not included in this probabilistic analysis. It is sufficient to note here that the seismic ground motion on Canadian territory in the southwestern Yukon (we are not attempting to predict ground motion on U.S. territory in which most of this zone is located) at moderate probabilities is dominated by the large earthquakes in the zone (see Figure 28). In essence, the analysis includes the effects of a gap-filling earthquake, because the model assumes that an earthquake near the maximum magnitude can occur with equal probability anywhere in the zone.

A maximum magnitude of 8.5 has been used for his zone, on grounds similar to those described above for the Queen Charlotte Fault zone. However, in this case the largest earthquake could be either primarily strike-slip on the Fairweather fault system, or primarily underthrusting on the Chugach-St. Elias fault system.

### 3.13 Denali-Shakwak (DSK) (Figures 29, 30)

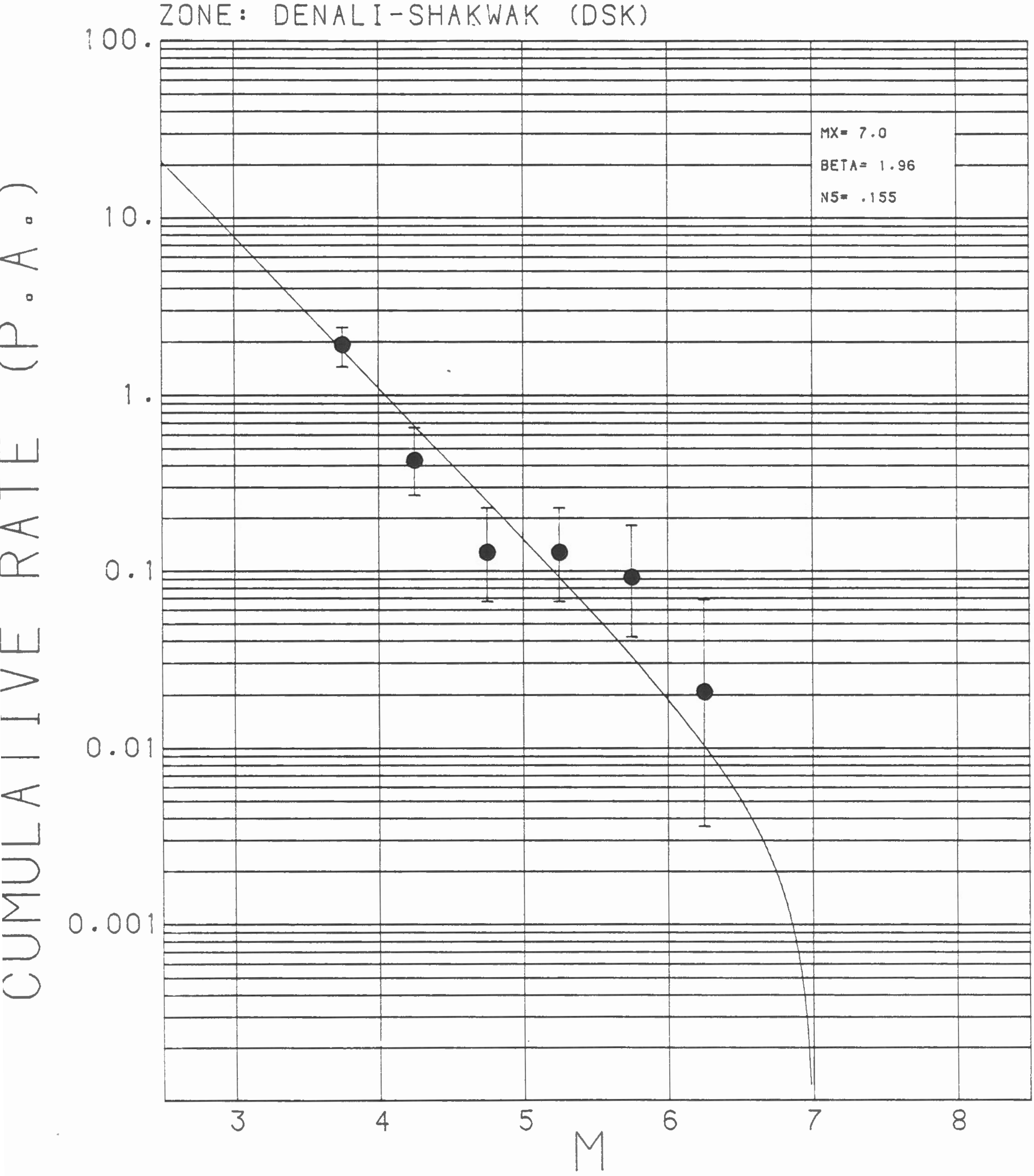
This zone includes the seismicity between the Fairweather-Yakutat zone and the Denali-Shakwak-Dalton fault system. Its northeast edge includes this fault system, but the area further northeast to the Tintina Trench is relatively aseismic and has been included with the Northern B.C. zone described above. The easternmost boundary is drawn to include the inferred faulting along Chatham Strait (see, e.g., Figure 1 in Perez and Jacob (1980)), although recent results (Horner, 1983) have shown Chatham Strait to be essentially aseismic at low levels, with the seismicity trending southward toward the coast through the region of Glacier Bay. As with the Fairweather-Yakutat zone, the western boundary is selected as 145°W, with the seismicity further west in Alaska included in separate zones described below.

Horner (1983) has shown that both the larger historical events and the low level seismicity in recent years is quite restricted, west of the Alaska-Yukon border, to a narrow zone following the Duke River, Shakwak and Dalton Fault zones, i.e., the seismicity is likely confined to a narrower zone along known faults than the source zone employed here (Figure 29). The largest known historic event was magnitude 6.5 in 1944 near Haines Junction.



EARTH PHYSICS BRANCH EMR OTTAWA CANADA

Figure 29



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DIRECTION DE LA PHYSIQUE DU GLOBE OTTAWA CANADA Figure 30

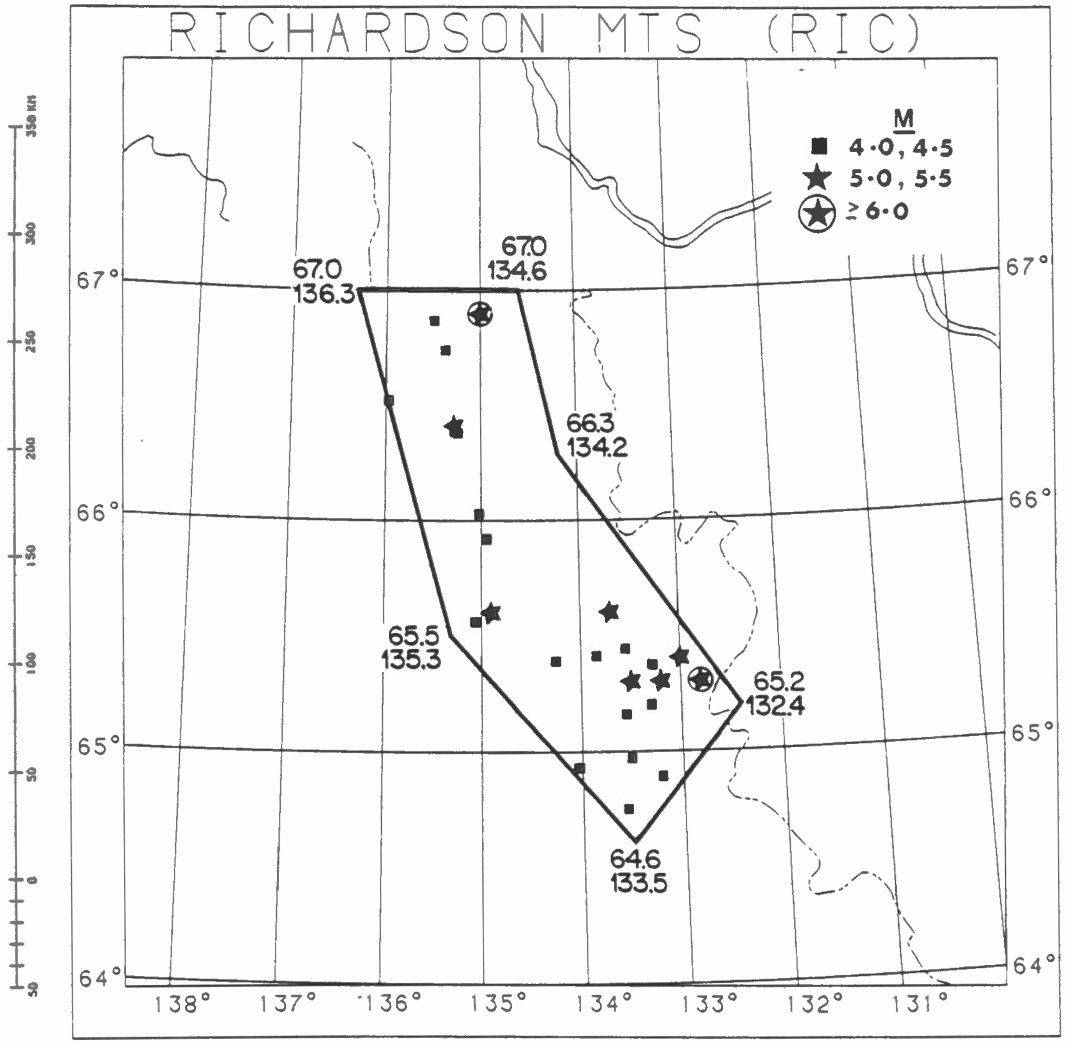
The upper-bound magnitude of 7.0 selected for this zone carries the assumption that larger events typical of major plate interactions in the Fairweather-Yakutat zone will not occur. However, the tectonics of the zone, which must bear some relation to the plate interactions along the margin of the Gulf of Alaska, is not well-understood.

### 3.14 Richardson Mountains (RIC) (Figures 31, 32)

This zone is a relatively confined, but highly active region of the northeastern Yukon. Recent reassessment of the locations of the larger pre-1966 events has enabled the dominant seismicity to be enclosed by a zone about 80 by 250 km (Figure 31). There is evidence, however, (Leblanc and Wetmiller, 1974) that the zone may be made up of two clusters, one which is centred in the Richardson Mountains and another in the Mackenzie Mountains, with a relatively quiet region between the two in the area of the Bonnet Plume Basin.

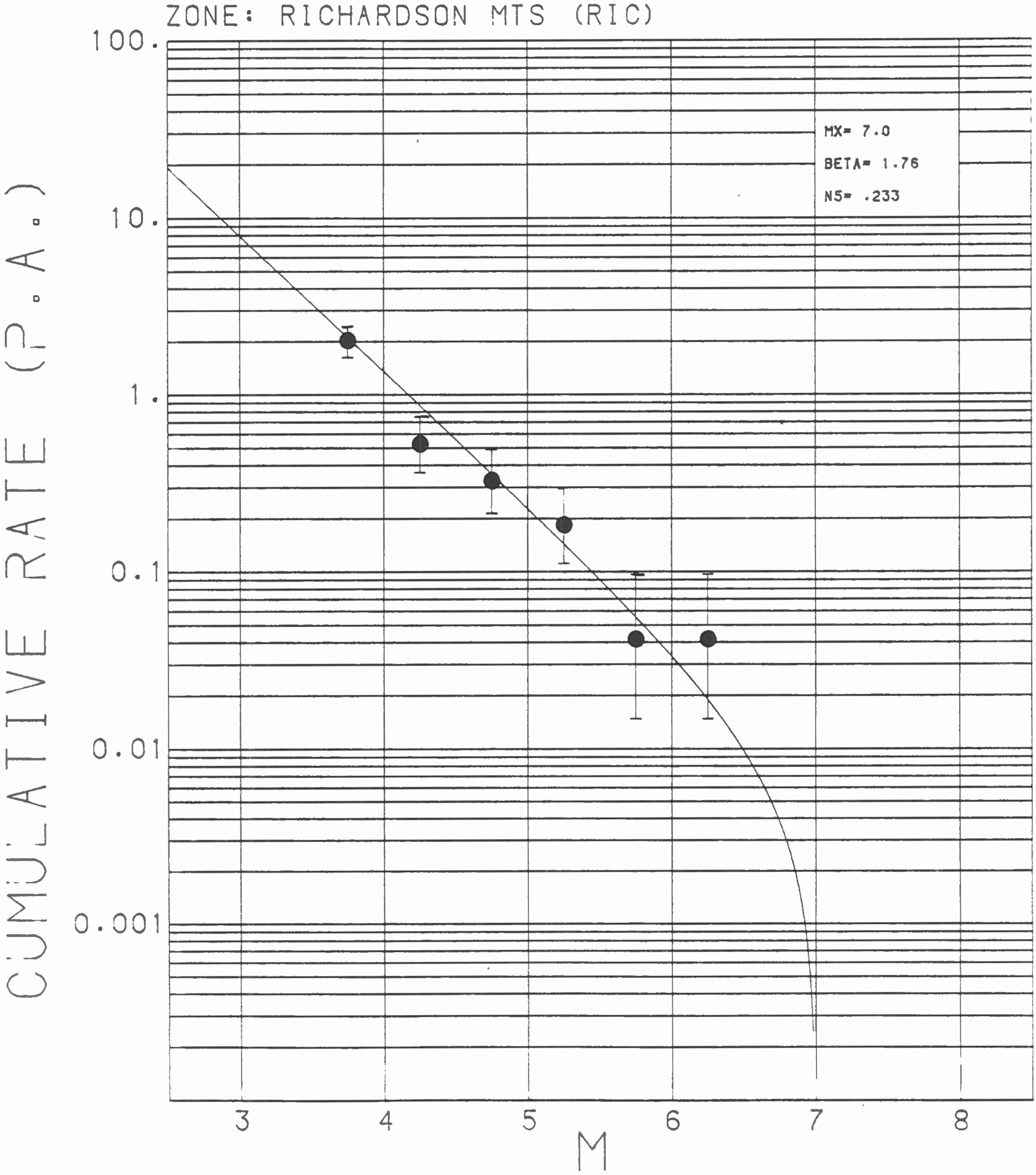
The tectonic process responsible for this cluster of seismicity, and any relationships between it and major plate interactions in the Gulf of Alaska or the opening of the Arctic Ocean basin are not yet understood. The only evidence to associate seismicity with local geological features (Norris, 1972) is given by Leblanc and Wetmiller (1974). They show a spatial correlation of low level activity detected in a 1972 field experiment with mapped extensional and transcurrent faults. A single, but poorly controlled, P-nodal solution for a magnitude 4.8 earthquake shows right-lateral motion on a nearly vertical fault with the same strike as the mapped faults.

The largest known historic event was magnitude 6.6 in 1955; the upper-bound magnitude is selected as 7.0.



EARTH PHYSICS BRANCH EMR OTTAWA CANADA

Figure 31



EARTH PHYSICS BRANCH EMR OTTAWA CANADA 29/10/81 10.21.08.

DIRECTION DE LA PHYSIQUE DU GLOBE OTTAWA CANADA

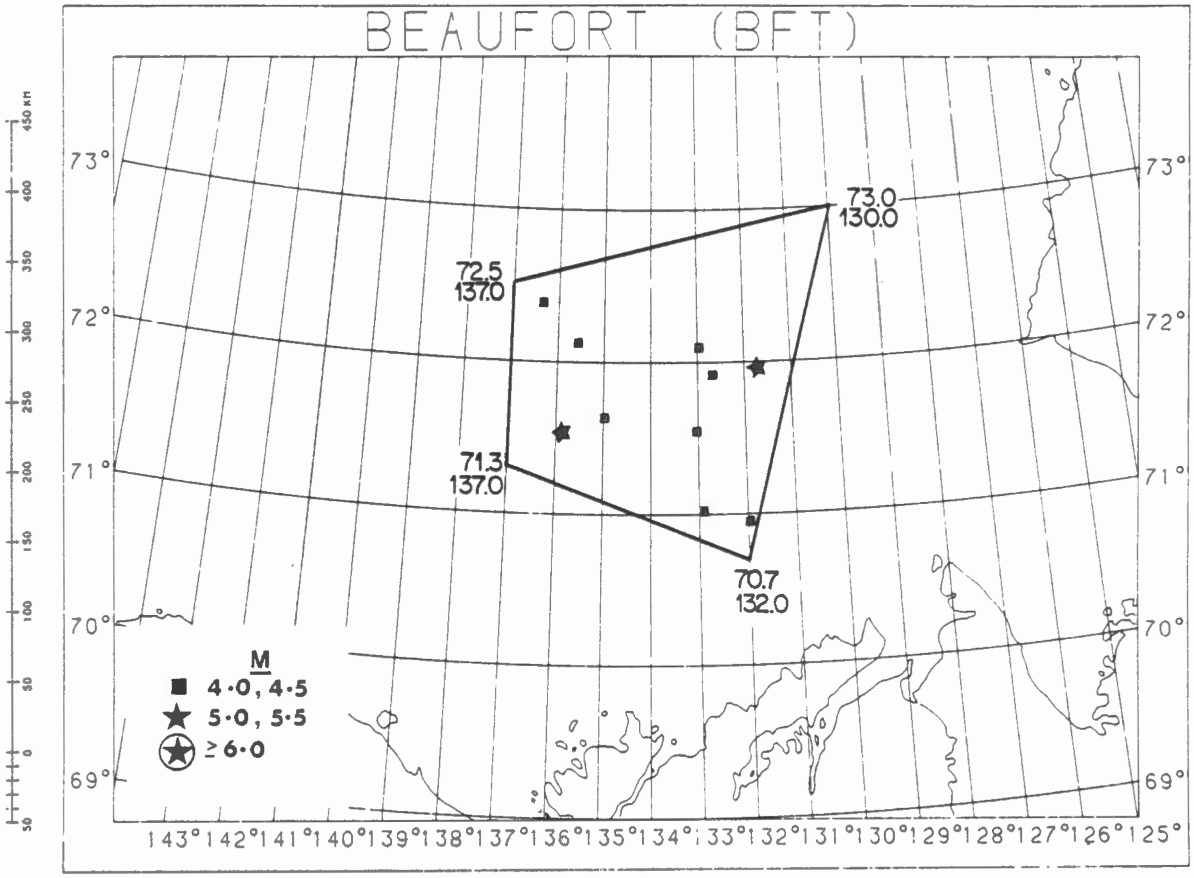
Figure 32

### 3.15 Beaufort Sea (BFT) (Figures 33, 34)

The cluster of seismicity in the Beaufort Sea is another example of relatively confined cluster with poorly-understood tectonic cause. The zone boundaries in Figure 33 have been drawn to enclose the distribution of activity that has been shown by joint-epicentre solutions (Hasegawa et al., 1979) to be real, and not due to mislocations of previously catalogued earthquakes. The largest historic event, magnitude about 6.5 in 1920, does not pass the test for completeness, set at 1930, and so is not included in Figure 33 or Appendix A. However, the northeastern corner of the zone has been drawn to enclose the best available location for this event derived by Basham et al. (1977).

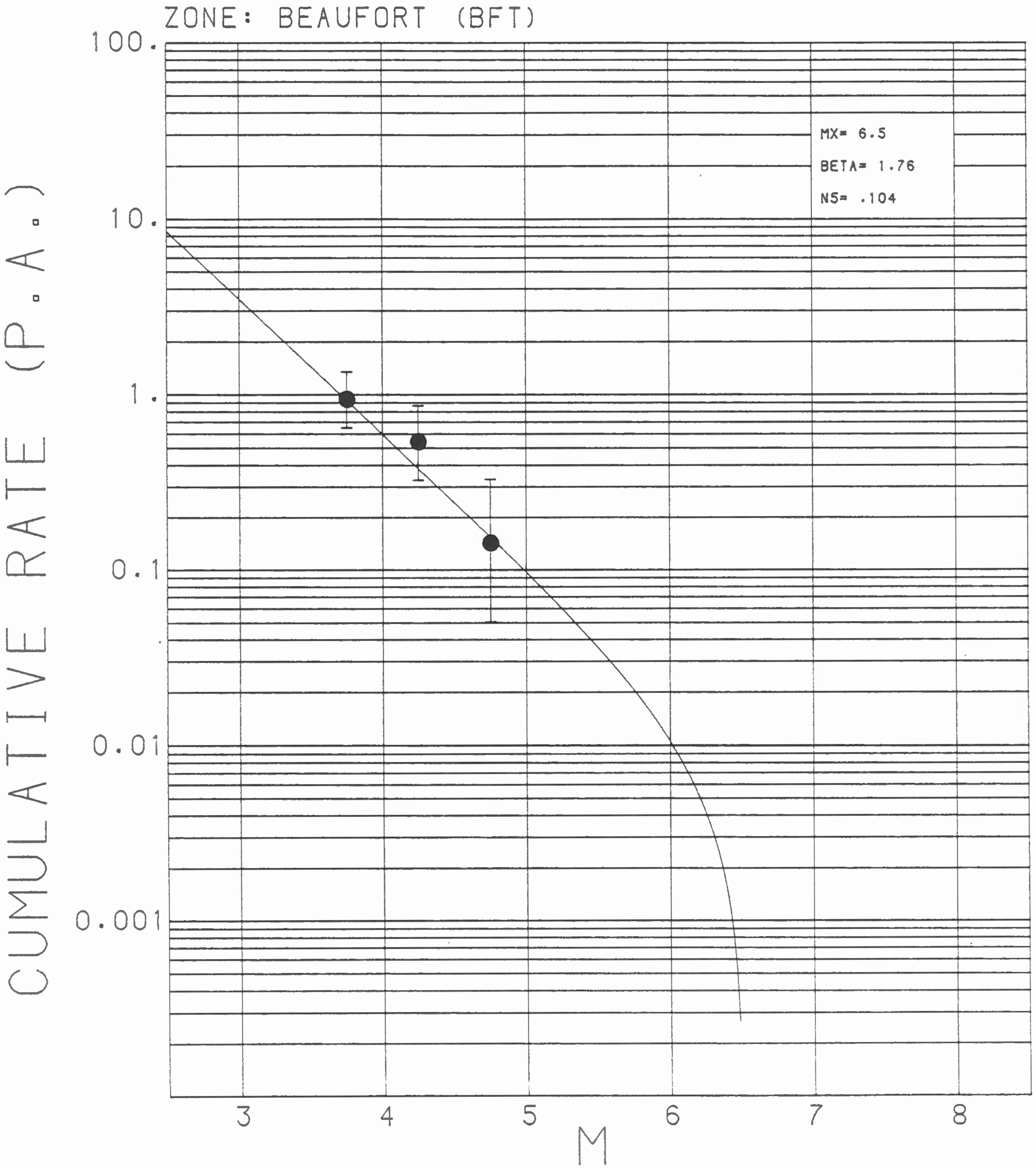
The earthquakes are confined to the region beneath the continental slope, between the 200 and 2400 m bathymetry contours, and fall between the seaward -20 mGal and landward +40 mGal contours of an elliptically shaped free-air gravity anomaly. Hasegawa et al. (1979) derived focal parameters for a 1975, magnitude 5.1 earthquake which suggested strike-slip motion on a steeply dipping fault plane at a depth of 40 km. The depth is unusual, as it may place the earthquake in the upper mantle beneath the continental margin. It is supported, however, by the hypothesis of high horizontal deviatoric stresses due to an uncompensated load of Quaternary sediments, which would produce maximum stress at approximately this depth. This, or some other stress, is acting on unhealed faults at, at least, lower crustal depths to produce the cluster of Beaufort Sea seismicity, but there is no geological or geophysical evidence to determine the real nature of the faulting beneath the continental slope.

There is only the one known earthquake in 1920 with magnitude of about 6



EARTH PHYSICS BRANCH EMR OTTAWA CANADA

Figure 33



EARTH PHYSICS BRANCH EMR OTTAWA CANADA 05/10/81 14.44.59.

DIRECTION DE LA PHYSIQUE DU GLOBE OTTAWA CANADA

Figure 34

and two with magnitude 5, in 1937 and 1975. The upper-bound magnitude has been set at 6.5, but the rates of the larger earthquakes and the maximum magnitude must be considered rather poorly defined (Figure 34).

### 3.16 Mackenzie (MKZ) (Figures 35, 36)

This is a zone of "background" seismicity in the western Yukon Cordillera, surrounding the active Richardson Mountains zone and abutting the Beaufort Sea zone. It is bounded on the southwest by the Tintina Trench, on the southeast by the physiographic limit of the Cordillera in the region of the Liard River, and on the northeast by the Mackenzie River.

The seismicity includes the swarm of earthquakes off Martin Point, Alaska, with magnitudes as large as 5.3, most of which occurred in 1968, and scattered events east of the Mackenzie Delta and throughout the Yukon-Northwest Territories border region. Basham et al. (1977; their Figure 11) suggest that this seismicity, like that in the Richardson Mountains zone, is spatially correlated with the areas of most severe geologically mapped faulting.

The upper-bound magnitude has been set a 6.0 but, even though there is a relatively large number of earthquakes in the zone, the rates of the larger events is poorly defined (Figure 36).

### 3.17 Alaska (ALC, ALI) (Figures 37, 38, 39)

Thenhaus et al. (1979) have defined 24 separate earthquake source zones for purposes of estimating probabilistic seismic ground motion in the region of Alaska and the adjacent continental shelves. For our purpose, of estimating the contributions of Alaskan earthquakes to seismic ground motion

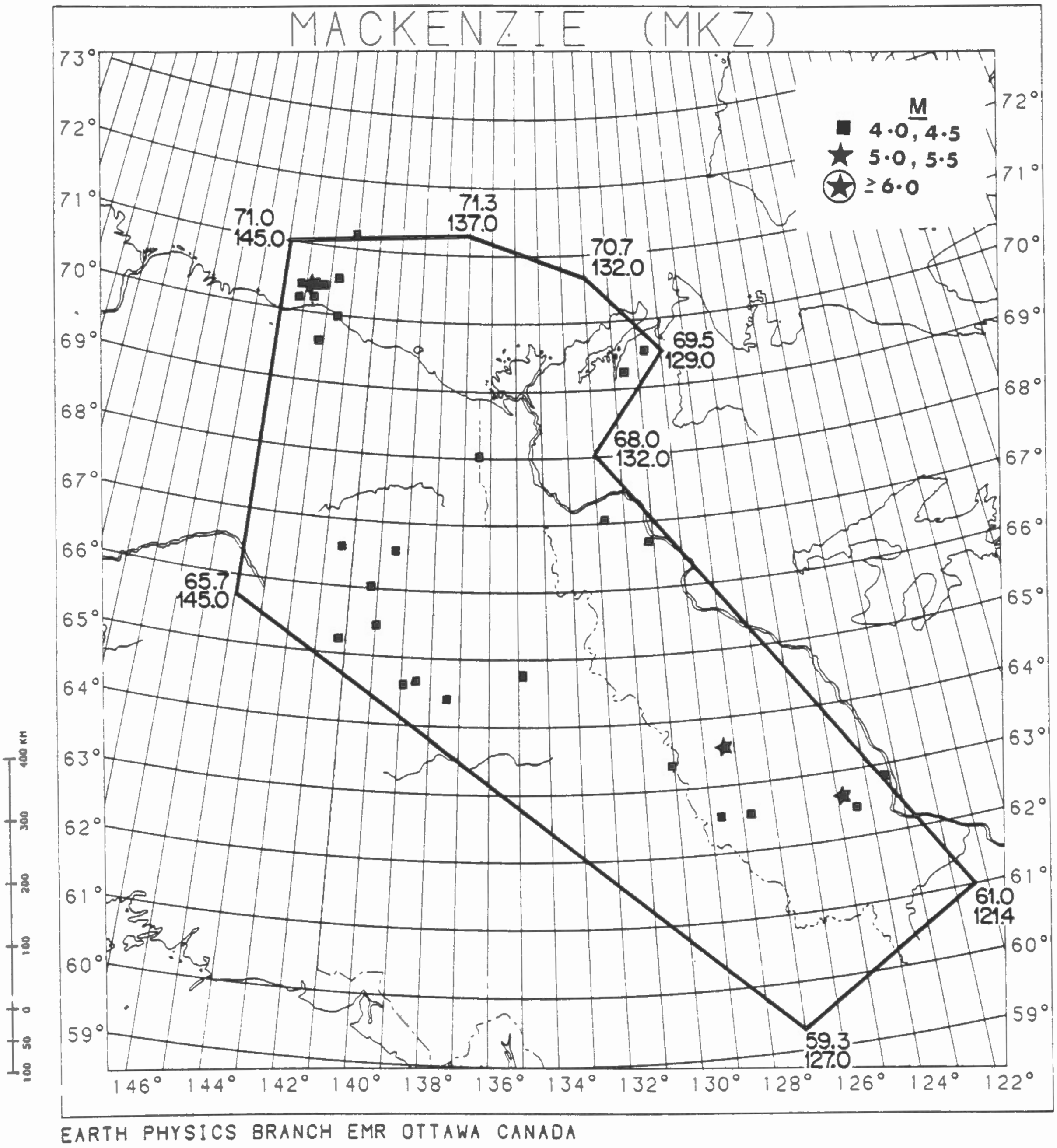
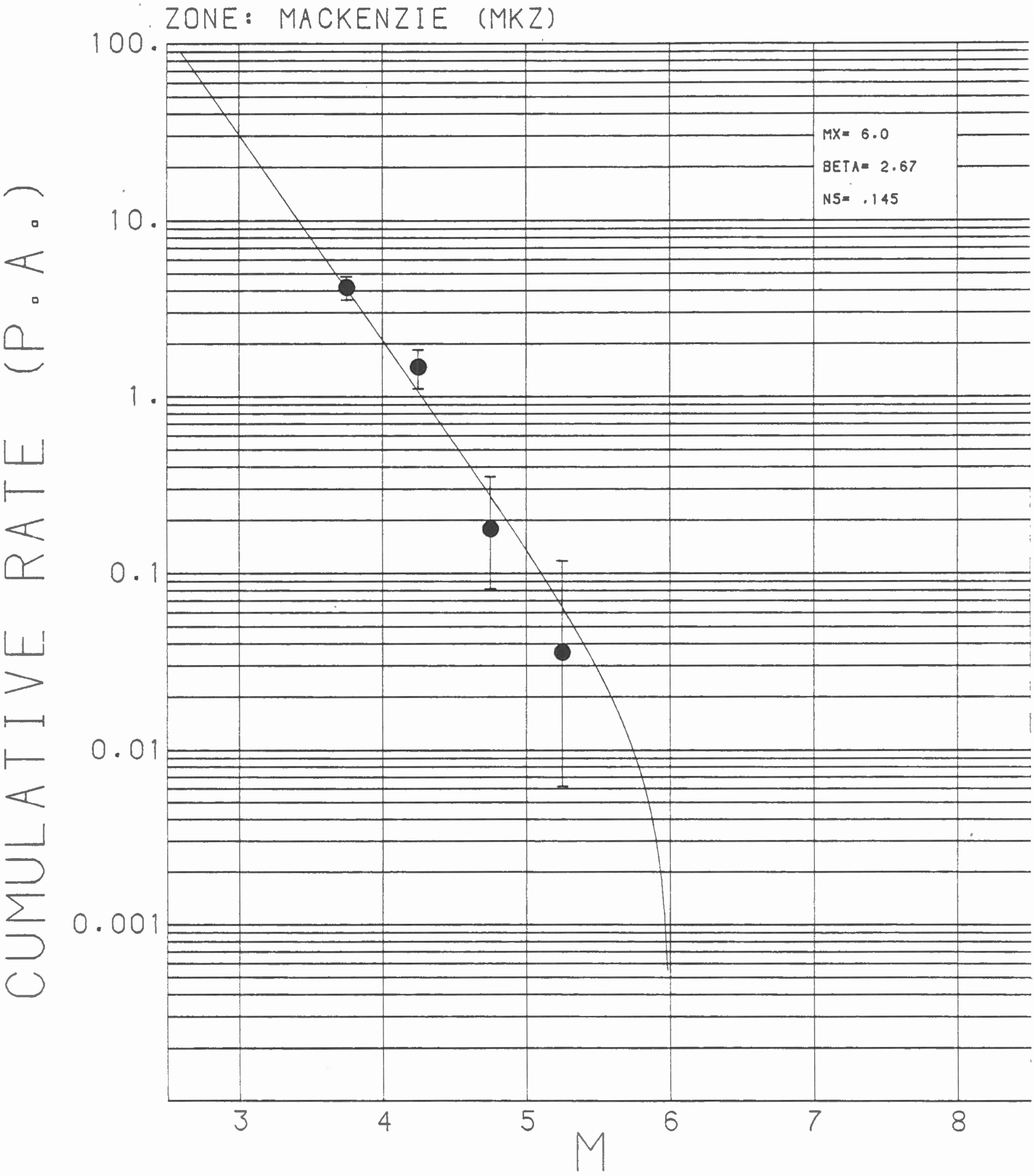

MACKENZIE (MKZ)
M
■ 4·0, 4·5
★ 5·0, 5·5
≥ 6·0
71.0 145.0
71.3 137.0
70.7 132.0
69.5 129.0
68.0 132.0
65.7 145.0
61.0 121.4
59.3 127.0
73°
72°
71°
70°
69°
68°
67°
66°
65°
64°
63°
62°
61°
60°
59°
146°
144°
142°
140°
138°
136°
134°
132°
130°
128°
126°
124°
122°
100
50
0
100
200
300
400 KM
EARTH PHYSICS BRANCH EMR OTTAWA CANADA

Figure 35



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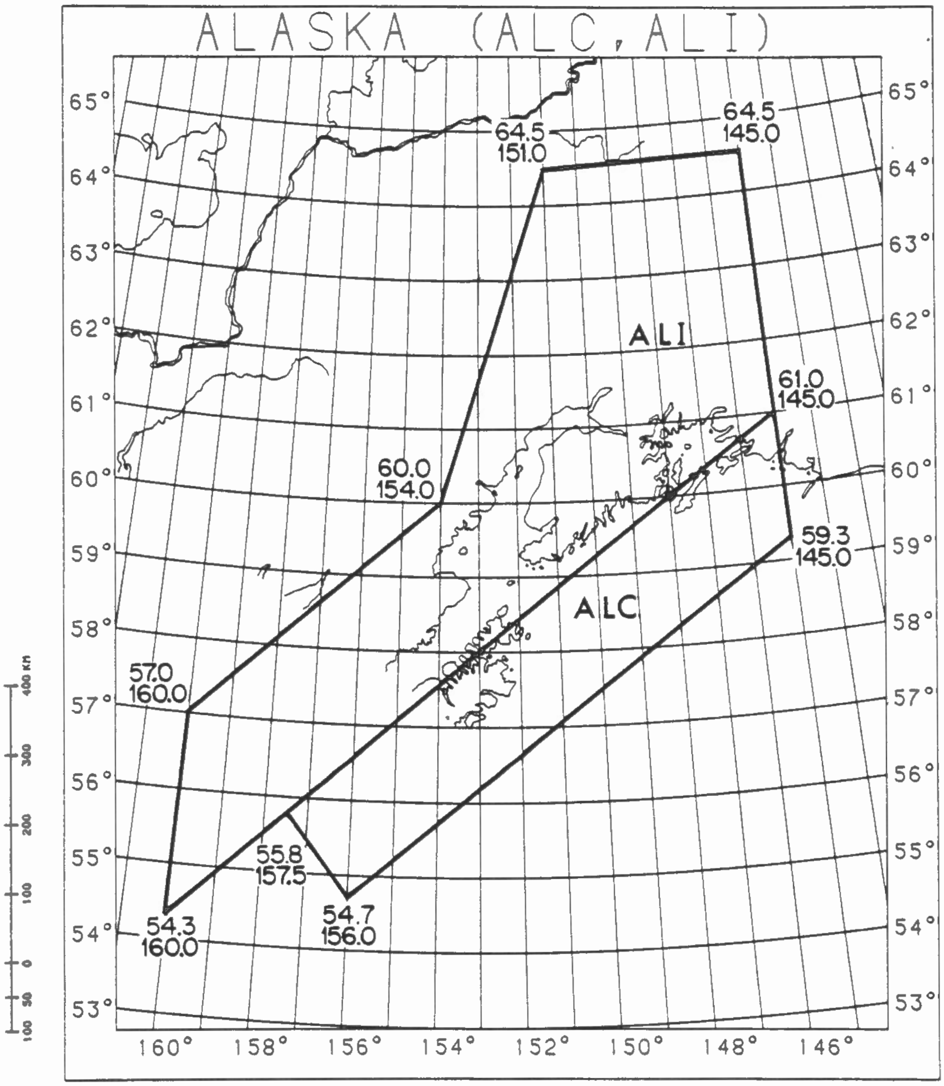
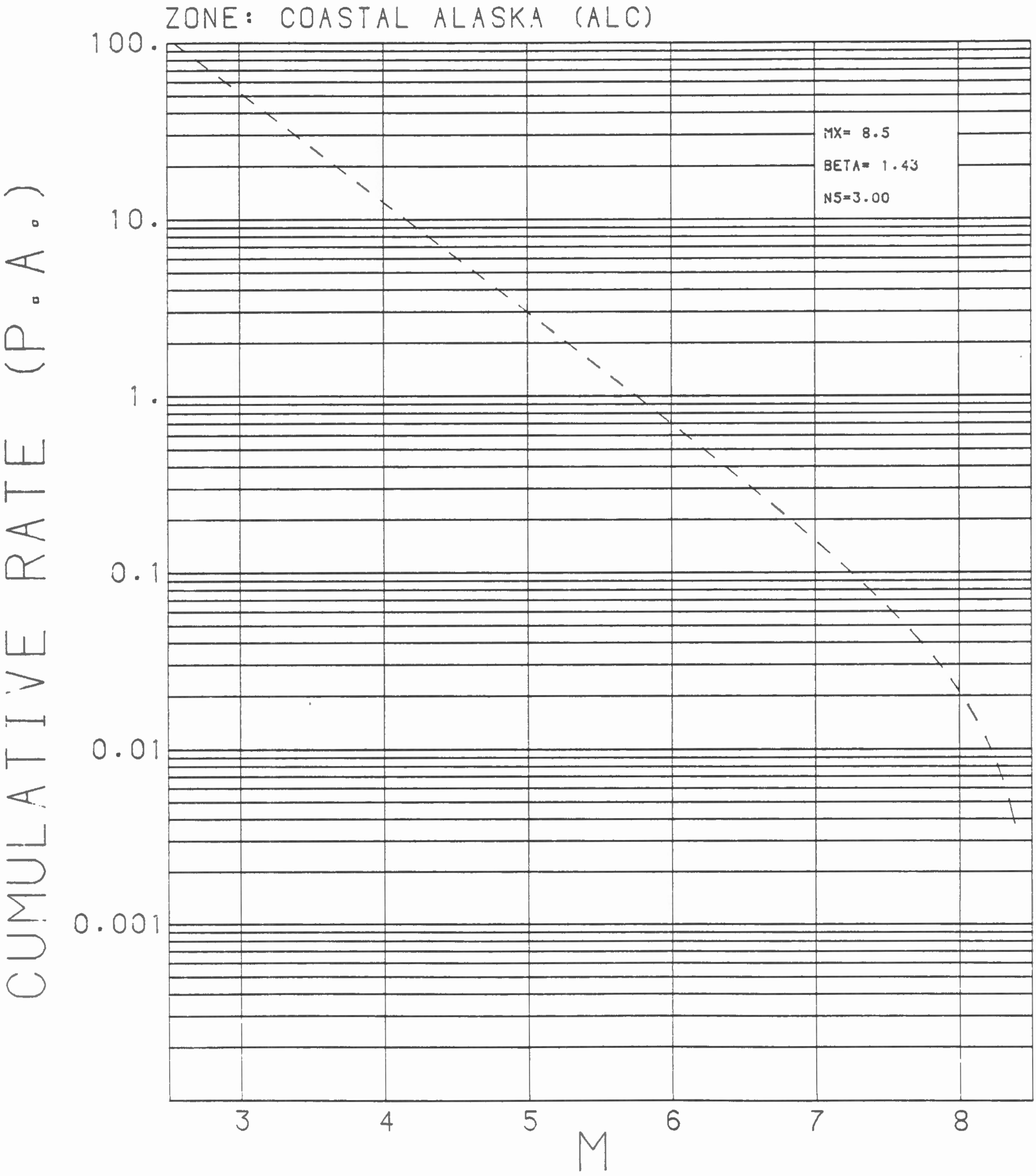
DIRECTION DE LA PHYSIQUE DU GLOBE OTTAWA CANADA Figure 36



EARTH PHYSICS BRANCH
DIRECTION DE LA PHYSIQUE DU GLOBE EMR OTTAWA CANADA

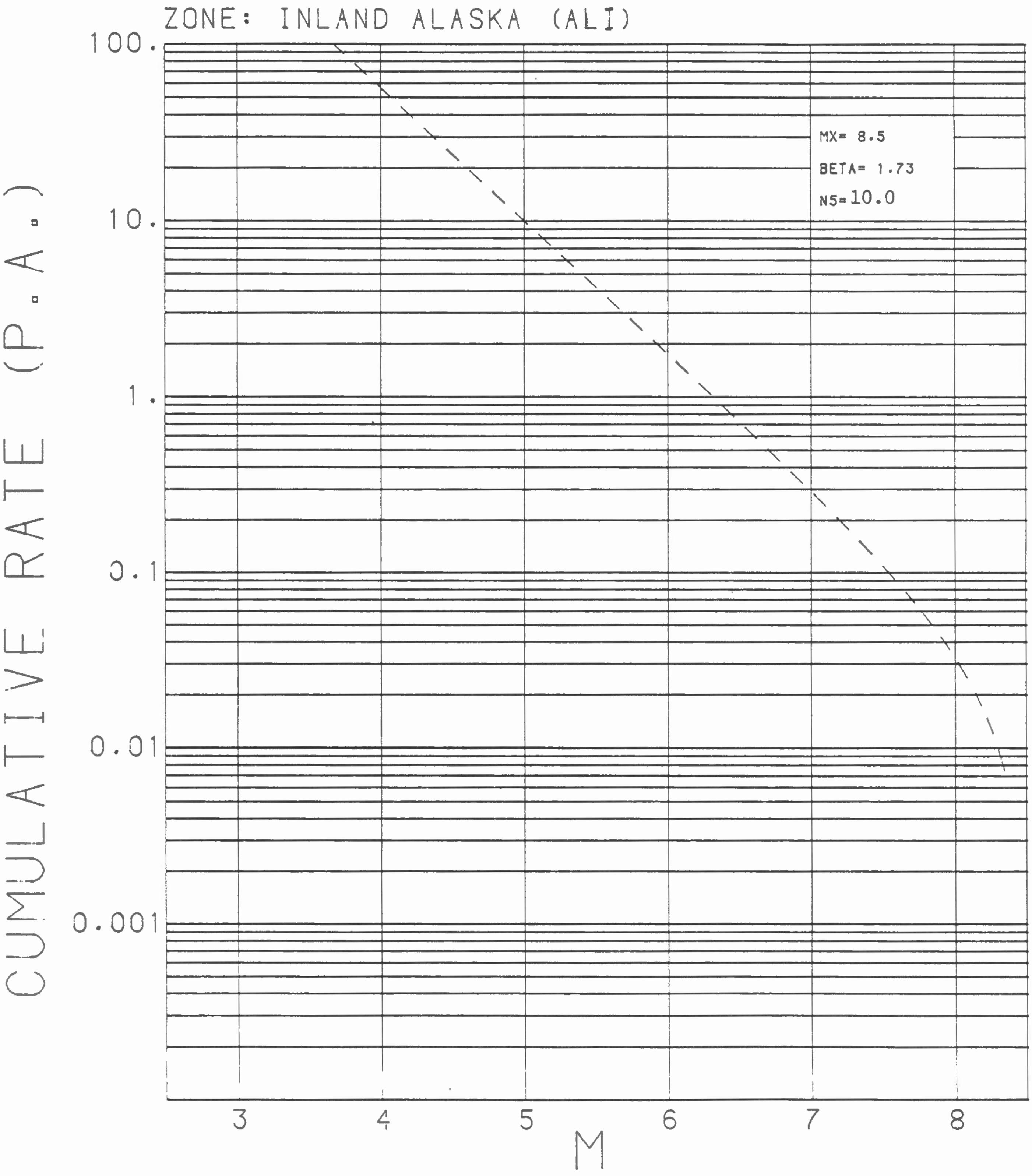
Figure 37



EARTH PHYSICS BRANCH EMR OTTAWA CANADA 30/10/81 10.39.43.

DIRECTION DE LA PHYSIQUE DU GLOBE OTTAWA CANADA

Figure 38



EARTH PHYSICS BRANCH EMR OTTAWA CANADA 30/10/81 10.39.43.

DIRECTION DE LA PHYSIQUE DU GLOBE OTTAWA CANADA

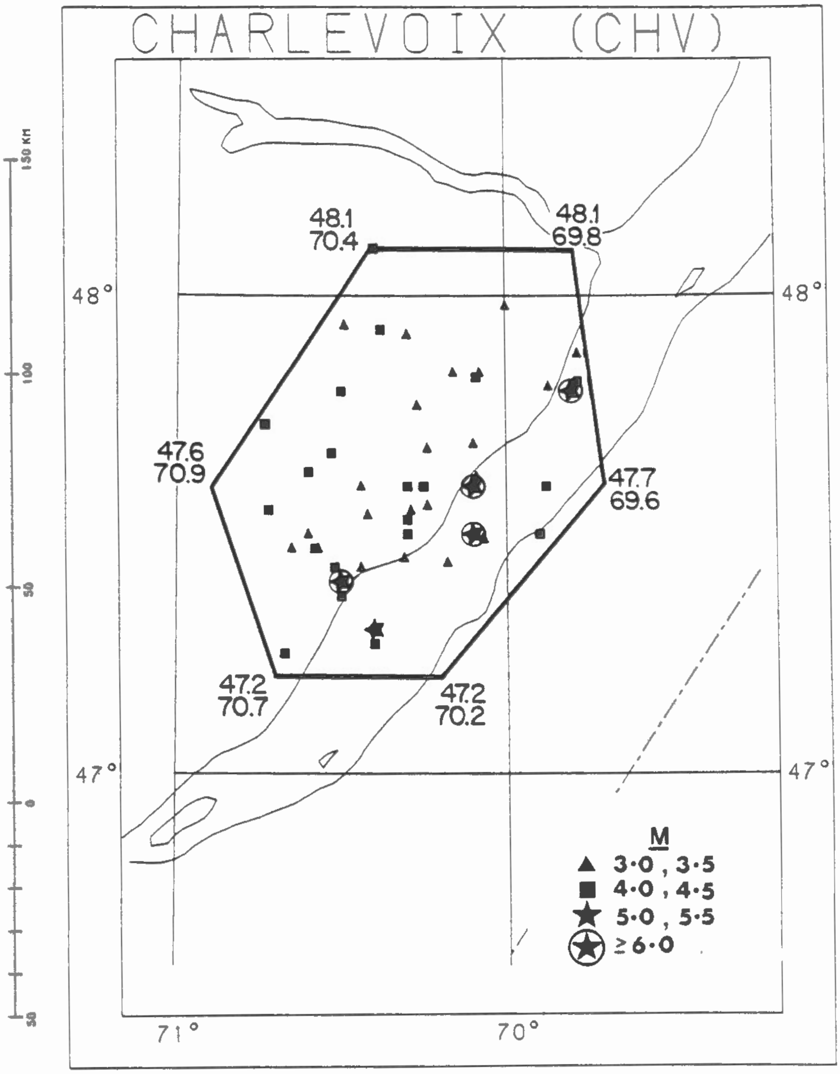
Figure 39

on Canadian territory, these source zones can be greatly simplified. For the region of Alaska west of 145°W the Thenhaus et al. source zones have been combined into two zones, Coastal Alaska (ALC) and Inland Alaska (ALI), (Figure 37). The ALC zone is essentially their zone number 23; the ALI zone a combination of seven of their zones, numbers 8, 14, 15, 16, 21, 22 and 24. The magnitude recurrence relation for ALC (Figure 38) is adopted directly from their zone 23; the relation for ALI (Figure 39) is the sum of the individual recurrence rates for their seven zones.

These zones have been extended only to 160°W as even large earthquakes further west in the Aleutian Islands will make negligible contributions to ground motion in Canada. Thenhaus et al. have derived minor source zones for northern Alaska, but this seismicity is adequately represented by the Mackenzie zone which extends to 145°W (Figure 35).

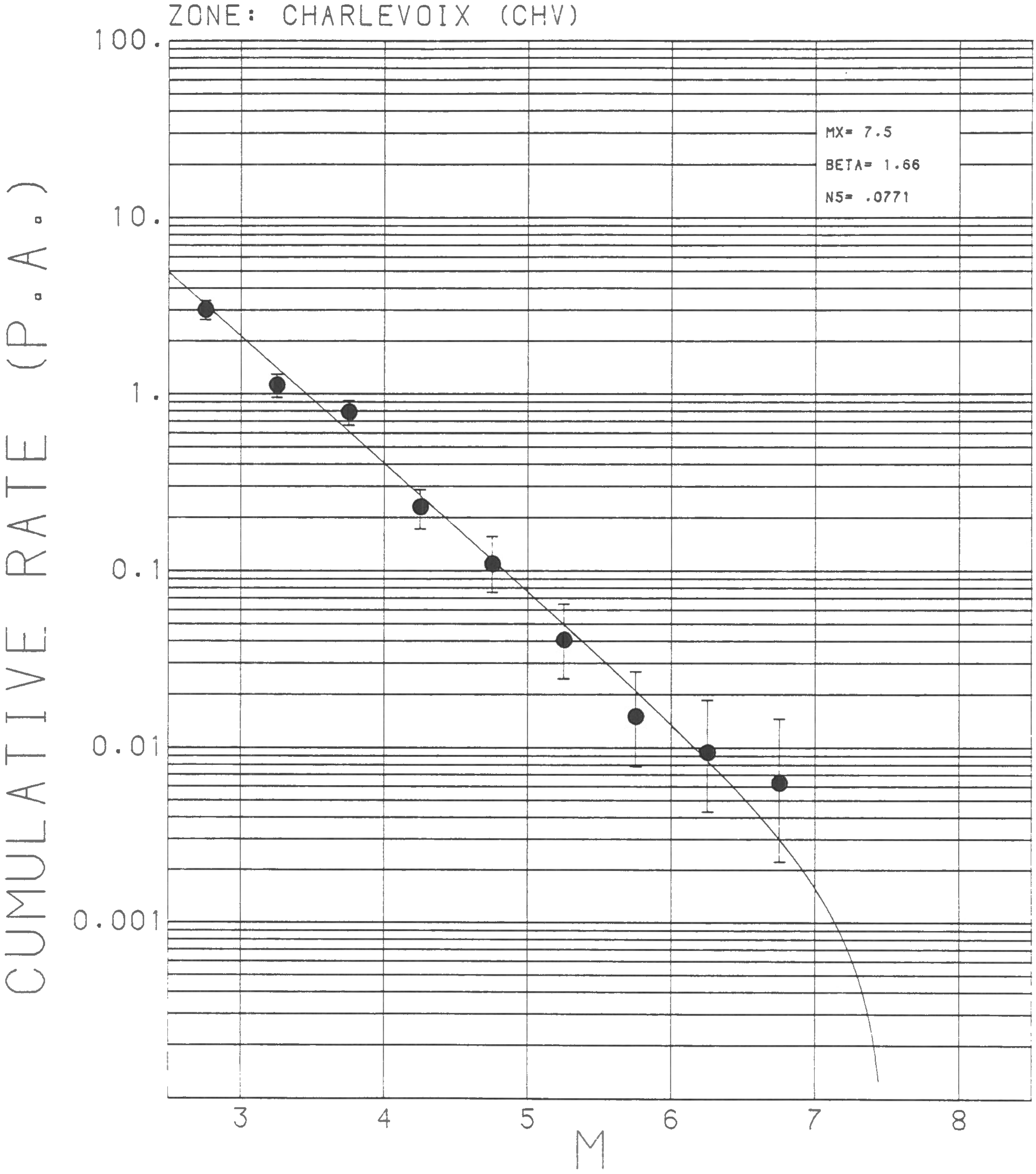
### 3.18 Charlevoix (CHV) (Figures 40, 41)

The Charlevoix zone is historically the most active zone in eastern Canada with at least five earthquakes with magnitude of 6 or greater (1663, 1791, 1860, 1870 and 1925). The 1925 event is the only earthquake with magnitude near 7 on land in eastern North America in the twentieth century. As part of the review of eastern Canadian seismicity by Basham et al. (1979), the magnitudes of a number of Charlevoix and other earthquakes were revised as listed in their Table 1. To provide the information necessary to make equivalent changes to the master Canadian Earthquake Epicentre File, a documentation of the revised parameters is included here as Appendix C. It should be noted that these revisions are based on a less than exhaustive



EARTH PHYSICS BRANCH
DIRECTION DE LA PHYSIQUE DU GLOBE EMR OTTAWA CANADA

Figure 40



EARTH PHYSICS BRANCH EMR OTTAWA CANADA
DIRECTION DE LA PHYSIQUE DU GLOBE OTTAWA CANADA

01/10/81 16.27.18.

Figure 41

reassessment of all available data, but they are considered improvements on the parameters originally determined by Smith (1962, 1966).

The Charlevoix zone is interpreted as a region of steeply-dipping rift faults at the Shield-Paleozoic contact that has been weakened by a Late Devonian meteorite impact (Rondot, 1979; Hasegawa and Wetmiller, 1980; Anglin and Buchbinder, 1981; Basham et al., 1982). A projection of microearthquake activity to the surface along the postulated faults suggests that the active zone is confined between mapped faults on the north shore and a bathymetric feature in, and parallel to, the river near the south shore (Berry et al., 1982). Focal mechanism solutions (Leblanc and Buchbinder, 1977; Hasegawa and Wetmiller, 1980) indicate that high horizontal compressive stresses are now producing thrusting on the preexisting faults (Hasegawa and Adams, 1981).

The source model employed (Figure 40) is based on the distribution of historical seismicity. It is recognized that some, if not all, of the epicentres in the northwestern portion of the zone may be mislocations of events that occurred in the more confined source centred along the river (see Figure 12 of Basham et al. (1982)). Stevens (1980) has demonstrated that the larger events in the twentieth century, previously located elsewhere, had epicentres at either end of the confined zone; but data are not available to demonstrate this conclusively for the older events. Most of the larger, pre-instrumental earthquakes have been assigned locations in or near the river on the basis of macroseismic effects, but these may be biased because much of the early settlement was along the river.

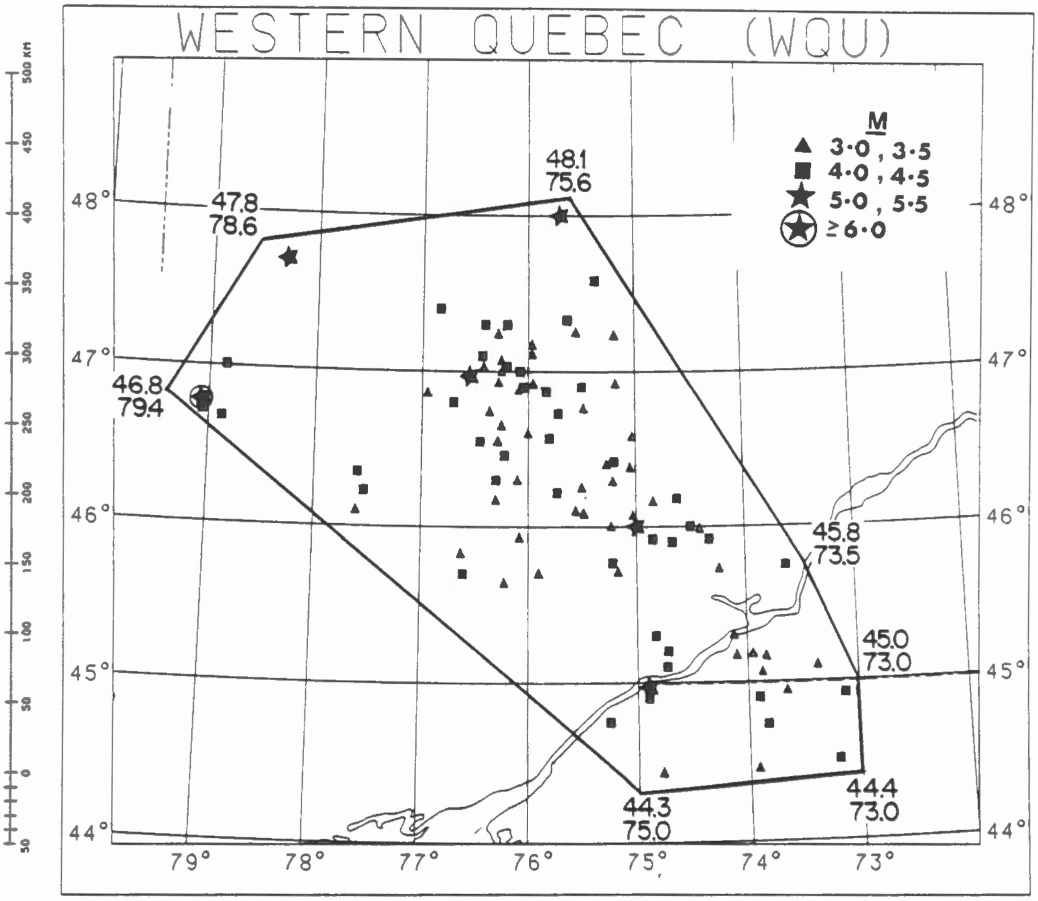
In any case, the effect on the probabilistic ground motion results of the choice between the more confined or the larger historical source zone is negligible away from the immediate vicinity of the zone. Near, or within, the zone the probabilistic results give little more than an indication of high earthquake risk; design considerations would be based on a more rigorous assessment of the expected near-field effects of large earthquakes.

The active zone described above has a length of about 80 km and the microearthquake activity suggests a depth of about 20 km. If a fault system the length and depth of the zone ruptured in one earthquake, it would have a magnitude of about 7.5 (Basham et al., 1982). This has been adopted as the maximum magnitude.

### 3.19 Western Quebec (WQU) (Figures 42, 43)

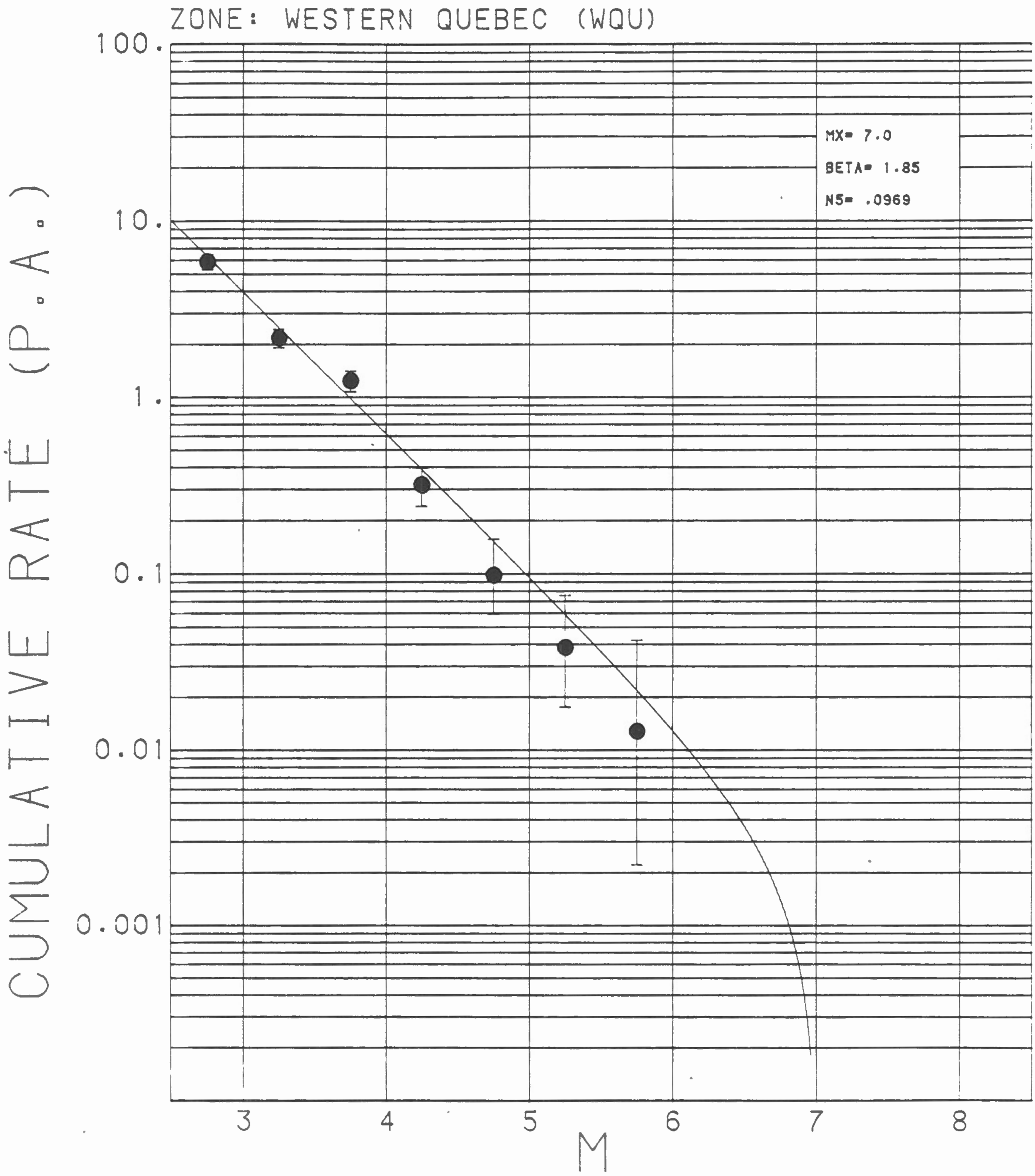
The boundaries of the Western Quebec zone (Figure 42) have been drawn to enclose a significant cluster of Shield earthquakes, the tectonic causes of which have been the subject of considerable research in recent years, but which remain poorly understood (Basham et al., 1979; Forsyth, 1981; Hasegawa and Adams, 1981; Forsyth et al., 1982).

The greatest number of earthquakes in this zone in recent years, although none with magnitude greater than 4.2, have been located in the central portion of the zone in Quebec north of the Ottawa river. Historically, the larger earthquakes have occurred on the fringes and outside of this concentration of recent events. An earthquake with magnitude about 6 occurred at or near Montreal in 1732. The magnitude of this event has been reduced to 6, from the previous 7, on the Canadian Earthquake Epicentre File on the basis of Leblanc's (1981) reassessment of the macroseismic data. During the twentieth century, earthquakes of magnitude 6.2 occurrred near



EARTH PHYSICS BRANCH EMR OTTAWA CANADA

Figure 42



EARTH PHYSICS BRANCH EMR OTTAWA CANADA 29/10/81 10.21.08.

DIRECTION DE LA PHYSIQUE DU GLOBE OTTAWA CANADA

Figure 43

Timiskaming in 1935 and magnitude 5.6 near Cornwall in 1944. The northern boundary of the zone is controlled by two earthquakes: a magnitude 5 that occurred the day following the Timiskaming event, but which Smith (1966) was convinced (by the available instrumental data) was at a different location; and a magnitude 5 event in 1950 near the headwaters of the Gatineau river. Both of these earthquakes are outside of the cluster of recent activity (see Figure 42). The southern boundary of the zone is extended into the Adirondacks and Lake Champlain region of New York State and Vermont, which has experienced similar low level activity but no large historic events.

Forsyth (1981) has shown that most of the earthquakes of western Quebec are located near or within the boundaries of the northeastern part of the Grenville metasedimentary belt and near the junction of the rift structures following the northern and eastern segments of the Ottawa river, the St. Lawrence river and Lake Champlain. The larger historic earthquakes (Montreal, Timiskaming, Cornwall) are spatially associated with these younger rift zones. The geological and aeromagnetic data indicate a Premcambrian shear zone is continuous along most of the eastern side of the belt. The aeromagnetic and gravity data show distinct anomalies that suggest unmapped features along the northwest side. The seismcity in the central portion of the zone coincides with the interval between two prominent anomalies in the smoothed Bouguer gravity field, and shows a spatial correlation with a topographic regional low.

It appears that the seismicity reflects adjustment to a stress field resulting from one or more of: regional density variations, continental deglaciation and intraplate forces (see also Hasegawa and Adams (1981)).

However, the relative effect of each stress field and the reason for greater recent seismicity in the Grenville metasedimentary belt remains unclear.

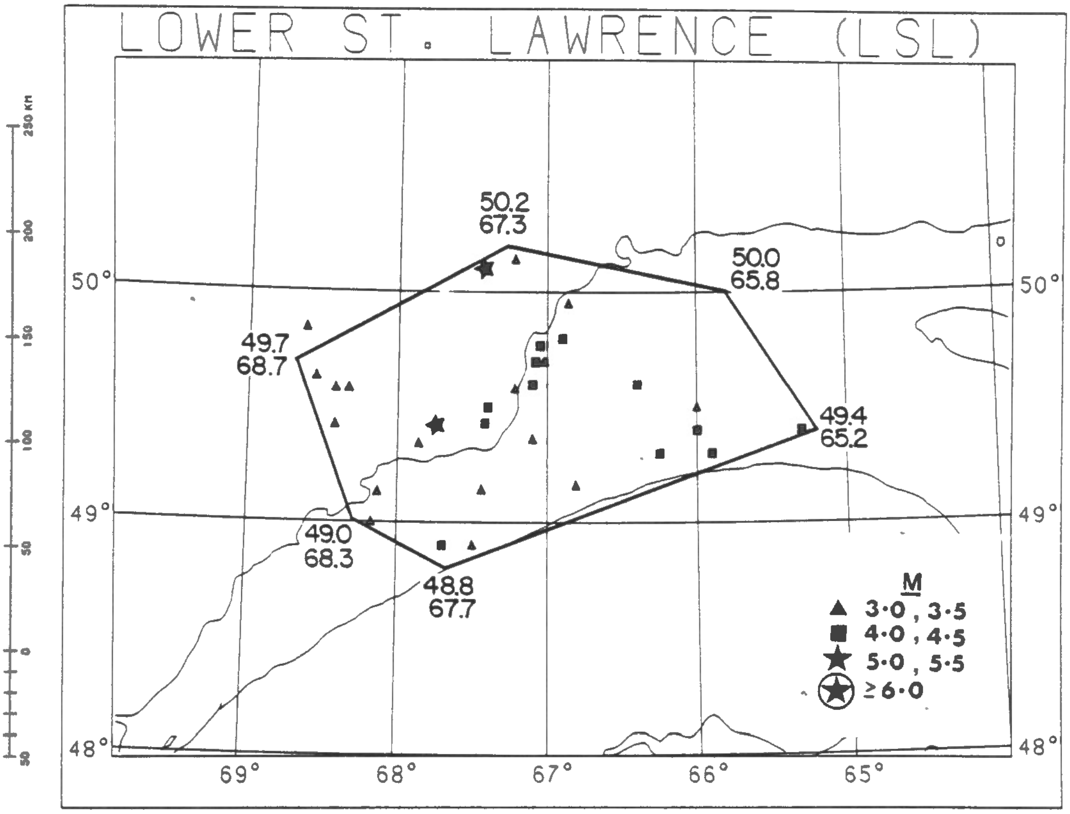
Forsyth et al. (1982) have recently extended these and Landsat lineament correlations northward toward the Kapuskasing Fault Zone. They also show that the Kapuskasing region has been more active than the Timiskaming region in recent years. However, for our purposes the Kapuskasing region has not been attached to the Western Quebec zone; it remains in the more diffuse Eastern Background zone discussed below.

A maximum magnitude of 7.0 has been chosen for the Western Quebec zone, but there is no seismological or geological evidence that we can employ to support this, or to demonstrate that some larger value may not be more appropriate.

### 3.20 Lower St. Lawrence (LSL) (Figure 44, 45).

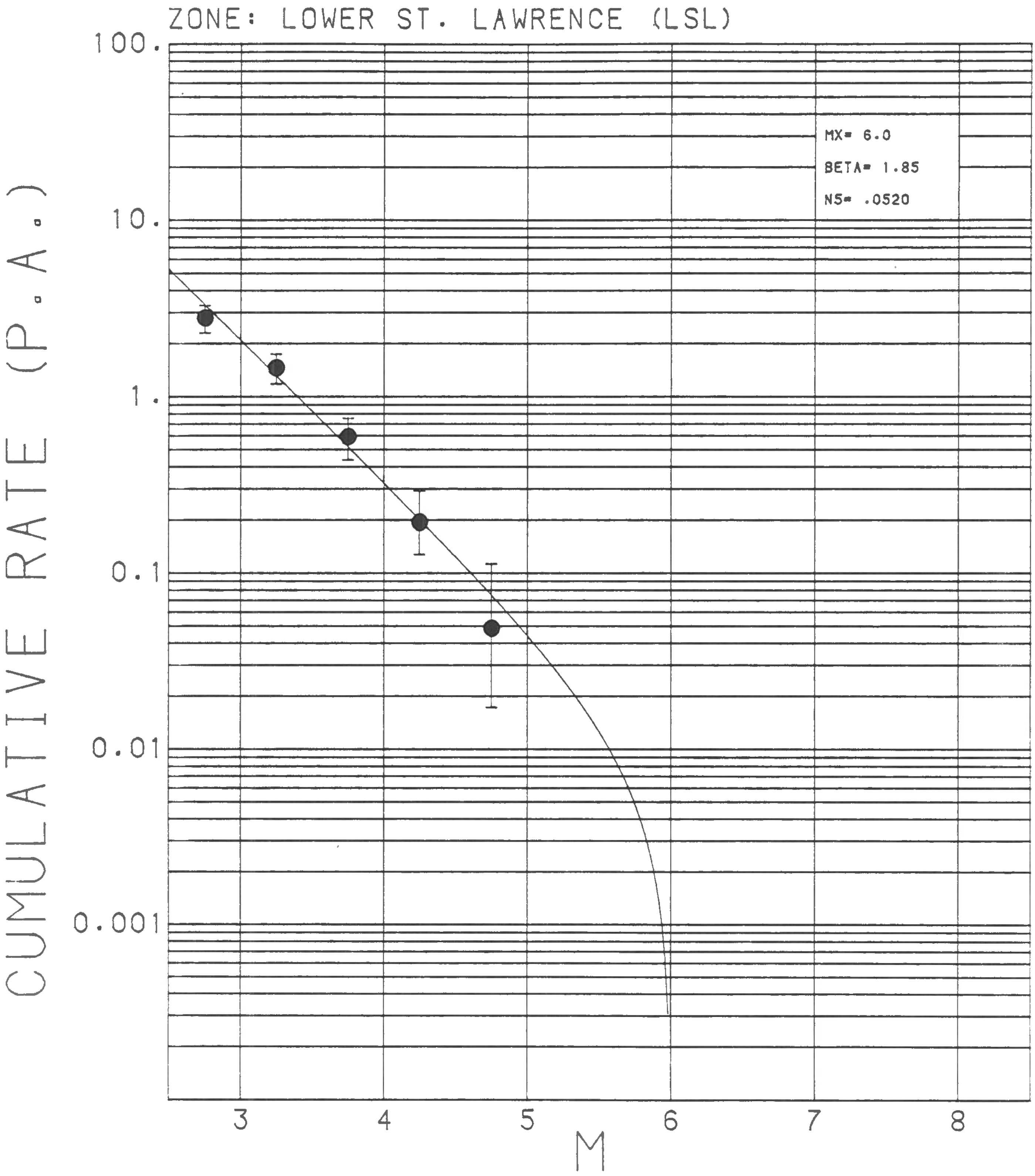
The Lower St. Lawrence zone is a cluster of seismicity centred approximately over the north shore of the river in the region from Baie Comeau to Sept-Iles. The better-located events in recent years have epicentres in the river and on the north shore (Figure 44); some of the older events that have epicentres on the south shore (northern portion of Gaspé Peninsula) may be mislocations due to poor network control. The small number of earthquakes, some quite recent, that have occurred in Jacques Cartier Passage and on the adjacent north shore are not included in this zone, but in the Eastern Background zone (see Figure 52).

The magnitude 4.1 earthquake that was induced by the filling of the Manic 3 reservoir (Leblanc and Anglin, 1978) is not included in this data set. The northwestern corner of the zone boundary has been confined to the



EARTH PHYSICS BRANCH EMR OTTAWA CANADA

Figure 44



EARTH PHYSICS BRANCH EMR OTTAWA CANADA
DIRECTION DE LA PHYSIQUE DU GLOBE OTTAWA CANADA

29/10/81 10.21.08.

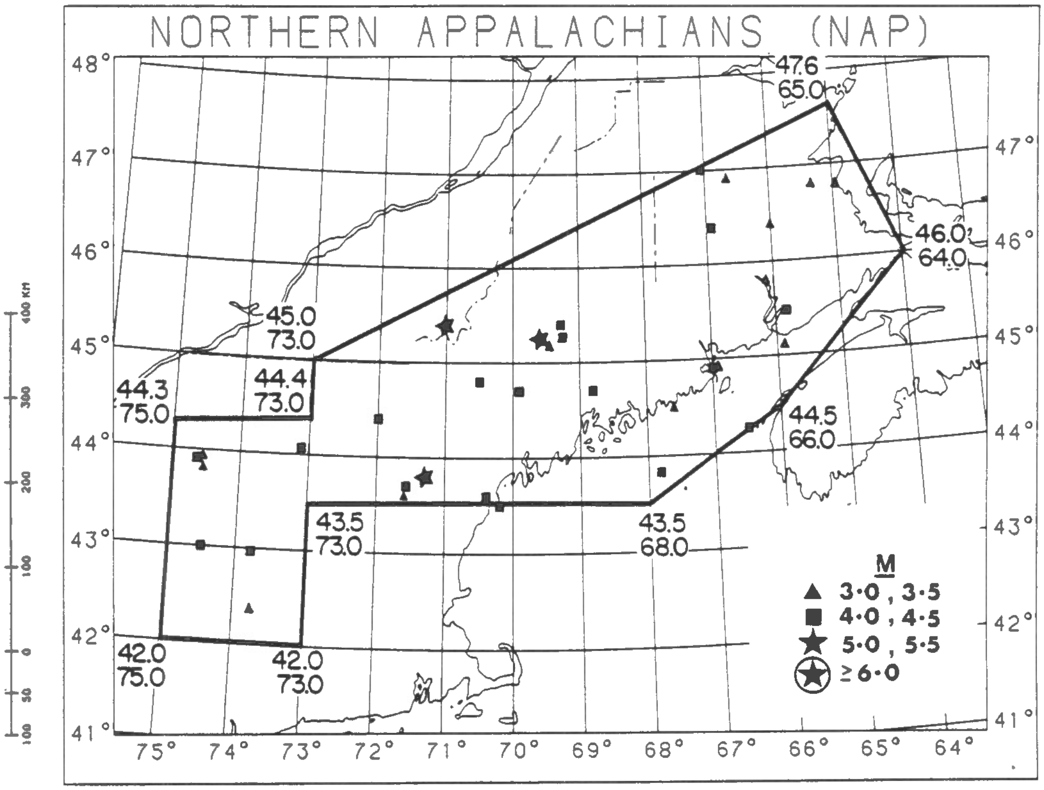
Figure 45

south of the Manic 3 dam. However, the small earthquakes that are included in the northwestern corner of the zone, most of which occurred in 1966, may have been related to the 1965 filling of the Manic 2 reservoir, but failed to be recognized as such (see Figures 1 and 2 of Leblanc and Anglin). Because of the uncertainty, they are assumed here to be natural tectonic events.

Geological and geophysical features that may correlate with and control the Lower St. Lawrence zone are much less well known than is the case for the Charlevoix and Western Quebec zones. Among the sparse evidence is the study by Goodacre and Hasegawa (1980) showing that earthquakes in the Quebec City to Sept-Iles region of the St. Lawrence valley tend to cluster in regions of negative free-air gravity anomalies that are adjacent to major free-air gravity highs. In the region of the Lower St. Lawrence zone there is a small gravity high south of Sept-Iles, with the St. Lawrence river negative anomaly on each side, and a positive anomaly on the northern portion of the Gaspé peninsula that is part of the linear belt of positive anomalies south of the Appalachian front. Goodacre and Hasegawa suggest that gravitationally induced stresses, superimposed on an ambient tectonic stress field may be sufficient to activate pre-existing faults.

### 3.21 Northern Appalachians (NAP) (Figures 46, 47)

The Northern Appalachians zone is a relatively large zone of rather uniform seismicity throughout New Brunswick, Maine, New Hampshire and Vermont. The southeastern boundary of the zone is drawn to include the seismicity in the Bay of Fundy and off the coast of Maine. The southern boundary is an arbitrary one, adopted by Basham et al. (1979), that excludes from consideration the seismicity in southern New Hampshire and Massachusetts,



EARTH PHYSICS BRANCH EMR OTTAWA CANADA

Figure 46

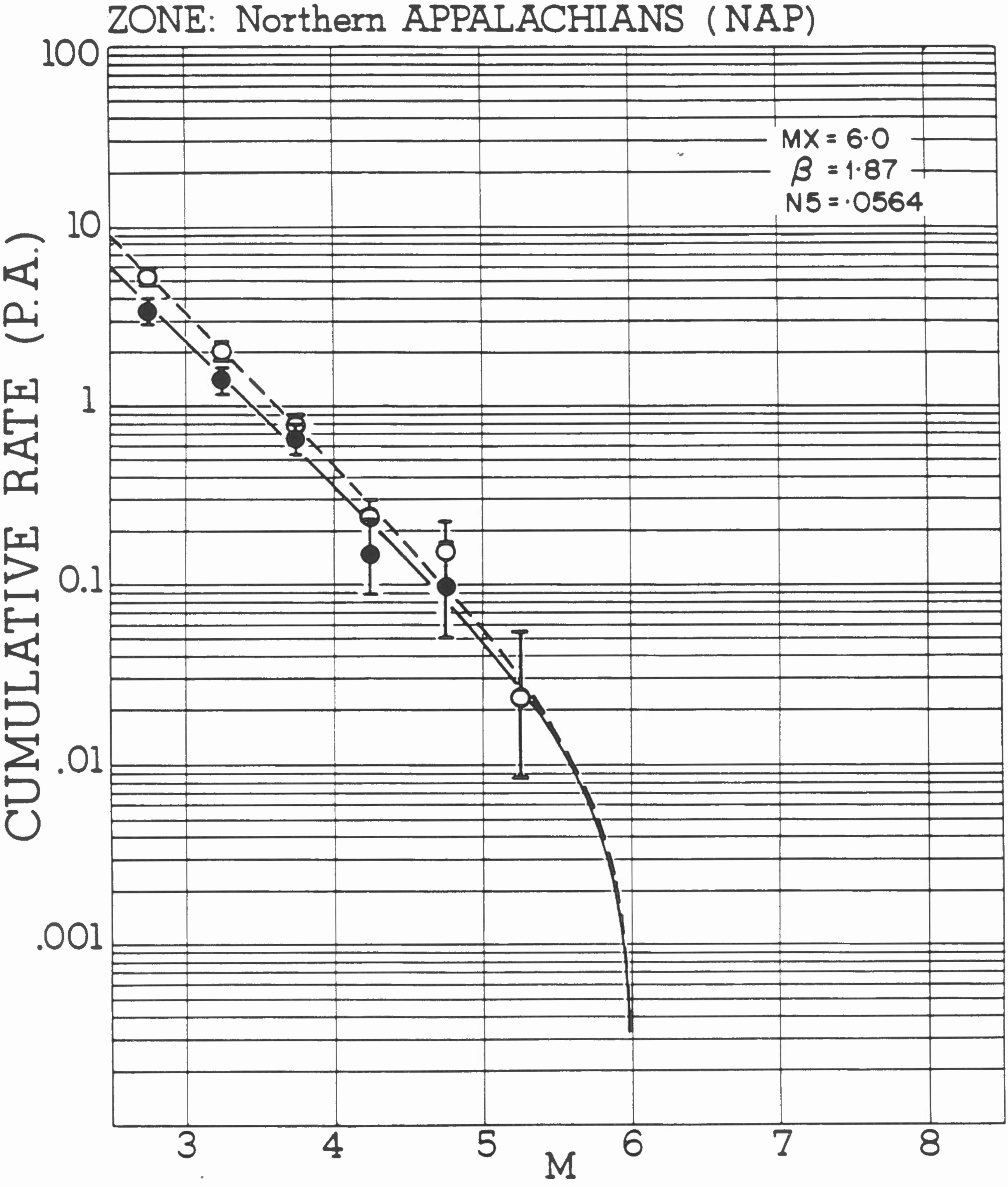

ZONE: Northern APPALACHIANS (NAP)
CUMULATIVE RATE (P.A.)
100
10
1
0.1
.01
.001
MX = 6·0
β = 1·87
N5 = ·0564
3
4
5
6
7
8
M

Figure 47

in particular the large number of historic events that are catalogued for the Boston region during the time of early settlement. The zone is extended to the southeast far enough to include the seismicity of southeastern New York along the Hudson River, but it is terminated north of the Ramapo fault system shown by Aggarwal and Sykes (1978) and Yang and Aggarwal (1981) to be active at low magnitudes. The northern boundary of the zone is drawn along the southern edge of the 100- to 200-km wide, relatively aseismic band that extends from the eastern side of Lake Champlain to the Gaspé Peninsula. Thus, the boundaries of this zone in the United States are arbitrary ones that are not intended to bear a particular relation to the structural geology and tectonics; the Canadian boundaries distinguish the zone from the relatively aseismic areas that include the Gulf of St. Lawrence, P.E.I. and Nova Scotia.

The structural grain of the Northern Appalachians is controlled by northeasterly trending belts of volcanic and sedimentary rocks of Devonian to Ordovician age that are intruded by post-Ordovician granites and basic dykes. Wetmiller (1975) found one plane of the focal mechanism of the 1973, M4.8 Quebec-Maine border earthquake to be on strike with the regional Appalachian trend. However, Yang and Aggarwal (1981) determined thrust faulting on a north-striking plane for this earthquake, and high-angle reverse faulting on north- to northeast-striking planes for 12 other earthquakes along the eastern margin of the Appalachians. The results available at the time of writing for the 1982 Miramichi, New Brunswick earthquakes (Wetmiller et al., 1982; Stevens, 1982) also suggest thrust faulting on north-striking planes. The Miramichi earthquakes, however, present an excellent example of the difficulties of making a clear correlation between even exceptionally well-documented and shallow earthquakes and the local geological features, a difficulty that, no doubt, pertains to much of the Northern Appalachian zone.

The larger historic earthquakes in the Northern Appalachian zone, as defined in Figure 46, have magnitudes estimated as about 5. These include the 1869 and 1904 events that caused minor damage in southern New Brunswick and eastern Maine, the 1940 events near Ossipee Lake, New Hampshire, the 1943 event near Dover-Foxcraft, Maine, and the 1973 Quebec-Maine border event. On the basis of these events, the maximum magnitude adopted for the recurrence relation is 6.0 (Figure 47). There is no geological or seismological evidence on which to base the maximum magnitude.

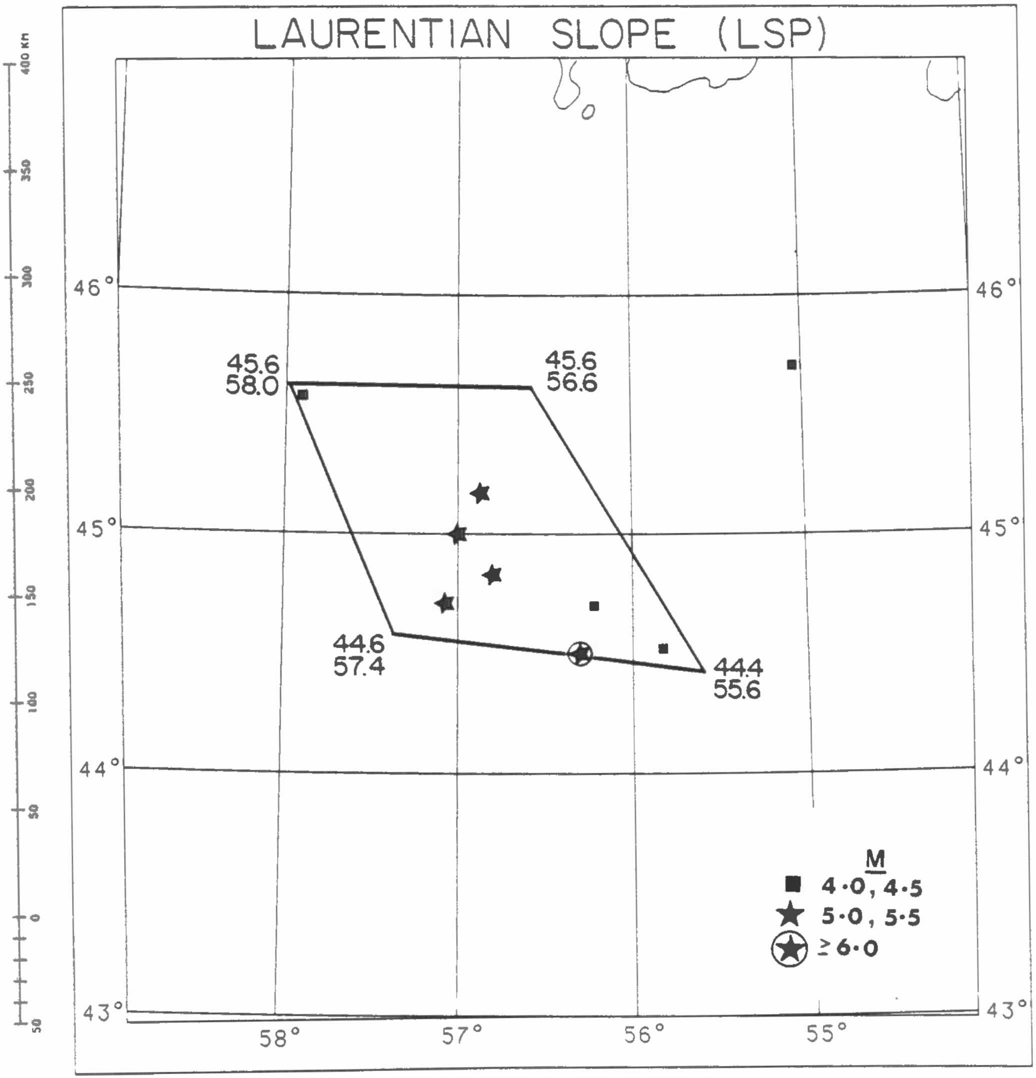
The Miramichi earthquake sequence of 1982 is an unprecedented sequence for eastern Canada, although the larger events, M5.7 and 5.4, are considered typical of the more significant earthquakes that can occur in the Northern Appalachian zone. To illustrate the influence this sequence has on the magnitude recurrence relation adopted for the zone, the earthquakes have been updated to mid-1982 (listed in Appendix A) and the magnitude recurrence relation recomputed as shown by the open circles and dashed curve in Figure 47. The large numbers of small earthquakes in the Miramichi aftershock sequence increases the slope of the recurrence relation. However, with the maximum magnitude kept at 6.0, the addition of the Miramichi events does not significantly affect the estimated rates at larger magnitudes. In fact, the recent events provide an estimate of the rate at magnitude 5.5 that agrees very well with the extrapolation based on the pre-1978 events. The updated recurrence relation would increase the Northern Appalachian probabilistic ground motion only slightly (about 5 percent) and would not significantly change the contour patterns of Figures 2 and 3.

### 3.22 Laurentian Slope (LSP) (Figures 48, 49)

The Laurentian Slope zone is a small cluster of earthquakes at the edge of the continental slope at the mouth of the Laurentian Channel that includes one major event, the magnitude 7.2 earthquake of 1929 (Doxsee, 1948), one of only two magnitude 7 earthquakes known to have occurred offshore of eastern Canada.

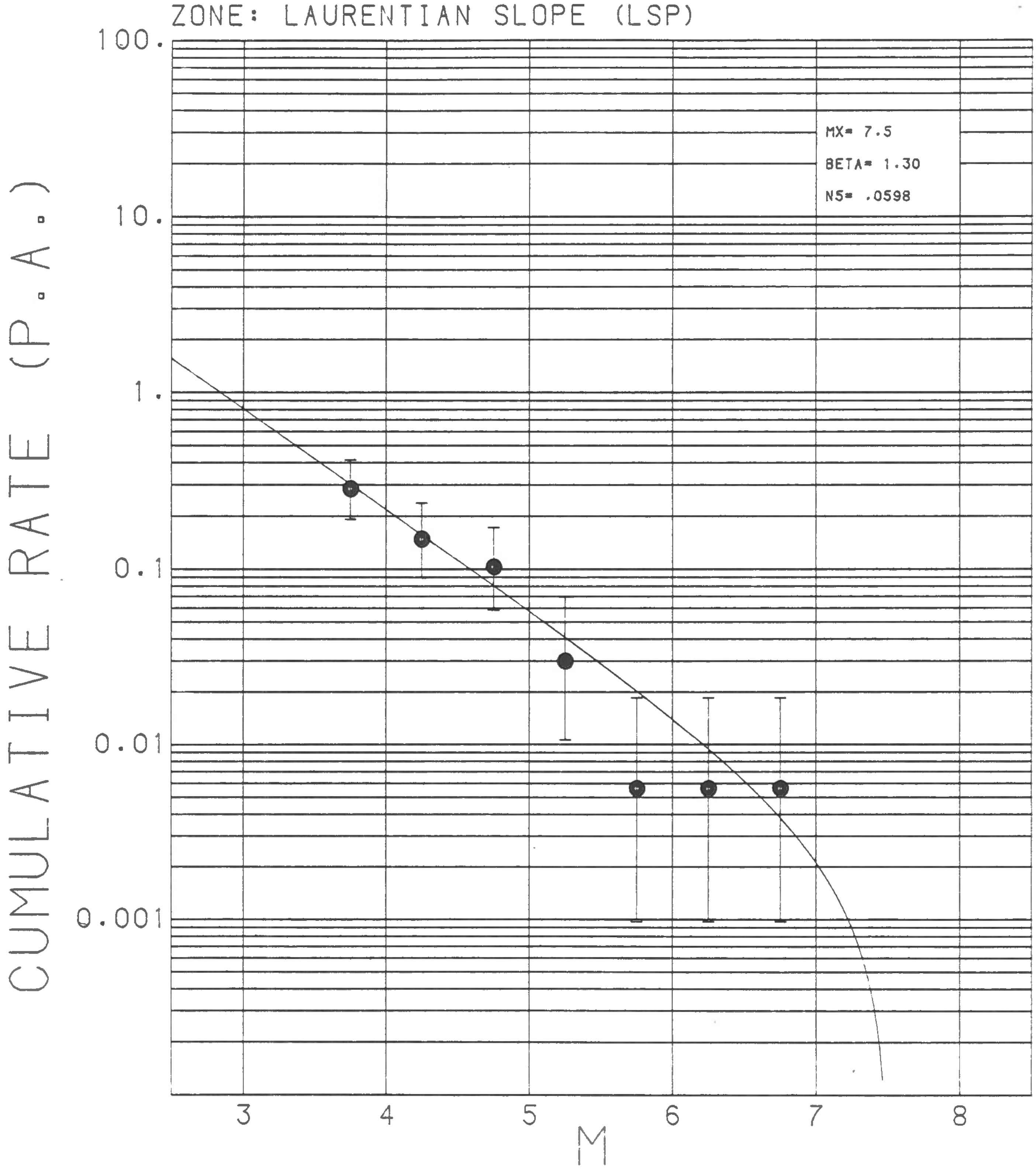
Preliminary examination of available data suggests that the zone of earthquakes is spatially distributed approximately as seen in Figure 48; i.e., the scatter is not due to mislocations of events that occurred at or near one epicentre (Basham and Adams, 1982). The zone boundaries drawn to enclose the cluster are controlled on the east and west by the margins of the Laurentian Channel, on the north by the faults associated with the Orpheus Graben, and on the south approximately at the base of the continental slope (see Figure 3 of Basham and Adams). King (1979) has suggested that the earthquakes appear to be associated with the Glooscap fault, the combined Cobequid-Chetabucto-Orpheus Graben-Laurentian Channel fault system. The seismic reflection profiling used to locate the faults in the region of the channel indicate that most, and perhaps all, of the offset is pre-Pleistocene, but there is not sufficient resolution in the profiling to detect recent offsets if they were present in the youngest sediments. A study of aerial photography of this fault system where it crosses Nova Scotia has shown no evidence of fault linears or scarps in surface deposits that would suggest recent movement (D.R. Grant, personal communication, 1982).

The rate of 1929-sized earthquakes is poorly determined by the magnitude recurrence data. For purposes of computing Figure 49 it has been assumed that magnitude 7 earthquakes would have been completely reported since 1800 (see



EARTH PHYSICS BRANCH EMR OTTAWA CANADA

Figure 48



EARTH PHYSICS BRANCH EMR OTTAWA CANADA 15/11/82 10.21.44.

DIRECTION DE LA PHYSIQUE DU GLOBE OTTAWA CANADA Figure 49

Table 1), although we are by no means certain that reports of effects would even approximately locate such an offshore event in the early 1800's, had one occurred. Nevertheless, the result is a recurrence relation that shows reasonable agreement between the rates of larger earthquakes and the rates in the magnitude 4-5 range, although the slope of the curve tends to be lower than that of most other source zones.

This source zone produces a small region of high amplitude ground motion on the probabilistic maps (Figures 2 and 3), similar to that produced by the Charlevoix zone. Implicit in the adoption of this model is the assumption that the next large earthquake in the region will occur within the restricted zone at the mouth of the Laurentian Channel, i.e., rather than at some other location on the Newfoundland or Scotian Shelf. The evidence to support this assumption is not very strong, but we consider the model to be the best available for the present purposes. The result, however, is that the remainder of the Newfoundland and Scotia shelves falls within a zone of low background seismicity (Figure 52), which may under-estimate the real risk in these regions.

### 3.23 Attica (ATT) (Figures 50, 51)

The Attica zone has been drawn to enclose the M 5.5, 1929 Attica earthquake and the smaller M 3.5 - 4.5 events that have occurred near the south shore of Lake Ontario. Basham et al. (1979) defined this zone as extending through the Niagara Peninsula to the Hamilton-Burlington region. We now believe that many of the small earthquakes around the western end of Lake Ontario are the result of shallow pop-up phenomena, and have included this area in the general Eastern Background zone.

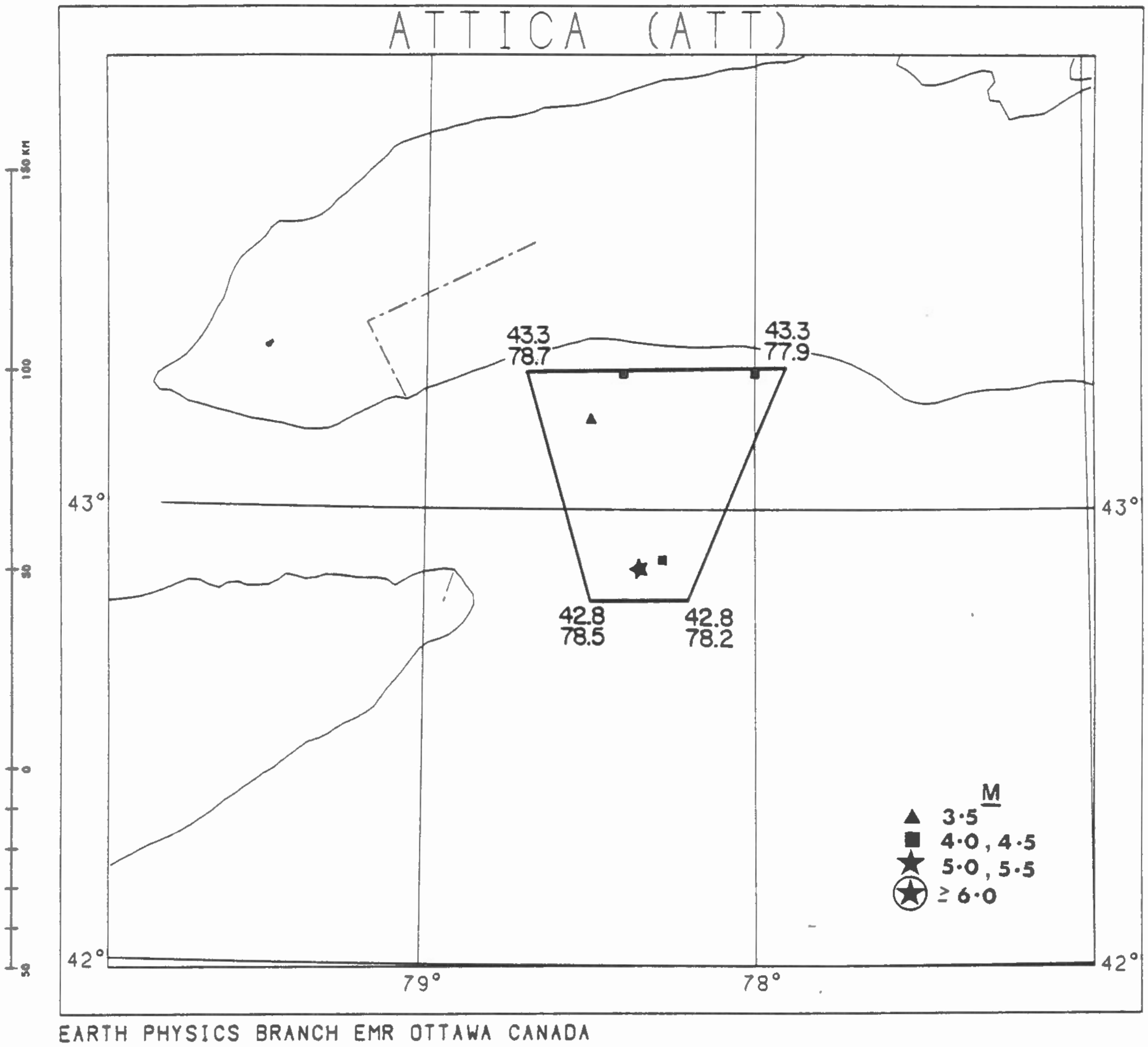
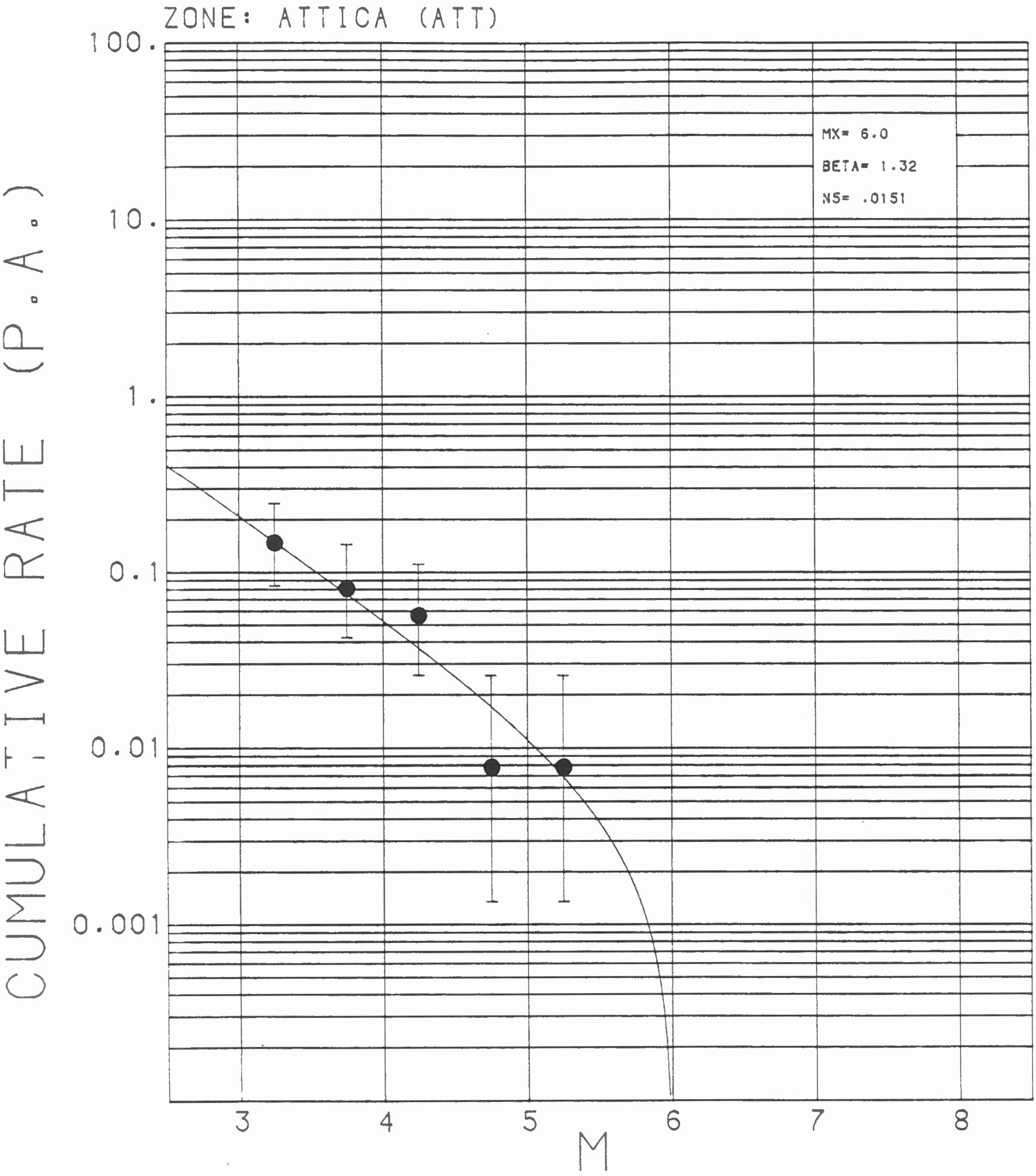

ATTICA (ATT)
43.3
78.7
43.3
77.9
42.8
78.5
42.8
78.2
43°
43°
42°
42°
79°
78°
150 KM
100
50
0
50
M
▲ 3·5
■ 4·0, 4·5
★ 5·0, 5·5
≥ 6·0
EARTH PHYSICS BRANCH EMR OTTAWA CANADA

Figure 50



EARTH PHYSICS BRANCH EMR OTTAWA CANADA 29/10/81 10.21.08.
DIRECTION DE LA PHYSIQUE DU GLOBE OTTAWA CANADA

Figure 51

The most significant tectonic feature in the region is the north-south trending Clarendon-Linden structure that extends for over 100 km from Lake Ontario to the New York - Pennsylvania border (Fletcher and Sykes, 1977). There is no conclusive evidence that the 1929 earthquake occurred on this structure, but Fletcher and Sykes have shown seismicity induced by hydraulic mining activity to have thrust mechanisms on a plane nearly parallel to the Clarendon-Linden fault, and that other nearby natural events may be associated with branches of the fault.

An apparently anomalous feature of the zone is the lack of small earthquakes in recent years. Magnitude 4 events would have been completely reported since at least 1950, if not much earlier, magnitude 3 events since at least the early 1970's with the development of the Lamont-Doherty network in New York State. There have been very few such events in the last 15 years; consequently the data base for magnitude recurrence calculation is very sparse. There are only five Attica zone events that pass the completeness test (Figure 50 and Appendix A).

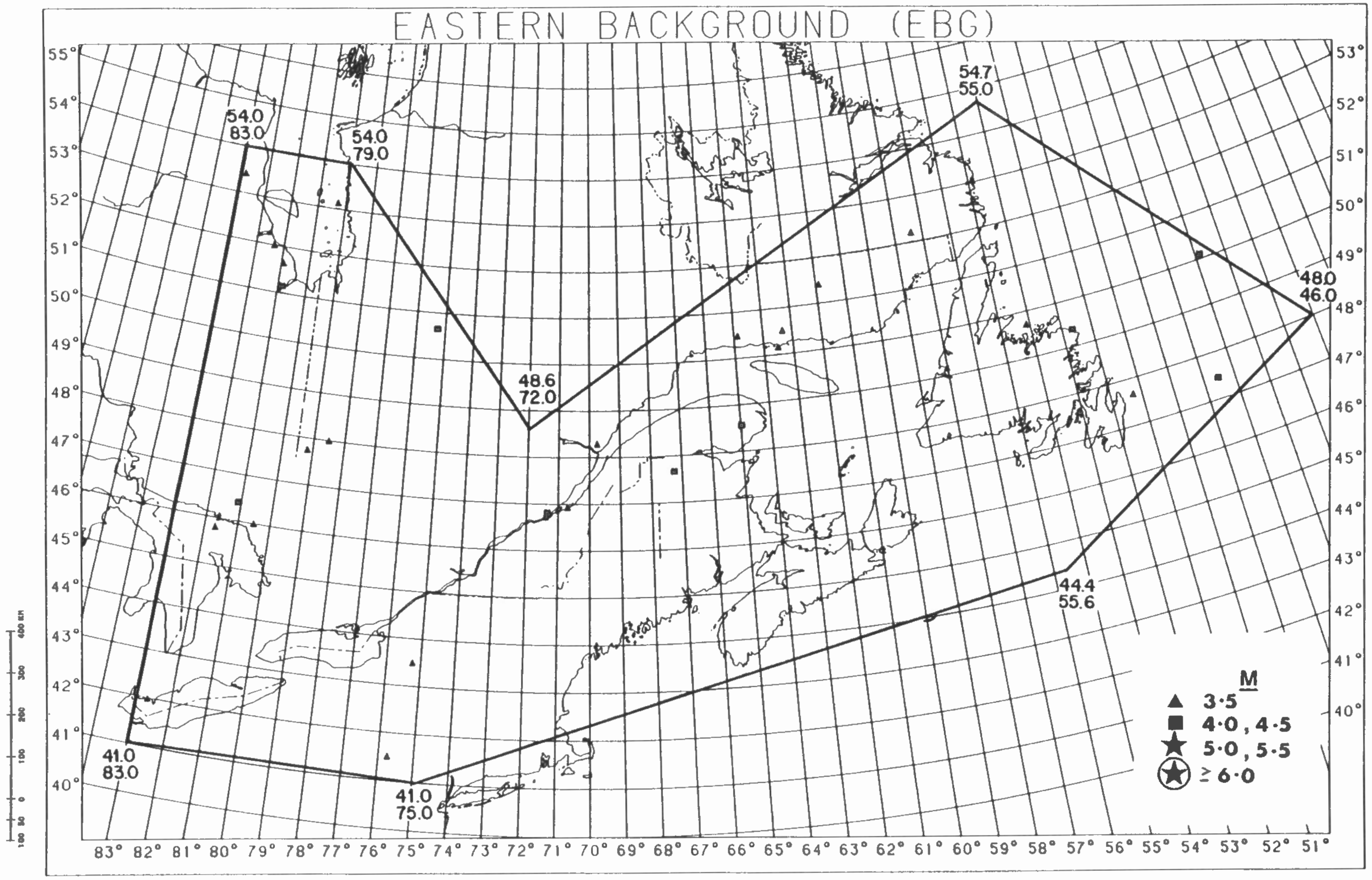
This is also an example of a zone that has experienced only one known significant earthquake in historic time, albeit only M 5.5, and it is therefore difficult to estimate the expected rate of such events. Consultations with G. Leblanc and P.W. Pomeroy (personal communications, 1981) have provided evidence that the settlement of western New York State was sufficiently dense by 1850 to have provided written accounts of Attica-sized earthquakes since that time. This date has been used (Table 1) to estimate rates of M 5.5 events for the magnitude recurrence relation (Figure 51). The maximum magnitude has been chosen as one-half magnitude unit larger, at 6.0.

### 3.24 Eastern Background (EBG) (Figures 52, 53)

The Eastern Background zone (Figure 52) has been drawn to encompass the entire region of eastern Canada that shows some evidence of minor historical, or recent low-level seismicity. As such, it extends beyond the more concentrated activity defined by the above zones and includes seismicity in regions of James Bay, northeast of Georgian Bay, western Lake Erie, the north shore of the Gulf of St. Lawrence and the northeastern Newfoundland Shelf. Defining the zone is primarily a recognition that low-level, but occasionally significant, seismicity can occur in regions surrounding the active zones; i.e., this region of eastern Canada should not be considered aseismic. The maximum magnitude is selected as 5.0, but the area is so large and the rates so low (Figure 53) that the zone makes a negligible contribution to the probabilistic ground motion in Figures 2 and 3. An earthquake in 1922 that may have had a magnitude near 5 has an epicentre on the northeastern Newfoundland shelf (see Figure 3 of Basham and Adams (1982)). This event does not pass the completeness test (Table 1) and its location is very uncertain.

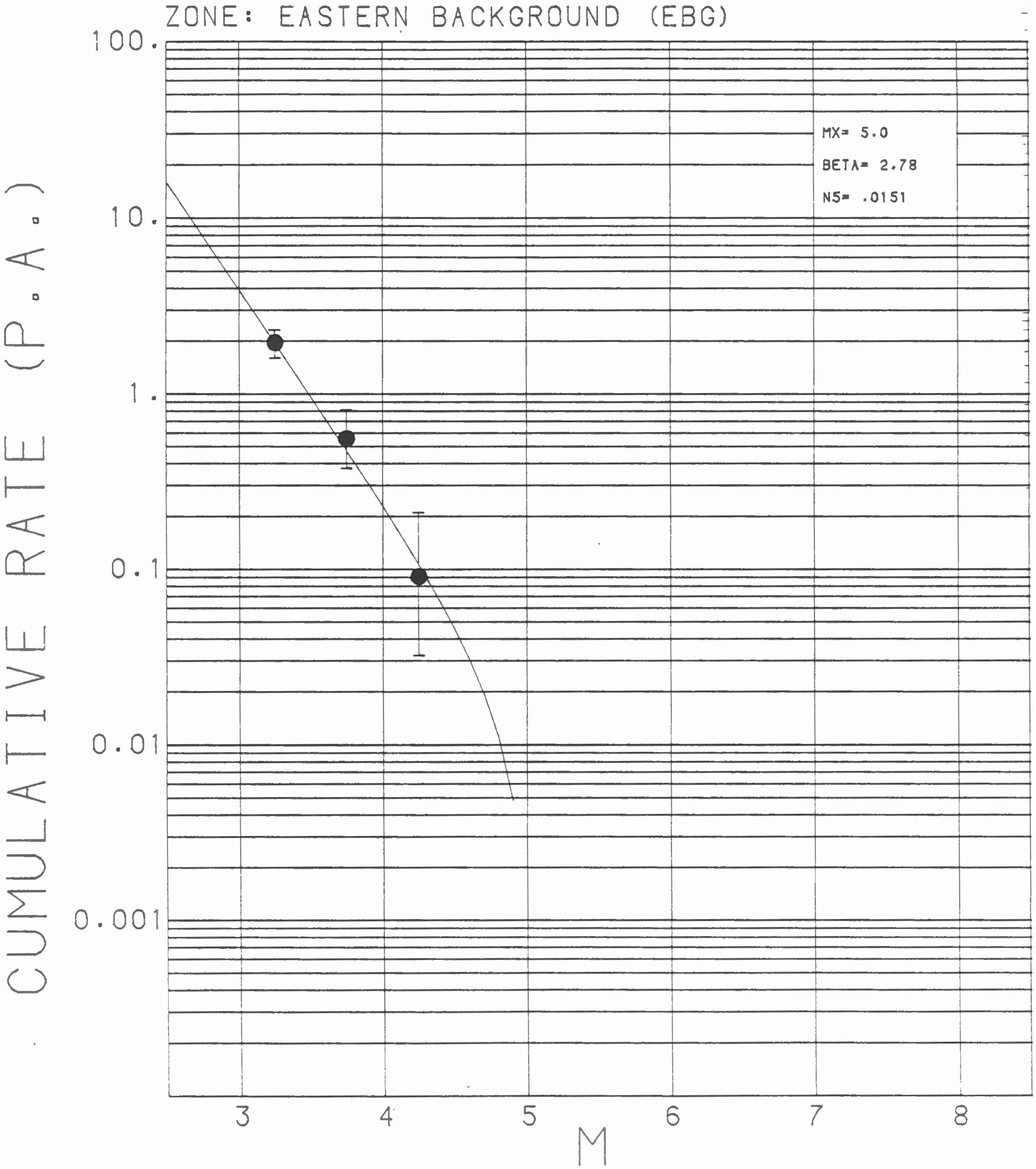
### 3.25 Baffin Bay (BAB) (Figures 54, 55)

The largest earthquake known to have occurred in northern Canada was the magnitude 7.3 event in Baffin Bay in 1933 (Figure 54). This earthquake had aftershocks as large as M 6.5. Magnitude 6 events in Baffin Bay have since occurred in 1945, 1947 and 1957. It is difficult to define boundaries for the Baffin Bay zone on the basis of geological and geophysical evidence (Basham et al., 1977; Wetmiller and Forsyth, 1978, 1982; Reid and Falconer, 1982), but there seems to be a clear separation between the activity in the Bay and that on Baffin Island. Therefore, the zone boundaries shown in Figure 54 are



EARTH PHYSICS BRANCH
DIRECTION DE LA PHYSIQUE DU GLOBE EMR OTTAWA CANADA

Figure 52



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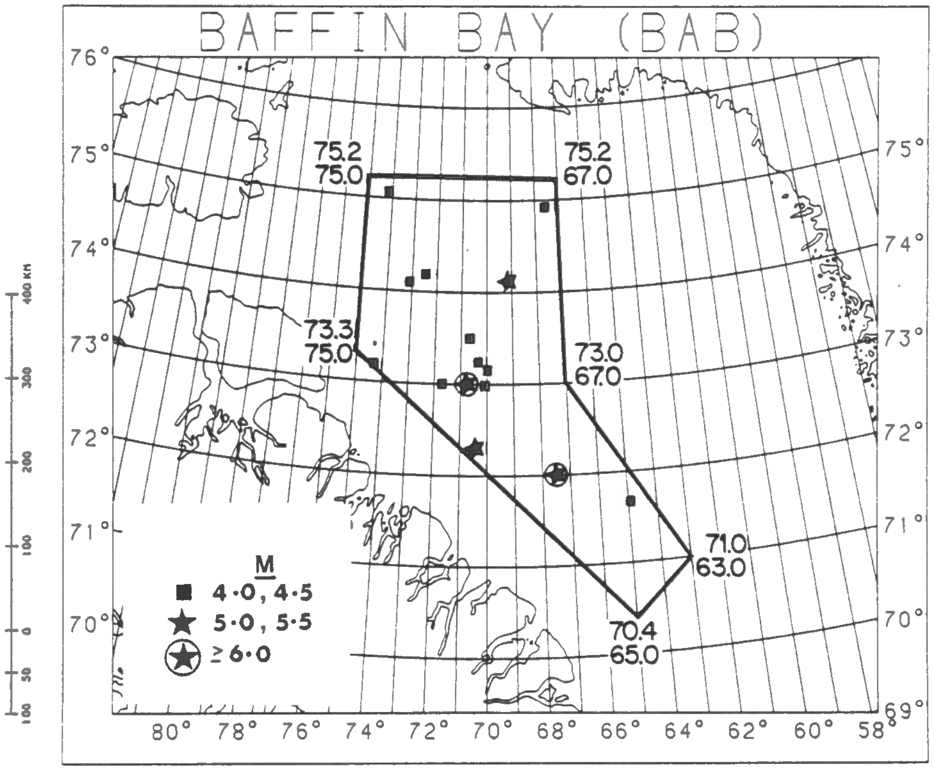
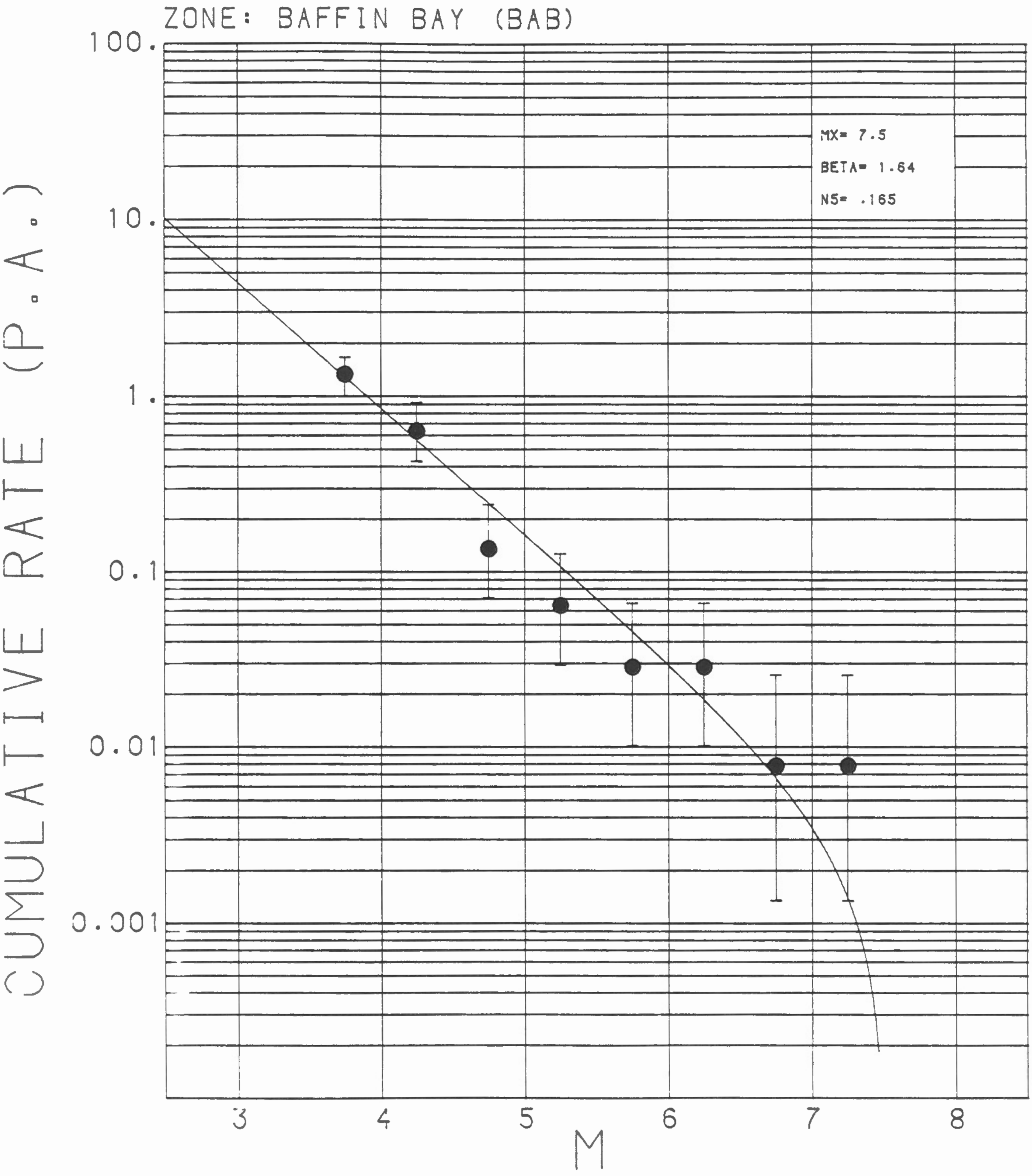
DIRECTION DE LA PHYSIQUE DU GLOBE OTTAWA CANADA Figure 53



EARTH PHYSICS BRANCH EMR OTTAWA CANADA

Figure 54



EARTH PHYSICS BRANCH EMR OTTAWA CANADA 29/10/81 10.21.08.
DIRECTION DE LA PHYSIQUE DU GLOBE OTTAWA CANADA

Figure 55

arbitrary ones drawn to distinguish the significant seismicity of the Bay from surrounding events in the Baffin Island and Eastern Arctic Background zones discussed below.

Jackson et al. (1979) have found evidence for sea-floor spreading and an extinct spreading centre in the deep central region of the Bay. However, there is little or no seismic activity in this region; the seismicity is confined almost exclusively to the landward side of the 2000m bathymetric contour in the northwestern segment of the Bay that outlines the thick sedimentary sequence. This sedimentary sequence is also reflected by a broad positive free air gravity anomaly which suggests uncompensated loads may be acting on zones of weakness along the rifted margin (Wetmiller and Forsyth, 1982).

Stein et al. (1979) have found thrust mechanisms for the 1933 and a magnitude 5.6, 1976 earthquake in Baffin Bay and suggest that the stresses due to glacial unloading are sufficient to reactivate old faults parallel to the margin. They used synthetic seismogram calculations to suggest a 65-km focal depth for the 1933 earthquake, a surprisingly large value that must be considered poorly controlled because of the sparse seismic data available. Reid and Falconer (1982), however, employed the results of a microearthquake survey using ocean-bottom seismographs to make a speculative suggestion that current seismicity might be occurring on the deep 1933 thrust plane.

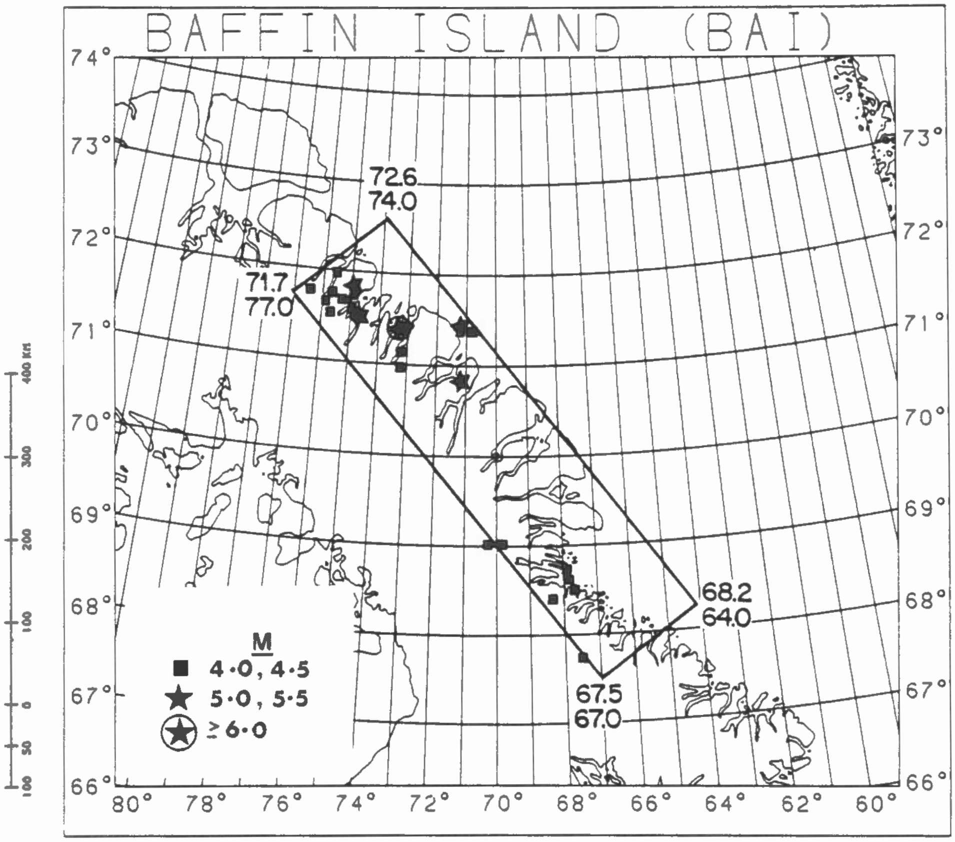
The magnitude recurrence relation for the Baffin Bay zone is reasonably well defined (Figure 55), but, as for the Laurentian Slope zone discussed above, the single large earthquake, when counted for the time period of complete reporting, produces too high a rate for that magnitude category. In this case a starting date of 1850 is imposed arbitrarily on the largest magnitude category (Table 1). The assigned maximum magnitude is 7.5; thus, we suggest that the 1933 earthquake was near to the maximum size that can occur at any location in Canada away from active plate boundaries.

Because the zone is poorly defined and the seismicity dominated by one large earthquake, the implications of this model for seismic risk in Baffin Bay are similar to those discussed above for the Laurentian Slope zone.

### 3.26 Baffin Island (BAI) (Figures 56, 57)

Prior to 1960 only one earthquake is known to have occurred on Baffin Island, a moderate M5.5-6 event in 1935. With the development of the seismograph network in the north in the 1960's, in particular the station at Frobisher in 1963, the northeastern portion of the island was found to be highly active. This activity appears to be confined to the coastal region, and does not occur much further inland than the heads of the fjords, although there are scattered epicentres, perhaps mislocations, that extend to the centre of the island (see Figure 8 of Basham et al., 1977). The seismicity is concentrated in the regions of Buchan Gulf and Home Bay. There is a possible gap between these two concentrations, but, because of the short history and the nature of the seismicity, the gap is not recognized in drawing the crude rectangular boundary for the zone shown in Figure 56.

The seismicity tends to occur in swarms, with many events of similar magnitude, rather than as typical mainshock-aftershock sequences. All available evidence on focal depths suggests the earthquakes are shallow. Hashizume (1973) determined depths of 4-6 km for the 1970, M4.4 and 1972, M5.1 earthquakes; Liu and Kanamori (1980) a depth of 7 km for the 1963, M6.1



EARTH PHYSICS BRANCH EMR OTTAWA CANADA

Figure 56

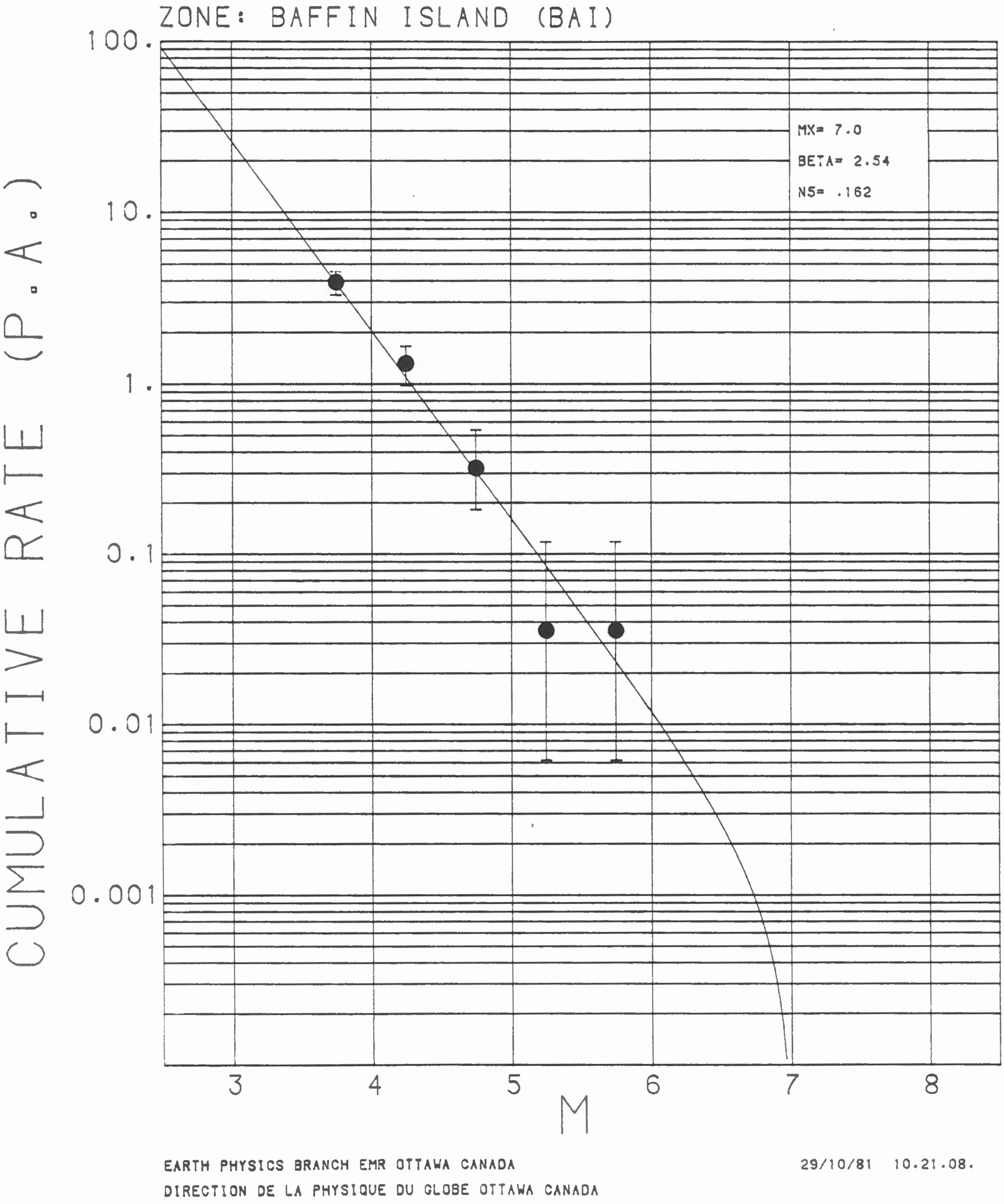

ZONE: BAFFIN ISLAND (BAI)
MX= 7.0
BETA= 2.54
N5= .162
CUMULATIVE RATE (P.A.)
100.
10.
1.
0.1
0.01
0.001
3
4
5
6
7
8
M
EARTH PHYSICS BRANCH EMR OTTAWA CANADA
DIRECTION DE LA PHYSIQUE DU GLOBE OTTAWA CANADA
29/10/81 10.21.08.

Figure 57

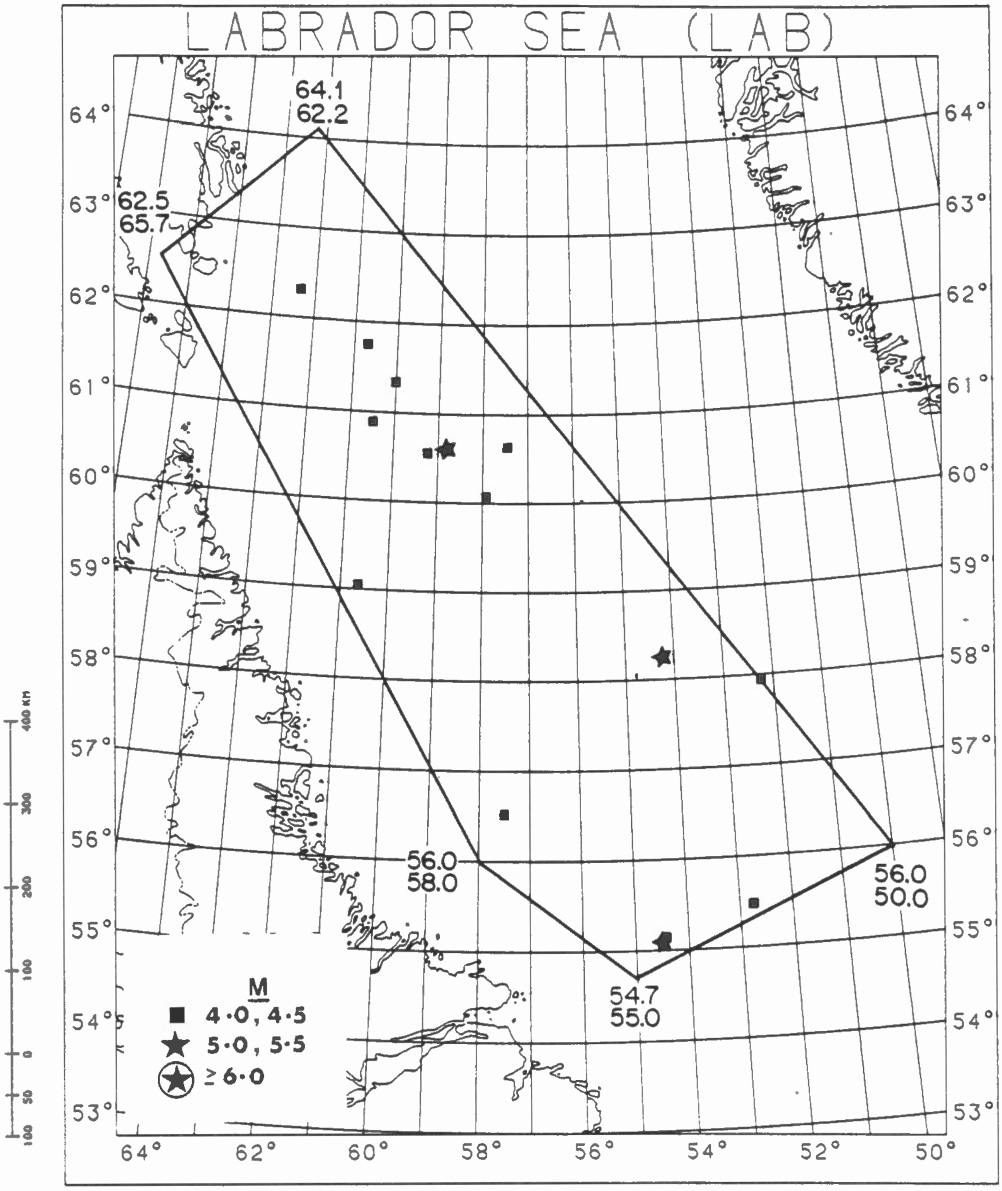
earthquake. Each of these earthquakes shows normal faulting, which Stein et al. (1979) attribute to reactivation of the basement faults by flexure caused by deglaciation. Basham et al. (1977) suggested that the centre of postglacial uplift over Foxe Basin is producing tilting of Baffin Island with a high differential uplift rate, or a hinge zone, in the region of seismicity along the northeastern coast.

The swarm-like nature of the Baffin Island seismicity results in a relatively large slope to the magnitude recurrence relation (Figure 57). The maximum magnitude selected is 7.0. This may be too large for shallow swarm seismicity but given the short earthquake history of the island it is considered a prudent choice.

### 3.27 Labrador Sea (LAB) (Figures 58, 59)

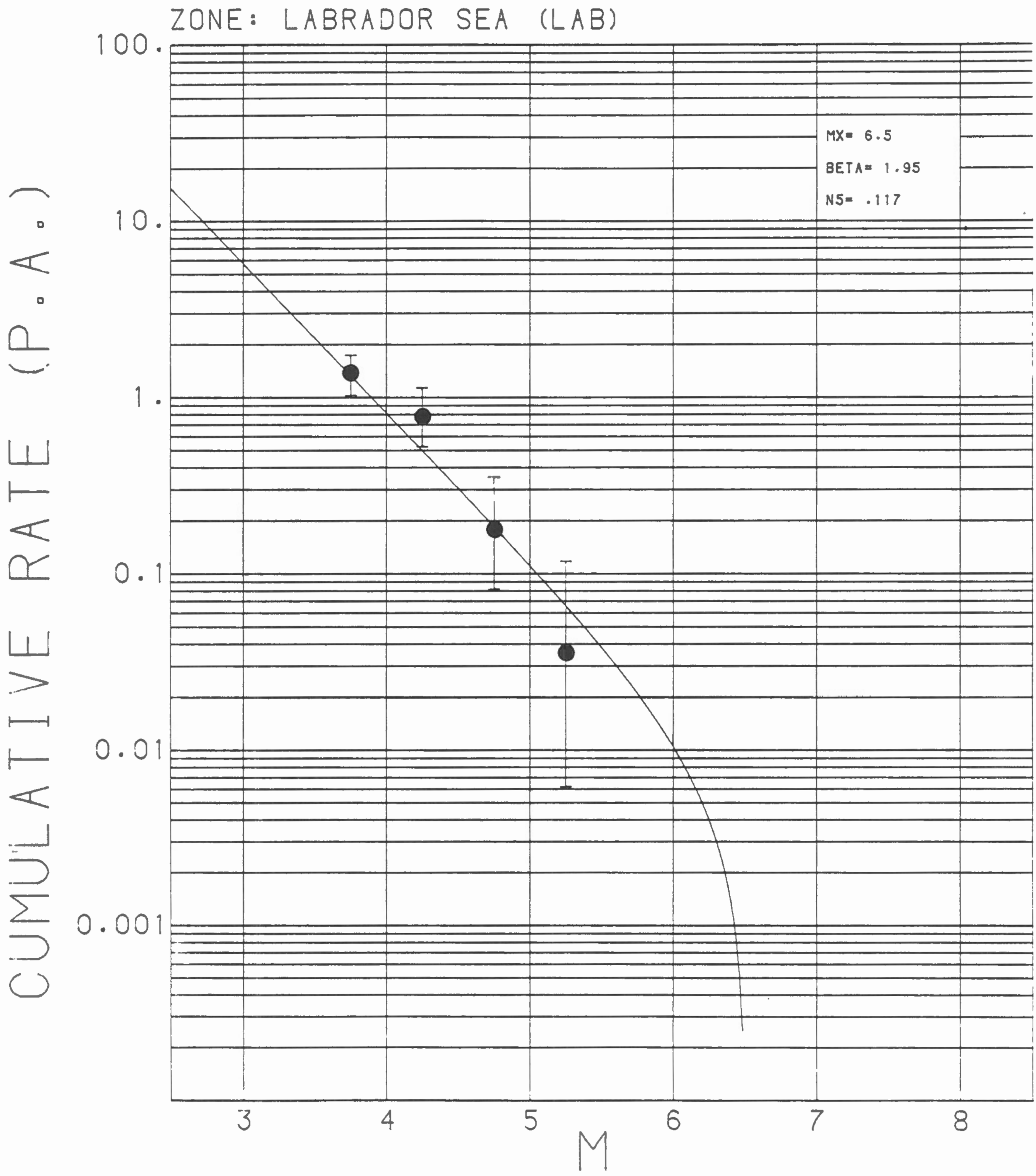
The known seismicity of the Labrador Sea includes six earthquakes in the M5.0 - 5.6 range (1934, 1952, 1956, 1958, 1962 and 1971, three of which pass the completeness test and are plotted in Figure 58), but none larger. There are reports of felt earthquakes from fishing villages along the Labrador coast as early as 1809 (Smith, 1962), and epicentres for these events have been assigned to the locations at which they were felt. However, there is no evidence from recent instrumental data that significant earthquakes are occurring onshore in this region. These older events likely occurred offshore and the zone defined here (Figure 58) is confined to the offshore region.

The Labrador Sea is a product of seafloor spreading and Srivastava (1978) has identified a central ridge and associated fracture zones from seismic and gravity profiles and linear magnetic anomalies. The central



EARTH PHYSICS BRANCH EMR OTTAWA CANADA

Figure 58



EARTH PHYSICS BRANCH EMR OTTAWA CANADA 29/10/81 16.09.48.
DIRECTION DE LA PHYSIQUE DU GLOBE OTTAWA CANADA

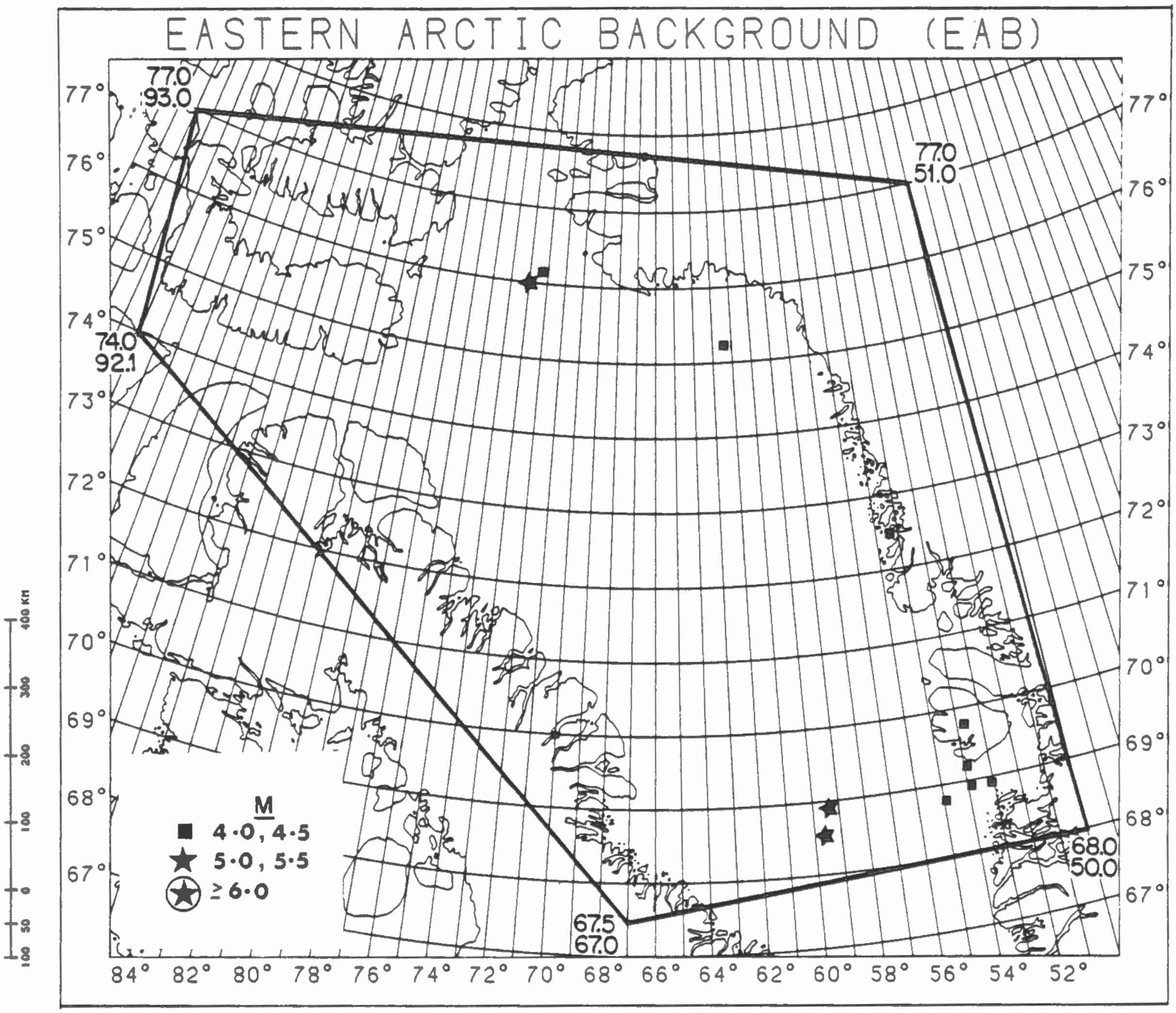
Figure 58

Labrador Sea epicentres lie near, but southwest of, the ridge structures; i.e., the ridge appears to be the northeastern boundary of the activity rather than a locus. No earthquakes have been located between the ridge and Greenland (see Figure 2 of Basham and Adams, 1982). There is an apparently separate trend of earthquakes that follows the ocean-continent boundary northward from a fracture zone offshore from Hamilton Inlet, merging with the ridge trend near the northernmost seafloor ridge features. Thus, in general terms, the earthquakes must be associated with pre-existing faults near the inactive ridge and beneath the rifted continental margin. With further research, it may be possible to divide the source zone into two parts based on these trends. The best known earthquake is the M5.6, 1971 event (the southernmost epicentre in Figure 58) for which Hashizume (1977) determined a dip-slip mechanism at a depth of 16 km due to deviatoric compressive stresses normal to the margin.

The magnitude recurrence relation (Figure 59) is not well defined and the choice of maximum magnitude is a difficult one. A value of 6.5 has been chosen, but there is no evidence to suggest that the continental margin of the Labrador Sea cannot experience a magnitude 7 earthquake similar to the two that have occurred in historic time in the Baffin Bay and Laurentian Slope zones discussed above.

### 3.28 Eastern Arctic Background (EAB) (Figures 60, 61)

The region surrounding the Baffin Bay and Baffin Island zones (as defined above) has experienced low levels of both historic and recent seismicity. This includes the regions of the continental margin of Greenland, northern Davis Strait, the northern portion of Baffin Bay and Lancaster Sound



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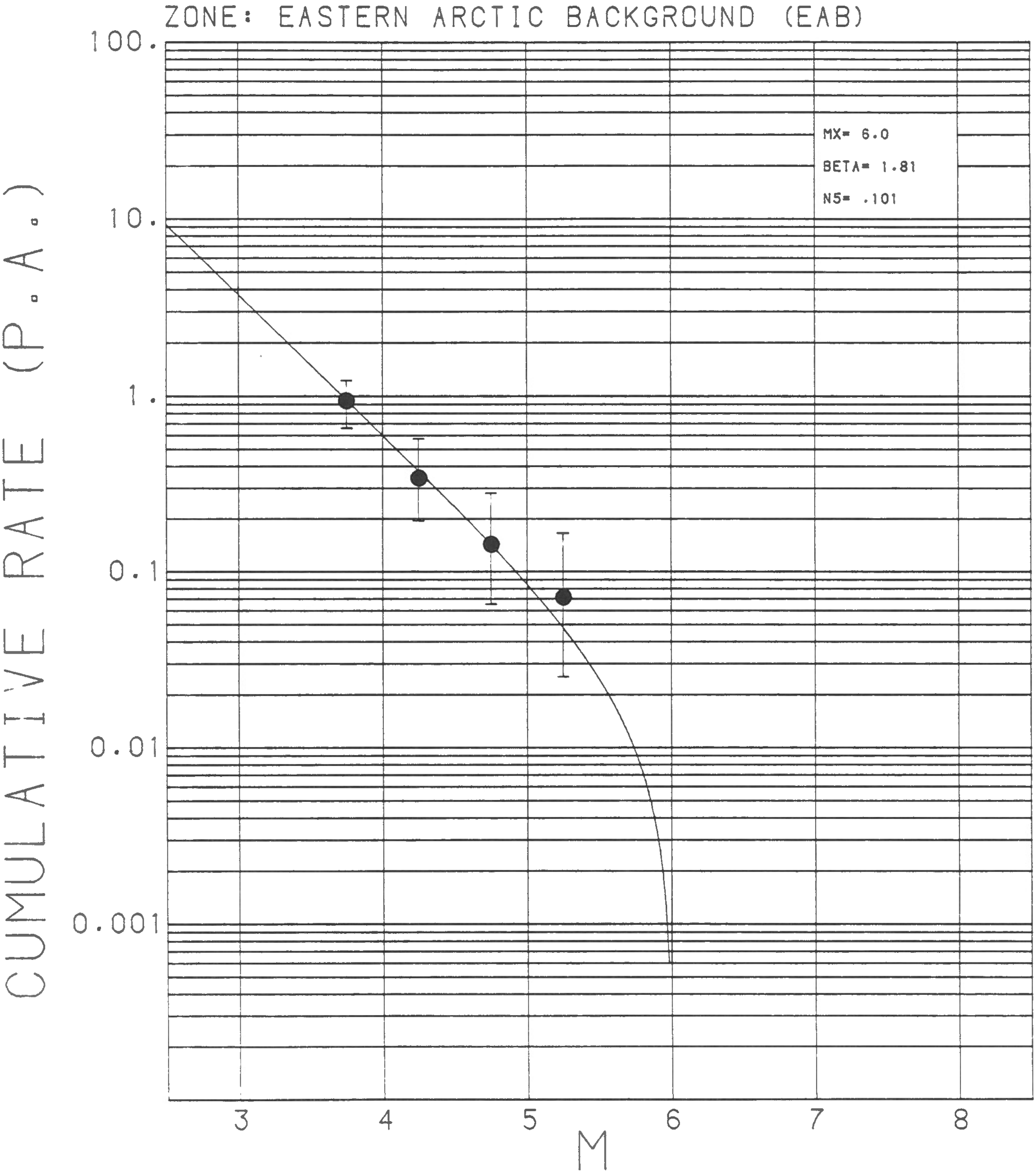
DIRECTION DE LA PHYSIQUE DU GLOBE EMR OTTAWA CANADA

Figure 60



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DIRECTION DE LA PHYSIQUE DU GLOBE OTTAWA CANADA

Figure 61

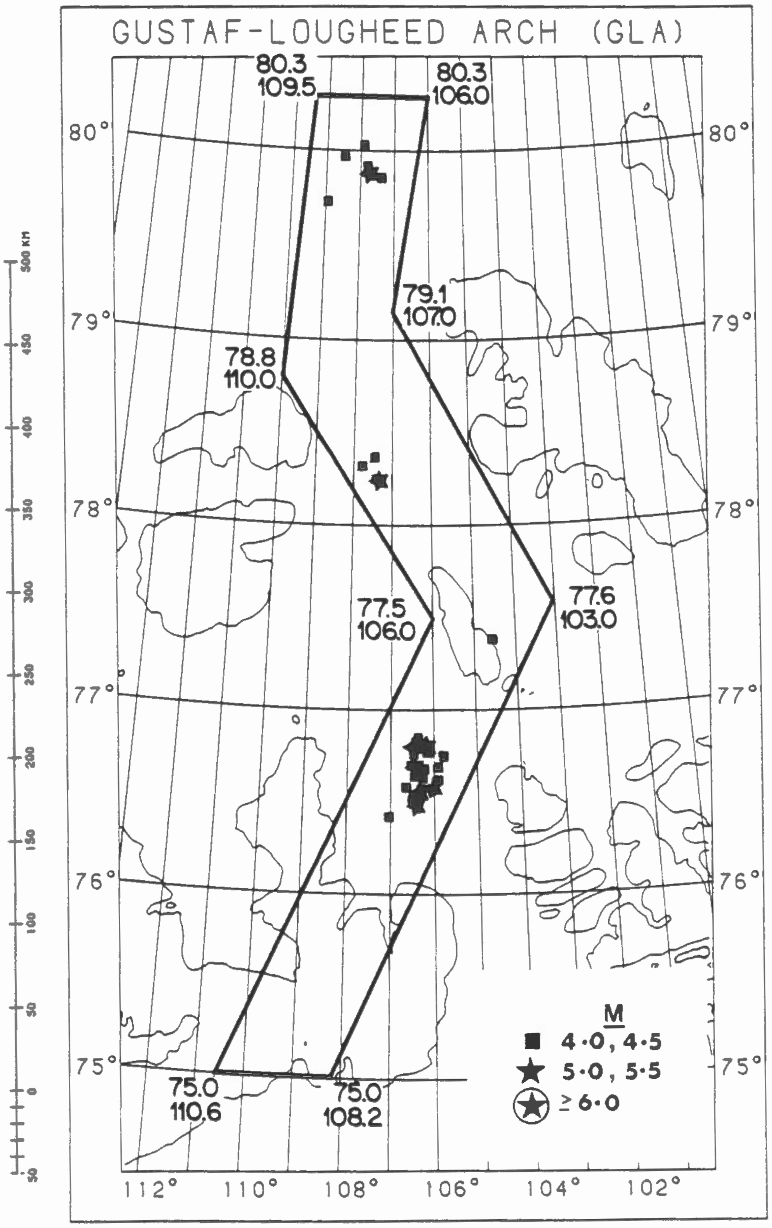
(Figure 60; see also Figure 2 of Basham et al., 1977). The Eastern Arctic Background zone, with rather arbitrary boundaries, is intended to account for this scattered seismicity.

Wetmiller and Forsyth (1982) have shown that Nares Strait, between Ellesmere Island and Greenland, is currently aseismic, but that a trend of epicentres from northern Baffin Bay appears to extend into Lancaster Sound. The Lancaster Sound events in their Figure 8 do not pass the completeness test for inclusion in Figure 60, although the northwestern boundary of the zone has been drawn to include this region. No earthquakes with magnitude greater than 4 have occurred in Davis Strait between the Eastern Arctic Background and the Labrador Sea zones since at least 1962 (Basham et al., 1977), and this region is considered to be aseismic in the present model (see Figure 5).

### 3.29 Gustaf-Lougheed Arch (GLA) (Figures 62, 63)

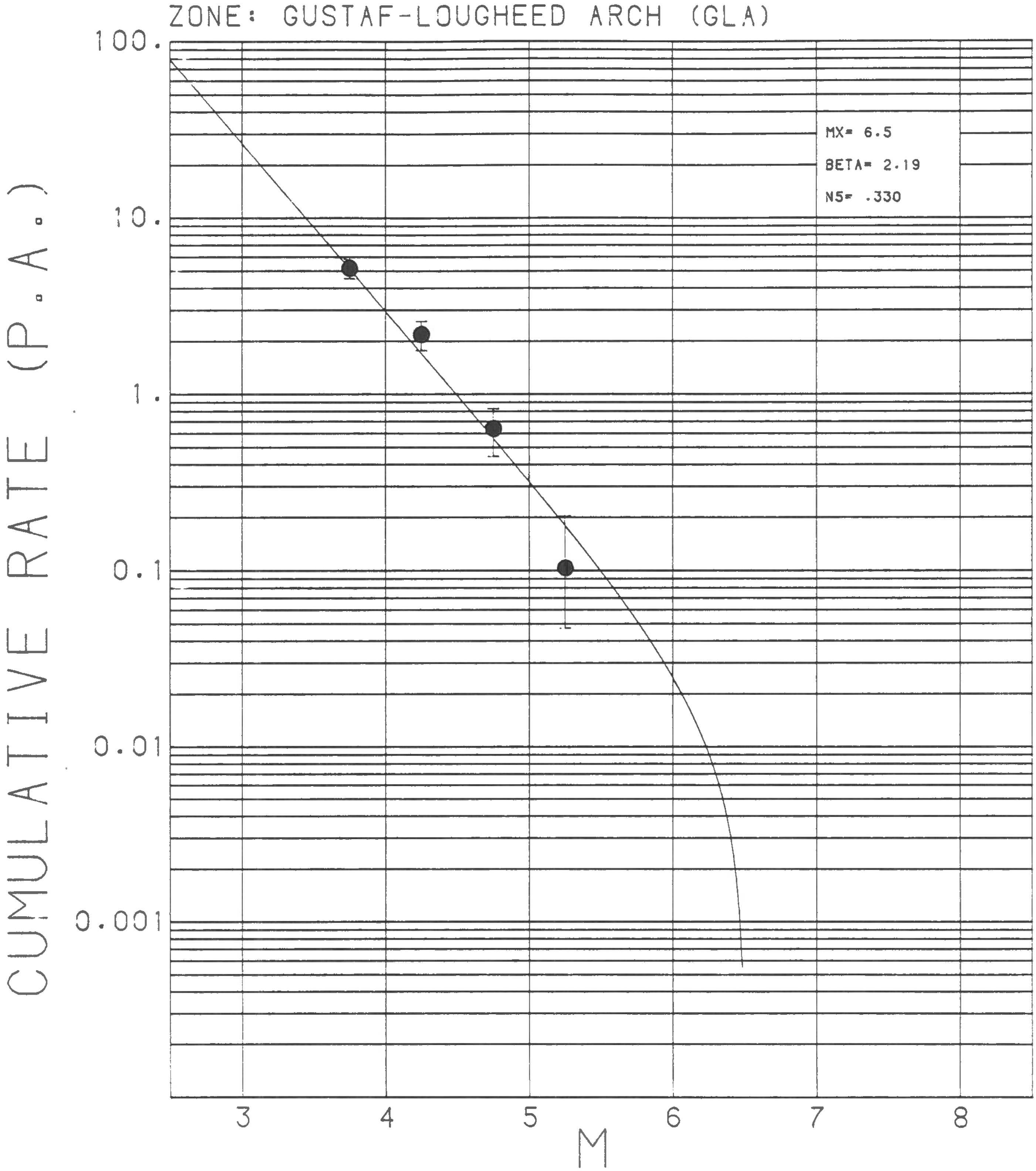
The Queen Elizabeth Islands seismicity is characterized by low to moderate magnitude, but often intense, earthquake swarms. The general cause of this seismicity is movement, suggested to be in response to the contemporary stress field, on unhealed faults that were formed or reactivated by Paleozoic and later orogenic phases (Basham et al., 1977; Forsyth et al., 1979; Wetmiller and Forsyth, 1982). However, because of the swarm-like nature of the seismicity, which has been observed to start abruptly in previously quiet areas, and the short observation period (about 20 years) it is highly unlikely that all potentially active regions of the islands have been identified.

A section through the Queen Elizabeth Islands that shows the highest levels of seismicity and for which there is some geological and geophysical



EARTH PHYSICS BRANCH EMR OTTAWA CANADA

Figure 62



EARTH PHYSICS BRANCH EMR OTTAWA CANADA 29/10/81 16.09.48.
DIRECTION DE LA PHYSIQUE DU GLOBE OTTAWA CANADA

Figure 63

evidence is defined here as the Gustaf-Lougheed Arch zone (Figure 62). The cluster of earthquakes in the Byam Martin Channel northeast of Melville Island occurred as intense swarms that started abruptly in 1972 (Basham et al., 1977). A similar but, to date, a less intense swarm occurred in Prince Gustaf Adolf Sea east of Borden Island in 1978. These latter events are included here, as an exception to the 1977 cut-off date used for a majority of the source zones, because they are important in defining the trend of the zone and are considered typical of the swarm activity to be expected along the zone in future. The zone is extended offshore to include the cluster of earthquakes on the continental slope north of Borden Island.

The name for this zone is taken from the Gustaf-Lougheed Arch, a structurally significant feature reflected in Bouguer gravity anomaly contours, that divides the western Sverdrup Basin into two separate sub-basins (Hea et al., 1979; Forsyth et al., 1979). The zone boundary in Figure 62 follows the outline of the arch from west of Elles Ringnes Island to southern Melville Island. Superimposed on the arch is a series of northeasterly trending minor magnetic highs reflecting mineralized faults or intrusive dykes.

The focal mechanisms for the four largest earthquakes in the Byam Martin Channel swarm (magnitudes 5.1 - 5.7) show deviatoric tension at depths from 9 km (just beneath the sediments of the Sverdrup Basin) to 31 km (Hasegawa, 1977), suggesting the fractures or dykes are loci of current seismic activity. A tensional regime along the Gustaf-Lougheed Arch suggests that current tectonic forces are similar to those in the Early Cretaceous responsible for the opening of the Arctic Ocean Basin (Sweeney et al., 1978).

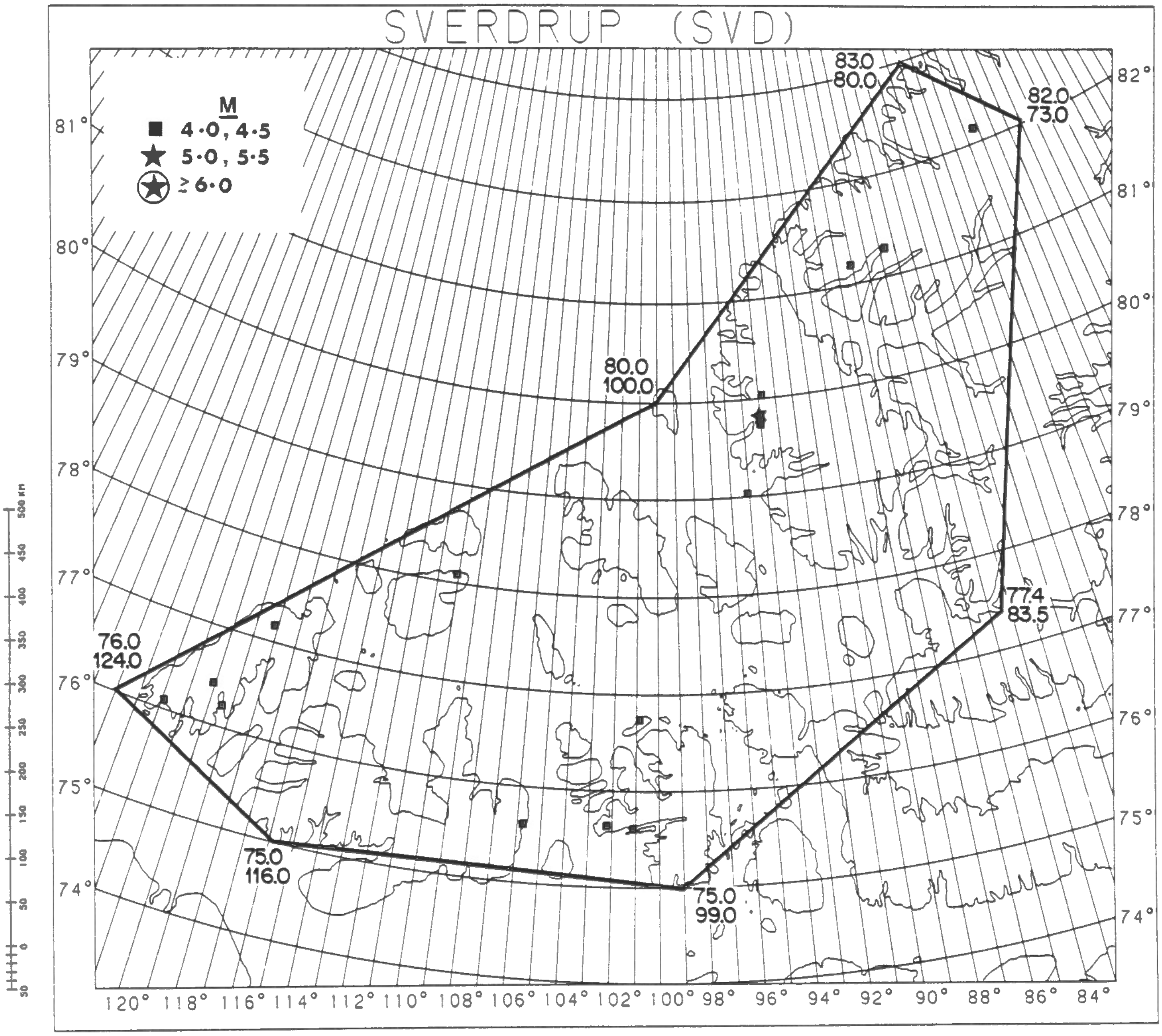
There is little evidence to extend the Gustaf-Lougheed Arch, itself, offshore to the cluster of epicentres on the continental slope, but there is other evidence of significant structures in the area. Submarine physiography indicates as much as 400 m of drowning over the continental shelf and slope offshore of Elles Ringnes Island, and submarine valleys on either side of the island trend toward the offshore cluster. This seismicity is on the seaward gradient of a large free air gravity anomaly, suggesting a region of stress adjustment to an uncompensated wedge of sediments (Basham et al., 1977).

There is no evidence on which to base a maximum magnitude (chosen as 6.5), but the choice does have an influence on the resulting probabilistic ground motion. The Gustaf Lougheed Arch zone produces a narrow zone of high acceleration (Figure 2), but a less pronounced zone of velocity (Figure 3).

### 3.30 Sverdrup (SVD) (Figures 64, 65)

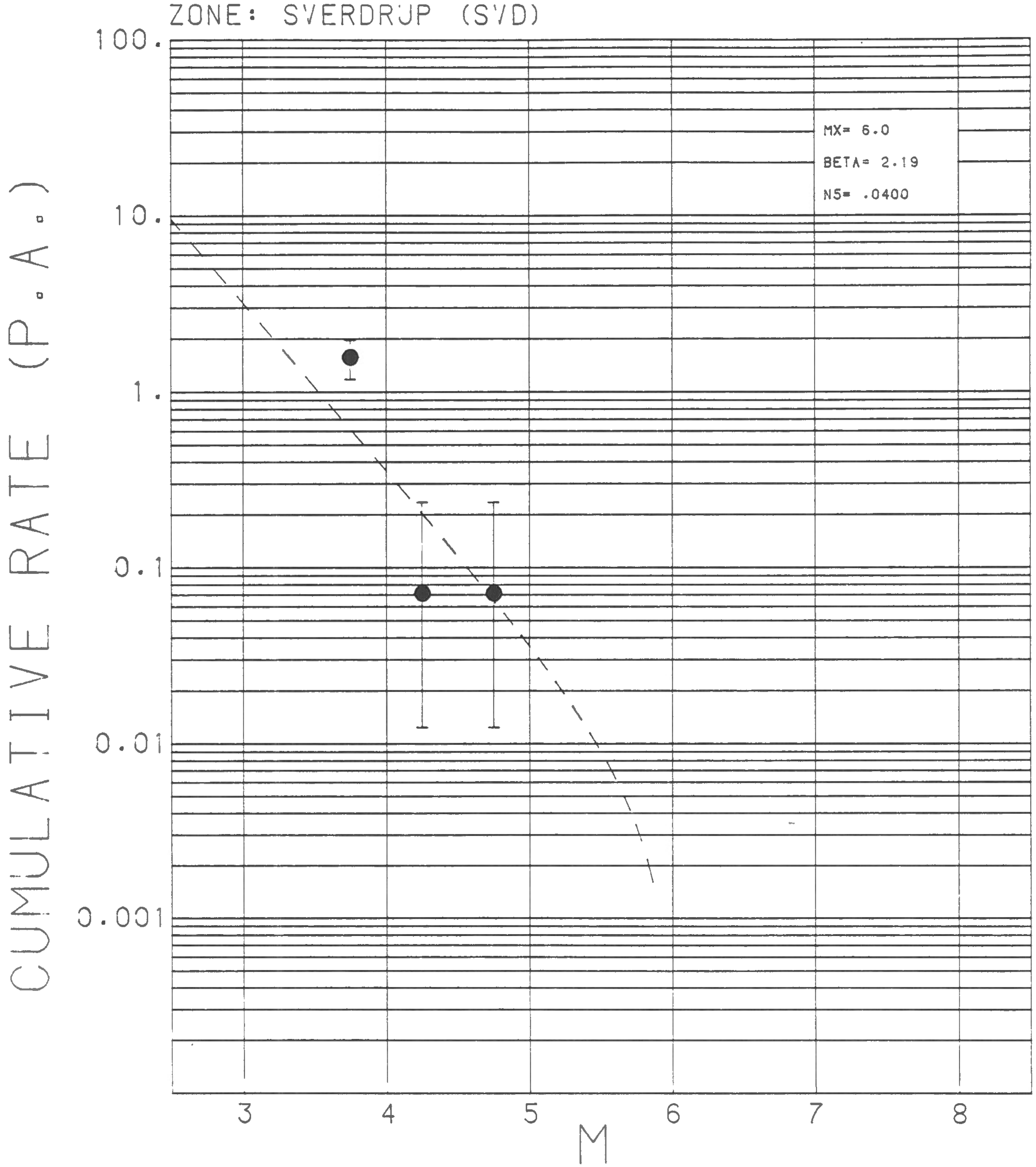
With the Gustaf-Lougheed Arch zone (above) defined separately, the remainder of the Sverdrup Basin is seen as having a broad scattering of low level seismicity. It is characterized by both intense low-magnitude swarms such as that which occurred on Prince Patrick Island in 1965 (Smith et al., 1968), and single larger events with few detectable aftershocks such as the M 5.2 event on western Axel Heiberg Island in 1975. There are, however, numerous smaller earthquakes, that do not pass the completeness test used here, with epicentres in the Sverdrup Basin. The boundaries for the zone shown in Figure 64 follow, as closely as possible with long straight-line segments, the outer edge of the Franklinian province that surrounds the basin (see Figure 1 in Sweeney (1976)).

The small number of earthquakes that pass the completeness test produces difficulties in defining a magnitude recurrence relation. The curve in Figure 65 is defined by imposing the recurrence slope for the Gustaf-Lougheed Arch zone on the rates estimated from the small number of Sverdrup zone earthquakes.



EARTH PHYSICS BRANCH EMR OTTAWA CANADA

Figure 64



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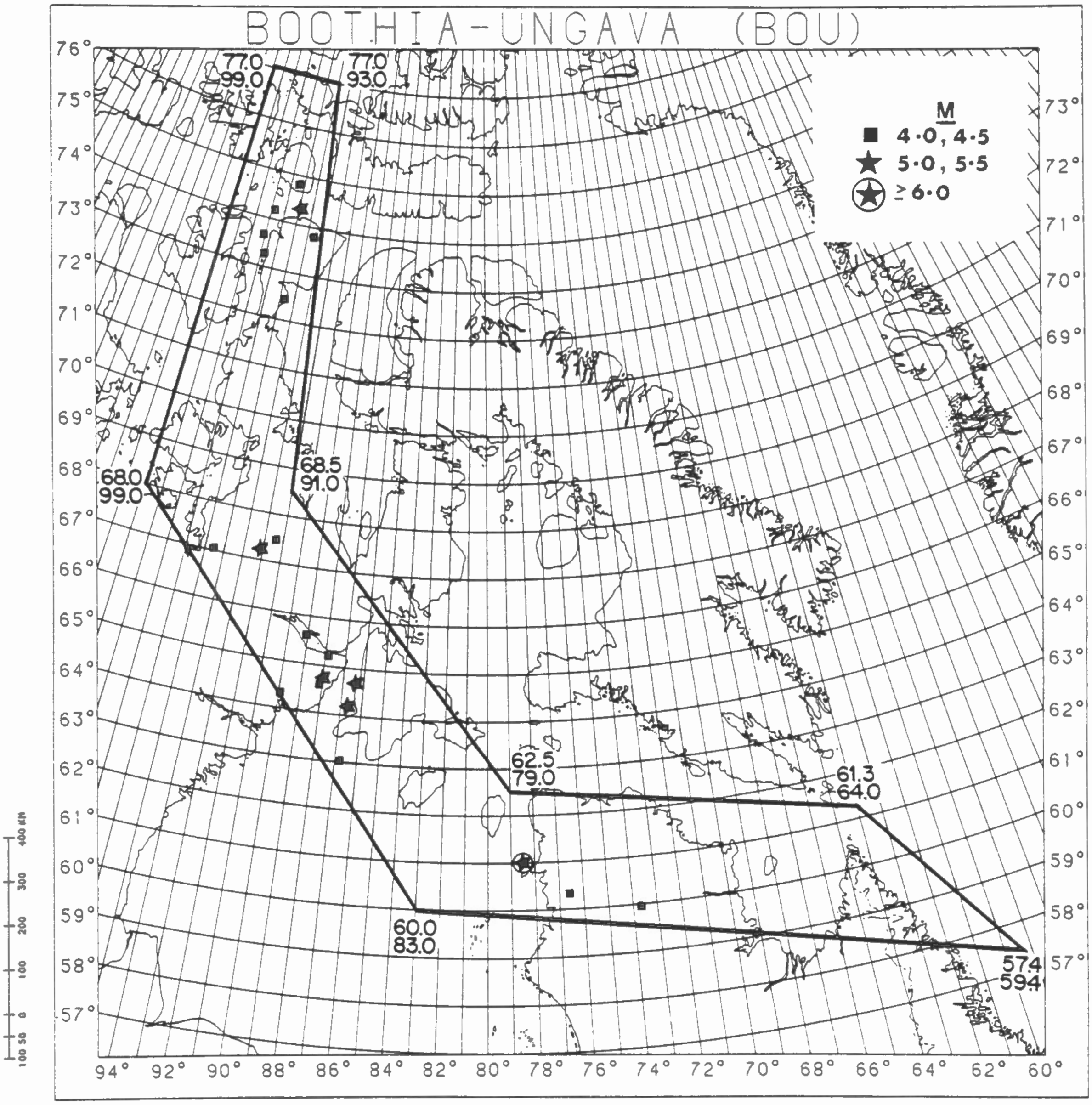
DIRECTION DE LA PHYSIQUE DU GLOBE OTTAWA CANADA

Figure 65

### 3.31 Boothia-Ungava (BOU) (Figures 66, 67)

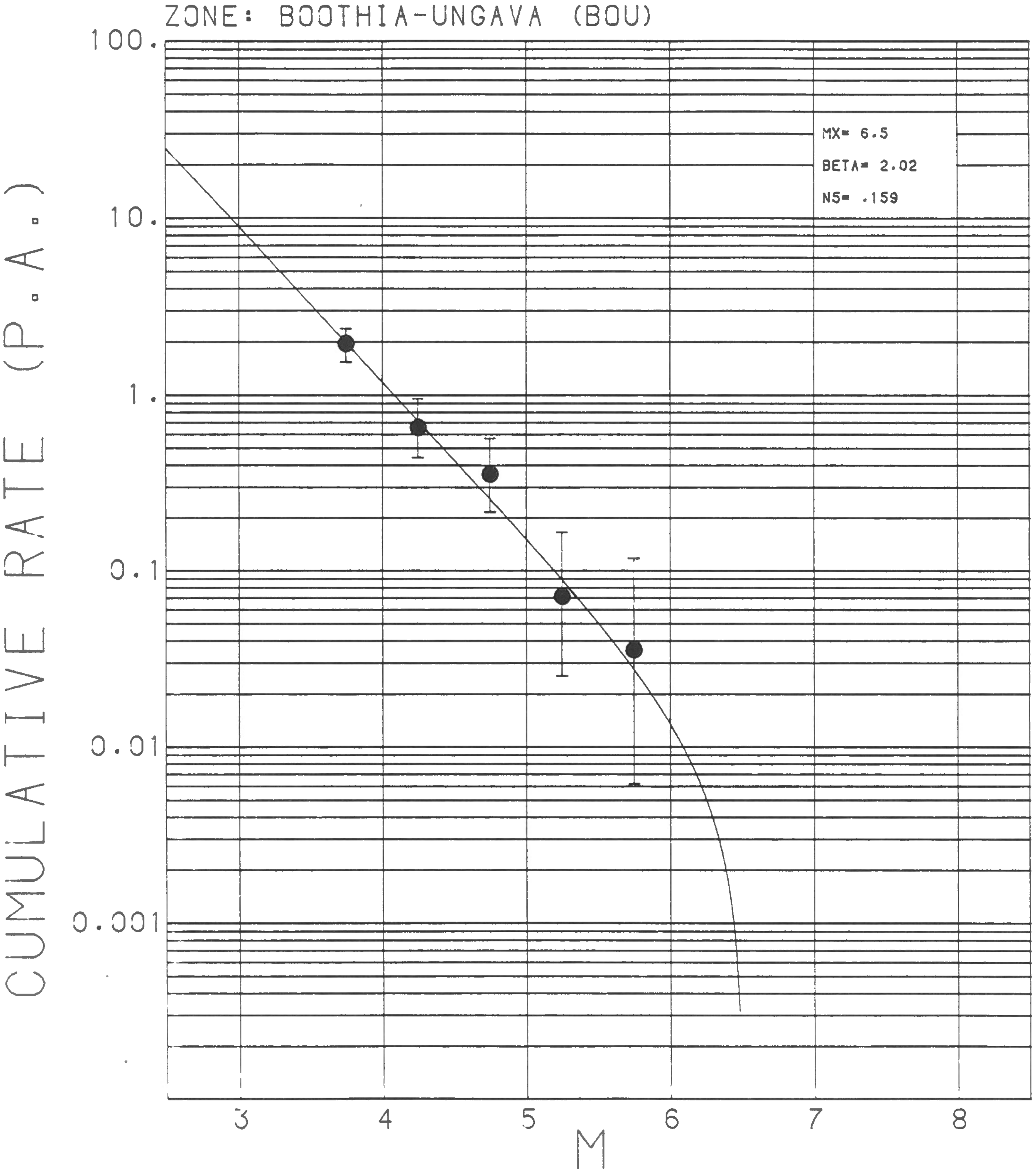
The seismicity of the Queen Elizabeth Islands is connected to the south by a concentration of epicentres in Barrow Strait south of Cornwallis Island, with a more diffuse trend through Somerset Island, down Boothia Peninsula and thence southeastward to a major cluster in the area of Wager Bay and Roes Welcome Sound. A less well-defined trend continues across the Ungava Peninsula and through Hudson Strait, connecting to the seismicity in the Labrador Sea. This seismicity is modelled here as one continuous narrow zone (Figure 66).

In general terms the seismicity in this arcuate band surrounds the southwestern half of the area of postglacial uplift centred over Foxe Basin, which led Basham et al., (1977) to speculate that the Baffin Island-Foxe Basin block is responding independently to postglacial uplift and may be decoupled from the rest of the shield to the southwest. Geological correlations are best at the north end where the seismicity shows a close relationship to the Boothia Uplift from Somerset and Prince of Wales Islands northward, meeting the Sverdrup Basin in the region of Grinnell Peninsula (Wetmiller and Forsyth, 1982). The Boothia Uplift, which has geologically demonstrated tectonic activity from the Paleozoic to the Cretaceous, continues to be active in present times. Seismological analysis shows that two earthquakes on the western edge of Southampton Island had focal depths of 17-21 km with thrust mechanisms due to northeast-southwest compression (Hashizume, 1974). The remaining seismicity through to the eastern end of Hudson Strait follows a broad deformational trend suggested by the Bell Arch and a series of horst-graben structures indicated in the bathymetry (Basham et al., 1977).



EARTH PHYSICS BRANCH EMR OTTAWA CANADA

Figure 66



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DIRECTION DE LA PHYSIQUE DU GLOBE OTTAWA CANADA

Figure 67

# 4. PROBABILISTIC SEISMIC GROUND MOTION ANALYSIS

The seismic risk calculations are made with an adaption of the McGuire (1976) computer program. This program has been modified for the Cyber system in the Energy, Mines and Resources Computer Science Centre and a program listing is included here as Appendix B. McGuire (1976) provides details of the functioning of the program and the various options available in its use. It is the purpose of this section to document special features of the program that are of concern in our application, some changes and additions that were made for this purpose, and the procedures used to make the calculations on a national-scale grid for purposes of contouring probabilistic peak acceleration and velocity (as shown in Figures 2 and 3).

## 4.1 Regionalization

There are two purposes for regionalizing the national-scale risk calculations: one is to accommodate the difference in strong seismic ground motion attenuation in western and eastern Canada; the other to avoid excessive calculations for a particular grid point by excluding source zones that will make no contribution to the resulting risk.

Hasegawa et al., (1981), in deriving separate strong motion attenuation relations for western and eastern Canada, defined a boundary between the two attenuation regions as following the eastern edge of Cordilleran tectonic province. This boundary is a distinctive physiographic feature at all locations along its length, except where it approaches the Beaufort Sea. The Beaufort Sea is included here in the western attenuation region, as it is viewed as being more analogous to the more recently tectonically active western region than to the less active eastern region. Thus, with reference to Figure 5, it can be seen that all of the contiguous western source zones are in the western attenuation region, and all of the contiguous eastern source zones and the Southern Saskatchewan zone are in the eastern attenuation region. In one area only, the western Arctic islands region, are the two sets of source zones close enough to produce significant ground motion in the other region. This is handled as described below.

To accommodate the two attenuation regions and to avoid excessive calculations for source zones that make no contribution, the country has been divided into the eight regions described in Table 3. Each of the eight regions has a separate computational grid for calculations of contributions from the indicated source zones within the indicated latitude and longitude bounds. Some source zones are included for two or three regions because they make contributions outside of their own region.

In the "Northwest-Northeast" region the calculations are made assuming that the ground motion propagates from the western source zones with western attenuation into the eastern region, and from the eastern source zones with eastern attenuation into the western region. The computer program normally cumulates risk at fixed ground motion levels and then interpolates to produce ground motion at fixed risk levels. For this region there is a special version of the program in which the two sets of risk cumulations are done separately, and then added together prior to the interpolation to produce ground motion at fixed risk levels.

## 4.2 Integration over Source Zones

Source zones and site locations are defined by geographical coordinates given in degrees of latitude and longitude. As the McGuire program was designed as a planar version using Cartesian coordinates, all of the

## Table 3

## Regionalization for Risk Calculations

### a) Region of eastern attenuation

1. "East": 41.0 to 50.0°N, 49.0 to 86.0°W
   Source zones: CHV, WQU, LSL, NAP, ATT, LSP and EBG

2. "East-North": 50.0 to 60.0°N, 50.0 to 90.0°W
   Source zones: CHV, WQU, LSL, NAP, LSP, EBG, LAB, GLA, SVD, BOU, BAI, BAB and EAB

3. "North-East": 60.0 to 85.0°N, 50.0 to 105.0°W
   Source zones: GLA, SVD, BOU, BAI, BAB, LAB and EAB

4. "Central": 46.0 to 51.0°N, 100.0 to 110.0°W
   Source zones: SAS, SBC, and FHL

### b) Region of western attenuation

5. "West": 47.0 to 53.0°N, 109.0 to 142.0°W
   Source zones: CAS, PGT, CSM, NVI, JFE, QCF, SPT, SBC, NBC and FHL

6. "West-North": 53.0 to 60.0°N, 110.0 to 145.0°W
   Source zones: CAS, PGT, CSM, NVI, JFE, SBC, FHL, QCF, SPT, NBC, FWY, DSK, RIC, MKZ, BFT, ALC and ALI

7. "North-West": 60.0 to 68.0°N, 110.0 to 145.0°W
   Source zones: FWY, DSK, RIC, MKZ, BFT, QCF, SPT, NBC, ALC and ALI

### c) Region requiring eastern and western attenuation

8. "Northwest-Northeast": 68.0 to 82.0°N, 91.0° to 145.0°W
   Source zones with western attenuation: FWY, DSK, RIC, MKZ, BFT, QCF, SPT, NBC, ALC and ALI

   Source zones with eastern attenuation: GLA, SVD, BOU, BAI, BAB, LAB and EAB.

geographic coordinates are transformed into eastings and northings in kilometres using a Lambert Conformal projection, with each region given its own central meridian. Any distortion in the calculated distances is well below the accuracy of the distances required in estimating ground motion.

In integrating the contributions to the risk at a site from a source zone, the source zone is divided into finite arc segments, the radii of which pivot on the site. The size of the arc segments is a function of the gross source dimensions and the program parameter NSTEP. As NSTEP is increased the area covered by the arc segments tends to the correct area of the source zone. A value of NSTEP = 10 is found to be adequate in most cases, as increasing it does not significantly change the calculated values. However, the computation time does increase with NSTEP so NSTEP is kept as small as possible, the limitation being the area error that will be tolerated. For some site-source combinations, a value of NSTEP = 10 leads to significant area errors. If the area error is greater than ERRBND percent (20 is used in current applications) then NSTEP is automatically doubled and the calculation repeated until either the error is less than ERRBND or NSTEP reaches the assigned maximum value of NSTEPMX. If NSTEP reaches NSTEPMX, the flag LERR is set for the calculation. After contributions from all source zones are integrated, the ratio of the flagged to unflagged risk cumulations is computed. If this ratio is less than RKRATO (0.05 is used in current applications), the result is accepted; otherwise the total risk for the site is flagged. When contouring risk computed on a grid (see section 4.6), flagged grid points are omitted.

The program parameter RZ2 defines the closest distance from site to source zone beyond which the earthquakes are considered lumped at the centre of the source zone. In the original program RZ2 was fixed at 300 km with no provision for redefinition. To allow for various source zone geometries for which RZ2 = 300 is not the most appropriate, a change has been made to read in this parameter with the other source zone parameters. In the current application RZ2 = 600 has been used for the following source zones: FWY, ALC, ALI, QCF, SPT, LAB, GLA and BOU.

## 4.3 Treatment of Other Errors

In subroutines INSIDE and OUTSIDE some types of errors can occur which are a function of the site-source geometry and result in no risk being computed. For example, the distance to the nearest zone boundary may become zero. Again NSTEP is increased as described above to try to eliminate the problem. If the error persists LERR2 is set "true" and the result is flagged.

In all cases a message is printed when these errors occur giving the site location and the source zone in which the error is encountered. If an output is desired in order to see what values are being calculated, the omission of erroneous results can be cancelled by setting INCLUD and/or INCLUD2. Re-definition of source zone geometries in the area of the site will usually be necessary if a valid estimate is required in these cases.

In the current calculations for Figures 2 and 3, only three grid points, out of more than 6000, had to be omitted. These were at 51.0°N, 122.0°W, at the junction of the CSM, SBC and CAS zones in southern British Columbia; at 61.0°N, 145.0°W, at the junction of the FWY, DSK, ALI and ALC zones in Alaska; and at 67.5°N, 67.0°W, at the common corner of the BAI and EAB zones on Baffin Island (see Figure 5). Five other grid points had area errors greater than 20 percent for NSTEP=10, but these were reduced to less than 20 percent by the automatic recalculation with NSTEP increased.

### 4.4 Limiting Ground Motion from Large Magnitudes

As noted in Section 2.3, the expressions for strong seismic ground motion attenuation derived by Hasegawa et al. (1981) did not limit ground motion contributions at large magnitudes. For current computations this has been implemented in the program (see subroutine RISK1 in Appendix B) by modifying the magnitude recurrence relation so that all expected events greater than M7.5 are compressed into a Delta function (a spike) at M7.5.

### 4.5 Statistical Scatter on Attenuation

The program provides for the inclusion of a standard deviation on the logarithm of the ground motion parameter whose mean value is defined by the attenuation relation, and a normal distribution is assumed. In the current application this variable (SIG) is set to 0.7, the natural logarithm of 2; i.e., the standard deviation on both peak acceleration and velocity are assumed to be a factor of 2.

### 4.6 Computation Grid and Contouring

The ground motion values for Figures 2 and 3 were computed using the grid of points listed in Table 4. This grid has a maximum spacing of 57 km in latitude and 90 km in longitude, with progressively smaller longitude spacing to the north. The computations were stored on a computer file containing latitude, longitude, risk values and their corresponding acceleration and velocity values.

The contouring of the data was done in five regions, east, northeast, west, northwest and central. For each region the data from the risk program were first combined through a program that projects latitude and longitude

## Table 4

## Computation Grid used for Contouring

| Map Sheet | Lat. Boundaries | Step | Long. Boundaries | Step |
|---|---|---|---|---|
| 1 | 41.0 - 49.5 | 0.5 | 86.0 - 50.0 | 1.0 |
| 2 | 50.0 - 59.5 | 0.5 | 90.0 - 50.0 | 1.0 |
| 3 | 60.0 - 62.5 | 0.5 | 95.0 - 50.0 | 1.0 |
|  | 63.0 - 65.5 | 0.5 | 100.0 - 50.0 | 1.0 |
|  | 66.0 - 67.5 | 0.5 | 105.0 - 50.0 | 1.0 |
|  | 68.0 - 79.5 | 0.5 | 90.0 - 50.0 | 1.0 |
|  | 80.0 - 85.0 | 1.0 | 90.0 - 50.0 | 2.0 |
| 4 | 68.0 - 79.5 | 0.5 | 145.0 - 91.0 | 1.0 |
|  | 80.0 - 85.0 | 1.0 | 145.0 - 90.0 | 2.0 |
| 5 | 60.0 - 67.5 | 0.5 | 145.0 - 110.0 | 1.0 |
| 6 | 53.0 - 59.5 | 0.5 | 145.0 - 110.0 | 1.0 |
| 7 | 47.0 - 52.5 | 0.5 | 142.0 - 110.0 | 1.0 |
| 8 | 42.0 - 46.5 | 0.5 | 137.0 - 110.0 | 1.0 |
| 9 | 46.0 - 51.0 | 0.5 | 110.0 - 101.0 | 1.0 |
| 10 | 66.0 - 67.5 | 0.5 | 109.0 - 106.0 | 1.0 |
|  | 63.0 - 65.5 | 0.5 | 109.0 - 101.0 | 1.0 |
|  | 60.0 - 62.5 | 0.5 | 109.0 - 96.0 | 1.0 |

into eastings and northings (x and y) on a Lambert projection at a fixed scale. The input data were selected so as to extend beyond the area to be contoured in order to obtain continuity in the contours between regions and to avoid edge effects. The output from this program was formatted so as to be compatible with the program GPCP described below.

The contouring was done with the "General Purpose Contouring Program" (GPCP), a product of the Calcomp Company, which resides on the EM&R Computer Science Centre Cyber system. By using the x and y dimensions obtained from the projection program, the contours are properly scaled to the scale selected for the map area. The GPCP program requires the x-y grid to be specified so that each cell contains no more than one data point. Cell size can be calculated knowing the latitude-longitude grid, as specified in Table 4, and the x and y dimensions as provided by the projection program.

The method of contouring is described in detail by the GPCP users guide prepared by the Computer Science Centre. Briefly, the method is as follows. Using data supplied on the "SIZX" input card, a uniform x-y grid is established, the data at each grid point being approximated by a function defined by the nearest "n" data points. "n" can be defined on the"CNTL" card; the default value of n=8 was used. To generate smooth contours, each grid cell is divided into a finer sub-grid using a third-order interpolation, and the contour lines are drawn as short straight-line segments between the sub-grid points. The default value of 5 was used to divide both the x and y sides of each grid cell.

The final contour maps were drafted from the five partially-overlapping region maps. Some "chatter" in the contours occurs due to the finite grid spacing of the calculations (Table 4), which is smoothed by hand during drafting. This "chatter" could be removed by a denser original grid, but the extra computations are not considered justified for the resolution required in the final maps.

## 4.7 Site-Specific Risk Calculations

The earthquake source zones as defined in Section 3 above and the computer program listed in Appendix B will be maintained by the Earth Physics Branch on the Computer Science Centre Cyber system. This package of input data and computation method will remain intact for some years in order that computations can be made at any time, equivalent to those used for the contour maps recommended as new zoning maps for the National Building Code.

Using this package, the Earth Physics Branch will undertake site-specific risk calculations on request for a nominal fee. A sample of the output information for a site-specific calculation is given in Table 5. The request will specify a site with geographical coordinates. The output will be peak acceleration and velocity for the four risk levels indicated. The risk level of 0.002105 per annum is equivalent to a probability of 10 percent exceedence in 50 years (e.g., Figures 2 and 3) that has been recommended for the National Building Code zoning maps.

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TABLE 5

```
ENERGY, MINES AND                          ENERGIE, MINES ET
RESOURCES CANADA                           RESSOURCES CANADA
EARTH PHYSICS BRANCH                       DIRECTION DE LA PHYSIQUE DU GLOBE



SEISMIC RISK CALCULATION *                 CALCUL DE RISQUE SEISMIQUE *



REQUESTED BY
                         SEISMIC HAZARDS AND APPLICATIONS EPB/EMR
DEMANDE PAR


FOR SITE
                                     OTTAWA, CANADA
POUR SITE


LOCATED AT
                        45.39 NORTH/NORD     75.72 WEST/OUEST
LOCATION


PROBABILITY OF EXCEEDENCE
PER ANNUM
                                .01       .005      .002105      .001
PROBABILITE DE
DEPASSEMENT PAR ANNEE

PEAK HORIZONTAL
ACCELERATION (%G)
                                8.4       12.3       20.0        28.3
ACCELERATION HORIZONTALE
MAXIMALE (%G)

PEAK HORIZONTAL
VELOCITY (CM/SEC)
                                3.1        5.4        9.8        15.2
VITESSE HORIZONTALE
MAXIMALE (CM/SEC)



* REFERENCE
NEW PROBABILISTIC STRONG SEISMIC GROUND
MOTION MAPS OF CANADA: A COMPILATION OF EARTHQUAKE
SOURCE ZONES, METHODS AND RESULTS
P.W. BASHAM, D.H. WEICHERT, F.M. ANGLIN, AND M.J. BERRY
EARTH PHYSICS BRANCH OPEN FILE NUMBER 82-
OTTAWA, CANADA 1982
                                                    09/12/82  12.48.13.
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# APPENDIX A

Earthquakes that pass the completeness test of Table 1, that are employed to estimate magnitude recurrence relations, and that are plotted on each of the source zone maps, are listed on the following pages.

## PUGET SOUND (PGT)

| YR | MO | DA | HR | MN | SC | LAT | LONG | M |
|---|---|---|---|---|---|---|---|---|
| 1909 | 01 | 11 | 23 | 49 |  | 48.7 | 122.8 | 6.0 |
| 1939 | 11 | 13 | 7 | 45 | 53 | 47.50 | 122.40 | 5.7 |
| 1943 | 11 | 29 | 01 | 43 |  | 48.40 | 122.90 | 5.0 |
| 1946 | 2 | 15 | 3 | 14 | 50 | 47.30 | 122.90 | 6.3 |
| 1949 | 4 | 13 | 19 | 55 | 36 | 47.20 | 122.60 | 7.1 |
| 1954 | 5 | 15 | 13 | 2 | 32 | 47.40 | 122.50 | 5.0 |
| 1957 | 01 | 26 | 01 | 16 | 07 | 48.29 | 122.60 | 5.0 |
| 1960 | 9 | 10 | 15 | 6 | 34 | 47.50 | 122.70 | 4.9 |
| 1962 | 12 | 31 | 20 | 49 | 35 | 47.00 | 122.00 | 5.0 |
| 1963 | 1 | 24 | 21 | 43 | 0 | 47.40 | 122.10 | 5.0 |
| 1964 | 10 | 14 | 6 | 33 | 0 | 47.70 | 122.10 | 4.6 |
| 1965 | 4 | 29 | 15 | 28 | 44 | 47.40 | 122.30 | 6.5 |
| 1965 | 10 | 23 | 16 | 28 | 3 | 47.50 | 122.40 | 4.8 |
| 1967 | 3 | 7 | 3 | 51 | 8 | 47.70 | 122.70 | 4.1 |
| 1967 | 05 | 25 | 23 | 22 | 35 | 48.20 | 122.81 | 4.3 |
| 1968 | 6 | 19 | 5 | 51 | 43 | 47.20 | 122.50 | 4.0 |
| 1968 | 9 | 6 | 12 | 16 | 30 | 47.95 | 122.80 | 3.9 |
| 1969 | 2 | 14 | 8 | 33 | 36 | 48.94 | 123.07 | 4.3 |
| 1970 | 5 | 18 | 5 | 29 | 54 | 48.60 | 122.70 | 4.0 |
| 1971 | 1 | 25 | 21 | 37 | 53 | 48.70 | 123.00 | 3.8 |
| 1971 | 12 | 28 | 7 | 50 | 0 | 47.60 | 122.20 | 4.0 |
| 1972 | 11 | 9 | 4 | 19 | 17 | 48.24 | 123.55 | 3.9 |
| 1974 | 5 | 16 | 13 | 4 | 36 | 48.14 | 122.92 | 3.8 |
| 1975 | 4 | 23 | 1 | 3 | 43 | 47.11 | 122.63 | 3.8 |
| 1976 | 5 | 16 | 8 | 35 | 15 | 48.80 | 123.34 | 5.4 |
| 1976 | 9 | 2 | 13 | 36 | 11 | 48.19 | 122.72 | 4.5 |
| 1976 | 9 | 8 | 8 | 21 | 2 | 47.38 | 123.08 | 4.8 |

## CASCADES (CAS)

| YR | MO | DA | HR | MN | SC | LAT | LONG | M |
|---|---|---|---|---|---|---|---|---|
| 1872 | 12 | 14 |  |  |  | 48.3 | 120.3 | 7.4 |
| 1904 | 3 | 17 | 4 | 21 | 0 | 47.50 | 124.00 | 6.0 |
| 1945 | 4 | 29 | 20 | 16 | 17 | 47.40 | 121.70 | 5.5 |
| 1959 | 11 | 23 | 18 | 15 | 25 | 46.67 | 121.75 | 4.8 |
| 1961 | 9 | 16 | 3 | 24 | 58 | 46.00 | 122.20 | 4.3 |
| 1961 | 9 | 17 | 15 | 56 | 0 | 46.00 | 122.20 | 5.0 |
| 1961 | 10 | 31 | 2 | 35 | 0 | 48.40 | 120.00 | 4.3 |
| 1964 | 1 | 26 | 21 | 41 | 0 | 46.10 | 122.40 | 4.3 |
| 1966 | 8 | 17 | 14 | 39 | 50 | 48.20 | 125.00 | 3.8 |
| 1966 | 12 | 8 | 12 | 44 | 26 | 48.30 | 120.00 | 3.8 |
| 1969 | 10 | 9 | 17 | 7 | 58 | 46.90 | 121.60 | 4.4 |
| 1969 | 11 | 1 | 15 | 44 | 25 | 47.90 | 121.70 | 4.1 |
| 1969 | 11 | 10 | 07 | 38 | 45 | 48.55 | 121.51 | 4.3 |

## CASCADES (CAS) (CONTINUED)

| YR | MO | DA | HR | MN | SC | LAT | LONG | M |
|---|---|---|---|---|---|---|---|---|
| 1971 | 11 | 23 | 2 | 12 | 19 | 48.32 | 121.44 | 4.1 |
| 1973 | 7 | 18 | 21 | 58 | 7 | 46.94 | 121.91 | 3.8 |
| 1974 | 4 | 20 | 3 | 0 | 9 | 46.76 | 121.52 | 4.8 |
| 1975 | 4 | 10 | 10 | 57 | 18 | 46.95 | 121.62 | 3.8 |
| 1975 | 11 | 30 | 10 | 48 | 21 | 49.23 | 123.62 | 4.9 |
| 1975 | 12 | 11 | 15 | 2 | 45 | 49.24 | 123.78 | 3.8 |
| 1976 | 1 | 18 | 8 | 38 | 11 | 48.52 | 124.63 | 3.9 |

## NORTHERN VANCOUVER ISLAND (NVI)

| YR | MO | DA | HR | MN | SC | LAT | LONG | M |
|---|---|---|---|---|---|---|---|---|
| 1918 | 12 | 06 | 08 | 41 | 06 | 49.62 | 125.92 | 7.0 |
| 1927 | 05 | 07 | 22 | | | 50.15 | 127.85 | 5.5 |
| 1946 | 6 | 23 | 17 | 13 | 25 | 49.76 | 125.34 | 7.3 |
| 1957 | 12 | 16 | 17 | 27 | 48 | 49.82 | 126.48 | 6.0 |
| 1965 | 12 | 30 | 4 | 0 | 40 | 50.20 | 127.30 | 3.4 |
| 1966 | 1 | 13 | 7 | 49 | 6 | 49.67 | 126.82 | 4.0 |
| 1972 | 7 | 5 | 10 | 16 | 39 | 49.59 | 127.18 | 5.7 |
| 1974 | 2 | 12 | 3 | 4 | 53 | 50.21 | 127.61 | 3.4 |
| 1974 | 7 | 20 | 19 | 15 | 57 | 49.70 | 127.04 | 4.2 |
| 1974 | 9 | 20 | 11 | 33 | 49 | 50.10 | 127.79 | 3.5 |
| 1975 | 3 | 31 | 5 | 48 | 38 | 49.27 | 125.96 | 5.4 |
| 1975 | 11 | 29 | 10 | 50 | 30 | 49.43 | 126.79 | 4.4 |
| 1976 | 11 | 17 | 23 | 24 | 32 | 49.44 | 126.15 | 4.3 |
| 1978 | 05 | 25 | 21 | 53 | 44 | 50.20 | 127.70 | 3.3 |
| 1978 | 06 | 02 | 20 | 41 | 45 | 50.13 | 127.64 | 5.1 |
| 1978 | 06 | 03 | 11 | 54 | 40 | 50.19 | 127.60 | 4.6 |
| 1978 | 06 | 12 | 10 | 52 | 23 | 50.22 | 127.64 | 3.9 |
| 1978 | 06 | 13 | 11 | 39 | 30 | 50.23 | 127.53 | 3.6 |
| 1978 | 07 | 25 | 23 | 30 | 55 | 50.19 | 127.37 | 5.3 |

## COAST MOUNTAINS (CSM)

| YR | MO | DA | HR | MN | SC | LAT | LONG | M |
|---|---|---|---|---|---|---|---|---|
| 1926 | 09 | 17 | 23 | 14 | 36 | 50.0 | 123.0 | 5.5 |
| 1942 | 01 | 31 | 06 | 49 | 11 | 51.18 | 123.58 | 5.5 |
| 1959 | 01 | 15 | 19 | 16 | 10 | 50.50 | 128.90 | 4.2 |
| 1959 | 12 | 29 | 12 | 7 | 15 | 52.30 | 127.80 | 3.8 |
| 1960 | 03 | 10 | 02 | 06 | 00 | 51.00 | 128.00 | 4.5 |
| 1961 | 7 | 24 | 10 | 39 | 24 | 50.60 | 128.90 | 3.9 |
| 1964 | 1 | 31 | 17 | 7 | 43 | 51.60 | 125.50 | 4.2 |
| 1964 | 5 | 10 | 13 | 44 | 2 | 51.40 | 129.20 | 4.1 |
| 1966 | 1 | 22 | 12 | 43 | 6 | 51.38 | 125.90 | 3.3 |
| 1966 | 6 | 10 | 5 | 47 | 50 | 51.00 | 125.20 | 3.4 |
| 1968 | 5 | 21 | 5 | 7 | 57 | 50.80 | 124.30 | 3.4 |
| 1968 | 6 | 18 | 5 | 37 | 57 | 51.10 | 129.00 | 4.1 |

## COAST MOUNTAINS (CSM) (CONTINUED)

| YR | MO | DA | HR | MN | SC | LAT | LONG | M |
|---|---|---|---|---|---|---|---|---|
| 1968 | 11 | 1 | 10 | 24 | 59 | 51.00 | 124.20 | 4.5 |
| 1971 | 12 | 23 | 18 | 48 | 57 | 50.50 | 124.50 | 3.3 |
| 1976 | 8 | 12 | 6 | 28 | 60 | 50.64 | 123.05 | 3.8 |
| 1977 | 05 | 26 | 06 | 49 | 51 | 51.15 | 124.43 | 3.5 |

## JUAN DE FUCA-EXPLORER (JFE)

| YR | MO | DA | HR | MN | SC | LAT | LONG | M |
|---|---|---|---|---|---|---|---|---|
| 1919 | 10 | 10 | 01 | 07 | 20 | 48.63 | 127.15 | 5.5 |
| 1920 | 3 | 29 | 5 | 7 | 53 | 50.50 | 129.50 | 6.4 |
| 1921 | 05 | 28 | 20 | 55 |  | 49.20 | 129.20 | 5.5 |
| 1924 | 3 | 30 | 0 | 8 | 56 | 50.50 | 129.50 | 6.0 |
| 1926 | 10 | 30 | 19 | 41 | 55 | 48.50 | 129.00 | 6.1 |
| 1926 | 11 | 1 | 1 | 39 | 18 | 48.75 | 128.50 | 6.6 |
| 1929 | 04 | 16 | 14 | 30 | 40 | 49.73 | 129.33 | 5.5 |
| 1929 | 09 | 17 | 19 | 17 | 39 | 50.92 | 129.58 | 6.3 |
| 1930 | 05 | 31 | 10 | 21 | 51 | 48.64 | 128.95 | 5.4 |
| 1932 | 08 | 18 | 20 | 23 | 00 | 48.39 | 127.62 | 5.5 |
| 1933 | 05 | 05 | 04 | 14 | 08 | 48.85 | 129.65 | 5.5 |
| 1935 | 09 | 24 | 22 | 12 | 20 | 49.63 | 129.17 | 6.2 |
| 1937 | 9 | 29 | 11 | 30 | 16 | 49.08 | 130.24 | 5.5 |
| 1938 | 04 | 22 | 04 | 15 | 54 | 50.03 | 128.45 | 5.5 |
| 1939 | 02 | 08 | 06 | 39 | 26 | 49.08 | 128.04 | 6.5 |
| 1939 | 07 | 18 | 03 | 26 | 38 | 49.01 | 129.22 | 6.5 |
| 1941 | 10 | 01 | 19 | 49 | 38 | 49.18 | 129.85 | 6.0 |
| 1941 | 11 | 06 | 17 | 31 | 54 | 49.35 | 129.83 | 6.0 |
| 1942 | 03 | 19 | 11 | 59 | 26 | 51.21 | 130.08 | 6.0 |
| 1942 | 6 | 9 | 11 | 6 | 45 | 49.20 | 129.90 | 5.7 |
| 1944 | 08 | 10 | 01 | 52 | 54 | 50.92 | 130.13 | 6.2 |
| 1944 | 08 | 13 | 08 | 22 | 28 | 50.13 | 130.46 | 5.8 |
| 1945 | 10 | 20 | 00 | 32 | 55 | 49.02 | 128.44 | 5.5 |
| 1946 | 7 | 17 | 22 | 7 | 0 | 50.00 | 129.00 | 6.5 |
| 1946 | 07 | 18 | 06 | 06 | 58 | 49.54 | 129.71 | 6.5 |
| 1946 | 11 | 12 | 14 | 35 | 44 | 49.10 | 128.40 | 5.5 |
| 1948 | 07 | 22 | 20 | 05 | 18 | 50.13 | 129.72 | 5.5 |
| 1948 | 07 | 22 | 20 | 52 | 43 | 49.84 | 129.65 | 5.5 |
| 1948 | 12 | 30 | 23 | 49 | 55 | 50.99 | 130.32 | 6.0 |
| 1951 | 09 | 27 | 19 | 24 | 13 | 49.45 | 128.60 | 5.8 |
| 1953 | 05 | 20 | 23 | 14 | 20 | 50.26 | 130.33 | 5.5 |
| 1953 | 12 | 04 | 14 | 54 | 48 | 49.41 | 129.02 | 6.3 |
| 1956 | 06 | 28 | 22 | 58 | 49 | 48.92 | 129.35 | 6.3 |
| 1957 | 03 | 24 | 08 | 22 | 23 | 50.85 | 130.36 | 6.0 |
| 1959 | 08 | 26 | 10 | 27 | 40 | 50.60 | 130.47 | 5.7 |
| 1960 | 4 | 14 | 0 | 37 | 52 | 48.50 | 130.40 | 5.7 |
| 1960 | 12 | 01 | 20 | 49 | 46 | 49.03 | 129.15 | 6.0 |
| 1961 | 02 | 01 | 00 | 36 | 01 | 50.26 | 129.63 | 5.5 |
| 1961 | 10 | 29 | 09 | 12 | 15 | 48.95 | 128.64 | 5.7 |
| 1962 | 06 | 02 | 12 | 26 | 07 | 50.00 | 129.65 | 5.7 |

JUAN DE FUCA-EXPLORER (JFE) (CONTINUED)

| YR | MO | DA | HR | MN | SC | LAT | LONG | M |
|---|---|---|---|---|---|---|---|---|
| 1964 | 03 | 31 | 09 | 01 | 29 | 50.83 | 130.05 | 5.7 |
| 1964 | 10 | 1 | 18 | 30 | 4 | 49.10 | 128.80 | 5.3 |
| 1965 | 2 | 26 | 15 | 43 | 17 | 50.30 | 129.80 | 4.5 |
| 1965 | 5 | 31 | 3 | 20 | 42 | 49.20 | 127.80 | 4.7 |
| 1965 | 7 | 2 | 22 | 55 | 56 | 49.20 | 129.80 | 3.9 |
| 1965 | 7 | 26 | 13 | 45 | 21 | 50.10 | 129.60 | 4.0 |
| 1965 | 8 | 12 | 9 | 4 | 37 | 50.20 | 129.70 | 4.9 |
| 1965 | 8 | 23 | 13 | 32 | 39 | 49.10 | 129.00 | 4.5 |
| 1965 | 8 | 31 | 1 | 9 | 15 | 50.50 | 129.00 | 3.9 |
| 1965 | 9 | 2 | 10 | 51 | 8 | 48.60 | 128.20 | 4.0 |
| 1965 | 9 | 2 | 11 | 37 | 50 | 48.60 | 128.00 | 4.6 |
| 1965 | 9 | 2 | 14 | 2 | 37 | 48.40 | 128.20 | 4.3 |
| 1965 | 9 | 2 | 15 | 42 | 26 | 48.30 | 128.40 | 4.4 |
| 1965 | 9 | 2 | 15 | 43 | 40 | 48.20 | 128.50 | 4.7 |
| 1965 | 9 | 2 | 18 | 1 | 20 | 48.30 | 128.30 | 4.4 |
| 1965 | 9 | 2 | 19 | 41 | 26 | 48.60 | 128.10 | 4.9 |
| 1965 | 9 | 2 | 21 | 16 | 44 | 48.60 | 128.00 | 4.0 |
| 1965 | 9 | 2 | 21 | 27 | 17 | 48.40 | 128.20 | 5.0 |
| 1965 | 9 | 3 | 0 | 30 | 31 | 48.50 | 128.00 | 4.0 |
| 1965 | 9 | 3 | 4 | 42 | 36 | 48.60 | 128.40 | 4.8 |
| 1965 | 9 | 11 | 7 | 13 | 19 | 50.30 | 129.50 | 4.9 |
| 1965 | 10 | 11 | 15 | 47 | 52 | 50.60 | 129.70 | 4.8 |
| 1965 | 10 | 11 | 17 | 54 | 48 | 50.60 | 129.90 | 4.2 |
| 1966 | 2 | 7 | 9 | 8 | 35 | 50.70 | 131.00 | 4.1 |
| 1966 | 2 | 7 | 13 | 45 | 42 | 50.60 | 131.50 | 3.8 |
| 1966 | 2 | 7 | 15 | 40 | 45 | 50.90 | 130.90 | 3.9 |
| 1966 | 2 | 8 | 7 | 58 | 20 | 50.90 | 130.30 | 3.9 |
| 1966 | 3 | 16 | 4 | 40 | 20 | 50.80 | 131.20 | 3.9 |
| 1966 | 3 | 30 | 12 | 39 | 56 | 49.80 | 129.90 | 5.1 |
| 1966 | 5 | 20 | 23 | 58 | 49 | 50.00 | 129.60 | 4.2 |
| 1966 | 9 | 1 | 14 | 11 | 21 | 49.30 | 129.30 | 4.6 |
| 1966 | 9 | 7 | 14 | 44 | 58 | 49.10 | 129.70 | 4.3 |
| 1966 | 9 | 9 | 18 | 33 | 52 | 49.20 | 129.40 | 4.8 |
| 1966 | 10 | 26 | 13 | 36 | 32 | 50.40 | 129.30 | 4.3 |
| 1966 | 11 | 4 | 20 | 30 | 9 | 48.90 | 128.90 | 4.2 |
| 1967 | 2 | 16 | 2 | 58 | 34 | 49.80 | 130.10 | 3.8 |
| 1967 | 3 | 5 | 11 | 11 | 2 | 51.20 | 129.50 | 3.8 |
| 1967 | 4 | 24 | 10 | 5 | 4 | 50.60 | 129.80 | 4.0 |
| 1967 | 4 | 29 | 0 | 4 | 42 | 51.10 | 130.10 | 5.3 |
| 1967 | 4 | 30 | 2 | 44 | 24 | 50.40 | 129.90 | 3.8 |
| 1967 | 8 | 27 | 13 | 34 | 51 | 50.20 | 130.00 | 4.3 |
| 1967 | 8 | 27 | 17 | 51 | 54 | 49.90 | 129.70 | 3.8 |
| 1967 | 8 | 27 | 18 | 29 | 5 | 50.10 | 129.80 | 3.9 |
| 1967 | 8 | 28 | 13 | 16 | 35 | 49.70 | 130.50 | 3.9 |
| 1967 | 8 | 28 | 13 | 49 | 40 | 49.80 | 129.70 | 3.8 |
| 1967 | 8 | 28 | 15 | 25 | 49 | 50.00 | 129.60 | 4.2 |
| 1967 | 8 | 28 | 16 | 20 | 4 | 50.20 | 129.70 | 4.1 |
| 1967 | 8 | 31 | 19 | 6 | 44 | 49.60 | 128.00 | 4.9 |
| 1967 | 10 | 16 | 13 | 27 | 33 | 49.20 | 129.30 | 4.9 |
| 1967 | 11 | 3 | 15 | 57 | 54 | 50.70 | 130.10 | 4.2 |

JUAN DE FUCA—EXPLORER (JFE) (CONTINUED)

| YR | MO | DA | HR | MN | SC | LAT | LONG | M |
|---|---|---|---|---|---|---|---|---|
| 1967 | 11 | 10 | 13 | 47 | 18 | 50.50 | 129.90 | 3.8 |
| 1967 | 12 | 9 | 18 | 31 | 40 | 49.20 | 128.70 | 4.0 |
| 1967 | 12 | 13 | 22 | 20 | 36 | 50.00 | 129.80 | 3.9 |
| 1968 | 2 | 1 | 3 | 5 | 1 | 50.20 | 130.40 | 4.2 |
| 1968 | 2 | 1 | 7 | 58 | 3 | 49.96 | 129.86 | 5.2 |
| 1968 | 2 | 15 | 18 | 27 | 30 | 51.35 | 129.68 | 3.8 |
| 1968 | 2 | 27 | 6 | 39 | 52 | 50.12 | 129.62 | 4.0 |
| 1968 | 3 | 2 | 3 | 14 | 45 | 49.25 | 128.92 | 4.5 |
| 1968 | 4 | 25 | 9 | 58 | 26 | 50.58 | 130.02 | 4.3 |
| 1968 | 6 | 18 | 5 | 37 | 54 | 50.87 | 130.10 | 3.8 |
| 1968 | 7 | 16 | 1 | 47 | 19 | 50.50 | 129.78 | 4.0 |
| 1968 | 7 | 28 | 21 | 16 | 49 | 50.53 | 129.70 | 4.0 |
| 1968 | 10 | 3 | 6 | 19 | 2 | 49.85 | 130.12 | 3.9 |
| 1968 | 11 | 17 | 21 | 11 | 34 | 49.00 | 128.90 | 4.4 |
| 1968 | 11 | 20 | 8 | 24 | 48 | 50.60 | 129.60 | 4.2 |
| 1968 | 11 | 22 | 11 | 59 | 26 | 49.00 | 128.70 | 4.0 |
| 1969 | 1 | 28 | 3 | 24 | 30 | 49.13 | 129.00 | 3.9 |
| 1969 | 3 | 10 | 22 | 50 | 47 | 50.50 | 129.60 | 4.1 |
| 1969 | 3 | 18 | 19 | 45 | 1 | 50.10 | 129.70 | 4.5 |
| 1969 | 3 | 18 | 20 | 31 | 28 | 50.17 | 129.88 | 5.1 |
| 1969 | 5 | 21 | 7 | 55 | 50 | 50.60 | 129.50 | 3.8 |
| 1969 | 5 | 21 | 9 | 20 | 27 | 50.68 | 129.50 | 3.9 |
| 1969 | 7 | 17 | 1 | 3 | 4 | 49.20 | 128.30 | 4.2 |
| 1969 | 9 | 4 | 13 | 22 | 58 | 49.40 | 129.20 | 4.2 |
| 1969 | 10 | 19 | 10 | 45 | 17 | 50.60 | 129.40 | 3.9 |
| 1969 | 10 | 23 | 21 | 36 | 41 | 50.40 | 129.90 | 4.1 |
| 1969 | 11 | 3 | 14 | 58 | 34 | 50.77 | 129.52 | 4.6 |
| 1970 | 2 | 1 | 23 | 2 | 31 | 50.00 | 129.00 | 4.0 |
| 1970 | 2 | 18 | 2 | 7 | 40 | 50.30 | 129.80 | 4.7 |
| 1970 | 7 | 23 | 13 | 31 | 40 | 48.50 | 128.00 | 3.8 |
| 1970 | 11 | 10 | 2 | 10 | 43 | 50.60 | 129.50 | 4.1 |
| 1970 | 11 | 16 | 12 | 49 | 21 | 49.30 | 128.10 | 4.5 |
| 1970 | 12 | 31 | 1 | 27 | 8 | 50.20 | 129.50 | 4.3 |
| 1970 | 12 | 31 | 5 | 34 | 14 | 47.78 | 128.77 | 5.2 |
| 1970 | 12 | 31 | 10 | 46 | 16 | 47.80 | 128.20 | 4.2 |
| 1971 | 1 | 1 | 6 | 50 | 53 | 47.80 | 128.60 | 4.5 |
| 1971 | 3 | 10 | 15 | 38 | 26 | 49.35 | 127.46 | 5.0 |
| 1971 | 3 | 13 | 23 | 51 | 38 | 50.56 | 129.90 | 6.4 |
| 1971 | 3 | 14 | 0 | 10 | 39 | 50.60 | 129.90 | 4.3 |
| 1971 | 3 | 14 | 0 | 44 | 16 | 50.60 | 129.90 | 4.0 |
| 1971 | 3 | 14 | 0 | 51 | 7 | 50.60 | 129.90 | 4.3 |
| 1971 | 3 | 14 | 4 | 41 | 58 | 50.60 | 129.90 | 4.1 |
| 1971 | 3 | 15 | 5 | 18 | 56 | 50.60 | 129.90 | 4.2 |
| 1971 | 6 | 29 | 6 | 28 | 54 | 51.20 | 129.60 | 4.2 |
| 1971 | 7 | 22 | 14 | 5 | 30 | 50.60 | 129.20 | 4.2 |
| 1971 | 11 | 20 | 21 | 24 | 37 | 48.60 | 129.40 | 5.0 |
| 1971 | 11 | 25 | 23 | 1 | 33 | 49.10 | 129.00 | 4.4 |
| 1971 | 11 | 25 | 23 | 40 | 8 | 49.00 | 129.10 | 5.1 |
| 1971 | 12 | 5 | 5 | 50 | 8 | 49.40 | 129.50 | 5.2 |
| 1971 | 12 | 5 | 6 | 12 | 51 | 49.80 | 129.20 | 5.0 |

JUAN DE FUCA-EXPLORER (JFE) (CONTINUED)

| YR | MO | DA | HR | MN | SC | LAT | LONG | M |
|---|---|---|---|---|---|---|---|---|
| 1971 | 12 | 8 | 8 | 25 | 2 | 49.20 | 128.10 | 4.6 |
| 1971 | 12 | 8 | 8 | 35 | 25 | 49.20 | 128.10 | 5.0 |
| 1971 | 12 | 10 | 20 | 25 | 14 | 49.80 | 129.00 | 4.0 |
| 1971 | 12 | 11 | 10 | 39 | 11 | 49.20 | 128.40 | 4.2 |
| 1971 | 12 | 20 | 9 | 15 | 8 | 49.20 | 128.50 | 3.8 |
| 1971 | 12 | 25 | 18 | 18 | 35 | 49.30 | 128.50 | 4.3 |
| 1971 | 12 | 30 | 7 | 45 | 11 | 49.10 | 128.80 | 4.0 |
| 1972 | 1 | 14 | 22 | 23 | 43 | 50.32 | 130.79 | 4.4 |
| 1972 | 5 | 14 | 20 | 35 | 41 | 50.55 | 130.47 | 3.9 |
| 1972 | 7 | 23 | 10 | 52 | 33 | 50.11 | 129.09 | 4.8 |
| 1972 | 7 | 23 | 19 | 13 | 9 | 50.10 | 129.30 | 5.8 |
| 1972 | 7 | 23 | 21 | 43 | 5 | 50.06 | 129.30 | 4.8 |
| 1972 | 7 | 23 | 20 | 17 | 32 | 50.21 | 129.16 | 4.8 |
| 1972 | 7 | 23 | 21 | 43 | 5 | 50.06 | 129.30 | 4.8 |
| 1972 | 11 | 1 | 16 | 11 | 35 | 49.93 | 130.12 | 3.9 |
| 1973 | 3 | 28 | 6 | 23 | 7 | 51.19 | 129.69 | 3.9 |
| 1973 | 4 | 17 | 2 | 16 | 6 | 50.71 | 130.65 | 3.8 |
| 1973 | 6 | 3 | 7 | 23 | 29 | 50.55 | 130.31 | 4.2 |
| 1973 | 7 | 13 | 2 | 59 | 30 | 49.12 | 127.84 | 4.8 |
| 1973 | 7 | 13 | 2 | 59 | 39 | 49.02 | 128.02 | 4.5 |
| 1974 | 1 | 29 | 6 | 13 | 11 | 49.43 | 129.04 | 3.8 |
| 1974 | 3 | 7 | 7 | 50 | 26 | 50.59 | 130.36 | 3.9 |
| 1974 | 5 | 30 | 1 | 0 | 2 | 49.28 | 127.65 | 3.8 |
| 1974 | 8 | 1 | 22 | 10 | 43 | 50.64 | 130.35 | 3.9 |
| 1975 | 1 | 29 | 16 | 16 | 56 | 50.06 | 129.99 | 3.8 |
| 1975 | 1 | 29 | 17 | 43 | 10 | 49.97 | 130.14 | 3.8 |
| 1975 | 2 | 18 | 20 | 21 | 9 | 50.75 | 130.55 | 3.8 |
| 1975 | 2 | 18 | 21 | 6 | 48 | 50.71 | 129.77 | 4.0 |
| 1975 | 2 | 21 | 16 | 43 | 28 | 50.81 | 130.57 | 3.8 |
| 1975 | 3 | 20 | 20 | 36 | 54 | 50.54 | 130.25 | 4.1 |
| 1975 | 8 | 1 | 14 | 4 | 26 | 49.27 | 128.96 | 3.8 |
| 1975 | 11 | 24 | 10 | 35 | 46 | 50.51 | 130.49 | 4.0 |
| 1975 | 12 | 11 | 6 | 28 | 34 | 50.05 | 130.19 | 4.1 |
| 1975 | 12 | 11 | 7 | 3 | 14 | 50.09 | 130.11 | 3.9 |
| 1975 | 12 | 12 | 1 | 48 | 41 | 49.68 | 130.16 | 4.1 |
| 1975 | 12 | 12 | 1 | 52 | 40 | 50.02 | 130.23 | 4.3 |
| 1975 | 12 | 12 | 2 | 14 | 32 | 49.98 | 130.24 | 4.1 |
| 1976 | 1 | 1 | 4 | 11 | 43 | 50.19 | 130.18 | 4.3 |
| 1976 | 1 | 2 | 3 | 36 | 21 | 50.38 | 130.02 | 4.4 |
| 1976 | 2 | 27 | 13 | 8 | 18 | 50.87 | 130.71 | 4.0 |
| 1976 | 2 | 28 | 0 | 40 | 5 | 50.96 | 130.64 | 3.8 |
| 1976 | 4 | 25 | 11 | 20 | 11 | 49.41 | 127.11 | 4.4 |
| 1976 | 6 | 6 | 2 | 17 | 18 | 49.04 | 127.86 | 5.0 |
| 1976 | 8 | 26 | 6 | 43 | 10 | 50.61 | 130.26 | 3.8 |
| 1976 | 11 | 9 | 20 | 17 | 19 | 50.61 | 129.84 | 4.4 |
| 1976 | 12 | 20 | 17 | 12 | 45 | 49.00 | 128.88 | 4.7 |
| 1976 | 12 | 20 | 20 | 33 | 8 | 48.80 | 129.29 | 6.7 |
| 1976 | 12 | 20 | 21 | 6 | 39 | 48.90 | 128.72 | 5.1 |
| 1976 | 12 | 20 | 21 | 12 | 52 | 49.19 | 129.17 | 4.1 |
| 1976 | 12 | 20 | 21 | 21 | 37 | 48.94 | 128.41 | 3.8 |

## JUAN DE FUCA-EXPLORER (JFE) (CONTINUED)

| YR | MO | DA | HR | MN | SC | LAT | LONG | M |
|---|---|---|---|---|---|---|---|---|
| 1976 | 12 | 26 | 10 | 52 | 48 | 49.38 | 130.03 | 3.8 |
| 1977 | 04 | 03 | 18 | 45 | 46 | 50.56 | 130.18 | 4.0 |
| 1977 | 07 | 09 | 08 | 04 | 18 | 50.86 | 130.72 | 4.2 |
| 1977 | 12 | 25 | 07 | 21 | 01 | 50.61 | 129.98 | 4.1 |

## QUEEN CHARLOTTE FAULT (QCF)

| YR | MO | DA | HR | MN | SC | LAT | LONG | M |
|---|---|---|---|---|---|---|---|---|
| 1917 | 7 | 1 | 13 | 20 | 50 | 50.00 | 128.00 | 6.4 |
| 1919 | 5 | 18 | 10 | 23 | 56 | 56.00 | 136.00 | 6.0 |
| 1921 | 04 | 10 | 13 | 40 | 16 | 54.42 | 133.66 | 6.5 |
| 1929 | 05 | 26 | 22 | 40 | 01 | 51.19 | 130.16 | 7.0 |
| 1938 | 03 | 22 | 15 | 22 | 20 | 52.54 | 131.90 | 6.3 |
| 1940 | 9 | 29 | 5 | 57 | 12 | 54.00 | 134.00 | 5.5 |
| 1945 | 10 | 29 | 10 | 54 | 17 | 51.59 | 130.98 | 5.5 |
| 1948 | 02 | 28 | 01 | 58 | 05 | 53.41 | 132.74 | 6.5 |
| 1949 | 08 | 22 | 04 | 01 | 12 | 53.62 | 133.27 | 8.0 |
| 1949 | 8 | 23 | 19 | 43 | 34 | 52.49 | 132.65 | 5.5 |
| 1949 | 08 | 23 | 20 | 24 | 31 | 52.69 | 132.23 | 6.4 |
| 1949 | 08 | 24 | 22 | 37 | 13 | 52.78 | 132.11 | 5.5 |
| 1949 | 8 | 26 | 22 | 39 | 29 | 54.50 | 136.00 | 5.5 |
| 1949 | 10 | 31 | 1 | 39 | 28 | 56.00 | 136.00 | 6.7 |
| 1950 | 05 | 22 | 19 | 49 | 43 | 51.56 | 130.51 | 5.7 |
| 1950 | 9 | 28 | 21 | 47 | 1 | 54.50 | 134.50 | 5.5 |
| 1956 | 02 | 19 | 02 | 18 | 00 | 51.61 | 131.37 | 6.8 |
| 1956 | 11 | 17 | 20 | 27 | 15 | 54.50 | 134.00 | 6.5 |
| 1956 | 12 | 21 | 08 | 58 | 55 | 51.29 | 130.60 | 6.7 |
| 1959 | 01 | 16 | 16 | 50 | 43 | 51.98 | 131.21 | 5.4 |
| 1960 | 07 | 04 | 04 | 28 | 35 | 51.79 | 131.19 | 6.6 |
| 1960 | 07 | 04 | 13 | 10 | 07 | 51.79 | 131.09 | 6.0 |
| 1965 | 3 | 5 | 9 | 39 | 24 | 51.50 | 131.10 | 4.0 |
| 1965 | 3 | 5 | 12 | 40 | 39 | 52.70 | 132.00 | 3.9 |
| 1965 | 6 | 28 | 23 | 15 | 8 | 51.00 | 133.00 | 4.1 |
| 1966 | 1 | 20 | 19 | 51 | 14 | 51.30 | 131.20 | 4.2 |
| 1966 | 1 | 20 | 19 | 59 | 42 | 51.30 | 132.10 | 3.8 |
| 1966 | 1 | 21 | 11 | 27 | 52 | 51.30 | 131.50 | 3.8 |
| 1966 | 2 | 7 | 14 | 12 | 26 | 50.90 | 131.20 | 4.0 |
| 1966 | 2 | 7 | 14 | 32 | 21 | 51.30 | 130.70 | 3.8 |
| 1966 | 3 | 3 | 7 | 11 | 55 | 51.60 | 131.50 | 3.8 |
| 1966 | 3 | 25 | 21 | 59 | 26 | 56.60 | 135.40 | 4.7 |
| 1966 | 4 | 16 | 22 | 49 | 39 | 56.70 | 136.20 | 4.1 |
| 1966 | 4 | 17 | 16 | 46 | 47 | 54.10 | 133.60 | 5.0 |
| 1966 | 7 | 16 | 6 | 22 | 43 | 52.20 | 133.60 | 3.8 |
| 1966 | 7 | 23 | 19 | 34 | 58 | 54.20 | 135.20 | 4.3 |
| 1966 | 12 | 8 | 9 | 33 | 48 | 51.30 | 130.60 | 3.9 |
| 1967 | 4 | 12 | 0 | 54 | 42 | 56.20 | 136.00 | 4.4 |
| 1967 | 4 | 19 | 18 | 12 | 31 | 52.50 | 132.10 | 4.6 |
| 1968 | 1 | 15 | 12 | 24 | 14 | 52.20 | 131.60 | 4.3 |

QUEEN CHARLOTTE FAULT (QCF) (CONTINUED)

| YR | MO | DA | HR | MN | SC | LAT | LONG | M |
|---|---|---|---|---|---|---|---|---|
| 1968 | 1 | 15 | 14 | 29 | 20 | 52.20 | 131.60 | 3.9 |
| 1968 | 6 | 13 | 8 | 51 | 16 | 51.40 | 131.55 | 4.5 |
| 1968 | 9 | 22 | 3 | 51 | 51 | 51.38 | 131.22 | 4.4 |
| 1968 | 11 | 16 | 14 | 3 | 22 | 56.20 | 138.70 | 3.8 |
| 1969 | 12 | 15 | 8 | 31 | 30 | 53.00 | 135.00 | 4.0 |
| 1970 | 2 | 18 | 9 | 23 | 2 | 52.40 | 131.50 | 4.8 |
| 1970 | 6 | 24 | 7 | 30 | 28 | 51.86 | 130.97 | 4.9 |
| 1970 | 06 | 24 | 13 | 09 | 08 | 51.77 | 130.76 | 7.0 |
| 1970 | 6 | 24 | 13 | 17 | 4 | 51.74 | 131.20 | 5.2 |
| 1970 | 7 | 3 | 6 | 20 | 10 | 51.80 | 131.00 | 4.0 |
| 1971 | 2 | 5 | 7 | 33 | 28 | 51.75 | 130.65 | 5.5 |
| 1971 | 2 | 11 | 6 | 24 | 46 | 54.70 | 135.20 | 4.6 |
| 1971 | 5 | 28 | 12 | 11 | 3 | 52.40 | 132.40 | 4.6 |
| 1971 | 11 | 6 | 11 | 12 | 52 | 51.15 | 135.28 | 4.0 |
| 1971 | 12 | 9 | 20 | 33 | 15 | 56.43 | 135.59 | 4.2 |
| 1972 | 6 | 17 | 23 | 50 | 23 | 54.27 | 133.61 | 4.3 |
| 1972 | 6 | 18 | 20 | 43 | 12 | 54.32 | 133.62 | 3.8 |
| 1972 | 7 | 30 | 21 | 45 | 16 | 56.77 | 135.91 | 7.6 |
| 1972 | 7 | 30 | 22 | 51 | 54 | 56.30 | 136.10 | 4.5 |
| 1972 | 7 | 31 | 3 | 13 | 55 | 56.63 | 135.78 | 4.3 |
| 1972 | 7 | 31 | 9 | 47 | 14 | 56.01 | 135.53 | 4.2 |
| 1972 | 7 | 31 | 11 | 25 | 33 | 56.67 | 135.76 | 3.9 |
| 1972 | 8 | 4 | 9 | 48 | 11 | 56.23 | 135.64 | 4.9 |
| 1972 | 8 | 4 | 11 | 38 | 8 | 56.19 | 135.42 | 5.5 |
| 1972 | 8 | 7 | 8 | 31 | 45 | 55.99 | 136.40 | 3.8 |
| 1972 | 8 | 9 | 19 | 20 | 46 | 56.23 | 135.61 | 3.9 |
| 1972 | 8 | 10 | 21 | 39 | 52 | 55.98 | 135.67 | 4.0 |
| 1972 | 8 | 15 | 10 | 56 | 13 | 56.31 | 135.57 | 5.4 |
| 1972 | 11 | 7 | 17 | 33 | 29 | 56.23 | 135.71 | 4.4 |
| 1972 | 11 | 15 | 9 | 11 | 38 | 56.34 | 136.15 | 4.2 |
| 1972 | 11 | 17 | 16 | 41 | 35 | 56.03 | 135.60 | 4.8 |
| 1972 | 12 | 8 | 18 | 56 | 56 | 56.30 | 135.90 | 4.2 |
| 1973 | 1 | 12 | 5 | 59 | 32 | 56.10 | 135.51 | 4.3 |
| 1973 | 1 | 14 | 1 | 23 | 7 | 56.27 | 135.52 | 4.3 |
| 1973 | 9 | 5 | 1 | 14 | 3 | 53.87 | 133.07 | 4.0 |
| 1973 | 9 | 6 | 17 | 15 | 48 | 51.17 | 130.40 | 4.3 |
| 1974 | 4 | 8 | 23 | 24 | 41 | 54.13 | 134.10 | 4.0 |
| 1974 | 8 | 20 | 4 | 25 | 4 | 51.06 | 130.70 | 4.3 |
| 1975 | 2 | 14 | 12 | 15 | 6 | 52.68 | 132.04 | 3.8 |
| 1975 | 4 | 7 | 1 | 47 | 45 | 51.64 | 130.88 | 4.7 |
| 1975 | 5 | 23 | 15 | 12 | 30 | 51.22 | 131.23 | 4.7 |
| 1975 | 7 | 14 | 18 | 19 | 25 | 51.46 | 131.83 | 3.9 |
| 1975 | 8 | 20 | 2 | 6 | 1 | 51.22 | 130.76 | 4.5 |
| 1976 | 2 | 23 | 12 | 12 | 31 | 51.46 | 130.76 | 4.1 |
| 1976 | 2 | 23 | 14 | 58 | 59 | 51.60 | 130.51 | 4.3 |
| 1976 | 2 | 23 | 15 | 14 | 16 | 51.50 | 130.50 | 6.0 |
| 1976 | 2 | 23 | 16 | 12 | 23 | 51.47 | 130.68 | 4.7 |
| 1976 | 2 | 23 | 18 | 12 | 35 | 51.43 | 130.73 | 4.5 |
| 1976 | 2 | 27 | 10 | 39 | 31 | 51.07 | 130.57 | 3.8 |
| 1976 | 2 | 28 | 1 | 7 | 17 | 51.00 | 130.76 | 4.1 |

## QUEEN CHARLOTTE FAULT (QCF) (CONTINUED)

| YR | MO | DA | HR | MN | SC | LAT | LONG | M |
|---|---|---|---|---|---|---|---|---|
| 1976 | 5 | 13 | 7 | 11 | 44 | 52.86 | 132.24 | 4.8 |
| 1976 | 6 | 18 | 9 | 19 | 24 | 53.92 | 133.06 | 4.3 |
| 1976 | 7 | 17 | 23 | 40 | 1 | 53.91 | 132.94 | 3.9 |
| 1976 | 10 | 15 | 20 | 29 | 33 | 54.31 | 133.67 | 3.8 |
| 1976 | 11 | 10 | 19 | 16 | 34 | 51.37 | 130.67 | 4.1 |
| 1977 | 01 | 14 | 14 | 55 | 58 | 51.34 | 130.33 | 3.8 |
| 1977 | 08 | 08 | 14 | 23 | 58 | 55.56 | 135.26 | 4.6 |

## SANDSPIT FAULT (SPT)

| YR | MO | DA | HR | MN | SC | LAT | LONG | M |
|---|---|---|---|---|---|---|---|---|
| 1929 | 03 | 01 | 07 | 31 | 14 | 51.79 | 129.74 | 6.1 |
| 1936 | 12 | 21 | 19 | 03 | 16 | 53.02 | 131.65 | 6.0 |
| 1945 | 08 | 02 | 20 | 44 | 45 | 53.89 | 132.63 | 6.2 |
| 1965 | 5 | 15 | 3 | 14 | 32 | 55.00 | 133.50 | 4.1 |
| 1965 | 6 | 5 | 8 | 38 | 56 | 54.00 | 133.00 | 4.1 |
| 1966 | 6 | 22 | 16 | 55 | 24 | 52.40 | 130.10 | 3.9 |
| 1967 | 2 | 22 | 17 | 9 | 25 | 52.40 | 131.20 | 3.8 |
| 1968 | 6 | 28 | 18 | 4 | 42 | 56.00 | 133.60 | 3.9 |
| 1970 | 2 | 19 | 8 | 9 | 18 | 53.30 | 132.30 | 4.0 |
| 1970 | 6 | 24 | 17 | 16 | 53 | 51.90 | 130.40 | 3.9 |
| 1970 | 6 | 24 | 19 | 10 | 19 | 51.90 | 130.20 | 3.9 |
| 1971 | 7 | 15 | 0 | 24 | 2 | 54.60 | 133.60 | 5.3 |
| 1974 | 4 | 3 | 22 | 46 | 33 | 54.12 | 133.41 | 4.5 |
| 1974 | 4 | 8 | 23 | 24 | 41 | 54.25 | 133.36 | 4.5 |
| 1976 | 2 | 23 | 12 | 12 | 35 | 51.60 | 130.10 | 3.8 |
| 1976 | 7 | 17 | 23 | 40 | 1 | 53.91 | 132.94 | 3.9 |
| 1977 | 07 | 19 | 17 | 22 | 10 | 54.17 | 133.17 | 4.6 |

## SOUTHEASTERN B.C. (SBC)

| YR | MO | DA | HR | MN | SC | LAT | LONG | M |
|---|---|---|---|---|---|---|---|---|
| 1918 | 02 | 04 | 20 | 37 |  | 52.28 | 118.37 | 6.0 |
| 1942 | 11 | 01 | 18 | 50 | 06 | 48.00 | 116.70 | 5.5 |
| 1962 | 08 | 28 | 19 | 19 | 59 | 51.7 | 121.9 | 4.3 |
| 1965 | 03 | 23 | 00 | 28 | 18 | 49.7 | 117.4 | 4.0 |
| 1965 | 03 | 24 | 12 | 44 | 55 | 49.9 | 117.4 | 3.8 |
| 1965 | 04 | 21 | 11 | 47 | 30 | 52.3 | 117.2 | 3.7 |
| 1965 | 04 | 28 | 19 | 00 |  | 48.6 | 116.9 | 4.3 |
| 1965 | 07 | 28 | 18 | 33 | 45 | 52.3 | 119.8 | 3.5 |
| 1966 | 01 | 02 | 10 | 10 | 51 | 51.5 | 116.5 | 4.5 |
| 1966 | 05 | 29 | 13 | 47 | 27 | 49.4 | 114.9 | 3.5 |
| 1966 | 11 | 06 | 10 | 50 | 54 | 48.3 | 119.5 | 3.8 |
| 1967 | 04 | 05 | 02 | 55 | 25 | 48.2 | 119.1 | 3.4 |
| 1967 | 04 | 20 | 15 | 19 | 33 | 48.2 | 119.42 | 3.3 |
| 1967 | 06 | 04 | 03 | 26 | 23 | 52.2 | 120.0 | 3.4 |

## SOUTHEASTERN B.C. (SBC) (CONTINUED)

| YR | MO | DA | HR | MN | SC | LAT | LONG | M |
|---|---|---|---|---|---|---|---|---|
| 1967 | 06 | 06 | 17 | 12 | 56 | 48.2 | 119.4 | 3.3 |
| 1968 | 04 | 12 | 10 | 26 | 08 | 48.6 | 116.17 | 3.6 |
| 1968 | 07 | 14 | 03 | 32 | 36 | 50.58 | 117.50 | 3.7 |
| 1968 | 07 | 26 | 22 | 23 | 30 | 52.28 | 118.68 | 3.3 |
| 1968 | 08 | 31 | 08 | 31 | 18 | 49.42 | 116.92 | 3.7 |
| 1968 | 12 | 13 | 08 | 50 | 08 | 52.40 | 120.20 | 3.7 |
| 1969 | 05 | 10 | 17 | 48 | 49 | 49.14 | 118.77 | 3.4 |
| 1970 | 05 | 30 | 19 | 36 | 51 | 49.20 | 113.70 | 3.7 |
| 1970 | 11 | 27 | 22 | 17 | 50 | 52.64 | 119.13 | 3.8 |
| 1973 | 03 | 04 | 02 | 47 | 32 | 52.06 | 118.07 | 3.9 |
| 1973 | 03 | 04 | 05 | 02 | 43 | 52.03 | 118.04 | 3.5 |
| 1973 | 03 | 16 | 06 | 28 | 56 | 48.91 | 114.80 | 3.5 |
| 1973 | 03 | 22 | 21 | 21 | 51 | 52.06 | 118.01 | 3.9 |
| 1974 | 07 | 26 | 23 | 36 | 03 | 48.72 | 114.89 | 3.7 |
| 1977 | 06 | 12 | 02 | 57 | 06 | 51.54 | 118.46 | 3.6 |
| 1977 | 10 | 09 | 16 | 42 | 39 | 53.65 | 118.29 | 4.4 |

## NORTHERN B.C. (NBC)

| YR | MO | DA | HR | MN | SC | LAT | LONG | M |
|---|---|---|---|---|---|---|---|---|
| 1965 | 09 | 05 | 10 | 04 | 17 | 55.0 | 130.6 | 4.5 |
| 1969 | 10 | 20 | 01 | 48 | 55 | 57.3 | 126.6 | 4.4 |
| 1971 | 10 | 12 | 19 | 09 | 53 | 59.78 | 135.29 | 3.4 |
| 1973 | 11 | 05 | 12 | 36 | 17 | 54.43 | 129.06 | 4.2 |
| 1973 | 11 | 06 | 15 | 57 | 12 | 54.46 | 128.93 | 3.7 |
| 1974 | 02 | 18 | 03 | 53 | 25 | 57.22 | 124.92 | 3.5 |
| 1975 | 06 | 05 | 05 | 52 | 40 | 57.95 | 124.80 | 4.2 |
| 1975 | 07 | 11 | 01 | 14 | 10 | 58.47 | 133.38 | 3.3 |
| 1976 | 04 | 07 | 01 | 53 | 34 | 57.64 | 125.27 | 3.5 |
| 1976 | 07 | 11 | 12 | 58 | 09 | 58.45 | 133.38 | 3.3 |
| 1977 | 09 | 29 | 22 | 19 | 23 | 54.83 | 126.97 | 3.3 |

## SOUTHERN SASKATCHEWAN (SAS)

| YR | MO | DA | HR | MN | SC | LAT | LONG | M |
|---|---|---|---|---|---|---|---|---|
| 1909 | 05 | 16 | 04 | 15 |  | 49. | 104. | 5.5 |
| 1943 | 06 | 25 | 04 | 25 |  | 48.5 | 105.0 | 4.0 |
| 1968 | 10 | 11 | 12 | 28 | 04 | 49.61 | 104.49 | 2.8 |
| 1969 | 10 | 06 | 20 | 24 | 53 | 48.29 | 106.58 | 3.1 |
| 1972 | 07 | 26 | 03 | 58 | 19 | 49.35 | 104.93 | 3.7 |
| 1973 | 09 | 26 | 18 | 38 | 27 | 47.12 | 106.13 | 2.8 |
| 1975 | 09 | 05 | 20 | 47 | 41 | 48.36 | 104.38 | 3.5 |
| 1976 | 03 | 23 | 22 | 31 | 47 | 49.56 | 104.37 | 3.2 |
| 1976 | 03 | 25 | 00 | 12 | 16 | 49.39 | 104.27 | 3.5 |

## FAIRWEATHER-YAKUTAT (FWY)

| YR | MO | DA | HR | MN | SC | LAT | LONG | M |
|---|---|---|---|---|---|---|---|---|
| 1899 | 9 | 4 | 0 | 22 | 0 | 60.00 | 142.00 | 8.2 |
| 1899 | 9 | 10 | 17 | 4 | 0 | 60.00 | 140.00 | 7.8 |
| 1899 | 9 | 10 | 21 | 41 | 0 | 60.00 | 140.00 | 8.6 |
| 1900 | 10 | 9 | 12 | 28 | 0 | 60.00 | 142.00 | 8.2 |
| 1927 | 10 | 24 | 15 | 59 | 55 | 57.50 | 137.00 | 7.1 |
| 1947 | 4 | 30 | 4 | 49 | 46 | 59.00 | 139.00 | 6.3 |
| 1957 | 6 | 23 | 3 | 27 | 2 | 58.50 | 137.00 | 5.6 |
| 1958 | 7 | 10 | 6 | 15 | 51 | 58.60 | 137.10 | 7.9 |
| 1958 | 7 | 13 | 8 | 10 | 2 | 58.30 | 136.90 | 5.6 |
| 1958 | 9 | 24 | 3 | 44 | 14 | 59.50 | 143.50 | 6.2 |
| 1963 | 6 | 17 | 18 | 32 | 14 | 60.50 | 140.80 | 5.4 |
| 1965 | 04 | 26 | 01 | 57 | 14 | 58.90 | 142.70 | 5.3 |
| 1965 | 04 | 28 | 09 | 40 | 19 | 58.60 | 143.30 | 4.9 |
| 1965 | 06 | 07 | 11 | 24 | 49 | 60.30 | 140.90 | 4.8 |
| 1965 | 6 | 27 | 11 | 8 | 56 | 60.28 | 141.13 | 5.1 |
| 1965 | 09 | 30 | 23 | 47 | 40 | 59.70 | 143.40 | 5.0 |
| 1965 | 10 | 12 | 08 | 16 | 23 | 59.50 | 144.60 | 4.8 |
| 1965 | 12 | 23 | 20 | 47 | 36 | 60.60 | 140.70 | 5.8 |
| 1966 | 01 | 15 | 11 | 59 | 58 | 59.50 | 144.60 | 5.3 |
| 1966 | 08 | 07 | 14 | 11 | 55 | 59.60 | 144.60 | 4.8 |
| 1966 | 10 | 10 | 21 | 17 | 35 | 57.40 | 136.10 | 4.8 |
| 1967 | 05 | 17 | 00 | 33 | 12 | 60.80 | 143.65 | 4.8 |
| 1969 | 06 | 02 | 09 | 47 | 59 | 59.45 | 144.67 | 4.7 |
| 1969 | 06 | 11 | 00 | 58 | 10 | 59.60 | 144.80 | 5.3 |
| 1969 | 06 | 11 | 01 | 05 | 03 | 59.59 | 144.76 | 4.9 |
| 1970 | 01 | 10 | 04 | 21 | 43 | 59.45 | 144.97 | 4.9 |
| 1970 | 02 | 24 | 08 | 05 | 40 | 59.57 | 143.87 | 5.0 |
| 1970 | 04 | 11 | 04 | 05 | 41 | 59.70 | 142.70 | 6.2 |
| 1970 | 04 | 11 | 09 | 59 | 46 | 59.51 | 142.75 | 4.6 |
| 1970 | 04 | 11 | 12 | 55 | 38 | 59.77 | 142.66 | 4.5 |
| 1970 | 04 | 16 | 05 | 33 | 17 | 59.80 | 142.60 | 6.2 |
| 1970 | 04 | 17 | 15 | 31 | 47 | 59.55 | 142.70 | 4.3 |
| 1970 | 04 | 19 | 01 | 15 | 47 | 59.60 | 142.80 | 6.0 |
| 1970 | 04 | 21 | 06 | 44 | 25 | 59.62 | 142.65 | 4.9 |
| 1970 | 8 | 21 | 11 | 58 | 50 | 60.77 | 142.60 | 4.5 |
| 1970 | 9 | 6 | 15 | 43 | 19 | 60.17 | 141.14 | 4.7 |
| 1971 | 1 | 1 | 4 | 45 | 30 | 59.62 | 144.65 | 5.1 |
| 1971 | 1 | 2 | 19 | 9 | 51 | 59.58 | 144.70 | 4.8 |
| 1971 | 3 | 26 | 17 | 35 | 17 | 60.33 | 140.94 | 5.8 |
| 1971 | 3 | 27 | 22 | 0 | 5 | 60.05 | 140.92 | 4.5 |
| 1972 | 3 | 12 | 5 | 56 | 17 | 58.98 | 137.90 | 4.3 |
| 1972 | 4 | 17 | 2 | 29 | 50 | 60.81 | 144.61 | 3.8 |
| 1972 | 5 | 29 | 12 | 8 | 12 | 57.40 | 137.50 | 4.2 |
| 1972 | 8 | 13 | 2 | 30 | 36 | 59.31 | 144.90 | 4.6 |
| 1972 | 8 | 18 | 22 | 4 | 45 | 57.40 | 136.10 | 4.1 |
| 1972 | 9 | 29 | 9 | 0 | 36 | 60.21 | 141.03 | 4.7 |
| 1972 | 12 | 7 | 22 | 19 | 44 | 57.09 | 136.52 | 3.9 |
| 1973 | 2 | 7 | 15 | 26 | 44 | 59.40 | 143.32 | 4.5 |
| 1973 | 6 | 26 | 0 | 41 | 49 | 59.41 | 144.69 | 4.4 |
| 1973 | 7 | 1 | 13 | 33 | 35 | 57.84 | 137.33 | 6.1 |

## FAIRWEATHER—YAKUTAT (FWY) (CONTINUED)

| YR | MO | DA | HR | MN | SC | LAT | LONG | M |
|---|---|---|---|---|---|---|---|---|
| 1973 | 7 | 1 | 15 | 6 | 37 | 57.62 | 137.74 | 3.8 |
| 1973 | 7 | 1 | 15 | 12 | 5 | 57.78 | 137.28 | 5.2 |
| 1973 | 7 | 1 | 16 | 3 | 10 | 57.68 | 137.50 | 4.2 |
| 1973 | 7 | 2 | 13 | 36 | 52 | 57.93 | 136.92 | 3.8 |
| 1973 | 7 | 2 | 22 | 54 | 45 | 57.93 | 137.69 | 4.5 |
| 1973 | 7 | 3 | 16 | 30 | 37 | 58.05 | 137.73 | 4.6 |
| 1973 | 7 | 3 | 16 | 59 | 35 | 57.98 | 138.02 | 6.0 |
| 1973 | 7 | 3 | 17 | 44 | 16 | 57.99 | 137.88 | 5.1 |
| 1973 | 7 | 4 | 7 | 17 | 6 | 58.06 | 137.31 | 4.5 |
| 1973 | 7 | 4 | 13 | 26 | 20 | 58.01 | 137.85 | 4.6 |
| 1973 | 7 | 5 | 7 | 45 | 24 | 58.01 | 137.29 | 4.5 |
| 1973 | 7 | 5 | 7 | 49 | 4 | 57.90 | 137.90 | 5.4 |
| 1973 | 7 | 5 | 8 | 51 | 30 | 58.03 | 137.37 | 3.9 |
| 1973 | 7 | 11 | 23 | 16 | 27 | 57.92 | 138.06 | 4.6 |
| 1973 | 7 | 13 | 5 | 11 | 5 | 60.08 | 140.89 | 3.9 |
| 1973 | 7 | 14 | 5 | 8 | 22 | 58.00 | 138.00 | 5.0 |
| 1973 | 7 | 16 | 21 | 20 | 16 | 57.69 | 137.60 | 3.8 |
| 1973 | 7 | 27 | 13 | 54 | 50 | 58.05 | 137.66 | 4.0 |
| 1973 | 7 | 28 | 19 | 58 | 47 | 58.00 | 137.89 | 4.7 |
| 1973 | 8 | 9 | 6 | 28 | 24 | 57.83 | 137.39 | 3.8 |
| 1973 | 9 | 9 | 2 | 54 | 47 | 60.25 | 140.80 | 3.8 |
| 1973 | 9 | 12 | 7 | 0 | 23 | 60.15 | 140.85 | 3.9 |
| 1974 | 2 | 21 | 16 | 28 | 4 | 60.33 | 140.59 | 4.1 |
| 1974 | 2 | 23 | 8 | 9 | 46 | 60.66 | 142.86 | 3.9 |
| 1974 | 3 | 4 | 6 | 54 | 33 | 60.11 | 140.67 | 3.9 |
| 1974 | 3 | 4 | 6 | 54 | 33 | 60.11 | 140.67 | 3.9 |
| 1974 | 4 | 18 | 21 | 54 | 26 | 59.16 | 139.97 | 3.9 |
| 1974 | 7 | 21 | 16 | 33 | 34 | 59.13 | 140.27 | 4.1 |
| 1974 | 08 | 28 | 18 | 43 | 26 | 59.51 | 144.45 | 4.9 |
| 1974 | 9 | 20 | 1 | 49 | 37 | 59.96 | 141.45 | 3.9 |
| 1974 | 9 | 28 | 17 | 33 | 33 | 60.05 | 140.62 | 4.1 |
| 1974 | 11 | 5 | 10 | 24 | 54 | 60.05 | 140.43 | 4.0 |
| 1975 | 4 | 30 | 20 | 9 | 55 | 57.26 | 135.79 | 3.8 |
| 1975 | 9 | 24 | 14 | 17 | 54 | 59.88 | 141.85 | 4.2 |
| 1976 | 1 | 25 | 18 | 52 | 41 | 59.89 | 141.55 | 4.5 |
| 1976 | 2 | 15 | 21 | 15 | 49 | 57.91 | 138.57 | 4.1 |
| 1976 | 4 | 20 | 14 | 27 | 21 | 60.28 | 140.58 | 4.5 |
| 1976 | 7 | 2 | 16 | 28 | 40 | 60.52 | 141.24 | 4.0 |
| 1976 | 7 | 8 | 3 | 59 | 49 | 60.32 | 140.89 | 3.8 |
| 1976 | 11 | 7 | 14 | 48 | 48 | 57.88 | 137.79 | 4.2 |
| 1976 | 11 | 12 | 18 | 48 | 37 | 59.61 | 138.95 | 3.8 |
| 1977 | 01 | 13 | 22 | 05 | 59 | 59.43 | 142.23 | 4.5 |
| 1977 | 01 | 20 | 15 | 45 | 26 | 57.86 | 137.86 | 4.3 |
| 1977 | 10 | 30 | 10 | 51 | 58 | 59.79 | 141.32 | 3.8 |

## DENALI-SHAKWAK (DSK)

| YR | MO | DA | HR | MN | SC | LAT | LONG | M |
|---|---|---|---|---|---|---|---|---|
| 1944 | 02 | 03 | 12 | 14 | 59 | 60.10 | 137.88 | 6.5 |
| 1952 | 03 | 09 | 20 | 00 | 17 | 59.10 | 136.70 | 6.0 |
| 1958 | 08 | 31 | 23 | 00 | 16 | 63.30 | 144.20 | 5.9 |
| 1968 | 2 | 16 | 2 | 42 | 34 | 61.19 | 139.99 | 4.5 |
| 1971 | 4 | 24 | 0 | 39 | 18 | 60.53 | 139.05 | 4.5 |
| 1972 | 06 | 10 | 03 | 31 | 24 | 61.52 | 140.21 | 5.3 |
| 1972 | 6 | 10 | 9 | 46 | 19 | 61.37 | 140.12 | 3.8 |
| 1972 | 6 | 11 | 1 | 11 | 57 | 61.51 | 139.91 | 3.8 |
| 1973 | 9 | 30 | 17 | 33 | 50 | 61.71 | 141.21 | 4.1 |
| 1974 | 1 | 27 | 4 | 39 | 38 | 59.35 | 136.37 | 4.0 |
| 1974 | 2 | 7 | 13 | 51 | 55 | 59.17 | 137.03 | 4.0 |
| 1974 | 04 | 15 | 16 | 27 | 36 | 59.19 | 136.43 | 4.2 |
| 1974 | 08 | 01 | 02 | 02 | 30 | 60.86 | 137.99 | 4.5 |
| 1975 | 2 | 17 | 0 | 38 | 3 | 60.78 | 139.76 | 3.8 |
| 1977 | 01 | 28 | 23 | 29 | 02 | 59.01 | 136.82 | 3.8 |
| 1977 | 11 | 06 | 19 | 11 | 03 | 62.09 | 144.87 | 3.8 |

## RICHARDSON MTS (RIC)

| YR | MO | DA | HR | MN | SC | LAT | LONG | M |
|---|---|---|---|---|---|---|---|---|
| 1940 | 6 | 5 | 11 | 1 | 10 | 66.90 | 135.00 | 6.5 |
| 1940 | 6 | 5 | 11 | 1 | 10 | 66.90 | 135.00 | 6.5 |
| 1952 | 6 | 15 | 15 | 12 | 40 | 65.60 | 134.90 | 5.5 |
| 1953 | 1 | 11 | 22 | 53 | 30 | 65.30 | 133.20 | 5.5 |
| 1955 | 3 | 1 | 4 | 42 | 59 | 65.30 | 132.80 | 6.6 |
| 1956 | 1 | 7 | 16 | 41 | 4 | 65.60 | 133.70 | 5.5 |
| 1957 | 12 | 9 | 22 | 7 | 43 | 65.30 | 133.50 | 5.7 |
| 1965 | 10 | 5 | 0 | 17 | 14 | 65.40 | 133.00 | 5.2 |
| 1968 | 1 | 27 | 18 | 17 | 54 | 66.03 | 135.02 | 4.0 |
| 1968 | 4 | 26 | 15 | 49 | 26 | 65.37 | 133.28 | 4.2 |
| 1971 | 3 | 4 | 13 | 43 | 11 | 66.74 | 135.37 | 4.1 |
| 1971 | 11 | 21 | 13 | 24 | 57 | 65.92 | 134.94 | 4.2 |
| 1972 | 2 | 11 | 8 | 15 | 12 | 65.20 | 133.30 | 4.0 |
| 1972 | 2 | 18 | 6 | 33 | 6 | 64.89 | 133.21 | 4.0 |
| 1972 | 7 | 1 | 17 | 6 | 53 | 65.44 | 133.55 | 3.8 |
| 1972 | 7 | 26 | 18 | 46 | 22 | 66.52 | 135.97 | 4.6 |
| 1973 | 2 | 16 | 8 | 34 | 22 | 66.87 | 135.49 | 4.3 |
| 1974 | 5 | 12 | 18 | 15 | 13 | 65.41 | 133.84 | 3.9 |
| 1974 | 12 | 9 | 4 | 27 | 7 | 64.97 | 133.51 | 4.0 |
| 1975 | 6 | 25 | 5 | 44 | 7 | 64.75 | 133.56 | 3.8 |
| 1976 | 1 | 16 | 12 | 37 | 18 | 65.39 | 134.25 | 4.2 |
| 1976 | 2 | 19 | 4 | 55 | 42 | 66.41 | 135.28 | 5.0 |
| 1976 | 4 | 8 | 18 | 59 | 40 | 64.93 | 134.03 | 4.2 |
| 1976 | 11 | 3 | 10 | 29 | 20 | 65.16 | 133.55 | 4.2 |
| 1976 | 11 | 28 | 1 | 23 | 41 | 66.38 | 135.24 | 4.2 |
| 1977 | 10 | 13 | 22 | 02 | 04 | 65.56 | 135.06 | 4.0 |

## BEAUFORT (BFT)

| YR | MO | DA | HR | MN | SC | LAT | LONG | M |
|---|---|---|---|---|---|---|---|---|
| 1968 | 4 | 4 | 0 | 33 | 30 | 71.92 | 132.68 | 3.8 |
| 1968 | 8 | 6 | 9 | 9 | 54 | 72.39 | 136.33 | 4.4 |
| 1970 | 5 | 4 | 15 | 14 | 59 | 72.10 | 132.95 | 4.0 |
| 1971 | 9 | 27 | 21 | 49 | 27 | 70.95 | 131.96 | 4.3 |
| 1972 | 12 | 15 | 9 | 8 | 35 | 71.64 | 134.96 | 4.5 |
| 1975 | 4 | 6 | 19 | 25 | 36 | 71.55 | 133.02 | 4.3 |
| 1975 | 6 | 14 | 20 | 50 | 26 | 71.96 | 131.72 | 5.1 |
| 1975 | 12 | 8 | 13 | 36 | 3 | 71.02 | 132.90 | 4.2 |
| 1976 | 6 | 30 | 6 | 29 | 54 | 72.13 | 135.55 | 4.2 |
| 1976 | 11 | 12 | 6 | 40 | 41 | 71.54 | 135.86 | 4.9 |

## MACKENZIE (MKZ)

| YR | MO | DA | HR | MN | SC | LAT | LONG | M |
|---|---|---|---|---|---|---|---|---|
| 1968 | 1 | 22 | 9 | 51 | 24 | 70.20 | 144.28 | 3.8 |
| 1968 | 1 | 22 | 14 | 4 | 52 | 70.35 | 143.88 | 4.3 |
| 1968 | 1 | 22 | 23 | 44 | 34 | 70.41 | 143.77 | 5.3 |
| 1968 | 1 | 23 | 8 | 30 | 45 | 70.40 | 144.24 | 4.1 |
| 1968 | 1 | 23 | 20 | 57 | 52 | 70.36 | 144.29 | 4.3 |
| 1968 | 1 | 30 | 9 | 28 | 33 | 70.25 | 144.32 | 3.8 |
| 1968 | 2 | 5 | 4 | 7 | 21 | 70.32 | 144.24 | 3.9 |
| 1968 | 2 | 6 | 16 | 36 | 22 | 70.36 | 143.91 | 4.5 |
| 1968 | 2 | 6 | 18 | 42 | 54 | 70.39 | 144.13 | 3.9 |
| 1968 | 2 | 10 | 17 | 29 | 0 | 70.34 | 143.89 | 4.3 |
| 1968 | 2 | 10 | 17 | 29 | 19 | 70.23 | 143.63 | 4.3 |
| 1968 | 2 | 10 | 17 | 39 | 50 | 70.54 | 142.65 | 3.9 |
| 1968 | 2 | 13 | 0 | 59 | 2 | 70.42 | 143.27 | 4.1 |
| 1968 | 2 | 28 | 8 | 36 | 16 | 70.41 | 143.16 | 4.1 |
| 1968 | 3 | 9 | 13 | 55 | 37 | 70.27 | 144.10 | 4.2 |
| 1968 | 4 | 25 | 10 | 33 | 50 | 70.21 | 144.46 | 4.4 |
| 1969 | 3 | 13 | 18 | 43 | 50 | 63.56 | 128.36 | 5.0 |
| 1969 | 7 | 3 | 21 | 30 | 26 | 66.03 | 140.26 | 3.8 |
| 1969 | 10 | 20 | 1 | 48 | 55 | 57.30 | 126.60 | 4.4 |
| 1969 | 10 | 28 | 0 | 46 | 4 | 68.03 | 136.46 | 4.0 |
| 1970 | 5 | 19 | 11 | 32 | 53 | 69.24 | 130.59 | 4.0 |
| 1970 | 12 | 19 | 15 | 24 | 16 | 64.60 | 138.94 | 3.8 |
| 1971 | 1 | 28 | 5 | 6 | 44 | 66.59 | 141.44 | 4.2 |
| 1971 | 3 | 2 | 0 | 32 | 5 | 70.23 | 144.07 | 4.3 |
| 1971 | 3 | 29 | 16 | 39 | 8 | 62.82 | 123.39 | 4.0 |
| 1971 | 12 | 14 | 15 | 18 | 31 | 66.58 | 139.46 | 3.8 |
| 1972 | 2 | 12 | 17 | 52 | 35 | 62.62 | 124.84 | 4.9 |
| 1973 | 3 | 23 | 15 | 15 | 37 | 66.69 | 130.21 | 4.6 |
| 1974 | 8 | 14 | 19 | 55 | 39 | 62.43 | 124.45 | 4.1 |
| 1974 | 9 | 22 | 11 | 7 | 50 | 65.22 | 141.26 | 4.3 |
| 1975 | 3 | 5 | 9 | 46 | 52 | 63.35 | 130.09 | 4.1 |
| 1975 | 3 | 30 | 11 | 33 | 34 | 69.60 | 143.23 | 3.9 |
| 1975 | 3 | 31 | 12 | 53 | 3 | 69.98 | 142.54 | 3.8 |
| 1975 | 6 | 5 | 5 | 52 | 40 | 57.95 | 124.80 | 4.2 |

## MACKENZIE (MKZ) (CONTINUED)

| YR | MO | DA | HR | MN | SC | LAT | LONG | M |
|---|---|---|---|---|---|---|---|---|
| 1975 | 8 | 24 | 0 | 27 | 47 | 62.54 | 127.76 | 4.3 |
| 1975 | 9 | 3 | 1 | 23 | 54 | 64.66 | 138.51 | 4.7 |
| 1976 | 2 | 25 | 18 | 15 | 28 | 65.46 | 139.99 | 3.8 |
| 1976 | 3 | 5 | 3 | 18 | 20 | 71.21 | 142.09 | 4.2 |
| 1976 | 3 | 17 | 23 | 59 | 58 | 67.05 | 131.76 | 4.3 |
| 1976 | 8 | 8 | 19 | 55 | 27 | 64.40 | 137.46 | 4.2 |
| 1976 | 8 | 16 | 13 | 36 | 54 | 64.77 | 134.87 | 4.1 |
| 1977 | 01 | 06 | 12 | 51 | 28 | 69.54 | 129.70 | 4.2 |
| 1977 | 07 | 03 | 17 | 41 | 16 | 62.54 | 128.69 | 4.0 |

## CHARLEVOIX (CHV)

| YR | MO | DA | HR | MN | SC | LAT | LONG | M |
|---|---|---|---|---|---|---|---|---|
| 1663 | 2 | 5 | 17 | 30 |  | 47.60 | 70.10 | 7.0 |
| 1860 | 10 | 17 | 11 | 15 |  | 47.50 | 70.10 | 6.0 |
| 1870 | 10 | 20 | 16 | 30 |  | 47.40 | 70.50 | 6.5 |
| 1924 | 9 | 30 | 8 | 52 | 30 | 47.80 | 69.80 | 5.5 |
| 1925 | 3 | 1 | 2 | 19 | 20 | 47.80 | 69.80 | 7.0 |
| 1925 | 3 | 1 | 4 | 30 | 42 | 47.80 | 69.80 | 5.0 |
| 1925 | 3 | 21 | 15 | 22 | 4 | 47.80 | 69.80 | 5.0 |
| 1930 | 12 | 25 | 22 | 7 | 34 | 47.30 | 70.40 | 4.5 |
| 1931 | 1 | 8 |  | 13 | 36 | 47.30 | 70.40 | 5.5 |
| 1939 | 6 | 24 | 19 | 20 | 21 | 47.30 | 70.40 | 4.5 |
| 1939 | 10 | 19 | 11 | 53 | 58 | 47.80 | 69.80 | 5.0 |
| 1939 | 10 | 21 | 8 | 7 | 13 | 47.80 | 69.80 | 4.0 |
| 1939 | 10 | 27 | 1 | 36 | 36 | 47.80 | 69.80 | 4.5 |
| 1939 | 11 | 7 | 2 | 40 | 32 | 47.80 | 70.50 | 4.0 |
| 1939 | 12 | 25 | 10 | 29 | 13 | 48.10 | 70.40 | 4.0 |
| 1940 | 4 | 13 | 8 | 13 | 34 | 47.73 | 70.73 | 3.8 |
| 1940 | 10 | 13 | 19 | 50 | 51 | 47.80 | 69.80 | 4.5 |
| 1941 | 9 | 6 | 17 | 4 | 56 | 47.43 | 70.52 | 3.8 |
| 1941 | 10 | 6 | 16 | 34 | 27 | 47.63 | 70.60 | 4.0 |
| 1943 | 9 | 28 | 16 | 30 | 25 | 47.27 | 70.40 | 3.8 |
| 1943 | 11 | 6 |  | 6 | 40 | 47.60 | 70.30 | 3.9 |
| 1944 | 2 | 5 | 12 | 37 | 52 | 47.40 | 70.50 | 4.0 |
| 1945 | 10 | 9 | 13 | 18 | 44 | 47.80 | 69.80 | 4.5 |
| 1947 | 2 | 2 | 16 | 50 | 32 | 47.67 | 70.53 | 4.0 |
| 1947 | 3 | 29 | 12 | 28 | 52 | 47.37 | 70.50 | 4.0 |
| 1947 | 10 | 22 | 9 | 36 | 38 | 47.55 | 70.72 | 3.8 |
| 1948 | 1 | 1 | 18 | 33 | 45 | 47.30 | 70.40 | 4.5 |
| 1952 | 3 | 30 | 13 | 11 | 7 | 47.60 | 69.88 | 4.0 |
| 1952 | 4 | 19 | 2 | 50 | 52 | 47.47 | 70.58 | 3.8 |
| 1952 | 10 | 14 | 22 | 3 | 42 | 47.80 | 69.80 | 5.0 |
| 1954 | 2 | 7 | 20 | 24 | 16 | 47.60 | 70.25 | 3.8 |
| 1955 | 2 | 1 | 12 | 40 | 27 | 47.50 | 70.30 | 4.0 |
| 1957 | 8 | 6 | 23 | 50 | 38 | 47.30 | 70.42 | 4.0 |
| 1958 | 8 | 8 | 22 | 15 | 3 | 47.93 | 70.38 | 3.9 |
| 1960 | 4 | 23 | 11 | 47 | 52 | 47.53 | 70.30 | 4.0 |

CHARLEVOIX (CHV) (CONTINUED)

| YR | MO | DA | HR | MN | SC | LAT | LONG | M |
|---|---|---|---|---|---|---|---|---|
| 1962 | 7 | 27 | 17 | 56 | 57 | 47.25 | 70.67 | 4.0 |
| 1965 | 12 | 16 | 13 | 53 | 19 | 47.50 | 69.90 | 4.0 |
| 1968 | 3 | 30 | 15 | 28 | 59 | 47.94 | 70.49 | 3.1 |
| 1968 | 4 | 11 | 9 | 18 | 33 | 47.60 | 70.44 | 3.5 |
| 1968 | 10 | 20 | 2 | 36 | 58 | 47.47 | 70.57 | 3.6 |
| 1969 | 5 | 10 | 18 | 43 | 29 | 47.47 | 70.65 | 3.6 |
| 1969 | 5 | 10 | 20 | 1 | 55 | 47.47 | 70.65 | 3.6 |
| 1969 | 7 | 14 | 3 | 6 | 59 | 47.83 | 70.09 | 4.0 |
| 1969 | 8 | 31 | 7 | 20 | 27 | 47.49 | 70.07 | 3.2 |
| 1970 | 9 | 7 | 21 | 39 | 27 | 47.92 | 70.30 | 3.2 |
| 1971 | 9 | 12 | 8 | 31 | 43 | 47.56 | 70.24 | 3.2 |
| 1972 | 2 | 13 | 11 | 8 | 7 | 47.77 | 70.27 | 3.2 |
| 1972 | 8 | 2 | 1 | 3 | 1 | 47.40 | 70.50 | 2.9 |
| 1972 | 9 | 25 | 11 | 30 | 21 | 47.50 | 70.60 | 3.0 |
| 1973 | 1 | 28 | 13 | 7 | 50 | 47.98 | 70.00 | 3.1 |
| 1973 | 9 | 10 | 6 | 11 | 12 | 47.68 | 70.24 | 2.9 |
| 1973 | 11 | 16 | 1 | 36 | 34 | 47.55 | 70.29 | 3.1 |
| 1974 | 6 | 30 | 16 | 55 | 10 | 47.84 | 70.08 | 3.1 |
| 1975 | 08 | 21 | 04 | 29 | 37 | 47.44 | 70.18 | 3.1 |
| 1975 | 11 | 25 | 23 | 29 | 14 | 47.62 | 70.09 | 2.9 |
| 1976 | 05 | 20 | 14 | 55 | 16 | 47.45 | 70.31 | 2.8 |
| 1976 | 07 | 11 | 05 | 15 | 02 | 47.43 | 70.44 | 2.9 |
| 1976 | 08 | 03 | 02 | 57 | 13 | 47.69 | 70.10 | 2.9 |
| 1976 | 10 | 23 | 20 | 58 | 18 | 47.82 | 69.78 | 4.2 |
| 1976 | 10 | 23 | 21 | 23 | 06 | 47.88 | 69.78 | 3.1 |
| 1976 | 10 | 24 | 10 | 49 | 46 | 47.81 | 69.87 | 3.5 |
| 1977 | 02 | 14 | 00 | 35 | 04 | 47.54 | 70.42 | 3.1 |
| 1977 | 06 | 20 | 05 | 05 | 53 | 47.84 | 70.16 | 3.1 |

WESTERN QUEBEC (WQU)

| YR | MO | DA | HR | MN | SC | LAT | LONG | M |
|---|---|---|---|---|---|---|---|---|
| 1914 | 2 | 10 | 18 | 31 |  | 46.00 | 75.00 | 5.5 |
| 1931 | 9 | 23 | 22 | 47 | 37 | 47.00 | 76.07 | 4.5 |
| 1934 | 4 | 15 | 2 | 58 | 13 | 44.90 | 73.90 | 4.5 |
| 1935 | 11 | 1 | 6 | 3 | 40 | 46.78 | 79.07 | 6.0 |
| 1935 | 11 | 2 | 14 | 31 | 58 | 47.70 | 78.30 | 5.0 |
| 1937 | 11 | 6 | 14 | 31 | 20 | 46.73 | 75.72 | 4.0 |
| 1937 | 11 | 12 | 16 | 57 | 32 | 45.92 | 74.33 | 4.0 |
| 1938 | 11 | 18 | 22 | 19 | 6 | 44.75 | 75.25 | 4.0 |
| 1938 | 11 | 26 | 7 | 47 | 57 | 47.03 | 76.20 | 4.0 |
| 1938 | 12 | 25 | 7 | 46 | 19 | 47.58 | 75.37 | 4.0 |
| 1940 | 2 | 10 | 20 | 57 | 17 | 46.30 | 76.30 | 4.0 |
| 1941 | 6 | 26 | 4 | 5 | 44 | 47.40 | 76.83 | 4.0 |
| 1942 | 5 | 20 | 12 | 19 | 22 | 45.90 | 74.67 | 4.5 |
| 1942 | 5 | 24 | 11 | 33 | 57 | 44.73 | 73.83 | 3.9 |
| 1942 | 12 | 5 | 21 | 10 | 51 | 46.97 | 76.07 | 4.0 |
| 1943 | 7 | 6 | 22 | 10 | 14 | 44.92 | 73.13 | 4.0 |

WESTERN QUEBEC (WQU) (CONTINUED)

| YR | MO | DA | HR | MN | SC | LAT | LONG | M |
|---|---|---|---|---|---|---|---|---|
| 1944 | 1 | 22 | 21 | 55 | 9 | 45.70 | 76.60 | 4.5 |
| 1944 | 3 | 8 | 12 | 49 | 56 | 46.68 | 78.87 | 4.0 |
| 1944 | 9 | 5 | 4 | 38 | 45 | 44.97 | 74.90 | 5.6 |
| 1944 | 9 | 5 | 8 | 51 | 6 | 44.98 | 74.90 | 4.5 |
| 1944 | 9 | 9 | 23 | 24 | 48 | 44.98 | 74.90 | 4.0 |
| 1944 | 10 | 31 | 8 | 42 | 25 | 44.98 | 74.90 | 4.0 |
| 1945 | 6 | 12 | 7 | 58 | 15 | 46.90 | 75.50 | 4.5 |
| 1947 | 1 | 19 |  | 45 | 1 | 46.80 | 76.70 | 4.0 |
| 1948 | 5 | 7 | 12 | 2 | 26 | 45.75 | 73.63 | 4.0 |
| 1949 | 10 | 16 | 23 | 33 | 42 | 45.30 | 74.83 | 4.0 |
| 1950 | 3 | 6 | 16 | 14 | 11 | 46.00 | 74.50 | 4.0 |
| 1950 | 4 | 14 | 18 | 20 | 48 | 48.00 | 75.70 | 5.0 |
| 1950 | 8 | 4 | 14 | 29 | 28 | 45.20 | 74.72 | 4.0 |
| 1951 | 10 | 25 | 7 | 7 | 52 | 45.10 | 74.73 | 4.0 |
| 1952 | 1 | 30 | 4 |  |  | 44.50 | 73.20 | 4.5 |
| 1952 | 3 | 17 | 4 | 14 | 41 | 47.30 | 76.40 | 4.0 |
| 1952 | 7 | 19 | 1 | 16 | 17 | 46.87 | 75.83 | 4.5 |
| 1954 | 4 | 12 | 21 | 22 | 1 | 46.90 | 76.05 | 4.5 |
| 1954 | 9 | 11 | 18 | 55 | 52 | 47.33 | 75.63 | 4.5 |
| 1955 | 2 | 3 | 2 | 30 |  | 44.50 | 73.22 | 4.0 |
| 1956 | 6 | 15 |  | 53 | 37 | 47.10 | 76.43 | 4.0 |
| 1956 | 11 | 4 | 11 | 53 | 24 | 46.22 | 75.73 | 4.0 |
| 1958 | 3 | 1 | 17 | 41 | 49 | 46.90 | 76.03 | 3.9 |
| 1958 | 5 | 14 | 17 | 41 | 21 | 46.97 | 76.55 | 5.0 |
| 1958 | 7 | 25 | 3 | 45 | 11 | 46.57 | 75.80 | 3.8 |
| 1959 | 5 | 21 | 9 | 38 | 51 | 46.55 | 76.45 | 4.0 |
| 1962 | 1 | 27 | 12 | 11 | 17 | 45.92 | 74.85 | 4.0 |
| 1963 | 8 | 26 | 16 | 29 | 35 | 45.18 | 73.95 | 3.5 |
| 1963 | 10 | 15 | 12 | 29 | 2 | 46.35 | 77.59 | 4.0 |
| 1963 | 10 | 15 | 13 | 59 | 53 | 46.30 | 77.59 | 4.0 |
| 1964 | 1 | 8 | 8 | 59 | 28 | 46.23 | 77.53 | 3.3 |
| 1964 | 1 | 8 | 10 | 3 | 26 | 46.23 | 77.53 | 4.0 |
| 1964 | 1 | 8 | 10 | 4 | 31 | 46.23 | 77.53 | 4.5 |
| 1964 | 3 | 29 | 4 | 16 |  | 44.90 | 74.90 | 4.0 |
| 1964 | 7 | 24 | 10 | 34 | 11 | 46.65 | 76.25 | 3.3 |
| 1965 | 9 | 15 | 17 | 56 | 28 | 46.72 | 79.05 | 3.8 |
| 1965 | 11 | 7 | 20 | 57 | 44 | 47.30 | 76.20 | 4.0 |
| 1965 | 11 | 24 | 21 | 28 | 1 | 46.93 | 76.28 | 3.7 |
| 1965 | 12 | 19 | 1 | 5 | 52 | 47.03 | 76.42 | 3.5 |
| 1966 | 6 | 25 |  | 5 | 51 | 45.16 | 73.83 | 3.4 |
| 1966 | 11 | 13 | 15 | 43 | 29 | 47.00 | 76.25 | 3.6 |
| 1967 | 6 | 11 | 1 | 49 | 39 | 46.58 | 75.03 | 3.7 |
| 1968 | 10 | 19 | 10 | 37 | 18 | 45.30 | 74.12 | 3.2 |
| 1968 | 11 | 3 | 20 | 50 | 49 | 46.17 | 76.30 | 3.1 |
| 1969 | 3 | 19 | 7 |  | 37 | 45.64 | 76.22 | 2.8 |
| 1969 | 6 | 12 | 11 |  | 11 | 46.92 | 75.95 | 2.9 |
| 1969 | 10 | 10 |  | 7 | 7 | 46.42 | 75.20 | 4.0 |
| 1969 | 10 | 10 | 8 | 16 | 12 | 46.38 | 75.05 | 2.8 |
| 1970 | 4 | 6 | 11 | 29 | 16 | 46.16 | 74.84 | 2.8 |
| 1970 | 10 | 15 | 18 | 56 | 11 | 47.07 | 76.25 | 3.3 |

WESTERN QUEBEC (WQU) (CONTINUED)

| YR | MO | DA | HR | MN | SC | LAT | LONG | M |
|---|---|---|---|---|---|---|---|---|
| 1971 | 1 | 6 | 6 | 22 | 8 | 47.17 | 75.96 | 3.0 |
| 1971 | 1 | 19 | 13 | 44 | 25 | 46.92 | 75.18 | 3.1 |
| 1971 | 5 | 14 | 6 | 20 | 9 | 45.10 | 73.37 | 3.2 |
| 1971 | 7 | 6 | 17 | 47 | 49 | 46.55 | 76.28 | 3.0 |
| 1971 | 9 | 27 | 8 | 47 | 23 | 45.71 | 75.17 | 3.2 |
| 1971 | 11 | 15 | 10 | 38 | 55 | 45.06 | 73.87 | 3.0 |
| 1971 | 11 | 22 | 5 | 29 | 7 | 47.24 | 76.28 | 3.0 |
| 1971 | 11 | 23 | 16 | 32 | 30 | 45.83 | 76.62 | 3.0 |
| 1971 | 12 | 18 | 15 | 36 | 24 | 46.18 | 74.62 | 4.0 |
| 1972 | 4 | 25 | 3 | 24 | 25 | 46.60 | 76.00 | 3.5 |
| 1972 | 6 | 2 | 4 | 24 | 57 | 45.70 | 75.90 | 2.8 |
| 1972 | 7 | 30 | 10 | 42 | 16 | 46.30 | 76.10 | 3.1 |
| 1972 | 9 | 12 | 9 | 15 | 40 | 46.10 | 77.60 | 3.1 |
| 1972 | 12 | 16 | 19 | 1 | 36 | 45.77 | 75.22 | 4.0 |
| 1973 | 2 | 2 | 23 | 9 | 30 | 44.43 | 74.78 | 2.8 |
| 1973 | 2 | 25 | 19 | 46 | 46 | 45.23 | 73.97 | 2.9 |
| 1974 | 2 | 13 | 18 | 14 | 53 | 46.40 | 75.27 | 2.9 |
| 1974 | 3 | 18 | 16 | 5 |  | 44.45 | 74.85 | 3.0 |
| 1974 | 4 | 29 | 6 | 10 | 48 | 46.00 | 75.23 | 2.8 |
| 1974 | 8 | 8 | 11 | 55 | 33 | 45.93 | 76.08 | 3.2 |
| 1974 | 10 | 23 | 22 | 52 | 57 | 46.08 | 75.48 | 3.2 |
| 1974 | 11 | 2 | 13 | 47 | 56 | 46.07 | 75.03 | 3.2 |
| 1974 | 11 | 3 | 4 | 27 | 4 | 46.07 | 75.05 | 2.8 |
| 1974 | 12 | 2 | 10 | 58 | 5 | 46.25 | 75.50 | 3.5 |
| 1975 | 04 | 03 | 19 | 03 | 17 | 45.73 | 74.24 | 3.1 |
| 1975 | 05 | 29 | 21 | 19 | 16 | 47.23 | 75.19 | 3.2 |
| 1975 | 06 | 09 | 18 | 39 | 22 | 44.94 | 73.65 | 3.5 |
| 1975 | 07 | 12 | 12 | 37 | 15 | 46.46 | 76.22 | 4.2 |
| 1975 | 12 | 19 | 15 | 25 | 11 | 47.01 | 78.84 | 3.8 |
| 1976 | 01 | 13 | 21 | 15 | 58 | 46.88 | 76.09 | 2.9 |
| 1976 | 02 | 02 | 14 | 44 | 13 | 46.10 | 75.56 | 2.9 |
| 1976 | 07 | 13 | 03 | 51 | 14 | 45.17 | 74.10 | 3.1 |
| 1976 | 11 | 05 | 16 | 50 | 00 | 46.76 | 75.48 | 2.9 |
| 1976 | 11 | 06 | 06 | 09 | 29 | 47.11 | 75.96 | 3.0 |
| 1977 | 01 | 08 | 05 | 05 | 23 | 47.25 | 75.55 | 2.9 |
| 1977 | 07 | 14 | 07 | 39 | 30 | 45.98 | 74.41 | 3.4 |
| 1977 | 09 | 28 | 17 | 21 | 44 | 44.45 | 73.92 | 2.9 |
| 1977 | 11 | 07 | 20 | 48 | 52 | 46.29 | 75.21 | 3.0 |
| 1977 | 11 | 25 | 18 | 47 | 22 | 46.74 | 76.36 | 3.0 |
| 1977 | 12 | 22 | 14 | 57 | 00 | 46.86 | 76.94 | 3.5 |

## LOWER ST. LAWRENCE (LSL)

| YR | MO | DA | HR | MN | SC | LAT | LONG | M |
|---|---|---|---|---|---|---|---|---|
| 1944 | 4 | 9 | 12 | 44 | 37 | 50.10 | 67.43 | 5.0 |
| 1944 | 6 | 23 | 6 | 37 | 52 | 49.42 | 67.75 | 5.0 |
| 1950 | 6 | 29 | 9 | 13 | 33 | 49.50 | 67.40 | 4.5 |
| 1951 | 9 | 19 | 8 | 19 | 37 | 49.30 | 66.25 | 4.5 |
| 1953 | 1 | 24 | 9 | 58 | 36 | 49.40 | 66.00 | 4.5 |
| 1953 | 9 | 14 | 22 | 52 | 57 | 49.40 | 65.30 | 4.5 |
| 1961 | 7 | 5 | 22 | 43 | 44 | 49.80 | 66.90 | 4.5 |
| 1964 | 7 | 1 | 21 | 41 | 30 | 49.43 | 67.42 | 3.8 |
| 1965 | 10 | 5 | 14 | 36 | 55 | 49.60 | 67.10 | 4.0 |
| 1966 | 1 | 14 | 15 | 29 | 25 | 48.90 | 67.70 | 4.0 |
| 1966 | 1 | 14 | 16 | 14 | 7 | 48.90 | 67.50 | 3.4 |
| 1966 | 7 | 12 | 1 | 6 | 38 | 49.50 | 66.00 | 3.3 |
| 1966 | 7 | 17 | 7 | 32 | 19 | 49.58 | 68.42 | 3.6 |
| 1966 | 7 | 24 | 22 | 19 | 46 | 49.63 | 68.55 | 3.7 |
| 1966 | 7 | 27 | 11 | 12 | 43 | 49.42 | 68.42 | 3.4 |
| 1966 | 8 | 20 | 13 | 13 | 33 | 49.58 | 68.33 | 3.5 |
| 1966 | 12 | 12 | 21 | 4 | 12 | 49.00 | 68.17 | 3.4 |
| 1967 | 9 | 30 | 22 | 39 | 51 | 49.30 | 65.90 | 4.5 |
| 1968 | 9 | 29 | 10 | 4 | 48 | 50.14 | 67.22 | 3.6 |
| 1972 | 8 | 22 | 19 | 17 | 49 | 49.60 | 66.40 | 4.0 |
| 1974 | 7 | 2 | 4 | 46 | 51 | 49.58 | 67.22 | 3.4 |
| 1974 | 12 | 27 |  | 50 | 12 | 49.14 | 67.44 | 3.5 |
| 1975 | 07 | 18 | 04 | 21 | 06 | 49.16 | 66.81 | 3.1 |
| 1975 | 10 | 21 | 20 | 50 | 02 | 49.13 | 68.13 | 3.1 |
| 1976 | 03 | 29 | 21 | 23 | 27 | 49.34 | 67.86 | 3.3 |
| 1976 | 05 | 15 | 21 | 06 | 52 | 49.84 | 68.62 | 3.3 |
| 1976 | 09 | 18 | 00 | 40 | 32 | 49.36 | 67.10 | 3.4 |
| 1977 | 08 | 08 | 23 | 06 | 12 | 49.70 | 67.08 | 3.8 |
| 1977 | 08 | 08 | 23 | 08 | 40 | 49.77 | 67.05 | 3.9 |
| 1977 | 08 | 08 | 23 | 29 | 27 | 49.70 | 67.02 | 2.8 |
| 1977 | 10 | 04 | 07 | 32 | 04 | 49.95 | 66.86 | 2.8 |

## NORTHERN APPALACHIANS (NAP)

| YR | MO | DA | HR | MN | SC | LAT | LONG | M |
|---|---|---|---|---|---|---|---|---|
| 1937 | 9 | 30 | 7 | 58 | 10 | 45.47 | 65.83 | 4.5 |
| 1938 | 8 | 22 | 12 | 48 | 13 | 44.70 | 68.80 | 4.0 |
| 1940 | 3 | 28 | 11 | 42 | 34 | 44.70 | 69.90 | 3.8 |
| 1940 | 12 | 20 | 7 | 27 | 26 | 43.80 | 71.30 | 5.0 |
| 1940 | 12 | 24 | 13 | 43 | 44 | 43.80 | 71.30 | 5.0 |
| 1940 | 12 | 25 | 5 | 3 | 43 | 43.80 | 71.30 | 3.9 |
| 1940 | 12 | 27 | 19 | 56 | 9 | 43.80 | 71.30 | 3.9 |
| 1943 | 1 | 14 | 21 | 32 | 38 | 45.25 | 69.60 | 5.0 |
| 1943 | 3 | 14 | 14 | 2 | 27 | 43.70 | 71.57 | 3.9 |
| 1945 | 7 | 15 | 10 | 44 | 59 | 44.90 | 67.00 | 3.9 |
| 1947 | 12 | 28 | 19 | 58 | 18 | 45.27 | 69.25 | 4.0 |
| 1948 | 1 | 6 | 20 | 46 | 51 | 45.40 | 69.28 | 3.9 |
| 1949 | 10 | 5 | 2 | 33 | 47 | 44.80 | 70.50 | 4.0 |

NORTHERN APPALACHIANS (NAP) (CONTINUED)

| YR | MO | DA | HR | MN | SC | LAT | LONG | M |
|---|---|---|---|---|---|---|---|---|
| 1952 | 8 | 25 |  | 7 |  | 43.00 | 74.50 | 4.0 |
| 1953 | 3 | 31 | 12 | 58 | 34 | 44.07 | 73.12 | 3.9 |
| 1955 | 1 | 21 | 8 | 40 |  | 42.97 | 73.78 | 4.0 |
| 1957 | 4 | 23 | 19 | 42 |  | 44.40 | 72.00 | 4.0 |
| 1957 | 4 | 24 |  | 41 | 59 | 44.42 | 72.00 | 4.0 |
| 1957 | 4 | 26 | 11 | 40 | 6 | 43.60 | 70.40 | 4.0 |
| 1958 | 9 | 19 | 12 | 45 |  | 43.50 | 70.20 | 4.0 |
| 1961 | 1 | 29 |  | 49 | 39 | 46.38 | 66.93 | 3.8 |
| 1961 | 12 | 14 | 1 | 49 | 35 | 43.83 | 67.82 | 4.0 |
| 1962 | 4 | 10 | 14 | 30 | 48 | 44.15 | 73.05 | 4.5 |
| 1963 | 7 | 1 | 19 | 59 | 12 | 42.37 | 73.75 | 3.3 |
| 1963 | 12 | 4 | 21 | 32 | 34 | 43.60 | 71.60 | 3.7 |
| 1966 | 5 | 20 |  | 5 | 42 | 44.25 | 66.50 | 3.8 |
| 1966 | 7 | 24 | 1 | 59 | 58 | 44.50 | 67.60 | 3.6 |
| 1967 | 7 | 1 | 16 | 5 | 40 | 44.70 | 69.87 | 4.0 |
| 1968 | 5 | 27 | 19 | 21 | 56 | 46.90 | 66.66 | 3.3 |
| 1968 | 9 | 23 | 15 | 38 | 50 | 45.17 | 69.45 | 3.3 |
| 1970 | 8 | 8 |  | 10 | 30 | 45.80 | 66.12 | 3.3 |
| 1971 | 5 | 23 | 6 | 24 | 27 | 43.82 | 74.54 | 3.7 |
| 1971 | 5 | 23 | 9 | 29 | 59 | 43.94 | 74.55 | 3.6 |
| 1971 | 7 | 10 | 8 | 15 | 2 | 43.93 | 74.53 | 3.4 |
| 1973 | 6 | 15 | 1 | 9 | 5 | 45.39 | 71.03 | 5.0 |
| 1973 | 7 | 15 | 8 | 20 | 31 | 43.97 | 74.49 | 3.4 |
| 1973 | 7 | 16 | 8 | 41 | 58 | 43.76 | 74.47 | 3.3 |
| 1975 | 01 | 17 | 00 | 10 | 39 | 44.91 | 66.91 | 3.1 |
| 1975 | 02 | 28 | 18 | 40 | 21 | 46.39 | 66.01 | 2.9 |
| 1975 | 08 | 27 | 22 | 28 | 22 | 46.80 | 65.34 | 3.0 |
| 1975 | 10 | 15 | 03 | 26 | 17 | 45.11 | 65.89 | 3.1 |
| 1975 | 11 | 11 | 20 | 54 | 55 | 43.91 | 74.64 | 4.0 |
| 1976 | 03 | 08 | 18 | 08 | 40 | 46.78 | 64.96 | 2.8 |
| 1977 | 10 | 24 | 18 | 09 | 12 | 47.00 | 67.05 | 3.0 |
| 1979 | 04 | 18 | 02 | 34 | 14 | 43.95 | 69.75 | 4.0 |
| 1979 | 04 | 20 | 10 | 32 | 49 | 45.18 | 66.00 | 2.8 |
| 1980 | 09 | 08 | 05 | 59 | 55 | 44.68 | 69.00 | 3.2 |
| 1981 | 04 | 13 | 17 | 31 | 38 | 45.92 | 65.69 | 3.7 |
| 1981 | 05 | 08 | 18 | 56 | 13 | 45.90 | 65.97 | 2.8 |
| 1982 | 01 | 09 | 12 | 53 | 53 | 47.00 | 66.60 | 5.7 |
| 1982 | 01 | 09 | 13 | 09 | 40 | 47.00 | 66.60 | 3.4 |
| 1982 | 01 | 09 | 13 | 52 | 21 | 47.00 | 66.60 | 3.9 |
| 1982 | 01 | 09 | 16 | 36 | 45 | 47.00 | 66.60 | 5.1 |
| 1982 | 01 | 09 | 17 | 27 | 56 | 47.00 | 66.60 | 3.7 |
| 1982 | 01 | 09 | 17 | 37 | 37 | 47.00 | 66.60 | 3.3 |
| 1982 | 01 | 09 | 22 | 45 | 10 | 47.00 | 66.60 | 3.7 |
| 1982 | 01 | 11 | 21 | 41 | 09 | 47.00 | 66.60 | 5.5 |
| 1982 | 01 | 11 | 22 | 36 | 33 | 47.00 | 66.60 | 3.4 |
| 1982 | 01 | 12 | 01 | 58 | 01 | 47.00 | 66.60 | 3.5 |
| 1982 | 01 | 12 | 02 | 01 | 41 | 47.00 | 66.60 | 3.2 |
| 1982 | 01 | 12 | 11 | 49 | 31 | 47.00 | 66.60 | 2.9 |
| 1982 | 01 | 12 | 13 | 38 | 34 | 47.00 | 66.60 | 3.3 |
| 1982 | 01 | 13 | 17 | 56 | 46 | 47.00 | 66.60 | 4.0 |

## NORTHERN APPALACHIANS (NAP) (CONTINUED)

| YR | MO | DA | HR | MN | SC | LAT | LONG | M |
|---|---|---|---|---|---|---|---|---|
| 1982 | 01 | 13 | 17 | 59 | 46 | 47.00 | 66.60 | 3.6 |
| 1982 | 01 | 15 | 12 | 37 | 39 | 47.00 | 66.60 | 3.7 |
| 1982 | 01 | 17 | 13 | 33 | 58 | 47.00 | 66.60 | 3.5 |
| 1982 | 01 | 23 | 08 | 56 | 49 | 47.00 | 66.60 | 2.8 |
| 1982 | 03 | 01 | 09 | 33 | 58 | 47.00 | 66.60 | 3.1 |
| 1982 | 03 | 04 | 06 | 06 | 33 | 47.00 | 66.60 | 2.8 |
| 1982 | 03 | 16 | 11 | 14 | 02 | 47.00 | 66.60 | 3.7 |
| 1982 | 03 | 20 | 03 | 08 | 11 | 47.00 | 66.60 | 3.1 |
| 1982 | 03 | 21 | 02 | 33 | 43 | 47.00 | 66.60 | 3.1 |
| 1982 | 03 | 26 | 05 | 36 | 41 | 47.00 | 66.60 | 2.8 |
| 1982 | 03 | 26 | 13 | 38 | 08 | 47.00 | 66.60 | 3.0 |
| 1982 | 03 | 31 | 21 | 02 | 22 | 47.00 | 66.60 | 4.8 |
| 1982 | 03 | 31 | 21 | 29 | 21 | 47.00 | 66.60 | 3.1 |
| 1982 | 04 | 02 | 13 | 50 | 13 | 47.00 | 66.60 | 4.3 |
| 1982 | 04 | 08 | 04 | 54 | 34 | 47.00 | 66.60 | 3.4 |
| 1982 | 04 | 10 | 01 | 59 | 00 | 47.00 | 66.60 | 2.9 |
| 1982 | 04 | 11 | 18 | 27 | 19 | 47.00 | 66.60 | 3.2 |
| 1982 | 04 | 18 | 22 | 47 | 21 | 47.00 | 66.60 | 4.1 |
| 1982 | 04 | 28 | 06 | 36 | 02 | 47.00 | 66.60 | 3.4 |
| 1982 | 05 | 02 | 01 | 42 | 45 | 47.00 | 66.60 | 3.1 |
| 1982 | 05 | 02 | 23 | 31 | 37 | 47.00 | 66.60 | 3.3 |
| 1982 | 05 | 06 | 16 | 28 | 08 | 47.00 | 66.60 | 4.0 |
| 1982 | 05 | 16 | 22 | 45 | 16 | 47.00 | 66.60 | 2.8 |
| 1982 | 05 | 28 | 06 | 24 | 26 | 47.00 | 66.60 | 3.0 |
| 1982 | 06 | 16 | 11 | 43 | 27 | 47.00 | 66.60 | 4.6 |
| 1982 | 06 | 16 | 16 | 15 | 41 | 47.00 | 66.60 | 3.0 |
| 1982 | 06 | 18 | 11 | 24 | 36 | 47.00 | 66.60 | 3.0 |
| 1982 | 06 | 25 | 06 | 47 | 10 | 47.00 | 66.60 | 2.9 |

## LAURENTIAN SLOPE (LSP)

| YR | MO | DA | HR | MN | SC | LAT | LONG | M |
|---|---|---|---|---|---|---|---|---|
| 1929 | 11 | 18 | 20 | 32 |  | 44.50 | 56.30 | 7.0 |
| 1951 | 6 | 27 | 13 | 17 | 50 | 45.00 | 57.00 | 5.0 |
| 1954 | 8 | 28 | 15 | 23 | 1 | 45.17 | 56.87 | 5.2 |
| 1954 | 10 | 16 | 6 | 45 | 0 | 44.83 | 56.80 | 5.3 |
| 1965 | 11 | 28 | 23 | 26 | 10 | 45.57 | 57.90 | 4.2 |
| 1971 | 6 | 11 | 10 | 33 | 10 | 45.70 | 55.05 | 4.2 |
| 1975 | 3 | 31 | 17 | 8 | 2 | 44.70 | 56.22 | 4.6 |
| 1975 | 10 | 06 | 22 | 21 | 41 | 44.71 | 57.07 | 5.2 |
| 1977 | 7 | 16 | 11 | 37 | 43 | 44.52 | 55.83 | 3.8 |

## ATTICA (ATT)

| YR | MO | DA | HR | MN | SC | LAT | LONG | M |
|---|---|---|---|---|---|---|---|---|
| 1929 | 8 | 12 | 11 | 24 | 48 | 42.87 | 78.35 | 5.5 |
| 1955 | 8 | 16 | 7 | 35 |  | 42.89 | 78.28 | 4.0 |
| 1965 | 7 | 16 | 11 | 6 | 55 | 43.20 | 78.50 | 3.5 |
| 1966 | 1 | 1 | 13 | 23 | 38 | 43.30 | 78.40 | 4.5 |
| 1967 | 6 | 13 | 19 | 8 | 54 | 43.30 | 78.00 | 4.5 |

## EASTERN BACKGROUND (EBG)

| YR | MO | DA | HR | MN | SC | LAT | LONG | M |
|---|---|---|---|---|---|---|---|---|
| 1963 | 3 | 2 | 20 | 24 | 32 | 41.51 | 75.73 | 3.4 |
| 1963 | 5 | 19 | 19 | 14 | 18 | 43.50 | 75.23 | 3.5 |
| 1963 | 10 | 25 | 8 | 49 | 39 | 51.40 | 61.90 | 3.3 |
| 1964 | 1 | 20 | 18 | 57 | 55 | 46.83 | 71.33 | 3.9 |
| 1964 | 4 | 5 | 13 | 21 | 6 | 46.42 | 81.08 | 3.8 |
| 1964 | 6 | 27 | 19 | 17 | 46 | 47.75 | 79.17 | 3.7 |
| 1964 | 7 | 12 |  |  | 41 | 46.72 | 71.41 | 3.4 |
| 1964 | 8 | 12 | 9 | 35 | 27 | 50.47 | 64.87 | 3.7 |
| 1964 | 10 | 17 | 14 | 13 | 7 | 47.67 | 67.25 | 3.9 |
| 1965 | 1 | 8 | 12 | 29 | 45 | 48.00 | 78.50 | 3.5 |
| 1965 | 4 | 1 | 6 | 30 | 20 | 46.00 | 80.50 | 3.4 |
| 1965 | 10 | 18 | 12 | 10 | 17 | 53.13 | 79.27 | 3.6 |
| 1965 | 11 | 15 | 11 | 12 | 30 | 49.37 | 53.66 | 4.0 |
| 1965 | 12 | 19 | 0 | 49 | 17 | 51.17 | 80.83 | 4.5 |
| 1967 | 2 | 21 | 0 | 53 | 57 | 52.00 | 81.33 | 3.5 |
| 1967 | 2 | 22 | 14 | 21 | 55 | 50.50 | 63.33 | 3.5 |
| 1967 | 8 | 5 | 8 | 8 | 32 | 48.57 | 64.97 | 3.9 |
| 1967 | 9 | 17 | 1 | 19 | 38 | 50.67 | 75.25 | 4.0 |
| 1967 | 9 | 23 | 16 | 27 | 55 | 46.93 | 70.70 | 3.4 |
| 1967 | 10 | 25 | 7 | 5 | 31 | 50.15 | 63.52 | 3.4 |
| 1967 | 11 | 2 | 3 | 35 | 38 | 52.20 | 58.40 | 3.4 |
| 1968 | 10 | 10 | 20 | 10 | 41 | 45.80 | 81.66 | 3.4 |
| 1969 | 2 | 2 | 4 | 24 | 28 | 49.71 | 55.13 | 3.5 |
| 1969 | 8 | 5 | 21 | 53 | 23 | 47.66 | 52.29 | 3.4 |
| 1969 | 11 | 17 | 7 | 32 | 27 | 53.42 | 82.81 | 3.5 |
| 1971 | 08 | 15 | 06 | 17 | 15 | 47.46 | 49.53 | 4.6 |
| 1971 | 10 | 13 | 2 | 38 | 59 | 51.65 | 80.90 | 3.4 |
| 1975 | 9 | 2 | 6 | 21 | 17 | 48.29 | 69.74 | 3.3 |
| 1976 | 2 | 2 | 21 | 14 | 2 | 41.98 | 82.67 | 3.4 |
| 1976 | 08 | 28 | 19 | 23 | 30 | 50.10 | 48.85 | 4.0 |

## BAFFIN BAY (BAB)

| YR | MO | DA | HR | MN | SC | LAT | LONG | M |
|---|---|---|---|---|---|---|---|---|
| 1933 | 11 | 20 | 23 | 21 | 32 | 73.00 | 70.75 | 7.3 |
| 1957 | 5 | 2 | 3 | 55 | 34 | 72.00 | 67.50 | 6.3 |
| 1969 | 11 | 27 | 8 | 25 | 24 | 73.50 | 70.64 | 4.2 |
| 1971 | 1 | 6 | 13 | 25 | 51 | 73.19 | 74.30 | 4.1 |
| 1971 | 6 | 2 | 20 | 47 | 49 | 74.92 | 67.56 | 4.6 |
| 1971 | 7 | 21 | 7 | 36 | 24 | 72.98 | 70.05 | 3.9 |
| 1972 | 2 | 3 | 6 | 21 | 52 | 73.00 | 71.68 | 4.3 |
| 1972 | 5 | 14 | 14 | 19 | 48 | 75.07 | 74.15 | 4.1 |
| 1972 | 5 | 30 | 19 | 47 | 26 | 71.66 | 64.91 | 3.8 |
| 1972 | 9 | 16 | 5 | 14 | 5 | 74.10 | 73.09 | 4.2 |
| 1974 | 2 | 2 | 20 | 11 | 26 | 74.19 | 72.45 | 4.4 |
| 1974 | 3 | 5 | 6 | 32 | 15 | 73.24 | 70.32 | 4.0 |
| 1974 | 3 | 8 | 17 | 48 | 8 | 74.12 | 69.16 | 4.8 |
| 1975 | 6 | 14 | 4 | 7 | 35 | 73.33 | 70.25 | 4.4 |
| 1976 | 3 | 20 | 0 | 47 | 29 | 73.15 | 69.98 | 4.7 |
| 1976 | 11 | 12 | 14 | 47 | 19 | 72.30 | 70.43 | 5.6 |

## BAFFIN ISLAND (BAI)

| YR | MO | DA | HR | MN | SC | LAT | LONG | M |
|---|---|---|---|---|---|---|---|---|
| 1963 | 9 | 4 | 13 | 32 | 12 | 71.40 | 73.30 | 6.1 |
| 1966 | 12 | 26 | 4 | 12 | 58 | 71.50 | 74.67 | 4.9 |
| 1967 | 5 | 18 | 20 | 56 | 44 | 70.83 | 71.17 | 4.9 |
| 1968 | 1 | 22 | 3 | 1 | 39 | 70.97 | 73.22 | 4.3 |
| 1969 | 3 | 3 | 8 | 49 | 42 | 71.68 | 75.31 | 3.9 |
| 1969 | 3 | 3 | 9 | 15 | 8 | 71.66 | 75.27 | 3.8 |
| 1969 | 3 | 3 | 15 | 35 | 5 | 71.67 | 75.22 | 4.1 |
| 1969 | 3 | 4 | 1 | 52 | 9 | 71.65 | 75.88 | 4.4 |
| 1969 | 3 | 4 | 2 | 5 | 0 | 71.65 | 75.21 | 4.7 |
| 1969 | 3 | 6 | 16 | 37 | 53 | 71.69 | 75.08 | 3.9 |
| 1969 | 3 | 6 | 17 | 3 | 24 | 71.66 | 75.25 | 4.7 |
| 1969 | 3 | 6 | 17 | 8 | 3 | 71.74 | 75.34 | 4.2 |
| 1969 | 3 | 6 | 18 | 53 | 22 | 71.72 | 75.17 | 4.0 |
| 1969 | 3 | 10 | 11 | 35 | 51 | 71.66 | 75.13 | 3.8 |
| 1969 | 6 | 10 | 18 | 23 | 30 | 71.75 | 75.66 | 3.8 |
| 1970 | 10 | 20 | 17 | 0 | 48 | 70.96 | 73.24 | 4.3 |
| 1970 | 12 | 2 | 11 | 3 | 7 | 68.50 | 67.66 | 4.4 |
| 1971 | 1 | 16 | 23 | 11 | 16 | 71.68 | 75.24 | 4.2 |
| 1971 | 1 | 17 | 12 | 9 | 36 | 71.63 | 75.31 | 4.1 |
| 1971 | 1 | 17 | 15 | 48 | 7 | 71.62 | 75.34 | 3.9 |
| 1971 | 1 | 19 | 5 | 42 | 43 | 71.53 | 75.68 | 3.8 |
| 1971 | 3 | 22 | 8 | 58 | 5 | 68.40 | 68.32 | 3.9 |
| 1971 | 7 | 25 | 20 | 43 | 54 | 67.73 | 67.51 | 4.2 |
| 1971 | 7 | 31 | 22 | 57 | 52 | 71.76 | 76.43 | 4.0 |
| 1972 | 1 | 21 | 14 | 43 | 39 | 71.84 | 74.96 | 5.1 |
| 1972 | 5 | 10 | 20 | 1 | 41 | 71.60 | 74.96 | 4.0 |
| 1973 | 1 | 16 | 14 | 58 | 19 | 68.73 | 67.89 | 3.9 |
| 1973 | 4 | 24 | 3 | 55 | 5 | 71.38 | 71.22 | 4.7 |

### BAFFIN ISLAND (BAI) (CONTINUED)

| YR | MO | DA | HR | MN | SC | LAT | LONG | M |
|---|---|---|---|---|---|---|---|---|
| 1973 | 5 | 29 | 9 | 3 | 55 | 71.74 | 74.92 | 4.4 |
| 1973 | 5 | 29 | 16 | 6 | 33 | 71.71 | 75.26 | 4.5 |
| 1973 | 5 | 29 | 16 | 7 | 0 | 71.70 | 75.30 | 4.0 |
| 1973 | 8 | 17 | 5 | 31 | 26 | 71.38 | 70.78 | 4.1 |
| 1973 | 12 | 7 | 8 | 2 | 49 | 69.02 | 69.81 | 4.1 |
| 1973 | 12 | 7 | 8 | 3 | 31 | 69.05 | 69.93 | 4.3 |
| 1973 | 12 | 14 | 18 | 21 | 32 | 71.70 | 75.24 | 4.2 |
| 1974 | 7 | 19 | 16 | 38 | 23 | 71.97 | 75.56 | 4.0 |
| 1975 | 5 | 3 | 16 | 19 | 32 | 71.14 | 73.20 | 4.0 |
| 1975 | 6 | 30 | 18 | 48 | 55 | 71.44 | 71.19 | 5.2 |
| 1976 | 8 | 17 | 4 | 30 | 2 | 69.02 | 70.27 | 3.8 |
| 1976 | 10 | 11 | 20 | 43 | 2 | 68.62 | 67.82 | 3.8 |
| 1977 | 12 | 19 | 07 | 42 | 06 | 71.80 | 75.08 | 4.0 |

### LABRADOR SEA (LAB)

| YR | MO | DA | HR | MN | SC | LAT | LONG | M |
|---|---|---|---|---|---|---|---|---|
| 1969 | 9 | 27 | 22 | 53 | 58 | 56.52 | 57.49 | 4.1 |
| 1969 | 11 | 24 | 21 | 14 | 14 | 60.60 | 58.80 | 5.0 |
| 1969 | 11 | 30 | 14 | 38 | 6 | 60.55 | 59.22 | 4.2 |
| 1970 | 7 | 3 | 0 | 32 | 36 | 60.89 | 60.47 | 4.2 |
| 1971 | 1 | 12 | 17 | 36 | 4 | 62.31 | 62.33 | 3.9 |
| 1971 | 4 | 16 | 1 | 31 | 45 | 61.75 | 60.68 | 4.3 |
| 1971 | 7 | 13 | 1 | 32 | 12 | 60.63 | 57.45 | 3.8 |
| 1971 | 12 | 7 | 12 | 4 | 18 | 55.09 | 54.51 | 5.6 |
| 1972 | 1 | 25 | 2 | 40 | 1 | 55.14 | 54.42 | 4.5 |
| 1973 | 8 | 27 | 1 | 49 | 36 | 60.07 | 57.91 | 4.4 |
| 1973 | 10 | 12 | 3 | 54 | 28 | 61.34 | 59.99 | 4.4 |
| 1975 | 12 | 13 | 9 | 24 | 27 | 57.94 | 52.25 | 4.5 |
| 1976 | 5 | 26 | 18 | 26 | 33 | 55.47 | 52.74 | 4.4 |
| 1977 | 9 | 24 | 17 | 19 | 44 | 58.25 | 54.24 | 4.8 |
| 1977 | 11 | 5 | 8 | 49 | 31 | 59.05 | 60.61 | 4.2 |

### EASTERN ARCTIC BACKGROUND (EAB)

| YR | MO | DA | HR | MN | SC | LAT | LONG | M |
|---|---|---|---|---|---|---|---|---|
| 1951 | 4 | 22 | 12 | 36 | 16 | 76.00 | 73.00 | 5.7 |
| 1957 | 7 | 21 | 8 | 53 | 31 | 68.90 | 59.40 | 5.7 |
| 1971 | 5 | 31 | 4 | 58 | 52 | 68.92 | 53.88 | 4.2 |
| 1971 | 7 | 4 | 5 | 32 | 50 | 68.91 | 53.09 | 3.9 |
| 1972 | 4 | 15 | 14 | 29 | 49 | 72.48 | 55.37 | 4.0 |
| 1972 | 5 | 28 | 23 | 8 | 3 | 76.16 | 72.30 | 4.2 |
| 1973 | 1 | 20 | 0 | 24 | 17 | 68.53 | 59.63 | 4.9 |
| 1975 | 7 | 20 | 6 | 28 | 38 | 75.23 | 62.39 | 4.4 |
| 1976 | 4 | 4 | 3 | 4 | 26 | 68.78 | 54.93 | 4.0 |
| 1976 | 11 | 2 | 13 | 30 | 2 | 69.77 | 53.70 | 4.4 |

### EASTERN ARCTIC BACKGROUND (EAB) (CONTINUED)

| YR | MO | DA | HR | MN | SC | LAT | LONG | M |
|---|---|---|---|---|---|---|---|---|
| 1977 | 06 | 01 | 05 | 27 | 33 | 69.20 | 53.91 | 3.8 |

### GUSTAF-LOUGHEED ARCH (GLA)

| YR | MO | DA | HR | MN | SC | LAT | LONG | M |
|---|---|---|---|---|---|---|---|---|
| 1970 | 5 | 25 | 7 | 24 | 10 | 76.75 | 105.77 | 4.3 |
| 1972 | 7 | 7 | 10 | 9 | 0 | 79.86 | 107.36 | 4.4 |
| 1972 | 7 | 21 | 21 | 11 | 35 | 79.97 | 108.45 | 4.0 |
| 1972 | 9 | 30 | 22 | 51 | 30 | 79.88 | 107.72 | 5.0 |
| 1972 | 11 | 17 | 10 | 36 | 15 | 76.69 | 106.44 | 4.8 |
| 1972 | 11 | 17 | 10 | 53 | 16 | 76.71 | 106.32 | 4.9 |
| 1972 | 11 | 19 | 17 | 33 | 44 | 76.55 | 106.33 | 5.6 |
| 1972 | 11 | 19 | 18 | 45 | 48 | 76.47 | 106.38 | 4.7 |
| 1972 | 11 | 20 | 6 | 7 | 13 | 76.57 | 106.02 | 3.9 |
| 1972 | 11 | 21 | 10 | 6 | 27 | 76.58 | 106.02 | 5.7 |
| 1972 | 11 | 21 | 13 | 58 | 18 | 76.57 | 106.29 | 4.1 |
| 1972 | 11 | 21 | 17 | 42 | 49 | 76.54 | 106.46 | 4.2 |
| 1972 | 11 | 25 | 19 | 43 | 37 | 76.55 | 106.44 | 3.9 |
| 1972 | 12 | 7 | 21 | 48 | 22 | 76.64 | 106.46 | 3.9 |
| 1972 | 12 | 13 | 18 | 38 | 39 | 76.58 | 106.63 | 4.7 |
| 1972 | 12 | 13 | 19 | 55 | 19 | 76.54 | 106.71 | 4.0 |
| 1972 | 12 | 20 | 17 | 30 | 21 | 76.56 | 106.75 | 4.7 |
| 1972 | 12 | 22 | 19 | 32 | 3 | 76.52 | 106.51 | 3.9 |
| 1972 | 12 | 27 | 22 | 59 | 26 | 76.80 | 106.49 | 5.4 |
| 1972 | 12 | 28 | 12 | 18 | 44 | 76.76 | 106.47 | 4.1 |
| 1972 | 12 | 28 | 13 | 49 | 43 | 76.79 | 106.64 | 3.9 |
| 1972 | 12 | 28 | 14 | 1 | 2 | 76.73 | 106.61 | 4.1 |
| 1972 | 12 | 28 | 14 | 36 | 5 | 76.80 | 106.16 | 5.1 |
| 1972 | 12 | 29 | 20 | 1 | 44 | 76.77 | 106.35 | 4.0 |
| 1973 | 1 | 1 | 0 | 21 | 2 | 76.68 | 106.22 | 4.0 |
| 1973 | 1 | 3 | 8 | 32 | 3 | 76.69 | 105.90 | 3.8 |
| 1973 | 1 | 9 | 13 | 17 | 41 | 76.62 | 105.90 | 4.4 |
| 1973 | 1 | 9 | 13 | 23 | 20 | 76.61 | 106.22 | 4.4 |
| 1973 | 1 | 31 | 21 | 33 | 23 | 76.74 | 106.39 | 4.4 |
| 1973 | 2 | 12 | 10 | 56 | 33 | 76.42 | 107.03 | 3.8 |
| 1973 | 2 | 14 | 3 | 38 | 38 | 76.77 | 106.14 | 4.0 |
| 1973 | 3 | 5 | 5 | 20 | 59 | 76.54 | 106.76 | 3.8 |
| 1973 | 3 | 16 | 11 | 13 | 37 | 76.50 | 106.42 | 3.8 |
| 1973 | 4 | 30 | 21 | 27 | 24 | 76.59 | 106.29 | 3.8 |
| 1973 | 5 | 3 | 5 | 42 | 32 | 76.48 | 106.41 | 4.9 |
| 1973 | 5 | 15 | 15 | 40 | 52 | 76.58 | 106.61 | 3.9 |
| 1973 | 8 | 19 | 10 | 36 | 42 | 76.52 | 106.45 | 3.8 |
| 1974 | 2 | 21 | 15 | 30 | 50 | 76.70 | 106.54 | 4.2 |
| 1974 | 3 | 28 | 17 | 30 | 17 | 76.68 | 106.28 | 4.6 |
| 1974 | 9 | 14 | 2 | 2 | 56 | 80.03 | 107.89 | 4.6 |
| 1974 | 9 | 24 | 9 | 13 | 59 | 76.73 | 106.37 | 3.9 |
| 1974 | 9 | 24 | 10 | 23 | 54 | 76.85 | 106.36 | 3.9 |
| 1974 | 11 | 8 | 11 | 28 | 13 | 79.73 | 108.92 | 4.1 |

GUSTAF-LOUGHEED ARCH (GLA) (CONTINUED)

| YR | MO | DA | HR | MN | SC | LAT | LONG | M |
|---|---|---|---|---|---|---|---|---|
| 1974 | 12 | 27 | 22 | 53 | 44 | 76.62 | 106.06 | 4.9 |
| 1974 | 12 | 27 | 23 | 0 | 16 | 76.68 | 106.38 | 4.8 |
| 1974 | 12 | 27 | 23 | 21 | 38 | 76.65 | 106.30 | 4.6 |
| 1974 | 12 | 28 | 6 | 17 | 46 | 76.70 | 106.19 | 4.3 |
| 1975 | 1 | 3 | 2 | 3 | 50 | 76.63 | 106.26 | 4.3 |
| 1975 | 1 | 3 | 11 | 8 | 52 | 76.71 | 106.44 | 4.7 |
| 1976 | 3 | 14 | 14 | 4 | 10 | 79.92 | 107.77 | 4.4 |
| 1976 | 8 | 27 | 8 | 18 | 23 | 76.65 | 106.11 | 3.8 |
| 1976 | 9 | 16 | 10 | 14 | 34 | 76.64 | 106.55 | 4.6 |
| 1977 | 02 | 18 | 19 | 24 | 09 | 76.69 | 106.32 | 3.9 |
| 1977 | 05 | 25 | 23 | 01 | 04 | 77.38 | 104.56 | 4.2 |
| 1978 | 02 | 05 | 16 | 07 | 12 | 78.24 | 107.33 | 4.8 |
| 1978 | 02 | 05 | 16 | 13 | 40 | 78.37 | 107.45 | 4.2 |
| 1978 | 02 | 19 | 22 | 59 | 12 | 78.25 | 107.42 | 4.0 |
| 1978 | 02 | 23 | 23 | 32 | 38 | 78.32 | 107.76 | 3.8 |
| 1978 | 02 | 26 | 20 | 50 | 40 | 78.28 | 107.62 | 4.1 |
| 1978 | 03 | 08 | 21 | 15 | 26 | 78.26 | 107.57 | 4.3 |
| 1978 | 04 | 16 | 03 | 27 | 41 | 78.35 | 107.53 | 4.1 |

SVERDRUP (SVD)

| YR | MO | DA | HR | MN | SC | LAT | LONG | M |
|---|---|---|---|---|---|---|---|---|
| 1968 | 11 | 11 | 19 | 45 | 2 | 79.03 | 95.12 | 3.8 |
| 1969 | 4 | 23 | 18 | 59 | 42 | 75.64 | 102.22 | 3.9 |
| 1970 | 12 | 24 | 12 | 19 | 48 | 75.61 | 101.11 | 4.0 |
| 1971 | 2 | 3 | 13 | 47 | 39 | 77.17 | 118.18 | 3.8 |
| 1974 | 9 | 7 | 23 | 50 | 39 | 76.74 | 100.88 | 3.8 |
| 1975 | 3 | 8 | 5 | 20 | 34 | 79.82 | 94.07 | 5.2 |
| 1975 | 3 | 28 | 4 | 18 | 8 | 78.09 | 110.08 | 3.8 |
| 1975 | 4 | 15 | 12 | 17 | 40 | 81.19 | 87.14 | 4.1 |
| 1975 | 4 | 23 | 18 | 31 | 9 | 79.73 | 94.01 | 4.0 |
| 1975 | 5 | 22 | 21 | 54 | 41 | 76.09 | 121.91 | 3.8 |
| 1975 | 6 | 3 | 2 | 38 | 56 | 76.22 | 119.44 | 4.0 |
| 1975 | 7 | 15 | 21 | 10 | 21 | 76.42 | 120.11 | 3.8 |
| 1975 | 9 | 19 | 11 | 34 | 2 | 80.03 | 93.82 | 3.8 |
| 1976 | 2 | 12 | 3 | 29 | 16 | 82.14 | 76.38 | 4.2 |
| 1976 | 3 | 15 | 8 | 50 | 30 | 81.28 | 84.68 | 3.8 |
| 1977 | 07 | 08 | 05 | 27 | 31 | 75.61 | 105.74 | 4.0 |

## BOOTHIA-UNGAVA (BOU)

| YR | MO | DA | HR | MN | SC | LAT | LONG | M |
|---|---|---|---|---|---|---|---|---|
| 1959 | 1 | 30 | 5 | 17 | 32 | 61.00 | 78.50 | 5.9 |
| 1960 | 9 | 6 | 21 | 24 | 26 | 64.70 | 86.40 | 5.5 |
| 1966 | 3 | 22 | 22 | 10 | 3 | 64.75 | 88.00 | 5.1 |
| 1968 | 12 | 19 | 16 | 49 | 18 | 67.47 | 91.41 | 3.8 |
| 1971 | 3 | 17 | 16 | 47 | 29 | 74.82 | 94.37 | 3.9 |
| 1971 | 6 | 27 | 3 | 34 | 23 | 73.27 | 95.77 | 4.0 |
| 1971 | 7 | 24 | 22 | 25 | 55 | 73.65 | 96.13 | 4.0 |
| 1971 | 9 | 20 | 23 | 1 | 41 | 73.81 | 92.52 | 3.9 |
| 1971 | 9 | 26 | 7 | 1 | 6 | 59.95 | 73.67 | 3.9 |
| 1971 | 10 | 2 | 3 | 19 | 28 | 64.20 | 86.67 | 5.1 |
| 1972 | 1 | 22 | 12 | 21 | 25 | 72.44 | 93.68 | 4.2 |
| 1972 | 1 | 24 | 18 | 26 | 37 | 64.60 | 88.13 | 4.0 |
| 1972 | 5 | 18 | 5 | 8 | 47 | 74.19 | 95.77 | 4.5 |
| 1972 | 7 | 4 | 10 | 12 | 21 | 73.73 | 96.65 | 4.0 |
| 1972 | 10 | 27 | 1 | 59 | 20 | 67.05 | 94.55 | 4.4 |
| 1973 | 1 | 25 | 14 | 52 | 3 | 65.60 | 89.07 | 3.8 |
| 1974 | 4 | 21 | 4 | 48 | 50 | 74.33 | 93.91 | 4.9 |
| 1975 | 5 | 22 | 15 | 5 | 52 | 67.23 | 92.14 | 4.9 |
| 1976 | 2 | 29 | 16 | 18 | 42 | 60.33 | 76.59 | 3.9 |
| 1976 | 4 | 14 | 17 | 16 | 12 | 64.33 | 89.93 | 4.3 |
| 1976 | 8 | 6 | 11 | 14 | 16 | 63.03 | 86.78 | 3.9 |
| 1976 | 12 | 6 | 6 | 9 | 52 | 65.22 | 87.88 | 4.0 |

# APPENDIX B

Listing of Modified McGuire (1976) Seismic Risk Program

```
      PROGRAM CANRSK(INPUT,OUTPUT,TAPE1=INPUT,TAPE6=OUTPUT,TAPE2)
      COMMON NRD,NWR,RSKTI(12)
      COMMON C1,C2,C3,SIG,RZERO,RONE,AAA,BBB
      COMMON NGS,NRS(23),AM0(24),AM1(24),LORS(24)
      COMMON BETA(24),RATE(24),COEF(24),FDEPTH(24)
      COMMON NSTEP0,NSTEPI
      COMMON INDIC(4),AREA(23,11),X(23,11,2),Y(23,11,2)
      COMMON/DEBG/SXNOT,SYNOT,ERRBND,NSTEPMX,LERR,RZ2,LERR2,RISKER
      COMMON /MDATA/NSTEP,JPRNT,JPRNT2,JPRNT3,NLEI,TI(12),RISKS(9),
     1ATTEN(8,2,2)
      COMMON/LERRS/INCLUD,INCLD2,LNLEI,LRISKS,RKRATO
      COMMON/CNM/RNAME(6),SNAME(6),TIFS(8,2),RZ2S(23),JEW,NRG,A,B
     1,IN,JN,NRGL
      DIMENSION CLAT(7)
      LOGICAL LERR,INCLUD,LERR2,INCLD2,LNLEI,LRISKS,LPR
      DATA INCLUD,INCLD2,LNLEI,LRISKS,ERRBND,NSTEPMX,RKRATO,NSTEP
     1/.F.,.F.,.F.,.F.,20.,40,0.05,10/
      DATA NLEI,TI/10,-2.,-1.,0.,1.,2.,3.,4.,5.,6.,7.,0.,0./
      DATA RISKS/0.01,0.005,0.002105,0.001,0.,0.,0.,0.,0./
      DATA ATTEN/-1.0788,1.3,-1.1,0.7,0.,0.,1000.,0.0001,
     1           -8.623,2.3,-1.0,0.7,0.,0.,1000.,0.0001,
     2           0.,1.3,-1.5,0.7,0.,0.,1000.,0.0001,
     3           -7.824,2.3,-1.3,0.7,0.,0.,1000.,0.0001/
      DATA CLAT/-70.,-70.,-80.,-105.,-123.,-123.,-138./
      IN=1$NWR=6$NRD=2$JN=6
      NRGL=0
      WRITE(JN,1000)
 1000 FORMAT(" CANADIAN SEISMIC RISK PROGRAM RUNNING"/)
    9 WRITE(JN,50)
   50 FORMAT(" NAME OF REQUESTOR ?",15H: "END" TO STOP/)
      LPR=.TRUE.
      READ(IN,1)RNAME
    1 FORMAT(6A10)
      IF(EOF(IN))99,2
    2 IF(RNAME(1).EQ.10HEND       ) GO TO 99
      IF(RNAME(1).EQ.10H          ) GO TO 9
      IF(RNAME(1).EQ.10H/         )GO TO 60
    5 WRITE(JN,51)
   51 FORMAT(" NAME OF SITE ?"/)
      READ(IN,1)SNAME
      IF(SNAME(1).EQ.10H          )GO TO 5
    6 WRITE(JN,53)
   53 FORMAT(" LAT & LONG ?"/)
      READ *,A,B
      IF(A.LT.0.)GO TO 9$IF(A.EQ.0..OR.B.EQ.0.)GO TO 6
      IF(.NOT.LPR) GO TO 21
      WRITE(JN,7)A,B
    7 FORMAT(1X,F7.3,"N ",F8.3,"W ? Y/N")
      READ(IN,8)YN
    8 FORMAT(A1)
      IF(YN.EQ.1HY) GO TO 21
      GO TO 6
   60 LPR=.FALSE.$GO TO 6
   21 A=ABS(A)$B=ABS(B)
      IF(B.LT.49..OR.B.GT.145.)GO TO 30
```

```
   IF(B.LE.145..AND.B.GE.91..AND.A.GE.68..AND.A.LE.82.)GO TO 10
   IF(B.GE.110.)GO TO 20
   JEW=1
   IF(A.LT.41..OR.A.GT.85.)GO TO 30
   IF(B.LE.86..AND.A.GE.41..AND.A.LT.50.) GO TO 11
   IF(B.LE.90..AND.A.GE.50..AND.A.LT.60.) GO TO 12
   IF(B.LE.105..AND.A.GE.60..AND.A.LE.85.) GO TO 13
   IF(A.GE.46..AND.A.LE.51..AND.B.GE.100.) GO TO 14
   GO TO 40
20 JEW=2
   IF(A.LT.47.)GO TO 30
   IF(A.GE.47..AND.A.LT.53.) GO TO 15
   IF(A.GE.53..AND.A.LT.60.) GO TO 16
   IF(A.GE.60..AND.A.LE.68.) GO TO 17
   GO TO 40
30 WRITE(JN,31)A,B
31 FORMAT(/" SITE AT",F6.2," LAT  ",F7.2," LONG"/
  1" IS OUTSIDE AREA WHERE RISK CAN BE DEFINED"/)
   GO TO 9
10 NRG=8$CALL INLCCM(-115.)$CALL NWNERK$GO TO 22
40 WRITE(JN,33)A,B
33 FORMAT(" THE RISK AT SITE",F6.2," LAT  ",F7.2," LONG"/
  1" IS INSIGNIFICANT"/)
   GO TO 9
11 NRG=1$GO TO 23
12 NRG=2$GO TO 23
13 NRG=3$GO TO 23
14 NRG=4$GO TO 23
15 NRG=5$GO TO 23
16 NRG=6$GO TO 23
17 NRG=7
23 IF(NRG.EQ.NRGL)GO TO 24$CALL INLCCM(CLAT(NRG))
24 CALL SRISK
22 IF(LPR)CALL OUTFRM$IF(.NOT.LPR) CALL SHOUT$IF(LPR)GO TO 9$GO TO 6
99 STOP$END
```

```
      SUBROUTINE AREAS(X1,Y1,X2,Y2,X3,Y3,X4,Y4,AREA)
C      SUBROUTINE TO CALCULATE AREA OF ARBITRARY QUADRILATERAL,
C      WHERE (X1,Y1) AND X4,Y4) ARE OPPOSITE CORNERS.
C         LOCATE INTERSECTIONS OF DIAGONALS:
      IF (X4-X1-0.001) 20,30,30
   20 IF (X4-X1+0.001) 30,30,25
   25 XX=X1
      A2=(Y3-Y2)/(X3-X2)
      YY=(XX-X3)*A2 +Y3
      DIST1=Y4-Y1
      IF (DIST1) 26,27,27
   26 DIST1=-DIST1
   27 DIST2=SQRT((X3-X2)*(X3-X2) + (Y3-Y2)*(Y3-Y2))
      GO TO 100
   30 IF (X3-X2-0.001) 50,70,70
   50 IF (X3-X2+0.001) 70,70,65
   65 XX=X3
      A1=(Y4-Y1)/(X4-X1)
      YY=(XX-X4)*A1+Y4
      DIST2=Y3-Y2
      IF (DIST2) 66,67,67
   66 DIST2=-DIST2
   67 DIST1=SQRT((X4-X1)*(X4-X1) + (Y4-Y1)*(Y4-Y1))
      GO TO 100
   70 A1=(Y4-Y1)/(X4-X1)
      A2=(Y3-Y2)/(X3-X2)
      XX=(Y2-Y1+A1*X1-A2*X2)/(A1-A2)
      YY=A1*(XX-X1) + Y1
      DIST1=SQRT((X4-X1)*(X4-X1) + (Y4-Y1)*(Y4-Y1))
      DIST2=SQRT((X3-X2)*(X3-X2) + (Y3-Y2)*(Y3-Y2))
C          CALCULATE LENGTH OF SIDES OF SUB-TRIANGLE
  100 SIDE1=SQRT((XX-X1)*(XX-X1) + (YY-Y1)*(YY-Y1))
      SIDE2=SQRT((XX-X2)*(XX-X2) + (YY-Y2)*(YY-Y2))
      SIDE3=SQRT((X1-X2)*(X1-X2) + (Y1-Y2)*(Y1-Y2))
C          SOLUTION ACCORDING TO C.R.C. HANDBOOK UNDER
C               'MENSURATION FORMULAE' AND 'TRIGONOMETRIC FORMULAE'
      SS=(SIDE1+SIDE2+SIDE3)/2.
      SINANG=2.*SQRT(SS*(SS-SIDE1)*(SS-SIDE2)*(SS-SIDE3))/(SIDE1*SIDE2)
      AREA=0.5*DIST1*DIST2*SINANG
      RETURN
      END
      SUBROUTINE BETWEN(X1,Y1,X2,Y2,XP,YP,INDIC,IANS)
C         SUBROUTINE TO DETERMINE IF (XP,YP) LIES BETWEEN
C            (X1,Y1) AND (X2,Y2).
      IF(INDIC.LT.1.OR.INDIC.GT.2) GO TO 300
      IF(INDIC.EQ.2) GO TO 200
      IF (X1-XP) 110,410,120
  110 IF (X2-XP) 420,420,410
  120 IF (X2-XP) 410,420,420
  200 IF (Y1-YP) 210,410,220
  210 IF (Y2-YP) 420,420,410
  220 IF (Y2-YP) 410,420,420
C        ERROR RETURN
  300 IANS=0
      GO TO 500
```

```
C         (XP,YP) LIES BETWEEN END POINTS, I.E. ON SOURCE BOUNDARY
 410  IANS=1
      GO TO 500
C         (XP,YP) DOESN'T LIE BETWEEN END POINTS, I.E. IT'S OUTSIDE SOURC
 420  IANS=-1
 500  RETURN
      END
      SUBROUTINE CIRCLE(RC,INGS,FRAREA,RSK)
      COMMON NRD,NWR,RSKTI(12)
      COMMON C1,C2,C3,SIG,RZERO,RONE,AAA,BBB
      COMMON NGS,NRS(23),AMO(24),AM1(24),LORS(24)
      COMMON BETA(24),RATE(24),COEF(24),FDEPTH(24)
      COMMON NSTEPO,NSTEPI
      COMMON INDIC(4),AREA(23,11)
      COMMON /MDATA/NSTEP,JPRNT,JPRNT2,JPRNT3,NLEI,TI(12),RISKS(9),
     1ATTEN(8,2,2)
      DIMENSION RSK(12)
C           SUBROUTINE TO CALCULATE RISK FROM A CIRCULAR
C           SOURCE WITH CENTER AR SITE, RADIUS RC.
      NRC=RC
C           CHOOSE STEP SIZE:
C                STEP SIZE = NSTEPI ULESS RESULTING STEP SIZE IS
C                LESS THAN ONE KILOMETRE, IN WHICH CASE RC+1
C                STEPS ARE USED.
      IF (NRC-NSTEPI) 10,12,12
  10  NSTEPX=NRC+1
      GO TO 14
  12  NSTEPX=NSTEPI
  14  ANSTEP=NSTEPX
      DO 90 II=1,NSTEPX
      AI=II
      R=((AI-0.5)*RC)/ANSTEP
      ANAREA=6.2831853072 *R*RC/ANSTEP
      RATEI=RATE(INGS)*ANAREA*FRAREA
      DO 80 JJ=1,NLEI
      CALL RISK1(TI(JJ),R,INGS,RISK)
      RSK(JJ)=RSK(JJ)+RISK*RATEI
  80  CONTINUE
  90  CONTINUE
      RETURN
      END
      SUBROUTINE COMBINI
      COMMON NRD,NWR,RSKTI(12)
      COMMON C1,C2,C3,SIG,RZERO,RONE,AAA,BBB
      COMMON NGS,NRS(23),AMO(24),AM1(24),LORS(24)
      COMMON BETA(24),RATE(24),COEF(24),FDEPTH(24)
      COMMON NSTEPO,NSTEPI
      COMMON INDIC(4),AREA(23,11),X(23,11,2),Y(23,11,2)
      COMMON/DEBG/SXNOT,SYNOT,ERRBND,NSTEPMX,LERR,RZ2,LERR2,RISKER
      COMMON /MDATA/NSTEP,JPRNT,JPRNT2,JPRNT3,NLEI,TI(12),RISKS(9),
     1ATTEN(8,2,2)
      COMMON/SRSKC/SRSK(12,4)
      COMMON/CNM/RNAME(6),SNAME(6),TIFS(8,2),RZ2S(23),JEW,NRG,SLAT,SLONG
     1,IN,JN,NRGL
      DIMENSION TIF(8)
```

```
      LOGICAL LERR,LERR2
      DO 424 J=1,2
      DO 13 I=1,NLEI
   13 RSKTI(I)=SRSK(I,J)+SRSK(I,J+2)
      DO 620 I=1,NLEI
 620  RSKTI(I)=1.-EXP(-RSKTI(I))
C         ESTIMATE INTENSITIES AT RISKS DESIRED.
      RISKS(9)=0.0
      IA=0
      IF(RISKS(1)-0.0000000001) 700,700,625
 625  DO 630 IRK=1,8
      IF (RISKS(IRK)-RSKTI(1)) 640,640,630
 630  TIF(IRK)=1000000.
      GO TO 700
 640  IA=IA+1
      IF (IA-NLEI) 650,645,645
 645  TIF(IRK)=1000000.
      IRK=IRK+1
      IF (RISKS(IRK)-0.0000000001)680,680,645
 650  IF(RISKS(IRK)-RSKTI(IA+1))640,655,655
 655  TIF(IRK)=(ALOG(RSKTI(IA)/RISKS(IRK)))
     1  /(ALOG(RSKTI(IA)/RSKTI(IA+1)))
      TIF(IRK)=TI(IA)+TIF(IRK)*(TI(IA+1)-TI(IA))
      IRK=IRK+1
      IF (RISKS(IRK)-0.0000000001)680,680,660
 660  IF(RISKS(IRK)-RSKTI(IA+1)) 640,655,655
 680  IRK=IRK-1
      DO 685 I=1,IRK
      IF (TIF(I)-999999.)683,685,685
 683  TIF(I)=EXP(TIF(I))
 685  CONTINUE
      DO 105 I=1,IRK
  105 TIFS(I,J)=TIF(I)
 700  CONTINUE
  424 CONTINUE
      RETURN$END
      SUBROUTINE ERISK(AMZ,AMM,C1,C2,C3,RLN,SIG,BETA,TIC,
     1  G1,G2,G3,G4,CON1,CON2,CON3)
C         EVALUATE RISK ASSOCIATED WITH EXPONENTIAL MAGNITUDE LAW
C             FOR MAGNITUDES BETWEEN AMZ AND AMM.
      Z=(TIC-C1-C2*AMM-C3*RLN)/SIG
      CALL NDTR(Z,G1,D)
      Z=Z-BETA*SIG/C2
      CALL NDTR(Z,G3,D)
      Z=(TIC-C1-C2*AMZ-C3*RLN)/SIG
      CALL NDTR(Z,G2,D)
      Z=Z-BETA*SIG/C2
      CALL NDTR(Z,G4,D)
      IF (C2-0.001) 10,10,20
  10  CON1=100000000.
      CON3=CON1
      GO TO 30
  20  CON1=((BETA*BETA*SIG*SIG)/(2.*C2*C2))+(BETA*AMZ)
     1 +((C1-TIC)*BETA/C2)
      CON3=CON1+BETA*(AMM-AMZ)
```

```
      CON1=EXP(CON1)
      CON3=EXP(CON3)
   30 CON2=BETA*C3/C2
      R=EXP(RLN)
      CON2=R**CON2
      RETURN
      END
      SUBROUTINE INLCCM(SLONG)
C     SLONG CAN.CENTRAL LONGITUDE
      COMMON/CTAS/SCALEK,CONE,TLONG,RO,RADCON
      DATA RAD,E,E2,A,ED2/0.01745329252,12.15482511000,0.00676865800218,
     C637820640.1,0.041135927122/
      DATA TSPAR,TNPAR,TLAT,TSCALE
     1    / 49. ,77.,  63.,  1E5/
C     PARAMS 1,2 +3 ARE STANDARD LATS. LONGS. FOR CAN. PROJECTION
C     1E5 IS TO CONVERT FROM AN EASTING(X) AND NORTHING(Y) TO KM.
C     REGCLN REMAINS ONLY INIT-PARAM. FIXING CENTRAL MERIDIAN, I.E. VERT
C     IN PLOTTING ROUTINE, WHERE X=0
C     INITILIZATION OF LAMBERT CONFORMAL CONIC PROJECTION
      P=TSPAR*RAD
      SP=SIN(P)
      ANSSPS=COS(P)/(1.+SP)*((E+SP)/(E-SP))**ED2
      P=TNPAR*RAD
      SP=SIN(P)
      ANSSPN=COS(P)/(1.+SP)*((E+SP)/(E-SP))**ED2
      SPS=TSPAR*RAD
      SPN=TNPAR*RAD
      TLONG=SLONG
      SS=SIN(SPS)
      QN1=SQRT(1.-SS*SS*E2)
      SS=SIN(SPN)
      QN2=SQRT(1.-SS*SS*E2)
      CONEN=ALOG(COS(SPS)*QN2/(COS(SPN)*QN1))
      CONE=CONEN/ALOG(ANSSPS/ANSSPN)
      RADCON=RAD*CONE
      SCALEK=A*COS(SPS)/(CONE*ANSSPS**CONE*TSCALE*QN1)
      P=TLAT*RAD
      SP=SIN(P)
      RO=SCALEK*(COS(P)/(1.+SP)*((E+SP)/(E-SP))**ED2)**CONE
      RETURN
      END
      SUBROUTINE INSIDE(XNOT,YNOT,INGS,INSS,XL,YL,XR,YR,AA,BB)
      COMMON NRD,NWR,RSKTI(12)
      COMMON C1,C2,C3,SIG,RZERO,RONE,AAA,BBB
      COMMON NGS,NRS(23),AMO(24),AM1(24),LORS(24)
      COMMON BETA(24),RATE(24),COEF(24),FDEPTH(24)
      COMMON NSTEPO,NSTEPI
      COMMON INDIC(4),AREA(23,11)
      COMMON/DEBG/SXNOT,SYNOT,ERRBND,NSTEPMX,LERR,RZ2,LERR2,RISKER
      COMMON /MDATA/NSTEP,JPRNT,JPRNT2,JPRNT3,NLEI,TI(12),RISKS(9),
     1ATTEN(8,2,2)
      DIMENSION XL(4),YL(4),XR(4),YR(4),AA(4),BB(4),XC(4),YC(4)
      DIMENSION RSK(10)
      LOGICAL LERR,LERR2
      NSTEPIS=NSTEPI
```

```
C         SUBROUTINE FOR CALCULATING RISK WHEN SITE IS INSIDE
C                 SOURCE AREA.
C           REFER TO DOCUMENTATION FOR ALGORITHM USED TO CHOOSE
C                 NUMBER OF INTEGRATION STEPS.
    3 DO 50 II=1,NLEI
   50 RSK(II)=0.
      APPROX=0.
      RC2=10000000000.
      RF2=0.
C          FIND CLOSEST SIDE AND FARTHEST POINT
      DO 160 II=1,4
      IF(INDIC(II).EQ.1) GO TO 120
      XS=XL(II)
      YS=YNOT
      GO TO 140
C          IS SLOPE ZERO?
  120 IF (AA(II)-0.001) 121,125,125
  121 IF (AA(II)+0.001) 125,125,122
  122 XS=XNOT
      YS=YL(II)
      GO TO 140
C        SLOPE NOT ZERO
  125 XS=(YNOT+(XNOT/AA(II))-BB(II))/(AA(II)+1./AA(II))
      YS=((XNOT-XS)/AA(II))+YNOT
C          CALCULATE SQUARE OF DISTANCE BETWEEN SITE AND CLOSEST POINT.
  140 DIST=(XNOT-XS)*(XNOT-XS)+(YNOT-YS)*(YNOT-YS)
      IF (DIST-RC2) 151,152,152
  151 RC=SQRT(DIST)
      RC2=DIST
      ICLO=II
C          CALCULATE DISTANCE BETWEEN SITE AND LEFT HAND POINT ON SIDE
  152 DIST=(XNOT-XL(II))*(XNOT-XL(II))+(YNOT-YL(II))*(YNOT-YL(II))
      IF (RF2-DIST) 154,160,160
  154 RF=SQRT(DIST)
      RF2=DIST
      IFAR=II
  160 CONTINUE
C          DETERMINE AZIMUTH OF FARTHEST POINT WITH RESPECT TO SITE
      AZIMF=ACOS((XL(IFAR)-XNOT)/RF)
      IF (YL(IFAR)-YNOT) 162,164,164
  162 AZIMF=6.2831853072 - AZIMF
  164 CONTINUE
C       RC IS NOW DISTANCE FROM SITE TO CLOSEST SIDE.
C       RF IS NOW DISTANCE FROM SITE TO FARTHEST CORNER.
      IF (RC-0.01) 200,200,170
C        CALL SUBROUTINE CIRCLE TO CALCULATE RISK FROM CIRCULAR
C            SOURCE WITH RADIUS RC
  170 NTOT=NRS(INGS)+1
      FRAREA=AREA(INGS,INSS)/AREA(INGS,NTOT)
      CALL CIRCLE(RC,INGS,FRAREA,RSK)
      APPROX=3.1415926536*RC*RC
C       LOOP ON R TO CALCULATE RISK FROM RC TO RF
  200 AN=NSTEPI
C        PICK STEP SIZE BASED ON FRACTION OF AREA LEFT
      FRLEFT=(AREA(INGS,INSS)-APPROX)/AREA(INGS,INSS)
```

```
      NSTEPX=FRLEFT*AN + 1.
      AN=NSTEPX
      STSIZE=(RF-RC)/AN
      DO 500 ISTEP=1,NSTEPX
      AI=ISTEP
      R=RC+(AI-0.5)*STSIZE
      NPT=0
      ANGLE=0.
C         LOOP ON EACH SIDE
      DO 400 II=1,4
      IF(INDIC(II).EQ.1) GO TO 330
C         SIDE II IS VERTICAL, DOES CIRCLE (RADIUS R) INTERSECT IT?
      A=XL(II)-XNOT
      IF (A) 322,322,323
 322  IF (R+A) 400,400,324
 323  IF (R-A) 400,400,324
C         COMPUTE 2 INTERSECTION POINTS
 324  X1=XL(II)
      B=SQRT(R*R-(X1-XNOT)*(X1-XNOT))
      Y1=YNOT+B
      X2=XL(II)
      Y2=YNOT-B
      GO TO 341
 330  A=1.+AA(II)*AA(II)
      B=2.*(-XNOT+AA(II)*(BB(II)-YNOT))
      C=XNOT*XNOT+YNOT*YNOT+BB(II)*(BB(II)-2.*YNOT)-R*R
      D=B*B-4.*A*C
      IF (D) 400,400,340
C          THERE ARE 2 INTERSECTION, CALCULATE THEIR COORDINATES.
 340  D=SQRT(D)
      X1=(-B+D)/(2.*A)
      Y1=AA(II)*X1+BB(II)
      X2=(-B-D)/(2.*A)
      Y2=AA(II)*X2+BB(II)
C          SEE IF (X1,Y1) IS ON BOUNDARY
 341  CALL BETWEN(XL(II),YL(II),XR(II),YR(II),X1,Y1,INDIC(II),IANS)
      IF (IANS) 350,342,345
 342  NERROR=4
      GO TO 800
C       IS SECOND POINT ALSO ON BOUNDARY?
 345  CALL BETWEN(XL(II),YL(II),XR(II),YR(II),X2,Y2,INDIC(II),IANS)
      IF (IANS) 348,346,360
 346  NERROR=5
      GO TO 800
C         STORE FIRST POINT ONLY
 348  NPT=NPT+1
      XC(NPT)=X1
      YC(NPT)=Y1
      GO TO 400
C        SEE IF SECOND POINT ONLY IS ON BOUNDARY
 350  CALL BETWEN(XL(II),YL(II),XR(II),YR(II),X2,Y2,INDIC(II),IANS)
      IF (IANS) 400,352,354
 352  NERROR=6
      GO TO 800
 354  NPT=NPT+1
```

```
      XC(NPT)=X2
      YC(NPT)=Y2
      GO TO 400
C         TWO INTERSECTION POINTS ON ONE SIDE BOTH LIE ON BOUNDARY,
C          CALCULATE ANGLE BETWEEN THEM.
 360  CONTINUE
 380  AD=SQRT((X1-X2)*(X1-X2)+(Y1-Y2)*(Y1-Y2))
      IF(AD.GT.ABS(2.*R))AD=2.*ABS(R)
      ANGLE=2.*ASIN(AD/(2.*R))+ANGLE
 400  CONTINUE
      IF (NPT) 402,404,408
 402  NERROR=7
      GO TO 800
 404  IF (ANGLE-0.001) 402,406,406
C        FOLLOWING IS FOR CASE OF NO SINGLE INTERSECTION POINTS;
C        ANGLE IS 2 * PI - ANGLE CALCULATED SO FAR.
 406  PANGLE=6.2831853072-ANGLE
      GO TO 460
  408 IF(NPT.LT.1.OR.NPT.GT.4) GO TO 409
      GO TO (402,410,402,440),NPT
  409 NERROR=8
      GO TO 800
C         2 INTERSECTION POINTS; DETERMINE AZIMUTHS.
 410  IF (XC(1)-XNOT-R) 414,413,411
 411  IF (XC(1)-XNOT-R-0.001) 413,413,412
 412  NERROR=18
      GO TO 800
 413  AZIM1=0.0
      GO TO 418
 414  IF (XC(1)-XNOT+R) 415,416,417
 415  IF (XC(1)-XNOT+R+0.001) 412,416,416
 416  AZIM1=3.1415926536
      GO TO 420
 417  AZIM1=ACOS((XC(1)-XNOT)/R)
 418  IF (YC(1)-YNOT) 419,420,420
 419  AZIM1=6.2831853072  - AZIM1
 420  IF (XC(2)-XNOT-R) 424,423,421
 421  IF (XC(2)-XNOT-R-0.001) 423,423,422
 422  NERROR=19
      GO TO 800
 423  AZIM2=0.0
      GO TO 428
 424  IF (XC(2)-XNOT+R) 425,426,427
 425  IF (XC(2)-XNOT+R+0.001) 422,426,426
 426  AZIM2=3.1415926536
      GO TO 430
 427  AZIM2=ACOS((XC(2)-XNOT)/R)
 428  IF (YC(2)-YNOT) 429,430,430
 429  AZIM2=6.2831853072 -AZIM2
 430  PANGLE=AZIM2-AZIM1
      IF (PANGLE) 431,439,435
 431  IF (AZIM1-AZIMF) 432,439,433
 432  PANGLE=6.2831853072 +PANGLE -ANGLE
      GO TO 460
 433  IF (AZIMF-AZIM2) 432,439,434
```

```
 434  PANGLE=-PANGLE-ANGLE
      GO TO 460
 435  IF (AZIM2-AZIMF) 436,439,437
 436  PANGLE=6.2831853072 -PANGLE -ANGLE
      GO TO 460
 437  IF (AZIMF-AZIM1) 436,439,438
 438  PANGLE=PANGLE-ANGLE
      GO TO 460
 439  NERROR=9
      GO TO 800
C        FOUR INTERSECTION POINTS (EACH ON A DIFFERENT SIDE).
C        DETERMINE ANGLE BY FINDING CLOSEST 2 INTERSECTIONS TO
C        FARTHEST CORNER, CALCULATE ANGLE BETWEN, AND ADD ANGLE
C        BETWEEN OTHER TWO INTERSECTIONS.
 440  DIST1=1000000000.
      I1=0
      I2=0
      I3=0
      I4=0
      DO 450 JJ=1,4
      DIST=(XL(IFAR)-XC(JJ))*(XL(IFAR)-XC(JJ))
     1   +(YL(IFAR)-YC(JJ))*(YL(IFAR)-YC(JJ))
      IF (DIST-DIST1) 442,444,444
 442  DIST2=DIST1
      DIST1=DIST
      I4=I3
      I3=I2
      I2=I1
      I1=JJ
      GO TO 450
 444  IF (DIST-DIST2) 445,446,446
 445  DIST2=DIST
      I4=I3
      I3=I2
      I2=JJ
      GO TO 450
 446  I4=I3
      I3=JJ
 450  CONTINUE
C        CALCULATE ANGLE BETWEEN 2 CLOSEST POINTS TO FARTHEST CORNER
      AD=SQRT((XC(I1)-XC(I2))*(XC(I1)-XC(I2))
     1  + (YC(I1)-YC(I2))*(YC(I1)-YC(I2)))
      IF(AD.GT.ABS(2.*R))AD=2.*ABS(R)
      PANGLE=2.*ASIN(AD/(2.*R))
C         CALCULATE ANGLE BETWEEN 2 FARTHEST POINTS FROM
C         FARTHEST CORNER AND ADD TO PREVIOUS ANGLE.
      AD=SQRT((XC(I3)-XC(I4))*(XC(I3)-XC(I4))
     1 + (YC(I3)-YC(I4))*(YC(I3)-YC(I4)))
      IF(AD.GT.ABS(2.*R))AD=2.*ABS(R)
      PANGLE=2.*ASIN(AD/(2.*R))+PANGLE
C       ANGLE FOR THIS RADIUS IS NOW KNOWN, CALCULATE RISK
 460  CONTINUE
      ANAREA=PANGLE*R*STSIZE
      APPROX=APPROX+ANAREA
      NTOT=NRS(INGS)+1
```

```
      RATEI=RATE(INGS)*ANAREA*AREA(INGS,INSS)/AREA(INGS,NTOT)
C       CALCULATE CONTRIBUTION TO RISK
      DO 480 JJ=1,NLEI
      CALL RISK1(TI(JJ),R,INGS,RISK)
      IF (RISK-0.0000000001) 500,490,490
 490  RSK(JJ)=RSK(JJ) +RISK*RATEI
 480  CONTINUE
 500  CONTINUE
      ARERR=((APPROX-AREA(INGS,INSS))/AREA(INGS,INSS))*100.
  510 IF(ABS(ARERR).LE.ERRBND) GO TO 540
      WRITE (NWR,903) ARERR,INGS,INSS,SXNOT,SYNOT,NSTEPI
 903  FORMAT(10X,"CAUTION: NUMERICAL INTEGRATION ERROR IN AREA IS ",
     1 F8.2," % FOR (INSIDE) SOURCE ",2I3,"  LAT",F6.2,"  LONG",F8.2,
     1" NSTEPI=",I3)
      NSTEPI=NSTEPI*2
      IF(NSTEPI.GT.NSTEPMX) GO TO 10
      GO TO 3
   10 LERR=.TRUE.
      RISKER=RISKER+COEF(INGS)*RSK(NLEI-2)/APPROX
 540  DO 550 JJ=1,NLEI
      RSK(JJ)=COEF(INGS)*RSK(JJ)/APPROX
 550  RSKTI(JJ)=RSKTI(JJ)+RSK(JJ)
      IF (JPRNT) 850,850,610
C          PRINT RISKS FOR THIS SOURCE.
 610  WRITE(NWR,902) INGS,INSS,(RSK(I),I=1,NLEI)
 902  FORMAT(" SOURCE",2I3," E(NO/YR): ",12E9.3)
      GO TO 850
C           ERROR PRINTOUT
 800  WRITE (NWR,901) NERROR,INGS,INSS,IFAR,NPT,XNOT,YNOT,(XL(I),YL(I),
     1 I=1,4),RC,RF,R,PANGLE,(XC(I),YC(I),I=1,4)
 901  FORMAT (" ***** ERROR",I4," IN SUBROUTINE INSIDE. SOURCE NO.",
     1 2I3," DEBUG VALUES FOLLOW......",/10X,2I10,10(/10X,2F12.6))
      WRITE(NWR,1)SXNOT,SYNOT,NSTEPI
    1 FORMAT("  LAT",F6.2,"  LONG",F8.2,"  NSTEPI=",I3)
      NSTEPI=NSTEPI*2
      IF(NSTEPI.LE.NSTEPMX)GO TO 3
      LERR2=.TRUE.
  850 NSTEPI=NSTEPIS
      RETURN
      END
      SUBROUTINE NDTR(X,P,D)
C          X  IS NO. OF STANDARDIZED NORMAL DEVIATES.
C          P  IS COMP. CUMULATIVE VALUE (OUTPUT).
C          D  IS DENSITY VALUE (OUTPUT)
      IF (X) 1,2,2
   1  AX=-X
      GO TO 3
   2  AX=X
   3  IF (AX-6.0) 5,4,4
   4  P=1.
      D=0.
      GO TO 6
   5  T=1./(1.0+.2316419*AX)
      D=0.3989423*EXP(-X*X/2.0)
      P = 1.0 - D*T*((((1.330274*T - 1.821256)*T + 1.781478)*T -
```

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     1  0.3565638)*T + 0.3193815)
    6 IF (X) 8,7,7
    7 P=1.0-P
    8 RETURN
      END
      SUBROUTINE NWNERK
C     INTERACTIVE VERSION FOR RISK CALCULATIONS IN THE NWNE REGION
C     DISC FILE INPUT OF ZONE DATA ON TAPE2
C     FOR A GIVEN LOCATION, WITH ROUTINE COMBINI, TO ADD RISKS FROM
C     SOURCES USING WESTERN ATTENUATIONS WITH RISKS FROM SOURCES USING
C     EASTERN ATTENUATIONS
C     DH WEICHERT MODIFIED FOR LAT. LONG. INPUT AND CONVERSION TO EASTIN
C     AND NORTHINGS(Y) IN KM.  THIS USE OF X + Y AGREES WITH MCGUIRES"S
C     MODIFIED BY FMA TO RUN VELOCITY AND ACCERATION DATA TOGETHER
C        R K MCGUIRE   U.S.G.S. JANUARY 1975
C       PLANAR VERSION (CARTESIAN COORDINATES)
      COMMON NRD,NWR,RSKTI(12)
      COMMON C1,C2,C3,SIG,RZERO,RONE,AAA,BBB
      COMMON NGS,NRS(23),AMO(24),AM1(24),LORS(24)
      COMMON BETA(24),RATE(24),COEF(24),FDEPTH(24)
      COMMON NSTEPO,NSTEPI
      COMMON INDIC(4),AREA(23,11),X(23,11,2),Y(23,11,2)
      COMMON/DEBG/SXNOT,SYNOT,ERRBND,NSTEPMX,LERR,RZ2,LERR2,RISKER
      COMMON /MDATA/NSTEP,JPRNT,JPRNT2,JPRNT3,NLEI,TI(12),RISKS(9),
     1ATTEN(8,2,2)
      COMMON/CNM/RNAME(6),SNAME(6),TIFS(8,2),RZ2S(23),JEW,NRG,SLAT,SLONG
     1,IN,JN,NRGL
      COMMON/LERRS/INCLUD,INCLD2,LNLEI,LRISKS,RKRATO
      COMMON/SRSKC/SRSK(12,4)
      DIMENSION BRISK(12)
      LOGICAL LERR,INCLUD,LERR2,INCLD2,LNLEI,LRISKS
      REWIND NRD$NRGS=NRG-1$DO 30 I=1,NRGS
   31 READ(NRD)$IF(EOF(NRD))30,31
   30 CONTINUE
      DO 14 JW =1,2
      IF(JW.EQ.1)GO TO 1
    2 READ(NRD)
      IF(EOF(NRD))1,2
    1 READ(NRD)    NGS,(NRS(I),I=1,NGS)
      NGS1=NGS+1
      DO 110 I=1,NGS1
      READ(NRD)    RZ2S(I),LORS(I),COEF(I),AMO(I),AM1(I),BETA(I),RATE(I)
     1,FDEPTH(I),NAME
  110 CONTINUE
      DO 200 II=1,NGS
      NRSII=NRS(II)+1
      DO 150 JJ=1,NRSII
      READ(NRD)     X(II,JJ,1),Y(II,JJ,1),X(II,JJ,2),Y(II,JJ,2)
     1,NAMES
      CALL PRJC(X(II,JJ,1),Y(II,JJ,1))
      CALL PRJC(X(II,JJ,2),Y(II,JJ,2))
C     DH WEICHERT CHANGES TO EASTING(X) + NORTHING(Y) IN KM. USING LAMBE
C     CONFORMAL PROJECTION
 150  CONTINUE
  200 CONTINUE
```

```
C         CALCULATE AREA OF EACH SUBSOURCE AND GROSS SOURCE.
      DO 400 II=1,NGS
      NTOT=NRS(II)+1
      AREA(II,NTOT)=0.0
      NAZIZ = NRS(II)
      DO 300 JJ=1,NAZIZ
      CALL AREAS(X(II,JJ,1),Y(II,JJ,1),X(II,JJ,2),Y(II,JJ,2),
     1 X(II,JJ+1,1),Y(II,JJ+1,1),X(II,JJ+1,2),Y(II,JJ+1,2),AREA(II,JJ))
 300  AREA(II,NTOT)=AREA(II,NTOT)+AREA(II,JJ)
  400 CONTINUE
      DO 424 J=1,2
      DO 90 I=1,NLEI
  90  BRISK(I)=0.0
      NSTEPO=NSTEPI=NSTEP
      C1=ATTEN(1,J,JW )
      C2=ATTEN(2,J,JW)
      C3=ATTEN(3,J,JW)
      SIG=ATTEN(4,J,JW)
      RZERO=ATTEN(5,J,JW)
      RONE=ATTEN(6,J,JW)
      AAA=ATTEN(7,J,JW)
      BBB=ATTEN(8,J,JW)
      JAV=J+2*(JW-1)
      IF (BBB+0.00001) 101,102,102
 101  WRITE (JN ,924)
 924  FORMAT(//" INPUT ERROR:  THE VALUE OF BBB MUST BE POSITIVE,"/
     1 " BETWEEN 0.0 AND THE VALUE OF C2. EXECUTION STOPPED.")
      RETURN
 102  IF (C2-BBB) 101,103,103
C          IF BBB=0.0, SET EQUAL TO A SMALL NUMBER
 103  IF (BBB-0.00001) 104,105,105
 104  BBB=0.000000001
C          COMPUTE BACKGROUND SEISMICITY
  105 IF(RATE(NGS1)-0.000000001) 420,420,405
C          RBACK IS RADIUS OUT TO WHICH RISK FROM
C            BACKGROUND SEISMICITY IS CALCULATED.
 405  RBACK=150.
C         FOR BACKGROUND SEISMICITY, NSTEPI IS DOUBLED (AND
C            THEN HALVED AFTER CALCULATIONS).
      NSTEPI=2*NSTEPI
      CALL CIRCLE(RBACK,NGS1,1.,BRISK)
      NSTEPI=NSTEPI/2
      DO 410 I=1,NLEI
 410  BRISK(I)=COEF(NGS1)*BRISK(I)/10000.
  420 XNOT=SLAT$YNOT=-SLONG
      SXNOT=XNOT
      SYNOT=YNOT
      RISKER=0.
      LERR=.FALSE.
      LERR2=.FALSE.
      DO 450 I=1,NLEI
 450  RSKTI(I)=BRISK(I)
      CALL PRJC(XNOT,YNOT)
      DO 600 II=1,NGS
      NAZIZ = NRS(II)
```

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      RZ2=RZ2S(II)
      DO 600 JJ=1,NAZIZ
      INGS=II
      INSS=JJ
      CALL RRISK(XNOT,YNOT,INGS,INSS,X(II,JJ,1),Y(II,JJ,1),X(II,JJ,
     X2),Y(II,JJ,2),X(II,JJ+1,1),Y(II,JJ+1,1),X(II,JJ+1,2),Y(II,JJ+1,2))
 600  CONTINUE
      IF(.NOT.LERR2.OR.INCLD2) GO TO 11
      WRITE(JN ,10)
   10 FORMAT(/" ERROR IN SUBROUTINE INSIDE OR OUTSID"/)
      RETURN
   11 IF(.NOT.LERR.OR.INCLUD) GO TO 12
      GDRISK=RSKTI(NLEI-2)-RISKER
      IF(GDRISK.LE.0.) GO TO 13
      RISKRR=RISKER/GDRISK
      IF(RISKRR.LT.RKRATO) GO TO 12
   13 WRITE(JN ,15)       ERRBND,RISKRR,RKRATO
   15 FORMAT(/" ERROR IN AREA CALCULATION GREATER THAN ",F6.1," &"/
     1" AND RATIO OF ERROR RISK CALC TO NON ERROR RISK CALC=",F6.2/
     2" GREATER THAN ",F5.2/)
      RETURN
   12 DO 610 I=1,NLEI
  610 SRSK(I,JAV)=RSKTI(I)
  424 CONTINUE
   14 CONTINUE
      CALL COMBINI
      RETURN
      END
      SUBROUTINE OUTSID(XNOT,YNOT,INGS,INSS,XL,YL,XR,YR,AA,BB)
      COMMON NRD,NWR,RSKTI(12)
      COMMON C1,C2,C3,SIG,RZERO,RONE,AAA,BBB
      COMMON NGS,NRS(23),AMO(24),AM1(24),LORS(24)
      COMMON BETA(24),RATE(24),COEF(24),FDEPTH(24)
      COMMON NSTEPO,NSTEPI
      COMMON INDIC(4),AREA(23,11)
      COMMON/DEBG/SXNOT,SYNOT,ERRBND,NSTEPMX,LERR,RZ2,LERR2,RISKER
      COMMON /MDATA/NSTEP,JPRNT,JPRNT2,JPRNT3,NLEI,TI(12),RISKS(9),
     1ATTEN(8,2,2)
      DIMENSION XL(4),YL(4),XR(4),YR(4),AA(4),BB(4),XC(4),YC(4)
      DIMENSION RSK(12)
      LOGICAL LERR,LERR2
      NSTEPOS=NSTEPO
C         SUBROUTINE FOR CALCULATING RISK WHEN SITE IS OUTSIDE
C          (QUADRILATERAL) SOURCE AREA.
C          DEFINE DISTANCE VALUES TO SELECT STEP SIZE.
C          (RC IS CLOSEST DISTANCE BETWEEN SITE AND SOURCE.)
C          RC BETWEEN 0.0 AND RZ1 IMPLIES STEP SIZE = NSTEPO.
C          RC BETWEEN RZ1 AND RZ2 IMPLIES STEP SIZE = NSTEPO/2.
C          RC BETWEEN RZ2 AND RZ3 IMPLIES LUMP RISK
C                AT CENTER OF SOURCE (DEFINED BY AVERAGING LOCATIONS
C                OF CORNER POINTS).
C          RC GREATER THAN RZ3 IMPLIES IGNORE SOURCE.
      RZ1=100.
      RZ3=3000.
C          TO BY-PASS THIS ALGORITHM, SET RZ1 TO A LARGE NUMBER.
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C          TO PRODUCE 0-1 ALGORITHM (DISREGARD, OR CALCULATE USING
C          NSTEPO), SET RZ1=RZ2=RZ3=DISTANCE WITHIN WHICH YOU
C          WISH TO CONSIDER RISK.
C      FIND CLOSEST (IC,RC) AND FARTHEST (IFAR,RF) POINTS AND DISTANCES.
      RC2=1000000000.
      RF2=0.
      DO 108 II=1,4
      DIST=(XNOT-XL(II))*(XNOT-XL(II))+(YNOT-YL(II))*(YNOT-YL(II))
      IF (RC2-DIST) 104,104,102
 102  RC=SQRT(DIST)
      RC2=DIST
      IC=II
 104  IF (DIST-RF2) 108,108,106
 106  RF=SQRT(DIST)
      RF2=DIST
      IFAR=II
 108  CONTINUE
      ICS=0
C        SEE IF ANY SIDE LIES CLOSER THAN CLOSEST POINT
      DO 150 II=1,4
C       IS SLOPE INFINITE?
      IF(INDIC(II).EQ.1) GO TO 130
      XS=XL(II)
      YS=YNOT
      GO TO 145
C       IS SLOPE ZERO?
 130  IF (AA(II)-0.001) 131,140,140
 131  IF (AA(II)+0.001) 140,140,132
 132  XS=XNOT
      YS=YL(II)
      GO TO 145
C        SLOPE IS NOT ZERO, SO CALCULATE NEAREST POINT.
 140  XS=(YNOT+(XNOT/AA(II))-BB(II))/(AA(II)+(1./AA(II)))
      YS=((XNOT-XS)/AA(II))+YNOT
 145  CALL BETWEN(XL(II),YL(II),XR(II),YR(II),XS,YS,INDIC(II),IANS)
      IF (IANS) 150,146,148
 146  NERROR=1
      GO TO 800
 148  DIST=(XNOT-XS)*(XNOT-XS)+(YNOT-YS)*(YNOT-YS)
      IF (DIST-RC2) 149,150,150
 149  RC2=DIST
      RC=SQRT(DIST)
      ICS=II
 150  CONTINUE
    3 APPROX=0.0
      DO 290 II=1,NLEI
 290  RSK(II)=0.
C         DETERMINE STEP SIZE FROM RZ1,RZ2, AND RZ3.
      IF (RC-RZ1) 308,308,292
 292  IF (RC-RZ2) 294,294,296
 294  NSTEPX=NSTEPO/2
      GO TO 310
 296  IF (RC-RZ3) 298,298,850
C          IF RC IS BETWEEN RZ2 AND RZ3, CALCULATE RISK
C          ASSUMING SEISMICITY IS LUMPED AT CENTER (AVERAGE
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C           OF CORNER POINTS).
 298  XAVE=(XL(1)+XL(2)+XL(3)+XL(4))/4.
      YAVE=(YL(1)+YL(2)+YL(3)+YL(4))/4.
      R=SQRT((XAVE-XNOT)*(XAVE-XNOT)+(YAVE-YNOT)*(YAVE-YNOT))
      NTOT=NRS(INGS)+1
      RATEI=RATE(INGS)*AREA(INGS,INSS)/AREA(INGS,NTOT)
      DO 306 JJ=1,NLEI
      CALL RISK1(TI(JJ),R,INGS,RISK)
      IF (RISK-0.0000000001) 600,600,305
 305  RSK(JJ)=COEF(INGS)*RISK*RATEI
 306  RSKTI(JJ)=RSKTI(JJ) + RSK(JJ)
      GO TO 600
 308  NSTEPX=NSTEPO
 310  AN=NSTEPX
      STSIZE=(RF-RC)/AN
C         STEP THRU SOURCE AREA.
      DO 500 ISTEP=1,NSTEPX
      AI=ISTEP
      R=RC+(AI-0.5)*STSIZE
      NPT=0
      ANGLE=0.
      SIGNAL=1.
C         LOOP ON EACH SIDE
      DO 400 II=1,4
      IF(INDIC(II).EQ.1) GO TO 330
C           SIDE II IS A VERTICAL LINE
C           DOES CIRCLE (RADIUS R) INTERSECT IT?
      A=XL(II)-XNOT
      IF (A) 322,322,323
 322  IF (R+A) 400,400,324
 323  IF (R-A) 400,400,324
C           COMPUTE TWO INTERSECTION POINTS
 324  X1=XL(II)
      B=SQRT(R*R-(X1-XNOT)*(X1-XNOT))
      Y1=YNOT+B
      X2=XL(II)
      Y2=YNOT-B
      GO TO 341
 330  A=1.+AA(II)*AA(II)
      B=2.*(-XNOT+AA(II)*(BB(II)-YNOT))
      C=XNOT*XNOT+YNOT*YNOT+BB(II)*(BB(II)-2.*YNOT)-R*R
      D=B*B-4.*A*C
      IF (D) 400,400,340
C         TWO INTERSECTIONS, CALCULATE FIRST INTERSECTION POINT.
 340  D=SQRT(D)
      X1=(-B+D)/(2.*A)
      Y1=AA(II)*X1 + BB(II)
      X2=(-B-D)/(2.*A)
      Y2=AA(II)*X2+BB(II)
C         SEE IF (X1,Y1) IS ON BOUNDARY
 341  CALL BETWEN(XL(II),YL(II),XR(II),YR(II),X1,Y1,INDIC(II),IANS)
      IF (IANS) 360,342,345
 342  NERROR=4
      GO TO 800
C         CALCULATE OTHER POINT, SEE IF IS ON BOUNDARY.
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```
  345 CALL BETWEN(XL(II),YL(II),XR(II),YR(II),X2,Y2,INDIC(II),IANS)
      IF (IANS) 348,346,350
  346 NERROR=5
      GO TO 800
C         STORE FIRST POINT
  348 NPT=NPT+1
      XC(NPT)=X1
      YC(NPT)=Y1
      GO TO 400
C         SEE IF THIS SIDE IS CLOSEST TO POINT, IF SO, TREAT SPECIALLY.
  350 IF (II-ICS) 352,355,352
C           BOTH POINTS ARE ON BOUNDARY, CALCULATE ANGLE BETWEN THEM.
  352 SIGN=-1.
      GO TO 357
  355 SIGN=1.
      SIGNAL=-1.
  357 AD=SQRT((X1-X2)*(X1-X2)+(Y1-Y2)*(Y1-Y2))
      IF (AD-2.*R) 358,359,359
  358 ANGLE=SIGN*2.*ASIN(AD/(2.*R)) + ANGLE
      GO TO 400
  359 ANGLE=3.1415926536 +ANGLE
      GO TO 400
C         SEE IF SECOND POINT ONLY IS ON BOUNDARY
  360 CALL BETWEN(XL(II),YL(II),XR(II),YR(II),X2,Y2,INDIC(II),IANS)
      IF (IANS) 400,362,370
  362 NERROR=6
      GO TO 800
  370 NPT=NPT+1
      XC(NPT)=X2
      YC(NPT)=Y2
  400 CONTINUE
      IF(NPT.LT.1.OR.NPT.GT.4) GO TO 404
      GO TO (410,420,410,440),NPT
   404 IF(SIGNAL)460,405,405
  405 NERROR=7
      GO TO 800
  410 NERROR=8
      GO TO 800
  420 AD=SQRT((XC(1)-XC(2))*(XC(1)-XC(2))+(YC(1)-YC(2))*(YC(1)-YC(2)))
      IF(AD.GT.ABS(2.*R))AD=2.*ABS(R)
      ANGLE=ANGLE + SIGNAL*2.*ASIN(AD/(2.*R))
      GO TO 460
C           FOUR INTERSECTION POINTS (EACH ON A DIFFERENT SIDE).
C           DETERMINE ANGLE BY FINDING CLOSEST 2 INTERSECTIONS TO
C           FARTHEST CORNER, CALCULATE ANGLE BETWEEN, AND ADD ANGLE
C           BETWEEN OTHER TWO INTERSECTIONS.
  440 DIST1=1000000000.
      I1=0
      I2=0
      I3=0
      I4=0
      DO 450 JJ=1,4
      DIST=(XL(IFAR)-XC(JJ))*(XL(IFAR)-XC(JJ))
     1  +(YL(IFAR)-YC(JJ))*(YL(IFAR)-YC(JJ))
      IF (DIST-DIST1) 442,444,444
```

```
 442  DIST2=DIST1
      DIST1=DIST
      I4=I3
      I3=I2
      I2=I1
      I1=JJ
      GO TO 450
 444  IF (DIST-DIST2) 445,446,446
 445  DIST2=DIST
      I4=I3
      I3=I2
      I2=JJ
      GO TO 450
 446  I4=I3
      I3=JJ
 450  CONTINUE
C           CALCULATE ANGLE BETWEEN 2 CLOSEST POINTS TO FARTHEST CORNER.
      AD=SQRT((XC(I1)-XC(I2))*(XC(I1)-XC(I2))
     1  + (YC(I1)-YC(I2))*(YC(I1)-YC(I2)))
      IF(AD.GT.ABS(2.*R))AD=2.*ABS(R)
      ANGLE=2.*ASIN(AD/(2.*R))
C         CALCULATE ANGLE BETWEEN 2 POINTS FARTHEST FROM
C         FARTHEST CORNER AND ADD TO PREVIOUS ANGLE.
      AD=SQRT((XC(I3)-XC(I4))*(XC(I3)-XC(I4))
     1  +(YC(I3)-YC(I4))*(YC(I3)-YC(I4)))
      IF(AD.GT.ABS(2.*R))AD=2.*ABS(R)
      ANGLE=2.*ASIN(AD/(2.*R)) + ANGLE
 460  CONTINUE
C        ANGLE FOR THIS RADIUS NOW KNOWN, CALCULATE RISK.
C        COMPUTE RATE OF EARTHQUAKES IN THIS ANNULAR SOURCE
      ANAREA=ANGLE*R*STSIZE
      APPROX=APPROX+ANAREA
      NTOT=NRS(INGS)+1
      RATEI=RATE(INGS)*ANAREA*AREA(INGS,INSS)/AREA(INGS,NTOT)
C        CALCULATE CONTRIBUTION TO RISK
      DO 480 JJ=1,NLEI
      CALL RISK1(TI(JJ),R,INGS,RISK)
      IF (RISK-0.0000000001) 500,490,490
 490  RSK(JJ)=RSK(JJ)+RISK*RATEI
 480  CONTINUE
 500  CONTINUE
      ARERR=((APPROX-AREA(INGS,INSS))/AREA(INGS,INSS))*100.
  510 IF(ABS(ARERR).LE.ERRBND) GO TO 540
      WRITE(NWR,903) ARERR,INGS,INSS,SXNOT,SYNOT,NSTEPO
 903  FORMAT(10X,"CAUTION: NUMERICAL INTEGRATION ERROR IN AREA IS ",
     1 F8.2," % FOR (OUTSIDE) SOURCE ",2I3,"  LAT",F6.2,"   LONG",F8.2,
     1" NSTEPO=",I3)
      NSTEPO=NSTEPO*2
      IF(NSTEPO.GT.NSTEPMX) GO TO 10
      GO TO 3
   10 LERR=.TRUE.
      RISKER=RISKER+COEF(INGS)*RSK(NLEI-2)/APPROX
C           NORMALIZE BY COMPUTED (APPROXIMATE) AREA
 540  DO 550 JJ=1,NLEI
      RSK(JJ)=COEF(INGS)*RSK(JJ)/APPROX
```

```
 550  RSKTI(JJ)=RSKTI(JJ)+RSK(JJ)
 600  IF (JPRNT) 850,850,610
C         PRINT RISKS FOR THIS SOURCE
 610  WRITE(NWR,902) INGS,INSS,(RSK(I),I=1,NLEI)
 902  FORMAT(" SOURCE",2I3," E(NO/YR): ",12E9.3)
      GO TO 850
C        ERROR PRINTOUT
 800  WRITE(NWR,901)NERROR,INGS,INSS,IC,NPT,XNOT,YNOT,
     1(XL(I),YL(I),I=1,4),R,ANGLE,RC,RF,(XC(I),YC(I),I=1,4)
 901  FORMAT(" ***** ERROR",I4," IN SUBROUTINE OUTSID. SOURCE NO.",2I3,
     1" DEBUG VALUES FOLLOW.....",/10X,2I5,5(/10X,4F14.6))
      WRITE(NWR,1)SXNOT,SYNOT,NSTEPO
    1 FORMAT("  LAT",F6.2,"  LONG",F8.2,"  NSTEPO=",I3)
      NSTEPO=NSTEPO*2
      IF(NSTEPO.LE.NSTEPMX.AND.NERROR.NE.1) GO TO 3
      LERR2=.TRUE.
  850 NSTEPO=NSTEPOS
      RETURN
      END
      SUBROUTINE OUTFRM
      COMMON NRD,NWR,RSKTI(12)
      COMMON C1,C2,C3,SIG,RZERO,RONE,AAA,BBB
      COMMON NGS,NRS(23),AM0(24),AM1(24),LORS(24)
      COMMON BETA(24),RATE(24),COEF(24),FDEPTH(24)
      COMMON NSTEPO,NSTEPI
      COMMON INDIC(4),AREA(23,11),X(23,11,2),Y(23,11,2)
      COMMON /MDATA/NSTEP,JPRNT,JPRNT2,JPRNT3,NLEI,TI(12),RISKS(9),
     1ATTEN(8,2,2)
      COMMON/CNM/RNAME(6),SNAME(6),TIFS(8,2),RZ2S(23),JEW,NRG,SLAT,SLONG
     1,IN,JN,NRGL
      DIMENSION NCC(60)
      WRITE(NWR,1)
    1 FORMAT(1H1,T5 ,"ENERGY, MINES AND",T47,"ENERGIE, MINES ET"/
     1T5 ,"RESOURCES CANADA",T47,"RESOURCES CANADA"/
     2T5 ,"EARTH PHYSICS BRANCH",T47,"DIRECTION DE LA PHYSIQUE DU GLOBE"
     1//
     1///T5 ,"SEISMIC RISK CALCULATION *"
     4T47,"CALCULE DE RISQUE SEISMIQUE *"///)
      WRITE(NWR,2)
    2 FORMAT(//T5,"REQUESTED BY")
      DECODE(60,50,RNAME)NCC
   50 FORMAT(60A1)
      DO 51 I=1,60$J=61-I$IF(NCC(J).EQ.10H          )GO TO 51$GO TO 52
   51 CONTINUE
   52 NBCH=(61-J)/2+20
      ENCODE(10,54,LINEF)NBCH,J
   54 FORMAT(2H(T,I2,1H,,I2,3HA1))
      WRITE(NWR,LINEF)(NCC(I),I=1,J)
      WRITE(NWR,12)
   12 FORMAT(T5,"DEMANDE PAR"/)
      WRITE(NWR,3)
    3 FORMAT(//T5 ,"FOR SITE")
      DECODE(60,50,SNAME)NCC
      DO 55 I=1,60$J=61-I$IF(NCC(J).EQ.10H           )GO TO 55$GO TO 56
   55 CONTINUE
```

```
   56 NBCH=(61-J)/2+20
      ENCODE(10,54,LINEF)NBCH,J
      WRITE(NWR,LINEF)(NCC(I),I=1,J)
      WRITE(NWR,13)
   13 FORMAT(T5 ,"POUR SITE"/)
      WRITE(NWR,4)SLAT,SLONG
    4 FORMAT(//T5 ,"LOCATED AT"/T29,F5.2," NORTH/NORD"
     2T49,F6.2," WEST/OUEST"/T5 ,"LOCATION"/)
      WRITE(NWR,5)(RISKS(J),J=1,4)
    5 FORMAT(/T5 ,"PROBABILITY OF EXCEEDENCE"/T5 ,"PER ANNUM"/
     235X,F4.2,6X,F5.3,5X,F8.6,6X,F5.3/
     3T5 ,"PROBABILITE DE"/T5 ,"DEPASSEMENT PAR ANNEE")
      WRITE(NWR,8)(TIFS(J,1),J=1,4)
    8 FORMAT(/ T5 ,"PEAK HORIZONTAL"/T5 ,"ACCELERATION (%G)"/
     135X,F4.1,7X,F4.1,8X,F4.1,8X,F4.1/
     2T5 ,"ACCELERATION HORIZONTAL"/T5 ,"MAXIMALE (%G)")
      WRITE(NWR,7)(TIFS(J,2),J=1,4)
    7 FORMAT(/ T5 ,"PEAK HORIZONTAL"/T5 ,"VELOCITY (CM/SEC)"/
     135X,F4.1,7X,F4.1,8X,F4.1,8X,F4.1/
     2T5,"VITESSE HORIZONTALE"/T5 ,"MAXIMALE (CM/SEC)")
      WRITE(NWR,10)
   10 FORMAT(//////             T5 ,"* REFERENCE"/
     1T5,"NEW PROBABILISTIC STRONG SEISMIC GROUND"/
     2T5 ,"MOTION MAPS OF CANADA: A COMPILATION OF EARTHQUAKE"/
     3T5 ,"SOURCE ZONES, METHODS AND RESULTS"/
     4T5 ,"P.W. BASHAM, D.H. WEICHERT, F.M. ANGLIN, AND M.J. BERRY"/
     6T5 ,"EARTH PHYSICS BRANCH OPEN FILE NUMBER 82-    "/
     7T5 ,"OTTAWA, CANADA 1982")
      CALL DATE(IDATE)$CALL TIME(ITIME)$WRITE(NWR,20)IDATE,ITIME
   20 FORMAT(60X,2A10)
      WRITE(NWR,9)
    9 FORMAT(/////)
      RETURN$END
      SUBROUTINE PRJC(RLAT1,RLONG1)
      COMMON/CTAS/SCALEK,CONE,TLONG,RO,RADCON
      DATA RAD,E,E2,A,ED2/0.01745329252,12.15482511000,0.00676865800218,
     C637820640.1,0.041135927122/
      IF(RLAT1.GE.90.) GO TO 2
      P=RLAT1*RAD
      SP=SIN(P)
      RI=SCALEK*(COS(P)/(1.+SP)*((E+SP)/(E-SP))**ED2)**CONE
      QI=(TLONG-RLONG1)*RADCON
      RLAT1=-RI*SIN(QI)
      RLONG1=RO-RI*COS(QI)
C     NOTE THE TRANSPOSED INTERPRETATION OF THE ARGUMENT SEQUENCE.
C     THE FIRST ARG, LAT. IS NOW X,  SECOND Y
      RETURN
    2 RLAT1=1.E8
      RETURN
      END
      SUBROUTINE RISK1(TIC,REPIS,INGS,RISK)
C     D WEICHERT S VERSION MAY 1981
C     MODIFIED MAY 28
      COMMON NRD,NWR,RSKTI(12)
      COMMON C1,C2,C3,SIG,RZERO,RONE,AAA,BBB
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      COMMON NGS,NRS(23),AMO(24),AM1(24),LORS(24)
      COMMON BETA(24),RATE(24),COEF(24),FDEPTH(24)
      COMMON NSTEPO,NSTEPI
      COMMON INDIC(4),AREA(23,11)
      COMMON /MDATA/NSTEP,JPRNT,JPRNT2,JPRNT3,NLEI,TI(12),RISKS(9),
     1ATTEN(8,2,2)
C
C           SUBROUTINE TO CALCULATE RISK WHEN THE FOLLOWING SPECIAL
C           FORM OF ATTENUATION FUNCTION IS USED:
C                I = C1 + C2*M + C3*ALOG(R+RZERO)
C
      SIGG=SIG
      RFOC=SQRT(REPIS*REPIS + FDEPTH(INGS)*FDEPTH(INGS))
      IF (RFOC-RONE) 10,10,20
   10 R=RONE
C          IF DIFFERENT STANDARD DEVIATION INSIDE RADIUS RONE IS
C          DESIRED, SET SIGG TO THIS STANDARD DEVIATION HERE.
      GO TO 30
   20 R=RFOC
   30 RLN=ALOG(R+RZERO)
      FM7LIM=7.5
      BETAJ=BETA(INGS)
      SPIKE=EXP(-BETAJ*FM7LIM)-EXP(-BETAJ*AM1(INGS))
      IF(SPIKE.LE.0.)SPIKE=0.
      AM1J=AM1(INGS)
      IF(FM7LIM.LT.AM1J)AM1J=FM7LIM
      CALL NDTR((TIC-C1-C2*FM7LIM-C3*RLN)/SIG,PHISTR,D)
C
C           IS THIS LOOSE OR STRICT SOURCE?
C           IF STRICT, RISK COMPUTED IS THAT FOR A SINGLE EARTHQUAKE
C           WITH (EXPONENTIALLY-DISTRIBUTED) RANDOM MAGNITUDE
C           (OR INTENSITY) BETWEEN AMO AND AM1.  IF A LOOSE
C           SOURCE, RISK COMPUTED IS THAT FOR 'ANEQ' EARTHQUAKES
C           WITH (EXPONENTIALLY-DISTRIBUTED) RANDOM MAGNITUDE
C           (OR INTENSITY) BETWEEN 0.0 AND AM1, WITH 'ANEQ' CALCULATED
C           SO THAT THE EXPECTED NUMBER OF EVENTS BETWEEN AMO AND AM1
C           IS UNITY.
C
      IF (LORS(INGS)) 40,40,50
   40 AK=1./(1.-EXP(-BETAJ     *AM1(INGS)))
      ANEQ=1./(1.-AK+AK*EXP(-BETAJ     *AMO(INGS)))
      AMZ=0.0
      GO TO 60
   50 AK=1./(1.-EXP(-BETAJ     *(AM1(INGS)-AMO(INGS))))
      ANEQ=1.
      AMZ=AMO(INGS)
C           CALCULATE MAGNITUDE 'AMSTAR' ASSOCIATED WITH MAX. INTENSITY
C           AT THIS DISTANCE (R); IF LESS THAN AM1, EVALUATE RISK
C           FOR MAGNITUDES BETWEEN AMSTAR AND AM1 SEPARATELY.
   60 AMSTAR=(AAA-C1-C3*RLN)/(C2-BBB)
      IF (AM1(INGS)-AMSTAR) 65,65,70
C          NONE OF MAGNITUDE INTEGRATION LIES ABOVE AMSTAR.
   65 CALL ERISK(AMZ,AM1J     ,C1,C2,C3,RLN,SIGG,BETAJ     ,TIC,
     1 G1,G2,G3,G4,CON1,CON2,CON3)
      GO TO 77
```

```
  70  IF (AMZ-AMSTAR) 80,75,75
C         ALL OF MAGNITUDE INTEGRATION LIES ABOVE AMSTAR.
  75  CALL ERISK(AMZ,AM1J        ,AAA,BBB,0.,RLN,SIGG,BETAJ     ,TIC,
     1  G1,G2,G3,G4,CON1,CON2,CON3)
  77  RISK=((1.-AK)*G1 + AK*G2 + AK*(G3-G4)*CON1*CON2+AK*SPIKE*PHISTR)*
     1ANEQ
      GO TO 100
C         SOME OF MAGNITUDE INTEGRATION LIES ABOVE MSTAR, SOME BELOW.
  80  CALL ERISK(AMZ,AMSTAR,C1,C2,C3,RLN,SIGG,BETAJ     ,TIC,
     1  G1,G2,G3,G4,CON1,CON2,CON3)
      CALL ERISK(AMSTAR,AM1J     ,AAA,BBB,0.,RLN,SIGG,BETAJ     ,TIC,
     1  GG1,GG2,GG3,GG4,CCON1,CCON2,CCON3)
      RISK=((1.-AK)*G1 +AK*G2 +AK*(G3-G4)*CON1*CON2
     1 + (1.-AK)*(GG1-GG2) + AK*(GG3-GG4)*CCON1*CCON2
     2*EXP(BETAJ*(AMZ-AMSTAR))+AK*SPIKE*PHISTR)*ANEQ
 100  RETURN
      END
      SUBROUTINE RRISK(XNOT,YNOT,INGS,INSS,
     1 X1,Y1,X2,Y2,X3,Y3,X4,Y4)
      COMMON NRD,NWR,RSKTI(12)
      COMMON C1,C2,C3,SIG,RZERO,RONE,AAA,BBB
      COMMON NGS,NRS(23),AM0(24),AM1(24),LORS(24)
      COMMON BETA(24),RATE(24),COEF(24),FDEPTH(24)
      COMMON NSTEP0,NSTEPI
      COMMON INDIC(4),AREA(23,11)
      COMMON /MDATA/NSTEP,JPRNT,JPRNT2,JPRNT3,NLEI,TI(12),RISKS(9),
     1ATTEN(8,2,2)
      DIMENSION XL(4),YL(4),XR(4),YR(4),AA(4),BB(4)
C         SUBROUTINE WHICH LOADS TEMPORARY ARRAYS WITH THIS
C           SUBSOURCE'S CORNERS AND DETERMINES IF THIS SITE IS
C           WITHIN OR WITHOUT THE SUBSOURCE.
      XL(1)=X1
      YL(1)=Y1
      XR(1)=X2
      YR(1)=Y2
      XL(2)=X2
      YL(2)=Y2
      XR(2)=X4
      YR(2)=Y4
      XL(3)=X3
      YL(3)=Y3
      XR(3)=X1
      YR(3)=Y1
      XL(4)=X4
      YL(4)=Y4
      XR(4)=X3
      YR(4)=Y3
C        DETERMINE IF ANY SIDES ARE VERTICAL LINES
      DO 200 II=1,4
      DIF=XL(II)-XR(II)
      IF (DIF) 140,180,160
 140  IF (DIF+0.01) 190,190,180
 160  IF (DIF-0.01) 180,190,190
C        INDIC(I)=1  IMPLIES NOT A VERTICAL LINE
C        INDIC(I)=2  IMPLIES A VERTICAL LINE (INFINITE SLOPE).
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```
 180  INDIC(II)=2
      AA(II)=0.
      BB(II)=0.
      GO TO 200
 190  INDIC(II)=1
      AA(II)=(YL(II)-YR(II))/(XL(II)-XR(II))
      BB(II)=YL(II)-AA(II)*XL(II)
C          AA(II) IS SLOPE OF II'TH SIDE
C          BB(II) IS INTERCEPT OF II'TH SIDE
  200  CONTINUE
C        DETERMINE IF SITE IS INSIDE SOURCE AREA.
      DO 220 II=1,4
      IJ=5-II
      IF(INDIC(II).GE.2) GO TO 215
      DIFNOT=YNOT-AA(II)*XNOT-BB(II)
      DIF=YL(IJ)-AA(II)*XL(IJ)-BB(II)
 211  IF (DIF) 214,214,212
 212  IF (DIFNOT) 400,400,220
 214  IF (DIFNOT) 220,400,400
 215  DIF=XL(IJ)-XL(II)
      DIFNOT=XNOT-XL(II)
      GO TO 211
 220  CONTINUE
C        IF DO LOOP FINISHED, POINT LIES WITHIN AREA.
      CALL INSIDE(XNOT,YNOT,INGS,INSS,XL,YL,XR,YR,AA,BB)
      GO TO 900
 400  CALL OUTSID(XNOT,YNOT,INGS,INSS,XL,YL,XR,YR,AA,BB)
 900  RETURN
      END
      SUBROUTINE SHOUT
      COMMON /MDATA/NSTEP,JPRNT,JPRNT2,JPRNT3,NLEI,TI(12),RISKS(9),
     1ATTEN(8,2,2)
      COMMON/CNM/RNAME(6),SNAME(6),TIFS(8,2),RZ2S(23),JEW,NRG,A,B
     1,IN,JN,NRGL
      WRITE(JN,4)A,B
    4 FORMAT(//" SITE ",F7.3,"N",F9.3,"W"/)
      WRITE(JN,1)(RISKS(J),J=1,4)
    1 FORMAT(" PROB",4F10.6/)
      WRITE(JN,2)(TIFS(J,1),J=1,4)
    2 FORMAT(" ACCL",4F10.2/)
      WRITE(JN,3)(TIFS(J,2),J=1,4)
    3 FORMAT(" VELC",4F10.2//)
      RETURN$END
      SUBROUTINE SRISK
C     INTERACTIVE VERSION FOR RISK CALCULATIONS AT SPECIFIC SITES
C     DISC FILE INPUT OF ZONE DATA ON TAPE2
C     PRINTED OUTPUT ON TAPE6
C        MAINROUTINE
C     DH WEICHERT MODIFIED FOR LAT. LONG. INPUT AND CONVERSION TO EASTIN
C     AND NORTHINGS(Y) IN KM.  THIS USE OF X + Y AGREES WITH MCGUIRES"S
C     MODIFIED BY FMA TO RUN VELOCITY AND ACCERATION DATA TOGETHER
C        R K MCGUIRE   U.S.G.S. JANUARY 1975
C       PLANAR VERSION (CARTESIAN COORDINATES)
C
      COMMON NRD,NWR,RSKTI(12)
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      COMMON C1,C2,C3,SIG,RZERO,RONE,AAA,BBB
      COMMON NGS,NRS(23),AMO(24),AM1(24),LORS(24)
      COMMON BETA(24),RATE(24),COEF(24),FDEPTH(24)
      COMMON NSTEPO,NSTEPI
      COMMON INDIC(4),AREA(23,11),X(23,11,2),Y(23,11,2)
      COMMON/DEBG/SXNOT,SYNOT,ERRBND,NSTEPMX,LERR,RZ2,LERR2,RISKER
      COMMON /MDATA/NSTEP,JPRNT,JPRNT2,JPRNT3,NLEI,TI(12),RISKS(9),
     1ATTEN(8,2,2)
      COMMON/CNM/RNAME(6),SNAME(6),TIFS(8,2),RZ2S(23),JEW,NRG,SLAT,SLONG
     1,IN,JN,NRGL
      COMMON/LERRS/INCLUD,INCLD2,LNLEI,LRISKS,RKRATO
      DIMENSION BRISK(12),TIF(8)
      LOGICAL LERR,INCLUD,LERR2,INCLD2,LNLEI,LRISKS
      IF(NRG.EQ.NRGL)GO TO 1$NRGL=NRG
      REWIND NRD
C     SKIP TO APPROPRIATE FILE
      IF(NRG.LE.1) GO TO 712$NRGS=NRG-1$DO 710 I=1,NRGS
  711 READ(NRD)$IF(EOF(NRD))710,711
  710 CONTINUE
  712 READ(NRD)    NGS,(NRS(I),I=1,NGS)
      NGS1=NGS+1
      DO 110 I=1,NGS1
  110 READ(NRD)    RZ2S(I),LORS(I),COEF(I),AMO(I),AM1(I),BETA(I),RATE(I)
     1,FDEPTH(I),NAME
      DO 200 II=1,NGS
      NRSII=NRS(II)+1
      DO 150 JJ=1,NRSII
      READ(NRD)      X(II,JJ,1),Y(II,JJ,1),X(II,JJ,2),Y(II,JJ,2)
     1,NAMES
      CALL PRJC(X(II,JJ,1),Y(II,JJ,1))
      CALL PRJC(X(II,JJ,2),Y(II,JJ,2))
C     DH WEICHERT CHANGES TO EASTING(X) + NORTHING(Y) IN KM. USING LAMBE
C     CONFORMAL PROJECTION
 150  CONTINUE
  200 CONTINUE
C        CALCULATE AREA OF EACH SUBSOURCE AND GROSS SOURCE.
      DO 400 II=1,NGS
      NTOT=NRS(II)+1
      AREA(II,NTOT)=0.0
      NAZIZ = NRS(II)
      DO 300 JJ=1,NAZIZ
      CALL AREAS(X(II,JJ,1),Y(II,JJ,1),X(II,JJ,2),Y(II,JJ,2),
     1 X(II,JJ+1,1),Y(II,JJ+1,1),X(II,JJ+1,2),Y(II,JJ+1,2),AREA(II,JJ))
 300  AREA(II,NTOT)=AREA(II,NTOT)+AREA(II,JJ)
  400 CONTINUE
    1 DO 424 J=1,2
      NSTEPO=NSTEPI=NSTEP
      DO 90 I=1,NLEI
  90  BRISK(I)=0.0
      C1=ATTEN(1,J,JEW)
      C2=ATTEN(2,J,JEW)
      C3=ATTEN(3,J,JEW)
      SIG=ATTEN(4,J,JEW)
      RZERO=ATTEN(5,J,JEW)
      RONE=ATTEN(6,J,JEW)
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      AAA=ATTEN(7,J,JEW)
      BBB=ATTEN(8,J,JEW)
      IF (BBB+0.00001) 101,102,102
 101  WRITE (JN ,924)
 924  FORMAT(//" INPUT ERROR:  THE VALUE OF BBB MUST BE POSITIVE,"/
     1 " BETWEEN 0.0 AND THE VALUE OF C2. EXECUTION STOPPED.")
      RETURN
 102  IF (C2-BBB) 101,103,103
C         IF BBB=0.0, SET EQUAL TO A SMALL NUMBER
 103  IF (BBB-0.00001) 104,105,105
 104  BBB=0.0000000001
  105 CONTINUE
C         COMPUTE BACKGROUND SEISMICITY
      IF(RATE(NGS1)-0.0000000001) 420,420,405
C         RBACK IS RADIUS OUT TO WHICH RISK FROM
C           BACKGROUND SEISMICITY IS CALCULATED.
 405  RBACK=150.
C        FOR BACKGROUND SEISMICITY, NSTEPI IS DOUBLED (AND
C           THEN HALVED AFTER CALCULATIONS).
      NSTEPI=2*NSTEPI
      CALL CIRCLE(RBACK,NGS1,1.,BRISK)
      NSTEPI=NSTEPI/2
      DO 410 I=1,NLEI
 410  BRISK(I)=COEF(NGS1)*BRISK(I)/10000.
  420 YNOT=-SLONG$XNOT=SLAT
      SXNOT=XNOT
      SYNOT=YNOT
      RISKER=0.
      LERR=.FALSE.
      LERR2=.FALSE.
      DO 450 I=1,NLEI
 450  RSKTI(I)=BRISK(I)
      CALL PRJC(XNOT,YNOT)
      DO 600 II=1,NGS
      NAZIZ = NRS(II)
      RZ2=RZ2S(II)
      DO 500 JJ=1,NAZIZ
      INGS=II
      INSS=JJ
      CALL RRISK(XNOT,YNOT,INGS,INSS,X(II,JJ,1),Y(II,JJ,1),X(II,JJ,
     X2),Y(II,JJ,2),X(II,JJ+1,1),Y(II,JJ+1,1),X(II,JJ+1,2),Y(II,JJ+1,2))
 500  CONTINUE
 600  CONTINUE
      IF(.NOT.LERR2.OR.INCLD2) GO TO 11
      WRITE(JN ,10)
   10 FORMAT(/" ERROR IN SUBROUTINE INSIDE OR OUTSID"/)
      RETURN
   11 IF(.NOT.LERR.OR.INCLUD) GO TO 12
      GDRISK=RSKTI(NLEI-2)-RISKER
      IF(GDRISK.LE.0.) GO TO 13
      RISKRR=RISKER/GDRISK
      IF(RISKRR.LT.RKRATO) GO TO 12
   13 WRITE(JN ,15)       ERRBND,RISKRR,RKRATO
   15 FORMAT(/" ERROR IN AREA CALCULATION GREATER THAN ",F6.1," &"/
     1" AND RATIO OF ERROR RISK CALC TO NON ERROR RISK CALC=",F6.2/
```

```
     2" GREATER THAN ",F5.2/)
      RETURN
   12 CONTINUE
      DO 620 I=1,NLEI
 620  RSKTI(I)=1.-EXP(-RSKTI(I))
C         ESTIMATE INTENSITIES AT RISKS DESIRED.
      RISKS(9)=0.0
      IA=0
      IF(RISKS(1)-0.0000000001) 700,700,625
 625  DO 630 IRK=1,8
      IF (RISKS(IRK)-RSKTI(1)) 640,640,630
 630  TIF(IRK)=1000000.
      GO TO 700
 640  IA=IA+1
      IF (IA-NLEI) 650,645,645
 645  TIF(IRK)=1000000.
      IRK=IRK+1
      IF (RISKS(IRK)-0.0000000001)680,680,645
 650  IF(RISKS(IRK)-RSKTI(IA+1))640,655,655
  655 CONTINUE
      TIF(IRK)=(ALOG(RSKTI(IA)/RISKS(IRK)))
     1  /(ALOG(RSKTI(IA)/RSKTI(IA+1)))
      TIF(IRK)=TI(IA)+TIF(IRK)*(TI(IA+1)-TI(IA))
      IRK=IRK+1
      IF (RISKS(IRK)-0.0000000001)680,680,660
 660  IF(RISKS(IRK)-RSKTI(IA+1)) 640,655,655
 680  IRK=IRK-1
      DO 685 I=1,IRK
      IF (TIF(I)-999999.)683,685,685
 683  TIF(I)=EXP(TIF(I))
 685  CONTINUE
  700 DO 722 I=1,IRK
  722 TIFS(I,J)=TIF(I)
  424 CONTINUE
      RETURN$END
```

# APPENDIX C

## Revised Parameters for Eastern Canadian and some Northeastern U.S. Earthquakes

For the preparation of the earthquake source models of eastern Canada by Basham et al. (1979), a review was made of most of the pre-1968 earthquakes in the region that had previously catalogued magnitudes of 4 or greater. Revised parameters with magnitudes quoted to the nearest half-magnitude category were listed in their Table 1. It is the purpose of this appendix to document the reasons for the changes that were made, particularly in magnitude, so that corresponding changes can be made to the master Canadian Earthquake Epicentre File (CEEF) maintained by the Earth Physics Branch.

The review of information available for most of the earthquakes was not exhautive and in many, if not most, of the cases a further review would be justified to either confirm or adjust the revised parameters. However, the changes that have been made are considered a significant improvement on previously catalogued data for the purposes, in both Basham et al. (1979) and this report, of estimating magnitude recurrence relations for eastern Canadian earthquake source zones.

The two general categories of review were the following. During the first preparation of the CEEF the magnitudes of most of the historical earthquakes were based on Smith's (1962, 1966) epicentral intensities. Comprehensive review of macroseismic information for a number of earthquakes has shown that many of Smith's epicentral intensities were based on exaggerated effects or were not representative of the epicentral region. For the additional earthquakes treated here, this information has been reviewed and revisions made to magnitude if a change of at least one-half unit is appropriate. For many of the smaller earthquakes the original sources of information have not been reviewed; the revisions are based solely on Smith's summary description.

For many earthquakes in the time period 1935 to 1967, the original amplitude data, used to compute $M_L$ which appears in the catalogues and on the CEEF, was available. These data have been used directly to compute $m_b$(Lg) and magnitude has been revised if a change of at least one magnitude category is appropriate. The original seismograms were not used to check the original amplitude data.

Basham et al. (1979; their Table 1) listed earthquakes with magnitude categories (i.e., to the nearest half unit) of 4 or greater. Thus, earthquakes with revisions that resulted in magnitude categories less than 4 did not appear in that list. All such revisions are included in the following table. In those cases for which the revised magnitude is a recomputed $m_b$(Lg), the magnitude is quoted to the nearest tenth of a unit (although it should not be considered this accurate) and the remark is a simple statement "$m_b$(Lg) from n stations." It should be noted that many of the earthquakes in the following table do not appear in Appendix A, the individual source zone lists, because they do not pass the completeness test used for magnitude recurrence calculations.

In the following table the first entry for each earthquake gives the parameters currently on the CEEF, the second entry the revision. This is followed by a brief explanation for the change.

| No. | Year | M | D | H | M | Lat.(°N) | Long.(°W) | Mag. |
|---|---|---|---|---|---|---|---|---|
| 1. | 1663 | 02 | 05 | 17 | 30 | 47.6 | 70.1 | 7.7<br>7.0 |

For this earthquake and three later earthquakes in the Charlevoix zone described below (Nos. 3, 10 and 13), revised magnitude estimates are made on the basis of comparison of intensity information with the well-defined intensity and iososeismal data available for the 1925, M7 earthquake. For this event the intensity effects in the distance range 100-1000 km (i.e., ignoring the near-in landslide phenomena that are not a good indication of earthquake size) are very similar to those of 1925, with only a slight tendency to larger intensities. Therefore the earthquake has been assigned M7.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 2. | 1665 | 02 | 24 | | | 47.8 | 70.0 | 6.4<br>5.5 |

The Smith (1962) epicentral intensity, from which magnitude 6.4 was derived, is considered to be an over-estimate. Reports of low intensities in New England suggest a magnitude of 5.5 or smaller.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 3. | 1791 | 12 | 06 | 20 | | 47.4 | 70.5 | 6.3<br>6.0 |

A comparison of the well-defined intensities for this earthquake with those of 1925 suggests that it is approximately one magnitude unit smaller; it has therefore been assigned M6.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 4. | 1817 | 05 | 22 | 20 | | 46.0 | 69.0 | 5.7<br>5.0 |

The evidence for Smith's (1962) epicentral intensity is poor. The felt area, which translates to M5, is considered to provide a better estimate of magnitude.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 5. | 1831 | 07 | 14 | | | 47.6 | 70.1 | 5.7<br>5.0 |

Very little intensity information is available. The magnitude is reduced to 5 on the assumption that Smith's (1962) epicentral intensity represents the results of poor construction and not general effects in the epicentral region.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 6. | 1840 | 09 | 10 | | | 43.2 | 79.9 | 4.4<br>4.0 |

Described as "a violent shock" at Hamilton, this earthquake is most likely a shallow event of M4 or smaller, similar to such events in more recent years.

| No. | Year | M | D | H | M | Lat.(°N) | Long.(°W) | Mag. |
|---|---|---|---|---|---|---|---|---|
| 7. | 1853 | 03 | 12 | 07 |  | 43.7 | 75.5 | 5.0<br>4.5 |

Felt area not extensive and more consistent with M4.5.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 8. | 1853 | 03 | 13 | 10 |  | 43.1 | 79.4 | 4.4<br>4.0 |

Felt area more consistent with M4.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 9. | 1857 | 12 | 23 |  |  | 44.1 | 70.2 | 5.7<br>4.5 |

No evidence for high epicentral intensity or extensive felt area.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 10. | 1860 | 10 | 17 | 11 | 15 | 47.5 | 70.1 | 6.7<br>6.0 |

A comparison of the well-defined intensities of this earthquake with those of 1925 suggests that it is approximately one magnitude unit smaller; it has therefore been assigned M6.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 11. | 1861 | 07 | 12 |  |  | 45.4 | 75.4 | 5.7<br>5.0 |

Felt area (Montreal, Ottawa, Odgensburg) suggests M5 or smaller; chimney damage at Ottawa not considered representative of high epicentral intensity.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 12. | 1869 | 12 |  |  |  | 47.5 | 70.5 | 4.4<br>4.0 |

Felt information appropriate to M4 or smaller.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 13. | 1870 | 10 | 20 | 16 | 30 | 47.4 | 70.5 | 7.0<br>6.5 |

A comparison of the well-defined intensities of this earthquake with those of 1925 suggests that it is approximately one-half magnitude unit smaller; it has therefore been assigned M6.5

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 14. | 1871 | 01 | 09 |  |  | 47.5 | 70.1 | 4.4<br>4.0 |

Felt information consistent with M4 or smaller.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 15. | 1872 | 01 | 09 |  |  | 47.5 | 70.5 | 5.7<br>5.0 |

Felt area, suggesting M5, is considered more representative than Smith's (1962) epicentral intensity.

<table>
<tr><th>No.</th><th>Year</th><th>M</th><th>D</th><th>H</th><th>M</th><th>Lat.(°N)</th><th>Long.(°W)</th><th>Mag.</th></tr>
<tr><td>16.</td><td>1873</td><td>07</td><td>06</td><td>14</td><td>30</td><td>43.0</td><td>79.5</td><td>5.0<br>4.5</td></tr>
<tr><td></td><td colspan="8">Felt area consistent with M4.5 or smaller.</td></tr>
<tr><td>17.</td><td>1874</td><td>02</td><td>27</td><td></td><td></td><td>44.8</td><td>68.7</td><td>4.4<br>4.0</td></tr>
<tr><td></td><td colspan="8">Felt area consistent with M4 or smaller.</td></tr>
<tr><td>18.</td><td>1887</td><td>05</td><td>27</td><td>06</td><td>15</td><td>47.5</td><td>70.5</td><td>4.3<br>4.0</td></tr>
<tr><td></td><td colspan="8">Felt area consistent with M4 or smaller.</td></tr>
<tr><td>19.</td><td>1896</td><td>03</td><td>22</td><td></td><td></td><td>45.2</td><td>67.2</td><td>4.4<br>4.0</td></tr>
<tr><td></td><td colspan="8">Felt area consistent with M4.</td></tr>
<tr><td>20.</td><td>1897</td><td>03</td><td>23</td><td></td><td></td><td>45.5</td><td>73.6</td><td>5.7<br>5.0</td></tr>
<tr><td></td><td colspan="8">No evidence for high epicentral intensity. Felt area suggests much smaller event; M5 adopted as a compromise.</td></tr>
<tr><td>21.</td><td>1897</td><td>05</td><td>27</td><td></td><td></td><td>44.5</td><td>73.5</td><td>5.0<br>4.5</td></tr>
<tr><td></td><td colspan="8">Felt area quoted by Smith (1962) (150,000 mi$^2$) is not consistent with "felt from Montreal to Burlington, Vt.", which suggests M4.5 or smaller.</td></tr>
<tr><td>22.</td><td>1906</td><td>06</td><td>27</td><td></td><td></td><td>41.4</td><td>81.6</td><td>4.4<br>4.0</td></tr>
<tr><td></td><td colspan="8">No evidence for M larger than 4.</td></tr>
<tr><td>23.</td><td>1906</td><td>10</td><td>20</td><td></td><td></td><td>43.8</td><td>68.8</td><td>4.4<br>4.0</td></tr>
<tr><td></td><td colspan="8">No evidence for M larger than 4.</td></tr>
<tr><td>24.</td><td>1908</td><td>05</td><td>14</td><td>04</td><td>45</td><td>44.0</td><td>65.8</td><td>4.3<br>4.0</td></tr>
<tr><td></td><td colspan="8">Felt area consistent with M4.</td></tr>
<tr><td>25.</td><td>1909</td><td>12</td><td>19</td><td>20</td><td></td><td>46.5</td><td>60.5</td><td>5.0<br>4.0</td></tr>
<tr><td></td><td colspan="8">There is little evidence to support Smith's (1962) epicentral intensity. The felt area, "throughout Cape Breton", is more consistent with M4.</td></tr>
</table>

| No. | Year | M | D | H | M | Lat.(°N) | Long.(°W) | Mag. |
|---|---|---|---|---|---|---|---|---|
| 26. | 1910 | 01 | 23 | 01 | 30 | 43.8 | 70.4 | 3.7<br>4.0 |

Report of "articles thrown from shelves" suggests magnitude greater than 3.7

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 27. | 1910 | 10 | 25 | 09 | 30 | 47.6 | 69.8 | 4.3<br>4.0 |

Felt area consistent with M4.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 28. | 1912 | 12 | 11 | 10 | 15 | 45.0 | 68.0 | 3.7<br>4.0 |

Felt area suggests magnitude 4.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 29. | 1914 | 02 | 10 | 18 | 31 | 45.0<br>46.0 | 76.9<br>75.0 | 5.5 |

Klotz (1915) determined that this earthquake was felt over an area of 500,000 km$^2$, which is compatible with the magnitude ($M_L$) calculated by Smith (1962) from Ottawa data. Klotz chose an epicentre northeast of Ottawa, his paper implying that the Ottawa seismograms unambiguously indicated a northeast direction. Smith determined an epicentre southwest of Ottawa using recorded arrival times at Ottawa, Harvard and Ithaca. He did not use the Toronto arrival time which, in combination with Ottawa and Harvard, supports an epicentre northeast of Ottawa. The Ithaca arrival times are apparently no longer available (A.E. Stevens, unpublished notes, 1976). The revision is an epicentre northeast of Ottawa, which places this earthquake in the region north of the Ottawa River that has been most active in recent years, rather than in an essentially aseismic region of eastern Ontario. The revised epcientre must be considered to have a large uncertainty.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 30. | 1914 | 02 | 22 | 19 | 15 | 45.0 | 70.5 | 4.4<br>4.0 |

Felt area consistent with M4.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 31. | 1915 | 07 | 27 | 16 | 30 | 44.0 | 65.0 | 4.3<br>4.0 |

Felt information consistent with M4 or smaller.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 32. | 1916 | 01 | 05 | 13 | 56 | 43.7 | 73.7 | 4.4<br>4.0 |

Felt area consistent with M4 or smaller.

<table>
<tr><th>No.</th><th>Year</th><th>M</th><th>D</th><th>H</th><th>M</th><th>Lat.(°N)</th><th>Long.(°W)</th><th>Mag.</th></tr>
<tr><td>33.</td><td>1916</td><td>04</td><td>24</td><td>16</td><td>07</td><td>47.0</td><td>77.0</td><td>4.3<br>4.0</td></tr>
<tr><td></td><td colspan="8">Recorded by Ottawa seismograph but not instrumentally located and not reported felt. M reduced to 4 to give this earthquake less weight because of epicentral uncertainty.</td></tr>
<tr><td>34.</td><td>1917</td><td>06</td><td>12</td><td>02</td><td>00</td><td>49.0</td><td>68.0</td><td>4.3<br>4.0</td></tr>
<tr><td></td><td colspan="8">Felt area more consistent with M4.</td></tr>
<tr><td>35.</td><td>1918</td><td>08</td><td>21</td><td>04</td><td>20</td><td>44.2</td><td>70.6</td><td>5.7<br>4.5</td></tr>
<tr><td></td><td colspan="8">Felt area suggests M4.5 or lower. "Damaged chimneys" not sufficient for Smith's (1962) epicentral intensity.</td></tr>
<tr><td>36.</td><td>1925</td><td>03</td><td>07</td><td>02</td><td>30</td><td>47.8</td><td>69.8</td><td>4.4<br>4.0</td></tr>
<tr><td></td><td colspan="8">Felt area consistent with M4.</td></tr>
<tr><td>37.</td><td>1925</td><td>10</td><td>09</td><td>14</td><td>00</td><td>43.7</td><td>71.1</td><td>4.3<br>4.0</td></tr>
<tr><td></td><td colspan="8">Felt area consistent with M4.</td></tr>
<tr><td>38.</td><td>1926</td><td>08</td><td>28</td><td>21</td><td>30</td><td>44.7</td><td>70.0</td><td>4.4<br>4.0</td></tr>
<tr><td></td><td colspan="8">Felt area consistent with M4.</td></tr>
<tr><td>39.</td><td>1927</td><td>07</td><td>25</td><td>00</td><td>56</td><td>47.3</td><td>71.0</td><td>4.3<br>4.0</td></tr>
<tr><td></td><td colspan="8">Felt area consistent with M4.</td></tr>
<tr><td>40.</td><td>1928</td><td>02</td><td>08</td><td></td><td></td><td>45.3</td><td>69.0</td><td>5.0<br>4.5</td></tr>
<tr><td></td><td colspan="8">No evidence to suggest M greater than 4.5.</td></tr>
<tr><td>41.</td><td>1928</td><td>04</td><td>25</td><td>23</td><td>38</td><td>44.5</td><td>71.2</td><td>4.3<br>4.0</td></tr>
<tr><td></td><td colspan="8">No evidence to suggest magnitude greater than 4.</td></tr>
</table>

| No. | Year | M | D | H | M | Lat.(°N) | Long.(°W) | Mag. |
|---|---|---|---|---|---|---|---|---|
| 42. | 1929 | 08 | 12 | 11 | 24 | 42.9 | 78.4 | 5.8<br>5.5 |

The original magnitude by Smith (1966) was $M_L$. The felt area suggests a magnitude of about 5. Street and Trucotte (1977) derived $m_b$(Lg) 5.2. We have adopted M5.5 and leave more definitive work to our U.S. colleagues.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 43. | 1931 | 04 | 20 | 19 | 54 | 43.4 | 73.7 | 5.0<br>4.5 |

$M_L$5.0 was determined from one station and is reduced by one-half magnitude unit assuming similarity with recomputations of $m_b$(Lg) described below.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 44. | 1934 | 10 | 29 | 20 | 07 | 42.2 | 80.2 | 4.3<br>4.0 |

There is no evidence for Smith's (1966) high epicentral intensity (V).

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 45. | 1935 | 11 | 01 | 17 | 02 | 46.8 | 79.1 | 4.6<br>4.1 |

$m_b$(Lg) from 1 station.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 46. | 1935 | 11 | 02 | 00 | 42 | 46.8 | 79.1 | 4.7<br>4.2 |

$m_b$(LG) from 1 station.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 47. | 1935 | 11 | 02 | 14 | 31 | 47.2 | 78.2 | 5.4<br>4.9 |

$m_b$(Lg) from 1 station.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 48. | 1935 | 11 | 05 | 10 | 10 | 46.8 | 79.1 | 4.5<br>3.9 |

$m_b$(Lg) from 1 station.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 49. | 1935 | 11 | 25 | 06 | 19 | 46.8 | 79.1 | 4.7<br>4.1 |

$m_b$(Lg) from 1 station.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 50. | 1935 | 11 | 27 | 19 | 31 | 46.8 | 79.1 | 4.6<br>4.1 |

$m_b$(Lg) from 1 station.

| No. | Year | M | D | H | M | Lat.(°N) | Long.(°W) | Mag. |
|---|---|---|---|---|---|---|---|---|
| 51. | 1936 | 01 | 20 | 06 | 01 | 46.8 | 79.1 | 4.5<br>3.8 |
| | $m_b(Lg)$ from 1 station. | | | | | | | |
| 52. | 1936 | 03 | 25 | 01 | 27 | 46.8 | 79.1 | 4.6<br>4.0 |
| | $m_b(Lg)$ from 1 station. | | | | | | | |
| 53. | 1938 | 05 | 17 | 18 | 32 | 49.0 | 68.0 | 4.6<br>3.9 |
| | $m_b(Lg)$ from 1 station. | | | | | | | |
| 54. | 1939 | 06 | 24 | 17 | 20 | 47.3 | 70.4 | 4.8<br>4.5 |
| | Felt area consistent with M4.5. $m_b(Lg)$ from 1 station is 4.4. | | | | | | | |
| 55. | 1939 | 10 | 19 | 11 | 53 | 47.8 | 69.8 | 5.8<br>5.6 |
| | The original magnitude is $M_L$ at 1 station. Felt area gives a lower limit of M5.5. Street and Turcotte (1977) calculated $m_b(Lg)$ 5.6, which is accepted. | | | | | | | |
| 56. | 1939 | 10 | 27 | 01 | 36 | 47.8 | 69.8 | 5.2<br>4.5 |
| | $m_b(Lg)$ from 1 station is 4.8. Intensity information is sparce. Basham et al. (1979) assigned M4.5 as more representative of an aftershock of the 19 October, M5.8 mainshock. | | | | | | | |
| 57. | 1939 | 11 | 07 | 02 | 40 | 47.8 | 70.5 | 4.3<br>4.1 |
| | $m_b(Lg)$ from 1 station. | | | | | | | |
| 58. | 1940 | 12 | 20 | 07 | 27 | 43.8 | 71.3 | 5.8<br>5.0 |
| 59. | 1940 | 12 | 24 | 13 | 43 | 43.8 | 71.3 | 5.8<br>5.0 |
| | Felt areas for these two events are consistent with M5. More definitive reassessments that may be available from U.S. studies have not been searched. | | | | | | | |

| No. | Year | M | D | H | M | Lat.(°N) | Long.(°W) | Mag. |
|---|---|---|---|---|---|---|---|---|
| 60. | 1942 | 08 | 26 | 17 | 54 | 46.8 | 77.5 | 4.1<br>3.7 |

$m_b$(Lg) from 1 station.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 61. | 1942 | 09 | 11 | 11 | 05 | 49.2 | 67.4 | 4.4<br>3.7 |

$m_b$(Lg) from 1 station.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 62. | 1943 | 01 | 14 | 21 | 32 | 45.3 | 69.6 | 5.4<br>5.0 |

$M_L$ reduced by one-half magnitude unit. Intensity data have not been reassessed.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 63. | 1944 | 04 | 09 | 12 | 44 | 49.9 | 67.4 | 5.4<br>4.9 |

$m_b$(Lg) from 2 stations.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 64. | 1944 | 09 | 05 | 04 | 38 | 45.0 | 74.9 | 5.9<br>5.6 |

The original magnitude was from Gutenberg and Richter (1954) class "d" (5.3 to 5.9) from which Smith (1966) selected the maximum in the range, 5.9, believing that data were available suggesting at least this magnitude. The number of stations reporting this earthquake in the International Seismological Summary suggests a magnitude less than 5.9. Examination of epicentral effects, with due consideration to design and construction techniques and to soil conditions suggests an epicentral intensity of VII, corresponding to magnitude 5.7. Consideration of seismograph data available from Canadian stations suggests $m_b$ in the range 5.4 to 5.7 and $M_L$ 5.6 ± 0.3; the latter is adopted here. (From A.E. Stevens, unpublished notes, 1976; more details available on request.) Street and Turcotte (1977) subsequently determined $m_b$(Lg) 5.8.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 65. | 1944 | 11 | 05 | 19 | 07 | 48.7 | 80.8 | 5.1<br>4.4 |

$m_b$(Lg) from 3 stations.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 66. | 1945 | 10 | 09 | 13 | 18 | 47.8 | 69.8 | 4.9<br>4.7 |

Smith's (1966) $M_L$ magnitude was determined from 3 stations, one of which (Ottawa) was at large distance. An average $M_L$ from the nearest two stations is 4.7.

| No. | Year | M | D | H | M | Lat.(°N) | Long.(°W) | Mag. |
|---|---|---|---|---|---|---|---|---|
| 67. | 1947 | 08 | 08 | 05 | 39 | 46.5 | 81.1 | 4.4<br>3.7 |
| | $m_b$(Lg) from 1 station. | | | | | | | |
| 68. | 1947 | 08 | 10 | 02 | 46 | 41.9 | 84.5 | 4.8<br>4.5 |
| | Felt area consistent with M4.5, rather than M4 assigned by Basham et al. (1979). | | | | | | | |
| 69. | 1947 | 09 | 14 | 19 | 29 | 47.0 | 81.3 | 4.3<br>3.7 |
| | $m_b$(Lg) from 2 stations. | | | | | | | |
| 70. | 1947 | 11 | 03 | 19 | 51 | 45.7 | 81.2 | 4.5<br>3.8 |
| | $m_b$(Lg) from 1 station. | | | | | | | |
| 71. | 1947 | 12 | 28 | 19 | 58 | 45.3 | 69.3 | 4.5<br>4.1 |
| | $m_b$(Lg) from 1 station. | | | | | | | |
| 72. | 1948 | 01 | 01 | 18 | 33 | 47.3 | 70.4 | 4.9<br>4.5 |
| | $M_L$ reduced by one-half magnitude unit. Felt area more consistent with M4.5. | | | | | | | |
| 73. | 1948 | 01 | 16 | 06 | 02 | 50.0 | 69.0 | 4.3<br>3.7 |
| | $m_b$(Lg) from 1 station. | | | | | | | |
| 74. | 1950 | 06 | 29 | 09 | 13 | 49.9 | 68.1 | 4.8<br>4.3 |
| | $m_b$(Lg) from 2 stations. | | | | | | | |
| 75. | 1951 | 06 | 28 | 01 | 03 | 50.0 | 67.5 | 4.8<br>4.2 |
| | $m_b$(Lg) from 2 stations. | | | | | | | |
| 76. | 1951 | 09 | 19 | 08 | 19 | 49.3 | 66.3 | 5.1<br>4.3 |
| | $m_b$(Lg) from 3 stations. | | | | | | | |

| No. | Year | M | D | H | M | Lat.(°N) | Long.(°W) | Mag. |
|---|---|---|---|---|---|---|---|---|
| 77. | 1952 | 01 | 30 | 04 | 00 | 44.5 | 73.2 | 5.0<br>4.5 |
| | Felt only locally, suggesting M4.5 or smaller. | | | | | | | |
| 78. | 1952 | 03 | 30 | 13 | 11 | 47.6 | 69.9 | 4.4<br>4.1 |
| | $m_b$(Lg) from 2 stations. | | | | | | | |
| 79. | 1952 | 08 | 25 | 00 | 07 | 43.0 | 74.5 | 4.3<br>4.0 |
| | No evidence from felt information of M greater than 4. | | | | | | | |
| 80. | 1952 | 10 | 14 | 22 | 03 | 47.8 | 69.8 | 5.6<br>5.2 |
| | $M_L$ from nearest station considered more representative. | | | | | | | |
| 81. | 1953 | 01 | 24 | 09 | 58 | 49.1 | 66.0 | 5.3<br>4.6 |
| | $m_b$(Lg) from 4 stations. | | | | | | | |
| 82. | 1953 | 09 | 14 | 22 | 52 | 49.1 | 65.2 | 5.1<br>4.4 |
| | $m_b$(Lg) from 3 stations. | | | | | | | |
| 83. | 1954 | 01 | 10 | 21 | 04 | 49.2 | 68.2 | 3.9<br>3.1 |
| | $m_b$(Lg) from 1 station | | | | | | | |
| 84. | 1954 | 09 | 08 | 01 | 29 | 49.0 | 68.4 | 4.3<br>3.6 |
| | $m_b$(Lg) from 1 station. | | | | | | | |
| 85. | 1955 | 01 | 21 | 08 | 40 | 43.0 | 73.8 | 4.3<br>4.0 |
| | No evidence from felt information of M greater than 4. | | | | | | | |
| 86. | 1955 | 02 | 03 | 02 | 30 | 44.5 | 73.2 | 4.3<br>4.0 |
| | No evidence from felt information of M greater than 4. | | | | | | | |

| No. | Year | M | D | H | M | Lat.(°N) | Long.(°W) | Mag. |
|---|---|---|---|---|---|---|---|---|
| 87. | 1955 | 05 | 26 | 18 | 09 | 41.5 | 81.7 | 4.3<br>4.0 |
| | Felt only locally. | | | | | | | |
| 88. | 1955 | 08 | 16 | 07 | 35 | 42.9 | 78.3 | 4.3<br>4.0 |
| | Felt only locally. | | | | | | | |
| 89. | 1955 | 11 | 21 | 16 | 10 | 50.6 | 63.5 | 4.9<br>4.0 |
| | $m_b$(Lg) from 5 stations. | | | | | | | |
| 90. | 1956 | 08 | 03 | 12 | 51 | 49.4 | 66.2 | 4.1<br>3.5 |
| | $m_b$(Lg) from 4 stations. | | | | | | | |
| 91. | 1956 | 08 | 03 | 12 | 59 | 49.4 | 66.2 | 4.3<br>3.6 |
| | $m_b$(Lg) from 4 stations. | | | | | | | |
| 92. | 1957 | 04 | 24 | 00 | 41 | 44.4 | 72.0 | 4.3<br>4.0 |
| | Felt area consistent with M4 or smaller. | | | | | | | |
| 93. | 1957 | 04 | 26 | 11 | 40 | 43.6 | 69.8 | 4.7<br>4.1 |
| | $m_b$(Lg) from 1 station. | | | | | | | |
| 94. | 1957 | 10 | 16 | 19 | 13 | 50.5 | 64.9 | 4.8<br>4.1 |
| | $m_b$(Lg) from 6 stations. | | | | | | | |
| 95. | 1958 | 05 | 14 | 17 | 41 | 47.0 | 76.6 | 5.4<br>5.0 |
| | Felt area consistent with M5 or smaller. | | | | | | | |
| 96. | 1958 | 08 | 08 | 22 | 15 | 47.9 | 70.4 | 4.0<br>3.6 |
| | $m_b$(Lg) from 1 station. | | | | | | | |

| No. | Year | M | D | H | M | Lat.(°N) | Long.(°W) | Mag. |
|---|---|---|---|---|---|---|---|---|
| 97. | 1958 | 09 | 19 | 12 | 45 | 43.5 | 70.2 | 4.3<br>4.0 |
| | No evidence from felt information for M greater than 4. | | | | | | | |
| 98. | 1961 | 07 | 05 | 22 | 43 | 50.3 | 66.7 | 5.0<br>4.3 |
| | $m_b$(Lg) from 5 stations. | | | | | | | |
| 99. | 1962 | 01 | 27 | 12 | 11 | 45.9 | 74.9 | 4.3<br>3.8 |
| | $m_b$(Lg) from 1 station. | | | | | | | |
| 100. | 1962 | 04 | 10 | 14 | 30 | 44.2 | 73.1 | 5.0<br>4.3 |
| | $m_b$(Lg) from 3 stations. | | | | | | | |
| 101. | 1962 | 07 | 27 | 17 | 56 | 47.2 | 70.7 | 4.3<br>3.9 |
| | $m_b$(Lg) from 2 stations. | | | | | | | |
| 102. | 1962 | 08 | 11 | 03 | 05 | 47.5 | 70.1 | 4.1<br>3.6 |
| | $m_b$(Lg) from 2 stations. | | | | | | | |
| 103. | 1962 | 12 | 15 | 00 | 58 | 50.2 | 66.4 | 4.6<br>4.0 |
| | $m_b$(Lg) from 1 station. | | | | | | | |
| 104. | 1963 | 10 | 15 | 12 | 29 | 46.2 | 77.6 | 4.4<br>4.1 |
| | $m_b$(Lg) from 2 stations. | | | | | | | |
| 105. | 1963 | 10 | 15 | 13 | 59 | 46.2 | 77.6 | 4.5<br>4.2 |
| | $m_b$(Lg) from 2 stations. | | | | | | | |
| 106. | 1965 | 10 | 05 | 14 | 36 | 49.8 | 67.7 | 4.6<br>3.9 |
| | $m_b$(Lg) from 5 stations. | | | | | | | |

| No. | Year | M | D | H | M | Lat.(°N) | Long.(°W) | Mag. |
|---|---|---|---|---|---|---|---|---|
| 107. | 1965 | 11 | 07 | 20 | 57 | 47.1 | 76.1 | 4.5<br>4.2 |
|  | $m_b$(Lg) from 4 stations. |  |  |  |  |  |  |  |
| 108. | 1965 | 11 | 28 | 23 | 26 | 45.6 | 57.9 | 4.2<br>3.6 |
|  | $m_b$(Lg) from 2 stations. |  |  |  |  |  |  |  |
| 109. | 1966 | 01 | 14 | 15 | 29 | 48.9 | 67.5 | 4.5<br>3.9 |
|  | $m_b$(Lg) from 6 stations. |  |  |  |  |  |  |  |
| 110. | 1967 | 02 | 22 | 14 | 21 | 50.5 | 63.3 | 4.2<br>3.5 |
|  | $m_b$(Lg) from 6 stations. |  |  |  |  |  |  |  |
| 111. | 1967 | 06 | 13 | 19 | 08 | 42.9 | 78.2 | 3.9<br>4.5 |
|  | $m_b$(Lg) from 5 stations. |  |  |  |  |  |  |  |
| 112. | 1967 | 01 | 17 | 01 | 19 | 50.7 | 75.3 | 4.4<br>4.0 |
|  | $m_b$(Lg) from 6 stations. |  |  |  |  |  |  |  |
| 113. | 1967 | 09 | 30 | 22 | 39 | 49.5 | 65.8 | 4.2<br>4.7 |
|  | $m_b$(Lg) from 6 stations. |  |  |  |  |  |  |  |