THE DEVELOPMENT OF ATTENUATION RELATIONS IN THE ROCK SITES FOR PERIODS (T=0.04～10s, ξ =0.05) BASED ON NGA DATABASE

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ABSTRACT :

By the geotechnical criterion of Vs30⩾500m/s, 260 horizontal recordings are selected from the NGA (next generation attenuation) database, and the new attenuation relations about the moment magnitude and epicentral distance are obtained by regression analysis. The predictions fit better to the observations and generally agree with the newest researches of NGA（Boore & Atkinson，Chiou & Youngs，Compbell & Bozorgnia，2006；Idriss，2007). It is demonstrated by comparison that in the old attenuation relationships exist the following shortcomings: 1 In the PGA (peak ground motion acceleration) attenuation relationships with distance, the prediction with M = 5 is lower, which is prone to unsafe, the prediction with M = 8 is higher, which prone to conservative, and the prediction with M = 6 or 7 is higher near the source but lower far from the source. 2 In the attenuation relationships of response spectra, the weak-and-moderate-earthquake response spectra might be under-evaluated for short periods near the source and for the whole period range far from the source, while the large-earthquake response spectra might be over-evaluated in the short-period range near the source and under-evaluated far from the source.

KEYWORDS: attenuation relationship, NGA (Next Generation Attenuation) database, type Ⅱ model

1. CURRENT ATTENUATION RELATIONS IN ROCK SITES

Due to the lack of strong ground motion recordings, attenuation relations in China mainland can not be gained directly from the scattered recordings, therefore, the attenuation relations related to the ground motion parameters are often corrected and transformed from the attenuation relations of California in the United States of America (Huo Junrong,1989; Yu Yanxiang,2002; Shi Shuzhong,2004). In general, once the strong motion recordings from rock sites are collected, the sketchy geological description is usually used as the criterion because of the absence of shearing velocity in China. However, as we know that it is more accurate to use geophysical parameters from Vs30≥500m/s as the criterion. Fortunately, such kinds of the parameters could be obtained from the recordings of NGA (next generation attenuation) database, therefore, the criterion could be more accurate if these recordings are used in statistic analysis.

In fact, no matter what statistical model and source model have been used in the development of attenuation relations, all attenuation relations need to be improved by using new seismic data. From our knowledge, in NGA database, the old recordings were corrected and renewed, moreover, a great deal of new digital recordings is added in instantly. These recordings have given us such a good foundation for the statistical analysis that the rationality of our current attenuation relations can be validated. In this study, using these recordings, four attenuation models were studied for a comparison purpose. The models are labeled as: 1. BA (Boore & Atkinson, 2006, T=0.05～5s), 2. CY (Chiou & Youngs, 2006, T=0.01～10s), 3. CB (Compbell & Bozorgnia, 2006, T=0.01～10s), and 4. Idriss (Idriss, 2007, T=0.01～3s), respectively. The parameters in these models also include fault type, directivity effect, hanging-wall effect, and basin effect, respectively, in addition to the earthquake magnitude and distance. By comparison and contrast, a lot of useful information could be extracted from these models if the earthquake magnitude, distance, earthquake epicenter, and Vs30 were given. Furthermore, if we apply these solutions in the mainland China, many specific conditions must be taken into account, such as the different backgrounds of the geological structure. In addition, fault parameters and site conditions have to be known in detail. In our study, the new derived active fault data have been used in the development of attenuation model. Based on the NGA database, the new strong ground motion recordings are re-classified, and the attenuation relation is derived with a adopting of China Ⅱmodel. The major difference could be get through detailed comparison and contrast between the new attenuation relation and others which include previous published national or international models.

2. METHOD

2.1.Database

Since most of strong motion data come from the moderate earthquake within a range of moderate distance, therefore, the distributions of data samples could be uneven, which may lead to the instability in statistic regression. In order to solve the problem we have mentioned above, Huo's weighted method has been used in this study, and the two aspects related to the earthquake magnitude and epicenter distance are weighted separately (Huo, 1989).

Table 1 Distributions of recordings according to M and R

R(km) / M	0-2.9	3-9.9	10-29.9	30-59.9	60-99.9	100-200	>200
≤5.0	2	2	8	10	12	2	0
5.0-5.4	0	6	26	0	6	0	0
5.5-5.9	0	6	6	2	0	0	0
6.0-6.4	0	2	6	18	6	0	0
6.5-6.9	0	0	28	32	46	8	0
7.0-7.5	0	0	0	4	10	10	2

The data illustrated in Table 1 includes 130 stations and 260 recordings, respectively. All recordings are divided into six subsets according to their magnitude, i.e., M≤5.0, and M=5.0-5.4, 5.5-5.9, 6.0-6.4, 6.5-6.9, 7.0-7.5, and seven subsets according to their epicenter distance, i.e., R=0-2.9km, 3-9.9km, 10-29.9km, 30-59.9km, 60-99.9km, 100-200km, and R>200km.
The same weight function is endowed in each section and each recording in the section has the same weight function so that the weight coefficients distribute evenly on the (M, R) plane. Total of weight coefficients is equal to total of samples, and statistic freedom degree un-change through standardization in the end.

2.2. Attenuation relationship model

The generalized attenuation relation model is described as:

$$\lg Sa = C_1 + C_2M + C_3M^2 + C_4\lg[R + C_5\exp(C_6M)] \qquad (2.1)$$

The related attenuation model is type II, $C_3=0$ but $C_6\neq0$.The advantage of using type II model is that the type II not only has a simple form but also can reflect magnitude saturation. In fact, the model can also be used in the earthquake engineering application in which the data is absent. A single random variable method is used in the regression analysis in which the variable is lgSa and the coefficients of C_1、C_2、C_4、C_5 and C_6 are determined by using least root means square method.

2.3. C5 and C6 Determination

The near field saturation coefficient of R0(M), namely $C_5\exp(C_6M)$, must be determined in order to divide magnitude and distance before attenuation relationship is regressed.
Firstly, we consider six earthquakes which include Imperial Valley-06 (1979, M6.53), Livermore-02 (1980, M5.42). Loma Prieta (1989, M6.93), Landers (1992, M7.28), Hector Mine (1999, M7.13), and Parkfield (2004, M5.9). With a combination of Landers and Hector Mine earthquakes, five sub-group data can be

regressed, separately. Then, through a selection of other five sub-group data from Huo's seven groups, we determine the single magnitude R_0. Here, the mean of ten group data corresponds to R0 and M, respectively.

Secondly, through a regression analysis of ten group data, we can determine C_5 and C_6 , respectively, which is shown in fig.1. The resultant C_5 and C_6 are 1.15848 and 0.4311, respectively.

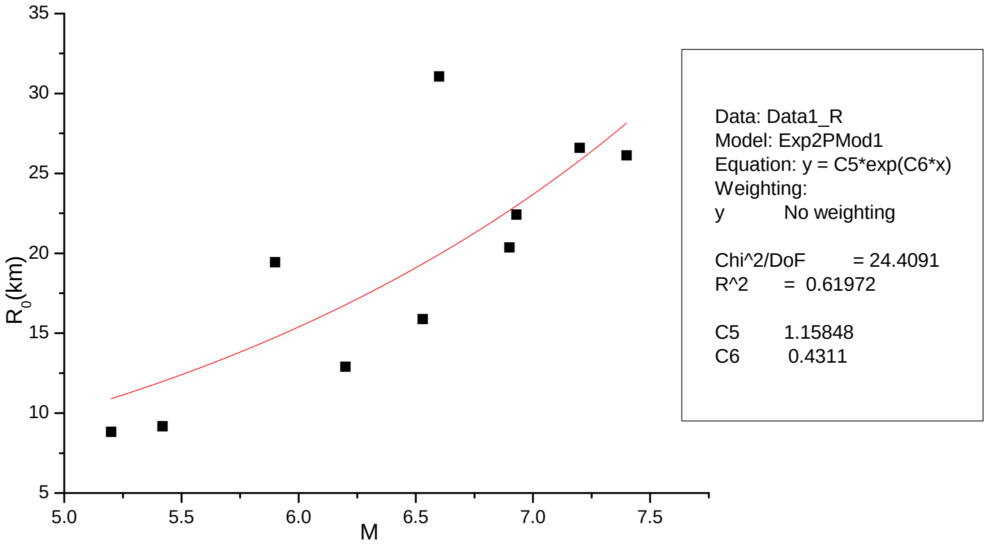


Fig.1 Ten group data are used in the regression analysis in order to determine coefficients of C_5 and C_6, respectively

2.4. Attenuation Relation

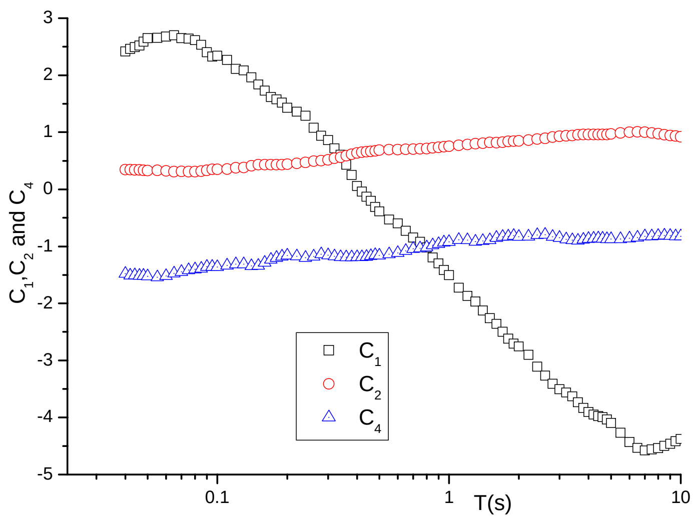


Fig.2 C_1、 C_2 and C_4 along with periods from 0.04s to 10s

Regressed coefficients: In figure 2, coefficient of C_1 varies with period, which reflects the value of response spectra could be large or small depending on the period. C_2 gets the maximum value at period of 0.04s and decreases along with the increase of period of T. In addition, C_2 reaches the minimum at period of T=7s and increase again after period of T=7s. C_2 reflects that the whole spectra values are controlled by the earthquake magnitude, the value of C_2 has a small increase from period of T=0.04s to T=10s. The coefficient of C_4 reflects that the whole spectra values attenuate along with distance from the near source point to the far field, behaving a small increase with the increase of period from T=0.04s to 10s.

3. COMPARISON OF HORIZONTAL PGA ON THE ROCK SITE

Comparing with NGA attenuation model and previous attenuation model developed by Yu and Huo for China, our result show that there is clear difference with Yu and Huo results and is almost the same with NGA results. The comparison results are shown in Figure 3 and 4, respectively. In figure 3: 1.The PGA value decreases slowly than that from Yu and Huo.. 2. The PGA value with magnitude of Ms=5 is higher than that of Yu and Huo.. 3. The PGA value with magnitude of Ms=6 are smaller than that of Yu and Huo at a distance of R⩽10km and larger with a distance of 10 ~ 200 km. 4. The PGA value with magnitude of Ms=7 is smaller that that of Yu and Huo with distance of R⩽40 km and larger with a distance between 40 ~ 200 km. 5. The PGA value with magnitude of Ms=8 is smaller than that of Yu and Huo.
This comparison results from figure 3 and 4 also implies that, for small to moderate earthquakes (Ms⩽5), the predicted PGA value may be underestimated from Yu and Huo, and for large earthquake (Ms⩾7), the predicted PGA value may be overestimated.

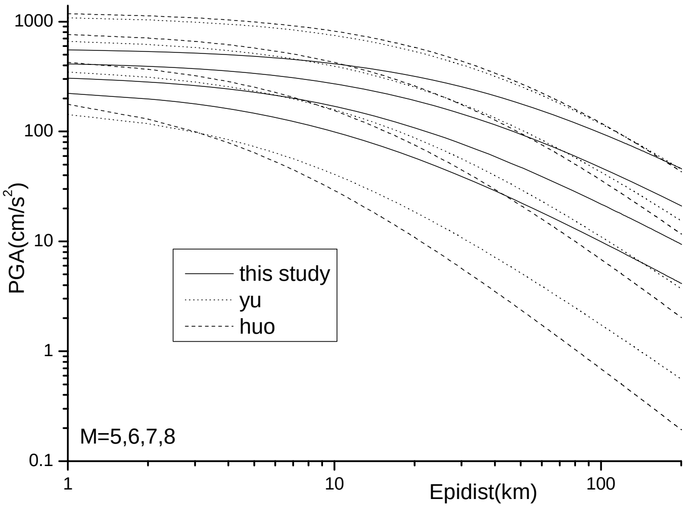
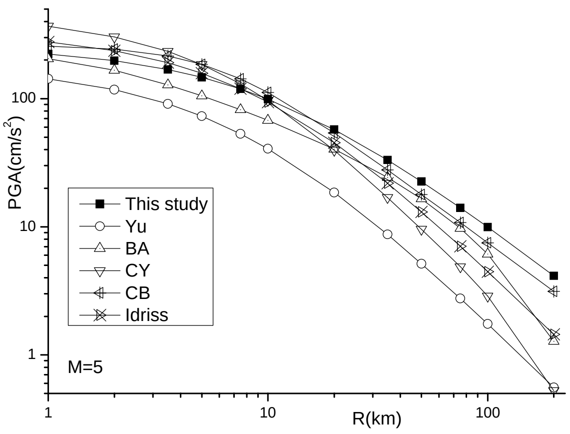
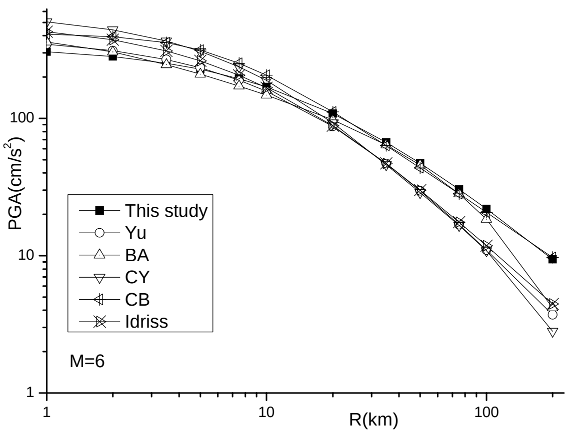


Fig.3 A comparison of horizontal PGA on rock site: For a comparison purpose, Yu and Huo attenuation models are included in this study





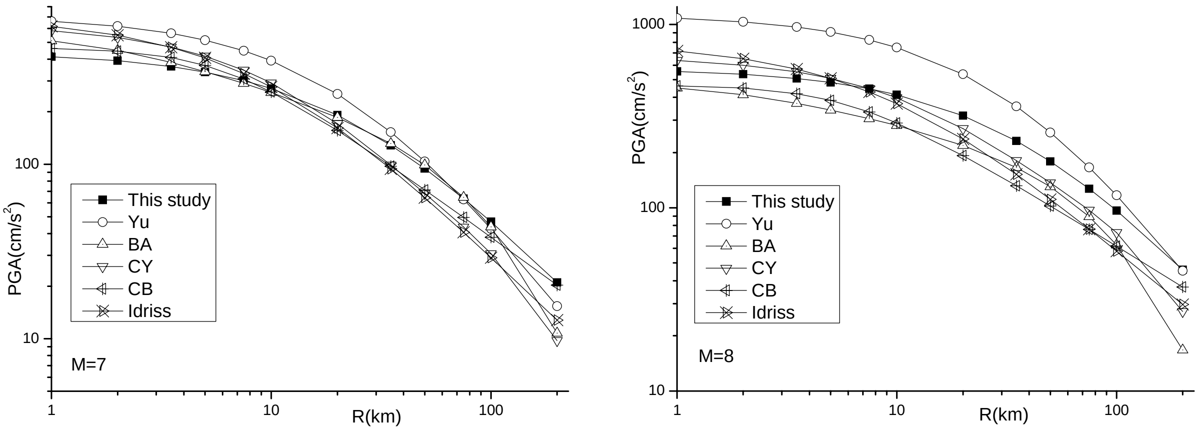
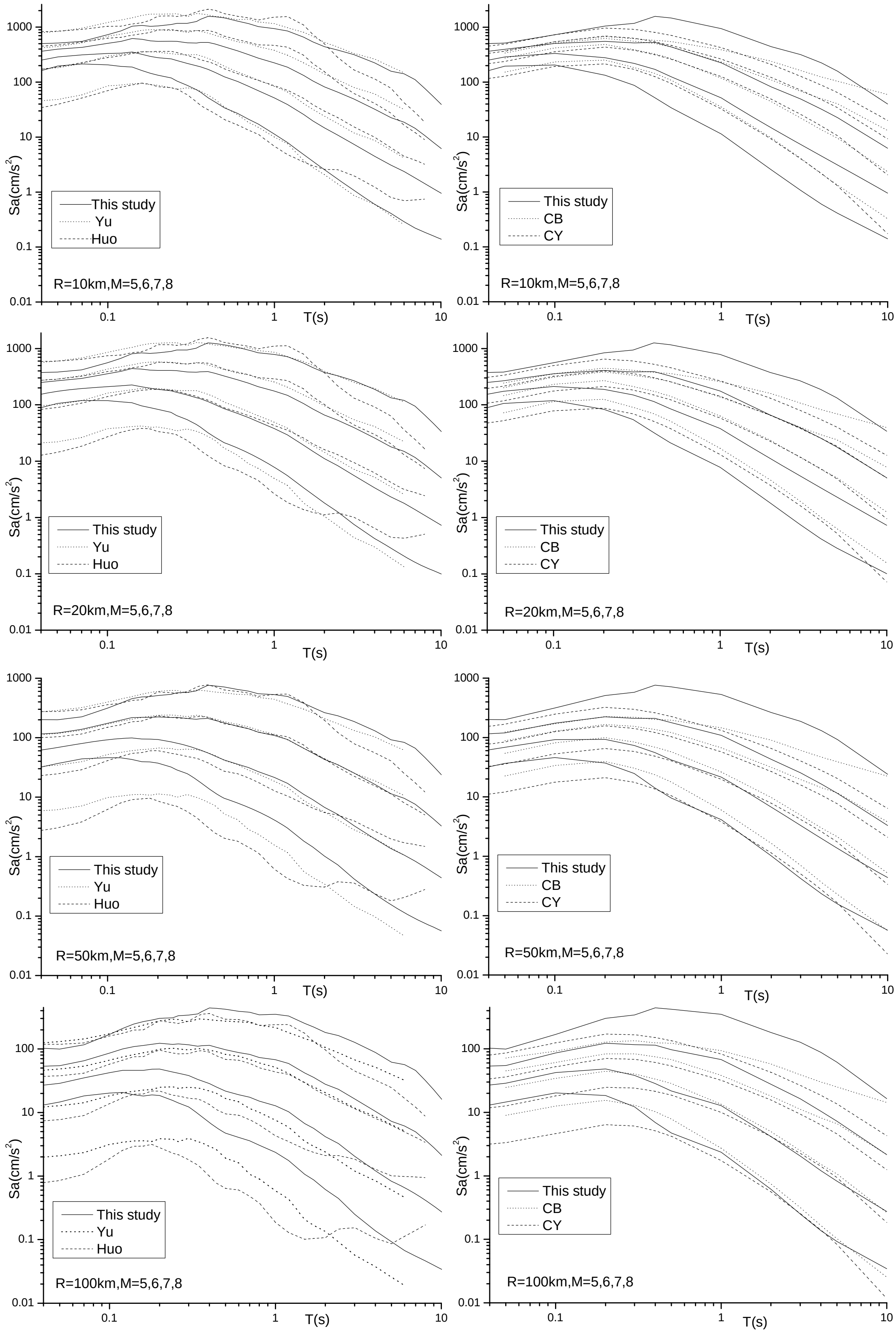


Fig.4 Horizontal PGA variations on rock site with different attenuation models: Six different attenuation models are used in this comparison, which include new developed model in this study given by the thick line with solid square.

4. COMPARISON OF HORIZONTAL RESPONSE SPECTRA ON THE ROCK SITE

In addition, we also have made a comparison of response spectra derived in this study with others, and the results are illustrated in figure 5. In the left panel of figure 5, a comparison is made about response spectral derived from this study with the results from Yu and Huo. From the figure we can see that, in the short period range, the response spectra in our study (Ms=5, 6) are much higher than that resultant from Yu and Huo, and the value of the response spectra in our study (Ms=7, 8) are lower in the near field and a lit bitter higher than that of Yu and Huo in the far field. In long period range, the value of response spectra in our study (Ms=5) are almost the same with Yu and Huo in the near field but higher than that of Yu and Huo in the far field, the value of response spectra in our study (Ms=6, 7) are the same with Yu and Huo in the near field but a lit bitter higher than that from Yu and Huo in the far field. The value of the response spectra in this study (Ms=8) are consistent with Yu and Huo in the near field but a lit biter higher than that derived from Yu and Huo in the far field. The results inferred from figure 5 also imply that, for small to moderate earthquake, Yu and Huo attenuation models may overestimate the spectra value in the far field with short period, and for large earthquake, Yu and Huo models could underestimate the spectral value within a short period range in the near field and overestimate the spectral value within a long period in the far field.

In the right panel of Fig.5, We have made a comparison of response spectra variation pattern derived in this study with NGA attenuation model. These results indicate that, comparing with CY spectra, the spectra value (Ms=8) in the far field is higher within the long period range, and the spectra value (Ms=5) is higher within a short period range. Comparing with CB and CY with magnitudes of Ms=5, 6, 7, and 8, the spectra values in short periods are almost the same or have a lit bitter difference. The small differences could come from the following reasons: 1 The predicted spectral value in this study with a magnitude of Ms=8 is resulted from an extrapolation only. 2 In current attenuation model, some parameter definition and strong recordings we have used exist some differences from CB and CY. Therefore, the different results with a comparison with CB and CY could be existed in anyway. In general, our result is agreement with that derived from NGA. At the same time, our study also demonstrates that the II-Type model usually used in China has its definite rationality on the development of next generation attenuation model.


Sa(cm/s²)
T(s)
This study
Yu
Huo
R=10km,M=5,6,7,8
This study
CB
CY
R=10km,M=5,6,7,8
This study
Yu
Huo
R=20km,M=5,6,7,8
This study
CB
CY
R=20km,M=5,6,7,8
This study
Yu
Huo
R=50km,M=5,6,7,8
This study
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CY
R=50km,M=5,6,7,8
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R=100km,M=5,6,7,8

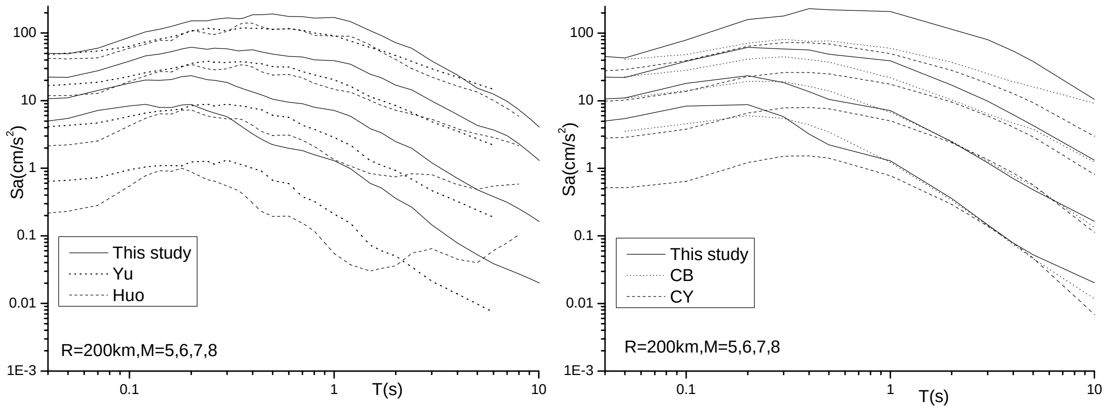

Fig 5 Comparison of attenuation relationship for plane direction response spectra on rock site.

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