THE USEFUL METHOD OF PREDICTING SEISMIC GROUND SEVERITY FOR SUBDUCTION ZONES

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SUMMARY

In this study, in order to make an easy and accurate method of estimation for the seismic intensity distributions, considering from subsurface to deep, we analyzed the detailed seismic intensity distributions of six damaging earthquakes occurred around Hokkaido, northern Japan. These data were results of questionnaire seismic intensity surveys and more precise than seismic intensity in JMA. Considering to wave propagation effect on subduction, we used two-layered simple model, calculated the lengths of paths, and understood clearly the attenuation of seismic intensity that had been discussed qualitatively. By this analysis, it made clear that the path effects of low-Q and high-Q zones were separated from the seismic intensity distributions for subduction zones. Consequently we constituted the useful and simple method predicting seismic intensity distribution with high accuracy. This method will be able to estimate seismic ground severity promptly. Accordingly it will be applicable to grasping accurate damage distribution immediately after earthquakes.

INTRODUCTION

Large and destructive earthquakes occur frequently in subduction zones all over the world. Simply and precisely predicting the distribution of ground motion severity by the earthquakes is a key to relief the inhabitants exposed to the above danger. With the aim of simplicity many experimental attenuation relationships for estimation of ground motion severity have been developed by means of regression analysis (e.g., Joyner and Boore, 1981; Fukushima and Tanaka, 1990). However these relations are inadequate to precisely estimate ground motions, because it is incapable of considering the complex Q-value structure in subduction zones, which affects the ground motion severity by using the proposed attenuation relationships.

At the direction to a precise estimation approach, 3-D attenuation structures beneath the Japanese islands have been developed using tomographic inversion method for simulation of intensity distribution (Nakamura et al., 1994). Nevertheless this method has a problem with difficulty requiring a large number of ground motion data and long computations.

In order to solve problems included in each approach we proposed useful method of estimation for the distributions of ground motion severity represented in seismic intensity. It is more accurate than the attenuation relationships, without the necessity of a large amount of ground motion data and long computations.

METHODS

We firstly discussed the scatter of attenuation of intensity distributions, using data by our seismic intensity surveys. With considering seismic wave propagation effects by subduction beneath the Hokkaido area, we used two-layered simple model, and calculated the lengths of seismic ray's paths. We considered the plate as high-Q zone and the layer of medium over the plate as low-Q zone. The attenuation relationships were developed by

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regression analysis on lengths of both zones. Finally, discussing the difference between the seismic intensity estimated by this study and observed, we got the additional terms on surface geological conditions at observation points.

DATA

In Hokkaido, the high-density seismic intensity investigation had been carried out for all damage earthquakes after the development of questionnaire seismic intensity research method (Ohta et al., 1979). The accuracy of this obtained intensity is about ten times as high as JMA (Japan Meteorological Agency) seismic intensity. Rounding to the nearest whole number, thus estimated intensity values correspond to that of JMA. In addition, the advantages of high-density survey and broad expanse of investigation field are more conspicuous for questionnaire method. From them, it is the suitable data for the discussion of the seismic intensity distribution property as a purpose of this study in the Hokkaido whole area. Six damage earthquakes to which a detailed seismic intensity was obtained by the whole area of Hokkaido (Kagami et. al., 1996) were targeted in the analysis (Fig.1).

CHARACTERISTICS OF SEISMIC INTENSITY DISTRIBUTION IN HOKKAIDO AREA

In view of deep tectonics

By the complicated tectonics, seismic intensity distribution generally observed in the Hokkaido region is not simple. It is necessary to grasp the positional relation of plate subduction property and seismic activity occurrence mechanism, hypocenter in order to understand seismic intensity distribution property of the Hokkaido region. In the Hokkaido region, Pacific plate has sink under Eurasian plate, while it changes the direction near Oshima Peninsula from each Kuril ocean trench and Japan Trench (Fig.1)(Umino et al., 1984). The seismic activity occurrence mechanism is also different by some patterns such as inland shallow earthquake, deep intraplate earthquake, shallow interplate earthquake and earthquake in the Sea of Japan side.

In view of site effect

The relation between seismic intensity and epicentral distance on the Hidaka-hokubu and Kushiro-oki earthquake was shown in Fig.2 with empirical attenuation relation of Kawasumi (Kawasumi, 1954). Seismic intensity was greatly variable in the equal epicentral distance. That is, it is impossible to think all the differences between the Kawasumi’s empirical attenuation relations and the observed seismic intensity to be an effect of the site.

The site effects on seismic intensity as an example of the Hidaka-hokubu earthquake and the Kushiro-oki earthquake was examined. Classification by area of observation point belonged to for southern part of Hokkaido district (South), northern part (North), and eastern part (East) is done so that the path effects move it (Fig.3). Fig.4 shows the relationship between seismic intensity and epicentral distance and mean value in each area. The dispersion from the average was also small on the each area. The seismic intensity difference is under 1.0, and it is the site effects that Okada and Kagami (1987) indicate. And, there are 2.0-3.0 seismic intensity differences between regions, and this seems to be the path effects.

ANALYSIS

Characterization of wave propagation effect

The seismic wave path follows the velocity structure on the basis of the Snell’s low. The velocity structure was made using Umino et al., (1984) as 2 layers, and they were Pacific plate of high-Q, high-V and upper mantle of low-Q, low-V. For instance, on Hidaka-hokubu earthquake, the seismic wave paths were obtained in A-A' and B-B' cross section of Fig.1. Hypocentral distance, path length of low-Q and path length of high-Q were calculated on each observation points (Fig.5).

Path length of the 2 layer model and hypocentral distance of were not so different in the B-B ' cross section. In the meantime, in A-A' cross section of which the plate gradient is small, the path length of low-Q is short, and it of high-Q is long. From them, it was proven to be the path effects that the South and the East region became high seismic intensity and the North became low seismic intensity at the same hypocentral distance (Fig.3).

HIGH PRECISE EVALUATION OF SEISMIC INTENSITY DISTRIBUTION

We analyzed the seismic intensity by using following expressions.

(A) $I=A-BX$ where, I is the seismic intensity, X is the hypocentral distance.

(B) $I=A-BX_1-CX_2$ where, I is the seismic intensity, X_1, X_2 are length of each layer.

Next, regression analysis was carried out at Hidaka-hokubu, Kushiro-oki earthquakes data. Fig.6 shows the relationship between prediction seismic intensity got by the regression analysis and observation seismic intensity. On both earthquakes, the difference of predicted value and observed value decreased, and it was clear that the accuracy of the prediction is improved. That is to say, the path effects on the seismic intensity could be evaluated.

It seems that the site effects is main factor on the difference of observed value left further and predictive value. Each observation point was classified using geological map, and the relationship between the seismic intensity differences was shown (Fig.7). The amplification in generally indicated soft soil was well evaluated. In making the mean value to be the compensation constant in the each every surface geology, further the prediction seismic intensity is corrected.

This method showed that the accuracy was improved from the Kawasumi empirical attenuation relations (Fig.8). By the above, it became possible that the site effect were discussed in the wide region by separating the path effects.

CONCLUSIONS

By this analysis it made clear that the path effects of low-Q and high-Q zones were separated from the seismic intensity distributions for subduction zones. Consequently we constituted the useful and simple method predicting seismic intensity distribution with high accuracy.

This method will be able to estimate seismic ground severity promptly; accordingly it will be applicable to grasping accurate damage distribution immediately after earthquakes. Moreover it will just exercise its strength in developing country, which have not so many observing stations.

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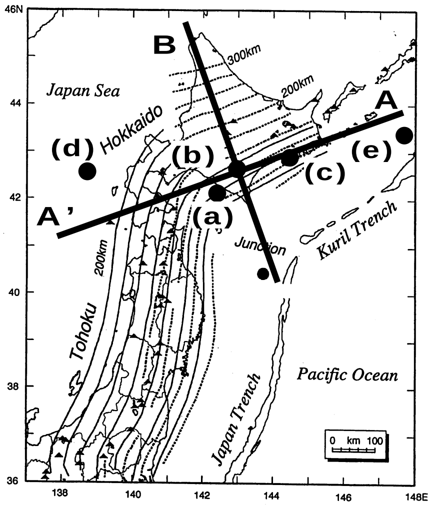

(Date, Depth (km), M),
(a)Urakawa-oki(21/Feb./1982, 40, 7.1),
(b)Hidaka-hokubu(14/Jan./1987, 119, 7.0),
(c)Kushiro-oki(15/Jan./1993, 107, 7.8),
(d)Hokkaido Nansei-oki(12/Jul./1993, 34, 7.8),
(e)Hokkaido Toho-oki(4/Oct./1994, 30, 8.1),
(f)Sanriku Haruka-oki(28/Dec./1994, 0, 7.5).

Fig.1: Epicenters of earthquakes used in this study. Solid and broken lines are the contours of hypocentral depths to the upper and the lower seismic planes [after Umino et al. (1984)].

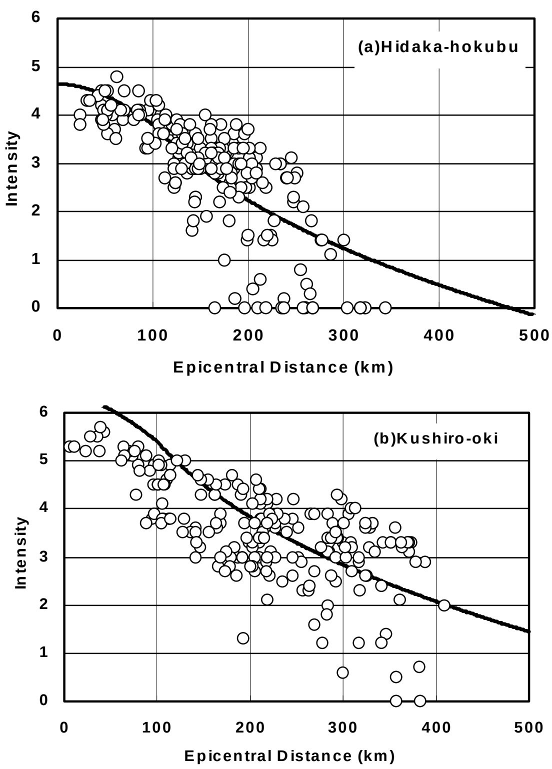

Fig.2: Relation between epicentral distance and intensity. (a)Hidaka-Hokubu earthquake, (b) Kushiro-oki Earthquake. Solid lines are the Kawasumi's empirical attenuation relations [after Kawasumi (1954)].

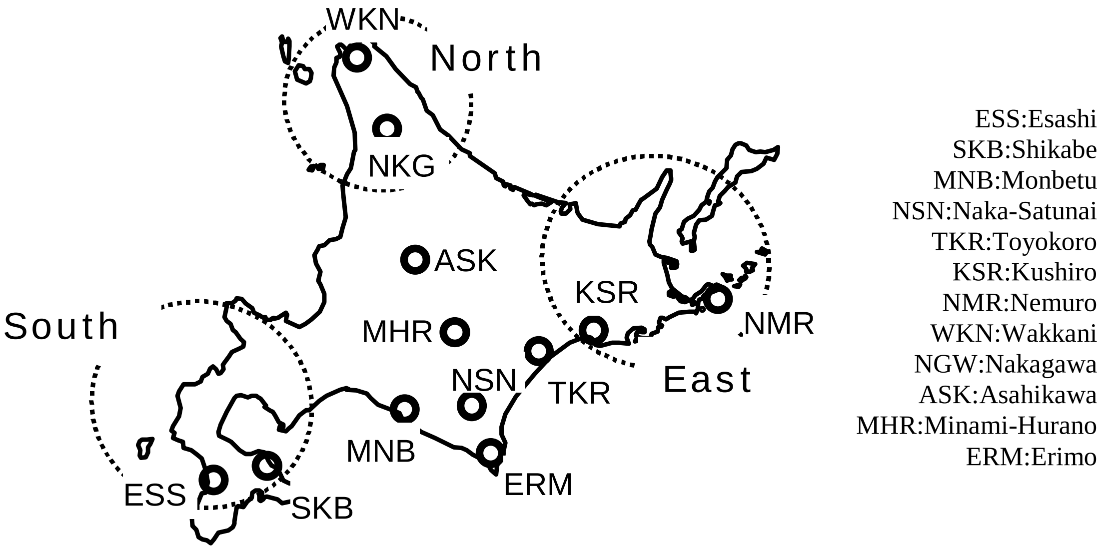

Fig.3: Test areas chosen in this study.

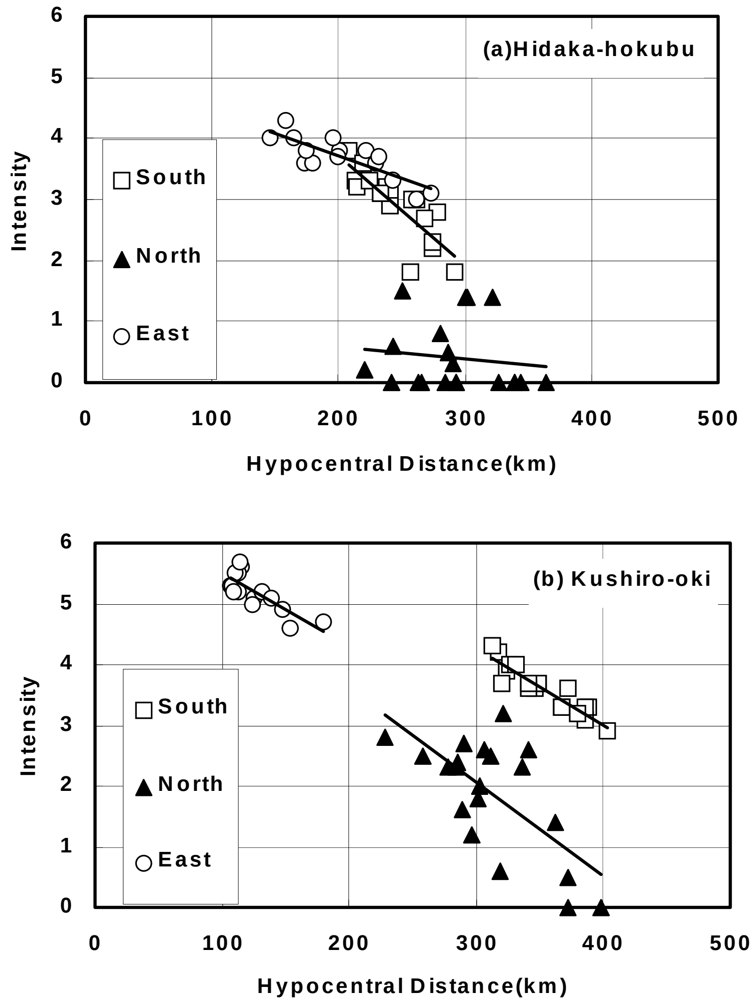

Fig.4: Relation between hypocentral distance and intensity in the test areas. (a)Hidaka-hokubu earthquake, (b) Kushiro-oki Earthquake. Solid lines show average attenuation in these areas.

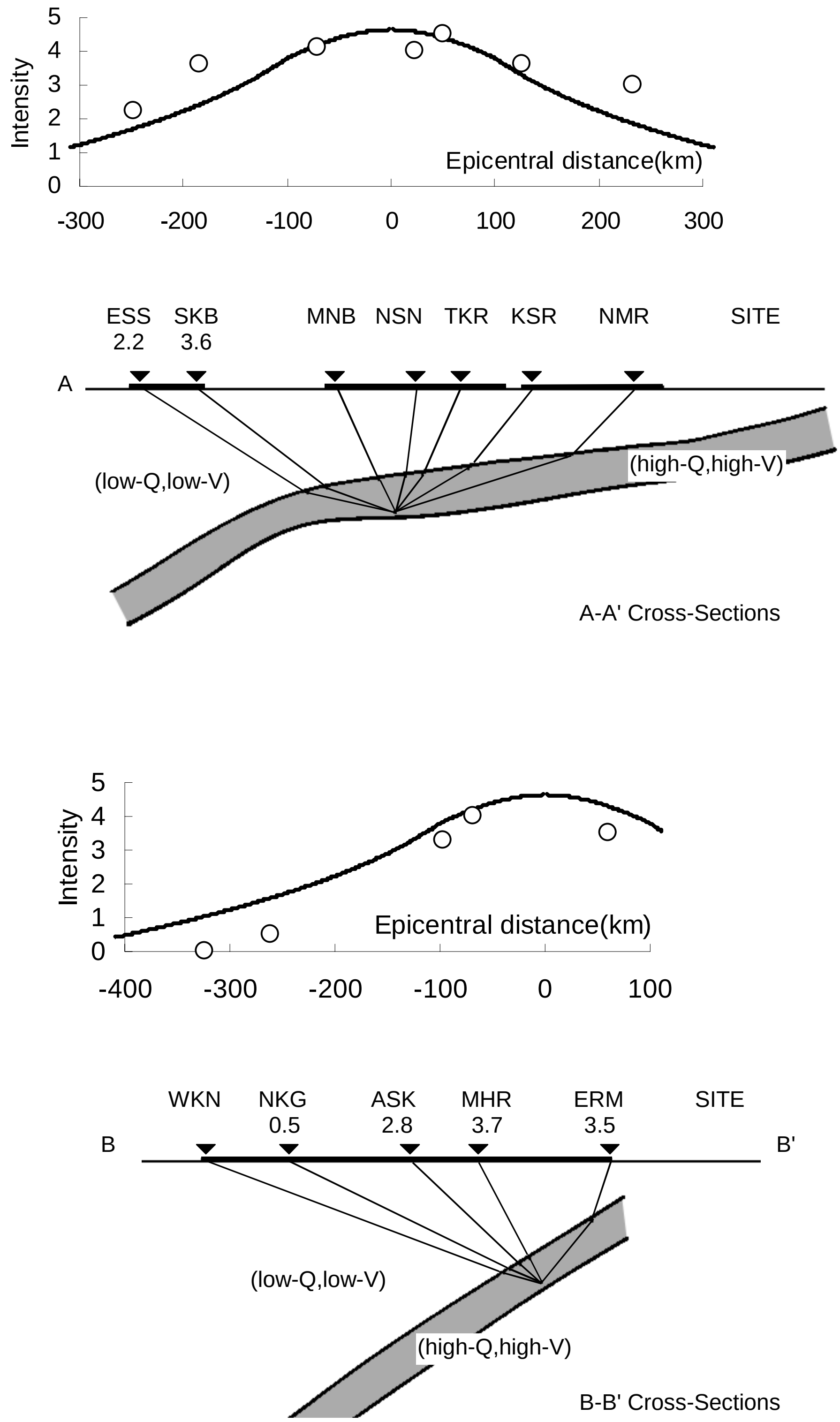

Fig.5: Seismic rays in the Hidaka-hokubu earthquake with relationships between epicnetral distance and intensity in same scale. The symbols are the same as those in Fig.1 and Fig.3. The solid lines are the Kawasumi's empirical attenuation relations [after Kawasumi (1954)] in the figures of relationships.

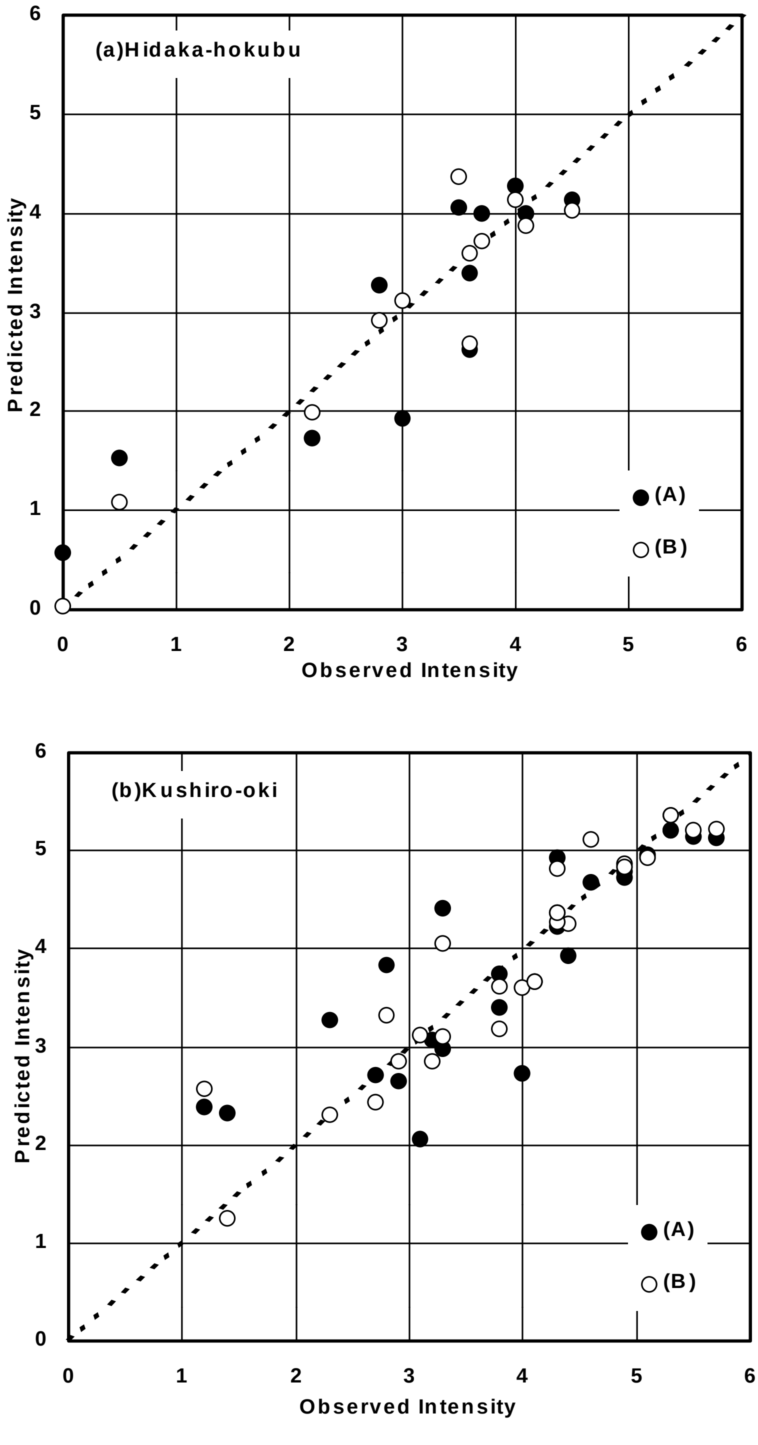

Fig.6: The comparison of observed intensity and predicted intensity. (A) Calculated with hypocentral distance, (B) Calculated with lengths of passes during high-Q and low-Q layers.

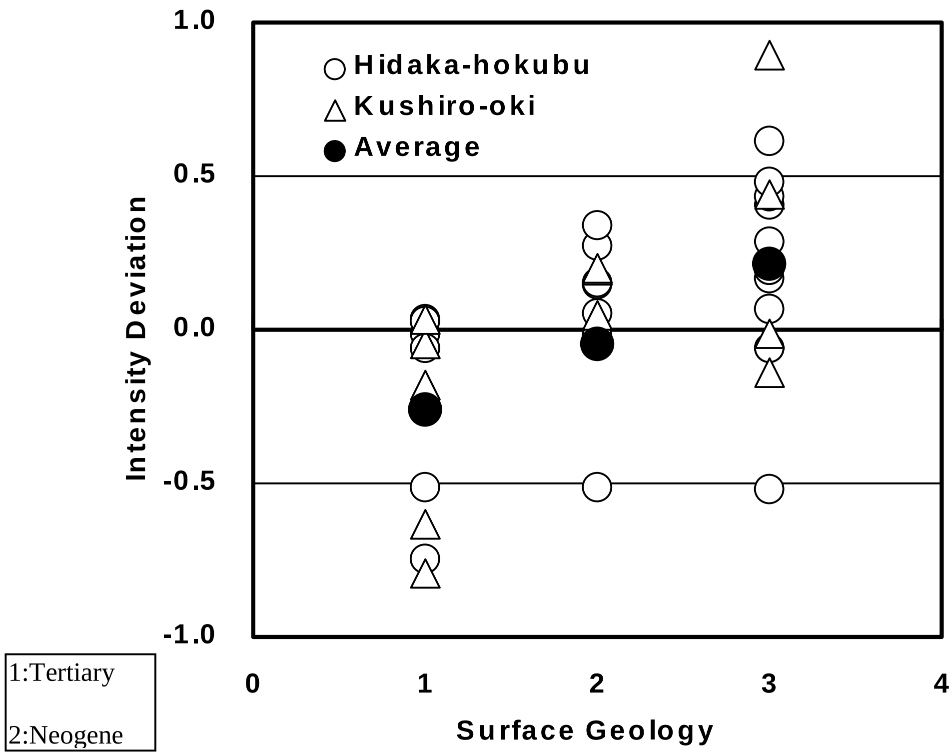

Fig.7: The comparison of surface geology and the intensity deviation. It becomes the intensity deviation when the observed intensity is subtracted from the predicted intensity.

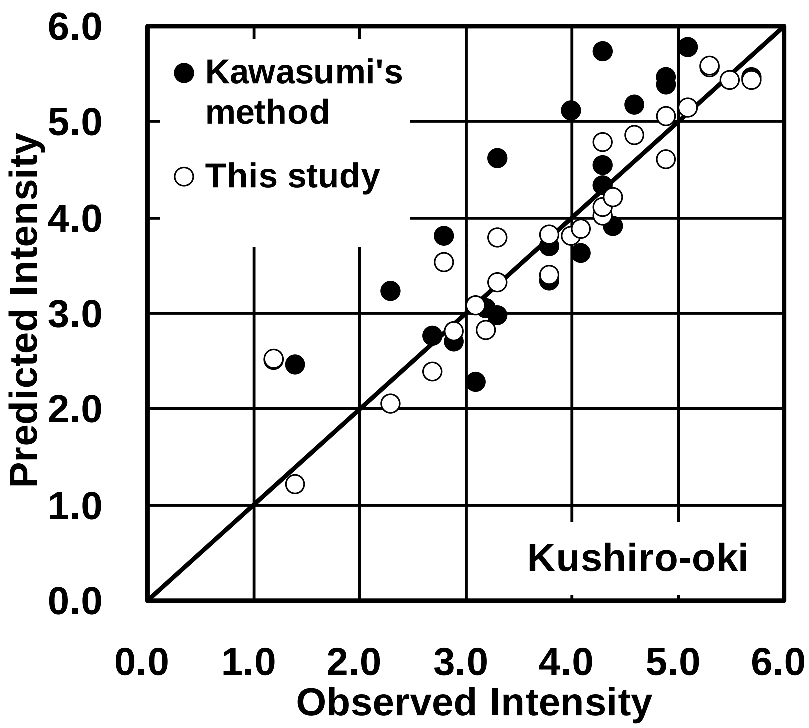

Fig.8: The comparison of Kawasumi's method and this study.