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OVERVIEW OF ALASKAN HISTORICAL SEISMICITY

By

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OVERVIEW OF ALASKAN HISTORICAL SEISMICITY

Alaska is one of the seismically most active areas in the world. Three of the 10 largest earthquakes in the world since 1904 have occurred in Alaska: vis: (1) the 1957 Andreanof-Fox Islands, (2) the 1964 Prince William Sound, and (3) the 1965 Rat Islands earthquakes (Table 1). A comparision with California (Figure 1) shows about 6 times as many events of $M_b > 5.5$ in Alaska during the 5 year period 1976-1980. Of the major earthquakes ($M_s > 7.0$) in Alaska (Figure 2 and Table 2) about 75% occur in the Alaska-Aleutian subduction zone, 15% in the S.E. Alaska transform zone, and the remaining 10% occur in the Central Alaska seismic zone (a broad area of mainland Alaska north of Anchorage to Fairbanks and west of Fairbanks toward the Seward Peninsula). The instrumental record for Alaska appears to be complete for $M_s > 7.0$ events back to the turn of the century (Figure 3); although it should be noted that there are some 4,000 Alaskan events listed in the NEIS data file for which no magnitudes have been assigned, so there may be a few large events missing from Table 2. Using the number of events of $M_s > 7.0$ (Table 2) and assuming a "b" value of 0.9 one can calculate the expected frequency of occurence of potentially damaging earthquakes ($M_s > 6.5$) for each of the three major seismic zones of Alaska. This computed frequency and the observed frequency for events of $M_s > 7.0$, and 7.8 are given in Table 3. For most regions of Alaska and most magnitude categories the elapsed time since the last event exceeds the mean interevent time by at least a factor of two and for several cases it exceeds the interevent time of 95% of previous cases (mean plus 1.645 times one standard deviation). More detailed discussions of the Alaska-Aleutian subduction zone and the S.E. Alaska transform zone will be given in other presentations, so only the central Alaska seismic zone will be discussed any further here. The central Alaska seismic zone is loosely defined as the region of mainland Alaska, north of Anchorage where most of the shallow (crustal) $M > 6.0$ earthquakes occur. Figure 4 shows the location of these earthquakes (north of 63.5 N latitude) plotted on a representation of a stress trajectory map for Alaska as propsed by Nakamura et al (1980). Focal mechanisms (Figures 5, 6, and 7) for the central Alaska seismic zone are generally consistent with the stress trajectories shown in Figure 3, showing roughly NW-SE trending axes of maximum horizontal compression. If the basic tenet of the stress trajectory model is correct, then the earthquakes in interior, northern and western Alaska are the consequence of a far-reaching regional deformation in response to the interaction of the Pacific and North American plates in South-central Alaska. The seismicity patterns shown in Figures 8, 9 and 10 also are consistent with this model of a regional deformation: (1) the overall pattern is one of the greatest activity being concentrated just north of the NE corner of the Pacific plate; (2) the larger events are sub-parallel to the principal slip line which would emanate from this corner if it were taken as a rigid indentor; and (3) there is a suggestion that some of the lineations of epicenters correspond with the major faults (Figure 11), in particular, the Kaltag and Tintina systems. The idea that most of the Alaskan crust is deforming is response to a large-scale right-lateral shear between the Pacific and North American plates has some implications for earthquake prediction research in mainland Alaska. First and foremost it underscores the need for a uniform long term seismic and geodetic monitoring program in all of Alaska including northern and western Alaska, areas which are now very inadequately instrumented. Secondly it points out the need for paleoseismic work on the major fault systems. These are large structures and might be capable of rare, great earthquakes, if we are to judge on the basis of their length alone. Lastly it suggests some interesting basic research questions which have to do with the seismotectonic framework. The major implication of the consistent pattern of stress trajectories extending clear across Alaska is that the crust must be decoupled from the upper mantle.

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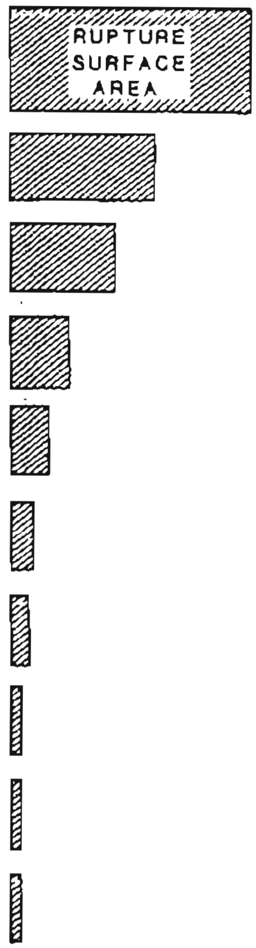
Table 1. The World's Ten Largest Earthquakes 1904 - 1984

No.	Location	Year	Mw	Energy*
1.	CHILE	1960	9.5	2000
2.	ALASKA	1964	9.2	820
3.	ALASKA	1957	9.1	585
4.	KAMCHATKA	1952	9.0	350
5.	ECUADOR	1906	8.8	204
6.	ALASKA	1965	8.7	125
7.	ASSAM	1950	8.6	100
8.	BANDA SEA	1938	8.5	70
9.	CHILE	1922	8.5	69
10.	KURILES	1963	8.5	67



*Energy in dyne-cm x 10^{27}

Source: Based on data from Kanamori[1] (1977)

Table 2

MAJOR SHALLOW ALASKAN EARTHQUAKES: 1897 -1980

(After Abe and Noguchi, 1981 and 1983)*

#	YEAR	MO	DY	TIME	LAT.	LONG.	M_s	LOCATION	ZONE*
1	1898	6	29	1836	52.	+172.	7.6	Near Is.	S+
2	1898	10	11	1637	50.	180.	6.9	Rat/Andreanof Is.	S-
3	1899	4	16	1342	58.	-138.	6.9	S.E. Alaska	T-
4	1899	7	14	1332	(60.)*	(-150.)*	7.2	(Kenai Penin.)*	S+
5	1899	9	4	0022	60.	-142.	7.9	Gulf of Alaska	T+
6	1899	9	4	0440	60.	-142.	6.9	Gulf of Alaska	T-
7	1899	9	10	1704	60.	-140.	7.4	S.E. Alaska	T+
8	1899	9	10	2141	60.	-140.	8.0	S.E. Alaska	T+
9	1899	9	17	1250	59.	-136.	6.9	S.E. Alaska	T-
10	1899	9	23	1104	60.	-143.	6.9	Gulf of Alaska	T-
11	1899	9	23	1250	60.	-143.	7.0	Gulf of Alaska	T+
12	1900	10	9	1228	(60.)*	(-142.)*	7.7	(Kodiak)*	S+*
13	1901	1	18	0439	60.	-135.	7.1	S.E. Alaska	T+
14	1901	12	31	0902	52.	-177.	7.1	Andreanof Is.	S+
15	1902	1	1	0520	55.	-165.	7.0	Unimak Is.	S+
16	1903	1	17	1605	50.	-170.	7.0	(Fox Is.)	S+
17	1903	2	5	1826	52.	+175.	6.8	Near/Rat Is.	S-
18	1903	6	2	1317	57.	-156.	6.9	Alaska Penin.	S-
19	1904	8	27	2156	64.	-151.	7.3	Central Alaska	M+
20	1905	2	14	0846	53.	-178.	7.3	Andreanof Is.	S+
21	1905	3	22	0338	50.	180.	7.0	Rat/Andreanof Is.	S+
22	1905	9	15	0602	55.	+165.	7.4	Komandorsky	O+
23	1905	12	10	1236	50.	180.	6.9	Rat/Andreanof Is.	S-
24	1906	8	17	0010	51.	+179.	7.8	Rat Is.	S+
25	1906	12	23	1722	53.	-165.	7.3	(Unimak Is.)	S+
26	1907	9	2	1601	52.	+173.	7.4	Near Is.	S+
27	1908	5	15	0831	59.	-141.	7.0	S.E. Alaska	T+
28	1909	4	10	1936	52.	+175.	7.0	Near/Rat Is.	S+
29	1910	9	9	0113	51.5	-176.	7.0	Andreanof Is.	S+
30	1910	11	6	2029	53.	-135.	6.8	Queen Charlotte Is.	O-
31	1911	9	17	0326	51.	180.	7.1	Rat/Andreanof Is.	S+
32	1911	11	13	1613	52.	+173.	6.9	Near Is.	S-
33	1912	6	10	1606	59.	-153.	6.9	Kodiak Is.	S-
34	1912	7	7	0757	64.	-147.	7.2	Central Alaska	M+
35	1915	7	31	0131	54.	+162.	7.6	Kamchatka	O+
36	1917	1	30	0245	56.5	+163.	7.8	Kamchatka	O+
37	1917	5	31	0847	54.5	-160.	7.9	Alaska Penin.	S+
38	1923	5	4	1626	55.5	-156.5	7.1	Alaska Penin.	S+
39	1925	8	19	1207	55.25	+168.	7.0	Unimak Is.	S+
40	1926	10	13	1908	52.	-176.	7.0	Andreanof Is.	S+

#	YEAR	MO	DY	TIME	LAT.	LONG.	M_s	LOCATION	ZONE*
41	1927	10	24	1559	57.5	-137.	7.1	S.E. Alaska	T+
42	1928	6	21	1627	60.	-146.5	6.8	Gulf of Alaska	S-
43	1929	3	7	0134	51.	-170.	7.5	Fox Is.	S+
44	1929	7	5	1419	51.	-178.	7.0	Andreanof Is.	S+
45	1929	7	7	2123	52.	-178.	7.3	Andreanof Is.	S+
46	1929	12	17	1058	52.5	+171.5	7.8	Near Is.	S+
47	1933	4	27	0236	61.25	-150.75	6.9	S. Central Alaska	M-
48	1935	2	22	1705	52.25	+175.	7.1	Near/Rat Is.	S+
49	1936	11	13	1231	55.5	+163.	7.1	Kamchatka	O+
50	1937	7	22	1709	64.75	-146.75	7.3	Central Alaska	M+
51	1938	11	10	2018	55.5	-158.	8.3	Alaska Penin.	S+
52	1938	11	17	0354	55.5	-158.5	7.3	Alaska Penin.	S+
53	1940	4	16	0607	52.	+173.5	6.8	Near Is.	S-
54	1940	4	16	0643	52.	+173.5	7.1	Near Is.	S+
55	1940	8	22	0327	53.	-165.5	7.0	Unimak Is.	S+
56	1943	11	3	1432	61.75	-151.	7.4	S. Central Alaska	M+
57	1944	12	12	0417	51.5	+179.5	6.9	Rat Is.	S-
58	1945	4	15	0235	57.	+164.	7.2	Komandorsky	O+
59	1946	1	12	2025	59.25	-147.25	6.7	Gulf of Alaska	S-
60	1946	4	1	1228	52.75	-163.5	7.3	Unimak Is.	S+
61	1946	11	1	1114	51.5	-174.5	7.0	Andreanof Is.	S+
62	1947	10	16	0209	64.5	-147.5	7.2	Central Alaska	M+
63	1948	5	14	2231	54.5	-161.	7.5	Alaska Penin.	S+
64	1949	8	22	0401	53.75	-133.25	8.1	Queen Charlotte Is.	O+
65	1949	9	27	1530	59.75	-149.	6.7	Kenai Penin.	S-
66	1951	2	13	2212	56.	-156.	7.1	Alaska Penin.	S+
67	1953	1	5	0748	54.	+170.5	7.1	Near Is.	S+
68	1957	3	9	1422	51.3	-175.8	(8.1)	Andreanof Is.	S+
69	1957	3	9	2039	52.25	-169.5	7.1	Fox Is.	S+
70	1957	3	11	0958	52.25	-169.25	7.0	Fox Is.	S+
71	1957	3	11	1455	51.5	-178.5	6.9	Andreanof Is.	S-
72	1957	3	12	1144	51.5	-177.	7.0	Andreanof Is.	S+
73	1957	3	14	1447	51.	-177.	7.1	Andreanof Is.	S+
74	1957	3	16	0234	51.5	-178.75	7.0	Andreanof Is.	S+
75	1957	3	22	1421	53.75	-165.75	7.0	Unimak Is.	S+
76	1957	4	10	1129	56.	-154.	6.9	Kodiak Is.	S-
77	1957	4	19	2219	52.25	-166.	6.5	Unimak Is.	S-
78	1958	4	7	1530	65.5	-155.5	7.3	Central Alaska	M+
79	1958	7	10	0615	58.3	-136.5	7.9	S.E. Alaska	T+
80	1960	11	13	0920	51.4	-168.9	6.7	Fox Is.	S-
81	1964	2	6	1307	55.7	-155.9	7.0	Alaska Penin.	S+
82	1964	3	28	0336	61.1	-147.5	(8.4)*	Gulf of Alaska	S+
83	1965	2	4	0501	51.3	+178.6	(8.2)*	Rat Is.	S+
84	1965	2	4	0840	51.4	+179.6	7.0	Rat Is.	S+
85	1965	3	30	0227	50.3	+177.9	7.4	Rat Is.	S+
86	1965	7	2	2058	53.0	-167.6	6.5	Fox/Unimak Is.	S-
87	1965	7	29	0829	51.1	-171.3	6.7	Fox Is.	S-
88	1965	9	4	1432	58.3	-152.5	6.8	Kodiak Is.	S-

#	YEAR	MO	DY	TIME	LAT.	LONG.	M_S	LOCATION	ZONE*
89	1966	7	4	1833	52.0	+179.9	6.8	Rat Is.	S-
90	1966	8	7	0213	50.6	-171.2	6.4	Fox Is.	S-
91	1969	11	22	2309	57.7	+163.6	7.1	Kamchatka	O+
92	1971	12	15	0829	56.0	+163.2	7.5	Kamchatka	O
93	1972	7	30	2145	56.8	-135.9	7.4	S.E. Alaska	T+
94	1975	2	2	0843	53.1	+173.6	7.4	Near Is.	S+
95	1979	2	28	2127	60.6	-141.6	7.0	S.E. Alaska	T+

*Explanation:

(1) Data for 1897-1912 from Abe, K. and S. Noguchi, "Review of magnitudes of large shallow earthquakes, 1897-1912", Physics of the Earth and Planetary Interiors, 33, 1-11, 1983.

(2) Data for 1913-1917 from Abe, K. and S. Noguchi, "Determinations of magnitude for large shallow earthquakes, 1898-1917", Physics of the Earth and Planetary Interios, 32, 45-59, 1983.

(3) Data for 1918-1980 from Abe, K., "Magnitudes of large shallow earthquakes from 1904 to 1980", Physics of the Earth and Planetary Interiors, 27, 72-92, 1981.

(4) The following notes apply to the respective earthquake number:
- 4 - location very uncertain, felt reports suggest a more westerly epicenter, perhaps near the Shumagin Islands
- 12 - location very uncertain, felt reports suggest a more westerly epicenter, perhaps near Kodiak Island
- 68 - moment magnitude 8.7
- 82 - moment magnitude 9.2
- 83 - moment magnitude 8.7

(5) Earthquake zones were defined as follows:

- S = Alaska-Aleutian subduction zone
- T = S.E. Alaska transform zone
- M = Mainland Alaska
- O = Outside of Alaska (Kamchatka, Komandorsky, Queen Charlotte)
- \+ = M_S greater than or equal to 7.0
- \- = M_S less than 7.0

Table 3
Alaskan Earthquake Statistics
January 1897 - August 1985

Region	Damaging (M_s > 6.5)	Major (M_s > 7.0)	Great (M_s > 7.8)
Alaska-Aleutian Subduction Zone			
Number in 88.7 years	130	46	7
Mean repeat time (years)	0.7	1.9	11.3
Time since last event (years)	2.5	4.6	20.6
Time for 95% of cases (years)	1.9	5.7	22.3
Date of the last event	2-14-83	1-30-81	2-4-65
S.E. Alaska Transform Zone			
Number in 88.7 years	28	10	3
Mean repeat time (years)	3.4	8.5	28.7
Time since last event (years)	6.6	6.6	27.1
Time for 95% of cases (years)	9.0	25.3	77.1
Date of the last event	2-28-79	2-28-79	7-10-58
Central Alaska Seismic Zone			
Number in 88.7 years	17	6	0
Mean repeat time (years)	5.2	13.5	>100
Time since last event (years)	16.8	27.4	>100
Time for 95% of cases (years)	13.8	30.1	>265
Date of last event	10-28-68	4-7-58	?
All of Alaska			
Number in 88.7 years	175	62	10
Mean repeat time (years)	0.5	1.4	8.6
Time since last event (years)	2.5	4.6	20.6
Time for 95% of cases (years)	1.3	4.2	20.3
Date of last event	2-14-83	1-30-81	2-4-65

NOTES

1) The data base for these calculations is the catalog of M_s > 7.0 events based on the papers of Abe and Noguchi given in Table 2 augmented by data for the period Jan. 1981 - Aug. 1985 from the National Earthquake Information Service (NEIS).
2) The statistics for M_s 6.5 are calculated from the Gutenberg and Richter relation: $\log N = a - b M$, assuming a "b" value of 0.9 and using the data for M_s > 7.0 events from Table 2 for the period 1897 - 1980.
3) The mean repeat time for M_s > 6.5 is 88.7 years divided by the number of events during that period; for M_s > 7.0 and M_s > 7.8 it is the average of the observed interevent times, including the time since the last event as one of the interevent times.
4) The "time for 95% of cases" is the mean interevent time plus 1.645 times one standard deviation of the interevent times about the mean.

Figure Captions

Figure 1. International Seismological Center reports for earthquakes greater than or equal to magnitude 5.5 during the 5-year period from 1976 to 1980.

Figure 2. The dots show the epicenter locations of all shallow (depth less than 70 km) earthquakes in Alaska of magnitude 7.2 or more from 1897 through 1980. The map shows 31 events, but two dots in the Yakutat-Yakaaga area actually represent two events each, and two in the westernmost Aleutians are off the map. The 83-year record thus indicates that Alaska had 35 earthquakes of at least magnitude 7.2, or one every 2.3 years.

Figure 3. Histogram of the number of large, shallow earthquakes in Alaska, 1897-1980. In the top graph six events are plotted with $M_S \geq 8.0$; in the bottom graph 60 events with $M_S \geq 7.0$ are plotted. The ratio of about 10:1 for the number of events with $M_S \geq 7.0$ vs. those with $M_S \geq 8.0$ implies the record of $M_S \geq 7.0$ is probably complete. This assumes that all events of $M_S \geq 8.0$ have been detected and that the "b" value for all of Alaska is close to 1; both reasonable assumptions. Note, also that the distribution in time of the $M_S \geq 7.0$ events is reasonably uniform. The data for this histogram are from Abe and Noguchi; see Table 2 for references.

Figure 4. Stress trajectory map from Estabrook, (1985). Stress trajectories, heavy broken lines, after Nakamura et al (1980). Earthquake epicenters for $M > 6.0$ events, solid dots, from National Earthquake Information Service (NEIS). The 50 km depth contour of the Wadati-Benioff zone, medium heavy lines, from Stone (1983) and Stephens et al (1984). The RM-1 line and the plate convergence rate are after Minster et al (1974). The rigid indentor, shown by stippled area between the trench and the 50 km depth contour, is after Davies (1983).

Figure 5. Focal mechanisms in Interior Alaska, from Gedney (1982). Mechanisms are shown by lower hemisphere, stereographic plots of first-motion directions where the shaded quadrants represent compressions and the unshaded represent rarefactions.

Figure 6. Focal mechanisms in Northern Alaska from Estabrook (1985). Mechanisms are as shown in Figure 4. Also shown are $M > 4.0$ earthquakes, open circles (NEIS); and faults after King (1969). Mechanisms are plotted with north up, not parallel to the map grid.

Figure 7. Focal mechanisms in Western Alaska, from Biswas (1985). Mechanisms are upper hemisphere, sterographic plots of first-motion where the shaded quadrant represent rarefactions and the unshaded ones represent compressions.

Figure 8. Epicenter map for northern Alaska from Estabrook (1985). The open circles represent epicenters for all $M > 5.0$ events in the NEIS files for this region through 1983.

Figure 9. Epicenter map for northern Alaska from Estabrook (1985). The open circles represent epicenters for all $M > 3.0$ events for the years 1976-1979, a time period of relatively good station coverage.

Figure 10. Epicenter map for northern Alaska from Estabrook (1985). The open circles represent the relocated epicenters of all earthquakes located by the Geophysical Institute for the period 1967-1983. Note NW-SE trending lineation of epicenters at about 65.5 N and 145 W which is coparallel with the trace of the Tintina Fault.

Figure 11. Map of major fault systems in Alaska from Estabrook (1985) after Stone (pers. comm., 1985).

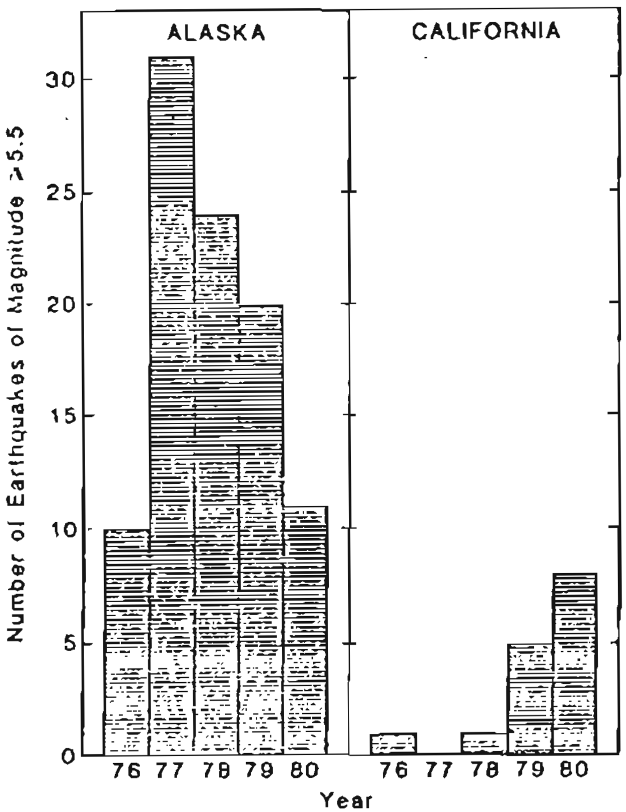


Figure 1. International Seismological Center reports for earthquakes of magnitude ≥ 5.5 during the 5-year period from 1976 to 1980.

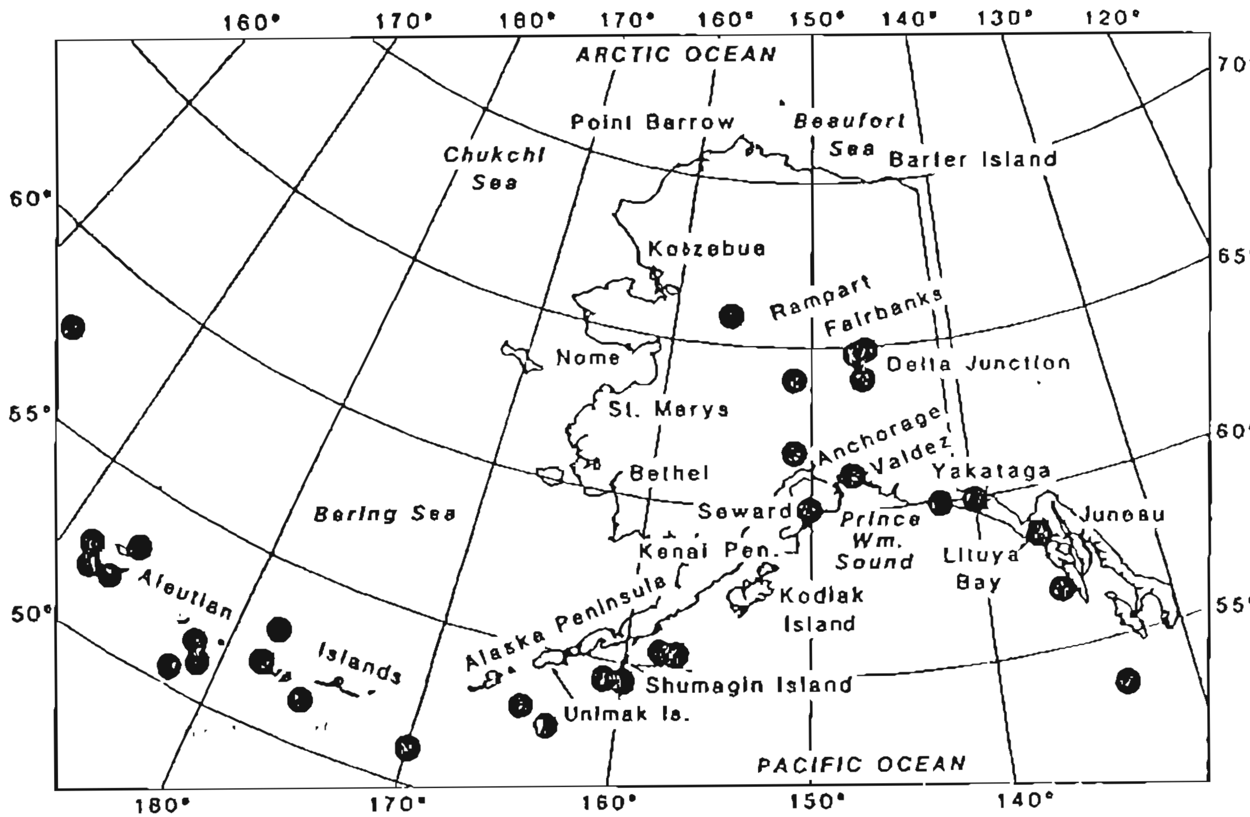


Figure 2. The dots show the epicenter locations of all shallow (depth less than 70 km) earthquakes in Alaska of magnitude 7.2 or more from 1897 through 1980. The map shows 31 events, but two dots in the Yakutat-Yakataga area actually represent two events each, and two in the westernmost Aleutians are off the map. The 83-year record thus indicates that Alaska had 35 earthquakes of at least magnitude 7.2, or one every 2.3 years.

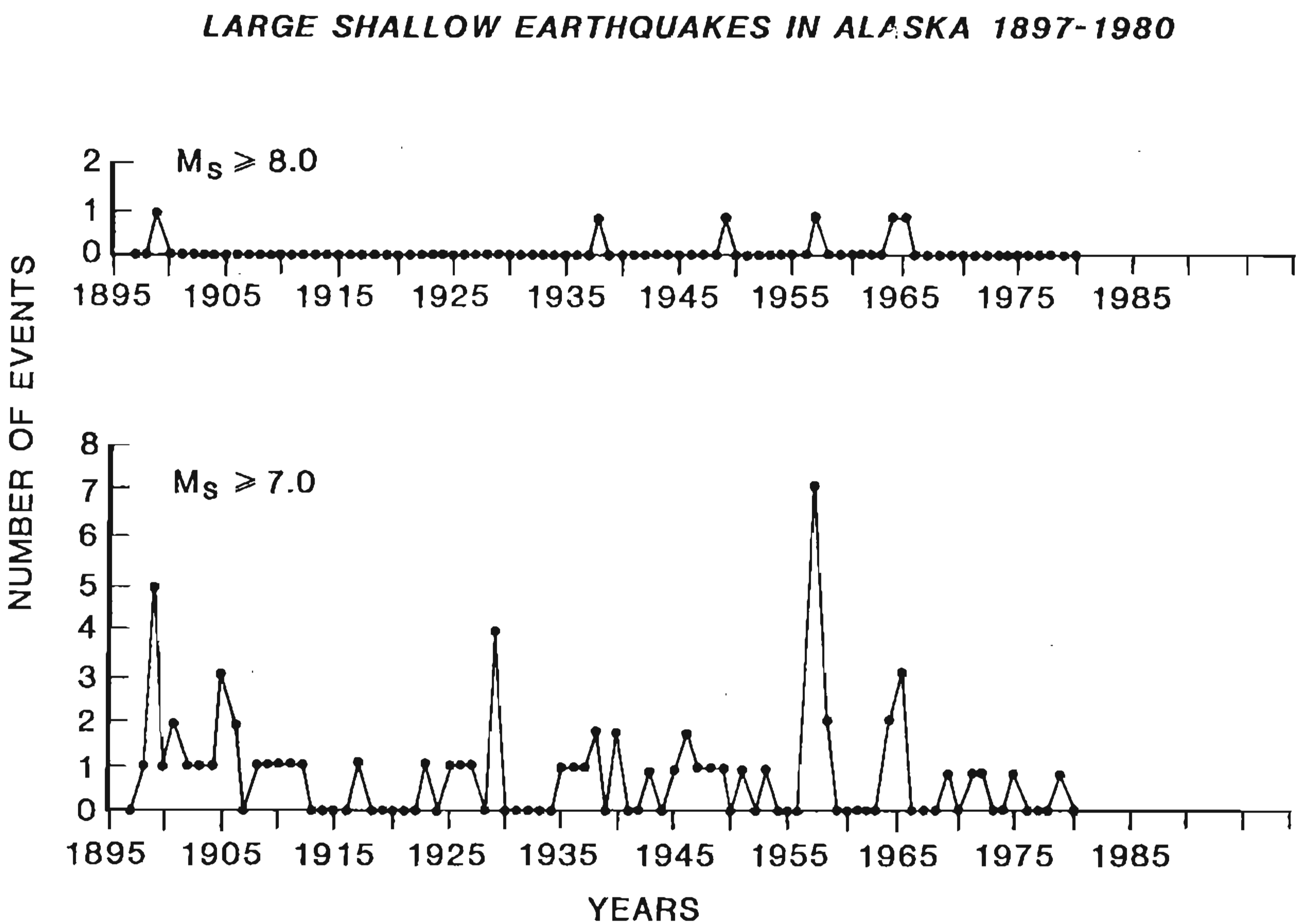

LARGE SHALLOW EARTHQUAKES IN ALASKA 1897-1980
NUMBER OF EVENTS
Ms ≥ 8.0
Ms ≥ 7.0
2
1
0
8
7
6
5
4
3
1895
1905
1915
1925
1935
1945
1955
1965
1975
1985
YEARS

Figure 3

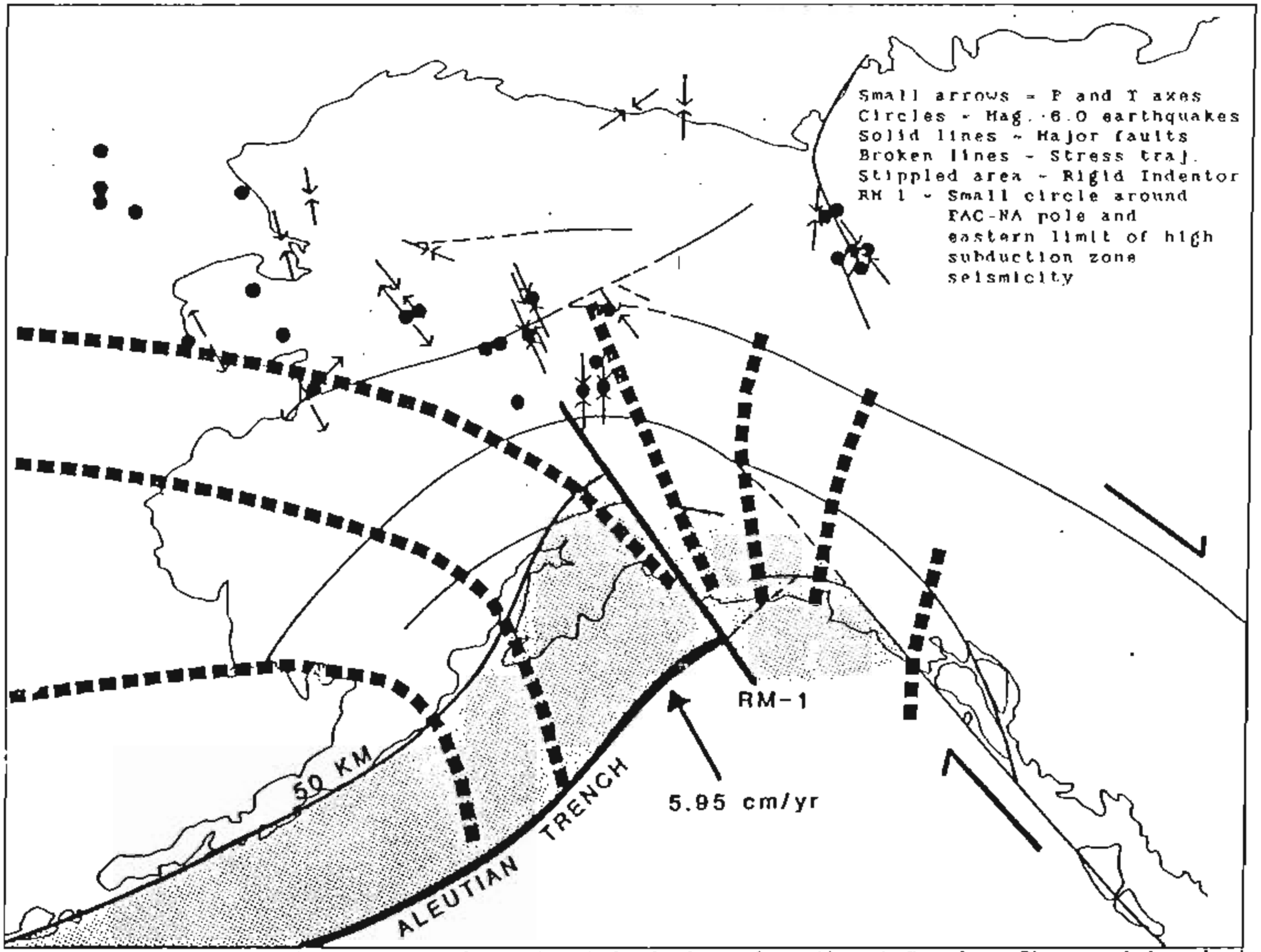


Figure 4. Model proposed for deformation of continental Alaska and northwest Canada. The exact boundaries of the "Rigid Indentor" are speculative. The 50 km Wadati-Benioff Zone contour of Stephens et al. (1984) and Stone (1983). Pacific North America pole of rotation (RM-1) is from Minster et al. (1974). The convergence rate is from Stone (1983). Stress trajectories are from Nakamura et al (1980), earthquakes are from NEIS, faults are from Stone (pers.comm., 1985). Large arrows represent shear zone discussed in the text.

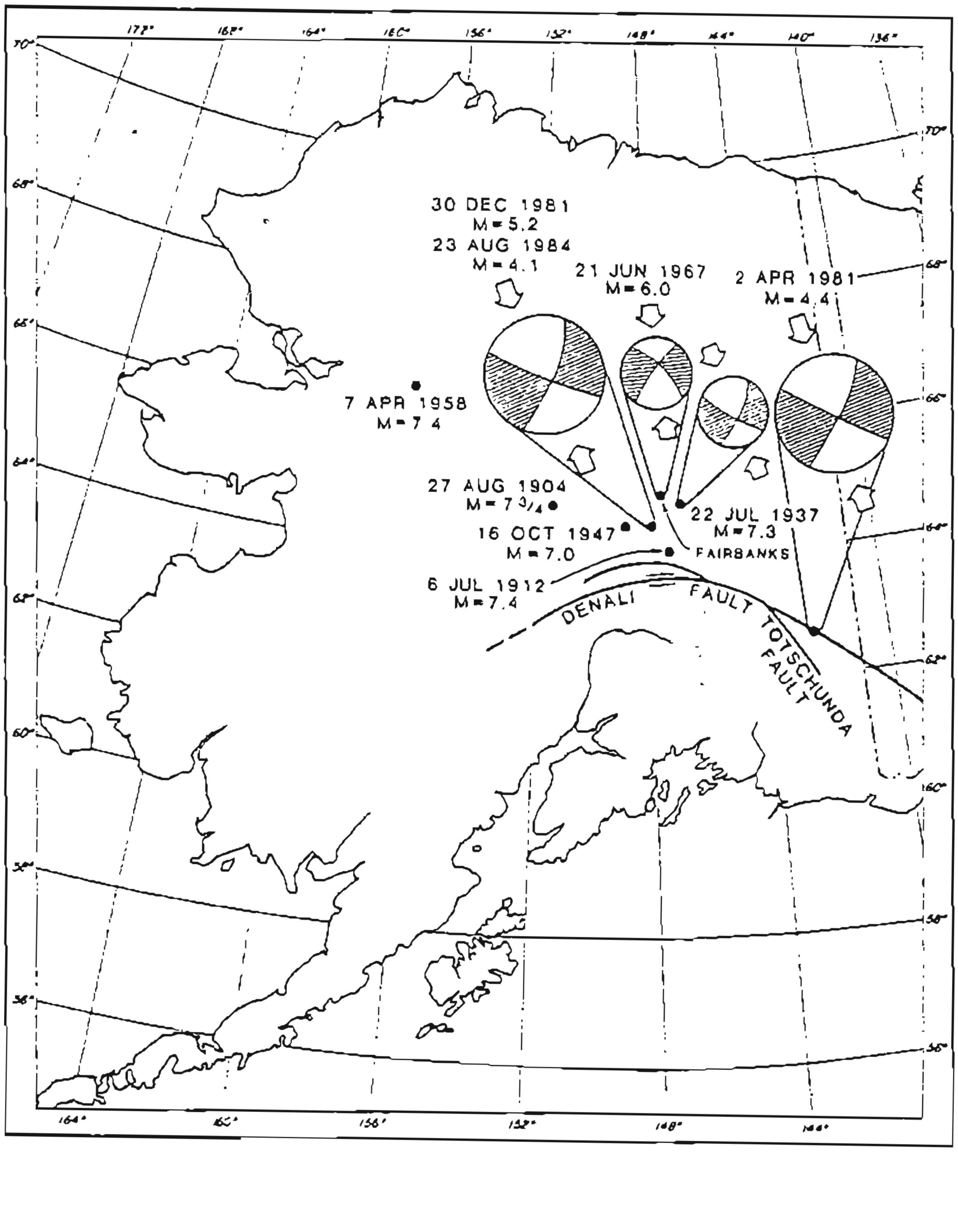

30 DEC 1981
M = 5.2
23 AUG 1984
M = 4.1
21 JUN 1967
M = 6.0
2 APR 1981
M = 4.4
7 APR 1958
M = 7.4
27 AUG 1904
M = 7 3/4
16 OCT 1947
M = 7.0
22 JUL 1937
M = 7.3
FAIRBANKS
6 JUL 1912
M = 7.4
DENALI FAULT
TOTSCHUNDA FAULT

Figure 5

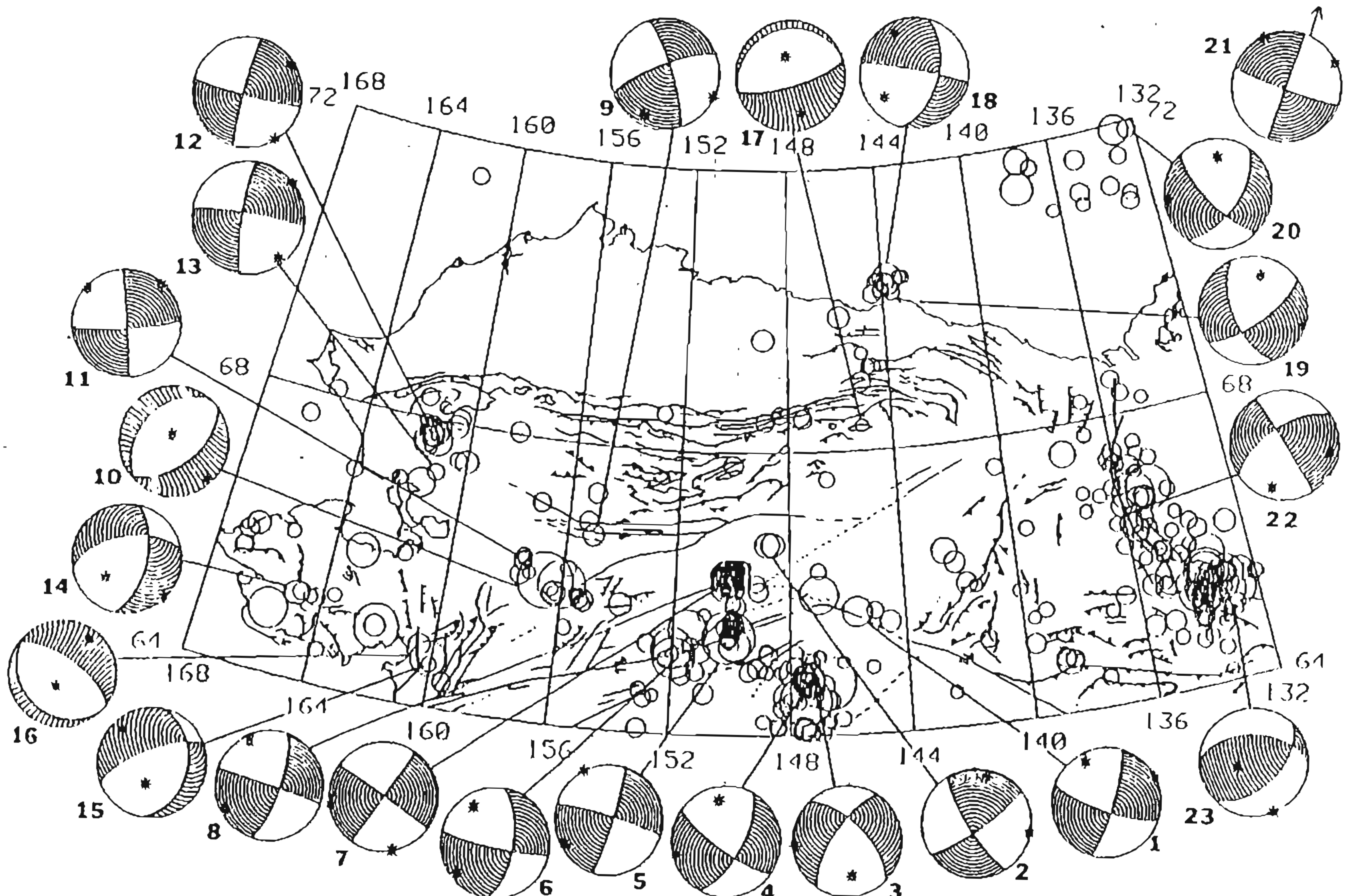


Figure 6   Map showing fault plane solutions, mag. 4 and larger earthquakes (source NEIS) and geologic faults (after King, 1969). Fault plane solutions are equal-area lower hemisphere projections showing quadrants of compressional (shaded) and tensional first motion, containing the T and P axes respectively. Mechanisms are oriented with north parallel to the right edge of the paper, not parallel to map north.

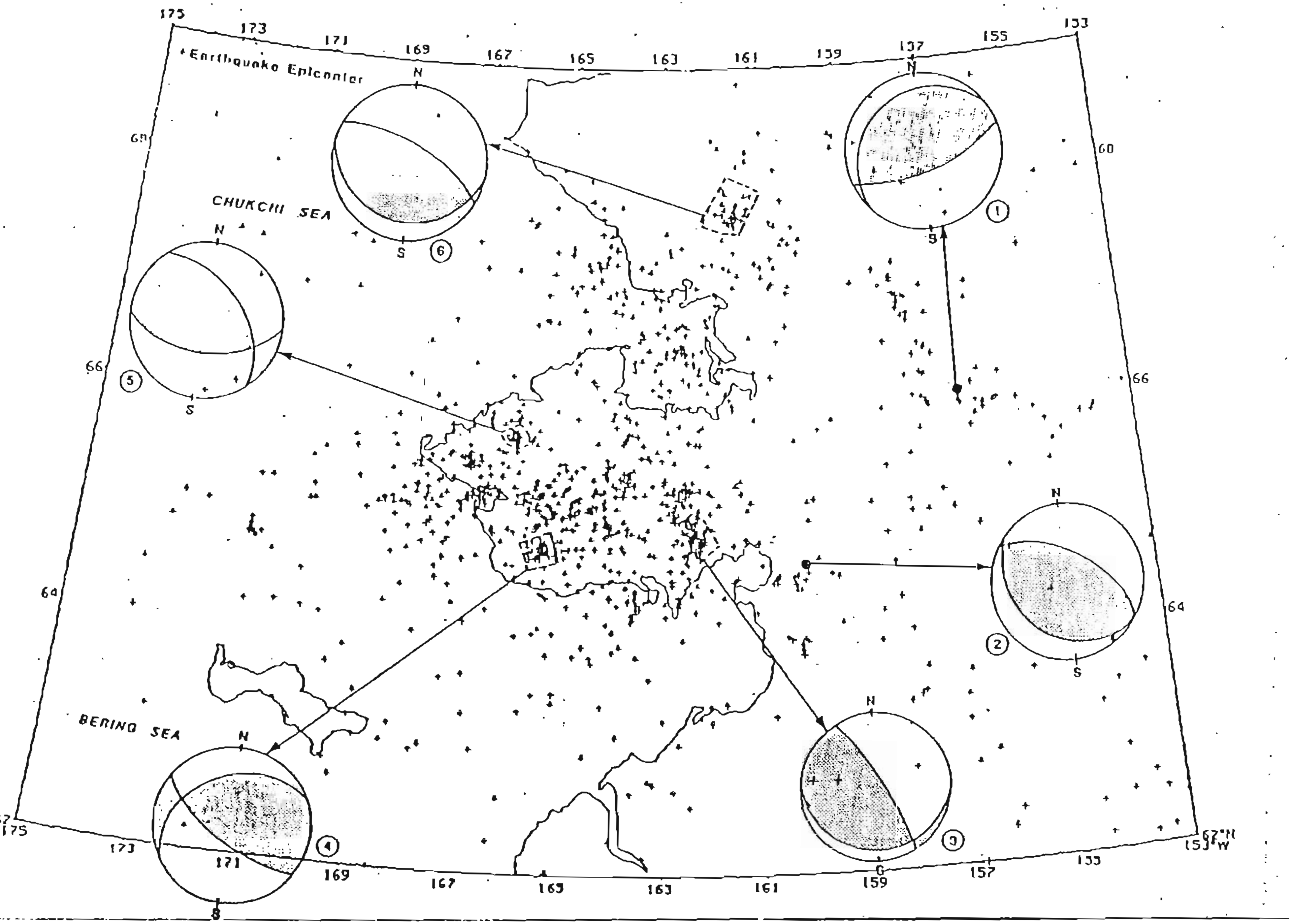

Earthquake Epicenter
CHUKCHI SEA
BERING SEA
N
S
1
2
3
4
5
6
175
173
171
169
167
165
163
161
159
157
155
153
66
64
67°N
153°W

Figure 7

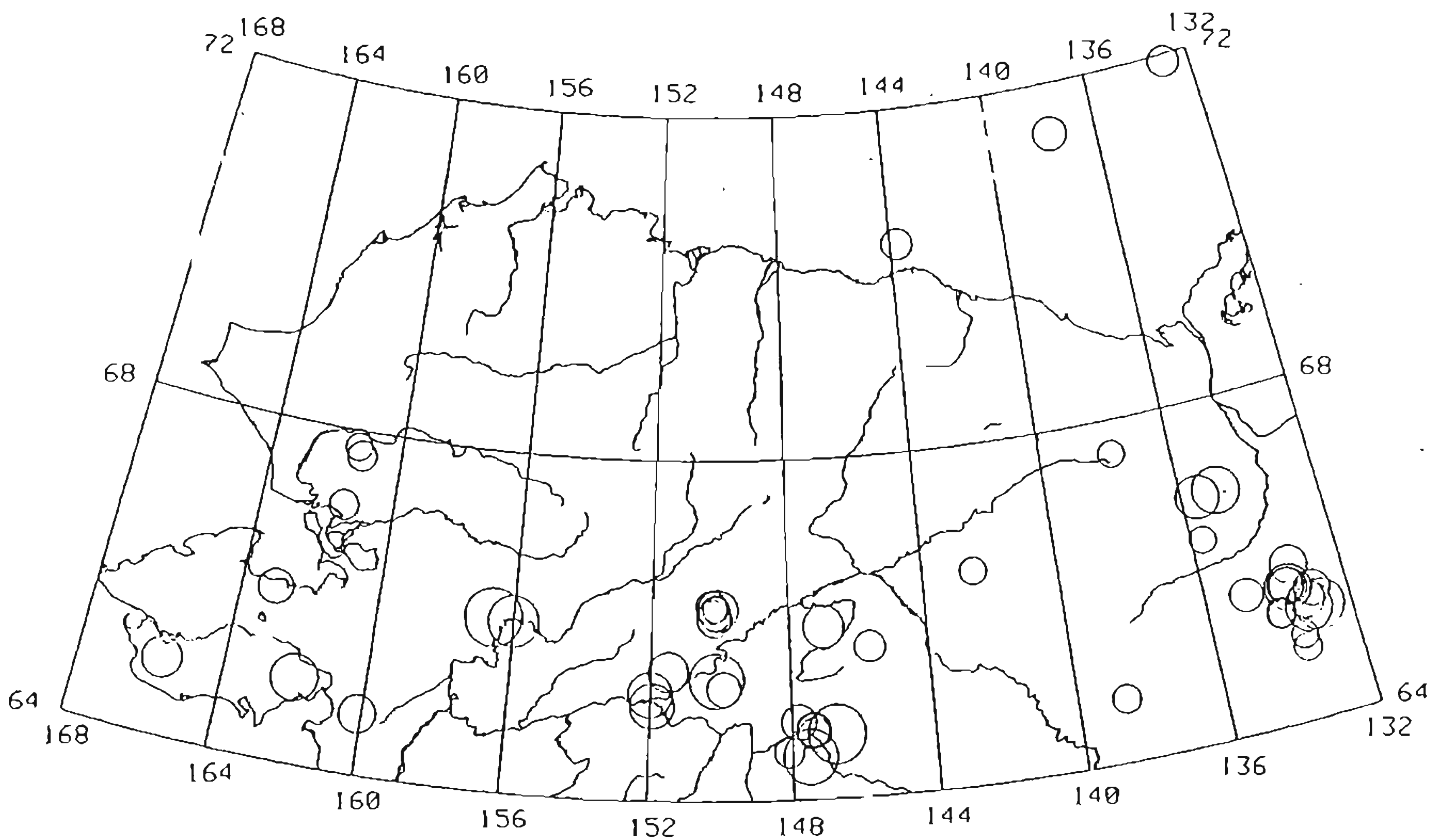

72
168
164
160
156
152
148
144
140
136
132
72
68
68
64
168
164
160
156
152
148
144
140
136
64
132

Figure 8

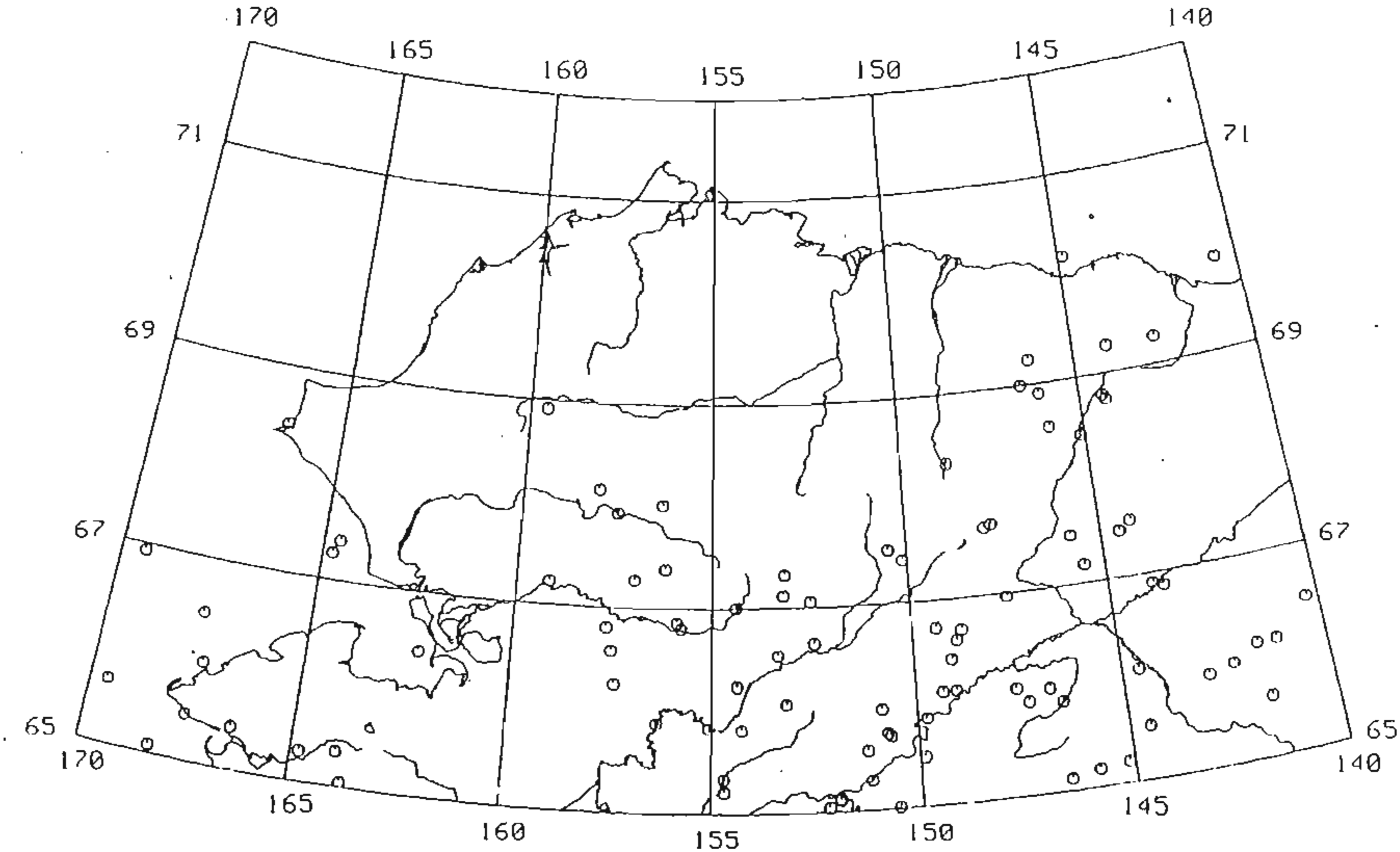


Figure 9 Earthquakes with magnitudes greater than 3 for the years 1976 to 1979. Source this study.

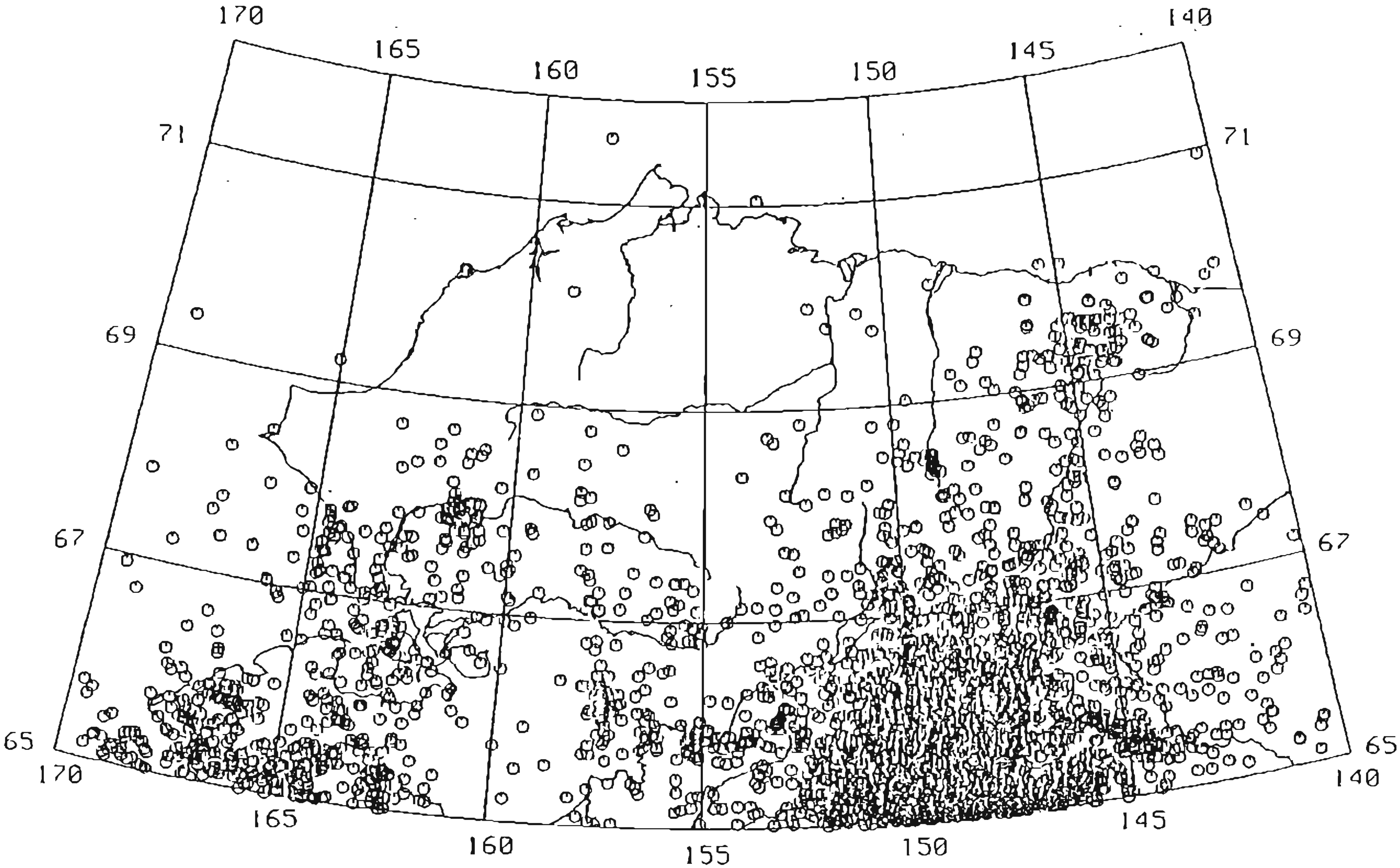

170
165
160
155
150
145
140
71
71
69
69
67
67
65
65
170
165
160
155
150
145
140

Figure 10

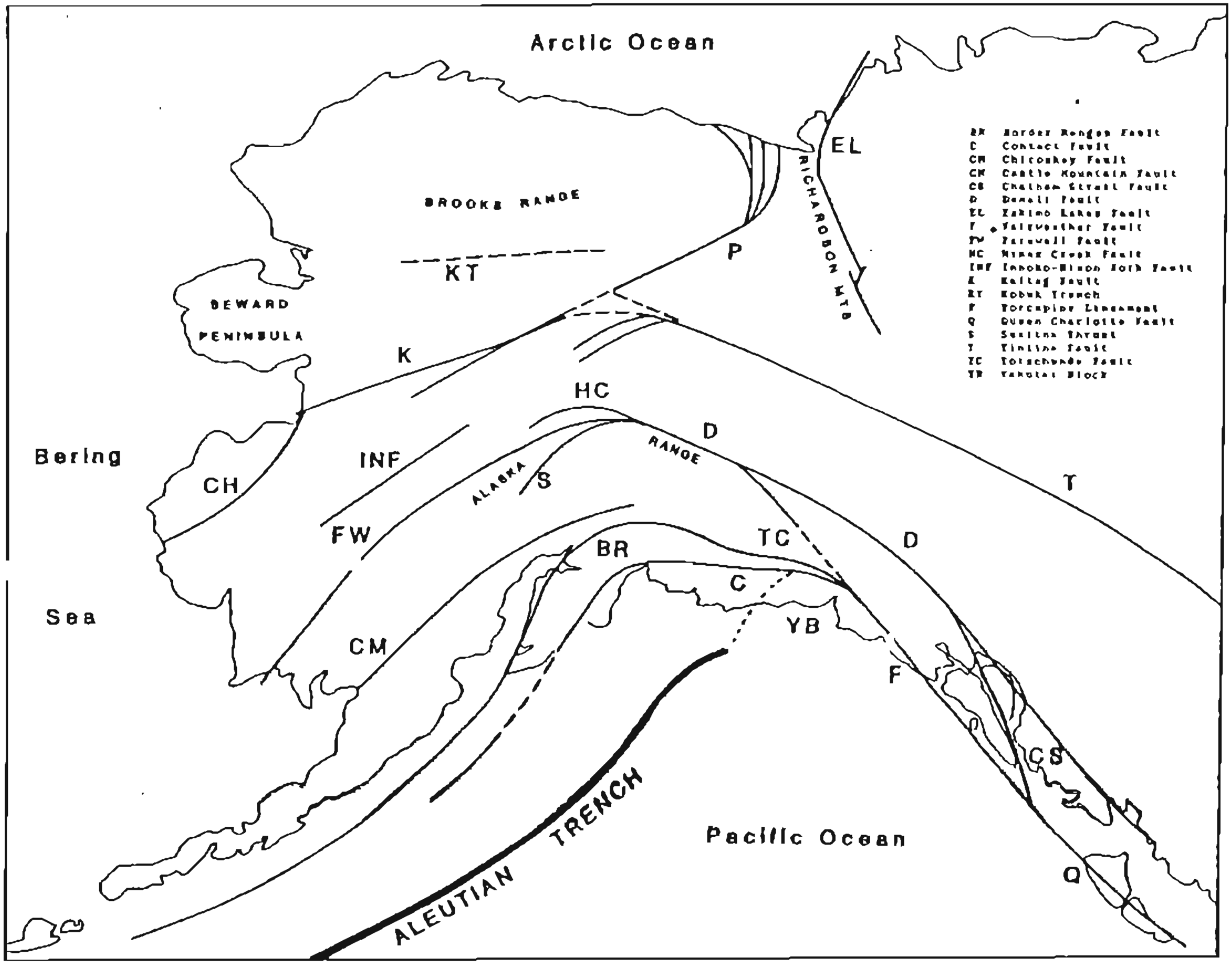


Figure 11 Map of major faults in Alaska. After Stone (pers. comm., 1985).