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EARTHQUAKE PRECURSORS

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ABSTRACT

An analysis of existing earthquake precursor data leads to a conclusion that the precursors reported so far can be classified into three types, i.e., A_1, A_2 and B types. Most of type B precursors, observed in terms of anomalous tilts and strains or foreshocks, have no magnitude-dependent precursor time. Meanwhile the A_2-type precursors observed by means of geodetic work, changes in seismic-wave velocities and the like seem to have a precursor time which is closely correlated to the magnitude of coming earthquakes. A precursor of this type may possibly be interpreted by the current theory of dilatancy. The A_1-type precursors, observed mostly several hours prior to the main shock, may be caused by a creep-like failure before the main rupture of the Earth's crust.

Probabilities for an anomalous signal of various geophysical elements to be related to a forthcoming earthquake are estimated on the basis of the existing data of precursors.

A feasible strategy for predicting a large earthquake as suggested by the present study will be as follows: First of all, we monitor accumulation of crustal strain by means of geodetic work. The next task is to detect an A_2 signal which would arise from a highly strained crust sooner or later. If the spatial extent of the A_2-type precursor is known, it is possible to estimate roughly the magnitude as well as the occurrence time of the coming earthquake. Finally, detection of an A_1-type precursor, if it should occur, would provide a short-range forecast having a time span of hours.

INTRODUCTION

Since the beginning of modern seismology, much effort has been made toward accumulating data relevant to premonitory effects of an earthquake. Progress in this line was especially remarkable in the last decade as nation-wide programs on earthquake prediction research were launched notably in Japan, the United States, and the USSR.

Quite a few legends about precursory phenomena such as unusual behavior of fish and animals, extraordinary weather, and mysterious light preceding an earthquake were told in earlier years although most of them can hardly provide data for scientific analysis. Even data taken during the early period of modern seismology were often vague and fragmentary, so that no detailed analyses of earthquake precursors were possible until recent years.

Progress in understanding earthquake phenomena was so considerable in recent years, however, that one can conceive of a series of physical processes—i.e., strain accumulation, dilatancy development, and possible occurrence of creep-like failure immediately before the main rupture in the Earth's crust—as a plausible course of earthquake generation. As many of the concepts are discussed by many authors these days on the basis of geophysical elements which may well provide some premonitory effects, the writer thinks that it is high time to review the precursors reported so far and to see which of them can possibly be used for actual prediction. It would be highly rewarding if a criterion to make better use of a precursor is suggested through such a study. Myachkin and Zubkov (1973) made similar statistics of earthquake precursors, but their work does not indicate the various natures of precursors of different kinds in detail.

The author did not attempt to collect all precursors hitherto reported. Only precursors that came to his knowledge in recent years will be analyzed. Much stress will therefore be put on Japanese and American data because they are readily accessible to him. In addition a fair amount of Soviet data are also taken from literature published in, or translated into, either Japanese or English. The writer regrets that he has no Chinese data that can be treated in this paper in spite of the reported advancement of earthquake prediction research in the People's Republic of China. This is also the case for New Zealand, Italy, Turkey, and other countries where, the writer believes, many data suitable for the present study probably exist.

DATA

The precursors, 282 in all, are classified into 15 categories according to observational methods and are listed in the tables in the Appendix. The name of the earthquake (name of district, county, city, town or other subdivision when no official name is given), year of earthquake occurrence, earthquake magnitude (M), epicenter (mostly in terms of longitude and latitude), quantitative description of precursor whenever possible, precursor time, epicentral distance when available, and other remarks including the reference are given.

The following are brief descriptions of each discipline for observing precursors:

Land deformation as revealed by geodetic work. Most of the data were taken by means of repetition of leveling surveys. In addition to these, there are a few data taken by geodimeter surveys and the measurements of 100-m base lines of rhombic shape near Tokyo. Premonitory land uplifts as indicated by anomalous sea retreat and tide-gauge observation are also included.

Tilt and strain. A fairly extensive set of precursory changes has been obtained by means of tiltmeter and strain meter observations, although the signal-to-noise ratio of observations of this kind is usually low. In particular, tilts observed by a horizontal pendulum-type tiltmeter often suffer a large drift of unknown origin.

It has sometimes been reported that a ground tilting observed by a water-tube tiltmeter having a length of several tens of meters harmonizes very well with that deduced from repeated leveling surveys around the observation point. In such a case, the tilting must reflect the crustal movement of regional extent. A precursor observed by such an instrument may be important for earthquake prediction.

Foreshock. There are many reports that foreshocks occurred prior to a main shock. Precursor times reported, so far, for foreshocks range from a few minutes to a few hundreds of days. It is feared that the definition of foreshock is not always clear. Precursor time for a foreshock sequence is defined in this paper by the interval between the first shock and the main one.

b-value. The coefficient b, that is involved in the Gutenberg-Richter formula for relationship between earthquake frequency (N) and magnitude (M), i.e. $N = a-bM$, has been said to decrease prior to an earthquake.

Microseismicity. Decrease in the number of microearthquakes before a main shock has sometimes been reported.

Source mechanism. Precursory changes in the direction of stress axes as derived from focal mechanisms have been reported in Garm, the USSR.

Fault creep anomaly. A few reports are available on a precursory change in the creep rate of the San Andreas fault.

Seismic-wave velocities. Changes in the ratio of compressional-wave velocity (V_p) to shear-wave velocity (V_s) prior to an earthquake have been found in the USSR, the United States, and Japan. It has sometimes been reported that V_p itself changes. Shear-velocity anisotropy has also been reported.

Geomagnetic field and earth currents. They are one of the most classical problems in the search for precursors. Recent investigations (e.g., Rikitake, 1968; Johnston *et al.*, 1973) made it clear, however, that almost all of the existing data are spurious. Only a few data on geomagnetism can therefore be used in this paper. Earth-current data are taken from the observations in Kamchatka, although they do not harmonize with other precursors.

Resistivity. Short- and long-term resistivity precursors have been reported from Japan, the USSR and the United States.

Radon emission. Precursory changes in radon emission of underground water have been reported in the USSR.

Underground water. In spite of the fact that underground water is largely affected by a strong earthquake, only a few quantitative reports on precursors as detected by changes in water level and temperature are available.

Oil flow. Precursory changes in the amount of oil flow from petroleum wells have been reported in the Gulf of Suez.

In Table 1 are shown the numbers of data available for the respective disciplines mentioned in the above.

TABLE 1

NUMBER OF PRECURSORS

Discipline	Abbreviation	No. of data
Land deformation	*l*	19
Tilt and strain	*t*	84
Foreshock	*f*	73
b-value	*b*	11
Microseismicity	*m*	3
Source mechanism	*s*	6
Fault creep anomaly	*c*	2
V_p/V_s	*v*	27
V_p and V_s	*w*	11
Geomagnetism	*g*	2
Earth currents	*e*	13
Resistivity	*r*	17
Radon	*i*	9
Underground water	*u*	2
Oil flow	*o*	3
Total		282

HISTOGRAMS OF PRECURSOR TIME

First of all, let us produce a histogram of precursor-time T on the basis of the whole data regardless of disciplines. Because the precursor time reported ranges from a few minutes to a few thousand days, the following discussion will be made mostly on the basis of $\log_{10}T$ where T is measured in units of days.

Figure 1 shows the numbers of logarithmic precursor time falling in respective ranges having an interval of 0.5. It is apparent in the histogram that the frequency of logarithmic precursor time indicates two maxima around $\log_{10}T = -1$ and 1, respectively.

In view of the fact that there are a large number of precursors in disciplines t (tilt and strain) and f (foreshock), 84 and 74, respectively, similar histograms are produced

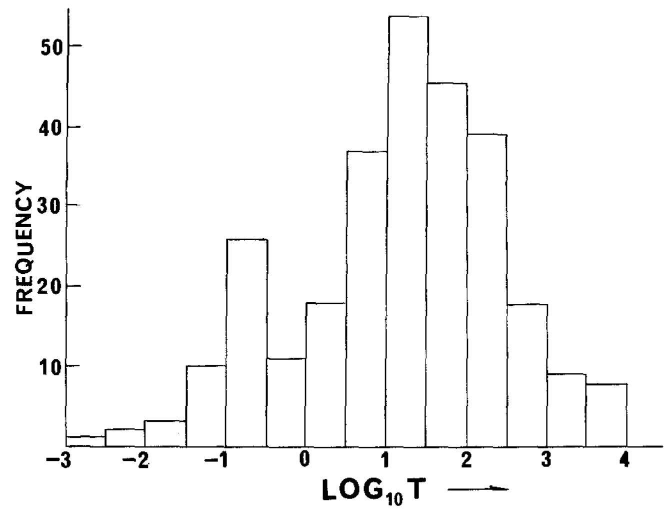

FIG. 1. The histogram for the whole data of precursor time T which is measured in units of days.

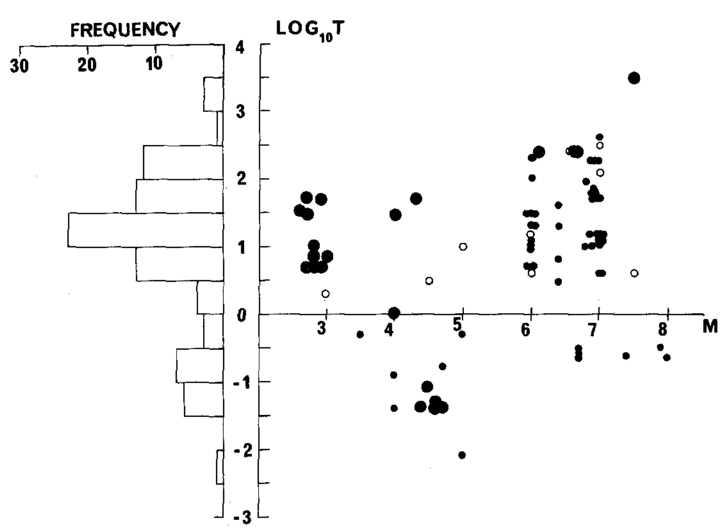

FIG. 2. The histogram of the data for discipline t (tilt and strain) combined with the logarithmic precursor time in days versus magnitude plots. As the histogram includes the data for which the magnitude is not known, there is some discrepancy in number between the histogram and the plots. Large solid, small solid, and open circles denote data taken by water-tube and bore-hole tiltmeters, horizontal pendulum tiltmeters, and strain meters, respectively.

for these precursors only. At the same time, dependency of precursor time on earthquake magnitude is examined, too. In Figures 2 and 3 are shown the histograms combined with the magnitude dependencies, respectively, for disciplines t and f. Looking at these figures, it may be said that no correlation between precursor time and magnitude seems to exist as far as the whole data of precursors of tilt and strain or foreshock are concerned. It should be pointed out, however, that there are two peaks in the histogram of tilt and strain around $\log_{10} T = -1$ and 1, as we have also seen in Figure 1. This might suggest that we sometimes monitor short-range precursors, that have nothing to do with earthquake magnitude, by tilt and strain observations. No such tendency can be observed in the foreshock histogram.

In order to see whether there is any difference in nature between tilt and strain precursors observed by different instruments, plots in Figure 2 are made by making use of large solid circles, small solid circles, and open circles, respectively, for data taken by

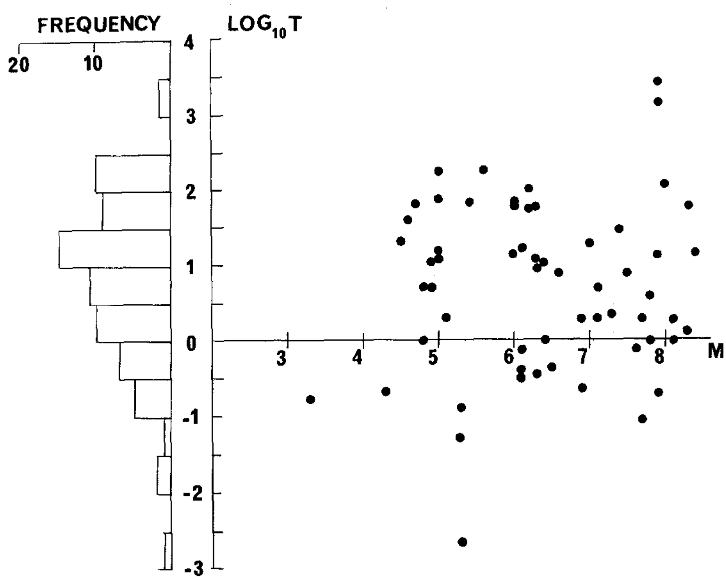

FIG. 3. The histogram of the data for discipline f combined with the logarithmic precursor time in days versus magnitude plots.

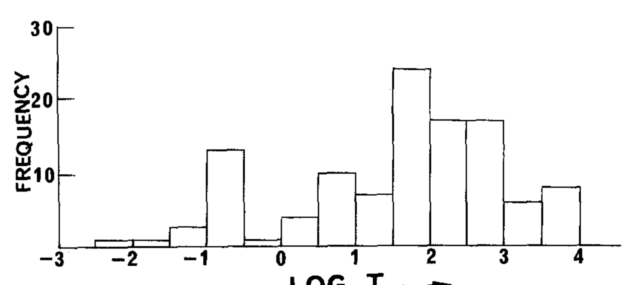

FIG. 4. The histogram of the data excluding those for disciplines t and f.

water-tube or bore-hole tiltmeters, horizontal pendulum tiltmeters (including bubble levels), and strain meters. A close look at the figure seems to suggest a tendency that the logarithmic precursor time becomes larger as the magnitude increases and that some isolated plots cluster around $\log_{10} T = -1$ for large solid circles. Such a tendency is very similar to the characteristics of precursors which the author calls the A-type ones in the following paragraphs. It might be said that most of the tilt precursors observed by water-tube and bore-hole tiltmeters are similar in nature to those for land deformation as detected by geodetic work, V_p/V_s changes, and resistivity changes. However, the scattering is so large for data taken by horizontal pendulum tiltmeters and strain meters that nothing systematic can be found.

Almost all earth-current precusor times (discipline e) take on a value around $\log_{10} T = 1.1$ regardless of the magnitude of associated earthquakes. Such a tendency does not fit into any of the statistics given here. As the number of precursors in this discipline is small, no detailed discussion will be attempted for earth-current precursors.

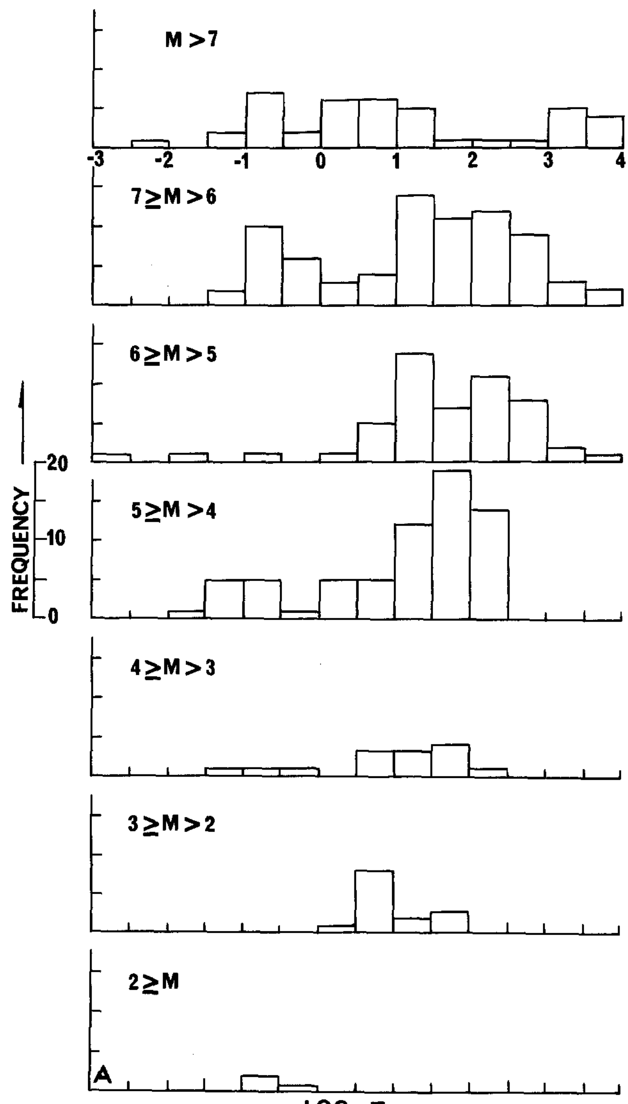

FIG. 5a. Histograms of logarithmic precursor time in days for the whole data as classified into successive magnitude ranges.

Precursor times for all other disciplines, i.e., disciplines l, b, m, s, c, v, w, g, r, i, u, and o, are put together, and their histogram is shown in Figure 4. The total number of precursors amounts to 112 in this case. It is again seen that the precursors may be divided into two kinds, the short-term ones around $\log_{10} T = -1$ and the long-term ones around $\log_{10} T = 2$. We call a precursor of these disciplines the A-type precursor.

Histograms For Different Magnitude Ranges

From a casual inspection of Figures 1 and 4 only, nothing is apparent about the difference in physical nature between the histograms for all these precursors and the A-type ones. However, a great difference is brought to light by making histograms for different magnitude ranges. Figure 5a presents such histograms for the whole data,

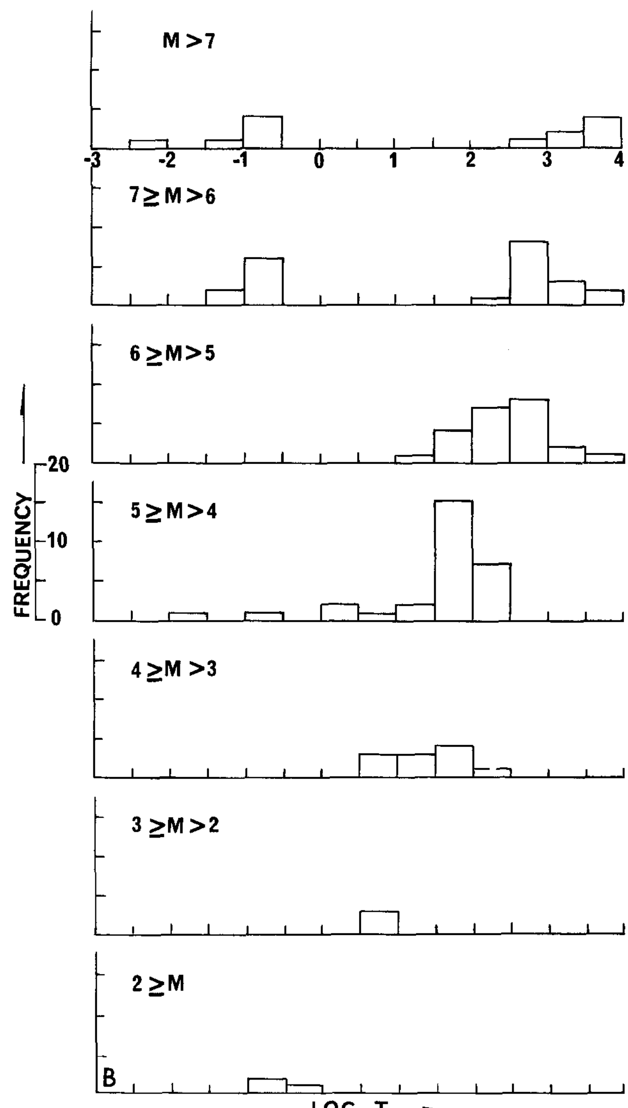

Fig. 5b. Histograms of logarithmic precursor time in days for the data, from which those for disciplines t and f are excluded, as classified into successive magnitude ranges.

while Figure 5b provides those for the A-type precursors. It is clearly demonstrated in Figure 5b that the maximum frequency for each magnitude range shifts to larger precursor times as earthquake magnitude becomes larger.

It is also interesting to note that, regardless of magnitude range, there is an isolated peak of precursor times around $\log_{10}T = -1$. The frequency of this short-term precursor seems to increase as the earthquake magnitude becomes larger.

It is therefore concluded that precursors of the A-type consist of A_1 and A_2 types. The A_1-type precursor is characterized by a short precursor time, i.e., $\log_{10}T = -1$ or so, while the A_2 type has a magnitude-dependent precursor time.

Precursor Time Versus Magnitude Relationship of A-Type Precursors

Dependence of precursor time on magnitude of the associated earthquake for A-type precursors is illustrated in Figure 6. Each point is designated with a letter used for the discipline abbreviations as given in Table 1. As expected, the points are clearly separated

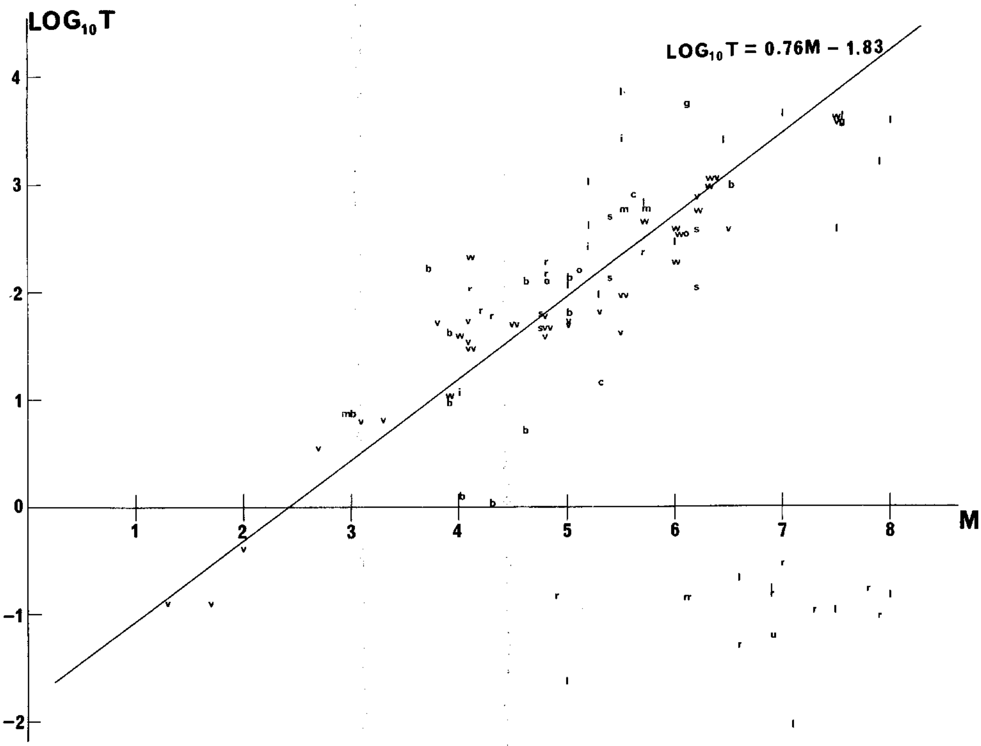

Fig. 6. Logarithmic precursor time in days versus magnitude plots for the data excluding those for disciplines t and f.

into two groups. The group for magnitudes larger than approximately 5 and distributed below the axis of abscissa does not seem to depend on magnitude, namely this being the A_1-type precursor group.

The remaining points, those for the A_2-type precursors, are evidently magnitude-dependent, the best-fitting straight line being obtained by means of the least-squares method as

$$\log_{10}T = 0.76\,M - 1.83 \tag{1}$$

which is also shown in the figure. It is interesting to note that equation (1) is compatible with the precursor time versus magnitude relationships as obtained by a few authors, i.e.

$$\log_{10}T = 0.685\,M - 1.57 \qquad \text{(Scholz } et\ al.\text{, 1973)} \quad (2)$$

$$\log_{10}T = 0.80\,M - 1.92 \qquad \text{(Whitcomb } et\ al.\text{, 1973)} \quad (3)$$

$$\log_{10}T = 0.79\,M - 1.88 \qquad \text{(Tsubokawa, 1969, 1973)} \quad (4)$$

Equations (2), (3) and (4) have been obtained from data which are one order of magnitude smaller in number than the present ones.

Weibull Distribution Analysis

In the hope of analyzing the precursor data in a little more quantitative way, a Weibull distribution analysis is attempted. It is assumed that logarithmic precursor time is governed by a distribution

$$\lambda(s) = K\,s^m \qquad (s = \log_{10}T + c) \tag{5}$$

where λ is the probability for a logarithmic precursor time to fall in an interval between s and $s+\Delta s$ where Δs is much smaller than s. c is a constant which may be chosen in such a way as to make actual calculation easy.

Much of Weibull distribution analysis in earthquake prediction study has been given in Hagiwara (1974) and Rikitake (1975). Only a very brief account of the analysis will be described below.

Denoting a cumulative probability for s to take on a value between 0 and s by $F(s)$, we define a function

$$R(s) = 1 - F(s). \tag{6}$$

In that case it is shown that the following relation holds good

$$\log_e \log_e (1/R) = \log_e \frac{K}{m+1} + (m+1) \log_e s. \tag{7}$$

Counting occurrence frequency of logarithmic precursor time n_i for each range having an interval Δs, probability density f_i for a range between $i\Delta s$ and $(i+1)\Delta s$ $(i = 0, 1, 2, \ldots)$ can be obtained from

$$f_i \Delta s = n_i/N \tag{8}$$

in which N is the total number of the data. Accordingly, the cumulative probability is obtained as

$$F = \Delta s \sum_{i=0}^{i} f_i = \sum_{i=0}^{i} n_i/N. \tag{9}$$

In an actual analysis, we make use of the values of R obtained from F thus calculated. In that case, K and m can be determined from (7) by means of the least-squares method. Once K and m are determined, mean logarithmic precursor time and its standard deviation can readily be calculated. Furthermore, cumulative probability, probability density and the like can also be determined by formulas presented in the former papers (Hagiwara, 1974; Rikitake, 1975).

Figure 7 is the $\log_e \log_e(1/R)$ versus $\log_e s$ points for the A-type precursors as obtained for a combination of $\Delta s = 0.5$ and $c = 2.5$. It is observed that the points are so scattered for $\log_e s$ smaller than 1 that it is hard to say that the distribution is represented by a Weibull one. However, the points for $\log_e s > 1$, i.e., the A_2-type data may be approximated by a straight line and so it may be said that a Weibull distribution approximately holds good for these data. Numerical values of parameters are determined by means of the least-squares method as $K = 0.0140$ and $m = 2.80$.

With the parameters thus obtained, cumulative probabilities for precursor time of the A_2-type precursor are calculated as shown in Figure 8. Supposing that an A_2-type precursor is observed, it is seen from the curve in the figure that the probabilities of an earthquake occurring within 10, 100 and 1000 days' time amount to 35, 68 and 91 per cent, respectively.

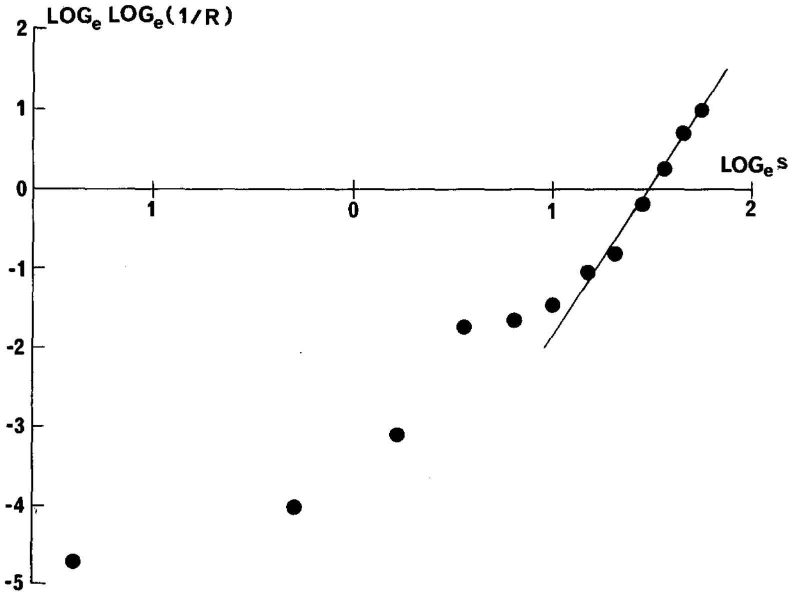

FIG. 7. $\log_e \log_e(1/R)$ versus $\log_e s$ plots and a Weibull distribution fitting for $\log_e s > 1$.

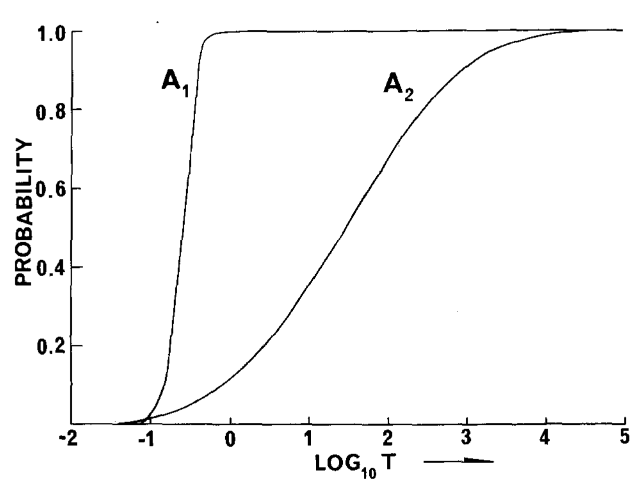

FIG. 8. Probabilities for an earthquake to occur during 0 to T days when A_1- and A_2-type precursors are observed at $T = 0$.

As for the A_1-type precursors, the analysis based on $\Delta s = 0.5$ is too rough for deducing an approximation by a Weibull distribution. Making use of a finer division, $\Delta s = 0.2$ say, however, the distribution centering on $\log_{10} T = 1.1$ can well be approximated by a Weibull one. Taking $c = 1.4$, we obtain $K = 15.4$ and $m = 5.00$ for this case.

The cumulative probabilities for the A_1-type precursors are then calculated as are also shown in Figure 8. It is seen that the probabilities for an earthquake to occur within 0.1, 0.5, and 0.7 days' time after observing an A_1-type precursor amount to 1, 25, and 70 per cent, respectively.

Discussion and Conclusions

An analysis of existing data of earthquake precursors made it clear that most precursors may be classified into the A_1, A_2, and B types.

An A_1-type precursor that is sometimes monitored by observations of land deformation, resistivity change and the like may possibly provide a means of predicting an earthquake within a time span of hours, although it would in many cases be no easy matter to detect it because of background noise. Precursors of this type seem more frequently to accompany earthquakes of large magnitude, e.g. $M > 6 \sim 7$. Physically speaking, it has been suggested that some sort of creep-like failure before the main rupture at the focal region might give rise to a precursor of this type.

An A_2-type precursor is characterized by the dependency of precursor time on magnitude of the up-coming earthquake. It is often observed in terms of land deformation, changes in seismic-wave velocities, and resistivity changes. Precursors of this type are useful for predicting an earthquake with a time-span of days, months, or even years depending upon the magnitude of the forthcoming earthquake. If we can foresee the magnitude by some other means such as the spatial extent of anomalous crustal deformation (e.g. Rikitake, 1969), it is possible to estimate the occurrence time very roughly. When we just observe an A_2-type precursor only without having any other information, a probabilistic approach for inferring the occurrence time as stated in the last section is possible. Many of the A_2-type precursors may well be interpreted in terms of geophysical phenomena associated with development of dilatancy (Scholz *et al.*, 1973; Whitcomb *et al.*, 1973).

Although fairly many data are available for precursors in disciplines t (tilt and strain) and f (foreshock), nothing certain is known about the physical nature of these precursors. Although some of them, e.g., those observed by water-tube or bore-hole tiltmeters, may be transferred to the A ($= A_1 + A_2$) type ones, most of them are hardly called a precursor in an exact sense because nothing has been established for their precursor times. Let us call them the B-type precursors.

When we observe an anomalous signal of geophysical phenomena as listed in Table 1, the probabilities for it to be classified into the A_1-, A_2-, and B-type precursors are estimated for the following three cases on the basis of the numbers of existing data of respective types. It is assumed that the numbers of data are sufficiently large for estimating such probabilities. Data for earth currents are excluded from the present discussion.

Case 1. Data for disciplines t (tilt and strain) and f (foreshock) are assigned to type B.

Case 2. Data only for discipline f are assigned to type B.

Case 3. Similar to case 2, but data taken by water-tube and bore-hole tiltmeters are transferred to the set of A-type data.

In Table 2 are given the probabilities based on the actual percentage of the data used for a precursory signal to be assigned to respective types of precursor. Although these probabilities will be modified provided a better set of data becomes available in the future, it may tentatively be said that about one-half of signals can be regarded as either short- or long-term precursors, i.e. A_1 and A_2 ones. There is no guarantee, however, that actual observations are not contaminated by background noise. Probabilities for observing A-type precursors would become small in very noisy circumstances. As it is difficult to see the overall noise level of the data treated in this paper, no exact discussion about this point can be made.

TABLE 2

PROBABILITIES, IN PERCENTAGE, FOR A PRECURSORY SIGNAL TO BE ASSIGNED TO RESPECTIVE TYPE PRECURSORS

	A_1 (%)	A_2 (%)	B (%)
Case 1	6	36	58
Case 2	8	49	43
Case 3	11	57	32

In addition to the A_1- and A_2-type precursors, i.e., short- and long-term ones, we may think of an extremely long-range precursor which may possibly be monitored by accumulation of crustal strain as can be observed by geodetic work. Such a signal may be called the C-type precursor. Probabilities of earthquake occurrence estimated from this type of precursor have been presented by Rikitake (1974, 1975) and Hagiwara (1974).

In summary, it is concluded that there are probably four kinds of earthquake precursors, i.e., the A_1, A_2, B, and C types, although the nature of the B-type precursor is not entirely clear at the moment.

In the light of the above analysis of earthquake precursors, a possible strategy for predicting major earthquakes is suggested as follows: First of all, we monitor a C-type precursor by repeating geodetic surveys. When a highly strained region is found by such surveys, we may well expect to have an A_2-type precursor by intensive geophysical observations over the region sooner or later. A rough guess of occurrence time may be made from the spatial extent of anomalous land deformation, if available. If a precursor such as the change in the V_p/V_s ratio, which recovers to a normal value before the earthquake occurrence, is observed, a more accurate guess of occurrence time is possibly made. Finally, it would not be absurd to expect an A_1-type signal which might occur prior to the main shock in a matter of hours.

Not much time has been spent for collecting data because the author refers only to literature which had already been known to him. It is almost certain, therefore, that many more data can be added to the present ones provided an intensive search for reports on earthquake precursors is made. Especially there would be many of them in literature from countries outside Japan and the United States. The writer will be greatly obliged if someone would inform him of data by which the present study may possibly be improved in the future.

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APPENDIX

Precursor Data

Earthquake	Year	Magnitude	Epicenter (deg)	Amount	Precursor Time (days)	Epicentral Distance (km)	Remarks
				Discipline I: Land Deformation			
Rhombus base line (Japan)							
Kanto	1923	7.9	35.2N 139.3E	10^{-5} in strain	1500	70	Tsuboi (1933)
Geodimeter (U.S.A.)							
Hollister, Calif.	1960	5.0	36.8N 121.4W	4×10^{-6}	0.0125	10	Hofmann (1968)
Corralitos, Calif.	1964	5.2	37.0 121.7	3×10^{-6}	400	10	Hofmann (1968)
Leveling							
(Japan)							
Sekihara	1927	5.3	37.5N 138.8E	1.5×10^{-5}	90	0	Tsuboi (1933)
Tonankai	1944	8.0	33.7 136.2	—	3600	150	Sudden change in secular movement. Geographical Survey Institute (1969)
				5×10^{-6}	0.15		Geographical Survey Institute (1969)
Nagaoka	1961	5.2	37.5 138.8	3×10^{-6}	1000	4	Kaminuma *et al.* (1973)
North Mino	1961	7.0	36.0 136.8	7×10^{-6}	4300	15	Tsubokawa (1973)
Niigata	1964	7.5	38.4 139.2	3×10^{-6}	3600	40	Dambara (1973)
Omi	1967	5.0	36.5 138.0	5×10^{-6}	120	3	Tsubokawa (1973)
(Hungary)							
Dunaharaszti	1956	6	Near Budapest	—	290	—	5.5 cm subsidence a few days before the shock, Bendefy (1966)
(USSR)							
Tashkent	1966	5.5	41.3 69.3	—	7000	—	Sudden change in secular movement, Mescherikov (1968)
Garm	1969	5.7	39.0 70.3	—	620	—	Sudden change in secular movement, Sadovsky and Nersesov (1974)
(U.S.A.)							
San Fernando	1971	6.4	34.4N 118.4W	1.2×10^{-5} in strain	2500	15	Castle *et al.* (1974)

Earthquake	Year	Magnitude	Epicenter (deg)		Amount	Precursor Time (days)	Epicentral Distance (km)	Remarks
Sea retreat (Japan)								
Ajikazawa	1793	6.9	40.7N	140.0E	1–2 m in land uplift	0.17	—	Imamura (1937)
Sado	1802	6.6	37.8	138.4	1 m	0.21	—	Imamura (1937)
Hamada	1872	7.1	34.8	132.0	2–3 m	0.008	—	Imamura (1937)
Tango	1927	7.5	35.6	135.1	1 m	0.10	—	Imamura (1937)
Tide-gauge (Japan)								
Niigata	1964	7.5	38.4	139.2	2 cm in subsidence	360	40	Tsubokawa *et al.* (1964)
					Discipline t: Tilt and Strain			
Horizontal pendulum tiltmeter (Japan)								
Kanto	1923	7.9	35.2	139.3	1.5×10^{-5} in tilt	0.33	80	Tokyo Univ. Obs., Imamura (1928)
Tottori	1943	7.4	35.5	134.2	5×10^{-7}	0.25	60	Ikuno Obs., Sassa and Nishimura (1951)
Tonankai	1944	8.0	33.3	136.2	2×10^{-7}	0.24	160	Kamigamo Obs., Sassa and Nishimura (1951)
Nanki	1950	6.7	33.9	135.8	7.5×10^{-7}	0.29	80	Tamamizu Obs.
					2×10^{-7}	0.28	120	Kamigamo Obs.
					1×10^{-7}	0.23	200	Kochi Obs., Sassa and Nishimura (1951)
Daishoji-oki	1952	6.8	36.5	136.2	3×10^{-4}	90	40	Ogoya Obs.
					1×10^{-4}	10		Ogoya Obs., Nishimura and Hosoyama (1953)
Yoshino	1952	7.0	34.5	135.8	—	400	80	Change in tilt direction. Kamigamo Obs.
					3×10^{-6}	15		Kamigamo Obs.
					1×10^{-5}	15	60	Kishu Obs.
					1×10^{-5}	15	80	Yura Obs., Tanaka (1965)

Earthquake	Year	Magnitude	Epicenter (deg)		Amount	Precursor Time (days)	Epicentral Distance (km)	Remarks
Odaigahara	1960	6.0	34.5N	136.0E	3×10^{-6}	200	40	Kishu Obs.
					5×10^{-6}	100		Kishu Obs.
					3×10^{-6}	10		Kishu Obs.
					1.5×10^{-5}	120	90	Shionomisaki Obs.
					2×10^{-6}	20		Shionomisaki Obs.
					3.3×10^{-5}	200	90	Yura Obs.
					4×10^{-6}	110		Yura Obs.
					3×10^{-6}	20	90	Yura Obs.
					—	30	90	Change in tilt direction. Akibasan Obs.
					—	5		Change in tilt direction. Akibasan Obs.
					1.5×10^{-5}	30	90	Oura Obs.
					3×10^{-6}	5		Oura Obs.
Odaigahara	1960	6.0	34.5	136.0	6×10^{-6}	30	100	Kamigamo Obs.
					1×10^{-6}	5		Kamigamo Obs., Tanaka (1965)
Hyuganada	1961	7.0	31.6	131.9	5×10^{-7}	12	120	Makimine Obs.
					5×10^{-7}	4		Makimine Obs. Tanaka (1965)
North Mino	1961	7.0	36.0	136.8	2.5×10^{-5}	50	40	Ogoya Obs.
					5×10^{-6}	15		Ogoya Obs.
					1×10^{-5}	50	60	Kamioka Obs.
					5×10^{-7}	15		Kamioka Obs., Tanaka (1965)
Shirahama-oki	1962	6.4	33.6	135.2	1×10^{-6}	20	35	Yura Obs.
					5×10^{-7}	7		Yura Obs.
					1×10^{-5}	40	65	Kishu Obs.
					1×10^{-6}	3		Kishu Obs., Tanaka (1965)
Echizenmisaki-oki	1963	6.9	35.8	135.8	1.8×10^{-5}	180	90	Kamigamo Obs.
					5×10^{-6}	60		Kamigamo Obs.
					3×10^{-6}	15		Kamigamo Obs.
					5×10^{-6}	180	80	Ogoya Obs.
Echizenmisaki-oki	1963	6.9	35.8	135.8	7×10^{-6}	70		Ogoya Obs.
					4×10^{-6}	15		Ogoya Obs.
					2×10^{-6}	180	110	Ikuno Obs.
					2×10^{-6}	60		Ikuno Obs.
					1×10^{-6}	10		Ikuno Obs., Tanaka (1965)

Earthquake	Year	Magnitude	Epicenter (deg)		Amount	Precursor Time (days)	Epicentral Distance (km)	Remarks
(USSR)								
Ashkhabad	1957	4	—	—	5×10^{-7}	0.042	25	Ashkhabad Obs., Ostrovskiy (1972, 1974)
Alma Ata	1958	4.0	—	—	3×10^{-7}	0.125	250	Alma Ata Obs., Ostrovskiy (1972, 1974)
		4.7						
Afghanistan	1959	5.0	—	—	3×10^{-6}	0.5	245	Kondara Obs., Ostrovskiy (1972, 1974)
Afghanistan	1959	3.5	—	—	3×10^{-6}	0.5	300	Kondara Obs., Ostrovskiy (1972, 1974)
Bubble level (U.S.A.)								
San Fernando (aftershock)	1971	4.7	34.4N	118.4W	6×10^{-4}	0.17	10	Observed by a level attached to a theodolite. Sylvester and Pollard (1972)
Water-tube tiltmeter								
(Japan)								
Fukui (aftershock)	1948	ca. 5	36.2N	136.2E	1×10^{-6}	0.008	20	Bandojima Obs., Hagiwara *et al.* (1949)
Niigata	1964	7.5	38.4	139.2	1.5×10^{-5}	3000	80	Maze Obs., Kasahara (1973)
Matsushiro	1966	4.5	36.0	138.0	1.5×10^{-7}	0.083	2.4	Matsushiro Obs., Yamada (1973)
		4.5					4.2	
		4.5					2.4	
Matsushiro	1966	4.6	36.0	138.0	3×10^{-7}	0.042	6.7	Matsushiro Obs., Yamada (1973)
Matsushiro	1966	4.7	36.0	138.0	8×10^{-7}	0.042	8.1	Matsushiro Obs., Yamada (1973)
Matsushiro	1966	4.4	36.0	138.0	6×10^{-7}	0.042	4.5	Matsushiro Obs., Yamada (1973)
		4.4					4.1	
Matsushiro	1966	4.6	36.0	138.0	5×10^{-7}	0.050	4.9	Matsushiro Obs., Yamada (1973)
Central Gifu	1969	6.6	35.8	137.1	5×10^{-7}/yr	250	48	Inuyama Obs.
					5×10^{-7}/yr	250	60	Kamitakara Obs., Shichi (1973)
Atsumi Peninsula	1971	6.1	34.5	137.1	5×10^{-7}/yr	250	90	Inyuama Obs., Shichi (1973)
(U.S.A.)								
Danville	1970	4.3	37.8N	121.9W	5×10^{-7}	30	30	Berkeley Obs.
		4.3	—	—				
		4.1	—	—	3×10^{-7}	1.0		Berkeley Obs., Wood and Allen (1971)
		4.0	—	—				

Earthquake	Year	Magnitude	Epicenter (deg)		Amount	Precursor Time (days)	Epicentral Distance (km)	Remarks
Bore-hole tiltmeter (U.S.A.)								
Hollister area	1973	3.0				7	3	Nutting Obs.
Hollister area	1973	2.8				5	7	Nutting Obs.
Hollister area	1973	2.7				5	6	Nutting Obs.
Hollister area	1973	2.9				5	7	Nutting Obs.
Hollister area	1974	4.3				15	17	Nutting Obs.
Hollister area	1973	2.8	Ranging 36.5–37.0N 121.1–121.7W		Sudden change in tilt direction	7	8	Libby Obs.
Hollister area	1973	2.6				33	5	Libby Obs.
Hollister area	1974	2.7				30	10	Libby Obs.
Hollister area	1973	2.9				15	6	Sage Obs.
Hollister area	1973	2.8				10	7	Sage Obs.
Hollister area	1974	2.7				15	4	Sage Obs.
								Data taken from Johnston and Mortensen (1974)
Strain meter								
(Japan)								
Yoshino	1952	7.0	34.5N	135.8E	2.5×10^{-6}	300	50	Osakayama Obs., Sassa and Nishimura (1955)
Yoshino	1952	7.0	34.5	135.8	1.5×10^{-6}	120	72	Ide Obs.
					3×10^{-6}	60		Ide Obs.
					1×10^{-6}	11		Ide Obs., Tanaka (1959)
Central Gifu	1969	6.6	35.8	137.1	5×10^{-7}/yr	250	48	Inuyama Obs., Shichi (1973)
(USSR)								
South Tien Shan	1965	6.0	41.8	79.4	9×10^{-8}	15	250	Talgar Obs.
					5×10^{-8}	4		Talgar Obs., Latynina and Karmaleyeva (1970)
Hindu Kush	1965	7.5	36.3	70.7	Change in strain rate	4	300	Kondara Obs., Latynina and Karmaleyeva (1972)
Dushambe	1965	4.5	—	—	Change in strain rate	3	100	Kondara Obs., Latynina and Karmaleyeva (1972)

Earthquake	Year	Magnitude	Epicenter (deg)		Amount	Precursor Time (days)	Epicentral Distance (km)	Remarks
Djungarskoie Ala-Tau	1967	5.0	45.4N	80.4E	5×10^{-8}	10	320	Talgar Obs., Laytnina and Karmaleyeva (1970)
Pamirs	1969	3.0	39.0	70.3	3×10^{-8}	2	5	Garm Obs., Latynina and Karmaleyeva (1970)
					Discipline f: Foreshock			
Japan								
Hachinoe-oki	1763	7.4	40.7	142.0		30		Utsu (1972)
Tokachi-oki	1843	8.4	41.8	144.8		15		Utsu (1972)
Iga	1854	6.9	34.8	136.2		2		Musha (1951)
Edo	1855	6.9	35.8	139.8		0.42		Musha (1951)
Hachinoe-oki	1856	7.8	40.5	143.5		4		Utsu (1972)
Hamada	1872	7.1	34.8	132.0		5		Kaminuma *et al.* (1973)
Nemuro-oki	1894	7.9	42.4	146.3		0.21		Utsu (1972)
Rikuu	1896	7.5	39.5	140.7		8		Kaminuma *et al.* (1973)
Kamitakai	1897	6.3	36.6	138.2		0.35		Kaminuma *et al.* (1973)
Ugosen	1914	6.4	39.5	140.4		11		Kaminuma *et al.* (1973)
Omachi	1918	6.1	36.5	137.8		0.42		Kaminuma *et al.* (1973)
		6.1						
Shimabara	1922	6.5	32.7	130.1		0.46		Kaminuma *et al.* (1973)
		5.9						
Kanto	1923	7.9	35.2	139.3		1500		Activity in Wakayama Pref., Kanamori (1972)
North Gifu	1927	4.6	36.1	137.0		40		Mogi (1963)
North Hiroshima	1927	6.0	35.0	132.8		70		Mogi (1963)
Sekihara	1927	5.3	37.5	138.8		0.029		Kaminuma *et al.* (1973)
Central Kumamoto	1929	4.9	32.9	130.8		11		Mogi (1963)
North Izu	1930	7.0	35.1	139.0		19		Mogi (1963)
North Hiroshima	1930	6.0	35.0	132.9		60		Mogi (1963)
East Yamanashi	1931	6.0	35.4	138.9		14		Mogi (1963)
Huganada	1931	6.6	32.2	132.1		8		Mogi (1963)
Sanriku	1933	8.3	39.1	144.7		60		Kaminuma *et al.* (1973)
North Kumamoto	1933	5.0	33.0	130.9		15		Mogi (1963)
West Oita	1935	4.8	33.1	131.1		1		Mogi (1963)
Central Kyoto	1936	4.5	35.1	135.8		21		Mogi (1963)

Earthquake	Year	Magnitude	Epicenter (deg)		Amount	Precursor Time (days)	Epicentral Distance (km)	Remarks
Central Kumamoto	1937	5.0	32.8N	130.8E		174		Mogi (1963)
South Nagasaki	1937	5.0	32.8	130.0		76		Mogi (1963)
Central Yamanashi	1940	5.0	35.6	138.5		12		Mogi (1963)
Nagano	1941	6.2	36.7	138.3		56		Mogi (1963)
Mikawa	1945	7.1	34.7	137.0		2		Kaminuma *et al.* (1973)
East Kumamoto	1946	5.1	32.7	130.6		2		Mogi (1963)
Imaichi	1949	6.4	36.7	139.7		1		Kaminuma *et al.* (1973)
		6.7						
Tokachi-oki	1952	8.1	42.3	143.9		2		Kaminuma *et al.* (1973)
Oshima Peninsula	1953	5.4	42.2	139.9		66		Mogi (1963)
Boso-oki	1953	7.5	34.3	141.8		2200		Activity in Wakayama Pref., Kanamori (1972)
Amami-oshima	1954	6.1	29.3	131.3		0.33		Mogi (1963)
Niijima Isl.	1957	6.3	34.3	139.4		12		Mogi (1963)
Kamikochi	1963	4.8	36.2	137.6		5		Mogi (1963)
Matsushiro	1964	3.3	36.0	138.0		0.17		Suyehiro *et al.* (1964)
Matsushiro	1967	ca. 5	36.0	138.0		180		Sakai Village, Hagiwara (1973)
Matsushiro	1967	ca. 5	36.0	138.0		210		Azuma Village, Hagiwara (1973)
Matsushiro	1967	ca. 5	36.0	138.0		120		Koshoku City, Hagiwara (1973)
Matsushiro	1967	ca. 5	36.0	138.0		120		Togura Town, Hagiwara (1973)
Matsushiro	1967	ca. 5	36.0	138.0		120		Kamiyamada Town, Hagiwara (1973)
Matsushiro	1967	ca. 5	36.0	138.0		150		Sanada Town, Hagiwara (1973)
Tokachi-oki	1968	7.9	40.7	143.6		14		Kaminuma *et al.* (1973)
Off Kii Peninsula	1968	4.9	33.0	135.6		5		Tsumura (1973)
Wachi	1968	5.6	35.2	135.4		180		Kyoto Pref., Okano and Hirano (1970)
Southeast Atika	1970	6.2	39.2	140.8		100		Res. Group Microearthquakes (1971)
Chizu	1970	4.3	35.3	134.2		0.21		Tottori Pref., Kishimoto and Nishida (1971)
Atsumi Peninsula	1971	6.1	34.5	137.1		0.75		Iida *et al.* (1971)
Hachijojima Is. -oki	1972	7.3	33.3	141.0		2.3		Kasahara *et al.* (1973)
Kuril Islands								
Off Itrup	1958	8.0	44.3	148.5		120		Utsu (1972)
Off Urup	1963	8.1	43.8	150.0		1		Utsu (1972)

Earthquake	Year	Magnitude	Epicenter (deg)		Amount	Precursor Time (days)	Epicentral Distance (km)	Remarks
Off Shikotan	1969	7.8	40.1N	142.5E		1		Utsu (1972)
United States								
Off South California	1812	—	34N	120.0W		0.021		NOAA (1973)
Soccoro	1906	—	34.0	107.0		10		New Mexico, NOAA (1973)
Northeast Arizona	1910	—	36.0	111.1		13		NOAA (1973)
Pleasant Valley	1915	7.6	40.5	117.5		0.8		Nevada, NOAA (1973)
Elsimore	1921	6.1	38.8	112.2		17		Utah, NOAA (1973)
Whittier	1929	4.7	34	118		64		California, Richter (1958); NOAA (1973)
Ellensburg	1934	—	47	121		4		NOAA (1973)
Montana	1935	6.3 6.0	46.6	112.0		9		NOAA (1973)
Belen	1935		34.7	106.8		5		New Mexico, NOAA (1973)
Kern County	1952	7.7	35.0	118.8		0.092		Richter (1958)
Hawthorne	1956	5.3	38.3	119.0		0.0021		Nevada, NOAA (1973)
Rat Isl.	1965	7.7	51.3	178.6		4		Mogi (personal communication, 1968)
Parkfield	1966	5.3	35.9	120.9		0.13		California, Mogi (personal communication, 1968)
Danville	1970	4.3 4.3 4.1 4.0	37.8	121.9		16		California, Lee *et al.* (1971)
Bear Valley South	1972	4.6	36.5	121.1		5		California, Wyss and Lee (1973)
Chile								
Off Chile	1960	8.3	39.5S	74.5W		1.38		Suyehiro (1966)
Greece								
Cremasta	1966	6.3	38.9N	21.5E		60		Rothé (1970)
Nicaragua								
Managua	1972	6.2	12.1N	86.2W		0.125		Matumoto and Latham (1973)

Earthquake	Year	Magnitude	Epicenter (deg)		Amount	Precursor Time (days)	Epicentral Distance (km)	Remarks
					Discipline b: b-Value			
United States								
Fairbanks	1970	3.0	—	—	1.3→0.8 decrease	7		Alaska, Scholz *et al.* (1973)
Fairbanks	1970	5.0	—	—	—	60		Alaska, Scholz *et al.* (1973)
Danville	1970	4.3	37.8N	121.9W	1.2→0.8	1		California, Bufe (1970)
Danville	1970	4.0	37.8	121.9	1.05→0.6	1.2		California, Bufe (1970)
Danville	1970	3.7 3.6	37.8	121.9	1.2→0.9	155		California, Wyss and Lee (1973)
Hollister	1971	3.9	36.7	121.3	0.8→0.6	40		California, Wyss and Lee (1973)
Hollister	1971	3.9	36.7	121.3	0.8→0.4	9		California, Wyss and Lee (1973)
Bear Valley North	1972	5.0	36.6	121.2	1.0→0.8	130		California, Wyss and Lee (1973)
Bear Valley South	1972	4.6	36.5	121.1	1.2→0.9	120		California, Wyss and Lee (1973)
Bear Valley South	1972	4.6	36.5	121.1	0.9→0.8	5		California, Wyss and Lee (1973)
Venezuela								
Caracas	1967	6.5	10.6	67.3	1.3→0.7	930		Fiedler (1974)
					Discipline m: Microseismicity			
United States								
Fairbanks	1970	3.0	—	—	Daily freq. 80→40 decrease	7		Alaska, Scholz *et al.* (1973)
USSR								
Garm	1969	5.7	39.0N	70.3E	—	550		Central Asia, Sadovsky and Nersesov (1974)
Garm	1966	5.5	39.0	70.3	—	550		Central Asia, Sadovsky and Nersesov (1974)
					Discipline s: Source Mechanism			
USSR								
Garm	1966	5.4	39.0	70.0		470 130		Central Asia, Sadovsky and Nersesov (1974)
Garm	1969	6.2	39.0	70.0		360 110		Central Asia, Sadovsky and Nersesov (1974)

Earthquake	Year	Magnitude	Epicenter (deg)		Amount	Precursor Time (days)	Epicentral Distance (km)	Remarks
Naryn	1963	4.8	41.4N	76.0E		720		Central Asia, Simbireva (1973)
Naryn	1966	4.8	41.4	76.0		45		Central Asia, Simbireva (1973)
				Discipline c: Fault Creep Anomaly				
United States								
Hollister	1961	5.6 5.5	36.7N	121.3W	Creep rate doubled	800		Nason (1973)
Parkfield	1966	5.3	35.9	120.9	—	14		Fresh cracks, Nason (1973)
				Discipline v: V_p/V_s				
USSR								
Garm	1956	5.5	39.0N	70.0E	10% decrease	90		
Garm	1956	4.8	39.0	70.0	12	57		
Garm	1957	4.1	39.0	70.0	12	53		
Garm	1959	5.5	39.0	70.0	10	72		
Garm	1961	4.1	39.0	70.0	9	51		
Garm	1961	4.8	39.0	70.0	12	36		
Garm	1962	4.5	39.0	70.0	8	48		
Garm	1962	4.5	39.0	70.0	10	48		
Garm	1963	4.1	39.0	70 0	17	30		
Garm	1963	4.8	39.0	70.0	9	45		
Garm	1964	4.1	39.0	70.0	13	30		
Garm	1966	5.5	39.0	70.0	12	90		
Garm	1967	4.8	39.0	70.0	9	45		Data taken from Semyenov (1969)
United States								
BML	1971	1.3	43.9N	74.4W	12	0.12		Blue Mountain Lake, N.Y.
BML	1971	1.7	43.9	74.4	—	0.12		
BML	1971	2.0	43.9	74.4	—	0.40		
BML	1971	2.7	43.9	74.4	12	3.4		
BML	1971	3.1	43.9	74.4	12	6.0		
BML	1971	3.3	43.9	74.4	15	6.1		Data taken from Scholz *et al.* (1973)
San Fernando	1971	6.4	34.4	118.4	10	1100 days		Whitcomb *et al.* (1973)
Windy Isl.	1971	3.8	51.6N	178.8E	5	50		Aleutian, Kisslinger and Engdahl (1974)

Earthquake	Year	Magnitude	Epicenter (deg)		Amount	Precursor Time (days)	Epicentral Distance (km)	Remarks
Japan								
North Miyagi	1962	6.5	38.7N	141.1E	70	360		Ohtake (1973)
Niigata	1964	7.5	38.4	139.2	40	3540		Res. Group Microearthquakes (1974)
Chugoku-Kinki	1967	5.0	35.0	135.0	9	50		Brown (1973)
Chugoku-Kinki	1968	5.0	35.0	135.0	7	52		Brown (1973)
North Nagano	1968	5.3	36.8	138.3	30	110		Ohtake (1973)
Southeast Akita	1970	6.2	39.2	140.8	20	730		Res. Group Microearthquakes (1974)
			Discipline w: V_p and V_s					
V_p anomaly (U.S.A.)								
San Fernando	1971	6.4	34.4N	118.4W	20% decrease	1100		Whitcomb *et al.* (1973)
Pt. Mugu, California	1973	6.0	34.1	119.0	20	380		Stewart (1973)
Riverside, California	1974	4.1	34.0	117.4	—	200		Whitcomb *et al.* (1974)
V_p residual								
(USSR)								
Garm	1969	5.7	39.0N	70.3E	0.4 sec increase	440	25	Wyss (1975)
(U.S.A.)								
Pt. Mugu	1973	6.0	34.1N	119.0W	1.0	180	10	Stewart (1973)
(Japan)								
Niigata	1964	7.5	38.4N	139.2E	10	3600	100	Research Group Microearthquakes (1974)
Matsushiro	1965–1967	6.3 (cumulative)	36.5	138.2	0.5	950	0	Wyss and Holcomb (1973)
(New Zealand)								
Seddon	1966	6.1	41.6S	174.3E	0.4	360	40	Wyss and Johnston (1974)
Gisborne	1966	6.2	38.6	177.7	0.4	550	18	Wyss and Johnston (1974)

Earthquake	Year	Magnitude	Epicenter (deg)	Amount	Precursor Time (days)	Epicentral Distance (km)	Remarks
V_s anisotropy (U.S.A.)							
Slate Mt., Nevada	1971	4.0	39.1N 118.2W	2.3% increase in $V_{SH}-V_{SV}$	38		Gupta (1973)
Mina, Nevada	1971	3.9	38.4 118.2	2.5	10		Gupta (1973)
			Discipline g: Geomagnetism				
Japan							
Tanabe	1962	6.1	33.7N 135.4E	7γ	3200	70	Tazima (1968)
Niigata	1964	7.5	38.4 138.2	10–15	3600	40	Fujita (1965)
			Discipline e: Earth Currents				
USSR							
Kamchatka	1959	7.8	— —	150 mV/km	17		
Kamchatka	1965	5.8	— —	80	16		
Kamchatka	1968	5.0	— —	120	17		
Kamchatka	1969	5.5	— —	100	20		
Kamchatka	1969	5.5	— —	90	13		
Kamchatka	1969	4.5	— —	70	10		
Kamchatka	1969	4.5	— —	50	10		
Kamchatka	1969	4.5	— —	50	8		
							Data taken from Myachkin *et al.* (1972) Epicentral distances are smaller than 150 km. Epicenters are off the eastern coast.
Kamchatka	1966	4.5	Russian Bay		0.13		Kronoki Obs., Sobolev and Morozov (1972)
Kamchatka	1968	6.0	53.0N 160.0E	300	9	30	Fedetov *et al.* (1970)
Kamchatka	1971	5.0	Kronotskiy Gulf	40	10	—	Sobolev (1974)
Kamchatka	1971	5.0	Kronotskiy Gulf	30	4	—	Sobolev (1974)
Kamchatka	1971	7.7	Kronotskiy Gulf	40	22	—	Sobolev (1974)

Earthquake	Year	Magnitude	Epicenter (deg)		Amount	Precursor Time (days)	Epicentral Distance (km)	Remarks
					Discipline r: Resistivity			
United States								
Hollister area	1973	3.9	36.6N	121.2W	24% decrease	60		Mazzella and Morrison (1974)
Hollister	1973	3.5	36.6	121.2	6	30		Mazzella and Morrison (1974)
USSR								
Garm	1967	4.2	39.0N	70.3E	12	66		
Garm	1968	4.3	39.0	70.3	3	57		
Garm	1969	5.7	39.0	70.3	18	225		
Garm	1969	4.8	39.0	70.3	14	141		
Garm	1970	4.8	39.0	70.3	12	180		
Garm	1972	4.2	39.0	70.3	8	102		
								Data taken from Baruskov (1974)
Japan								
Tokachi-oki	1968	7.9	44.7	143.6	-7.2×10^{-5} (rate of exchange)	0.096	712	
Central Saitama	1968	6.1	36.0	139.4	1.1×10^{-4}	0.14	96	
Off East Hokkaido	1969	7.8	43.1	148.2	1.0×10^{-4}	0.17	1094	
Central Gifu	1969	6.6	35.8	137.1	6.0×10^{-5}	0.050	205	
Erimozaki-oki	1971	7.0	41.2	143.7	-3×10^{-5}	0.29	780	
Hachijojima Isl.	1972	7.3	33.3	141.0	1×10^{-5}	0.10	252	
Tokyo Bay	1973	4.9	35.5	139.9	-3×10^{-5}	0.15	50	
Choshi-oki	1974	6.1	35.6	140.8	-3×10^{-5}	0.14	119	
Izu Peninsula	1974	6.9	34.6	138.8	-4×10^{-5}	0.17	100	
								Data taken from Yamazaki (1975). Observations were made at Aburatsubo, 60 km south of Tokyo.
					Discipline i: Radon			
USSR								
Tashkent	1966	4	41.3	69.3	14% increase	11		Scholz *et al.* (1973)
Tashkent	1966	5.2	41.3	69.3	20	250		Scholz *et al.* (1973)

Earthquake	Year	Magnitude	Epicenter (deg)		Amount	Precursor Time (days)	Epicentral Distance (km)	Remarks
Tashkent	1966	5.5	41.3N	69.3E	200	2500		Sadovsky *et al.* (1972)
Tashkent	1967	—	41.3	69.3	—	3		Hagiwara (1974, pers. comm.)
Tashkent	1967	—	41.3	69.3	—	3		Hagiwara (1974, pers. comm.)
Tashkent	1967	—	41.3	69.3	—	8		Hagiwara (1974, pers. comm.)
Tashkent	1967	—	41.3	69.3	—	7		Hagiwara (1974, pers. comm.)
Tashkent	1967	—	41.3	69.3	—	4		Hagiwara (1974, pers. comm.)
Ferganda	1969	—	40.4	71.3	—	13		Hagiwara (1974, pers. comm.)
				Discipline u: Underground Water				
USSR								
Przhevalsk	1970		42.5	78.4	15°C rise in temp. 15 cm rise in water level	72	30	Sadovsky *et al.* (1972)
Australia								
Meckering	1968	6.9	32.0S	117.0E	2.9 cm rise	0.063	110	Gordon (1970)
				Discipline o: Oil Flow				
Gulf of Suez	1969	6.1	27.5N	33.9E		330	100	Arieh and Merzer (1974)
Gulf of Suez	1971	4.8	27.5	33.9		120	100	Arieh and Merzer (1974)
Gulf of Suez	1972	5.1	27.5	33.9		150	100	Arieh and Merzer (1974)

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