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Technical Report C84-01
June 1984

**STUDY OF MAGNITUDES, SEISMICITY
AND EARTHQUAKE DETECTABILITY USING
A GLOBAL NETWORK**

Frode Ringdal

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Study of magnitudes, seismicity and earthquake detectability using a global network.

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Summary

Based on 10 years of observations reported in the ISC bulletins (1971-1980), m_b magnitudes for about 70000 earthquakes have been recomputed using a maximum-likelihood estimation technique. Reportings from a network of 115 globally distributed stations were used in these calculations. Comparison to conventional m_b estimates show that the network magnitude bias problem is quite significant at low and intermediate magnitudes. Recurrence statistics based on the revised m_b estimates give b-values consistent with those obtained from LASA and NORSAR data, and indicate that the number of earthquakes worldwide of $m_b \geq 4.0$ averages about 7500 annually. The teleseismic detection capability of the network (requiring at least four detecting stations) has been estimated based on recurrence statistics. The estimated 90 per cent incremental m_b threshold ranges from 3.9-4.5 in the northern hemisphere, and from 4.2-4.8 in the southern hemisphere. This is consistent with results obtained by the 'Networth' approach.

$m_{sub} b \geq 0.7$

1. Introduction

The problem of bias in magnitudes estimated by a network of stations has been addressed in a number of investigations, e.g. Husebye *et. al.* (1974), Ringdal (1976), Evernden and Kohler (1976), Chinnery (1978), Christoffersson (1980), Elvers (1980) and Clark (1983). Most of these studies have concluded that the bias problem is indeed significant, especially at low magnitudes. The maximum-likelihood estimation technique described by Ringdal (1976) and Christoffersson (1980) has been shown to reduce the bias significantly. In this paper, this method is adapted to a global network of the type reporting to the International Seismological Centre (ISC), and is applied to 10 years of ISC data (1971-1980). The revised magnitudes thus obtained are compared to those obtained through conventional estimation techniques, and are also used to develop seismicity recurrence relations and to estimate network detection capability.

2. Method

The basic model used in this paper has previously been described in detail by Ringdal (1976) and Christoffersson (1980). For a seismic network of N stations, let g_i ($i=1,2,\dots,N$) denote the P-wave detection threshold in terms of $\log(A/T)$ of the i 'th station. Furthermore, for a set of M seismic events of unknown "true" body wave magnitudes μ_j ($j=1,2,\dots,M$), let y_{ij} denote the P-wave signal level in terms of $\log(A/T)$ at the i 'th station for the j 'th event. Here, as

customary, A/T denotes zero-to-peak amplitude (nanometers) divided by signal period (seconds).

We assume that g_i and y_{ij} can be considered as sampled from normal (Gaussian) distributions as follows:

$$g_i \sim N(G_i, \gamma_i^2) \quad (1)$$

$$y_{ij} \sim N(\mu_j - Q_{ij} + B_i, \sigma_i^2) \quad (2)$$

Here:

G_i is the average station detection threshold in terms of $\log(A/T)$,
 Q_{ij} is the Gutenberg-Richter (1956) distance-depth correction factor,
 B_i is the average station magnitude bias,
 γ_i and σ_i are standard deviations within the distributions.

For the j 'th event, we will for the purpose of magnitude estimation consider only the subset of stations within the distance range 21-100 degrees. This is in accordance with procedures employed by the ISC. Based on actual ISC reportings, the stations are then further classified into three groups:

A_j : Stations reporting a P-detection with an associated $\log(A/T)$ value (y_{ij}),
 B_j : Stations reporting a P-detection with no associated $\log(A/T)$,
 C_j : Stations not reporting a P-detection for the event.

For group C_j , the reasons for not reporting at all could be either that the signal was too weak to be detected, or that the station was inoperative at the particular time. Since we do not have access to the station operations records, it is necessary to treat this problem statistically, as was also done by Ringdal *et al.* (1977). Thus, we will denote by P_{ij} the probability that the i 'th station was inoperative for the j 'th event, given nondetection at that station.

Using a procedure similar to that described by Ringdal (1976), we can now derive a likelihood function $L(\mu_j)$ corresponding to the actually observed pattern of detections, nondetections and reported $\log(A/T)$ values for the j 'th event, given that its true magnitude is μ_j :

$$L(\mu_j) = \prod_{i \in A_j} f_{ij}(\mu_j) \prod_{i \in B_j} h_{ij}(\mu_j) \prod_{i \in C_j} [1 - P_{ij}] [1 - h_{ij}(\mu_j)] \quad (3)$$

where

$$f_{ij}(\mu_j) = \frac{1}{\sigma_i} \varphi\left(\frac{\mu_j - (y_{ij} + Q_{ij} - B_i)}{\sigma_i}\right) \quad (4)$$

$$h_{ij}(\mu_j) = \Phi\left(\frac{\mu_j - (G_i + Q_{ij} - B_i)}{\sqrt{\sigma_i^2 + \gamma_i^2}}\right) \quad (5)$$

Here, φ and Φ denote the standard normal probability density and cumulative distribution functions, respectively.

The maximum likelihood estimate of the event magnitude μ_j is obtained through numerically maximizing the likelihood function (3). However, before applying this procedure it is necessary to estimate the station parameters $G_i, B_i, \sigma_i, \gamma_i$ as well as the probability P_{ij} .

Estimates of G_i and γ_i for each station can be obtained through the procedure developed by Kelly and Lacoss (1969). The parameters B_i and σ_i will be estimated using the procedure of North (1977).

In order to estimate the probabilities P_{ij} , it is necessary to introduce some simplifying assumptions. Thus, we will assume that the *a priori* probability of any station being inoperative is a constant value P . Furthermore, for the j 'th event, we will assume that all nondetecting stations have the same probability of being inoperative, i.e. $P_{ij}=P_j$. Let us for the j 'th event denote by N_j the total number of network stations (within 21-100 degrees) and by K_j the number of these that did not report. We then set:

$$P_{ij}=P_j = \begin{cases} N_j P / K_j & \text{if } N_j P < K_j \\ 1 & \text{otherwise} \end{cases} \quad (6)$$

Note that the larger the event, (i.e. the more stations that report), the more likely it becomes that a given nonreporting station is actually inoperative. The above procedure has the effect of adjusting the probability P_j so that the *conditional* expectation of the number of inoperative stations ($K_j P_j$) matches as closely as possible the *a priori* expectation ($N_j P$).

3. Station data.

The data base for this study consisted of the ISC reportings for the 10 year period 1971-1980. At any given time in this period, a typical number of about 1000 seismic stations reported observations to the ISC. An investigation of the station reports confirmed the conclusions of North (1977), who analyzed similar data for the period 1964-1973. Thus, the large majority of stations contribute very few observations, in particular of $\log(A/T)$, and would thus be of little use in this study.

For the purpose of magnitude estimation, we found it desirable to select a sub-network of about 100 globally distributed stations. The following basic criteria were applied:

- a) Consistent reporting, preferably over the entire 10 years period
- b) High detectability, i.e. a large number of teleseismic reports
- c) A sufficient number of $\log(A/T)$ reports to estimate station parameters
- d) Adequate geographical distribution.

Clearly, these criteria were sometimes in conflict. For example, several very sensitive stations, e.g. the large LASA array and some VELA arrays were only operational for part of the time period, but they were nevertheless selected. Also, the requirements were made less strict for stations in the southern hemisphere, in order to improve geographical coverage. Still, only a few useful stations could be found in Africa and South America. In the end, a total of 115 stations were selected, as listed in Table 1. At any time during the 10 years, about 100 of these were in actual operation.

Table 1 also summarizes estimates of the parameters G_i, γ_i, B_i and σ_i based on the procedures mentioned in the previous section. We note that in applying the Kelly-Lacoss (1969) procedure, a constrained value of $\beta=2.0$ was used. As shown by Chinnery and Lacoss (1978) such a constraint will have little effect on the estimated thresholds, but it serves to reduce the number of variables in the estimation procedure.

We further note that some stations reported $\log(A/T)$ for a low proportion of their detections. It is clearly possible that their detection threshold thus is significantly lower than their threshold for reporting $\log(A/T)$. This possibility was investigated for each station by comparing the average ISC event m_b for the total set of reported detections with the average m_b for the subset for which

$\log(A/T)$ was reported. As a first order approximation, we then adjusted the estimated thresholds according to the difference between these m_b values.

It should be observed that for some of the most sensitive stations, in particular some arrays, many of their reported detections are not associated with detected events in the ISC bulletin. Thus, the thresholds of Table 1 will be too high in these cases. In practice, this will make little difference in the maximum likelihood procedure since non-detections by these stations for ISC-reported events is usually due to the stations being inoperative. For array stations, we also note that reportings by sub-arrays or associated stations in some cases replaced the full array reporting.

4. Magnitude estimation results.

The previously described method and station network was applied to obtain maximum likelihood m_b estimates for ISC-reported events during 1971-1980. Known and presumed explosions were removed from the data set, so as not to bias the seismicity estimates. Furthermore, we restricted the data base to only those events which were reported by at least 4 stations of the 115 station network, and which had at least one detection in the distance range 21-100 degrees.

Since our network included most of the better stations reporting to the ISC, the resulting total of about 70000 events comprised nearly all those events for which any teleseismic reports were included in the ISC bulletins. However, it should be noted that these bulletins also include a large number of events reported by local stations only.

To simplify the calculations, we used in (3) constant values of $\sigma_i=0.35$ and $\gamma_i=0.20$, corresponding to the average values over all network stations (Table 1). Furthermore, based on reporting statistics for the largest events, we found a value of $P=0.15$ to be typical of the average down time of the stations. Simulation experiments showed that a very accurate value of P was not critically important, thus there was no reason to introduce variable P -values, e.g. depending upon year and epicentral region.

Figure 1 shows the resulting frequency-magnitude statistics for shallow events (depth < 80 km) globally. For comparison, similar statistics are also plotted using the magnitude estimation procedure currently employed by the ISC (i.e. averaging observed station magnitudes for all events with at least one $\log(A/T)$ report). The large difference in b-values ($b=0.90$ vs. $b=1.40$) illustrates the statistical bias resulting from using conventional magnitude estimation.

Figure 1 is quite similar to those obtained when comparing ISC magnitudes to magnitudes reported by sensitive array stations. (Chinnery, 1978, Ringdal and Husebye, 1982). Average b-values obtained from array data for large epicentral regions are typically in the range 0.8-1.0, as demonstrated e.g. for LASA, $b \sim 0.84$ (Dean, 1972), for NORSAR, $b \sim 0.83$ (Bungum and Husebye, 1974) and for the VELA arrays, $b \sim 0.93$ (Chinnery, 1978). Thus, the results using maximum-likelihood estimation are in good agreement with array studies. However, it must be realized that b-values can show significant regional variations (Evernden, 1970), and considerable caution in interpreting these data is therefore required.

Figures 2 and 3 shows incremental and cumulative statistics, respectively, averaged annually for shallow, intermediate and deep earthquakes. The slopes are approximately parallel, and have in the plots been constrained to the same value. The best-fitting cumulative relationships can be expressed as follows:

$$\log_{10}(N_C) = 7.33 - 0.90m_b \quad D \leq 60km \quad (7)$$

$$\log_{10}(N_C) = 6.85 - 0.90m_b \quad 60km < D \leq 300km \quad (8)$$

$$\log_{10}(N_C) = 6.13 - 0.90m_b \quad D > 300 \text{ km} \quad (9)$$

Here, N_C denotes the cumulative number of earthquakes, and D denotes depth of focus as given by the ISC. Thus, about 70 per cent of global earthquakes are shallow, 25 per cent of intermediate depth and 5 per cent deep. The estimated average annual number of earthquakes globally is about 7500 above $m_b = 4.0$, and the number ranges between 6000 and 9000 for individual years within the ten year period.

The distribution of estimated m_b bias values compared to conventional m_b estimation is illustrated in Figures 4 and 5. In most cases, conventional m_b values are biased high by between 0. and 0.5 units. Figure 5 shows that the bias problem is most significant at intermediate magnitudes. As expected, the bias values decrease somewhat when three or more station reports are required for m_b determination, but are even then significant.

At high magnitudes, our approach gives essentially the same m_b values as those of the ISC. Thus, we have not taken into account the possibility of bias introduced by clipping of strong signals at some stations for such events (Chinnery, 1978, von Seggern and Rivers, 1978). While this problem is important in many contexts, it would not significantly influence the seismicity statistics and detectability estimates in this study.

5. Earthquake detectability.

Based on the estimated magnitude data, an attempt was made to estimate the global teleseismic detectability of shallow events for the 115 station network. For this purpose a regional subdivision of the Earth in grids of 15×15 degrees was made, and recurrence statistics for observed shallow earthquakes were considered within each grid area. The method of Kelly and Lacoss (1969) was then used to obtain detectability estimates for regions with sufficient number of observations, and approximate contours were drawn corresponding to these estimates.

Figure 6 shows the results for 90 per cent incremental probability of detection at at least four stations. It is seen that the thresholds vary from better than $m_b = 4.2$ over much of the northern hemisphere to $m_b = 4.6$ or higher in parts of the southern hemisphere. It must be noted that a considerable amount of smoothing and interpolation was necessary in generating Figure 6, and very detailed interpretation of these contours should therefore be avoided.

For comparison, the 'Networth' approach (Wirth, 1970) was also applied to the network, using the threshold values of Table 1. The results are shown in Figure 7, and can be seen to be in good agreement with those of Figure 6. The actually observed differences are considered to be within the uncertainty limits of the estimation procedures employed.

In some earlier studies, e.g. the report CCD/558, theoretical detection capabilities of global networks were found to be inconsistent with actually reported magnitude data. It would appear that this inconsistency has been largely due to the network magnitude bias problem inherent in conventional magnitude estimation techniques.

The thresholds estimated in this paper relate to *average* operating conditions of the global network. Under special circumstances, the actual thresholds might be different, e.g. the thresholds would be higher immediately after a large earthquake and during a major aftershock sequence. For this reason, the estimated seismicity levels must also be interpreted with some caution.

As expressed by Ringdal(1976), the maximum-likelihood procedure ideally requires actual measurements of threshold levels at all nondetecting stations for any given event. The statistical approach to thresholds and station down-times used here, has been chosen for practical reasons. However, it has been found by Ringdal(1976) and Christoffersson(1980) that even under very unfavorable circumstances, i.e. during a large aftershock sequence, the maximum-likelihood procedure, using estimated thresholds, produces acceptable results. Thus, while some individual events, in particular those occurring closely after a large earthquake would be affected by occasional errors in the thresholds, the effect on the total earthquake statistics should be insignificant.

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Station Code	Parameters				Station Code	Parameters			
	G	γ	B	σ		G	γ	B	σ
ADK	1.73	0.23	0.22	0.42	KRP	1.71	0.18	0.43	0.30
ALE	0.80	0.21	-0.10	0.30	KTG	1.00	0.25	-0.07	0.29
ALQ	0.78	0.24	-0.20	0.33	LAO	0.43	0.25	0.04	0.35
ARE	1.33	0.15	0.17	0.32	LEM	1.46	0.15	0.11	0.39
ASP	1.34	0.31	0.09	0.39	LOR	0.89	0.25	-0.08	0.33
BAG	1.71	0.17	0.28	0.32	LPB	1.17	0.21	0.18	0.35
BDF	1.07	0.16	0.11	0.35	LPS	1.18	0.16	0.12	0.38
BDW	0.71	0.22	-0.15	0.35	MAIO	0.87	0.18	-0.11	0.37
BHA	0.78	0.08	-0.25	0.32	MAT	1.15	0.19	-0.01	0.38
BJI	1.24	0.18	0.06	0.34	MAW	1.18	0.27	0.04	0.31
BKR	1.20	0.19	0.38	0.33	MBC	0.75	0.28	0.09	0.35
BLC	1.02	0.21	0.21	0.29	MIR	1.48	0.15	0.22	0.33
BMO	0.30	0.17	-0.28	0.35	MNG	1.44	0.22	0.11	0.39
BNG	0.75	0.18	0.01	0.41	MOX	0.98	0.12	0.07	0.25
BOD	1.01	0.12	-0.02	0.34	MOY	1.22	0.14	0.12	0.29
BUL	0.83	0.10	-0.05	0.29	MSO	0.97	0.22	-0.08	0.44
CAN	1.62	0.22	0.11	0.31	MTD	0.82	0.08	-0.12	0.30
CAR	1.45	0.13	0.14	0.40	MTN	1.26	0.24	-0.08	0.38
CHG	1.00	0.23	-0.08	0.36	MUN	1.69	0.24	0.19	0.36
CIR	0.77	0.07	-0.24	0.30	NAO	0.37	0.24	-0.10	0.33
CLK	0.81	0.08	-0.24	0.29	NDI	1.57	0.24	0.30	0.38
CLL	0.97	0.10	0.16	0.26	NEW	0.94	0.23	-0.07	0.39
COL	0.87	0.12	0.07	0.34	NUR	0.98	0.17	0.11	0.46
CPO	0.82	0.16	-0.02	0.35	NVL	1.47	0.30	0.23	0.35
CTA	1.23	0.20	0.07	0.39	OBN	1.33	0.17	0.39	0.33
DAG	0.92	0.15	0.08	0.32	PET	1.61	0.22	0.24	0.36
DUG	0.95	0.26	-0.04	0.31	PMG	1.70	0.16	0.27	0.38
EDW	1.25	0.11	0.43	0.28	PMR	0.97	0.25	-0.11	0.39
EKA	1.04	0.26	0.	0.29	PNS	1.15	0.23	0.11	0.50
ELT	1.15	0.20	0.15	0.34	POO	1.50	0.16	0.19	0.35
EUR	0.54	0.29	-0.38	0.47	PPI	1.48	0.18	0.08	0.41
FFC	0.91	0.23	0.09	0.30	PRE	0.93	0.09	-0.08	0.40
FRB	1.26	0.14	0.37	0.29	PSI	1.14	0.11	-0.02	0.38
FRU	1.39	0.13	0.35	0.33	QUE	1.13	0.18	0.21	0.46
FVM	1.23	0.29	0.25	0.43	RAB	1.90	0.21	0.37	0.43
GBA	1.03	0.29	-0.07	0.42	RES	0.81	0.15	0.04	0.33
GDH	1.26	0.29	-0.05	0.30	SCH	1.48	0.28	0.27	0.34
GRF	1.20	0.26	0.25	0.28	SES	1.31	0.13	0.42	0.28
GRR	1.06	0.22	0.04	0.26	SHL	1.48	0.13	0.22	0.33
GUA	2.18	0.25	0.43	0.40	SJG	1.50	0.18	0.19	0.35
HFS	0.80	0.22	0.13	0.35	SPA	1.21	0.31	0.16	0.37
HYB	1.37	0.17	0.26	0.32	STK	1.55	0.22	0.27	0.38
ILT	1.09	0.17	0.08	0.32	SVE	1.37	0.19	0.37	0.31
IMA	0.83	0.24	-0.18	0.38	TIK	0.99	0.20	0.03	0.37
INK	1.08	0.10	0.25	0.29	TOO	1.50	0.23	0.13	0.35
IPM	1.34	0.13	0.10	0.36	TPT	1.60	0.24	0.09	0.34
IRK	1.17	0.19	-0.03	0.31	TUC	0.92	0.27	-0.17	0.32
JAY	1.70	0.07	0.15	0.41	TUL	1.03	0.23	0.21	0.34
KBL	1.09	0.16	0.15	0.30	TUP	0.76	0.12	-0.35	0.40
KBS	1.35	0.14	0.12	0.32	TVO	1.80	0.22	0.19	0.29
KEV	1.01	0.11	0.05	0.31	UBO	0.42	0.25	-0.13	0.38
KHC	0.88	0.20	0.03	0.26	UPP	1.36	0.09	0.60	0.33
KHE	1.63	0.21	0.37	0.31	WRA	0.71	0.28	-0.20	0.44
KHO	1.69	0.23	0.59	0.35	YAK	1.63	0.20	0.43	0.34
KIR	1.36	0.09	0.81	0.25	YKC	0.99	0.18	0.08	0.34
KJP	0.82	0.10	0.18	0.28	YSS	1.40	0.19	0.20	0.41
KOD	1.33	0.19	0.18	0.33	ZAK	0.86	0.18	-0.11	0.33
KRA	1.34	0.13	0.32	0.29					

Table 1. Estimates of the parameters G_i , γ_i , B_i and σ_i as defined in the text for the 115 seismic stations selected for this study. Each station is identified by its station code as used by the ISC.

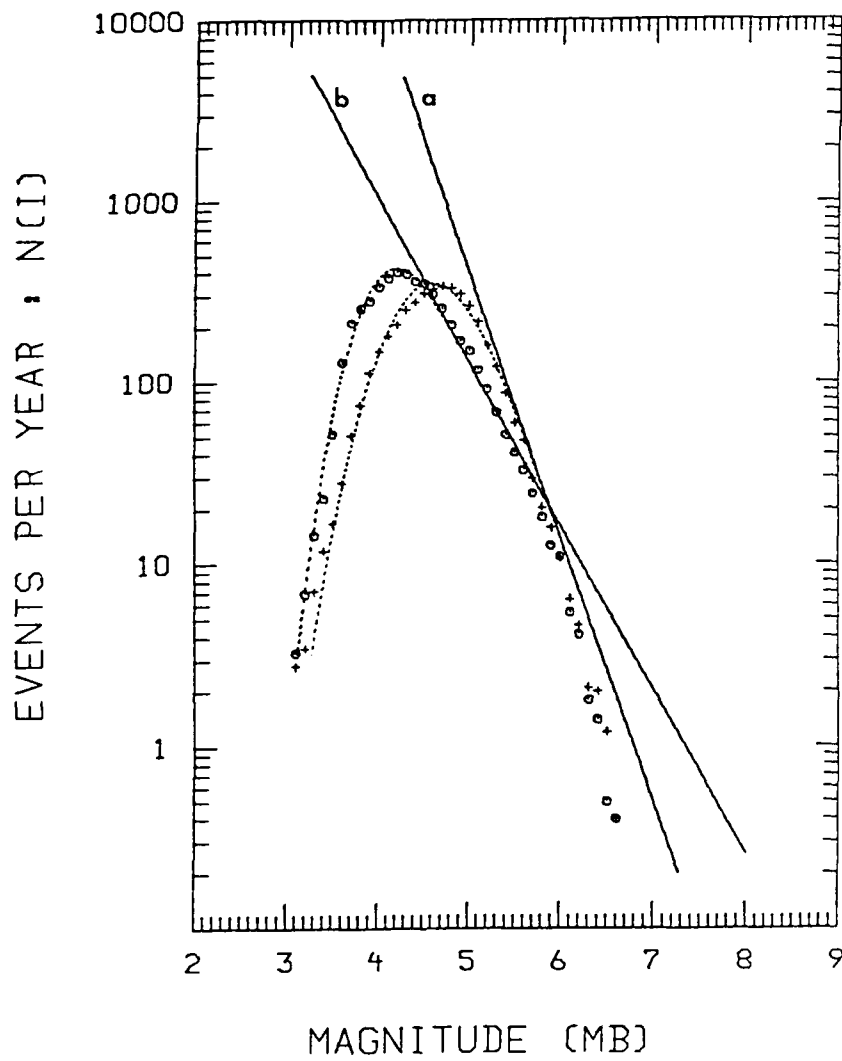


Figure 1. Incremental recurrence statistics for shallow events (averaged per year), (a) using conventional m_b (one or more station observations) and (b) using maximum-likelihood m_b . The dotted lines indicate the fit of the Kelly-Lacoss model. Note the significant difference in slopes between the two cases.

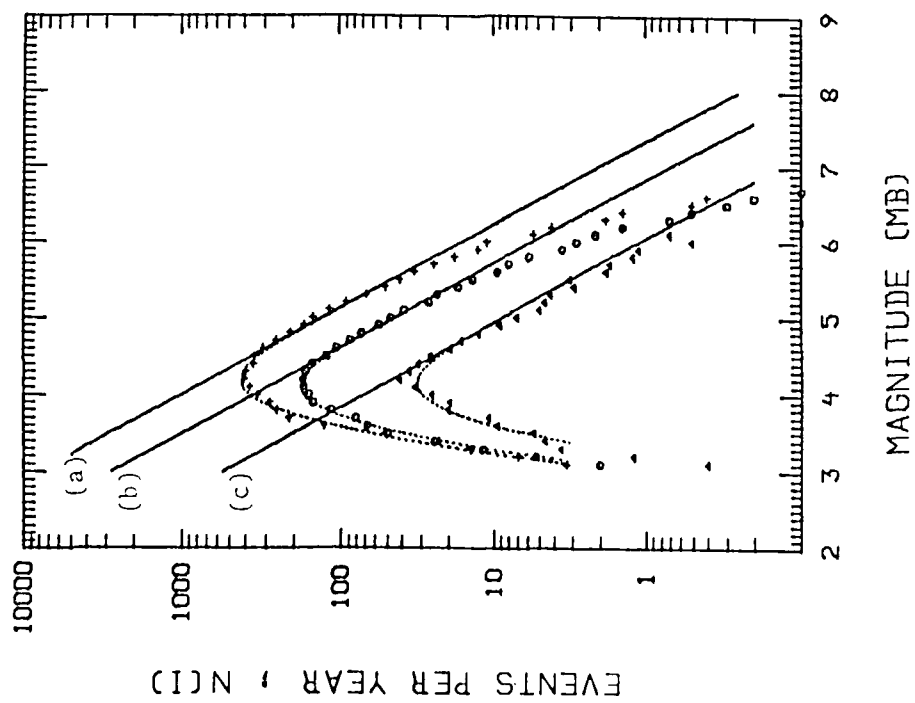


Figure 2. Incremental recurrence statistics averaged annually for (a) shallow, (b) intermediate and (c) deep earthquakes globally, using maximum likelihood m_0 estimates.

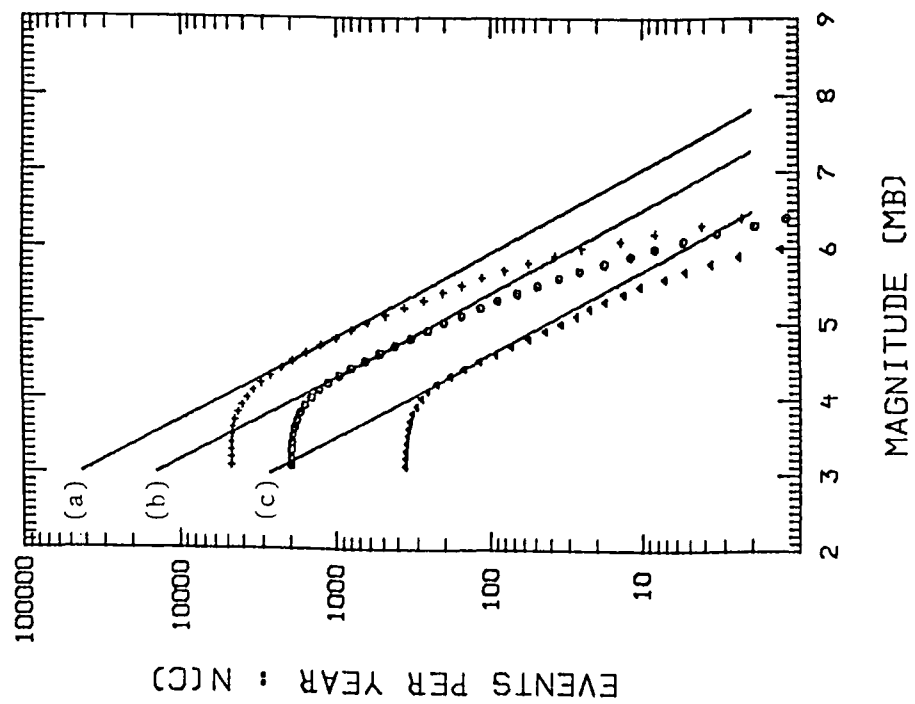


Figure 3. Cumulative recurrence statistics averaged annually for (a) shallow, (b) intermediate and (c) deep earthquakes globally, using maximum likelihood m_0 estimates.

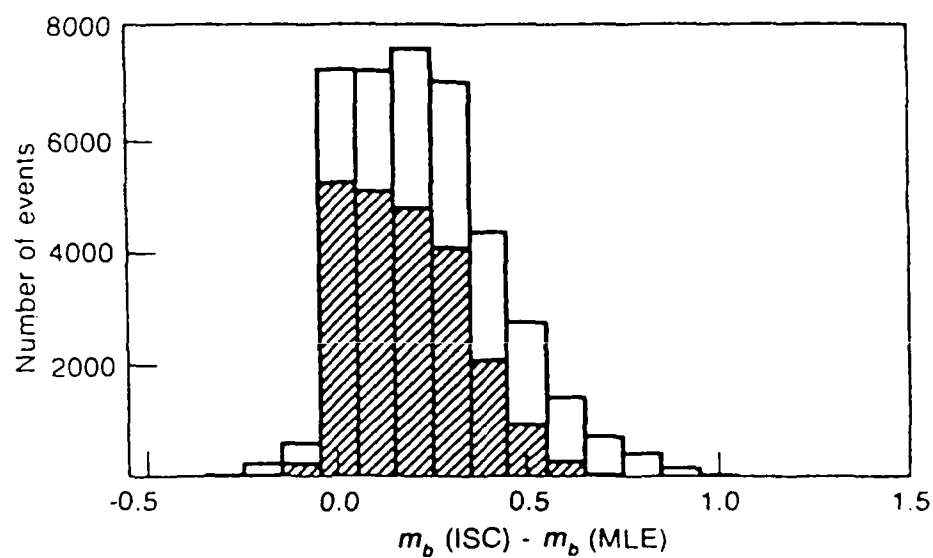


Figure 4. Distribution of differences between conventional m_b and maximum likelihood m_b . The filled columns correspond to requiring at least three observations in the conventional estimates.

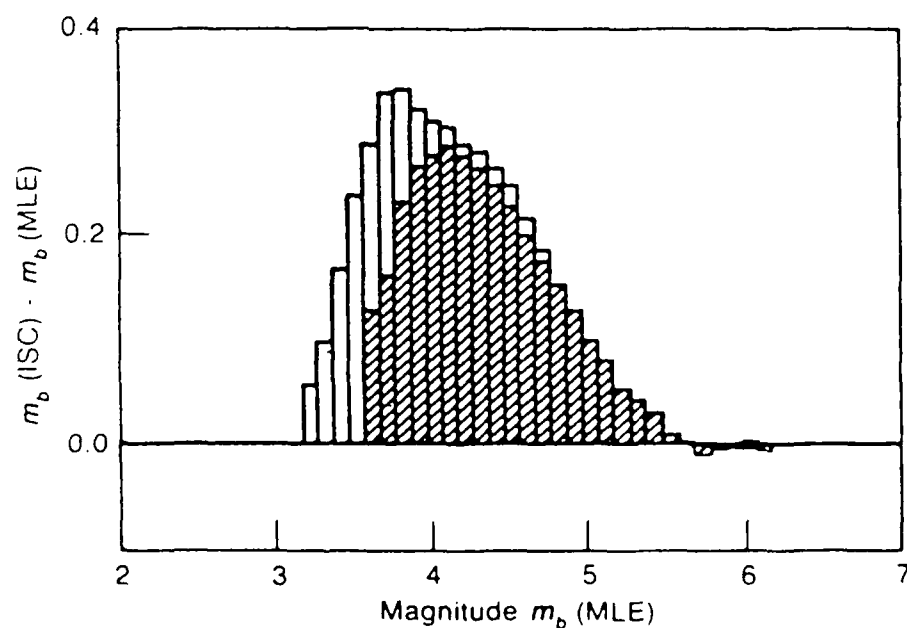


Figure 5. Average m_b differences (as in Figure 4) shown as a function of maximum likelihood m_b . Note that the bias is most pronounced at intermediate magnitudes.

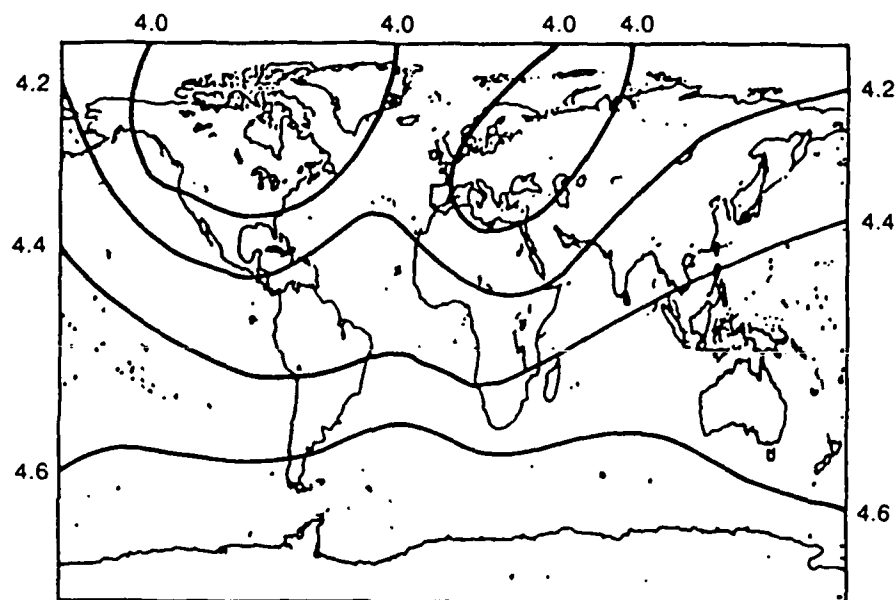


Figure 6. Contours corresponding to 90 per cent incremental probability of detection at at least 4 stations of the network, requiring at least 1 teleseismic detection. This figure is based on observed recurrence statistics using maximum-likelihood m_b .

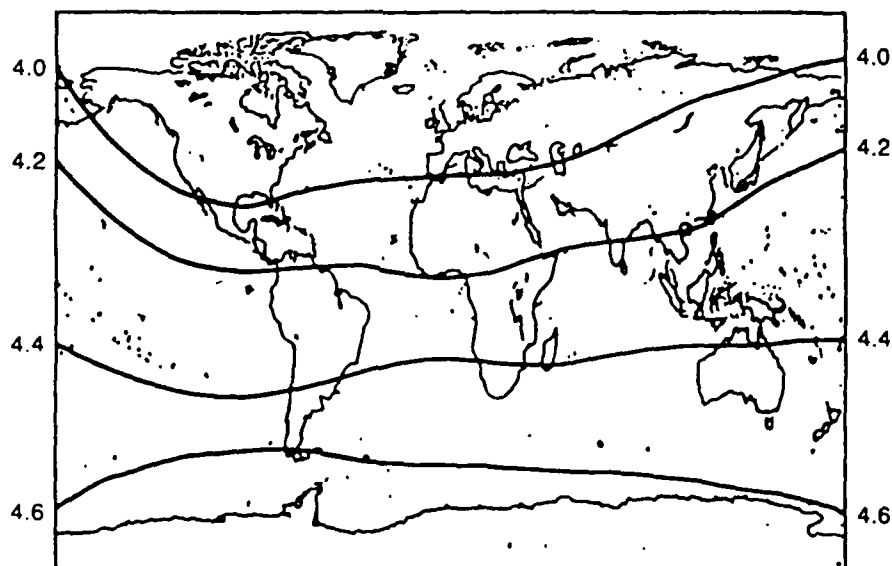


Figure 7. Contours corresponding to 90 per cent incremental probability of detection at at least 4 stations of the network, using the 'Network' approach with threshold parameters as in Table 1.

Appendices

Appendix A: Station names and locations

Appendix B: Annual statistics of reported events

Appendix C: Examples of station threshold estimation

Appendix D: Magnitudes of presumed explosions 1971-1980

Appendix E: Data file formats

Appendix A

Station names and locations

In this Appendix, information for each of the 115 seismograph stations used in this study is summarized:

- Station number
- Station code (as used in the ISC bulletins)
- Station name
- Station location (geographical area)
- "W" if the station is part of the WWSSN
- Station latitude, degrees (~ means south)
- Station longitude, degrees (~ means west)
- Station altitude (meters)

Station no, name and location				Lat	Lon	Alt
1	ADK	Adak	Alaska and Aleutians	51.884	-176.684	116
2	ALE	Alert	Northwest Territories	82.483	-62.400	65
3	ALQ	Albuquerque	New Mexico	W 34.943	-106.457	1849
4	ARE	Arequipa	Peru	W -16.462	-71.491	2452
5	ASP	Alice Springs	Northern Territory	-23.683	133.897	600
6	BAG	Baguio City	Luzon	W 16.411	120.580	1507
7	BDF	Brasilia Array (W)	Brazil	W -15.664	-47.903	1255
8	BDW	Boulder	Wyoming	42.776	-109.568	2190
9	BHA	Broken Hill	Zambia	-14.447	28.468	1206
10	BJI	Beijing	Beijing	40.040	116.175	43
11	BKR	Bakuriani	Gruzija	41.733	43.517	1500
12	BLC	Baker Lake	Northwest Territories	64.317	-96.017	16
13	BMO	Blue Mountains	Oregon	44.849	-117.306	1189
14	BNG	Bangui	Central African Repu	4.435	18.547	378
15	BOD	Bodaibo	Irkutskaya	57.850	114.183	250
16	BUL	Bulawayo	Zimbabwe Rhodesia	W -20.143	28.613	1341
17	CAN	Canberra	Australia	-35.321	148.999	700
18	CAR	Caracas	Venezuela	W 10.507	-66.928	1032
19	CHG	Chieng Mai	Thailand	W 18.790	98.977	416
20	CIR	Chiredzi	Zimbabwe Rhodesia	-21.013	31.580	430
21	CLK	Chileka	Malawi	-15.680	34.977	781
22	CLL	Collenberg	GDR	51.310	13.003	230
23	COL	College Outpost	Alaska and Aleutians	64.900	-147.793	320
24	CPO	Cumberland Plateau	Tennessee	35.595	-85.570	574
25	CTA	Charters Towers	Queensland	W -20.088	146.254	357
26	DAG	Danmarks Havn	Greenland	W 76.770	-18.770	16
27	DUG	Dugway	Utah	W 40.195	-112.813	1477
28	EDM	Edmonton	Alberta	53.222	-113.350	730
29	EKA	Eskdalemuir Ar	Scotland	55.333	-3.159	263
30	ELT	Yel'tsovka	Altayskiy	53.250	86.267	-
31	EUR	Eureka	Nevada	39.483	-115.970	2178
32	FFC	Flin Flon	Manitoba	54.725	-101.978	338
33	FRB	Frobisher Bay	Northwest Territories	63.747	-68.547	18
34	FRU	Frunze	Kirgiziya	42.833	74.617	655
35	FVM	French Village	Missouri	37.984	-90.426	310
36	GBA	Gauribidanur Ar	Karnataka	13.604	77.436	686
37	GDH	Godhavn	Greenland	W 69.250	-53.533	23
38	GRF	Grafenberg Ar	Bayern	49.692	11.222	500
39	GRR	Gorron	Normandie	48.388	-0.858	220
40	GUA	Guam	Mariana Islands	W 13.538	144.912	230
41	HFS	Hagfors	Sweden	60.134	13.696	265
42	HYB	Hyderabad	Andhra Pradesh	17.417	78.553	510
43	ILT	Iul'tin	Magadanskaya	67.833	-178.800	-
44	IMA	Indian Mountain	Alaska	66.068	-153.679	-
45	INK	Inuvik	Northwest Territories	68.292	-133.500	40
46	IPM	Ipoh	West Malaysia	4.600	101.055	-
47	IRK	Irkutsk	Irkutskaya	52.272	104.310	467
48	JAY	Djajapura	West Irian, Indonesia	-2.500	140.667	400
49	KBL	Kabul	Afghanistan	34.541	69.043	1920
50	KBS	Kingsbay	Svalbard	W 78.917	11.924	46
51	KEV	Kevo	Finland	69.755	27.007	80
52	KHC	Kasperske Hory	Czechoslovakia	49.131	13.578	695
53	KHE	Kheis	Arkhangel'skaya	80.617	58.050	100
54	KHO	Khorog	Tadzhikistan	37.483	71.533	1850
55	KIR	Kiruna	Sweden	67.840	20.417	390
56	KJF	Kajaani	Finland	64.199	27.715	160
57	KOD	Kodaikanal	Tamil Nadu	W 10.233	77.467	2345
58	KRA	Krakow	Poland	50.058	19.940	223

Station no, name and location				Lat	Lon	Alt
59	KRP	Karapiro	North Island	-37.925	175.538	64
60	KTG	Kap Tobin	Greenland	W 70.417	-21.983	6
61	LAO	LASA Centre	Montana	46.689	-106.222	744
62	LEM	Lembang	Java	W -6.833	107.617	1252
63	LOR	Lormes	Nivernais	W 47.268	3.859	520
64	LPB	La Paz	Bolivia	W -16.533	-68.098	3292
65	LPS	La Palma	El Salvador	W 14.292	-89.162	1000
66	MAIO	Mashhad (SRO)	Iran	36.308	59.472	1150
67	MAT	Matsushiro	Nagano	W 36.542	138.207	407
68	MAW	Mawson	Mac Robertson Land	-67.604	62.871	12
69	MBC	Mould Bay	Northwest Territories	76.242	-119.360	15
70	MIR	Mirnyy	Queen Mary Land	-66.550	93.000	30
71	MNG	Mangahao	New Zealand	-40.619	175.482	396
72	MOX	Moxa	GDR	50.646	11.616	454
73	MOY	Mondy	Buryatskaya	51.683	100.983	-
74	MSO	Missoula	Montana	46.829	-113.941	1264
75	MTD	Mount Darwin	Zimbabwe	-16.780	31.583	967
76	MTN	Manton	Northern Territory	-12.846	131.131	155
77	MUN	Mundaring	Western Australia	W -31.978	116.208	253
78	NAO	NORSAR A	Norway	60.824	10.832	379
79	NDI	New Delhi	Delhi	W 28.683	77.217	230
80	NEW	Newport	Washington	48.263	-117.120	760
81	NUR	Nurmijarvi	Finland	W 60.509	24.651	102
82	NVL	N'lazarevskaya	Dronning Maud Land	-70.767	11.833	87
83	OBN	Obninsk	Kaluzhskaya	55.167	36.600	-
84	PET	Petropavlovsk	Kamchatskaya	53.017	158.650	25
85	PMG	Port Moresby	Papua New Guinea	W -9.409	147.154	67
86	PMR	Palmer	Alaska and Aleutians	61.592	-149.131	100
87	PNS	Penas	Bolivia	-16.267	-68.473	3986
88	POO	Poona	Maharashtra	W 18.533	73.850	560
89	PPI	Padang Panjang	Sumatera	-0.452	100.389	-
90	PRE	Pretoria	Transvaal	-25.753	28.190	1333
91	PSI	Prapat	Sumatera	2.691	98.919	-
92	QUE	Quetta	Pakistan	W 30.188	66.950	1721
93	RAB	Rabaul	New Britain	W -4.191	152.170	184
94	RES	Resolute Bay	Northwest Territories	74.687	-94.900	15
95	SCH	Schefferville	Quebec	54.817	-66.783	540
96	SES	Suffield	Alberta	50.396	-111.042	770
97	SHL	Shillong	Assam	W 25.567	91.883	1600
98	SJG	San Juan (W)	Puerto Rico	W 18.112	-66.150	457
99	SPA	South Pole	Antarctica	W -90.000	0.	2927
100	STK	Stephens Creek	New South Wales	-31.882	141.592	213
101	SVE	Sverdlovsk	Sverdlovskaya	56.810	60.637	275
102	TIK	Tiksi	Yakutskaya	71.633	128.867	25
103	TOO	Toolangi	Victoria	-37.571	145.491	604
104	TPT	Tiputa	Tuamotu	-14.984	-147.620	3
105	TUC	Tucson	Arizona	W 32.310	-110.782	985
106	TUL	Tulsa (Univ.Okla.)	Oklahoma	35.911	-95.792	261
107	TUP	Tupik	Central Siberia	54.433	119.900	-
108	TVO	Taravao	Tahiti	-17.782	-149.252	660
109	UBO	Uinta Basin Array	Utah	40.322	-109.569	1600
110	UPP	Uppsala	Sweden	59.858	17.627	14
111	WRA	Warramunga Ar	Northern Territory	-19.944	134.341	366
112	YAK	Yakutsk	Yakutskaya	62.017	129.717	125
113	YKC	Yellow Knife	Northwest Territories	62.478	-114.473	198
114	YSS	Yuzh-Sakhalinsk	Sakhalinskaya	47.017	142.717	75
115	ZAK	Zakamensk	Buryatskaya	50.383	103.283	-

Appendix B

Annual statistics of reported events

In this Appendix, information on the reportings in the ISC bulletins by each station is listed by year. The following information is listed:

Name: Station code

nobs (Arrivals): Total number of P-arrivals for the station for the years 1971-1980

mavg (Arrivals): Average ISC-reported magnitudes (m_b) for the events reported

nobs (log A/T): Total number of P-arrivals with reported log A/T for the station (1971-1980)

mavg (log A/T): Corresponding average ISC m_b for this set of events

lavg (log A/T): Average log A/T reported for the station

Annual no. of Total number of P-arrivals per year (irrespective
detections of whether log A/T was reported) for the station
(1971-1980):

Name	**Arrivals**		****log(A/T)****			*****Annual no. of detections*****										
	nobs	mavg	nobs	mavg	lavg	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	
ADK	3337	5.38	623	5.43	2.07	386	401	421	386	407	289	263	293	230	261	
ALE	7323	5.00	4679	5.04	1.22	888	946	1052	493	784	701	541	729	643	546	
ALQ	9937	4.93	4770	4.95	1.11	712	746	878	893	682	663	877	1538	1555	1393	
ARE	2422	5.07	279	5.17	1.78	184	204	292	296	263	300	200	219	242	222	
ASP	16123	4.98	5385	5.15	1.75	1590	1800	1571	1471	1524	1396	1336	1800	1834	1801	
BAG	5155	5.30	1215	5.41	2.15	636	571	514	424	563	440	458	441	444	624	
BDF	1325	4.80	271	4.89	1.53	354	383	474	114	0	0	0	0	0	0	
BDW	4131	4.93	1466	4.95	1.08	0	0	0	0	0	0	515	1093	1189	1334	
BHA	1232	5.22	1191	5.21	1.15	285	230	0	0	253	132	332	0	0	0	
BJI	1473	5.17	456	5.24	1.68	0	0	0	0	0	0	0	0	550	923	
BKR	7192	5.05	1145	5.12	1.74	538	774	823	766	827	754	737	739	552	682	
BLC	5579	4.93	2580	4.96	1.42	698	794	726	929	1101	937	394	0	0	0	
BMO	11025	4.73	10615	4.72	0.70	2368	2553	2830	2504	770	0	0	0	0	0	
BNG	6408	4.82	6316	4.82	1.11	586	628	699	734	745	598	598	444	647	729	
BOD	9094	5.09	1566	5.16	1.49	783	925	866	835	1026	830	969	1027	862	971	
BUL	6166	5.04	5804	5.05	1.22	534	523	690	678	672	557	785	453	608	666	
CAN	9545	5.15	397	5.31	1.98	916	1010	748	635	925	994	1020	1017	1059	1221	
CAR	2066	5.18	1142	5.28	1.86	288	269	284	239	169	185	175	155	164	138	
CHG	9180	4.99	2986	5.06	1.39	133	0	131	368	1107	1238	962	1344	1825	2072	
CIR	3367	5.12	3164	5.12	1.12	394	367	517	448	405	353	138	225	312	208	
CLK	2447	5.17	2361	5.17	1.14	312	176	242	276	106	0	351	321	357	306	
CLL	11031	4.93	5343	5.11	1.54	878	956	1183	1082	1386	1275	960	1331	990	990	
COL	19219	4.90	8404	5.00	1.40	1968	1844	1842	1798	1874	1904	1748	2065	1841	2335	
CPO	4765	4.84	3197	4.86	1.26	840	711	1033	1065	684	194	238	0	0	0	
CTA	11796	5.01	918	5.21	1.77	869	1103	1005	966	1043	1111	1176	1200	1523	1800	
DAG	8400	4.96	6784	5.00	1.33	0	313	606	776	1303	1156	1227	1096	882	1041	
DUG	8100	5.00	2636	5.08	1.31	943	1061	960	635	553	1014	1063	1166	705	0	
EDM	11363	4.95	2431	5.30	1.99	1443	1386	1380	1351	1102	1237	889	1036	875	664	
EKA	5470	5.04	2473	5.18	1.49	442	486	621	525	698	656	523	658	302	559	
ELT	9205	5.06	1459	5.14	1.61	905	989	964	813	1117	990	1008	799	795	825	
EUR	13749	4.92	10992	4.96	0.87	1652	1568	1706	1692	1457	1229	1157	1211	1141	936	
FFC	9446	4.91	6038	4.96	1.30	987	1055	1169	1064	1060	1074	776	958	801	502	
FRB	4455	4.97	601	5.46	2.07	0	0	611	548	625	566	422	719	530	434	
FRU	6551	5.16	776	5.29	1.97	632	674	659	554	757	753	670	643	546	663	
FVM	2700	5.05	354	4.91	1.47	0	0	0	148	426	293	323	434	513	563	
GBA	10880	5.02	4069	4.97	1.25	860	981	688	856	1141	1158	1142	1209	1063	1782	
GDH	2462	5.35	1792	5.39	1.57	315	270	260	234	323	260	228	263	153	156	
GRF	7660	4.99	3166	5.14	1.66	732	782	842	880	996	986	625	763	518	536	
GRR	4723	5.10	2103	5.05	1.34	476	458	510	434	478	475	455	562	474	401	
GUA	2172	5.43	1079	5.46	2.48	177	217	234	279	257	175	253	212	180	188	
HFS	16232	4.74	13643	4.72	1.07	1091	1273	1919	1651	1909	1552	1325	2064	1645	1803	
HYB	6963	5.19	4485	5.26	1.85	785	638	501	481	634	606	740	844	774	960	
ILT	10158	5.10	1005	5.32	1.71	790	1013	1011	925	1269	1222	1045	976	903	1004	
IMA	6538	5.01	95	4.76	1.06	296	1216	1156	767	111	198	0	632	716	1446	
INK	13828	4.92	2229	5.38	1.91	893	1110	1374	1508	1834	1662	1249	1501	1421	1276	
IPM	1305	5.16	663	5.31	1.87	0	0	0	0	0	0	0	0	464	841	
IRK	5371	5.25	935	5.32	1.61	420	484	448	511	532	538	614	633	530	661	
JAY	1687	5.33	91	5.40	2.15	0	0	0	188	203	169	343	308	202	274	
KBL	6434	4.98	701	4.90	1.34	1196	1278	1019	750	542	496	0	302	441	410	
KBS	3681	5.28	900	5.38	1.81	445	323	328	319	441	314	296	435	367	413	
KEV	7418	5.08	3779	5.24	1.55	667	692	749	728	789	831	686	892	691	693	
KHC	10106	4.94	4268	5.13	1.42	818	943	1142	953	1165	1045	852	1244	965	979	
KHE	4777	5.24	674	5.36	2.01	410	404	361	407	552	569	481	671	497	425	
KHO	6311	5.13	117	5.70	2.60	526	720	727	645	842	774	692	606	458	321	
KIR	11135	4.94	1369	5.37	2.22	812	1111	1205	1308	1362	1146	1076	1232	866	1017	
KJF	15645	4.86	8159	5.04	1.47	1189	1430	1549	1584	1767	1701	1424	1797	1508	1696	
KOD	6828	5.14	1712	5.40	1.93	322	425	509	642	921	820	965	867	622	735	
KRA	6158	5.13	3036	5.27	1.83	480	542	642	520	712	715	585	778	562	622	

Arrivals			****log(A/T)****			*****Annual no. of detections*****									
Name	nobs	mavg	nobs	mavg	lavg	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
KRP	6243	5.21	970	5.37	2.24	760	799	678	568	561	418	633	653	585	588
KTG	4474	5.17	3163	5.25	1.39	488	451	582	324	681	439	488	439	324	258
LAO	12687	4.65	10717	4.61	0.77	1423	2450	2926	2894	1614	157	1066	157	0	0
LEM	5301	5.26	1552	5.23	1.80	379	538	535	509	654	556	500	601	363	666
LOR	6592	5.02	5500	4.99	1.18	565	595	707	609	758	678	578	755	704	643
LPB	4605	4.89	1394	5.03	1.65	317	373	514	514	423	526	374	447	592	525
LPS	1359	5.19	830	5.24	1.62	302	248	301	198	0	0	194	0	116	0
MAIO	3636	5.04	674	5.28	1.51	0	0	0	0	0	395	687	576	894	1084
MAT	9602	5.13	3408	5.22	1.62	1073	1095	919	971	1001	946	922	880	884	911
MAV	5764	5.20	937	5.37	1.67	706	747	417	433	619	776	579	676	481	330
MBC	17700	4.77	14184	4.76	1.06	1030	1521	1764	2224	2204	1723	1342	2119	2223	1550
MIR	3044	5.37	307	5.57	2.09	517	351	307	206	132	381	331	301	267	251
MNG	6012	5.18	645	5.33	1.92	703	821	512	568	503	444	597	606	668	590
MOX	9404	4.97	5954	5.08	1.22	802	896	1076	1009	1233	1064	807	1039	791	687
MOY	6556	5.18	964	5.26	1.72	468	675	684	642	745	689	722	719	578	634
MSO	6238	5.02	3814	5.07	1.28	0	0	0	910	1167	917	886	959	838	561
MTD	2931	5.11	2675	5.10	1.19	178	206	404	229	170	225	401	167	449	422
MTN	7290	5.07	173	5.01	1.50	0	655	927	1040	1069	879	760	629	519	812
MUN	4892	5.32	507	5.48	2.14	538	661	478	494	416	450	465	461	368	561
NAO	10819	4.65	10644	4.65	0.74	0	1633	2235	2390	2273	1591	0	141	112	444
NDI	7279	5.16	2160	5.35	2.03	753	785	657	521	822	731	756	850	689	715
NEW	9757	5.06	1264	5.31	1.52	1126	922	1108	1077	1028	1010	836	1029	855	766
NUR	15061	4.83	7350	5.03	1.43	1123	1310	1507	1508	1724	1707	1329	1872	1435	1546
NVL	2540	5.40	348	5.48	1.81	185	274	224	213	193	279	349	243	282	298
OBN	8196	5.08	1166	5.18	1.80	710	902	922	805	979	820	812	812	706	728
PET	3385	5.40	402	5.54	2.12	176	323	267	269	400	378	431	401	376	364
PMG	5368	5.21	2349	5.19	2.05	531	710	578	462	408	385	447	610	618	619
PMR	11506	5.07	7882	5.14	1.35	1370	1339	1189	1146	1171	1114	1006	1092	1004	1075
PNS	1813	4.82	246	4.89	1.52	335	434	549	495	0	0	0	0	0	0
POO	3700	5.33	908	5.38	1.88	333	379	366	348	395	432	377	423	284	371
PPI	1865	5.21	392	5.37	1.98	0	0	0	0	0	0	0	870	552	443
PRE	2995	5.18	2753	5.18	1.33	324	322	348	301	368	276	397	225	209	225
PSI	3574	5.09	1296	5.16	1.61	0	0	0	0	0	172	0	1285	1030	1087
QUE	6701	5.03	778	5.15	1.63	879	751	923	768	1044	1004	232	1100	0	0
RAB	3201	5.37	247	5.44	2.31	319	454	514	291	489	282	254	251	153	194
RES	8210	4.92	7125	4.90	1.22	575	485	627	1045	1261	839	681	1105	893	699
SCH	3323	5.14	847	5.35	1.95	427	370	334	360	328	239	303	339	317	306
SES	8027	5.02	1222	5.40	2.04	1294	1106	1112	905	842	770	538	639	486	335
SHL	7849	5.14	178	5.35	1.97	476	803	773	619	807	832	868	899	825	947
SJG	1028	5.21	635	5.24	1.87	246	0	205	185	0	0	140	125	127	0
SPA	10221	5.01	5249	5.09	1.55	1137	1134	749	1196	788	698	1156	887	1288	1188
STK	6929	5.10	1338	5.35	2.12	0	0	0	781	1285	1268	1119	1417	1059	0
SVE	6891	5.10	601	5.33	1.99	619	691	727	748	823	591	535	648	640	869
TIK	9019	5.07	1455	5.15	1.49	833	1095	940	1045	1275	978	0	723	999	1131
TOO	8098	5.19	1277	5.37	2.01	760	1027	840	775	757	757	802	805	890	685
TPT	2939	5.42	2401	5.42	1.91	315	253	289	350	319	330	288	278	258	259
TUC	9032	5.01	2302	5.13	1.32	959	887	906	921	806	834	1010	827	849	1031
TUL	8542	4.89	7902	4.90	1.41	834	757	1084	1027	1061	765	661	761	680	912
TUP	5812	5.13	111	5.16	1.19	373	610	670	634	771	866	685	482	516	205
TVO	2255	5.48	1658	5.45	2.05	291	220	230	253	230	232	218	188	193	200
UBO	5466	4.71	3618	4.72	0.79	2249	2367	850	0	0	0	0	0	0	0
UPP	10726	4.93	1348	5.35	2.20	770	1042	1188	1128	1317	1224	1021	1206	848	982
WRA	14521	4.77	7504	4.64	0.91	1462	1702	1546	1361	191	0	848	1551	2691	3169
YAK	8127	5.13	861	5.29	2.12	433	876	883	742	971	816	841	851	699	1015
YKC	7542	5.01	2739	5.16	1.50	854	883	847	1067	925	721	527	652	614	452
YSS	5545	5.25	605	5.40	1.93	353	516	489	500	568	625	710	575	564	645
ZAK	10922	5.06	2161	5.07	1.30	819	1020	972	1005	1229	1147	1200	1246	1043	1241

Appendix C

Examples of station threshold estimation

This Appendix is intended to illustrate the estimation procedure used to obtain the station threshold parameters G_i and γ_i (we use the same nomenclature as in the text. The procedure was first developed by Kelly and Lacoss (1969) and has since been applied, e.g., by Lacoss and Chinnery (1976) and Christoffersson (1980). Briefly, the procedure is based on modelling the actually observed $\log(A/T)$ values at a given seismic station by a distribution of the form (for simplicity, indices are omitted):

$$d(y) = e^{\alpha - \beta y} \Phi\left(\frac{y - G}{\gamma}\right) \quad (C1)$$

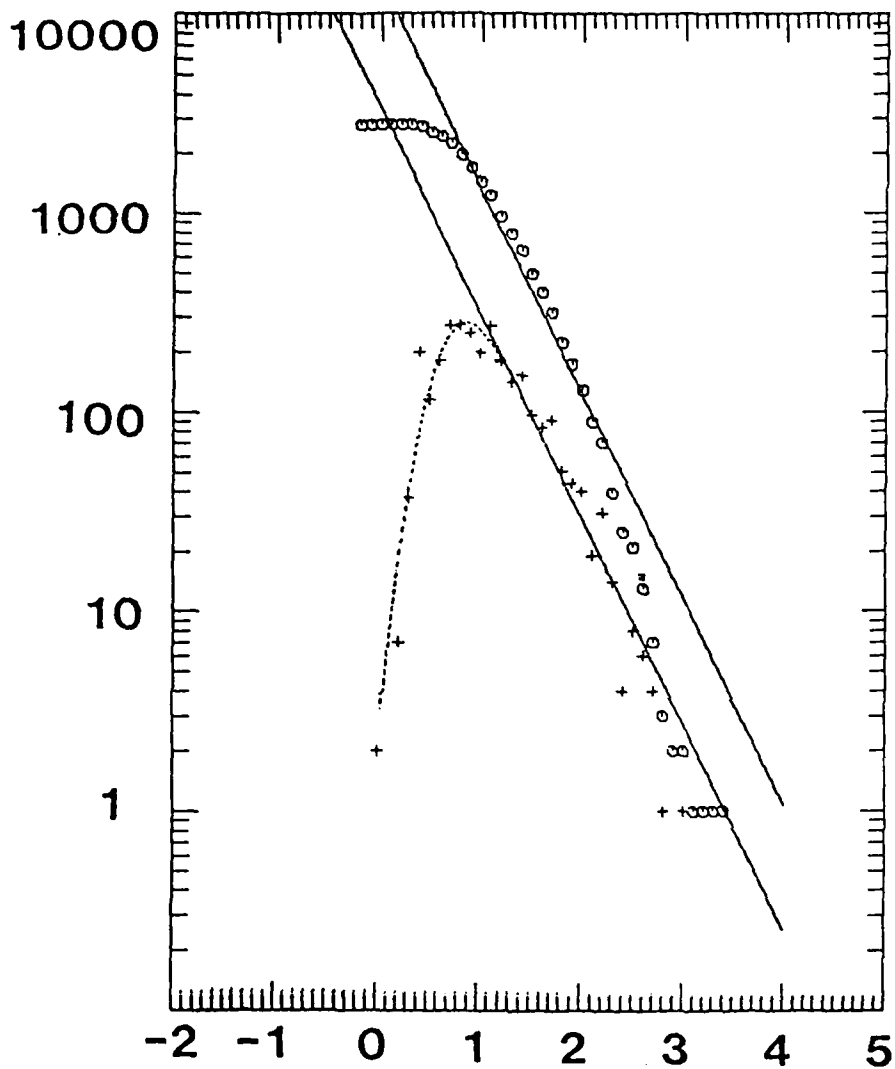
The parameters α and β are related to the commonly used parameters a and b of the frequency-magnitude distribution of earthquakes, and are estimated in the Kelly-Lacoss procedure together with the station parameters G and γ by maximum likelihood. In particular they show that the maximum likelihood estimates must satisfy the following equation:

$$G = \bar{y} - \frac{1}{\beta} + \beta \gamma^2 \quad (C2)$$

where $\bar{y}$ is the average observed $\log(A/T)$. Their method can also be applied directly to magnitudes (instead of $\log(A/T)$) and thus provides a way to estimate both station and network detection thresholds. When the number of observations is limited, the equation (C2) is often useful to estimate average thresholds directly, assuming that reasonable constraints can be given on β and γ .

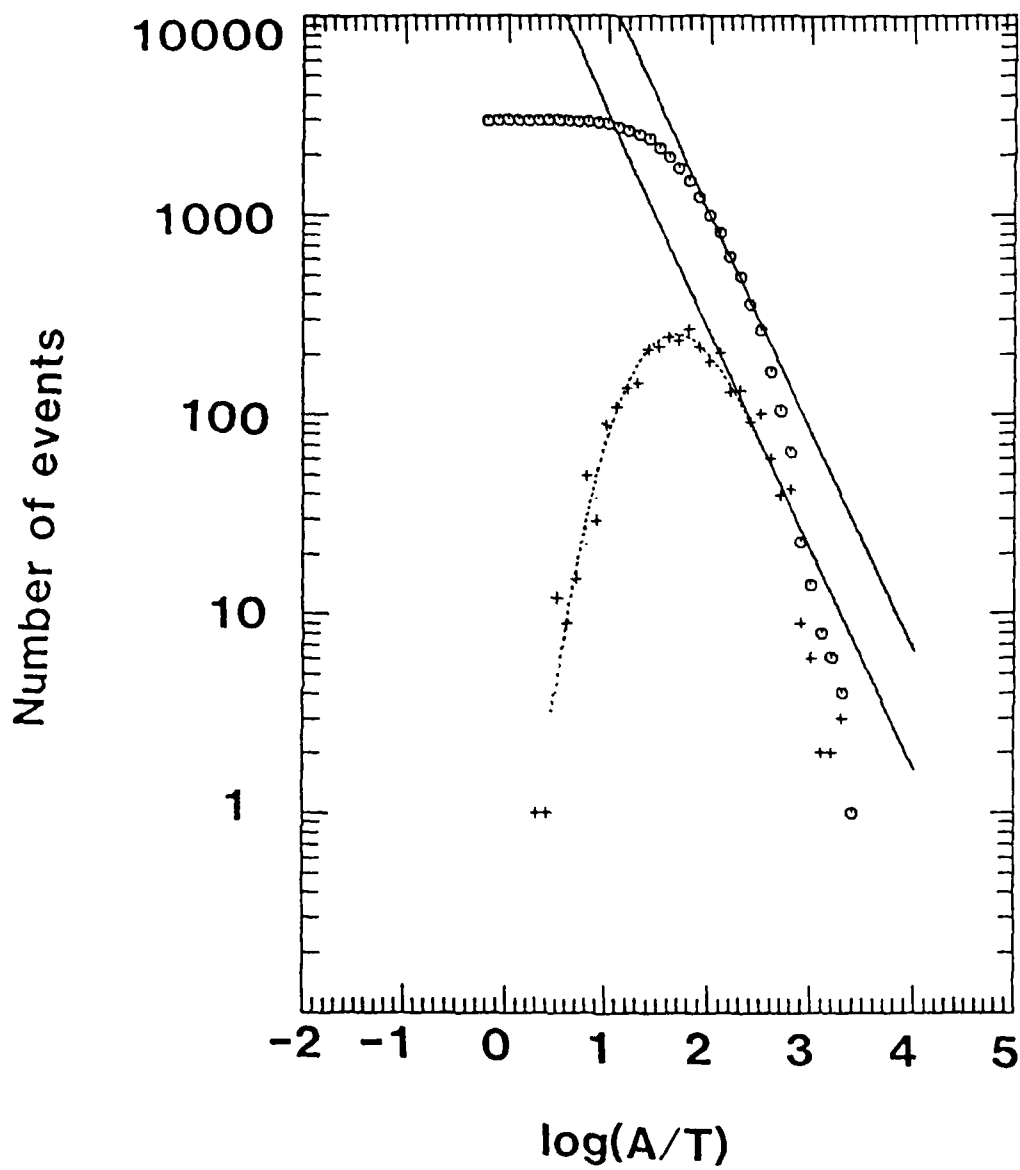
The examples given in the following cover the time interval 1974-79, and are intended to illustrate the fit of the Kelly-Lacoss model to the actual data for representative stations. On each figure, crosses mark incremental number of log A/T reports, circles mark cumulative numbers. The straight lines correspond to the estimated seismicity recurrence, and the dotted lines indicate the fit of equation (C1) to the incremental data points.

Number of events

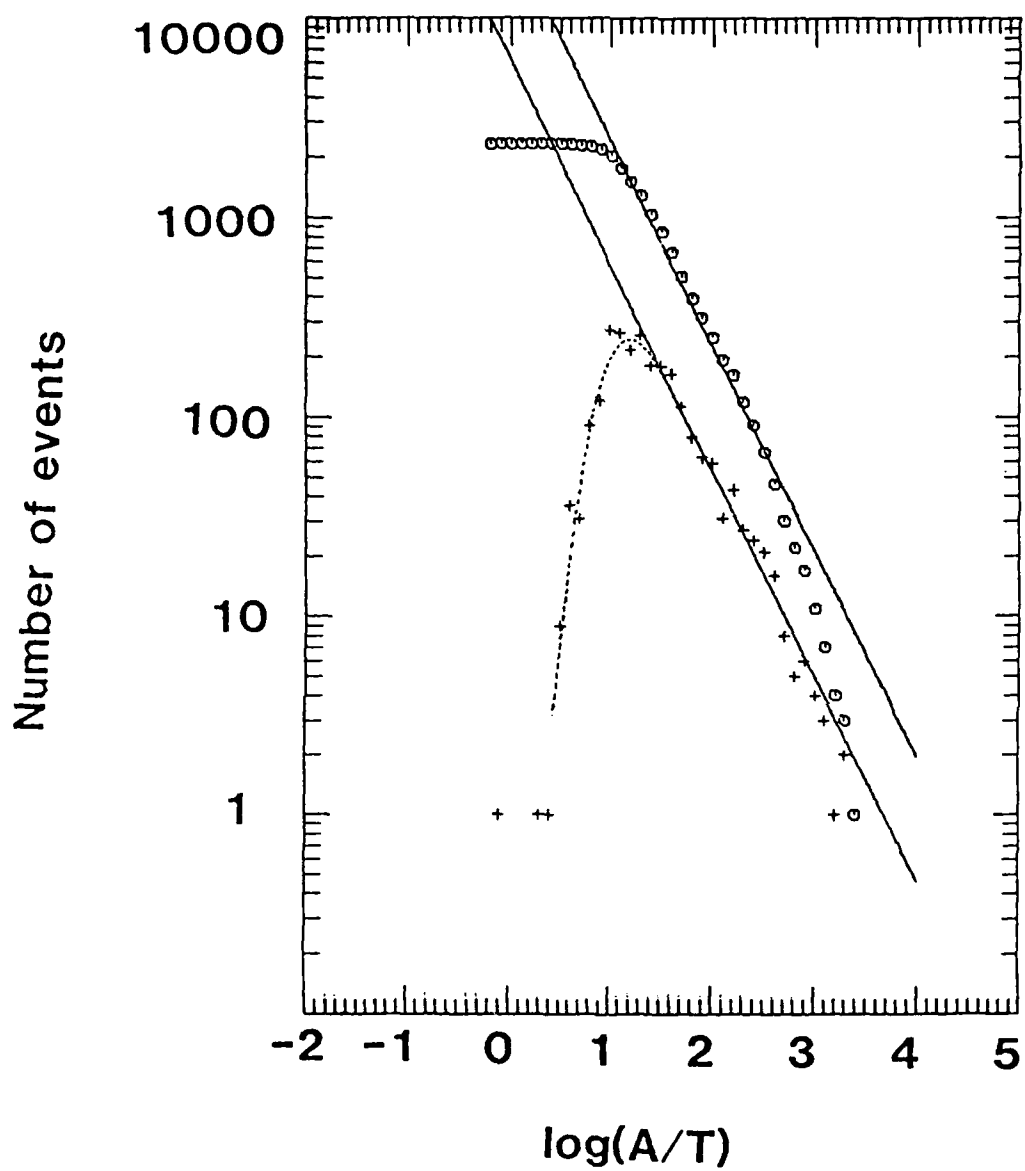


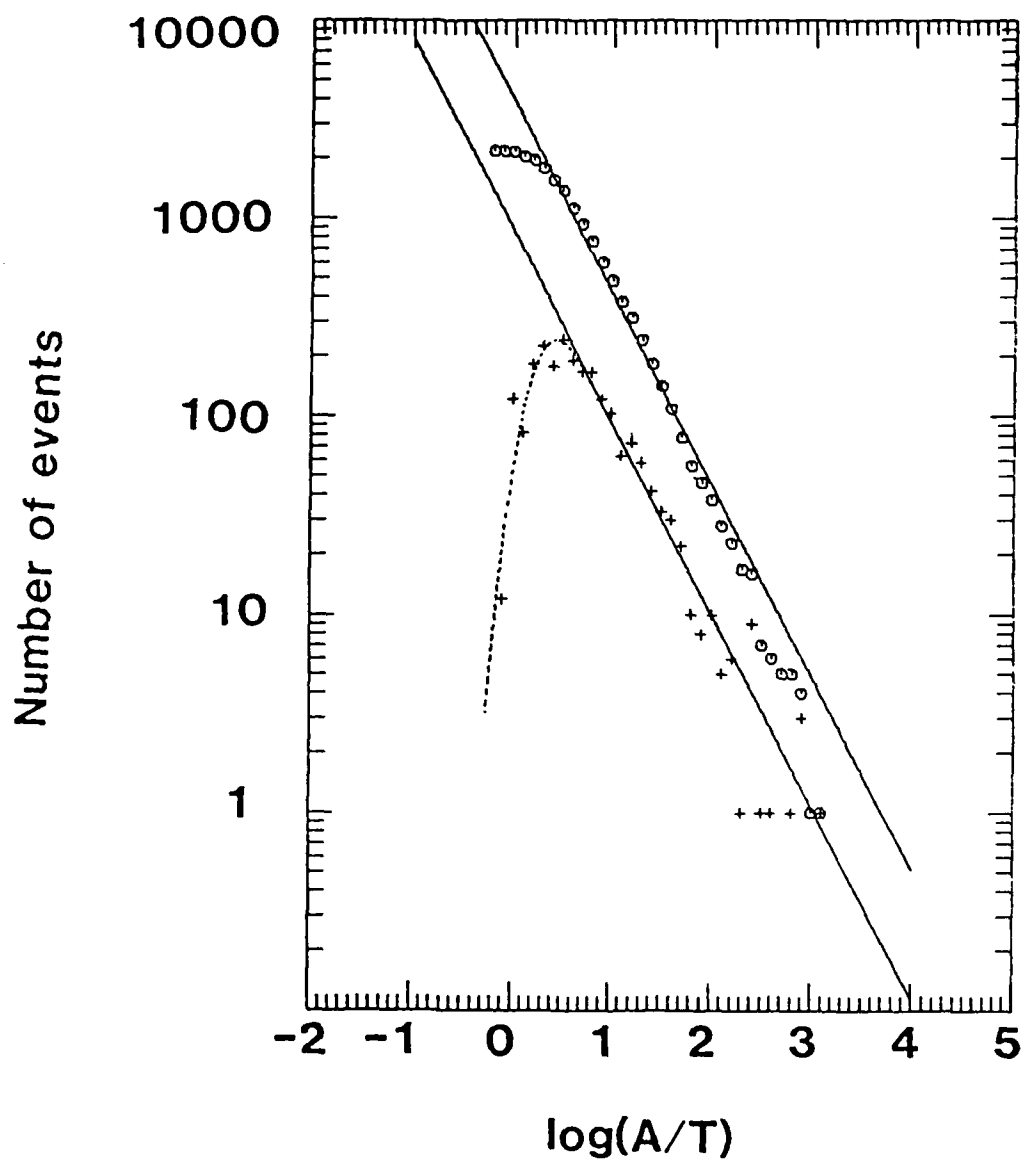
$\log(A/T)$

Station ALQ

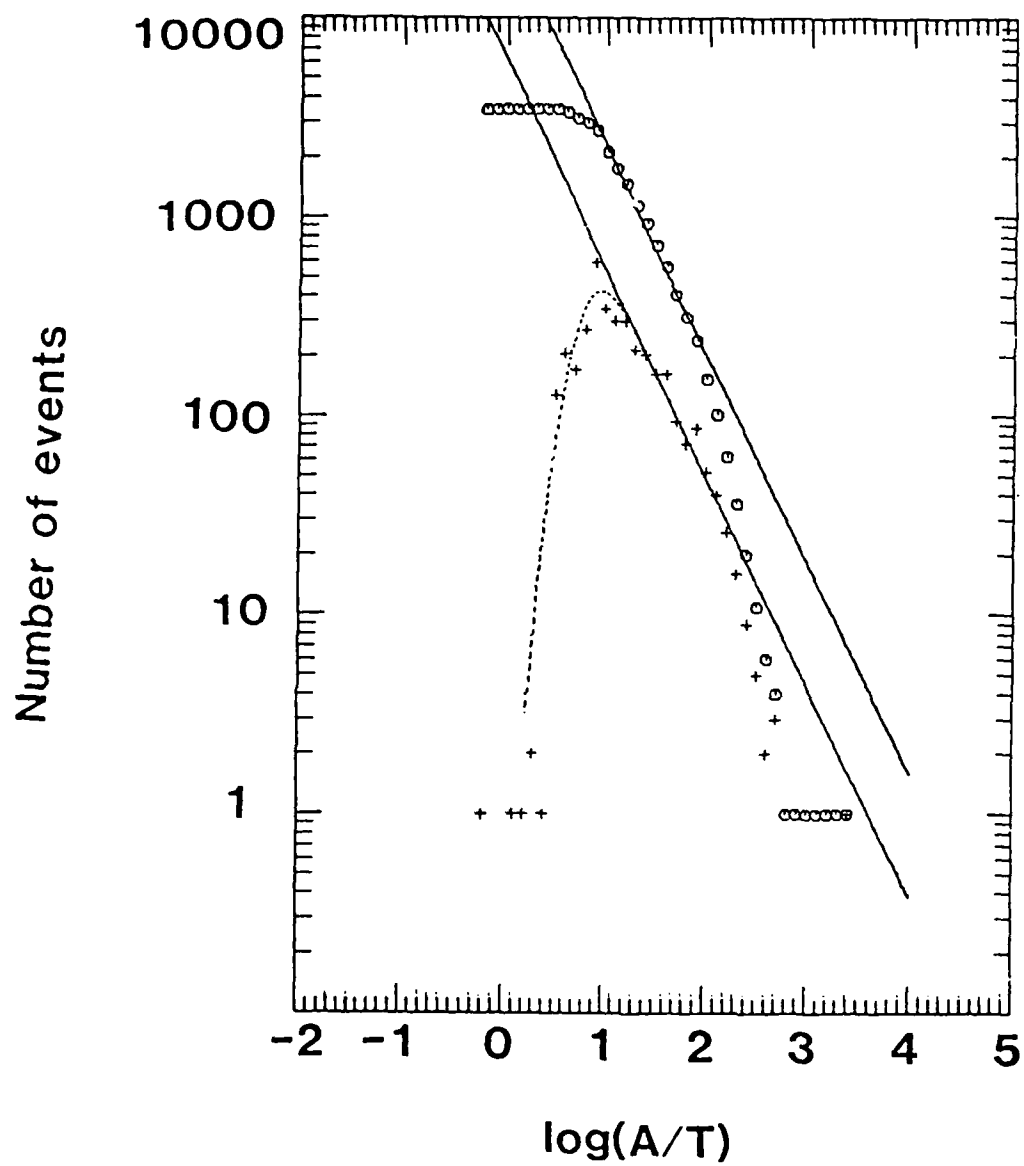


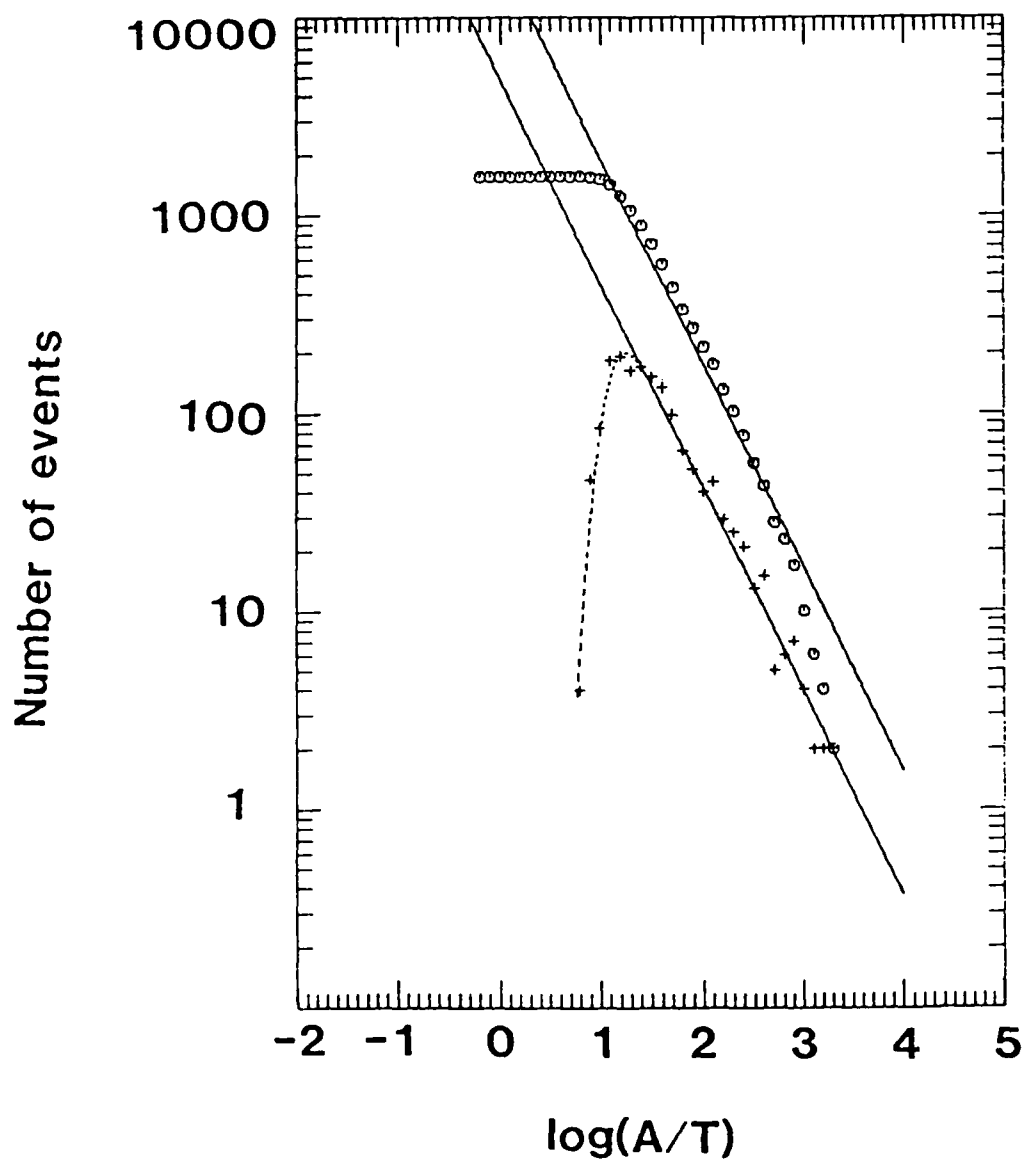
Station ASP



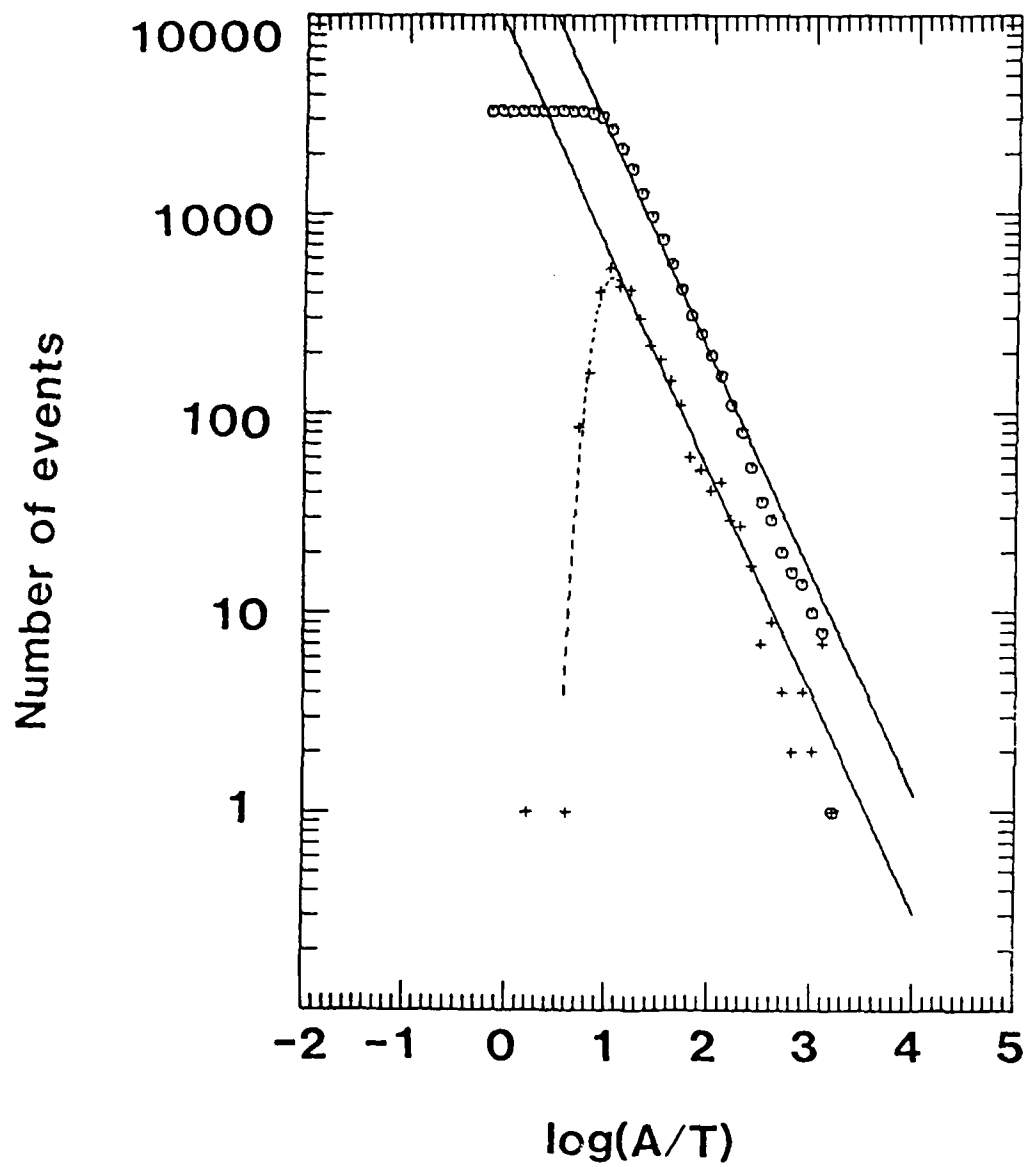


Station BMO





Station BOD



Appendix D

Magnitudes of presumed explosions 1971-1980

In this Appendix, a list is given summarizing some statistics on detection and m_b estimation of presumed explosions in the CSS data base (1971-1980). The estimation procedure described in this paper has been applied to these events, using the subset of the 115 station network in operation at any given time. Note that stations which systematically do not report explosion data have been deleted prior to m_b estimation.

The table contains the following entries, taken from the CSS file unless otherwise specified:

- (1) Origin time
- (2) Latitude, Longitude, depth
- (3) m_b and corresponding number of stations (incomplete in some cases)
- (4) m_b , averaged from the 115 station network; after application of station corrections; corresponding number of stations used and standard deviation of m_b within the network
- (5) Maximum likelihood m_b (115 station network)
- (6) Geographical and seismic region no.
- (7) Number of P arrivals (total)
- (8) Number of reportings by distance for the 115 station network:
 - 0 - 21 degrees
 - 21 - 100 degrees
 - 100 - 180 degrees

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	1	2	3	4	5	6	7	8
1971 322 432571 49.7 78.1	0. 5.7	54 5.65	30 0.32	5.67	329 28212	1 50	7	
1971 323 659561 61.3 56.2	0. 5.5	47 5.54	30 0.39	5.53	335 29203	6 45	10	
1971 425 332571 49.7 78.0	0. 5.9	62 5.85	37 0.27	5.86	329 28236	1 56	7	
1971 525 4 2571 49.8 78.2	0. 5.1	21 5.04	17 0.40	4.94	329 28 75	1 33	1	
1971 6 6 4 2571 49.9 77.7	0. 5.5	43 5.38	28 0.25	5.39	329 28155	1 53	4	
1971 6121914571-23.8-137.1	33. 0.	0 4.54	2 0.	4.58	631 39 14	0 9	2	
1971 6161450 01 37.0-116.0	0. 0.	0 0.	0 0.	3.82	41 3 0	8 1	0	
1971 619 4 3571 49.9 77.7	0. 5.4	52 5.39	36 0.34	5.40	329 28129	1 52	2	
1971 6231530 01 37.0-116.0	0. 0.	0 4.91	1 0.	4.53	41 3 0	10 9	0	
1971 62414 0 01 37.1-116.0	0. 0.	0 4.88	4 0.18	4.62	41 3 0	12 15	4	
1971 6291830 21 37.0-116.2	25. 4.9	5 4.86	3 0.19	4.73	41 3 62	10 16	3	
1971 630 357 21 49.9 79.0	33. 5.2	30 5.18	16 0.38	5.11	329 28115	1 43	1	
1971 7 217 0 11 67.6 61.9	0. 4.7	4 4.83	3 0.44	4.36	335 29 29	5 11	0	
1971 7 814 0 01 37.1-116.0	0. 0.	0 5.44	21 0.31	5.45	41 3 0	12 37	7	
1971 7 81914551 49.9-115.0	0. 0.	0 0.	0 0.	4.00	23 2 15	6 2	0	
1971 7101659591 64.1 54.7	0. 5.2	22 5.20	15 0.28	5.04	724 49104	7 33	0	
1971 720 833441 56.5 0.8	0. 4.3	3 4.42	3 0.54	4.03	534 36 40	12 3	0	
1971 8132059401 49.7-114.6	18. 0.	0 0.	0 0.	0.	23 2 7	3 0	0	
1971 8141859591-21.8-138.9	0. 4.7	6 4.85	6 0.16	4.72	631 39 24	0 12	4	
1971 8181359591 36.9-116.0	3. 5.3	20 5.25	14 0.23	5.16	40 3130	12 28	8	
1971 91911 0 61 57.7 41.4	33. 4.5	6 4.62	5 0.19	4.49	724 49 45	10 13	1	
1971 927 559551 73.3 54.9	0. 6.5	63 6.41	29 0.36	6.41	648 40344	7 53	15	
1971 9291359581 36.9-116.0	0. 0.	0 0.	0 0.	0.	40 3 28	9 0	0	
197110 410 0 21 61.6 47.2	13. 4.6	10 4.75	10 0.28	4.57	724 49 46	6 17	1	
197110 81430 01 37.1-116.0	0. 0.	0 0.	0 0.	3.81	41 3 0	10 1	0	
197110 9 6 2571 49.9 77.6	0. 5.3	46 5.27	30 0.35	5.31	329 28149	1 55	3	
197110141430 21 37.0-115.9	33. 0.	0 0.	0 0.	0.	41 3 18	8 0	0	
19711021 6 2571 50.0 77.6	0. 5.5	49 5.48	32 0.32	5.44	329 28143	0 50	5	
19711022 5 0 01 51.6 54.4	6. 5.2	34 5.26	21 0.19	5.18	724 49116	3 40	2	
197111 622 0 01 51.4 179.1	0. 0.	0 6.68	25 0.34	6.68	6 1 0	3 62	10	
19711129 6 2571 49.7 78.1	0. 5.4	41 5.34	28 0.36	5.27	329 28117	0 45	1	
197111301545 31 37.0-116.1	54. 0.	0 0.	0 0.	3.82	41 3 25	9 2	0	
1971121421 9591 37.1-116.0	0. 0.	0 0.	0 0.	4.40	41 3 0	9 7	0	
19711215 752591 50.0 77.8	0. 4.9	7 4.98	6 0.29	4.51	329 28 31	1 15	0	
19711222 659561 47.9 48.0	0. 6.0	50 5.95	28 0.35	5.96	336 29230	4 50	12	
19711230 620571 49.7 78.1	0. 5.7	56 5.71	34 0.29	5.73	329 28170	1 52	4	
1972 210 5 2571 50.0 78.9	0. 5.4	41 5.43	27 0.32	5.37	329 28151	1 50	6	
1972 3 91845 01 32.7-110.4	0. 4.5	2 0.	0 0.	3.76	495 34 0	5 1	0	
1972 310 456571 49.7 78.1	0. 5.4	54 5.35	35 0.33	5.36	329 28160	0 55	1	
1972 328 421571 49.7 78.1	0. 5.1	35 5.18	23 0.34	5.06	329 28113	0 41	3	
1972 33021 0 31 36.9-116.0	35. 0.	0 0.	0 0.	0.	40 3 13	6 0	0	
1972 411 6 0 21 37.3 62.0	20. 4.9	16 4.97	12 0.22	4.82	340 29 50	2 27	0	
1972 4191632 01 37.1-116.0	0. 0.	0 0.	0 0.	0.	41 3 0	7 0	0	
1972 5 21915 21 37.1-116.2	26. 4.7	8 4.68	5 0.34	4.83	41 3 83	8 28	5	
1972 5171410 01 37.1-116.0	0. 0.	0 0.	0 0.	4.09	41 3 0	7 3	0	
1972 51917 0 01 37.0-116.0	0. 0.	0 0.	0 0.	4.52	41 3 0	10 12	5	
1972 6 7 127571 49.7 78.1	0. 5.4	42 5.35	26 0.38	5.21	329 28147	1 46	1	
1972 61116 7561 57.0 -6.1	0. 0.	0 4.51	3 0.22	4.19	533 36 0	10 5	1	
1972 7 6 1 2581 49.9 77.8	0. 4.4	6 4.46	6 0.36	4.36	329 28 21	1 16	0	
1972 7 9 659571 49.7 35.4	0. 4.8	5 4.77	4 0.13	4.58	357 30 62	12 15	0	
1972 7141459491 49.9 46.3	0. 0.	0 3.71	2 0.	3.63	357 30 6	1 4	0	
1972 7201716 01 37.2-116.1	0. 0.	0 4.90	8 0.19	4.87	41 3 0	10 25	5	
1972 7251330 31 36.9-116.1	21. 0.	0 0.	0 0.	3.78	40 3 17	7 1	0	
1972 816 316571 49.7 78.1	0. 5.0	30 5.04	20 0.26	4.96	329 28 96	1 40	1	
1972 820 259571 49.3 48.0	0. 5.7	46 5.68	28 0.30	5.69	336 29209	4 47	4	
1972 826 346561 49.9 77.8	0. 5.3	37 5.34	21 0.30	5.19	329 28135	1 46	3	

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1	2	3	4	5	6	7	8
1972 828 559561	73.3 54.6	0. 6.3	71 6.27	30 0.31	6.27 648	40333	8 52 16
1972 9 2 856571	49.8 77.6	0. 4.9	10 5.02	8 0.37	4.74 329	28 38	1 27 0
1972 9 4 7 0 41	67.7 33.0	7. 4.6	6 4.79	4 0.30	4.53 724	49 47	11 14 2
1972 921 9 0 11	52.1 51.9	28. 5.0	19 4.97	12 0.26	4.79 724	49 83	4 31 3
1972 9211530 01	37.0-116.0	0. 0.	0 5.52	18 0.25	5.55 41	3 0 11	36 8
1972 9261430 01	37.1-116.0	0. 0.	0 4.00	1 0.	4.11 41	3 0 10	4 1
197210 3 9 0 01	46.9 44.9	0. 0.	0 5.61	31 0.29	5.66 357	30 0	4 52 5
197211 2 126571	49.9 78.8	0. 6.1	75 6.12	38 0.32	6.14 329	28293	1 61 11
19721124 9 0 21	52.1 51.8	33. 4.5	8 4.66	7 0.24	4.47 724	49 40	4 18 1
19721124 959581	51.8 64.1	0. 5.2	37 5.13	27 0.28	5.09 336	29104	1 47 1
19721210 426571	49.7 78.0	0. 5.6	62 5.56	33 0.37	5.59 329	28245	1 54 6
19721210 427 71	49.9 78.9	0. 6.0	26 6.00	15 0.35	5.77 329	28146	0 36 3
197212212015 01	37.1-116.0	0. 0.	0 4.87	5 0.24	4.86 41	3 0 10	22 4
1973 216 5 2571	49.8 78.2	0. 5.5	49 5.46	35 0.34	5.42 329	28162	1 53 4
1973 3 81610 01	37.1-116.0	0. 0.	0 5.24	20 0.16	5.22 41	3 0 11	35 9
1973 419 432571	49.9 77.6	0. 5.4	40 5.32	31 0.32	5.25 329	28140	0 49 3
1973 4252225 01	37.0-116.0	0. 0.	0 4.38	2 0.	4.40 41	3 0 10	9 0
1973 4261715 01	37.1-116.0	0. 0.	0 5.46	19 0.24	5.48 41	3 0 10	41 8
1973 51716 0 01	39.7-108.3	0. 0.	0 5.20	16 0.23	5.19 479	34 0 12	32 2
1973 5241330 21	37.2-116.1	5. 0.	0 0.	0 0.	3.76 41	3 18	8 1 0
1973 6 517 0 01	37.1-116.2	0. 0.	0 4.99	10 0.28	4.90 41	3 0 11	24 5
1973 6 613 0 01	37.2-116.3	0. 0.	0 6.03	27 0.27	6.01 41	3 0 11	39 16
1973 627 359451	40.6 89.6	0. 4.8	14 4.69	10 0.25	4.44 321	27 33	1 16 0
1973 6281915121	37.1-116.0	0. 0.	0 4.89	8 0.10	4.85 41	3 0 11	23 4
1973 710 126581	49.8 78.0	0. 5.2	39 5.23	26 0.35	5.08 329	28130	1 42 0
1973 723 122571	49.9 78.8	0. 6.1	81 6.21	41 0.38	6.21 329	28291	1 64 8
1973 815 159571	42.6 67.4	0. 5.3	47 5.33	28 0.32	5.21 713	48151	3 43 3
1973 828 259571	50.5 68.3	0. 5.2	27 5.14	22 0.29	4.97 713	48 82	2 36 0
1973 912 659541	73.3 54.9	0. 6.8	53 6.67	20 0.45	6.67 648	40399	8 58 17
1973 919 259571	45.6 67.7	0. 5.1	21 4.99	15 0.32	4.96 713	48 98	3 38 0
1973 927 659581	70.8 53.4	0. 5.9	57 5.90	30 0.25	5.91 648	40237	9 51 10
1973 930 459571	51.6 54.5	0. 5.2	43 5.20	30 0.26	5.11 724	49134	2 44 2
1973101217 0 01	37.2-116.1	0. 0.	0 4.68	6 0.18	4.60 41	3 0 7	15 4
19731026 426571	49.7 78.1	0. 5.2	39 5.22	30 0.33	5.11 329	28117	0 44 1
19731026 559571	53.6 55.3	0. 4.8	17 4.86	12 0.33	4.64 335	29 65	3 24 0
19731027 659571	70.7 53.9	0. 6.9	61 6.69	26 0.47	6.69 648	40387	9 52 17
19731027 8 3581	71.0 52.6	0. 4.5	4 4.56	3 0.29	4.02 648	40 13	7 3 0
19731027 821211	70.9 52.5	0. 4.6	5 4.72	4 0.13	4.19 648	40 18	6 6 0
19731027 913511	71.2 51.7	0. 4.6	8 4.92	5 0.19	4.45 648	40 26	7 11 0
197311281530 01	36.9-116.0	5. 0.	0 4.26	2 0.	3.92 40	3 18	8 2 0
1973121219 0 31	36.9-116.0	26. 4.4	3 4.24	2 0.	4.30 40	3 30	8 7 0
19731214 746571	50.0 79.0	0. 5.8	67 5.78	40 0.43	5.80 329	28222	0 64 7
1974 130 456571	49.8 78.0	0. 4.9	13 4.94	10 0.43	4.70 329	28 56	1 25 1
1974 130 457 21	49.8 78.1	0. 5.4	36 5.30	24 0.23	5.14 329	28135	0 43 0
1974 22717 0 01	37.1-116.0	0. 5.8	0 5.58	24 0.27	5.58 41	3 0 13	37 9
1974 516 3 2571	49.7 78.1	0. 5.2	47 5.21	35 0.35	5.20 329	28135	1 52 1
1974 518 234551	26.9 71.7	0. 4.9	14 4.96	13 0.25	4.79 308	26 53	5 21 0
1974 5231338291	37.0-116.1	0. 4.8	13 4.74	9 0.18	4.61 41	3 76	11 16 5
1974 531 326571	49.9 78.9	0. 5.9	83 5.84	47 0.37	5.85 329	28251	0 62 6
1974 617 559521	40.5 89.6	0. 4.5	4 4.49	4 0.10	4.24 321	27 9	1 8 0
1974 61916 0 01	37.1-116.2	5. 4.8	14 4.77	11 0.21	4.77 41	3 97	10 25 4
1974 625 356581	49.9 78.1	0. 4.7	8 4.69	8 0.30	4.42 329	28 28	0 16 0
1974 7 8 559591	53.6 55.0	0. 4.6	11 4.73	7 0.56	4.39 335	29 41	3 15 0
1974 710 256571	49.7 78.1	0. 5.2	47 5.19	33 0.29	5.09 329	28119	1 45 1
1974 71016 0 01	37.0-116.0	0. 5.7	0 5.64	30 0.25	5.62 41	3 0 15	40 11
1974 722 132221	70.7 53.3	0. 4.5	5 4.43	4 0.14	4.00 648	40 17	7 4 0

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	1	2	3	4	5	6	7	8
1974 81414 0 01	37.0-116.0	0. 4.6	0 0.	0 0.	4.01	41	3 0	8 2 0
1974 8141459581	68.9 75.8	0. 5.4	53 5.36	32 0.30	5.23	725	49162	4 44 1
1974 829 959551	73.4 54.9	0. 6.4	67 6.29	30 0.45	6.30	648	40353	8 48 16
1974 8291459581	67.2 62.1	0. 5.0	21 5.04	17 0.26	4.84	335	29 78	6 28 1
1974 83015 0 01	37.1-116.0	0. 5.8	0 5.57	30 0.39	5.55	41	3 0	16 38 7
1974 913 3 2571	49.7 78.0	0. 5.2	40 5.11	30 0.29	5.00	329	28 97	0 41 1
1974 92514 0 01	36.9-116.0	5. 0.	0 4.14	2 0.	3.98	40	3 18	7 3 0
1974 92615 5 01	37.1-116.0	0. 5.6	0 5.37	20 0.27	5.26	41	3 0	15 33 6
19741016 632571	49.9 78.9	0. 5.5	63 5.50	35 0.42	5.52	329	28171	0 56 3
197411 2 459561	70.8 53.9	0. 6.4	87 6.43	28 0.48	6.43	648	40402	9 54 17
197412 7 559561	49.9 77.6	0. 4.7	4 4.67	4 0.29	4.27	329	28 23	1 12 0
19741216 622571	49.8 78.0	0. 5.0	26 4.99	23 0.34	4.89	329	28 70	1 38 0
19741216 640571	49.8 78.1	0. 4.8	24 4.86	18 0.42	4.72	329	28 71	1 31 0
197412161730 01	36.8-115.9	5. 0.	0 4.23	1 0.	3.93	40	3 17	5 2 0
19741227 546561	49.9 79.0	0. 5.6	60 5.56	41 0.36	5.59	329	28181	0 59 2
1975 220 532571	49.7 78.0	0. 5.7	70 5.58	40 0.38	5.60	329	28193	0 55 1
1975 2281515 01	37.1-116.0	0. 0.	0 5.55	27 0.23	5.55	41	3 0	16 36 12
1975 3 715 0 01	37.1-116.0	0. 0.	0 5.44	26 0.22	5.37	41	3 0	15 33 6
1975 311 542571	49.7 78.2	0. 5.4	56 5.34	38 0.33	5.31	329	28146	0 54 0
1975 31721 6 71	50.2-114.8	0. 0.	0 4.01	1 0.	3.67	24	2 15	8 1 0
1975 4 51945 01	37.1-116.2	0. 0.	0 4.79	17 0.21	4.81	41	3 0	13 26 2
1975 4241410 01	37.1-116.0	0. 0.	0 4.46	6 0.17	4.31	41	3 0	11 8 0
1975 425 5 0 21	48.0 47.2	0. 4.7	6 4.70	6 0.24	4.32	336	29 24	3 11 0
1975 427 536571	49.9 79.0	0. 5.6	71 5.56	41 0.43	5.58	329	28210	0 60 3
1975 43015 0 01	37.1-116.0	0. 0.	0 4.93	14 0.22	4.93	41	3 0	17 29 4
1975 51414 0 01	37.2-116.4	0. 0.	0 5.82	29 0.24	5.82	41	3 0	15 39 12
1975 6 31420 01	37.3-116.5	0. 0.	0 5.67	28 0.23	5.69	41	3 0	14 38 11
1975 6 31440 01	37.0-116.0	0. 0.	0 5.49	29 0.30	5.44	41	3 0	10 36 8
1975 6 8 326571	49.7 78.0	0. 5.5	61 5.42	38 0.44	5.35	329	28168	1 52 2
1975 61913 0 01	37.3-116.3	0. 0.	0 5.80	28 0.40	5.80	41	3 0	13 37 15
1975 6261230 01	37.2-116.3	0. 0.	0 6.04	27 0.26	6.03	41	3 0	13 36 20
1975 630 326571	49.9 78.9	0. 5.0	15 5.04	10 0.32	4.62	329	28 38	0 19 0
1975 8 7 356571	49.8 78.2	0. 5.2	41 5.13	26 0.38	4.98	329	28118	1 40 0
1975 823 859571	73.3 54.5	0. 6.3	83 6.27	32 0.38	6.31	648	40387	9 55 16
1975 9 617 0 01	37.0-116.0	0. 0.	0 4.39	2 0.	4.23	41	3 0	9 5 1
1975 9291059581	69.6 90.4	0. 4.8	15 4.82	13 0.35	4.68	726	49 55	0 29 1
19751018 859561	70.8 53.5	0. 6.7	67 6.47	24 0.42	6.43	648	40434	9 51 17
197510211159571	73.3 54.9	0. 6.6	66 6.41	25 0.33	6.36	648	40369	9 46 12
197510241711261	37.2-116.1	0. 0.	0 4.78	10 0.35	4.68	41	3 0	10 20 2
19751027 059591	41.4 88.4	7. 5.0	28 4.99	12 0.26	4.67	321	27 58	1 21 2
197510281430 01	37.2-116.4	0. 0.	0 6.06	26 0.30	6.02	41	3 0	14 34 22
19751029 446571	49.9 78.9	0. 5.8	64 5.68	32 0.38	5.69	329	28215	0 44 4
1975112015 0 01	37.2-116.3	0. 0.	0 5.78	24 0.25	5.74	41	3 0	14 31 17
197511261530 01	37.1-116.0	0. 0.	0 4.40	1 0.	3.96	41	3 0	4 2 0
19751213 456571	49.8 78.2	0. 5.1	43 5.05	26 0.28	4.93	329	28 84	0 39 0
1975122020 0 01	37.1-116.0	0. 0.	0 5.53	20 0.28	5.52	41	3 0	17 32 12
19751225 516571	50.0 78.8	0. 5.7	70 5.72	36 0.41	5.73	329	28241	0 61 2
1976 1 31915 01	37.3-116.3	0. 0.	0 6.04	28 0.21	6.02	41	3 0	15 39 23
1976 115 446571	49.8 78.2	0. 5.2	48 5.13	28 0.33	5.06	329	28109	1 47 1
1976 2 41420 01	37.0-116.0	0. 0.	0 5.58	22 0.24	5.58	41	3 0	14 31 13
1976 2 41440 01	37.1-116.0	0. 0.	0 5.58	21 0.26	5.56	41	3 0	15 32 10
1976 2121445 01	37.2-116.4	0. 0.	0 5.95	28 0.35	5.93	41	3 0	15 38 23
1976 2141130 01	37.2-116.4	0. 0.	0 5.67	24 0.26	5.65	41	3 0	11 30 11
1976 2261450 31	36.8-115.9	29. 0.	0 4.33	1 0.	3.81	40	3 22	6 1 0
1976 3 914 0 01	37.3-116.3	0. 0.	0 5.70	29 0.30	5.68	41	3 0	14 37 16
1976 3141230 01	37.3-116.4	0. 0.	0 6.08	26 0.26	6.06	41	3 0	15 39 22

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	1	2	3	4	5	6	7	8
1976 3171415 01	37.2-116.3	0. 0.	0 5.86	23 0.34	5.81	41 3 0	13 32 17	
1976 3171445 01	37.1-116.0	0. 0.	0 5.72	22 0.26	5.71	41 3 0	10 30 16	
1976 320 4 3391	50.0 77.3	0. 5.1	45 5.09	22 0.29	4.92	329 28128	1 39 1	
1976 421 457571	49.8 78.1	0. 5.1	42 5.08	22 0.29	4.87	329 28 77	0 35 0	
1976 421 5 2571	49.8 78.8	0. 5.3	70 5.37	36 0.38	5.19	329 28125	0 45 0	
1976 5121950 11	37.1-116.2	16. 4.7	14 4.72	9 0.30	4.66	41 3 85	10 19 5	
1976 519 256581	49.8 77.9	0. 5.0	28 4.94	12 0.46	4.65	329 28 47	0 24 0	
1976 6 9 3 2571	49.9 79.0	0. 5.3	47 5.31	28 0.29	5.17	329 28146	0 44 1	
1976 7 4 256571	49.8 78.9	0. 5.8	83 5.88	37 0.53	5.88	329 28249	0 55 5	
1976 711 029571	22.0-138.7	0. 5.0	9 5.19	6 0.14	4.74	631 39 55	0 10 11	
1976 723 232581	49.8 78.0	0. 5.1	49 5.07	24 0.24	4.87	329 28100	2 36 0	
1976 7272030 01	37.0-116.0	0. 0.	0 5.30	16 0.24	5.07	41 3 0	7 26 6	
1976 729 459571	47.8 48.1	0. 5.9	92 5.84	36 0.33	5.83	336 29297	5 49 7	
1976 8261430 01	37.1-116.0	0. 0.	0 5.15	18 0.26	4.99	41 3 0	10 26 5	
1976 828 256571	49.9 78.9	0. 5.8	82 5.77	33 0.38	5.74	329 28234	2 45 3	
1976 929 259571	73.4 54.5	0. 5.8	82 5.78	29 0.35	5.78	648 40298	9 48 8	
19761017 5 0 31	41.6 88.2	33. 4.9	18 5.00	13 0.23	4.78	321 27 56	4 28 1	
19761020 759571	73.4 54.4	0. 5.1	39 5.05	12 0.29	4.81	648 40115	8 29 2	
19761030 457 21	49.9 78.2	33. 4.9	15 4.70	8 0.20	4.39	329 28 33	0 18 0	
197611 5 359561	61.5 112.7	0. 5.3	43 5.13	24 0.34	5.02	726 49107	0 45 1	
19761117 6 0171	40.7 89.6	33. 4.6	8 4.66	4 0.31	4.31	321 27 25	0 13 0	
19761123 5 2571	49.9 79.0	0. 5.8	93 5.85	38 0.30	5.86	329 28278	2 62 4	
197611231514591	37.1-116.0	0. 0.	0 0.	0 0.	0.	41 3 17	4 0 0	
197612 7 456571	49.8 78.8	0. 5.9	76 5.90	31 0.43	5.90	329 28252	2 53 4	
197612 81449301	37.0-116.0	0. 0.	0 4.78	3 0.23	4.42	41 3 0	9 8 2	
1976122115 9 01	37.1-116.0	0. 0.	0 0.	0 0.	3.83	41 3 0	6 1 0	
1976122818 0 01	37.1-116.0	0. 0.	0 5.39	23 0.22	5.18	41 3 0	16 29 9	
19761230 356571	49.8 78.1	0. 5.2	40 5.10	25 0.29	4.90	329 28 78	1 37 0	
1977 2161752591	37.0-116.0	0. 4.6	3 4.49	2 0.	4.31	41 3 43	6 7 0	
1977 2192329571	22.1-138.7	0. 5.2	9 5.14	6 0.29	4.86	631 39 65	0 14 6	
1977 31923 0581	21.8-138.9	0. 5.8	39 5.68	23 0.41	5.70	631 39222	0 37 21	
1977 329 356571	49.7 78.1	0. 5.4	60 5.31	36 0.32	5.24	329 28172	0 51 2	
1977 4 515 0 01	37.1-116.0	0. 0.	0 5.57	26 0.25	5.59	41 3 0	13 36 11	
1977 425 4 6581	49.8 78.1	0. 5.1	46 5.15	19 0.34	4.90	329 28 92	1 34 0	
1977 42715 0 01	37.0-116.0	0. 0.	0 5.31	23 0.21	5.25	41 3 0	12 34 10	
1977 5251659591	37.0-116.0	0. 5.3	58 5.24	28 0.25	5.24	41 3205	13 37 8	
1977 529 256571	49.8 78.8	0. 5.8	97 5.80	47 0.44	5.79	329 28304	1 59 4	
1977 629 3 6571	49.9 78.9	0. 5.3	69 5.31	29 0.33	5.13	329 28174	1 43 1	
1977 7 62259551	22.3-139.0	0. 5.2	4 5.18	3 0.20	4.66	631 39 36	0 8 6	
1977 7261659571	69.5 90.5	0. 5.0	44 5.08	25 0.34	4.96	726 49112	0 43 1	
1977 730 156571	49.7 78.0	0. 5.1	58 5.18	24 0.26	4.96	329 28118	1 37 1	
1977 8 41640 01	37.0-116.0	0. 0.	0 5.12	19 0.15	5.03	41 3 0	12 29 9	
1977 817 426571	49.8 78.1	0. 5.1	35 5.03	18 0.18	4.81	329 28 81	0 33 0	
1977 8191755 01	37.1-116.0	0. 0.	0 5.34	25 0.65	5.37	41 3 0	11 34 11	
1977 8202159581	64.1 99.6	0. 5.0	52 5.02	28 0.37	4.88	726 49133	0 40 2	
1977 9 1 259571	73.3 54.4	0. 5.7	83 5.68	31 0.38	5.69	648 40313	10 46 8	
1977 9 5 3 2571	50.0 78.9	0. 5.8	97 5.88	43 0.30	5.89	329 28322	1 58 5	
1977 9151436301	37.0-116.0	0. 0.	0 4.41	1 0.	4.10	41 3 0	5 3 0	
1977 92714 0 01	37.1-116.0	0. 0.	0 4.85	13 0.23	4.73	41 3 0	9 21 5	
1977 930 659551	47.8 48.1	0. 5.0	43 5.11	18 0.32	5.01	336 29136	4 39 2	
197710 91059581	73.4 53.9	0. 4.6	28 4.75	12 0.31	4.60	648 40 69	9 21 0	
197710261415 01	37.1-116.0	0. 0.	0 4.21	1 0.	3.77	41 3 0	9 1 0	
19771029 3 6571	49.7 78.1	0. 5.6	68 5.53	27 0.34	5.62	329 28248	1 56 2	
19771029 3 7 31	50.0 78.8	0. 5.6	53 5.78	19 0.33	5.39	329 28162	0 32 4	
197711 118 6 01	37.1-116.2	0. 0.	0 6.34	1 0.	4.18	41 3 0	3 1 1	
197711 922 0 01	37.0-116.0	0. 0.	0 5.76	21 0.24	5.79	41 3 0	9 28 10	

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1	2	3	4	5	6	7	8
197711171930 01 37.0-116.0	0. 0.	0 4.56	3 0.13	4.39	41 3 0	9 8 1	
197711241659581-21.8-138.9	0. 6.0	16 5.92	10 0.25	5.32	631 39161	0 19 22	
19771130 4 6571 49.9 78.8	0. 6.0	90 5.91	41 0.35	5.91	329 28298	1 63 2	
197712141530 01 37.1-116.0	0. 0.	0 5.72	26 0.24	5.76	41 3 0	10 34 13	
19771226 4 2571 49.8 78.1	0. 4.9	38 4.88	15 0.21	4.61	329 28 69	1 25 0	
1978 2132152591 37.0-115.9	2. 0.	0 3.72	1 0.	3.56	41 3 17	6 1 0	
1978 22317 0 01 37.1-116.0	0. 0.	0 5.61	29 0.21	5.63	41 3 0	11 34 11	
1978 31615 0 01 37.0-116.1	2. 4.0	1 3.82	1 0.	3.61	41 3 22	6 1 0	
1978 319 346571 49.9 77.7	0. 5.2	53 5.20	24 0.30	5.04	329 28130	0 43 1	
1978 3221729571-21.9-138.7	0. 4.8	4 4.90	3 0.36	4.56	631 39 16	0 8 2	
1978 3231630 01 37.1-116.0	0. 0.	0 5.56	28 0.22	5.57	41 3 0	12 34 14	
1978 326 356571 49.7 78.0	0. 5.6	98 5.57	47 0.34	5.57	329 28261	1 60 3	
1978 4111530 01 37.3-116.3	0. 0.	0 5.23	25 0.40	5.23	41 3 0	11 34 11	
1978 4111745 01 37.2-116.3	0. 0.	0 5.41	26 0.25	5.40	41 3 0	10 35 11	
1978 422 3 6571 49.7 78.1	0. 5.3	83 5.25	38 0.29	5.27	329 28185	1 58 0	
1978 529 456571 49.8 78.1	0. 4.7	35 4.71	15 0.28	4.51	329 28 55	0 22 0	
1978 611 256571 49.8 78.8	0. 5.9	92 5.90	42 0.46	5.91	329 28297	0 61 4	
1978 7 5 246571 49.8 78.9	0. 5.8	96 5.88	45 0.38	5.88	329 28300	2 65 6	
1978 7 71359591 37.0-116.0	2. 4.0	1 3.82	1 0.	3.61	41 3 31	7 1 1	
1978 71217 0 01 37.0-116.0	0. 0.	0 5.59	28 0.25	5.62	41 3 0	11 37 8	
1978 728 246571 49.7 78.1	0. 5.7	90 5.61	37 0.31	5.63	329 28238	1 54 2	
1978 8 91759581 63.6 125.3	0. 5.6	89 5.56	37 0.21	5.61	726 49239	0 60 4	
1978 810 759571 73.3 54.6	0. 5.9	92 5.84	35 0.36	5.84	648 40328	9 51 10	
1978 82418 0 31 65.8 112.5	49. 5.1	65 5.14	27 0.33	4.99	726 49147	0 41 0	
1978 829 236571 49.8 78.1	0. 5.2	61 5.27	25 0.56	5.13	329 28154	2 44 2	
1978 829 237 61 49.9 79.0	0. 5.9	80 5.89	30 0.30	5.89	329 28271	0 46 6	
1978 83114 0 01 37.2-116.3	0. 0.	0 5.47	35 0.25	5.48	41 3 0	10 38 11	
1978 9131515 01 37.2-116.2	0. 0.	0 4.75	7 0.16	4.39	41 3 0	10 9 1	
1978 915 236571 49.9 78.9	0. 6.0	100 6.01	38 0.38	6.01	329 28299	2 53 3	
1978 9211459571 66.5 86.2	0. 5.2	70 5.18	27 0.34	5.09	726 49168	0 47 0	
1978 927 2 4581 73.3 54.4	0. 5.6	86 5.61	33 0.39	5.62	648 40273	7 47 8	
1978 92717 0 01 37.0-116.0	0. 0.	0 5.18	15 0.24	4.96	41 3 0	12 21 7	
1978 9271720 01 37.0-116.0	0. 0.	0 5.76	28 0.24	5.78	41 3 0	10 34 13	
197810 72359561 61.5 112.8	0. 5.2	57 5.25	17 0.30	4.93	726 49134	0 37 0	
19781015 536571 49.7 78.2	0. 5.2	71 5.12	30 0.27	4.96	329 28139	2 39 1	
19781017 459561 47.8 48.0	0. 5.8	101 5.91	35 0.34	5.93	336 29330	5 51 14	
197810171359581 63.2 63.2	0. 5.5	90 5.53	37 0.36	5.59	335 29266	4 53 2	
19781031 416571 49.7 78.1	0. 5.2	82 5.19	37 0.30	5.15	329 28151	1 52 0	
197811 21525 01 37.2-116.2	0. 0.	0 3.81	1 0.	3.61	41 3 0	10 1 0	
197811 4 5 5571 50.0 78.9	0. 5.6	106 5.67	45 0.37	5.69	329 28277	2 62 6	
1978111819 0 01 37.1-116.0	0. 0.	0 5.24	18 0.19	5.15	41 3 0	13 28 8	
19781129 432581 49.8 78.0	0. 5.3	75 5.32	37 0.46	5.27	329 28182	1 53 2	
19781129 433 21 49.9 78.7	0. 6.0	82 5.99	37 0.36	6.00	329 28226	0 44 2	
197811301731581-21.8-138.9	0. 5.8	37 5.69	21 0.38	5.71	631 39220	0 33 25	
19781214 442571 49.9 78.2	0. 4.8	18 4.70	11 0.18	4.41	329 28 33	0 17 0	
197812161530 01 37.2-116.4	0. 0.	0 5.44	23 0.25	5.41	41 3 0	13 33 8	
19781218 759561 47.7 48.1	0. 5.9	105 5.98	42 0.30	5.99	336 29346	5 51 12	
197812191656591-21.8-138.9	0. 4.9	9 5.08	7 0.41	4.76	631 39 43	0 12 6	
19781220 432571 49.8 78.2	0. 4.7	28 4.69	9 0.24	4.42	329 28 49	0 17 0	
1979 117 759551 47.8 48.0	0. 6.0	102 5.95	39 0.31	5.95	336 29301	4 49 10	
1979 12418 0 01 37.1-116.0	0. 0.	0 4.39	3 0.18	4.13	41 3 0	8 4 0	
1979 2 1 412571 50.0 78.8	0. 5.4	93 5.47	39 0.36	5.38	329 28179	1 51 1	
1979 2 820 0 01 37.1-116.0	0. 5.5	0 5.52	28 0.23	5.54	41 3 192	8 34 10	
1979 21518 5 01 37.1-116.0	0. 4.8	0 4.87	13 0.39	4.76	41 3 73	13 21 5	
1979 216 4 3581 49.9 77.7	0. 5.4	72 5.39	34 0.38	5.28	329 28154	1 50 1	
1979 3141829591 37.0-116.0	0. 4.4	2 4.34	2 0.	4.07	41 3 30	6 3 0	

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	1	2	3	4	5	6	7	8
1979 3241627581-21.8-139.0	0. 4.9	9 5.02	6 0.27	4.77	631	39 58	0 12 12	
1979 4 418 6581-22.0-138.6	0. 4.7	6 4.87	6 0.37	4.55	631	39 23	0 8 5	
1979 5 6 316571 49.7 78.1	0. 5.2	78 5.15	31 0.33	5.03	329	28139	2 44 0	
1979 5111559591 36.9-116.0	0. 0.	0 0.	0 0.	3.85	40	3 40	6 1 0	
1979 531 554571 49.8 78.1	0. 5.3	71 5.18	30 0.39	5.04	329	28134	2 44 0	
1979 61114 0 01 37.2-116.4	0. 0.	0 5.46	26 0.26	5.36	41	3 0	10 31 10	
1979 6182326581-22.0-138.6	0. 4.7	3 4.74	2 0.	4.52	631	39 21	0 7 5	
1979 62015 0131 37.1-116.0	0. 0.	0 3.91	1 0.	3.67	41	3 0	6 1 0	
1979 623 256591 49.8 78.9	0. 6.2	121 6.20	50 0.41	6.20	329	28373	2 66 7	
1979 6281444 01 37.1-116.0	0. 0.	0 5.19	21 0.22	5.18	41	3 0	7 31 6	
1979 6291855581-21.8-138.9	0. 5.4	7 5.27	5 0.30	4.93	631	39 66	0 16 11	
1979 7 7 346571 50.0 79.0	0. 5.8	109 5.88	43 0.39	5.89	329	28315	1 62 6	
1979 714 459551 47.8 48.0	0. 5.6	92 5.68	41 0.36	5.69	336	29298	5 52 5	
1979 718 317 21 49.9 77.8	0. 5.2	58 5.18	28 0.40	5.10	329	28132	2 48 0	
1979 7251756581-21.8-139.0	0. 6.0	46 5.91	21 0.46	5.93	631	39318	0 39 32	
1979 7281955581-21.8-138.8	0. 4.4	2 4.60	2 0.	4.72	631	39 27	0 12 3	
1979 8 315 7301 37.0-116.0	0. 0.	0 4.78	11 0.20	4.66	41	3 0	9 17 1	
1979 8 4 356571 49.8 78.9	0. 6.1	137 6.17	46 0.41	6.16	329	28369	2 64 6	
1979 8 815 0 01 37.0-116.0	0. 0.	0 4.84	8 0.14	4.63	41	3 0	12 14 3	
1979 8121759571 61.8 122.2	0. 4.9	42 4.96	21 0.28	4.86	726	49119	0 40 1	
1979 818 251571 49.9 78.9	0. 6.1	135 6.11	54 0.38	6.10	329	28370	2 66 6	
1979 82915 8 01 37.1-116.0	0. 0.	0 4.90	10 0.20	4.70	41	3 0	10 16 3	
1979 9 615 0 01 37.0-116.0	0. 0.	0 5.78	26 0.24	5.80	41	3 0	13 35 14	
1979 9 61759571 64.0 99.6	0. 4.9	50 4.98	24 0.44	4.86	726	49115	0 41 1	
1979 924 329581 73.3 54.5	0. 5.7	109 5.68	33 0.34	5.70	648	40322	8 48 10	
1979 92615 0 01 37.2-116.3	0. 0.	0 5.41	22 0.37	5.24	41	3 0	12 28 10	
1979 927 412571 49.7 78.0	0. 4.5	19 4.59	6 0.35	4.27	329	28 30	0 13 0	
197910 41559581 60.6 71.4	0. 5.4	82 5.43	38 0.29	5.30	725	49206	2 51 2	
197910 72059571 61.8 113.1	0. 5.0	41 5.00	19 0.28	4.90	726	49110	0 42 0	
19791018 416571 49.8 78.1	0. 5.2	61 5.11	21 0.23	4.82	329	28105	2 30 0	
19791018 7 9581 73.3 54.7	0. 5.8	93 5.68	31 0.37	5.67	648	40303	9 41 8	
19791024 559561 47.7 48.1	0. 5.8	107 5.77	39 0.36	5.79	336	29315	5 52 7	
19791028 316571 49.9 79.0	0. 6.0	127 5.96	46 0.38	5.97	329	28326	1 64 4	
1979112915 0 01 36.9-116.0	0. 3.8	0 3.71	1 0.	3.56	40	3 12	2 1 0	
19791130 452571 49.8 78.2	0. 4.5	20 4.66	8 0.41	4.52	329	28 41	0 22 0	
197912 2 436571 49.8 78.8	0. 6.0	118 6.06	42 0.48	6.08	329	28298	2 61 5	
19791221 441571 49.8 78.2	0. 4.7	20 4.64	8 0.14	4.43	329	28 36	1 16 0	
19791223 456571 49.9 78.7	0. 6.2	116 6.17	40 0.39	6.18	329	28304	2 53 4	
1980 22815 0 01 37.1-116.0	0. 4.4	0 4.37	2 0.	4.07	41	3 21	7 3 0	
1980 3 81535 01 37.1-116.0	0. 3.9	0 3.81	1 0.	3.62	41	3 23	4 1 0	
1980 3231936581-21.8-138.9	0. 5.7	20 5.61	15 0.29	5.66	631	39153	0 28 21	
1980 4 11930581-21.7-138.8	0. 5.1	8 5.09	5 0.34	4.89	631	39 65	0 15 15	
1980 4 314 0 01 37.1-116.0	0. 4.7	0 5.05	10 0.35	4.85	41	3 80	9 20 4	
1980 4 4 532571 49.9 77.8	0. 4.9	26 4.89	11 0.47	4.65	329	28 58	1 24 0	
1980 4 41832571-22.1-138.6	0. 4.5	2 4.60	1 0.	4.52	631	39 15	0 6 3	
1980 410 4 6571 49.8 78.0	0. 5.0	47 5.00	22 0.35	4.75	329	28105	5 35 0	
1980 41620 0 01 37.1-116.0	0. 5.3	0 5.31	22 0.33	5.26	41	3165	11 32 7	
1980 425 356571 49.9 78.8	0. 5.5	103 5.54	43 0.42	5.59	329	28225	2 59 2	
1980 42617 0 01 37.2-116.4	0. 5.4	0 5.47	23 0.30	5.42	41	3208	13 33 9	
1980 5 21846301 37.0-116.0	0. 4.4	0 4.45	3 0.11	4.14	41	3 35	8 4 0	
1980 522 356571 49.7 78.1	0. 5.5	75 5.40	38 0.43	5.27	329	28176	2 51 1	
1980 612 326571 49.9 79.0	0. 5.6	91 5.64	40 0.42	5.66	329	28242	2 52 5	
1980 6121715 01 37.2-116.4	0. 5.6	0 5.50	28 0.31	5.54	41	3201	10 33 13	
1980 6161826581-21.8-138.9	0. 5.4	16 5.33	10 0.28	5.06	631	39 81	0 18 12	
1980 6241510 01 37.0-116.0	0. 4.4	0 4.41	1 0.	4.10	41	3 26	6 4 0	
1980 629 232571 49.9 78.8	0. 5.7	88 5.84	35 0.37	5.86	329	28228	2 52 4	

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	1	2	3	4	5	6	7	8
1980 7 61726591-21.7-138.9	0.	4.6	4	4.45	2	0.	4.41	631 39 17 0 5 4
1980 7192346581-21.8-139.0	0.	5.8	30	5.69	19	0.37	5.73	631 39184 0 33 23
1980 72519 5 01 37.2-116.4	0.	5.5	0	5.45	25	0.23	5.32	41 3178 10 31 8
1980 731 332571 49.8 78.1	0.	5.3	77	5.26	34	0.34	5.17	329 28158 1 48 1
1980 7311819 01 37.0-116.0	0.	4.3	0	4.21	1	0.	3.96	41 3 23 6 2 0
1980 914 242391 49.9 78.8	0.	6.2	104	6.15	42	0.40	6.13	329 28362 2 63 7
1980 925 621101 49.8 78.0	0.	4.7	32	4.67	10	0.21	4.40	329 28 55 1 17 0
1980 9251445 01 37.0-116.0	0.	4.6	0	4.52	2	0.	4.10	41 3 27 8 3 0
198010 8 559571 46.7 48.2	0.	5.2	62	5.30	25	0.30	5.05	357 30142 4 34 4
19801011 7 9571 73.3 54.8	0.	5.7	87	5.69	26	0.28	5.70	648 40297 8 38 9
19801012 334141 49.9 79.1	0.	5.9	118	5.90	44	0.34	5.91	329 28320 2 58 4
198010241915 01 37.0-115.9	0.	4.4	0	4.57	1	0.	3.86	41 3 26 8 1 0
1980103118 0 01 37.2-116.2	0.	4.7	0	4.81	7	0.20	4.65	41 3 77 10 16 5
198011 11259581 60.7 97.5	0.	5.2	59	5.21	33	0.37	5.11	726 49153 0 50 1
198011141650 01 37.1-116.0	0.	4.1	0	0.	0	0.	3.84	41 3 24 8 1 0
198012 31732581-21.8-138.9	0.	5.6	22	5.61	11	0.31	5.55	631 39146 0 23 15
19801210 659571 61.7 66.7	0.	4.6	14	4.72	8	0.26	4.53	725 49 47 3 20 0
19801214 347 61 49.8 78.9	0.	5.9	115	5.99	39	0.45	6.00	329 28307 1 54 3
198012171510 01 37.3-116.3	0.	5.1	0	5.13	13	0.21	4.82	41 3 94 7 19 3
19801226 4 7 71 49.9 78.0	0.	4.5	5	4.46	5	0.40	4.30	329 28 19 0 13 0
19801227 4 9 81 50.0 79.0	0.	5.9	90	5.88	44	0.45	5.88	329 28259 1 59 3

Appendix E

Data file formats

This Appendix specifies the formats of data files developed for the purpose of this study. These files are available at the CSS.

Magnitude Data Files 1971-1980.

1. Station file (115 station network).

This file, named 'glnet.115', contains 115 records, each of which is formatted as follows:

Byte:	Format:	Contents:
1-4	i4	Station No.
5	ix	
6-9	a4	Station Code (ISC)
10-15	f6.2	Station threshold G (in terms of $\log(A/T)$)
16-21	f6.2	Associated standard deviation
22-27	f6.2	Station bias B (mb units)
28-33	f6.2	Associated standard deviation
34-42	f9.3	Station latitude, degrees (+ means North)
43-51	f9.3	Station longitude, degrees (+ means East)
52-56	i5	Station altitude, meters
57	a1	'W' indicates WSSN station
58-101	a44	Alphanumeric station name (ISC)

2. Event data files (115 station network).

There are 10 such files, one for each year. They are named 'ev1971', 'ev1972', etc. up to 'ev1980'. Each file consists of about 7000 event records, for a total of about 2M bytes for each year of data. All ISC-reported events with at least one teleseismic detection have been included. Each event record gives information on origin time, ISC location, magnitudes (including MLE) and complete station detection information for the 115 station network. The format of each record is as follows:

Byte:	Format:	Contents:
1-4	i4	Year
5-6	i2	Month
7-8	i2	Day
9-10	i2	Hour
11-12	i2	Minute
13-14	i2	Second
15	i1	'1' for events in the Ingres EXPLOSION file
16-20	f5.1	Latitude, degrees (+ means North)
21-26	f6.1	Longitude, degrees (+ means East)
27-31	f5.0	Depth, km
32-35	f4.1	ISC mb
36-39	i4	No of observations for ISC mb
40-44	f5.2	Bias-corrected conventional mb : 115 stations
45-48	i4	Associated no of $\log(A/T)$ observations
49-53	f5.2	Associated standard dev. of station mb values
54-58	f5.2	Maximum likelihood mb
59-62	i4	Flinn-Engdahl region no
63-65	i3	Gutenberg-Richter region no
66-68	i3	Total no of ISC P-arrivals
69-77	3i3	Counts of local, teleseismic and core detections (includes both arrays and associated stations)
78-307	115i2	One entry for each network station: -1 : Station not listed by ISC as operational 0 : Station listed, but no reported arrival 1 : Station reported arrival without $\log(A/T)$ >1 : $10 \cdot \log(A/T) + 30$ for the station

3. Complete ISC amplitude data files.

There are 12 such files per year (one per month), named 'i71JAN', 'i71FEB', etc. up to 'i80DEC'. (The month is indicated by its first three letters, capitalized). These files are very voluminous, comprising about 0.5M bytes per month for a total of 60M bytes for the 10 years.

It has not been my intention to develop these files for general use, since I have been aware that efforts are currently underway to include these data together with arrival times in the Ingres system. However, until that project has been completed, these files may be quite useful to some research projects, and I therefore enclose a brief description. For additional aid in reading the files, reference is made to the FORTRAN program 'netmle.f' residing in my directory. I also suggest that anyone wishing to use these data files contact me for more detailed information.

One month's file contains the following information:

a) File header record :

File name, year, month

b) Station definition records:

One record for each station reporting for the actual month:

Byte 1-4 : station no (i4)

Byte 5-8 : station code (a4)

Byte 9-50: station coordinates (ISC format)

This set of records ends with '9999' in Byte 1-4.

c) Event records:

One event header record followed by zero or more station report records, and ending with '9999' in Byte 1-4.

The event header record contains:

Byte 1-16 : Origin time (ISC tape format)

Byte 17-42: Hypocentral information (ISC format)

Byte 43-73: mb, region no, no of stations (ISC format)

The station report records (one per detecting station) contain:

Byte 1-4 : Station no, corresponding to b) above (i4)

Byte 5-7 : Epicentral distance, degrees (i3)

Byte 8-10 : $10 \cdot \log(A/T)$, or '-98' if no $\log(A/T)$ report (i3)