Sequences of Microearthquakes Near the Yamasaki Fault

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Abstract

Data obtained by a long-running observation made by the Tottori Microearthquake Observatory reaveal separately distributed fractured regions where microearthquakes occur in clusters.

Near the central part of the Yamasaki fault a linear configuration of such fractured regions parallel to the fault trace over ten kilometers at a depth of about 11 km exists, whereas the depth of fractured regions around the eastern end of the fault is about 13 km.

Shallow-seated as well as deep-seated fractured regions are also confirmed.

In terms of the multiple time-series which consist of separate sequential events at the respective fractured regions, the space-time distribution of earthquake events near the Yamasaki fault can be described explicitly.

Adjacent regions within about 30 km have nearly common active periods and successive migration of activity occurs around the regions.

The life time of activity for each fractured region ranges from less than several months, a year or so, to more than several years.

Magnitude distributions for the respective fractured regions also show a regional difference between around the central part of the Yamasaki fault and around the eastern end of the fault.

1. Introduction

An earthquake is considered to be caused by a fracture in the crust or the upper mantle due to stress concentration. It is supposed that fracturing is initiated at a certain point and at a certain moment of time, and then the rupture is developed to other points in process of time generating an earthquake and finally ceases to develop. Moreover it may be considered that, once a fracured region is produced in a limited space, it will continue to be extended for some time in the form of stick-slip associated with a sequence of earthquake events.

How long the activity of a fractured region due to microearthquakes would continue is the question proposed by Tsukuda et al. (1976).[1] This problem is very important for making clear the whole process of microearthquake generation. One of the purposes of the present paper is to give an answer to this pending question surveying data obtained by a long-running observation made by the Tottori Microearthquake Observatory, Disaster Prevention Research Institute, Kyoto University.

The observatory has been keeping, for a long period from June, 1965 up to present, five observation stations or more (Fig. 1) around the Yamasaki fault, a conspicuous left-lateral strike-slip active fault,[2] and the data which have been com-

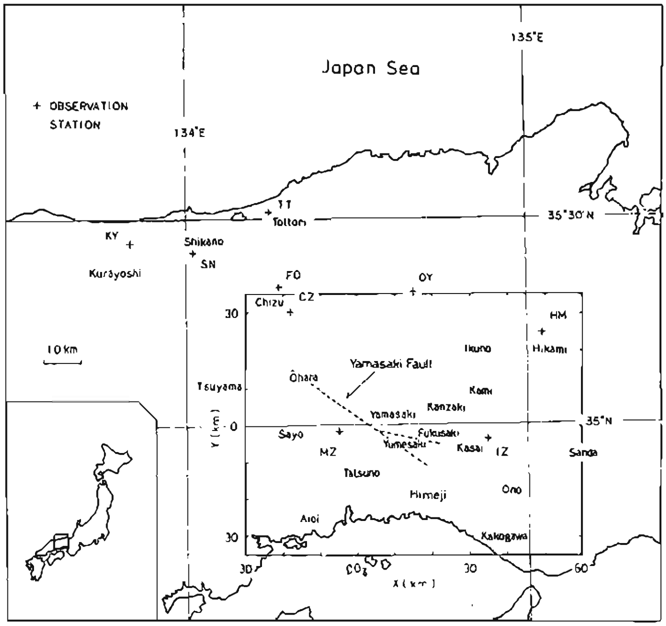

Fig. 1. Concerned regions and observation stations of the Tottori Microearthquake Observatory. Cartesian coordinates x and y are teken as eastward and northward from the origin (134°30'E, 35°N), respectively.

piled as a hypocentral list give us materials appropriate for the above purpose. The hypocentral file gives date, origin time, geographical location, focal depth, F-P time, magnitude, arrival times of P, S-P times, and polarities of initial onsets for each event.[3]

Another purpose of this paper is concerned with the location and the depth of a fractured region mentioned above where microearthquakes cluster. Studies along this line have been carried out by the author and his colleague using data from the recently introduced telemetering system at the Tottori Micreathquake Observatory.[1]

In this paper we deal with the space-time distribution of microearthquakes which occurred near the Yamasaki fault with special attention to the clustering feature of events. Data are adopted from the file above mentioned, making some corrections of errors.

As preliminaries a brief survey will be made with respect to the general feature of seismic activities in the region concerned.

2. General survey of seismicity near the Yamasaki fault

We will restrict the present study to the region surrounded by a rectangle as shown in Fig. 1. The geographical coordinates are the same as Oike (1975)[3] and will be used throughout this paper.

The seismicity map of shocks with magnitude 2.5 or larger is given in Fig. 2.

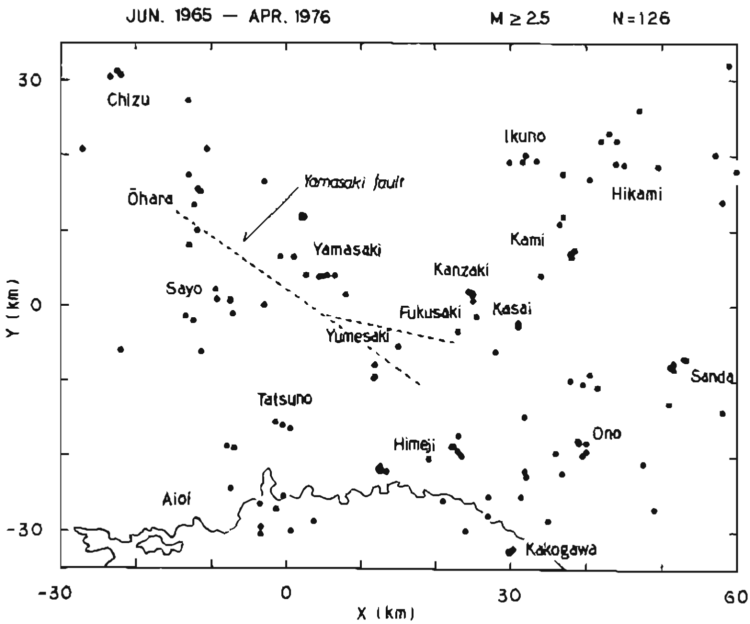

Fig. 2. Epicentral map for $M > 2.5$ with the period from June, 1965 to Apil. 1976. The extent of the region is: $-30\,\text{km} \leq x \leq 60\,\text{km}$, and $-35\,\text{km} < y \leq 35\,\text{km}$. The number of events involved is 126. Complete list of the events is given in Table 1 (Appendix).

In this epicentral distribution we can see a V-shaped seismic active zone and an aseismic region spread over the northern central area. Near and parallel to the boundary between active and inactive zones lies the Yamasaki fault.

As is apparent from Fig. 3, temporal variation of the number of shocks which occurred in the region concerned shows a big difference between the early half period from 1965 to 1970 and the later half from 1971 to 1976, or in other words, earthquake events there tend to cluster for limited periods. On the other hand the released energy is nearly stationary over the whole period merely showing slight periodical variation with a period of 4-5 years. The peak activities occurred three times; in around 1965, 1969 and 1973. This feature was also derived by Oike (1976).[4] The details of these activities will be given in later sections.

The fact that the occurrence of microearthquakes in this district is not random as suggested above is also ascertained by a statistical analysis. χ^2-test was applied to this time distribution of the number of events taking the sampling interval of time as one year rather than a month so that an expected or mean value of frequency would not be too small. For 10 data samples (from 1966 to 1975), the mean frequency is 11.4 per year and $\chi^2=21.76$. The hypothesis that the events are independent random samples or have been generated by a Poisson process cannot be accepted with a significance level of 0.01; that is, the probability that the process

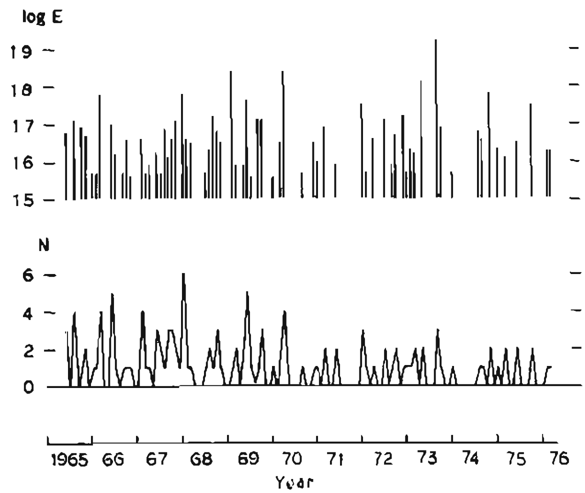

Fig. 3. Monthly number of shocks and the energy (in ergs) released monthly by the events. Data are the same as in Fig. 2.

is Poissonian is less than 0. 01.

Focal mechanisms are reportedly almost of strike-slip type closely relating to the Yamasaki fault except for around Hikami, where events of the dip-slip type ranging from thrust to normal fault are frequently occurring.[5] However, the presence of thrust type events such as the Yamasaki earthquake of 1973 (M5. 1)[6] even in the vicinity of the fault may imply that the process of an earthquake is more complicated than we have anticipated.

3. Sequences of microearthquakes

Earthquake events which originate in a limited fractured region are sequential messages from nature, which involve information about the process by which earthquakes are being generated. In the statistical point of view, the sequential data provide precise knowledge as to, for instance, location of a fractured region including its depth; the more the number of data, the better are the statistical estimations.

Utilizing the hypocentral list previously mentioned, a collection of the above sequences for various regions has been made in the following manner.

We start with the epicenters of major shocks surveyed in Section 2. With respect to the above shocks, searches are made for all the shocks whose epicenters are located in the neighborhood within a 2 km radius centering the focus of each parent shock. In addition, P arrival times are checked for each event. Let P_i be the P arrival time at the i-th station, and define P_i' as $P_i'=P_i-P_1$. When the set P_2', P_3', $\cdots$ of a certain event is approximately equivalent to that of a certain other event within the limit of accuracy ± 0.3 sec, then we assume that the locations of

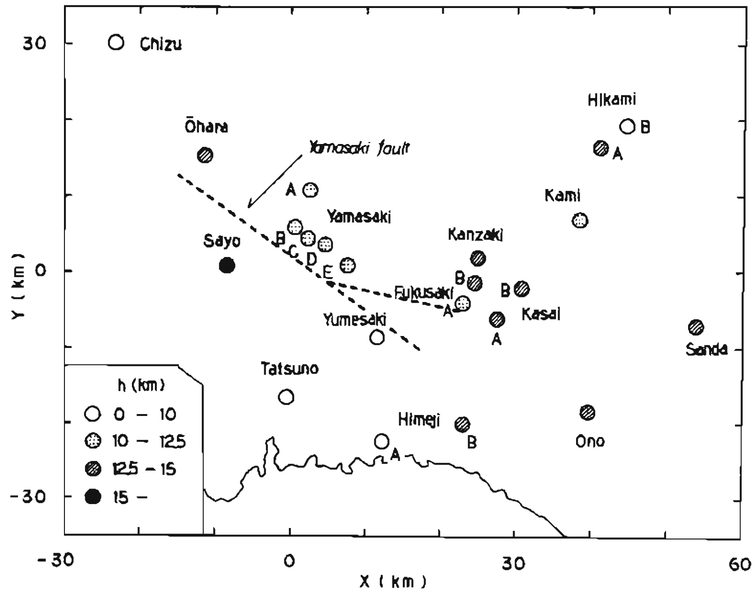

Fig. 4. Locations of the regions, where microearthquakes cluster, together with their depth ranges. Such a region is considered to be a fractured region. Complete list of the evets is given in Table 2 (Appendix).

hypocenters of the two events are the same in a statistical sense.

We deal with thus obtained sequences with more than or equal or equal to 10 events for each, and each sequence is termed after the name of its region, for example, *Chizu*, *Ōhara* etc. (Fig. 4). We also deal with a sequence which includes no event with magnitude 2.5 or larger if the number of events is larger than or equal to 20. Such a case is found in the Fukusaki region. The sequence is termed as *Fukusaki-B*.

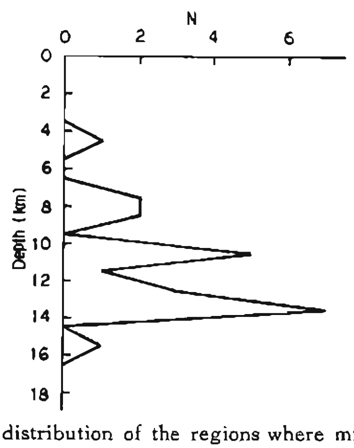

Fig. 5. Depth distribution of the regions where microearthquakes cluster. Data are the same as in Fig. 4.

The most probable location of each fractured region should be obtained by calculating the mean values of hypocentral parameters. In this calculation we had better remove extremely deviated values from the ensemble and treat epicenters and focal depths separately owing to uncertainty of focal depths compared with epicentral parameters. The results together with their standard deviations are presented in Table 2 (Appendix).

Standard deviations for each sequence may indicate an approximate size of the fractured region corresponding to it. The sequence termed as *Chizu* is the foreshock-main shock-aftershock sequence of April 1970. As Nishida (1971)[7] pointed out, the foreshock and aftershock areas were limited to 1-2 km in dimension, which is consistent with the standard deviations of x and y, 0.77 km and 0.66 km, respectively. However the depth obtained in this study, where MZ, OY and IZ are used as observation stations, is 7.46 km and deeper than the result of Nishida where the depth is estimated to be 5-6 km. This indicates that the precise evaluation of depth in such a region as Chizu which are remote from the center of the observation network is difficult.

For *Yamasaki-A* which includes the largest event of our data, the shock of 1973 (M 5.1), the size of the fractured region is estimated to be about 2 km, which was also derived by Tsukuda et al. (1977).[6]

The geographical distribution of above fractured regions is described in Fig. 4. We can see linear configuration of such fractured regions over ten kilometers parallel to the trace of the Yamasaki fault.

As shown in Fig. 4 and Fig. 5, the depths of the fractured regions near the Yamasaki fault are concentrated to such depth ranges as 10-11 km and 13-14 km. Moreover, the former depth range is prodominant around Yamasaki and the latter around Fukusaki, Kanzaki, Kasai and some other regions.

4. Time series and migration of activity

Based upon the compilation of clustering events made in Section 3, let us consider the multiple time-series, which consists of separate sequential events at the respective fractured regions and are tabulated according to the time common to all from June, 1965 to April, 1976. Fig. 6 represents this multiple time-series where monthly number of shocks are described. This diagram is an explicit expression of the time and space distribution of earthquake events.

It is observed from the figure that seismic activities in mutually adjacent regions tend to be nearly simultaneously high or low, and that the activity migrates successively from region to region.

The above disagram, however, is merely concerned with clustering events, so that an isolated event does not appear in it. In order to compensate this, we survey the seismicity for comparatively large shocks. Fig. 7 is the seismicity map for events with magnitude 2.9 or larger, which also shows occurrence time for each event.

The main features of microseismic activity near the Yamasaki fault are summa-

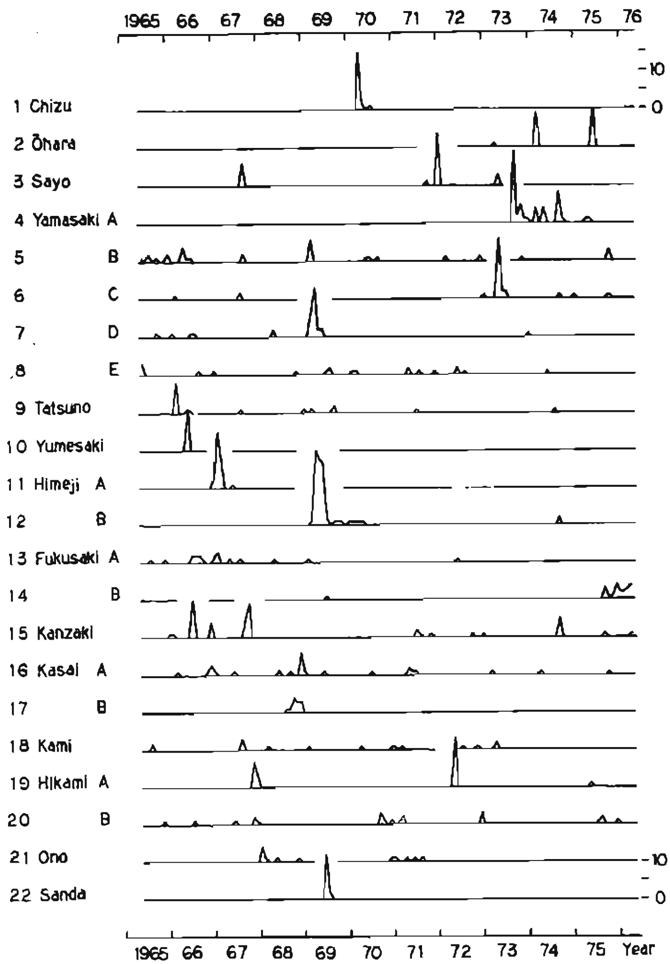

Fig. 6. Monthly numbers of shocks for the respecive regions given in Fig. 4.

rized as follows.

(i) During the period from June, 1965 to June, 1966, activity was high around Ōhara and Sayo as shown in Fig. 7. This activity was not accompanied with clustering events.

(ii) In 1966 and 1967, an active zone was formed around Tatsuno, Yumesaki and Himeji. This activity is characterized by its shallow-seated fractured regions, the depths of which range from 4 to 8 km. Moreover this activity was coupled with that at *Kanzaki*.

(iii) The period from July, 1966 to November, 1967 is characterized by successive migration of activity along Kanzaki, Kasa, Kami and Hikami.

(iv) In 1969, high active regions were separated into Yamasaki, Himeji and Sanda.

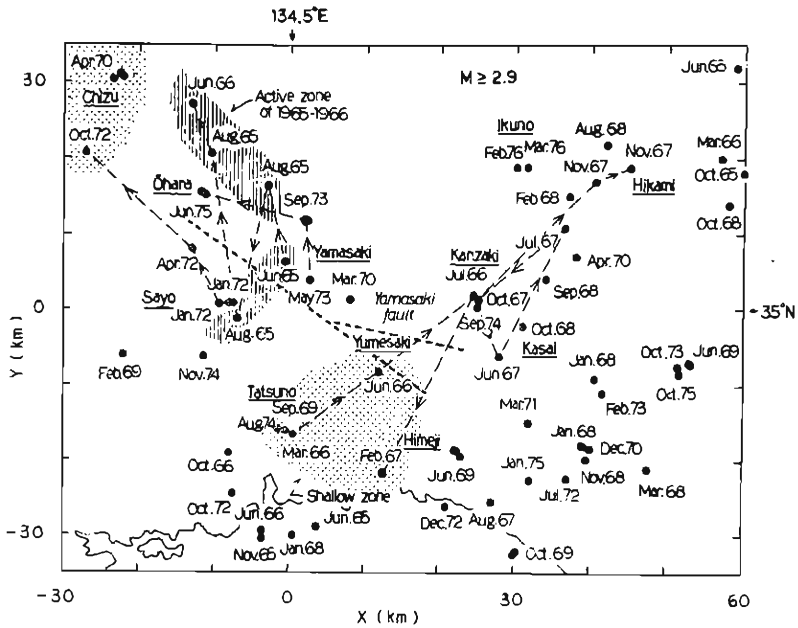

Fig. 7. Locations and times of occurrence of major shocks ($M \gtrsim 2.9$) in the concerned region. Broken lines with arrowheads indicate successive migration of hypocenters. Shaded zones represent the high activities during the period from 1965 to 1966. Dotted zones represent where shallow focal depths less than 10 km have been found The depth of the event of 1972 in the Chizu region is probably less than 5~6 km.[8]

(v) In 1972, earthquake foci successively migrated from the Sayo region to the Chizu region along a nearly straight line at a rate of 31 km/year.

(vi) During the period from May, 1973 to June, 1975, successive migration of activity from Yamasaki to Ōhara was remarkable. By comparison the two peak activities at *Yamasaki-A* in September, 1973 and September, 1974 are well correlated to those at *Ōhara* in March, 1974 and June, 1975, respectively (Fig. 6).

It is remarkable that active zones for the respective periods have never been overlapped by each other except for around Fukusaki, Kanzaki and Kasai. The recent activity ((vi)) also took place as if it had covered the seismicity gap.

5. Some properties of activities in the respective regions

In order to answer the question as to the length of time during which fractures or stick-slip type events are repeatedly occurring, we also employ the time series shown in Fig. 6.

The activity at *Fukusaki-B* which initiated substantially on Sep. 6, 1975 and has continued for more than about 10 months.[1] Long-life activities more than several

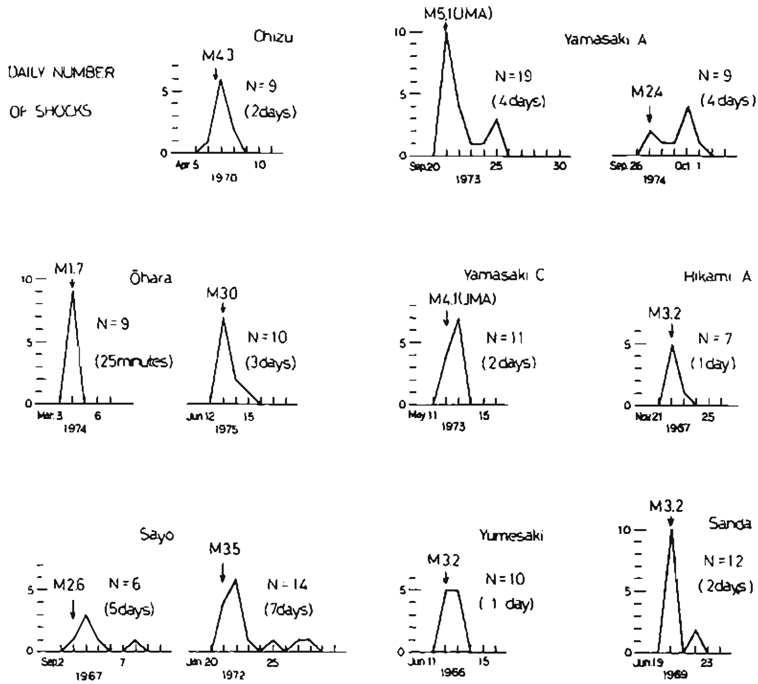

Fig. 8. Time distributions around the peaks. Occurrence time of the largest shock is represented by an arrow with its magnitude for each distribution. Number of events and the duration time in parenthesis are also shown.

years are observed at *Kanzaki*.

The activity at *Yamasaki-A* lasted for about a year and eight months from the sudden beginning on Sep. 21, 1973 to around May, 1975. At *Himeji-B* the activity lasted for more than a year and several months. In the case of *Ōhara* a long intermission in microearthquake occurrence for more than a year is clearly noticed.

On the other hand short-life activies whose periods are less than several months can be recognized at *Chizu*, *Yumesaki*, *Himeji-A*, *Kasai-B* and *Sanda*.

Activities around the the peaks in the time distributions are shown in Fig. 8 in the form of daily numbers. The duration time of each principal activity seems to be dependent upon magnitude of the largest event involved. In the case of *Yamasaki-A*, which includes the shock with magnitude 5.1, the duration time is about four days for peaks of both 1973 and 1974. For magnitude 3 or so, the duration time is about one or two days. At *Sayo*, due to subordinate peaks of the distribution, the duration time is apparently longer than other regions.

Typical examples of swarm-type sequences are given in Fig. 9. At *Himeji-A* the activity lasted for about a month and main shocks occurred during the early half period, while at *Himeji-B* the activity lasted for more than three months and main shocks occurred at the last stage of the period.

Consequently the length of time from the commencement to the termination of

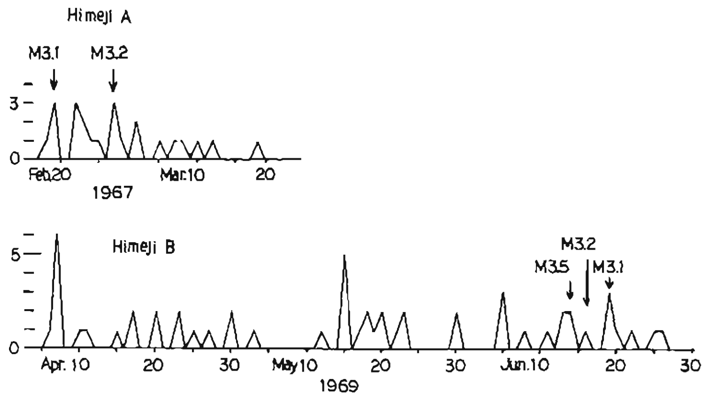

Fig. 9. Daily number of shocks at *Himeji-A* and *Himeji-B*. Arrows indicate the main shocks($M \geq 3$).

activity ranges from less than several months, a year or so, to more than several years for each fractured region of microearthquakes.

The last discussion in this section is concerned with the constitution of events in a sequence. Every event has its magnitude, so it is reasonable to begin with magnitude distribution for each sequence.

As seen from Fig. 10, regional difference of Gutenberg-Richter's b value is remarkable; b values for *Yamasaki* and *Sayo* are relatively low compared with those for *Himeji-B*, *Kanzaki* and *Kami*.

Putting all the data together we have obtained b values such as 0.65 and 0.79 for magnitude 1.0-3.0 and 3.0-5.0, respectively.

6. Concluding remarks

The present work mainly involves a compilation of sequential data for microearthquakes which have been occurring near the Yamasaki fault.

Microearthquakes frequently occur in cluster and their foci are concentrated in a limited space within 1-2 km in dimension. Such a concentrated region of foci is considered to be a region fractured by sequential earthquakes.

Generally speaking, the fractured regions near the Yamasaki fault have their depths at 10-12 km around Yamasaki, where exists a linear configuration of fractured regions parallel to the fault trace over ten kilometers, and at 13-14 km around Fukusaki, Kanzaki and Kasai.

Shallow-seated fractured regions with depths less than 10 km are found in such regions as Chizu, Tatsuno, Yumesaki and Himeji, while a deep fractured region exists at Sayo.

Observing the multiple time-series shown in Fig. 6 and the seismicity map shown in Fig. 7, it is noticed that adjacent regions within about a 30 km range have nearly commom active periods and the activity migrates successively from region to region.

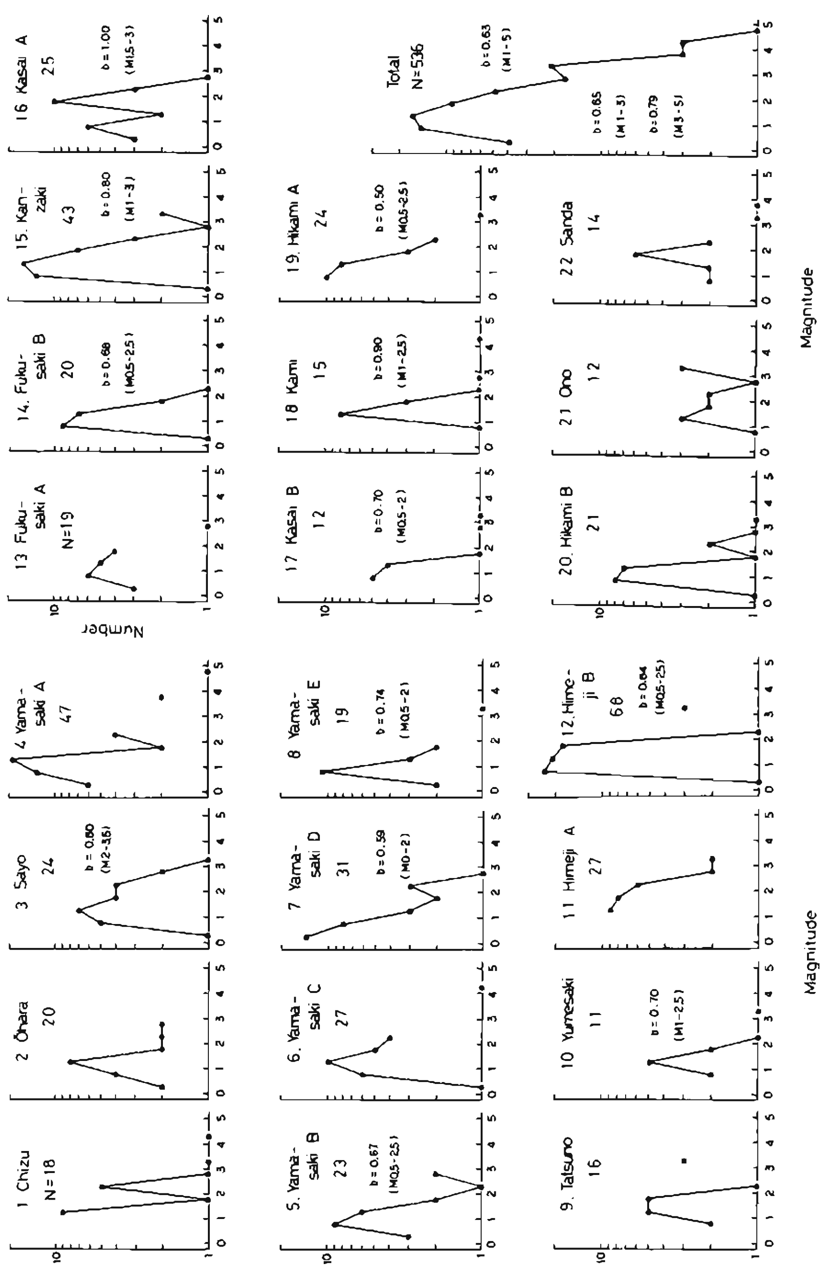

Fig. 10. Logarithm of the number of shocks versus F-P time magnitude for each fractured region. **N** denotes the total number of events for each graph. Gutenberg-Richter's *b* value is calculated by the least squares method for the magnitude range where the graph is nearly linear.

The life time or duration time of activity for each fractured region ranges from less than several months, a year or so, to more than several years.

Regional difference in Gutenberg-Richter's b value was found; b values around Yamasaki, near the central part of the Yamasaki fault, are lower than those around the estern end of the fault.

For the above results or findings no geophysical and geological interpretation has been given in this paper. Explanations for the features of microearthquake occurrence revealed here are reserved for future studies.

Acknowledgement

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Appendix

Table. 1. List of major earthquakes ($M \geq 2.5$) near the Yamasaki fault. As to epicentral range and coordinates used, see Fig. 2. Data are adopted from "the list of hypocenters of the Tottori Microearthquake Observatory".[3] The hypocenters to which asterisks are attached are re-located by the author; when S-P time is not available, P times of four stations are used.

No.	Date	Origin time h	Origin time m	Mag.	Hypocentral coordinates (km) x	y	h
1	Jun. 20, 1965	20	20	2.9	−0.68	6.61	10.20
2	Jun. 28, 1965	08	25	3.1	3.74	−28.77	12.90
3	Jun. 29, 1965	09	48	3.1	58.81	32.20	9.73
4	Aug. 2, 1965	16	34	3.4	−2.90	16.65	(0.0)*
5	Aug. 12, 1965	04	46	2.6	38.22	6.46	10.18*
6	Aug. 18, 1965	02	44	3.2	−7.25	−1.25	16.52*
7	Aug. 23, 1965	10	07	2.9	−10.60	20.82	8.99*
8	Oct. 7, 1965	09	07	3.4	59.95	17.89	9.89
9	Nov. 18, 1965	09	07	3.2	−3.43	−30.43	15.96
10	Nov. 24, 1965	11	18	2.7	31.52	−25.38	11.62
11	Jan. 3, 1966	11	45	2.6	−0.36	−25.60	14.68
12	Feb. 25, 1966	18	22	2.6	6.31	3.95	8.11
13	Mar. 7, 1966	08	58	4.0	57.23	19.82	(0.0)
14	Mar. 8, 1966	10	25	2.6	34.82	−28.44	22.23
15	Mar. 23, 1966	06	43	2.5	−1.56	−27.21	14.55
16	Mar. 28, 1966	03	38	3.1	0.65	−16.66	7.37
17	Jun. 12, 1966	16	51	3.2	11.78	−8.17	2.73
18	Jun. 13, 1966	21	21	2.5	11.73	−9.84	9.77
19	Jun. 14, 1966	02	59	2.6	1.15	6.37	9.05
20	Jun. 18, 1966	18	53	3.2	−12.95	27.32	5.24*
21	Jun. 25, 1966	01	07	2.9	−3.38	−29.53	15.24
22	Jul. 6, 1966	04	08	2.9	24.62	2.15	11.48*
23	Sep. 21, 1966	04	21	2.6	22.99	−3.69	12.76
24	Oct. 16, 1966	11	40	3.2	−8.09	−18.77	16.90
25	Nov. 6, 1966	22	47	2.5	46.86	26.18	(0.0)
26	Feb. 19, 1967	04	49	2.5	12.41	−22.11	(0.0)*
27	Feb. 19, 1967	08	07	3.1	12.41	−22.11	(0.0)
28	Feb. 22, 1967	18	53	2.8	12.69	−22.38	1.24
29	Feb. 27, 1967	15	56	3.2	12.41	−22.11	(0.0)*
30	Mar. 10, 1967	09	31	2.6	13.51	−22.36	10.17
31	Apr. 26, 1967	12	02	2.7	49.07	−26.97	6.66
32	Jun. 20, 1967	07	58	2.6	24.16	−29.69	7.94
33	Jun. 22, 1967	03	12	2.5	12.69	−22.38	1.71
34	Jun. 22, 1967	06	26	2.9	27.82	−6.30	13.07
35	Jul. 9, 1967	06	49	2.9	36.38	10.98	(0.0)
36	Jul. 26, 1967	04	35	2.6	57.80	−13.75	0.57
37	Aug. 23, 1967	08	33	3.4	27.24	−25.47	(0.0)
38	Sep. 3, 1967	13	31	2.6	−9.63	2.28	14.51
39	Sep. 6, 1967	01	08	2.5	25.20	1.71	12.53
40	Sep. 27, 1967	01	10	2.5	−13.06	17.39	8.37
41	Oct. 1, 1967	08	24	2.6	−12.41	−2.15	10.11
42	Oct. 17, 1967	02	31	3.1	25.19	1.62	14.13

No.	Date			Origin time		Mag.	Hypocentral coordinates (km)		
				h	m		x	y	h
43	Oct.	22,	1967	08	45	2.5	31.97	−26.87	14.14
44	Nov.	22,	1967	08	06	3.2	40.43	16.78	13.69
45	Nov.	26,	1967	15	57	3.4	45.03	18.69	2.07
46	Dec.	10,	1967	23	33	2.5	−3.56	−26.66	1.39*
47	Jan.	10,	1968	23	45	2.5	33.49	19.32	10.39
48	Jan.	12,	1968	11	33	3.5	39.10	−17.90	11.72
49	Jan.	12,	1968	11	48	2.9	40.49	−9.25	6.54
50	Jan.	12,	1968	17	35	2.9	38.86	−17.79	12.97
51	Jan.	13,	1968	12	41	2.6	38.03	−10.26	12.49
52	Jan.	29,	1968	14	08	3.9	0.62	−29.85	17.67
53	Feb.	1,	1968	20	09	3.2	36.95	15.20	9.20
54	Mar.	18,	1968	03	22	3.1	47.61	−21.00	13.04
55	Jul.	17,	1968	18	52	2.6	25.40	−1.58	13.01
56	Aug.	13,	1968	23	57	2.6	43.02	22.91	11.23
57	Aug.	17,	1968	13	13	2.9	41.81	21.98	11.03
58	Sep.	26,	1968	06	51	3.6	34.17	3.91	15.69*
59	Oct.	14,	1968	11	24	2.9	58.26	13.79	(0.0)
60	Oct.	25,	1968	17	32	3.2	30.89	−2.27	11.74
61	Oct.	27,	1968	11	03	2.6	30.79	−2.97	14.38
62	Nov.	5,	1968	01	47	3.1	39.50	−20.10	14.40
63	Feb.	18,	1969	06	57	4.4	−21.80	−5.99	19.15
64	Mar.	25,	1969	14	26	2.6	4.63	3.71	9.74
65	Mar.	29,	1969	12	30	2.5	4.84	4.07	8.31
66	May	15,	1969	16	04	2.5	23.61	−20.20	13.77
67	May	26,	1969	18	37	2.6	49.61	18.48	2.12
68	Jun.	14,	1969	01	03	3.5	22.38	−18.71	12.06
69	Jun.	16,	1969	18	53	3.2	22.32	−18.43	12.80
70	Jun.	19,	1969	18	05	3.1	23.02	−19.54	15.50
71	Jun.	20,	1969	15	33	3.2	53.02	−6.80	12.56
72	Jun.	20,	1969	16	07	3.6	53.18	−6.88	14.12
73	Jul.	7,	1969	18	56	2.5	26.98	−27.79	7.65
74	Sep.	24,	1969	11	26	3.5	−0.36	−15.98	9.66
75	Oct.	4,	1969	09	24	2.6	29.74	−32.68	14.01
76	Oct.	5,	1969	07	30	3.5	30.40	−32.22	14.30
77	Oct.	29,	1969	14	10	3.0	29.76	−32.59	14.77
78	Jan.	7,	1970	20	35	2.5	−12.34	13.65	15.35
79	Mar.	12,	1970	21	10	3.1	7.82	1.41	11.61
80	Mar.	15,	1970	06	07	2.5	37.09	11.94	2.81
81	Apr.	3,	1970	10	02	4.1	37.86	6.89	9.17
82	Apr.	6,	1970	20	35	2.9	−23.60	30.65	9.64
83	Apr.	7,	1970	01	41	4.3	−22.61	31.36	14.16
84	Apr.	21,	1970	01	35	3.4	−22.24	30.70	9.01
85	Sep.	1,	1970	10	02	2.6	50.88	−12.86	10.32
86	Dec.	8,	1970	17	44	3.1	40.16	−18.35	17.02
87	Jan.	29,	1971	19	16	2.8	5.59	4.07	12.47
88	Mar.	23,	1971	11	21	2.6	43.78	18.78	2.80
89	Mar.	31,	1971	20	39	3.4	31.91	−14.84	7.90
90	Jun.	7,	1971	04	36	2.5	40.11	−19.58	14.63
91	Jun.	21,	1971	19	15	2.6	31.86	20.11	11.18
92	Jan.	18,	1972	09	47	2.6	22.88	−17.40	(0.0)

No.	Date	Origin time h	Origin time m	Mag.	Hypocentral coordinates (km) x	y	h
93	Jan. 21, 1972	15	02	3.8	−7.65	0.83	15.43
94	Jan. 21, 1972	17	48	2.9	−9.38	0.72	16.59
95	Feb. 18, 1972	15	21	2.6	19.29	−20.41	2.88
96	Apr. 19, 1972	21	29	3.2	−13.10	8.36	1.05
97	Jul. 27, 1972	15	11	3.5	37.25	−22.44	15.10
98	Jul. 29, 1972	05	27	2.5	38.53	7.40	10.79
99	Sep. 2, 1972	07	46	2.7	−2.76	0.11	(0.0)
100	Oct. 18, 1972	06	02	3.2	−27.20	20.87	12.11
101	Oct. 22, 1972	11	36	2.9	−7.48	−24.45	15.46
102	Dec. 26, 1972	04	28	3.6	20.97	−26.22	14.76
103	Jan. 17, 1973	19	44	2.6	43.86	22.04	12.73
104	Feb. 14, 1973	04	51	3.0	41.60	−11.12	16.05
105	Mar. 8, 1973	20	46	2.7	−6.78	−19.18	14.86
106	Mar. 9, 1973	23	34	2.7	39.43	−10.45	14.91
107	May 12, 1973	23	08	4.2	2.60	4.06	11.03
108	May 22, 1973	04	47	2.8	−7.54	0.42	(0.0)
109	Sep. 21, 1973	11	21	4.9	1.99	12.02	10.39
110	Sep. 21, 1973	15	23	3.9	2.53	11.73	10.40
111	Sep. 22, 1973	10	09	3.9	1.99	12.02	10.39*
112	Oct. 21, 1973	04	15	3.4	51.64	−7.69	15.18
113	Jan. 19, 1974	21	48	2.6	−13.42	−1.69	8.17
114	Aug. 3, 1974	22	43	3.3	−1.46	−15.68	2.32
115	Sep. 13, 1974	10	54	3.2	25.19	0.57	14.38
115	Sep. 13, 1974	10	54	3.2	25.19	0.57	14.38
116	Nov. 17, 1974	02	52	4.0	−11.49	−6.26	21.30*
117	Nov. 25, 1974	04	29	2.6	35.78	−19.64	14.03
118	Jan. 7, 1975	17	10	3.0	32.07	−22.69	13.36
119	Mar. 13, 1975	21	01	2.5	−11.99	10.19	2.58
120	Mar. 15, 1975	17	43	2.8	15.05	−5.40	12.69
121	Jun. 13, 1975	21	27	3.0	−11.37	15.32	14.11
122	Jun. 14, 1975	10	44	2.9	−11.88	15.63	13.10
123	Oct. 17, 1975	16	13	2.7	51.01	−8.05	15.42
124	Oct. 28, 1975	14	03	3.8	51.68	−8.64	15.84
125	Feb. 2, 1976	11	22	3.0	29.83	18.89	1.08
126	Mar. 30, 1976	19	45	3.0	31.75	19.28	2.82

Table. 2. Earthquake sequences in various regions. Mean values of hypocentral coordinates in each region are presented together with standard deviations. Extremely deviated data are rejected and the numbers of data used for epicenters and focal depths are given in parentheses. Data source is "the list of the Tottori Microearthquake Observatory".[3]

No.	Date Y	M	D	Origin time h	m	Mag.	No.	Date Y	M	D	Origin time h	m	Mag.
1. *Chizu*				$x=-23.33\pm0.77$ km, $y=30.28\pm0.66$ km (16) $h=7.46\pm4.06$ km (14)									
1	1970	4	6	20	35	2.9	6	1970	4	7	02	25	1.4
2			7	00	38	1.3	7				03	54	1.8
3				01	41	4.3	8			8	23	00	1.1
4				01	46	1.3	9				23	00	2.3
5				02	20	2.3	10			15	09	50	2.1

No.	Date Y	M	D	Origin time h	m	Mag.	No.	Date Y	M	D	Origin time h	m	Mag.
11	1970	4	16	04	39	1.4	15	1970	4	26	19	31	2.2
12			21	01	35	3.4	16		5	2	09	52	2.4
13			24	01	47	1.3	17			11	09	58	1.3
14				11	01	1.4	18		7	26	17	59	1.4
2. *Ōhara*				$x=-11.66\pm0.47$ km, $y=15.57\pm0.48$ km (20) $h=13.74\pm0.94$ km (20)									
1	1973	4	27	00	23	0.8	11	1975	6	13	21	08	1.1
2	1974	3	4	06	22	1.1	12				21	16	1.2
3				06	22	1.1	13				21	18	1.4
4				06	22	1.6	14				21	18	0.9
5				06	24	1.5	15				21	27	2.4
6				06	37	1.7	16				21	27	3.0
7				06	38	1.1	17				21	53	0.5
8				06	41	1.1	18		6	14	03	06	0.9
9				06	47	0.6	19				10	44	2.9
10				06	47	0.5	20		6	15	15	25	2.1
3. *Sayo*				$x=-8.49\pm1.17$ km, $y=1.03\pm0.79$ km (24) $h=15.98\pm1.06$ km (17)									
1	1967	9	3	13	31	2.6	13	1972	1	22	00	46	0.4
2			4	14	58	1.7	14				15	28	1.7
3				18	31	0.8	15				15	35	1.6
4				23	44	2.2	16				19	33	2.1
5			5	02	15	1.4	17				20	18	0.9
6			8	14	40	2.1	18			23	12	03	0.8
7	1971	10	22	07	58	1.3	19			25	07	16	2.1
8	1972	1	21	15	02	3.5	20			27	08	21	1.4
9				15	17	1.1	21			28	12	28	0.6
10				15	36	1.8	22	1973	5	22	06	29	1.1
11				17	48	2.9	23				06	34	0.9
12			22	00	29	1.3	24				19	21	1.1
4. *Yamasaki-A*				$x=2.48\pm0.84$ km, $y=11.03\pm0.90$ km (46) $h=10.79\pm1.82$ km (46)									
1	1973	9	21	11	21	4.9	19	1973	9	25	19	26	1.5
2				11	45	1.3	20		10	8	05	00	0.8
3				12	34	0.5	21			15	05	22	1.1
4				12	42	1.1	22		11	3	04	38	0.7
5				13	35	1.1	23				11	30	2.0
6				15	23	3.9	24			6	19	10	1.1
7				18	20	1.0	25	1973	11	13	20	38	0.8
8				19	49	2.4	26			22	06	34	1.0
9				22	15	0.7	27		12	16	04	57	1.2
10				22	50	0.5	28	1974	1	10	08	45	1.3
11			22	07	26	1.2	29		3	24	05	15	0.7
12				10	09	3.9	30				07	22	1.1
13				18	24	1.1	31				23	17	2.1
14				20	04	0.7	32			28	10	49	0.4
15			23	18	58	0.6	33		5	15	18	29	0.4
16			24	23	14	1.1	34				18	36	1.0
17			25	00	49	1.4	35			26	05	03	0.6
18				09	53	0.5	36				05	05	1.1

No.	Date Y	M	D	Origin time h	m	Mag.	No.	Date Y	M	D	Origin time h	m	Mag.
37	1974	9	27	20	46	2.4	43	1974	9	30	22	26	1.8
38				21	50	2.1	44				22	23	1.2
39			28	02	08	1.0	45		10	1	19	56	1.1
40			29	20	23	1.1	46	1975	4	20	15	15	1.1
41			30	19	30	1.5	47		5	19	15	18	0.4
42				19	32	0.9							

5. *Yamasaki-B* $x=0.64\pm0.71$ km, $y=6.06\pm0.71$ km (23) $h=10.94\pm2.01$ km (22)

No.	Y	M	D	h	m	Mag.	No.	Y	M	D	h	m	Mag.
1	1965	6	20	20	20	2.9	13	1967	9	11	13	13	1.4
2		8	19	00	12	0.6	14			26	16	02	0.4
3				02	35	0.6	15	1970	6	14	23	27	1.0
4		10	23	12	37	1.8	16		7	19	09	39	0.6
5	1966	1	1	06	23	0.5	17		9	13	14	10	1.0
6			22	21	42	1.4	18	1972	3	4	12	28	0.6
7		5	12	23	38	1.3	19		12	13	21	41	1.3
8			17	07	25	0.2	20	1973	11	5	22	58	0.7
9				08	05	0.6	21	1975	10	22	20	56	1.3
10			18	07	26	2.2	22			23	10	11	1.3
11		6	14	02	59	2.6	23			24	02	18	1.9
12		7	20	17	48	0.7							

6. *Yamasaki-C* $x=2.24\pm0.78$ km, $y=4.50\pm0.66$ km (27) $h=10.99\pm0.98$ km (26)

No.	Y	M	D	h	m	Mag.	No.	Y	M	D	h	m	Mag.
1	1966	3	3	06	03	1.1	15	1973	5	13	16	10	1.3
2	1967	8	1	23	16	0.7	16			24	11	23	0.6
3			2	09	56	0.3	17			26	06	46	2.4
4	1973	1	20	20	29	0.9	18				06	57	0.9
5	1973	5	12	21	52	1.1	19			28	05	15	1.4
6				23	08	4.2	20			29	05	35	1.2
7				23	26	2.2	21		6	14	08	15	2.3
8				23	31	1.4	22			15	19	56	1.7
9			13	00	21	0.9	23		7	22	15	37	1.2
10				01	55	1.6	24			29	02	38	1.2
11				02	55	1.3	25	1974	9	4	15	55	2.4
12				05	50	1.0	26	1975	1	10	20	07	1.8
13				09	57	1.6	27		10	11	23	54	1.3
14				16	09	2.0							

7. *Yamasaki-D* $x=4.58\pm0.43$ km, $y=3.77\pm0.54$ km (31) $h=10.89\pm1.12$ km (31)

No.	Y	M	D	h	m	Mag.	No.	Y	M	D	h	m	Mag.
1	1965	10	11	16	38	0.3	13	1969	3	30	08	28	0.5
2	1966	2	12	17	28	1.6	14		4	1	17	11	2.1
3		7	12	03	45	0.5	15				17	20	0.8
4		8	4	05	23	0.9	16			2	03	31	1.4
5	1968	5	13	04	28	0.5	17			3	17	02	0.6
6			21	15	52	0.2	18			7	20	07	0.9
7	1969	3	6	22	16	0.5	19			8	11	41	0.3
8			25	14	26	2.6	20				15	40	2.3
9				14	31	1.6	21				23	24	0.6
10			29	09	20	0.3	22			21	19	19	0.8
11				12	30	2.5	23			23	22	15	0.3
12				13	49	1.2	24			25	21	44	1.2

No.	Date Y	M	D	Origin time h	m	Mag.	No.	Date Y	M	D	Origin time h	m	Mag.
25			26	02	04	0.4	29	1969	6	7	18	31	0.2
26				13	10	0.2	30			8	03	50	0.3
27		5	2	00	21	0.3	31	1974	1	9	21	32	0.8
28			13	00	47	0.9							

8. *Yamasaki-E* x=7.49±0.39 km, y=1.16±0.78 km (19) h=11.85±1.11 km (19)

No.	Y	M	D	h	m	Mag.	No.	Y	M	D	h	m	Mag.
1	1965	6	27	09	31	1.2	11	1970	3	12	21	10	3.1
2				11	13	0.8	12	1971	5	5	21	59	1.6
3				11	33	0.7	13			12	15	06	1.8
4	1966	9	12	19	26	0.9	14		8	30	20	49	0.6
5	1967	1	8	15	43	0.7	15		12	18	13	27	0.6
6	1968	11	28	10	22	0.9	16	1972	6	21	09	16	0.4
7	1969	7	8	00	33	1.4	17				09	46	0.3
8		8	2	14	47	0.6	18		8	16	19	39	0.9
9			12	08	32	1.5	19	1974	6	8	20	27	0.9
10	1970	2	22	12	32	0.9							

9. *Tatsuno* x=−0.41±0.81 km, y=−16.33±0.44 km (16) h=8.34±1.80 km (15)

No.	Y	M	D	h	m	Mag.	No.	Y	M	D	h	m	Mag.
1	1966	3	22	13	27	0.9	9	1966	6	14	16	18	1.8
2				14	53	1.8	10	1967	8	30	18	24	1.6
3				21	51	0.8	11	1969	1	2	04	51	1.4
4				23	40	1.3	12		3	2	19	06	1.7
5				23	44	1.4	13		9	24	11	26	3.5
6			23	03	25	1.1	14			25	04	21	2.1
7			28	02	20	1.6	15	1971	7	22	03	28	1.4
8				03	38	3.1	16	1974	8	3	22	43	3.3

10. *Yumesaki* x=11.69±0.60 km, y=−8.56±1.04 km (11) h=7.30±3.64 km (8)

No.	Y	M	D	h	m	Mag.	No.	Y	M	D	h	m	Mag.
1	1966	6	12	16	51	3.2	7	1966	6	13	17	38	0.8
2				17	52	2.0	8				21	21	2.5
3				18	10	1.2	9				21	23	1.4
4				18	23	1.3	10				23	49	1.1
5	1966	6	12	20	21	1.6	11			17	02	21	1.1
6			13	11	52	0.9							

11. *Himeji-A* x=12.71±0.56 km, y · −22.23±1.59 km (26) h=4.27±3.87 km (12)

No.	Y	M	D	h	m	Mag.	No.	Y	M	D	h	m	Mag.
1	1967	1	25	22	19	2.2	15	1967	2	27	15	25	1.0
2			26	01	35	1.7	16				15	32	1.5
3			30	23	15	1.2	17				15	56	3.2
4		2	18	15	32	1.8	18			28	09	00	1.7
5			19	04	49	2.5	19		3	2	18	32	1.2
6				08	07	3.1	20				20	20	1.5
7				12	57	1.8	21			5	23	42	1.9
8			22	18	53	2.8	22			7	00	18	1.7
9				19	05	1.7	23			8	13	12	1.3
10				19	40	2.2	24			10	09	31	2.6
11			23	15	55	2.0	25			12	00	29	2.2
12				18	45	2.4	26			19	01	20	1.3
13			24	14	59	1.5	27		6	22	03	12	2.5
14			25	01	01	1.5							

No.	Date Y	M	D	Origin time h	m	Mag.	No.	Date Y	M	D	Origin time h	m	Mag.
12. *Himeji-B*				$x=23.15\pm0.51$ km,		$y=-19.98\pm0.84$ km (67)				$h=13.59\pm1.19$ km (65)			
1	1969	3	20	06	10	0.9	35	1969	5	22	18	07	0.6
2		4	6	20	37	2.0	36			23	07	37	0.8
3			7	01	06	1.6	37				10	13	1.6
4				02	58	0.8	38			30	02	26	1.2
5				08	44	1.8	39				11	48	1.3
6				16	58	0.6	40		6	5	07	19	1.8
7				21	58	0.9	41				08	16	0.8
8				22	06	0.9	42				15	52	1.1
9			10	01	18	0.6	43			8	20	44	0.4
10			11	13	03	0.8	44			11	09	36	1.9
11			15	09	37	0.9	45			13	00	16	1.4
12			17	06	34	0.9	46				08	16	2.0
13				09	04	0.6	47			14	01	03	3.5
14			20	01	32	1.2	48				06	21	1.4
15				01	36	1.1	49			16	18	53	3.2
16			23	22	01	0.9	50			19	02	55	1.1
17				22	56	0.8	51				08	29	1.8
18			25	17	17	1.8	52				18	05	3.1
19			27	17	30	0.9	53			20	20	56	1.8
20			30	08	29	1.1	54			22	05	02	1.1
21				14	35	1.6	55			25	15	40	0.9
22		5	3	16	39	1.4	56			26	05	52	0.8
23			12	11	40	1.1	57		7	4	23	53	1.1
24			15	08	57	1.8	58			14	19	29	0.8
25				11	03	1.9	59		9	19	19	17	1.4
26				16	04	2.5	60		10	28	21	20	2.0
27				16	06	1.5	61		11	3	04	37	1.8
28				21	40	0.9	62	1970	1	5	00	00	1.4
29			17	16	21	1.7	63		2	12	07	03	1.4
30			18	06	06	0.9	64		3	19	15	14	1.2
31				06	16	1.5	65		4	4	19	54	0.9
32			19	11	18	1.6	66		5	4	00	26	0.8
33			20	07	58	0.6	67	1974	9	7	17	12	1.2
34				19	50	1.6	68			10	12	58	1.3
13. *Fukusaki-A*				$x=23.07\pm0.59$ km,		$y=-3.94\pm0.82$ km (19)				$h=12.31\pm1.21$ km (17)			
1	1965	8	16	08	42	1.4	11	1967	1	26	19	45	1.2
2		12	8	22	01	1.6	12		2	21	04	15	0.7
3	1966	7	16	17	24	0.1	13			24	06	58	0.6
4			17	12	46	1.1	14				10	59	0.7
5		8	25	15	37	0.8	15		5	2	21	50	1.4
6			27	13	32	1.6	16		8	10	08	15	0.4
7		9	15	15	28	1.2	17	1968	5	24	19	01	0.8
8			21	04	21	2.6	18	1969	2	27	23	26	0.5
9		10	8	06	11	1.6	19	1972	6	23	02	10	1.6
10	1967	1	8	00	33	1.0							
14. *Fukusaki-B*				$x=24.47\pm0.35$ km,		$y=-1.30\pm0.39$ km (20)				$h=13.64\pm0.73$ km (20)			
1	1969	7	2	06	26	0.4	2	1975	9	6	17	14	1.0

No.	Date Y	M	D	Origin time h	m	Mag.	No.	Date Y	M	D	Origin time h	m	Mag.
3	1975	9	7	09	22	0.9	12	1976	2	9	21	42	0.6
4				21	49	1.3	13			19	06	23	1.1
5		11	6	12	04	1.1	14		3	11	03	35	0.8
6		12	15	13	36	1.3	15			26	10	08	1.9
7				15	40	1.1	16			31	19	34	1.7
8			25	09	50	0.8	17		4	1	21	44	0.6
9			30	23	16	1.4	18			2	10	10	2.2
10	1976	1	1	09	06	1.2	19				11	29	0.8
11			19	04	41	0.9	20			18	21	12	0.7

15. *Kanzaki* $x=24.80\pm0.57$ km, $y=2.13\pm0.90$ km (42) $h=13.00\pm1.00$ km (40)

No.	Y	M	D	h	m	Mag.	No.	Y	M	D	h	m	Mag.
1	1966	1	19	16	47	0.6	23	1967	10	16	21	19	0.9
2		2	12	20	14	0.9	24				22	57	0.5
3		7	6	04	08	2.9	25			17	02	31	3.1
4				05	14	0.6	26				02	32	0.6
5			7	03	31	1.4	27			18	00	27	1.2
6			8	15	03	0.9	28				00	31	1.2
7				15	05	1.3	29				08	03	0.8
8			9	22	27	1.6	30				10	37	1.4
9			12	23	20	1.4	31	1971	7	3	04	32	1.1
10				23	37	0.9	32				11	05	1.4
11				23	44	0.9	33		8	6	23	17	1.1
12			15	16	29	2.3	34		11	2	18	07	0.9
13		12	3	09	26	1.1	35	1972	10	28	23	55	1.1
14				09	33	1.7	36	1973	1	18	11	19	1.1
15				11	01	2.3	37	1974	9	13	10	54	3.2
16				11	47	1.7	38				11	43	1.2
17	1967	9	5	21	40	1.7	39			14	01	19	1.0
18			6	01	08	2.5	40			16	21	41	1.8
19				01	49	1.5	41			28	09	45	1.1
20				01	50	1.2	42	1975	9	12	04	33	0.8
21				02	03	1.8	43	1976	4	10	00	49	2.0
22		10	16	20	25	0.9							

16. *Kasai-A* $x=27.38\pm0.56$ km, $y=-6.07\pm1.48$ km (25) $h=13.61\pm1.13$ km (20)

No.	Y	M	D	h	m	Mag.	No.	Y	M	D	h	m	Mag.
1	1966	3	31	09	33	2.0	14	1968	12	20	18	40	2.2
2		11	9	17	07	0.9	15			31	02	04	0.5
3		12	9	13	25	2.3	16	1969	1	20	10	55	1.8
4			11	00	16	1.9	17		6	9	01	53	0.3
5				00	18	2.0	18	1970	7	16	14	11	1.8
6	1967	1	9	06	11	1.2	19	1971	5	5	17	20	0.8
7		6	22	06	26	2.9	20			17	17	04	2.0
8	1968	6	15	05	57	1.4	21		6	7	01	41	0.8
9		9	12	20	43	1.8	22		7	6	01	14	1.6
10		12	7	09	38	0.4	23	1973	3	22	20	25	0.6
11			10	15	34	0.8	24	1974	4	26	06	27	2.0
12			11	12	04	0.6	25	1975	10	17	20	19	2.1
13			17	07	52	2.0							

No.	Date Y	M	D	Origin time h	m	Mag.	No.	Date Y	M	D	Origin time h	m	Mag.
17. *Kasai-B*				$x=30.73\pm0.85$ km, $y=-2.01\pm0.87$ km (12) $h=13.37\pm1.49$ km (4)									
1	1968	8	13	16	02	1.4	7	1968	11	2	23	00	1.1
2		9	17	19	31	0.9	8			13	08	33	1.8
3		10	25	17	32	3.2	9				08	58	0.6
4			26	12	48	0.9	10		12	14	08	16	0.8
5			27	08	58	1.2	11				08	23	0.8
6				11	03	2.6	12				10	25	1.1
18. *Kami*				$x=38.28\pm0.73$ km, $y=6.99\pm1.17$ km (14) $h=10.83\pm1.14$ km (12)									
1	1965	8	12	04	46	2.6	9	1970	12	22	17	24	1.1
2			15	09	13	1.4	10	1971	1	2	19	46	1.8
3	1967	8	5	15	17	1.1	11		3	19	04	27	1.2
4				16	43	1.7	12	1972	7	29	05	27	2.5
5			16	00	45	1.5	13		11	24	02	52	1.5
6	1968	3	27	06	47	1.4	14	1973	4	6	22	40	0.7
7	1969	2	24	17	01	1.4	15	1976	4	20	20	20	1.7
8	1970	4	3	10	02	4.1							
19. *Hikami-A*				$x=41.02\pm0.50$ km, $y=16.66\pm0.65$ km (24) $h=12.76\pm1.75$ km (24)									
1	1967	11	22	01	08	1.2	13	1972	5	18	09	52	1.1
2				02	03	1.1	14				11	35	0.8
3				06	49	0.9	15			19	02	27	0.8
4				08	06	3.2	16				03	09	0.8
5				09	27	1.1	17				13	10	1.2
6				17	35	1.4	18			20	03	31	0.7
7			23	07	45	1.8	19			21	21	45	1.3
8		12	6	03	43	2.0	20			22	01	57	2.3
9			7	03	02	2.3	21				02	03	0.6
10			21	13	52	1.6	22				05	58	0.8
11	1972	5	18	05	11	0.6	23				06	24	0.8
12				05	13	0.9	24	1975	5	29	08	32	1.1
20. *Hikami-B*				$x=44.66\pm1.29$ km, $y=19.28\pm1.22$ km (21) $h=8.04\pm5.17$ km (17)									
1	1965	11	19	23	23	1.2	12	1971	2	20	03	19	1.1
2	1966	7	28	08	53	2.1	13		3	23	11	19	2.2
3	1967	6	29	20	16	1.0	14				11	21	2.6
4		11	26	15	57	3.4	15	1972	12	11	04	22	1.1
5			29	18	02	1.6	16				05	32	1.1
6		12	1	03	38	1.4	17			20	20	15	1.4
7	1970	9	28	03	40	0.4	18	1975	7	29	12	57	1.0
8			30	02	14	0.9	19		8	28	00	52	0.9
9				17	22	0.9	20				01	04	0.9
10		10	4	22	22	0.9	21		12	5	03	24	0.9
11		12	22	22	34	1.4							
21. *Ono*				$x=39.69\pm0.70$ km, $y=-18.28\pm1.15$ km (12) $h=13.56\pm1.32$ km (11)									
1	1968	1	12	11	33	3.5	5	1968	2	19	12	28	1.6
2				17	35	2.9	6		5	1	14	08	1.1
3			16	02	05	2.2	7	1968	11	5	01	47	3.1
4			18	00	52	1.6	8	1970	12	8	17	44	3.1

No.	Date Y	M	D	Origin time h	m	Mag.	No.	Date Y	M	D	Origin time h	m	Mag.
9	1971	1	23	22	44	1. 2	11	1971	6	7	04	36	2. 5
10		4	13	08	18	1. 4	12		8	26	14	49	0. 9
22. *Sanda*				$x=53.81\pm1.37$ km, $y=-6.90\pm1.25$ km (14) $h=13.74\pm0.76$ km (14)									
1	1969	6	20	15	33	3. 2	8	1969	6	20	20	13	2. 4
2				15	56	1. 7	9				20	54	1. 9
3				15	59	1. 4	10				21	02	1. 8
4				16	07	3. 6	11			22	06	58	2. 4
5				16	09	0. 9	12				08	18	1. 2
6				16	14	0. 9	13		7	12	06	14	1. 6
7				16	21	1. 6	14				06	15	1. 6