43. *Measures of Earthquake Danger and Expectancy of Maximum Intensity Throughout Japan as Inferred from the Seismic Activity in Historical Times.*

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One of the urgent problems of the practical seismology in earthquake country is to determine the degree of danger threatening human lives at any locality. It has been demanded from the engineering circle to furnish these informations, and recently we are also requested from the Ministry of Construction to determine the maximum earthquake intensity to which we may possibly encounter at any locality for the reference in determining the standard strength of the earthquake proof constructions, the standard being to be designated in the building code in preparation. The following is the result of our study on the above problems.

Our feeling of danger depends not only to the magnitude and frequency of liable danger but also to the imminence and certainty of the coming danger. We must therefore determine these aspects to fulfil the request. However, notwithstanding Omori, Imamura and others have predicted some earthquakes from the knowledge of the time and space distributions of earthquakes and some precursory phenomena, yet our knowledge is still too meagre to guarantee the prediction of the earthquake occurrence determinately. Moreover evidences of stochastic nature of the earthquake occurrence have been accumulated so much that we are by no means able to discuss especially the imminence and certainty of the coming earthpuake danger from the deterministic point of view.

We must therefore discuss only the side of the magnitude and frequency of the future danger on the statistical point of view from the data of past seismic activity. In Japan seismic records remain since more than one thousand years in most part of her territories, so that we may obtain a reliable mean probability from the mean activity in these historical times, even if we consider the long cycle of reccurrence of large earthquakes at a locality, which according to Imamura, is from 800 to 1000 years. The resemblance of seismic activities in recent 80 years and in historical times may be another testimony in favour of this point.

Thus we may derive the probability spectrum $P(I)$ from the frequency spectrum $n(I)$ of seismic intensity I as experienced at a point by the following formula

$$NP(I)\,dt=\frac{n(I)}{T}\,dt \qquad \text{(1)}$$

where N is the total number of observed intensity at all the localities throughout historical times of length T. The right hand side of the eq. (1), which denotes the mean frequency of earthquakes of intensity I, serves as a direct measure of earthquake danger at a point, and if we want to know, for example, expectancies of total number of subversion of houses or total amount of damage in current price or number of casualties etc., they may be determined from this mean frequency, since these damages are respectively functions of the intensity of an earthquake. These expectancies themselves also serve as the practical indices of earthquake danger. It is also to be noted that we can also derive a physical index of earthquake danger from the parameter of the function denoting the mean frequency spectrum $n(I)/T$. Indeed we know that the functional form of $n(I)$ is $C\times 10^{-\varepsilon I}$ so that $n(I_0)/T$ or its sum $S(I_0)/T=\sum_{I_0}^{\infty} n(I)/T$ may be used as a physical index of earthquake danger.

Let us now consider the determination of the standerd intensity for designing earthquake proof constructions. It is most ideal to build a building so strong as to resist the strongest earthquake intensity which may be encountered in the life-time or the duration of endurence of the structure. But, as we have stated, the future earthquake cannot be predicted determinately, so that we have only to use the expectancy of the maximum intensity as the standard. Such expectancy in the interval t is determined from the condition that stronger earthquake than the critical intensity can never be expected in the interval, or in other words the expectancy of the number of stronger earthquake than I_0 just reaches unity in t, i. e.

$$S(I_0)t/T=1 \qquad \text{(2)}$$

Physically considered, the condition

$$n(I_0)t/T=1 \qquad \text{(3)}$$

may be more appropriate, but from the practical point of view the former is adopted here for safety.

Let us now enter the practical calculation. Earthquake records in Japan were collected by Sekiya and Omori and later enlarged by Imamura and Musya in the latest "Materials for the Earthquake History of Japan".

Imamura has determined the epicentres and magnitudes of the historical earthquakes from the perusal of these materials based on his knowledge and experience of his life-long seismological study. Recently Musya compiled a catalogue of large earthquakes in Japan and the writer revised the manuscript and supplemented it with all the data concerning the earthquake intensity at any locality. Based on this catalogue the writer redetermined

Fig. 1. Distribution of epicentres of major historical earthquakes in Japan. Radius of the spot denotes the magnitude.

the epicentres and magnitudes of these earthquakes. The results are tabulated in the annexed table 1 and shown in Fig. 1.

M_k in the table 1 denotes the magnitude in the writer's scale and represents the intensity at the epicentral distance of 100 km. According to the recent study the magnitude M_k is also related to the maximum ground amplitude A_{100} at the same distance and Richter magnitude M by the following formulas:

$$A_{100}=10^{1.5+0.5M_k} \quad \cdots\cdots(4)$$

and

$$M=4.85+0.5M_k \quad \cdots\cdots(5)$$

The intensity scale here in use is the Japanese scale in 8 degrees from 0 to 7 which is shown in Table 2. The relation between the intensity I and the maximum acceleration α of the earthquake motion is very closely approximated by the relation

$$\overline{\alpha}=0.45\times10^{0.5I} \quad \text{(in gals)}, \quad \cdots\cdots(6)$$

where $\overline{\alpha}$ is the geometrical mean value of α as observed at Hongo by means of the Ishimoto acceleration seismographs. The mean $I(\varDelta)$ curve which the writer determined from some 80 earthquakes is expressed in terms of M_k as follows:

$$e^I=\left(\frac{100}{\varDelta}\right)^2 e^{M_k-0.00183(\varDelta-100)} \quad (\varDelta \text{ in km}) \cdots\cdots(7)$$

for the epicentral distance $\varDelta$ greater than 100 km. The $I(\varDelta)$ curve in shorter distance was calculated for the case of an earthquake having a hypocentral depth of 18 km, taking the extinction coefficient as determined from the discussion of observed frequency spectrum $n(I, r)\,dr$ in the interval r and $r+dr$ of hypocentral distance. Thus using the relation

$$A=\frac{r_0A_0}{r}e^{-k(r-r_0)} \quad \cdots\cdots(8)$$

(where A_0 and r_0 denote the values at $\varDelta=100$ km) and the equations (6) and (7), we have

$$I=M_k+2\log_{10}(r_0/r)+2k(\log_{10}e)(r-r_0) \cdots\cdots(9)$$

whose k being 0.0192 per km for S waves.

By means of these formulas (7) and (9) the seismic intensity at any locality is found for any earthquake of known epicentre and magnitude, the focal depth being assumed at 18 km with Gutenberg and Richter.

In this way we determined the intensity at 350 mesh points of 1/2 degree intervals of longitude and latitude arronud the land area of our country in case of 342 historical earthquakes already mentioned. The frequency spectrum for I greater than 5 and the sum $S(I)$ are determined. The latter are shown at the mesh points on Fig. 2 A, B and C. The lengths of historical times T are different at respective districts. For simplicity's sake our country is devided into three parts: middle and west, north east and Hokkaido

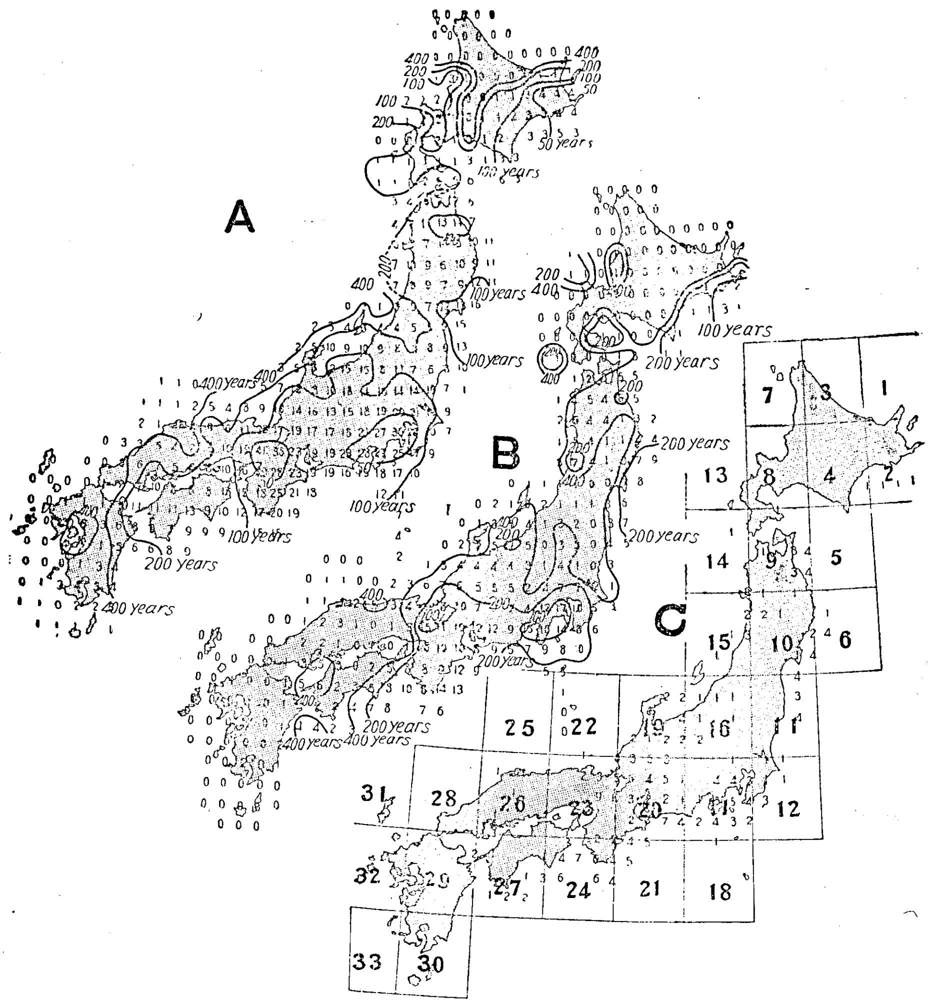

Fig. 2. Number S(I) of earthquakes with intencity over 5 (A), 6 (B) and 7 (C) as experienced at the locality in historical times. Contours in the maps denote the frequency, 1 in the assigned number of years.

districts where T are 1350, 1120 and 160 years respectively. The contours in the maps denote the mean frequency sum $S(I)/T$, such that one in 50, 100, 200 and 400 years respectively.

The expectancies of the maximum intensity I_0 for the interval t of 75, 100 and 200 years were determined by the relation (2). In the calculation $n(I)$ for I less than 4 was extrapolated where necessary by the relation $n(I)$

$=C\times10^{-0.5\,I}$. The resulting I_0 was transformed into acceleration by the formula (6), and the results are shown by contours in the maps Fig. 3 A, B and C.

From these figures we see that maximum frequencies and accelerations are found around Kyoto and Tokyo, the centres of civilization from historical times. But it seems from the nature of our historical records that larger earthquakes with intensities as strong as to cause demolition of houses (i. e. over 6) are not missing from the records so much as to invalidate the general features of the earthquake danger in our country. This is clearly seen from

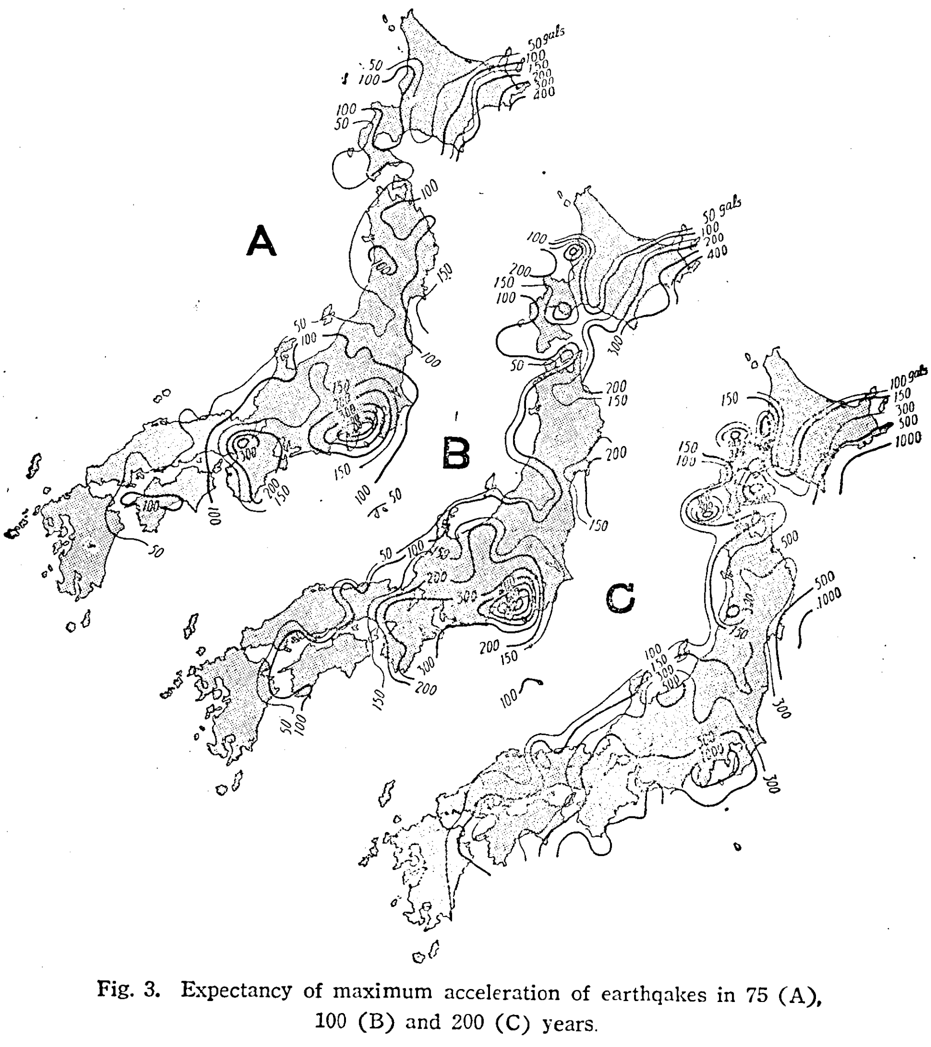

Fig. 3. Expectancy of maximum acceleration of earthqakes in 75 (A), 100 (B) and 200 (C) years.

the resemblance of the present result to that of recent 80 years as obtained by K. Kanai.

But it must be mentioned that the intensity of an earthquake is se much influenced by the condition of the underground, that the underground factor for each building cite must be multiplied to the accelerations shown in Fig. 3 A, B, C in determining the standard strength of earthquake proof constructions. Distributions of the underground factor in major cities as Tokyo, Osaka etc. have already been determined, and will be reported in future.

In conclusion the writer wishes to express his sincere thanks to Mr. K. Musya, for the preparation of the earthquake catalogue, and to the director and members of the Architecture Research Institute, Ministry of Construction for the support of the present study. It is also to be mentioned with thanks that kind suggestions were given to the writer by Drs. Takahasi and Kanai of the Earthquake Research Institute.

Table I. Catalogue of Large Earthquakes in Japan.

(Earthquakes marked by * were accompanied by tsunami.)

No.	Date.			Epicentre. φ degree N	Epicentre. λ degree E	M_k	No.	Date.			Epicentre. φ degree N	Epicentre. λ degree E	M_k
1	599	V	28			4.3	16	841			35.1	138.9	4.3
2	679			32.7	130.4	3.6	17	850			39.1	140.	4.3
3*	684	XI	29	32.5	134.	7.	18	856					3.1
4	701	V	12	35.6	135.4	4.3	19	857	IV	4	40.3	140.6	4.3
5	715	VII	4	35.1	137.9	3.1	20*	863	VII	10	37.1	138.1	4.3
6	715	VII	5	34.7	135.4	3.6	21	868	VIII	3	34.8	134.8	4.5
7	734	V	18	34.3	136.1	4.3	22*	869	VII	13	38.5	143.8	7.5
8	744	VI	30			3.	23	878	XI	1	35.5	139.3	5.0
9	745	VI	5	35.5	136.6	6.	24	880	XI	23	35.4	132.8	5.
10	762	VI	9	35.6	137.3	5.1	25	881	I	13			3.1
11*	799	IX	18				26*	887	VIII	2	37.5	138.1	4.3
12*	818			35.2	139.3	6.	27*	887	VII	26	33.	135.3	7.5
13	827	VIII	11	34.9	135.6	3.6	28	887	VIII	26	36.6	138.1	5.1
14	830	II	3	39.8	140.1	5.1	29	890	VII	10			2.6
15	841			36.6	137.8	3.6	30*	922			33.8	136.7	4.3

(to be continued.)

(continued.)

No.	Date.			Epicentre. φ degree N	Epicentre. λ degree E	M_k	No.	Date.			Epicentre. φ degree N	Epicentre. λ degree E	M_k
31	934	VII	16			2.6	61	1423	XI	23	39.2	140.1	3.6
32	938	V	22	34.8	135.8	4.0	62*	1433	XI	7	34.9	139.5	4.5
33	976	VII	22	34.9	135.8	3.6	63	1433	XI	7	37.7	139.8	3.6
34	1038	I	30	34.3	135.6	3.6	64	1449	V	13	35.	135.6	3.1
35	1041	VIII	25			3.1	65	1456	II	14			3.1
36	1070	XII	1	34.8	135.8	(3)	66	1466	V	29			2.6
37	1091	IX	28	34.3	135.8	2.6	67	1494	VI	19	34.6	135.7	3.
38	1093	III	19			3.1	68	1498	VII	9			
39*	1096	XII	17	34.2	137.3	7.0	69*	1498	IX	20	34.1	138.2	7.5
40	1099	II	22	34.7	135.7	3.	70	1502	I	28	37.2	138.2	4.
41	1099	IX	20			3.1	71	1510	IX	21	34.6	135.7	3.6
42	1137	VIII	10			2.6	72	1517	VII	18			3.1
43	1177	XI	26	34.7	135.8	2.6	73*	1520	IV	4	33.6	136.3	4.3
44	1185	VIII	13	35.9	136.1	5.	74	1525	IX	20			2.5
45	1213	VI	13			3.1	75	1555	IX	14			3.1
46	1227	IV	1			2.6	76	1579	II	25	34.7	135.5	2.6
47	1240	III	24			3.1	77	1586	I	18	36.	136.8	6.
48*	1241	V	22	35.25	137.25	4.3	78	1589	III	21	34.8	138.2	3.6
49	1245	VIII	27			2.6	79	1592	X	18			3.6
50*	1257	X	9	35.2	140.9	4.3	80*	1596	IX	4	33.3	131.7	4.
51	1293	V	28			4.5	81	1596	IX	5	34.8	135.7	4.3
52	1317	II	24	35.1	135.8	3.6	82	1597	IX	10	33.7	131.6	3.
53	1325	XII	5	35.6	136.1	3.6	83*	1605	I	31	A. 34.3 B. 33.	140.4 134.9	6. 6.
54	1331	VIII	15	33.7	135.2	4.3	84	1611	IX	27	37.5	139.7	4.
55	1350	VII	6			2.6	85*	1611	XII	2	37.7	144.3	6.5
56*	1360	XI	22	33.4	136.2	4.3	86*	1614	XI	26	37.5	138.	5.7
57*	1361	VIII	3	33.	135.	7.0	87	1615	VI	26	35.7	139.7	3.1
58	1369	IX	7			2.5	88*	1616	IX	9	38.1	142.	4.3
59*	1403			33.7	136.5	4.3	89	1619	V	1			2.6
60*	1408	I	21	33.8	136.9	4.3	90	1628	VIII	20			2.5

(to be continued.)

(continued.)

No.	Date.	Epicentre. φ degree N	Epicentre. λ degree E	M_k	No.	Date.	Epicentre. φ degree N	Epicentre. λ degree E	M_k
91	1630 VIII 2			3.7	121	1674 IV 15			2.
92*	1633 III 1	35.6	139.2	4.5	122	1675 IV 4			2.
93	1635 III 12			2.5	123	1676 VII 12	34.4	131.7	3.5
94	1639 XII	35.9	136.2	2.5	124*	1676			
95	1640 XI 23	36.2	136.2	3.6	125*	1677 IV 13	38.7	144	6.5
96	1643 XII 6			2.6	126*	1677 XI 4	36.6	141.5	5.1
97	1644 IV			2.	127	1678 X 2	38.6	142.3	5.
98	1644 X 18	39.4	140.1	4.	128	1683 VI 17	36.7	139.6	3.
99	1646 VI 9	37.7	141.7	5.5	129	1683 VI 18	36.8	139.7	4.8
100	1647 VI 16			3.	130	1683 X 20			3.8
101	1648 VI 12	35.1	139.3	4.5	131	1685			3.1
102	1649 III 17	33.7	132.4	4.5	132	1685 XII 29			2.
103	1649 VII 29	36.1	139.7	4.5	133	1686 I 4	34.	132.3	4.3
104	1649 IX 1	35.5	139.6	3.	134	1686 X 3	34.6	137.4	4.3
105	1650 IV 24			3.5	135*	1687 X 22			
106	1658 V 5			2.6	136	1691	36.3	136.3	2.6
107	1659 IV 21	37.2	139.8	3.7	137	1694 VI 19	40.2	140.2	4.3
108	1661 XII 10			2.5	138	1694 XII 12			2.5
109	1662 VI 16	35.3	136.	5.5	139	1696 VI 1			
110*	1662 X 31	31.7	132.	5.5	140*	1696 II 25			
111	1664 I 4			2.	141	1697 XI 25	35.8	139.5	4.
112	1664 VIII 3			3.5	142*	1703 XII 31	34.7	139.8	6.6
113	1665 VI 25			2.5	143	1704 V 27	40.4	140.	4.
114	1666 II 1	37.1	138.2	3.	144	1706			
115*	1666 V 31				145*	1707 X 28	33.2	135.9	7.
116	1667				146	1710 IX 13			3.0
117	1667 VIII 22			3.	147	1710 X 3	35.5	133.8	3.5
118	1668 VIII 28			2.	148	1711 III 19	35.4	133.8	3.5
119	1669 VI 29			2.	149*	1711 XII 20	34.3	134.	3.7
120	1670 VII 21	35.4	139.2	3.	150	1714 IV 28	36.7	137.8	3.

(to be continued.)

(continued.)

No.	Date.			Epicentre. φ degree N	Epicentre. λ degree E	M_k	No.	Date.			Epicentre. φ degree N	Epicentre. λ degree E	M_k
151	1715	II	1	35.4	136.6	2.7	181	1766	III	8	40.8	140 6	4.0
152	1717	V	13	39.	142.7	5.5	182	1767	V	4			
153	1718	II	26			2.6	183*	1768	VII	22			
154	1718	VIII	22			3.1	184	1768	IX	8			2.
155	1718	X	5			2.6	185	1769	VII	22			2.
156	1723	XII	18	33 2	130.4	2.6	186	1769	VIII	29	32.3	132.	5.
157	1725	V	29			3.5	187	1770	V	27	38.6	142.	5.
158	1725	VI	17	36.4	136.4	2.	188*	1771	IV	24			5.1
159	1725	VII	14	35 8	138.1	2.5	189	1772	VI	3	39 3	142.7	5.
160	1725	XI	8.9	32.7	129.8	2.6	190	1778	II	14	34.6	132.7	3.5
161	1729	VIII	1	37.6	137.6	4.	191*	1780					4.3
162	1731	X	7	37.9	140.6	3.5	192	1782	VIII	23	35.1	139.7	4.8
163	1732	XII	21			2.6	193	1782	IX	21			2.5
164	1733	IX	18			3.5	194	1784	VIII	29			2.5
165	1735	IV	6			2.	195	1789	V	10	32.9	134.5	5.
166	1736	IV	30	38.3	140.8	2.6	196*	1791	V	13			
167	1739	VIII	16			4.	197*	1792	V	21	32.8	130.3	3.
168*	1741	VIII	28	41.5	139.4	4.	198*	1792	VI	13	43.6	140.3	4.
169	1746	V	14			4.	199*	1793	II	8	40.7	140.	4.
170	1749	V	25	33.4	132.2	4.3	200*	1793	II	17	38 3	142.4	5.5
171	1751	III	26			3.	201	1799	VI	29	36.6	136.6	3.0
172	1751	V	20	37.2	138.	3.5	202	1801	V	26	35.3	140.	
173	1755	III	29			2.6	203	1802	XII	9	37.8	138.4	3.5
174	1755	IV	21			2.6	204*	1804	VII	10	39.	140.	4.5
175	1760	V	15				205	1810	II	4			
176	1762	III	29			2.	206*	1810	IX	25	39.9	139.9	3.5
177*	1762	X	31	38.1	138.7	3.5	207	1812	IV	21	33.8	132.5	4.
178*	1763	I	29	40.8	142.	5.	208	1812	XII	7	35.4	139.6	3.5
179	1763	III	11	40.7	142.	5.3	209	1814	XI	22			2.6
180*	1763	III	15			4.5	210	1815	III	1	36.4	136.5	2.7

(to be continued.)

(continued.)

No.	Date.			Epicentre. φ degree N	Epicentre. λ degree E	M_k	No.	Date.			Epicentre. φ degree N	Epicentre. λ degree E	M_k
211	1819	VIII	2	35.2	136.3	5.	241	1857	X	12	33.8	132.8	3.
212	1820					2.	242	1858	IV	9	36.1	137.2	4.
213	1821	IX	12			2	243				36.2	136.3	3.
214	1821	XII	13	37.4	139.5	2.5	244	1858	IV	23	36.6	138.2	2.
215	1823	X	23	40.	141.1	2.	245	1859	I	5	34.7	131.8	2.
216	1826	VIII	28	36.2	137.3	2.6	246	1859	III	9 ?	35.9	139.6	2.
217	1828	V	26	32.8	129.9	2.	247	1859	X	4	34.7	131.9	2.
218	1828	XII	18	37.6	138.9	4.	248*	1861	X	21	37.7	141.6	3.
219	1830	VIII	19	35.	135.7	3.	249*	1863	IX	20			2.
220	1831	XI	13	33.2	130.3	2.5	250	1864	III	6	35.	134.8	3.
221	1833	V	27	35.5	136.6	3.	251	1872	III	14	34.8	132.	4.5
222	1833	XII	7	38.7	139.2	5.	252	1874	II	28	43.9	141.6	3.
223	1834	II	9	43.3	141.4	3.	253	1880	II	22			2.
224	1835	VII	20	37.9	141.9	5.5	254	1881	X				
225	1836	IX	5			2.	255	1886	VII	23	37.1	138.4	2.4
226	1841			35.	138.5	3.	256	1887	VII	22	37.7	139.	2.6
227	1843	III	9	35.7	139.1	3.5	257	1889	VII	28	32.8	130.7	2.8
228*	1843	IV	25	41.8	144.8	7.	258	1890	IV	16	34.3	139.3	2.6
229	1847	V	8	36.7	138.2	5.	259	1891	X	28	35.6	136.6	7.0
230	1848	I	11	33.2	130.3	2.	260	1892	XII	9	36.9	136.6	1.9
231	1848	I	13	40.7	140.6	2.	261*	1893	VI	4			3.5
232	1853	I	26	36.5	138.1	2.	262	1893	IX	7	31.3	130.5	3.0
233	1853	III	11	35.8	139.1	3.3	263	1894	I	4			2.
234	1854	VII	9	34.8	136.2	4.	264*	1894	III	22			6.
235*	1854	XII	23	34.1	137.8	7.	265	1894	VI	20			5.2
236*	1854	XII	24	33.2	135.6	7.	266	1894	X	22	39	140.1	4.8
237	1854	XII	26	33.4	132.1	4.3	267	1895	I	18	35.9	140.4	4.8
238	1855	XI	11	35.8	139.8	4.	268	1896	IV	2	37.5	137.3	3.5
239*	1856	VIII	23	42.	141.1	4.	269*	1896	VI	15	39.4	144.4	5.4
240	1857	VII	14	34.8	138.2	3.	270	1896	VIII	31	39.5	140.7	5.2

(to be continued.)

(continued.)

No.	Date.			Epicentre. φ degree N	Epicentre. λ degree E	M_k	No.	Date.			Epicentre. φ degree N	Epicentre. λ degree E	M_k
271	1897	I	17	36.6	138.2	2.9	301*	1915	XI	1	38.8	143.2	5.2
272	1897	II	20	37.8	141.6	5.9	302	1916	II	22	36.4	138.4	2.3
273*	1897	VIII	5	38.2	143.7	5.6	303	1916	XI	26	34.6	135.	2.8
274	1898	IV	23	38.8	142.3	5 8	304	1917	V	18	35.2	138.1	2.8
275	1898	V	26			3.7	305*	1918	IX	8			6.1
276	1898	VIII	10	33.5	130.2	3.3	306*	1918	XI	8	44.5	151.5	5.1
277	1898	IX	1				307	1918	XI	11	36.5	137.8	2.4
278	1899	III	7	34.	136.2	5.4	308	1921	XII	8			4.5
279	1900	III	22	36.	136.2	3.6	309	1922	IV	26	35.7	139.7	4.0
280	1900	V	12			4.8	310	1922	XII	8	32.8	130.1	3.2
281	1900	XI	5	34.	139.5	3.8	311	1923	I	14			2.9
282	1901	VI	24			6.0	312*	1923	IX	1	35.	139.8	6.0
283*	1901	VIII	9	40.3	141.8	5.7	313	1924	I	15	35.5	139.2	4.6
284	1902	I	30	40.3	141.8	5.1	314	1925	V	23	35.7	134.8	4.3
285	1903	VIII	10			1.7	315	1927	III	7	35.6	135.	5.1
286	1905	VI	2	34.2	132.3	5.4	316	1927	X	27			1.
287	1905	VI	7	34.8	139.2	4.2	317	1929	XI	20			2.7
288	1908	V	13	33.4	138.3	5.6	318	1930	XI	26	35.	138.9	4.3
289	1908	VII	11			3.3	319	1931	IX	21	36.	139.2	3.7
290	1909	III	13	35.3	140.9	6.7	320*	1933	III	3	39.1	144.2	8.3
291	1909	VIII	14	35.4	136.3	4.1	321	1935	VII	11	35.	138.3	3.4
292	1909	VIII	29				322	1936	II	21	34.6	135.7	3.6
293	1909	XI	10	32.1	133.1	6.0	323	1936	XII	27	34.3	139.2	3.1
294	1910	VII	24	42.5	140.8	3.2	324	1938	I	12	33.6	135.2	4.3
295	1910	IX	8			2.	325	1938	V	23	36.7	141.5	5.3
296	1911	VI	15	29.	129.	8.0	326	1938	V	29	43.5	144.3	2.
297	1913	VI	29	31,6	130.5	3.0	327*	1938	XI	5	37.1	141.3	3.2
298	1914	I	12	31.6	130.7	2.6	328*	1939	III	20	32.4	131.8	3.7
299	1914	III	15	39.5	140.4	3.1	329*	1939	V	1	40.	139.8	3.5
300	1914	III	28	39.8	140.9	1.9	330*	1940	VIII	2	44.1	139.2	2.

(to be continued.)

(continued.)

No.	Date.			Epicentre. φ degree N	Epicentre. λ degree E	M_k	No.	Date.			Epicentre. φ degree N	Epicentre. λ degree E	M_k
331	1941	VII	15	36.7	138.3	3.0	336	1943	IX	10	35.4	134.1	4.8
332*	1941	XI	19	32.2	132.3	4.3	337	1943	X	13	36.8	138.2	2.2
333	1943	III	4	35.6	134.2	3.	338*	1944	XII	7	34.	137.1	6.8
334	1943	III	5	35.6	134.1	3.	339	1945	I	13	34.8	137.2	4.
335	1943	VIII	12	37.2	139.8	2.2	340*	1946	XII	21	33.	134.8	6.5
							341	1948	VI	28	36.1	136.2	4.7
							342	1949	XII	26	36.7	139.7	3.2

Table Ⅱ. Japanese Seismic Intensity Scale.

0; No feeling: too weak to cause human feeling, to be registered only by seismographs.

I; Slight: to be felt only feebly by persons at rest or by those who are observant to an earthquake.

II; Weak: to be felt by most persons, causing slight shaking of windows and Japanese latticed sliding doors (Shōji).

III; Rather strong: to cause shaking of houses and buildings, heavy rattling of windows and Japanese latticed sliding doors, swinging of hanging objects stopping sometimes pendulum clocks and moving of liquids in vessels. Some persons are so frightened as to run out of doors.

IV; Strong: to cause strong shaking of houses and buildings, overturning of unstable objects, spilling of liquids out of vessels.

V; Very strong: to cause cracks in the brick and plaster walls, overturing of stone lanterns and grave stones etc. and damaging of chimneys and mud-and-plaster warehouses. Landslides in steep mountains are to be observed.

VI; Disastrous: to cause demolition of Japanese wooden houses of more than 1%; intense landslides, fissures on the flat ground accompanied sometimes by spouting of mud and water in low fields.

VII; Ruinous: to cause demolition of almost all the houses, large fissures and fault are to be observed.

43. 有史以來の地震活動より見たる我國各地の地震危險度及び最高震度の期待値

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地震國の國民にとつて最大の關心事は地震の危險度であり，それに應じての對策が第一に要望されるわけである。さりながら地震豫知不可能な現狀に於ては絕對的な危險度を知る事は出來ないが，故きを溫ねて過去の地震活動の趨勢から，統計學的に將來を豫測する事は不可能ではない。最近建築基準法制定に伴ふこの要請に應へて，有史以來の破壞的地震の活動を調査し，我國各地の古來の震度別地震回數を求め，その平均頻度に基づき最高震度の期待値を計算した。

この調査は筆者年來の研究に基づく，地震の大きさと震度分布との關係（(7)及び(9)式）を用ひて出來たもので，それにより先づ第一表に示す古來の破壞的地震の記錄よりその地の震度を定め，その分布により，震央及び地震の大きさを決定した。次にそれによつて逆にすべての點の震度が決定出來るので，之等342箇の地震による全國各地(經度緯度各半度每の網目點350點)の震度を定め，各點について，震度5（强震）以上の震度別地震回數を統計した。その結果は第2圖に圖示してある。之を各地の記錄期間の長さで割つて平均頻度を求め，それらの震度別頻度の關係から，その割合では一定期間にそれ以上の强さの地震の起る確率が1に達しないと云ふ條件を充す最高震度の期待値を求めた。この結果を震度の等値線で第3圖に示した。但しその一定期間の長さ(t)としては 75年(A), 100年（B）及び 200年（C）をとつた。耐震構造物の壽命に應じて適當な（t）を選び基準震度をとることが出來るであらう。

但し實際の震度はその地の地盤の良否に關係するから震度の地盤係數を忘れてはならない。

尙筆者の用ひた地震の大きさ Mk と Richter, Gutenberg の M との關係(5)も最近の研究により記してある。