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Peak Ground Accelerations in the Kamchatka Peninsula from Data of Strong Motion Instruments

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Abstract—The peak ground accelerations in the Kamchatka Peninsula were estimated from 54 analogue records of strong motions obtained in 1969–1993. The records of acceleration and velocity from 33 earthquakes with magnitudes M_{LH} = 4.0–7.8 were obtained at 15 sites with rocky to medium ground conditions at epicentral distances Δ of 30 to 250 km. The peak accelerations $A_{\max}$ were determined from "true" acceleration time histories by the spectral deconvolution of the instrument response from digitized records. For the comparison of the relative levels of peak accelerations in Kamchatka and Japan, the $A_{\max}$ values were reduced to a fixed distance of 100 km and rocky ground, using the empirical relationship of Kawashima. The resulting relation $A_{\max}(M)$ has an unusually large scatter obviously caused by the specific ground conditions of two anomalous stations. Upon rejecting the data of these stations, the mean level of peak accelerations in Kamchatka was found to be close to that in Japan (at the same magnitude and distance).

INTRODUCTION

Peak accelerations $A_{\max}$ (along with intensity) are an important intensity characteristic of seismic motions. Thus, the calculated values of $A_{\max}$ are employed for estimating the seismic load as the dimensional factor of the dimensionless spectral function $\beta(T)$. This parameter is used in constructing the predictive relationships due to the simplicity of the $A_{\max}$ estimation from acceleration records, the large body of accumulated data, and the simplicity of the resulting analysis. The reviews of the publications on peak accelerations are given, for example, in [1, 2].

Although the results obtained from the analysis of certain records of strong motions in Kamchatka have been previously published [3–7], their systematic study has not been performed yet. This paper discusses the results of the $A_{\max}$ calculation from records obtained during 1969 through 1993. All of these results were calculated by a method including transfer characteristics of instruments and were compared with Japanese data.

This study could not have been performed without many years of observations conducted in 1962–1995 by the following organizations and scientists: the Institute of Physics of the Earth (IPE), Russian Academy of Sciences (V.V. Shteinberg); the Pacific Seismic Expedition, IPE (S.A. Fedotov); the Petropavlovsk seismic station, IPE (L.G. Sinel'nikova); the Institute of Volcanology (IV), Far East Division of the Russian Academy of Sciences (V.D. Feofilaktov); and the Experimental Seismological Party (ESP), IV (E.I. Gordeev and V.P. Mityakin).

KAMCHATKA STRONG MOTION SEISMIC NETWORK

The creation of the Kamchatka strong motion seismic network began in 1962 from the installation of the UAR instrumental set at the Petropavlovsk seismic station; later, the UAR sets were installed at the Bering (1964) and Krutoberegovo (1968) stations. At the same time, the deployment of the network of the S5S-ISO-II instruments began. In 1974–1975, the existing UAR sets were enlarged and reequipped, and new instruments (SSR3, S5SISO-II, and SMAC-Q) were installed at five regional seismic stations nearest to the seismic focal zone along the eastern Kamchatka coast and at five stations on the territory of the town of Petropavlovsk-Kamchatski, the latter being specially created for the microzoning studies. At that period, most records were obtained by the S5S-ISO-II velocigraphs. The next stage of the enlargement and reequipment of the strong motion network dates from 1981–1982. Three stations (Paratunka, Zhupanovo, and Mayak Petropavlovskii) were installed in addition to the five working regional stations. The Petropavlovsk-Kamchatski network was enlarged to eleven stations. The higher-sensitivity SSR3-M accelerographs, having a larger range of measured acceleration due to the wider-film (70-mm) recording, were installed at three stations. Also, the maintenance quality of instruments was considerably improved at that time.

Presently, the Kamchatka strong motion network consists of 25 stations (Fig. 1). Seventeen stations are located along the eastern coast of Kamchatka and on the Bering Island. Instruments are installed at regional

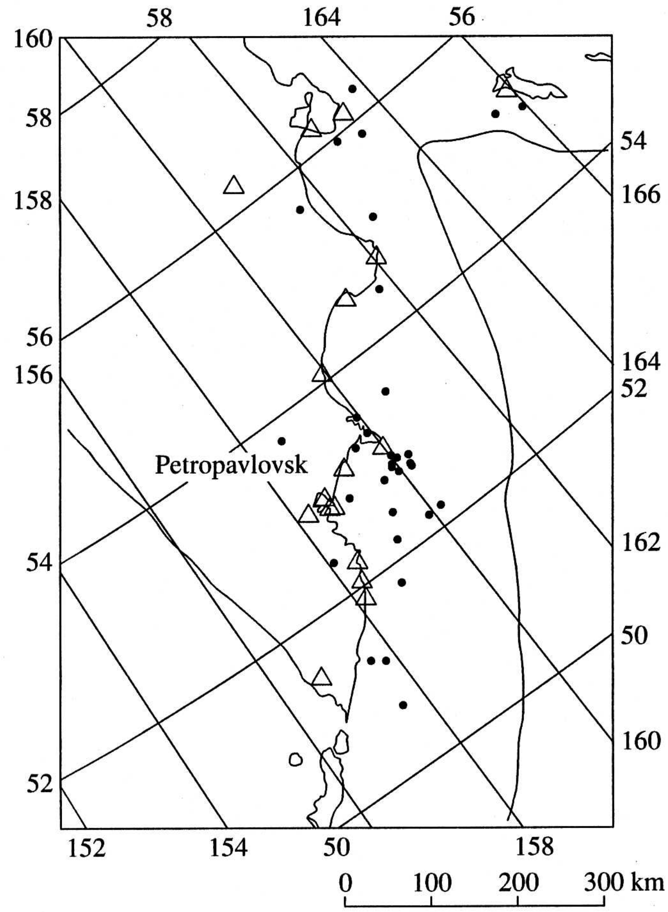

Fig. 1. Strong motion network in Kamchatka. The epicenters of the earthquakes from Table 3 are shown by dots. The names and coordinates of the stations are given in Table 1.

seismic stations, lighthouses, meteorological stations, and the like. Eight stations are located on the territory of the town of Petropavlovsk-Kamchatski. The main parameters of the stations and their instruments are given in Tables 1 and 2.

STRONG EARTHQUAKES FROM THE OBSERVATION PERIOD

Several strong earthquakes occurred during the whole period of observations in Kamchatka. Three of them had magnitudes of 7.5–8: Ozernovskii earthquake of November 22, 1969, with $M_{LH} = 7.7$; Petropavlovsk earthquake of November 24, 1971, with $M_W = 7.7$ and $M_S = 7.2$ ($H = 100$ km); and Ust'-Kamchatsk earthquake of December 15, 1971, with $M_{LH} = 7.8$. Individual records [6, 7] were obtained for each of these earthquakes, notwithstanding the technical imperfections of the instruments and difficulties in their maintenance. The intensity of the Petropavlovsk, November 24, 1971, earthquake was 7 in Petropavlovsk and 5–6 at the instrument installation site. The intensity of the Ust'-Kamchatsk, December 15, 1971, earthquake was 7 both in Ust'-Kamchatsk and at the recording site.

In 1972–1991, three earthquakes with a magnitude of about 7 were recorded in Kamchatka on August 17, 1983 (Krutoberegovo and Kronoki stations), December 28, 1984 (Afrika and Kronoki), and February 29, 1988 (Bering). Table 3 lists the Kamchatka earthquakes whose strong motion records were processed.

RESULTS OF THE MAXIMUM ACCELERATION MEASUREMENTS

For each earthquake, Table 3 presents the epicentral coordinates ϕ and λ, focal depth h, and magnitude M_{LH} and/or energy class K^{F68}. The epicentral (Δ) and hypocentral (R) distances are shown in Table 4 for each of the station–earthquake pairs. For regional stations, the hypocentral distance was calculated from t_{S-P} with the help of the Kamchatka-average travel–time curve. The earthquake epicenters are shown in Fig. 1. Their distribution reflects, rather than the actual seismicity pattern, the triggering mode operation of the instrumentation, whose maintenance is far from ideal at the stations remote from Petropavlovsk-Kamchatski. The records nearly uniformly cover the interval of magnitudes from 4.5 to 7.8 and distances from 30 to 250 km (Fig. 2).

The processing procedure described in detail in [8] includes the following main steps.

(1) Record digitization. The contact photocopies of the records were manually digitized with the help of the optical-mechanical digitizing apparatus UTsS-F004. The resolution in ordinate was 0.1 mm or less, and the digitizing frequency was 50 to 100 readings per second.

(2) Baseline correction. The baseline offset and slope were removed by fitting the approximating line. In some cases, the integration over a moving wide time window was applied to eliminate the long-period baseline drift caused by the photographic substrate deformation.

(3) Filtering. Low- and high-pass filtering was applied in the frequency domain. Typical cutoff frequencies of the corresponding filters were $f_l = 0.1$ Hz and $f_h = 25$ Hz.

(4) Reconstruction of the "actual" ground motion. The actual ground motion was reconstructed through the division of the Fourier spectrum of a record by the complex acceleration transfer function of the instrument and subsequent inverse Fourier transformation. Whenever spurious baseline drifts were found, the low-pass cutoff frequency was increased, and the procedure was repeated.

(5) The peak acceleration was calculated as the maximum signal amplitude between the reading and baseline.

The instrument transfer function for each record was calculated from the actual values of the instrument

Table 1. Main parameters of the strong motion stations in Kamchatka

No.	Station	Ground	Instrument	Siting conditions
1.	Bering (55.2, 166.0)	Rocky	ISO2M-S5S, SSR3-M, AS3-2	Basement of seismic station, pedestal
2.	Krutoberegovo (56.3, 162.7)	Medium	ISO2M-S5S, SSR3-M, AS3-2	Seismic station, pedestal
3.	Klyuchi (56.3, 160.9)	Medium	ISO2M-S5S	Deep borehole, pedestal
4.	Kronoki (54.6, 161.2)	Medium	ISO2M-S5S, SSR3-M, AS3-2	Seismic station, pedestal
5.	Shipunskii (53.1, 160.0)	Rocky	ISO2M-S5S, SSR3-M, AS3-2	Basement of two-storeyed house, pedestal
6.	Petropavlovsk (53.0, 158.7)	Rocky	ISO2M, SSR3-M, AS3-2, UAR	Seismic station, pedestal
7.	Berezovaya (52.3, 158.5)	Rocky	AS3-2	Basement of seismic station, pedestal
8.	Pauzhetka (51.5, 156.8)	Medium	ISO2M-S5S	Pedestal
9.	Afrika (56.2, 163.4)	Medium	SSR3-M	Concrete floor of lighthouse building
10.	Mayak Kronotskii (54.8, 162.1)	Medium	SSR3-M	Concrete floor of basement
11.	Zhupanovo (54.1, 160.0)	Rocky	SSR3-M	Weather station, free ground, pedestal
12.	Nalychevo (53.2, 159.2)	Soft	SSR3	Basement of dispatching office, pedestal
13.	Mayak Petropavlovskii (52.9, 158.7)	Rocky	SSR3-M	Concrete floor of lighthouse building
14.	Mayak Stanitskogo (52.9, 158.6)	Rocky	SSR3-M	Concrete floor of lighthouse building
15.	Paratunka (53.0, 158.3)	Medium	ISO2M	Ionospheric station, borehole
16.	Khodutka (51.9, 158.2)	Rocky	SSR3-M	Weather station, free ground, pedestal
17.	Kruglyi (52.1, 158.3)	Rocky	SSR3-M	Concrete floor of lighthouse building
		Petropavlovsk-Kamchatski network		
18.	Institute	Medium	ISO2M, SSR3-M, ASR3-2, SMAQ-Q	Basement of the Institute of Volcanology building
19.	Gor'kogo, 15	Medium	ISO2M, SSR3-M,	Basement of four-storeyed building, pedestal
20.	Dachnaya	Medium	ASR3-2	Basement of four-storeyed building, pedestal
21.	Klyuchevskaya	Medium	SSR3-M	Ground floor of four-storeyed building, pedestal
22.	Tsunami	Medium	SSR3-M	Ground floor of four-storeyed building, pedestal
23.	Nikol'skaya	Rocky	SSR3-M	Concrete floor of basement
24.	Mishennaya	Rocky	SSR3-M	Basement of two-storeyed TV center building, concrete floor
25.	Aerological station	Medium	SSR3-M	Basement of two-storeyed building, pedestal

parameters (by way of illustration, their rated values are listed in Table 2). The instrument parameters were determined by calibrations made once every several years, or their rated values were taken.

The resulting peak accelerations are shown in the last column of Table 4. For comparison, the values of the seismic intensity I at the receiver sites are also presented in the table (the Kamchatka ESP database was used). The intensity for Petropavlovsk-Kamchatski was averaged over the town area. Due to the ground conditions, the intensity at the Petropavlovsk station is about 1 lower than the town-average value [9].

ANALYSIS OF RESULTS

To analyze the results and compare them with the data from Japan (the nearest well-studied zone with similar tectonic conditions), we reduced the A_{max} values

Table 2. Typical values of the main parameters of the instruments recording earthquake-induced strong ground motions

Instrument	Recorded parameter	Number of channels	Recording mode	Intensity range	Frequency range, Hz	Recording duration, s	Sensitivity coefficient	T_s (s)	D_s	T_g (s)	D_g
UAR	Acceleration	3	Direct, photographic paper	5–9		30	16 mm/Gal	0.045	0.7	–	–
ISO2M-S5S	Velocity	5	Galvanometric, 35-mm film	2–7	0.25–30	30	2.5/0.1 s	5	0.55	0.0083	0.7
SSR3	Acceleration	3	Direct, 35-mm film	5–9	0–30	30	15 mm/Gal	0.05	0.6	–	–
SSR3-M	Acceleration	3	Direct, 70-mm film	5–9	0–30	30	20 mm/Gal	0.05	0.6	–	–
AS3-2	Acceleration	3	Direct, 70-mm film	5–9	0–30	unbounded	60 mm/Gal	0.06	0.55	–	–
ASR3-2	Acceleration	3	Direct, 70-mm film	5–9	0–30	unbounded	60 mm/Gal	0.06	0.55	–	–
SMAC-Q	Acceleration	3	Direct, scratching on 35-mm film	4–9	0–25	90	5 mm/Gal	0.05	0.6	–	–

Table 3. List of earthquake records

No.	Date	Time	Epicenter		H, km	Magnitudes			
			φ (N)	λ (E)		M_{LH}	M_S	K_S	M_W*
1.	November 22, 1969	23.09.35	57.76	163.75	30	7.7	7.3	14.4	7.7t
2.	November 24, 1971	19.35.49	52.77	159.66	100	7.2	–	16.0	7.7z
3.	December 15, 1971	08.29.55	55.85	163.35	25	7.8	7.8	16.0	7.7z
4.	December 19, 1971	07.50.23	55.95	162.90	0	5.8	5.3	11.9	5.9l
5.	March 12, 1973	19.39.21	50.80	157.20	70	–	–	14.4	6.7k
6.	July 11, 1975	05.23.22	53.23	159.60	115	–	–	11.7	5.1k
7.	November 6, 1977	02.39.38	53.50	159.96	60	4.6	–	13.2	5.3h
8.	December 21, 1977	16.39.36	52.19	159.90	39	5.3	5.0	12.8	5.6h
9.	June 25, 1979	18.45.52	52.74	160.20	31	4.0	–	13.1	4.7l
10.	February 11, 1980	15.29.47	53.30	159.90	57	–	–	12.7	5.1k
11.	November 23, 1980	15.45.03	52.44	159.42	20	–	–	11.8	4.6k
12.	December 4, 1980	10.46.27	52.21	160.17	26	5.6	5.2	12.8	5.4h
13.	December 9, 1981	19.31.30	54.94	165.94	20	5.1	4.9	12.2	5.3h
14.	June 25, 1981	01.47.56	52.85	159.90	42	4.2	4.3	12.5	4.9l
15.	October 13, 1981	15.54.02	51.30	157.60	101	–	–	13.0	5.4h
16.	March 8, 1982	15.16.31	52.89	160.08	38	4.2	–	12.1	5.1h
17.	April 17, 1982	10.27.12	54.44	161.72	42	–	–	10.9	4.6k
18.	May 14, 1982	03.37.58	52.20	159.20	121	–	–	11.9	5.1k
19.	May 31, 1982	10.21.21	55.07	165.48	56	6.5	6.4	14.7	6.5h
20.	November 14, 1982	08.29.20	52.84	158.98	91	–	–	13.2	5.6h
21.	April 4, 1983	19.04.23	52.95	160.02	40	5.7	5.5	13.3	5.9h
22.	June 24, 1983	23.07.30	53.77	158.62	180	5.4	–	14.3	5.6h
23.	August 5, 1983	00.33.47	52.87	159.93	41	4.7	4.7	12.6	5.5h
24.	August 17, 1983	10.55.55	55.64	161.52	98	6.8	6.7	15.0	7.0h
25.	December 28, 1984	10.37.47	56.28	163.77	5	7.5	7.0	14.5	6.7h
26.	March 6, 1985	22.31.52	55.09	162.48	46	6.0	5.4	14.3	5.9h
27.	May 19, 1985	08.07.48	53.54	160.65	40	5.6	–	13.7	5.8h
28.	February 24, 1987	07.40.09	52.38	158.08	126	4.0	–	12.8	4.7l
29.	October 6, 1987	20.11.36	52.85	160.25	34	6.6	6.3	13.9	6.5h
30.	March 2, 1992	12.29.38	52.76	160.20	20	7.1	6.8	14.6	6.9h
31.	March 5, 1992	14.39.11	52.77	159.95	31	6.2	6.1	14.0	6.3h
32.	June 8, 1993	13.03.37	51.20	157.80	40	7.4	7.3	14.9	7.5h
33.	November 13, 1993	01.18.07	51.79	158.83	40	7.1	7.0	14.6	7.0h

* The M_W estimates are based on (*t*) tsunami magnitudes from [13]; (*z*) M_0 values from [3]; (l) M_{LH} values, using the relations from [11]; (*k*) K^{F68} values, using the relations from [11]; and (*h*) M_0 from the Harvard catalog.

obtained at different distances and ground types to the standard distance and ground, for which we took Δ = 100 km and ground of class I (rocky). Two factors were taken into account in choosing the value Δ = 100 km: (1) it is close to the mean for the data set in use, and (2) earthquakes dangerous for the Kamchatka settlements occur approximately at this distance. The accelerations were recalculated by the formula

$$A_{\max}(M_{LH}, 100, 1) = \frac{A_{\max}(M_{LH}, \Delta, g)}{F(M_{LH}, \Delta, g)}, F(M_{LH}, 100, 1), \quad (1)$$

where M_{LH} is the magnitude, Δ is the epicentral dis-

Table 4. Maximum horizontal accelerations

No.	Date	Station	Instrument	Δ, km	*R*, km	M_W	*I*, ball	A_{max}, cm/s/s
1.	November 22, 1969	Bering	ISO	260	261	7.7	4–5	6.84
2.	November 24, 1971	Petropavlovsk	ISO	120	125	7.7	7	90.2
3.	December 15, 1971	Krutoberegovo	UAR	80	84	7.7	7	51.3
4.	December 19, 1971	Krutoberegovo	UAR	32	32	5.9	–	6.66
5.	March 12, 1973	Petropavlovsk	ISO	242	252	6.7	4	5.30
6.	July 11, 1975	Petropavlovsk	ISO	30	119	5.1	–	0.80
7.	November 6, 1977	Petropavlovsk	ISO	107	123	5.3	3–4	3.35
8.	December 21, 1977	Petropavlovsk	ISO	70	113	5.6	4	3.10
9.	June 25, 1979	Petropavlovsk	ISO	80	128	4.7	3–4	2.80
10.	February 11, 1980	Petropavlovsk	ISO	87	109	5.1	3–4	4.75
11.	November 23, 1980	Paratunka	ISO	101	104	4.6	–	2.61
12.	December 4, 1980	Petropavlovsk	ISO	140	167	5.4	3	1.86
13.	February 9, 1981	Bering	SSR3	30	36	5.3	5	68.8
14.	June 25, 1981	Petropavlovsk	ISO	85	114	4.7	3–4	2.02
15.	October 13, 1981	Petropavlovsk	ISO	180	206	5.4	3–4	1.13
16.	March 8, 1982	Petropavlovsk	ISO	110	112	5.1	3–4	2.50
17.	April 17, 1982	Kronoki	ISO	43	60	4.6	4	93.4
18.	May 14, 1982	Petropavlovsk	ISO	66	138	5.1	–	1.02
19.	May 31, 1982	Bering	SSR3	38	68	6.5	5–6	33.3
20.	November 14, 1982	Petropavlovsk	ISO	27	95	5.6	4–5	8.65
21.	April 4, 1983	Petropavlovsk	ISO	90	104	5.9	4–5	5.90
22.	July 24, 1983	Kronoki	ISO	200	204	5.9	4–5	32.1
23.	August 5, 1983	Kronoki	ISO	110	211	5.6	4–5	37.3
24.	August 17, 1983	Shipunskii	ISO	29	50	5.5	4	23.3
25.	December 28, 1984	Krutoberegovo	SSR3	101	153	7.0	6	192.0
26.	–	Kronoki	SSR3-M	120	155	7.0	6	231.0
27.	–	Afrika	SSR3-M	30	30	6.7	7–8	185.8
28.	–	Krutoberegovo	SSR3	66	66	6.7	6	174.4
29.	–	Kronoki	ISO	104	114	5.9	4	55.0
30.	–	Shipunskii	ISO	55	68	5.8	5	46.0
31.	March 6, 1985	Institute	SSR3	158	163	5.8	–	14.0
32.	May 19, 1985	Kronoki	ISO	117	124	5.8	–	58.6
33.	October 6, 1987	Shipunskii	SSR3-M	34	48	6.5	6–7	86.2
34.	March 2, 1992	Kronoki	AS3-2	212	213	6.9	5	42.5
35.	–	Zhupanovo	SSR3-M	150	151	–	4–5	47.1
36.	–	Mayak Petropavlovskii	SSR3-M	101	103	–	–	79.4
37.	–	Petropavlovsk	SSR3-M	105	107	–	5–6	25.1
38.	–	Mishennaya	SSR3-M	108	110	–	–	90.0
39.	–	Berezovaya	AS3-2	129	131	–	5–6	55.6
40.	–	Khodutka	SSR3-M	166	167	–	–	14.6
41.	May 5, 1992	Kronoki	AS3-2	217	219	6.3	4	21.4
42.	–	Shipunskii	SSR3-M	36	48	–	5–6	42.1
43.	–	Mayak Petropavlovskii	SSR3-M	85	90	–	–	68.7
44.	–	Aerological	AS3-2	97	102	–	–	48.7
45.	–	Mishennaya	SSR3-M	92	97	–	–	117.0
46.	–	Berezovaya	AS3-2	114	118	–	–	21.7
47.	–	Khodutka	SSR3-M	153	156	–	–	11.5
48.	June 8, 1993	Aerological	SSR3-M	214	218	7.5	–	32.8
49.	–	Petropavlovsk	SSR3-M	208	211	–	5	29.9
50.	–	Nikol'skaya	SSR3-M	208	211	–	–	40.5
51.	–	Mishennaya	SSR3-M	211	214	–	–	101.6
52.	–	Khodutka	SSR3-M	83	92	–	–	220.8
53.	November 13, 1993	Nikol'skaya	SSR3-M	137	142	7.0	–	108.2
54.	–	Petropavlovsk	SSR3-M	137	142	–	5–6	30.1

tance, g is the ground class, and $F(M_{LH}, \Delta, g)$ is the model dependence relating the peak accelerations to the magnitude, distance, and ground conditions. The empirical relationship obtained for Japan was used:

$$F(M_{jma}, \Delta, g) = \begin{cases} 974.4(10^{0.216M}jma)(\Delta + 30)^{-1.218}, & g = 1 \\ 232.5(10^{0.313M}jma)(\Delta + 30)^{-1.218}, & g = 2. \end{cases} \quad (2)$$

The relation $M_{jma} = M_{jma}(M_{LH})$ was taken from [10]. If the value M_{LH} was unknown, it was estimated from K^{F68} using the relation from the same paper.

The results reduced to $\Delta = 100$ km and the dependence (2) at $g = 1$ (shown as a line) are presented in Fig. 3. The scatter of data about the approximating line (2) is unusually large ($\sigma = 0.6$ log units). In order to analyze the origin of this scatter, the data from the Petropavlovsk and Kronoki stations are shown by special symbols (PET and KRI in the figure). The site conditions at these stations obviously influence the mean level of the recorded peak accelerations. The mean for all stations except Petropavlovsk and Kronoki is about seven times higher than the Petropavlovsk value and twice as high as the Kronoki value. The relative increase in A_{max} at the Kronoki station appears to be related to the resonance effect in the ground beneath the station. This effect is clearly visible: high frequencies with a period of about 0.1–0.2 s abnormally dominate the Kronoki records. This conclusion is confirmed by the Fourier spectral curves of the latter. The visual examination does not reveal any peculiarities in the spectra of the Petropavlovsk records. However, this station has long been known by a relative underestimation of amplitudes [12], assigned to the high strength of the underlying rock mass. Apparently, this is the main (though possibly not single) factor responsible for the amplitude attenuation. The scatter for the rest of the stations is $\sigma = 0.4$ log units, which exceeds the estimates of other authors by 0.1–0.15 log units. The reduced median value of A_{max} at $M_{LH} = 8$ amounts to about 90 Gal, which insignificantly differs from the expected Kawashima estimate for Japan (120 Gal at $M_{jam} = 7.65$ corresponding to $M_{LH} = 8$).

The limited amount of data, their large scatter, and strong differences in station conditions fail to provide the empirical prediction relationship $A_{max}(M, R)$ for Kamchatka.

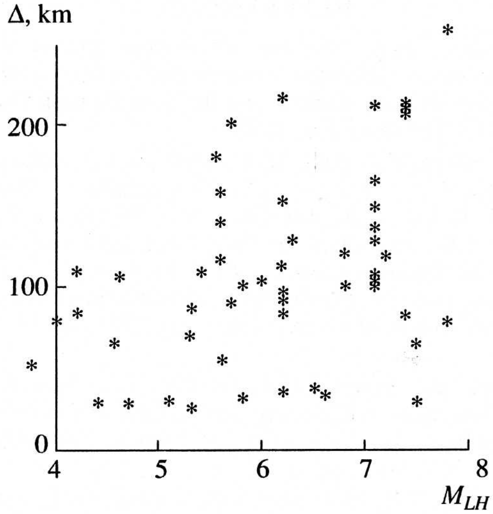

Fig. 2. Distribution of the processed records (see Table 4) over magnitudes and distances.

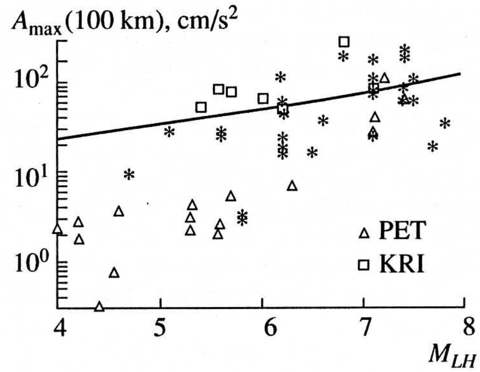

Fig. 3. Peak accelerations reduced to a distance of 100 km. The A_{max} values obtained from the data of the Petropavlovsk (PET) and Kronoki (KRO) stations are shown by individual symbols. The line is function (2) at $\Delta = 100$ km and $g = 1$.

CONCLUSION

The data collected during 30 years of observations of strong motions in Kamchatka, though being limited in volume, provide a basis for the quantification of the seismic risk for the Kamchatka buildings and structures. The importance of such local data is illustrated by the substantial differences (by a factor of about 2) in mean peak accelerations between well-studied regions such as California and Japan.

Our preliminary analysis of peak accelerations suggests two main conclusions.

(1) To a first approximation, the mean level of peak accelerations in Kamchatka (at fixed magnitude and distance) agrees with the values typical of Japan. Hence, some conclusions and estimates, obtained from much more extensive Japanese data, are applicable to the Kamchatka conditions.

(2) The peak acceleration effect of ground conditions is well-pronounced. This effect, also characteristic of Japanese conditions (and considerably less pronounced for the western United States), indicates the hazard of oversimplified estimates of ground effects and emphasizes the relevance of their direct instrumental measurements.

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