REGIONAL VARIATIONS IN THE RUPTURE LENGTH-MAGNITUDE RELATIONSHIPS

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SUMMARY

Regional relationships between earthquake magnitude and rupture length have been determined for different parts of the world, based primarily on aftershock data. It appears that a given rupture corresponds to an earthquake of different magnitude in different regions. The correlation between rupture length and magnitude is high for each region, and the noted scatter in such data for a given rupture is consistent with separation between extremes. This suggests that the scatter in worldwide data may be due to regional differences.

INTRODUCTION

A number of shallow earthquakes in various parts of the world have been found to be accompanied with surface rupture. Several authors have determined approximate correlations between magnitude M and the length of fault break (L). These relationships are of the form $M = A \log L + B$ and are widely used to estimate the maximum magnitude of earthquake that can occur on a particular fault.

Bonilla and Buchanan (1970) found that the maximum value of correlation coefficient for the above equation is less than 0.7 and that, in general, the correlation between magnitude and rupture length is poor. Smith (1976) noted the large range of earthquake magnitudes that can be associated with any given fault rupture and suggested that geological evidence for fault slip be used in estimating the maximum magnitude earthquake on a particular fault. It is, of course, possible that the noted scatter in rupture length-magnitude relationships reflects regional differences. Acharya (1978) suggested that earthquakes of given magnitude are accompanied by larger rupture in the Philippines than indicated by worldwide data. For several earthquakes with magnitude $\geqslant 7.8$, Kelleher et al (1973) noted that rupture zones are much larger in Chile, Alaska - Aleutians, and Kurile - Kamchatka than in Peru, Japan, Middle America, Taiwan, and New Hebrides region. Therefore, regional rupture length-magnitude relationships have been determined for many regions to examine possible differences.

DATA

The rupture length of earthquakes with magnitude > 6.0 has been determined by using the aftershock data. Independent measurements of the length of surface faulting and maximum dimensions of the aftershock zones have been shown to be in good agreement for 1952 Kern County earthquake, 1966 Parkfield earthquake, the 1964 Alaska earthquake, and 1960 earthquake in Chile. Every year more than 100 earthquakes occur with magnitude > 6.0, and the aftershock

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zones of these earthquakes can be determined accurately. Therefore, aftershock zones would provide a larger data base than surface rupture for comparison of regional relationships. In this study, aftershocks during the first 24-48 hours were used for estimation of rupture length. Surface rupture, tsunami records, and coastal deformation studies were also used for estimation of rupture length, when available. If the rupture length of these earthquakes was estimated to be less than about 100 km, then the size of these earthquakes was specified by surface wave magnitude M_S. Kanamori (1977) has suggested that for very large earthquakes (rupture length $\gtrsim$100 km) surface wave magnitude M_S gets saturated and is therefore not a true measure of its size. Therefore, for earthquakes with such large ruptures, new magnitudes determined by Kanamori (1977) were used. We have therefore used a parameter which truly reflects the energy released in an earthquake, and results can be interpreted for all earthquakes with $M_S > 6.0$ regardless of rupture length. Relationships between magnitude and rupture length for different regions were determined by linear regression and are listed in Table 1 and shown in Figure 1.

RESULTS

It is clear from Table 1 that the correlation between magnitude and rupture length is very high for most regions. This is in contrast to the observation of Bonilla and Buchanan (1970) that the correlation is $\approx$0.7. This suggests that in a specific region the correlation is very good and that scatter in such plots on a worldwide basis, resulting in poor correlation, may be related to regional differences. Figure 1 shows large differences in this relationship for different parts of the world. The difference in magnitude between extremes is $\approx$ 1.0 and means that a given rupture results in significantly different release of seismic energy in different regions. Furthermore, the difference in magnitude between two regions is not constant, i.e., is not independent of rupture length. At smaller rupture lengths, earthquake magnitude is higher in western United States and Alaska - Aleutian region than elsewhere. For rupture lengths greater than 100 km, earthquake magnitudes are higher in South America and Kurile - Kamchatka than in Japan, Turkey, and Philippines. Since large ruptures ($>$400 km) have occurred primarily in Alaska - Aleutians, South America, and Kurile - Kamchatka, Figure 1 suggests that earthquakes of magnitude $>$ 8.3 will primarily occur in these areas and that in other areas the maximum magnitude earthquake may be 8.3. As the correlation between rupture length and magnitude in a given region is good and Figure 1 shows regional differences, it is likely that the noted scatter in worldwide data probably arises from regional differences.

SIGNIFICANCE

If a rupture of certain length (which corresponds to a certain release of stress energy) results in different magnitude earthquakes in different areas, it suggests that radiated seismic energy varies. This suggests that seismic efficiency (efficiency of conversion of elastic energy to radiated seismic energy) may vary regionally if the stress drop is constant. Aki (1972) and Kanamori (1977) have shown a remarkably linear relation between log S (aftershock area) and log M_0 (seismic moment) and interpreted it in terms of constant average stress drop in earthquakes. Therefore, regional differences in rupture length-magnitude relationships can be interpreted as arising from regional variation in seismic efficiency. Figure 1 also suggests that seismic efficiency is dependent on rupture length or magnitude. Thatcher and Hanks (1973) deduced a wide variation in stress drop in Southern California, and therefore some regional difference may be due to deviation from the model of constant stress drop. This investigation suggests that one should not use worldwide data to predict maximum magnitude earthquake in a particular region. For engineering purposes, the use of mean magnitude in magnitude rupture length relationship should be sufficient, despite scatter in such data, since there is considerable evidence that beyond certain earthquake mamnitude, peak ground acceleration does not depend on magnitude. However, the size of the earthquake does determine the distance beyond which far-field approximation can be made for prediction of ground motion. Therefore, the scatter in rupture length-magnitude data should be utilized to conservatively estimate distance beyond which far-field approximation is valid.

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TABLE 1

PARAMETERS OF MAGNITUDE-RUPTURE LENGTH RELATIONSHIPS

$$M = A \text{ Log } L + B$$

REGION	A	B	CORR COEFF	S.D. (L)	S.D. (M)	NO. OF OBSERVATIONS
Philippines	1.79	3.5	0.9	0.3	0.6	16
Japan	1.25	4.86	0.81	0.3	0.5	33
Kurile - Kamchatka	2.84	1.51	0.94	0.3	0.8	20
Alaska - Aleutians	1.34	4.49	0.8	0.5	0.9	22
South America	2.54	2.47	0.8	0.3	0.9	31
Turkey	0.92	5.33	0.83	0.4	0.4	11
Western U.S.	1.17	5.2	0.87	0.5	0.6	16

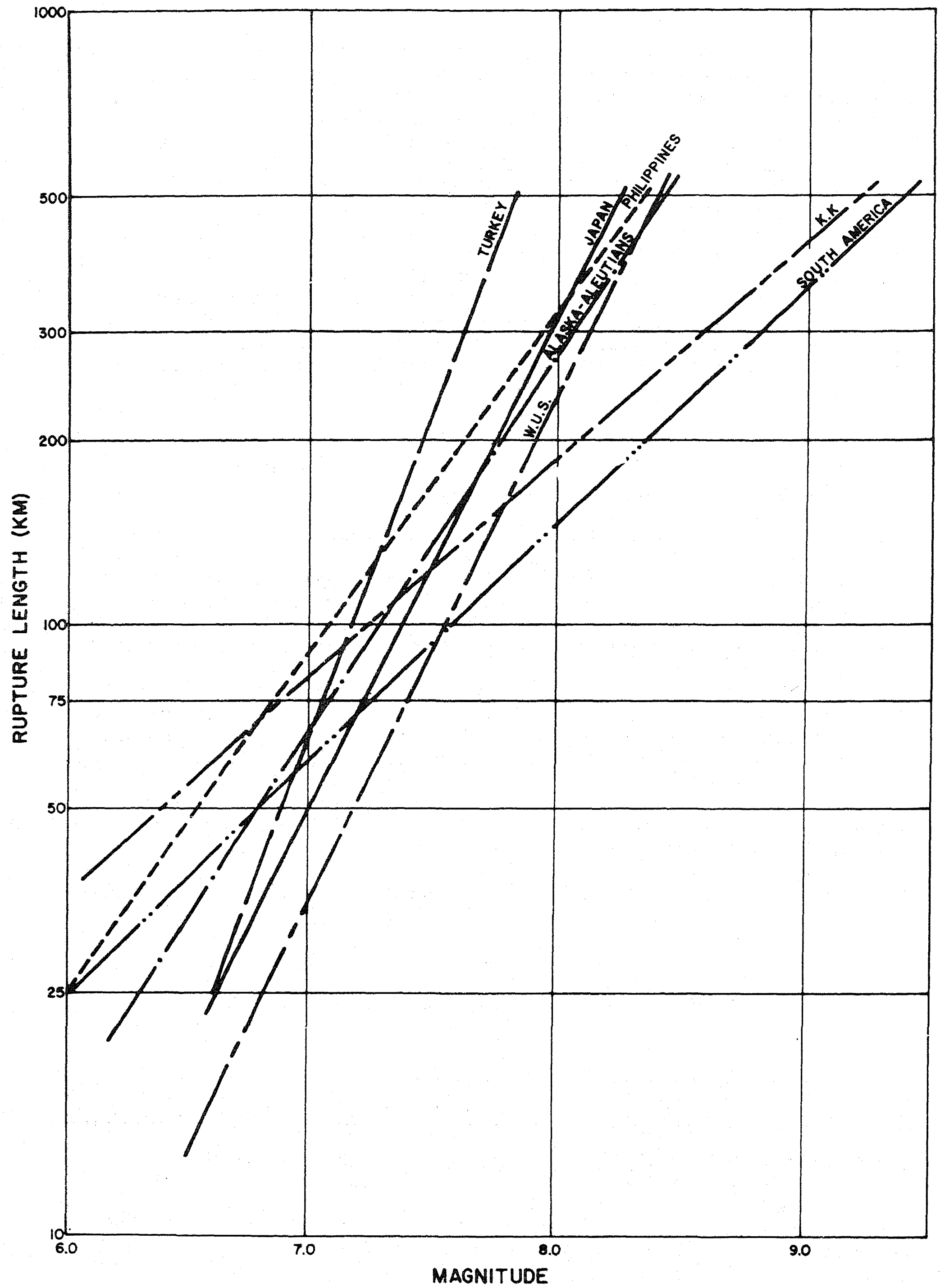

FIGURE 1 - REGIONAL VARIATION OF RUPTURE LENGTH-MAGNITUDE RELATIONSHIP