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Estimated strong ground motions during the Spitak, Armenia earthquake of December 7th, 1988

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ABSTRACT: The damage of the Spitak, Armenia, Earthquake of Dec. 7, 1988 were discussed on the view point of earthquake engineering. However, it is not so clear on the intensity of strong ground motions of disastered area, because of strong motion seismometer is not sufficient in these area. Author obtained only one strong motion record, which was obtained in Gukasyan station, northern part of Armenia, and some information of Yerevan. Then author performed the estimation of the intensity of strong ground motions of individual city and town, with regard to the fault rupture and subsoil conditions of disastered cities and towns. The results of estimated intensity of several cities showed good agreements against the observed MSK seismic intensity. And it was confirmed, that the used method of estimation is applicable for those cases.

INTRODUCTION

The Spitak, Armenia, Earthquake occured in December 7th, 1988, the Richiter Magnitude is M=7.0. And northern part of Armenia suffered severe damage by the Earthquake. Especially, Spitak, Leninakan (name of City changed to Kumairi), Kirovakan, and Stepanavan suffered most severe damage, See Figure 1.

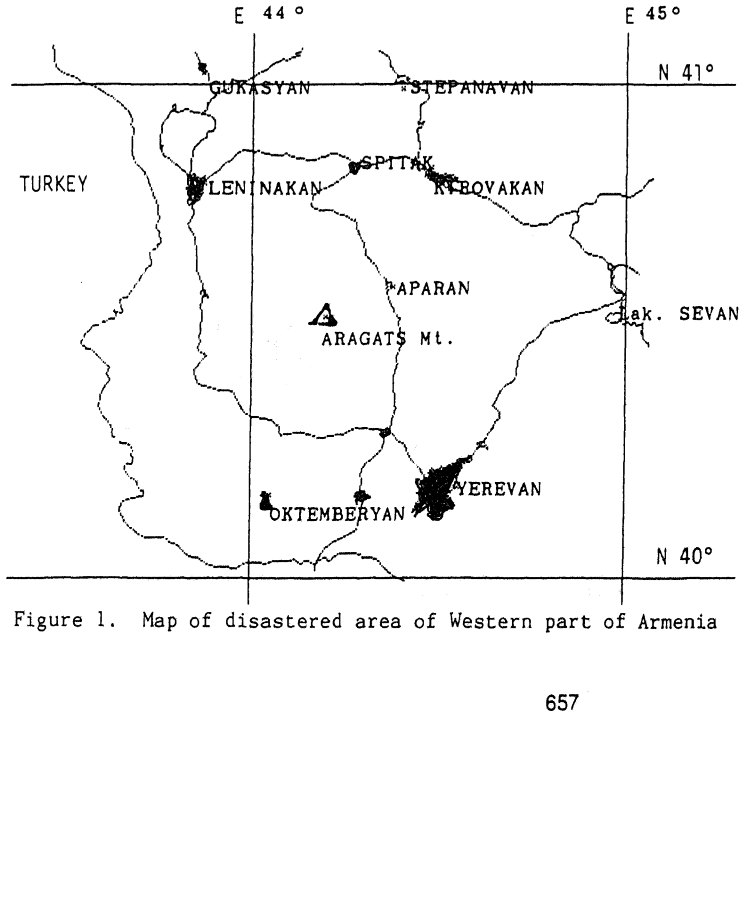

Figure 1. Map of disastered area of Western part of Armenia

Prefabricated reinforced concrete sturectures of apartment houses which are 9 storied or 5 storied sturcture, suffered most severe damage. Spitak is laid just on the source zone of earthquake, Kirovakan have 20km epicental distance and Leninakan have 30km epicentral distance. But the damage of Leninakan exceed the damage of Kirovakan. And this problem were discussed with the Sciences Academy of Armenia.

Author and S.Midorikawa reported the method for the estimation of near-field ground surface seismic intensity of the earthquake, with regard to fault rupture and subsoil conditions. (S.Midorikawa & H.Kobayashi 1980) (Kobayashi,H. & S.Midorikawa 1982) This method has been confirmed that is applicable for the case of interplate earthquake occured in the region of near Japan. For the field work of the survey on the damage due to the Spitak, Armenia Earthquake of December 7th, 1988, author applied this method to the estimation of strong ground motions of the disastered area of northern part of Armenia.

1. MECHANISM OF EARTHQUAKE

The Seismological Institute of

Sciences Academy of Armenia, as shown in Figure 2, decided the mechanism of the Earthquake. According to this data, the mechanism of the earthquake is dip fault associated right lateral strike slip, dip angle is 60 degree and strike direction is N 60 W.

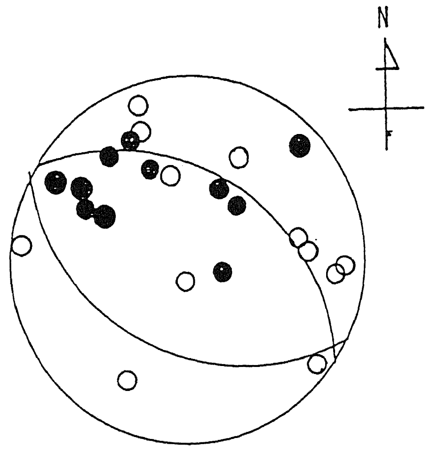

Figure 2. Mechanism of the Spitak Earthquake of 1988 (by Observatoty of Yerevan, Academy of Armenia)

2. DISTRIBUTION OF THE AFTERSHOCKS

Also the Seismological Institute measured aftershocks. In Figure 3, the Institute showed the distribution of epicenter of aftershocks, which occured during December 7th 1988 to January 15th 1989. Usually distribution of aftershocks during one day just after the main shock showed the area of source area of earthquake. So author make a map of distribution of aftershocks during one day as shown in Figure 4. Using this figure, author assumed length of fault is 35km and width of fault is 12km.

3. TRACE OF THE FAULT

Surface fault appeared at southwest of Spitak. From field survey of surface fault, dislocation of the fault is assumed as D=1.5m (mean value). So the seismic momemt of the earthquake assumed as log(Mo)=26.4 dyne.cm and magnitude of the earthquake is about M=7.0.

4. GEOLOGICAL CONDITION OF DISASTERED AREA

The Geological Research Institute of Armenian Academy performed the survey and pablished the geological map (Scale 1/600,000) (Institute of Geology 1971). Figure 5 is outline of the geological map of western part of Armenia. Author decided the amplification factor of soil structure of individual city referring the geological map. The relation between the classification of surface geology and the amplification factor of acceleration was shown in Table 1. Amplification factor is the ratio of peak ground acceleration versus acceleration of incident seismic waves at seismic bedrock.

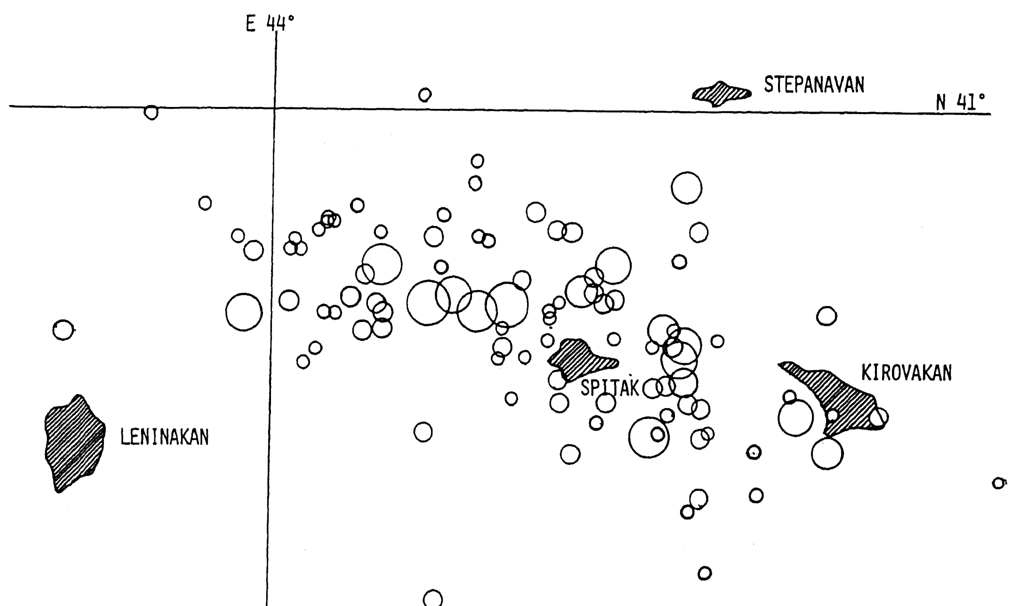

Figure 3. Epicenters of aftershocks Dec.7 1988 - Jan.15 1989 (by Observatory of Yerevan Academy of Armenia)

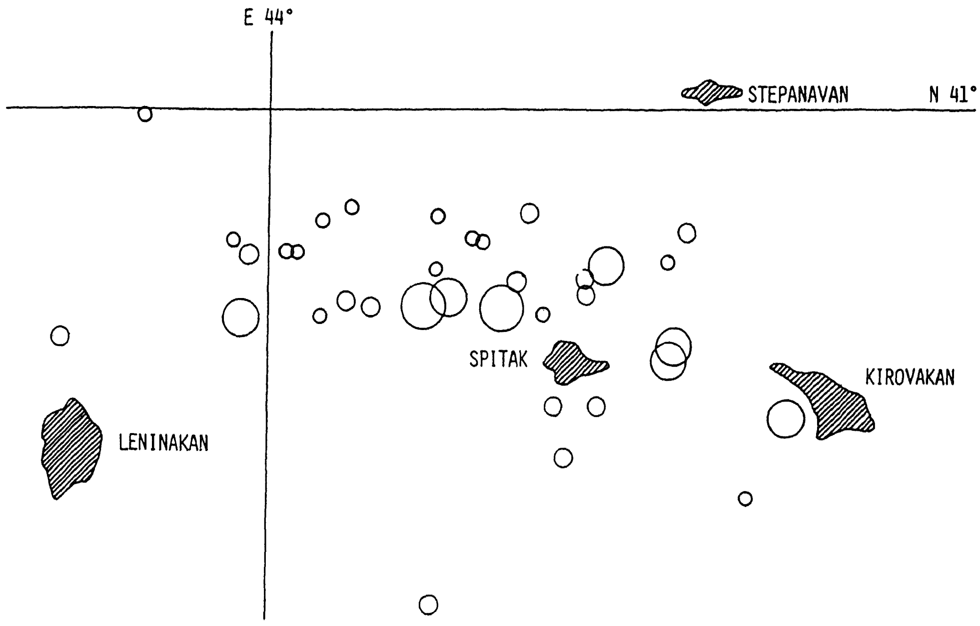

Figure 4. Epicenters of aftershocks Dec.7 1988

Table 1. Amplification factor of ground

Geological condition		Amplification factor
Thick sediment	Q	4.5
Hard sediment	Q	3.5
Tertiary period	N	2.5
Paleogene period	PN	2.0

5. ESTIMATION OF INTENSITIES OF DISASTERED AREA

5.1 Earthquake parameters

As metioned above, earthquake parameters decided as shown in Table 2.

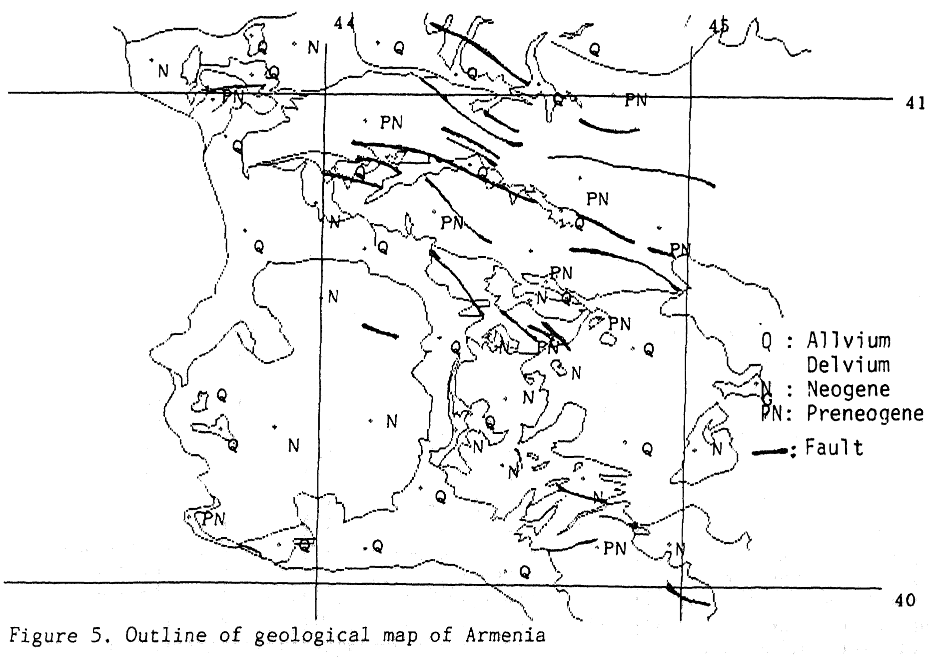

Figure 5. Outline of geological map of Armenia

Table 2. Estimated earthquake parameters

Magnitude		Ms	7.0
Seismic moment		log(Mo)	26.4 dyne.cm
Fault	Length	L	35 km
	Width	W	12 km
	Dislocation	D	1.5 m
	Dip angle		60 degree
	Strike direction		N 60 W
Ruptur velocity		Vr	2.5 km/sec
Location of fault			as shown in Figure 6

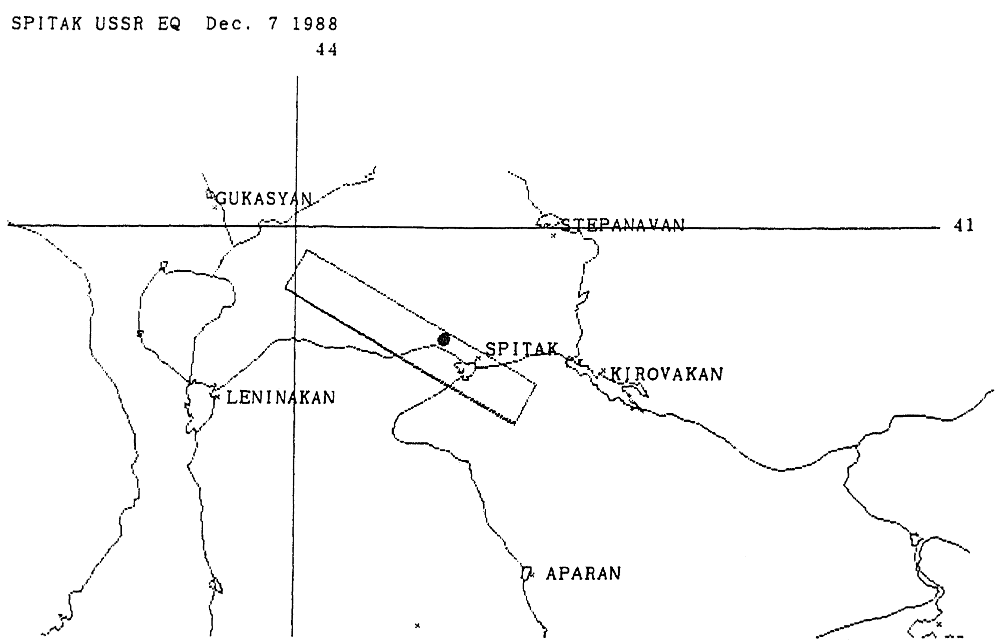

Figure 6. Assumed sourec region
Rectangle is assumed fault and full circle is epicenter

5.2 Estimated intensities of disastered area

With regard to the fault rupture, author divided the fault plain to small elements, which have a point source individually, and using the moving point source method and empirical formula of his attenuation of seismic waves, he calculated the response spectra of bedrock. (Kobayashi,H. & S.Nagahashi 1977)(Midorikawa,S & H.Kobayashi 1980) The acceleration of ground surface were calculated using the amplification factor showed in Table 1.

Estimated ground accelerations were shown in Table 3 and Figure 7. Author obtained strong motion accelerogram which was recorded at Gukasyan Station, in Figure 8, strong motion accelerogram was shown. Maximum acceleration value is almost same to the calculated value. Also he get an information of observation at Yerevan, maximum acceleration is about 60gal, this also correspond to the result.

Table 3. Maximum acceleration and MSK intensity at individual city

City	Maximum Acceleration gal	Seismic Intensity MSK	Remarks
Spitak 1	> 600	10	Deposit
Leninakan 1	530	10	Northern area
Spitak 2	520	10	Hard rock
Leninakan 2	470	9	Southern area
Stepanavan	460	9	
Aparan	370	9	
Kirovakan 2	360	9	Deposit
Kirovakan 1	250	8	Central area
Gukasyan	> 228	8	Unidentified
Yerevan	65	6	

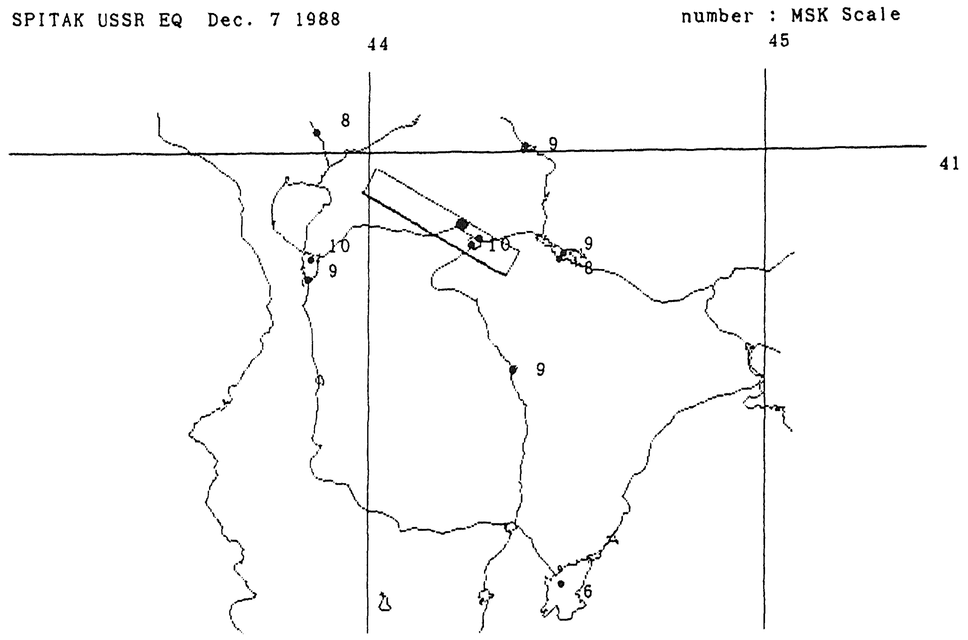

Figure 7. Distribution of MSK intensity

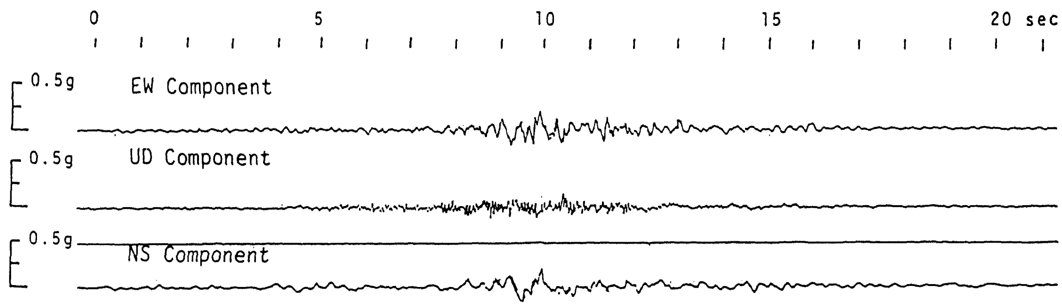

Figure 8. Strong motion accelerogram Gukasyan

CONCLUSIONS

The conclusions are following;

1. The results are fitting to the few seismological observations of Gukasyan and Yerevan.
2. The estimated results shows good agreements to the MSK intensities which measured in field works by Armenian investigators.
3. Leninakan was suffered very severe damage, but Kirovakan was not so severe. Epicentral distances are Leninakan is about 30 km and Kirovakan is about 20 km. These problems can be explained by the near field problem using the moving point source and under the consideration of surface giological effects.

These results were possible to get at the field, using the data of aftershocks and geological maps only. So the accuracy is not sufficient, because decision of fault parameters are tentative. However, such quick estimation also important for the decision making for reconstruction of disastered area.

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