RELATIONSHIP BETWEEN SEISMIC GROUND MOTION AND SUBSURFACE STRUCTURE BY ANALYSIS OF INSTRUMENTAL SEISMIC INTENSITY IN TOTTORI PREFECTURE, SOUTHWEST JAPAN

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ABSTRACT :

A dataset of instrumental seismic intensities recorded at 50starions in Tottori Prefecture, southwest Japan, including 1464 events (4833 records) has been compiled. An average difference between the seismic intensities obtained from the observation and those estimated by using the attenuation was defined as an index representing the site amplification; a standard deviation and the number of observations were also used. The relationship between the index and the subsurface ground structure was studied. There was a correlation of the index with AVS30. On the closed two stations in Sakaiminato City, we analyzed the difference of instrumental seismic intensities by using the same method. The case of the difference between the two stations was found in this analysis.

KEYWORDS: Instrumental seismic intensity, Tottori prefecture, site amplification, characteristics of subsurface structure

1. INTRODUCTION

The seismic intensity information is used as the initial information of the earthquake occurrences and the standard of the first action system in the public institutions such as municipalities. The detailed seismic intensity distribution could be provided after the arrangement of the observation system by the instrumental seismic intensity. In addition, the strong ground motion earthquake observation network (for example, NIED, K-NET, KiK-NET) by other research organizations was arranged and the data of the strong ground motion records could be obtained. The seismic intensity value in the K-NET observation network became public recently. After the current observation system, the data of the observed earthquake are utilized for the evaluation of the earthquake.

Nojima et.al. (2005) analyzed the instrumental seismic intensity records in the Gifu prefecture and made basic data of seismic intensity information to use them effectively, so that the effectiveness was shown. Therefore, in this study, the instrumental seismic intensity records in the Tottori prefecture were analyzed on 41 seismic intensity observation points and 9 K-NET observation points. In addition, the instrumental seismic intensity values of K-NET were obtained from the strong ground motion records.

We make clear the characteristics of an amplification effect and the relations with the ground characteristic are examined by this analysis on each observation point in Tottori Prefecture.

2. ANALYSIS OF INSTRUMENTAL SEISMIC INTENSITY

2-1. Analysis data

In this study, the database of the instrumental seismic intensity by the Meteorological Agency and a database by the record data of K-NET were used for the analysis. The seismic intensity database of the Meteorological Agency includes the data of more than level 1 of seismic intensity (more than level 0.5 of instrumental seismic intensity) at 41 stations in each city, town and village and Meteorological Agency. The database of the 9 K-NET stations was obtained with using a waveform of more than 1 gal of the maximum acceleration. This database was observed from 1,997 to 2,006.

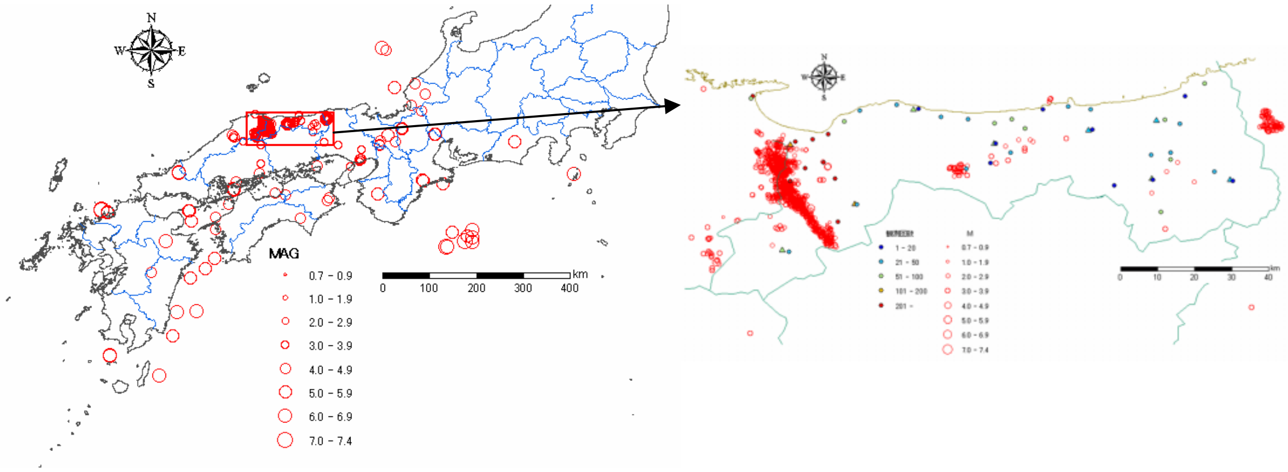

Figure 1 Epicenteral distribution map of used earthquake records

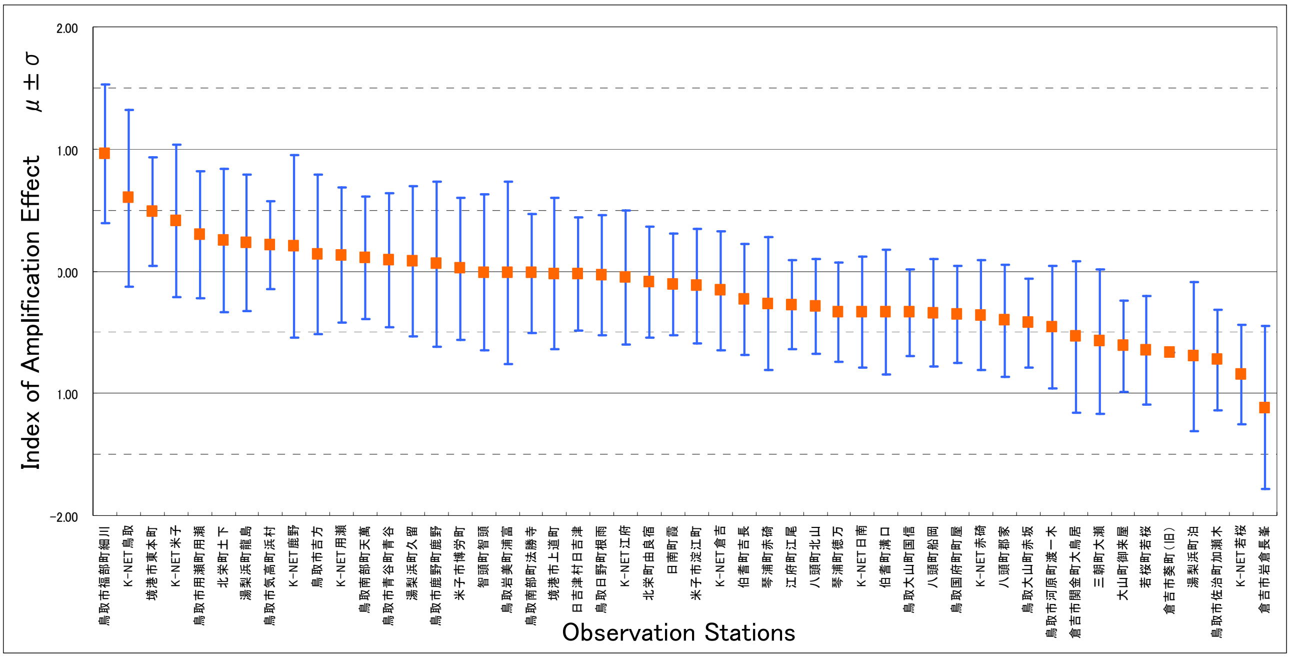

Figure 2 Mean of difference between estimated instrumental seismic intensity and observed value (the index of amplification effect) and the standard deviation of the estimate in the instrumental seismic intensity

In this period, 1,464 earthquakes were detected in the Meteorological Agency seismic intensity database, and the total number of data was 4,833. In the database of K-NET, 217 earthquakes were detected, and the total number of data was 619. The epicenter distribution of the Earthquakes is shown in Figure 1. The magnitude of almost all recorded earthquakes was lower than 5, and they are included in a group of aftershocks with the 2000 Western Tottori Prefecture Earthquake in the upper crust (shallower than 15km) of the inland. Therefore, the earthquakes more than 100 km away from the epicenter are those occurred in a plate border and slab.

2-1. Index of amplification effect

In this study, an equation of distance attenuation (2.1) (An-naka et. al., 1997) and a conversion equation of the instrumental seismic intensity (2.2) (Midorilawa et. al., 1999) were used to calculate the estimated seismic intensity *I*, taking distance attenuation of each observation point into the consideration. Differences between the estimated seismic intensity and the seismic intensity by the observation at all stations were calculated to get the mean and the standard deviation of these. The equations used for a calculation are as follows.

At first, an instrumental seismic intensity in each observation station was estimated. An epicentral distance was assumed as the minimum distance from a fault in this study.

$$\log V_{\max} = 0.725M + 0.00318H - 1.918\log(R + 0.334e^{0.653M}) - 0.519 \quad (2.1)$$

$$I = 1.82\log V_{\max} + 2.54 \quad (2.2)$$

where,

$V_{\max}$:Maximum velocity records
I: Estimated seismic intensity
M: Magnitude by Meteorological Agency
H: Depth of epicenter (km)
R: Minimum distance from fault (km)

Next, difference *Δij* between estimate value of the instrumental seismic intensity at observation stations *j* in earthquake *i* and the observation value are calculated.

$$\Delta I_{ij} = I_{ij}^{obs} - I_{ij}^{est} \quad (2.3)$$

$$\overline{\Delta I_j} = \frac{\sum_{i=1}^{m_j} \Delta I_{ij}}{m_j} \quad (2.4)$$

$$\sigma_j = \sqrt{\frac{\sum_{i=1}^{m_j} (\Delta I_{ij} - \overline{\Delta I_j})^2}{m_j - 1}} \quad (2.5)$$

where,

I_{ij}^{obs} : The instrumental seismic intensity which was observed in each earthquake *i* at an observation station *j*
I_{ij}^{est} : The instrumental seismic intensity which is estimated by an equation of distance attenuation
m_j : The total number of instrumental seismic intensity observed in observation station *j*

It is thought that the equation (2.1) of instrumental seismic intensity observed in observation stations j evaluates a ground motion which is equivalent to the engineering basement for the diluvium plateau of S wave velocity, 300-600m/s (An-naka et. al., 1997). Nojima et.al. (2005) mention that the ground amplification influences these differences. At the point where there is the sedimentation layer, the observed seismic intensity should be larger than the estimated one due to an amplification effect. Then, a difference value is thought to be positive. Therefore, we consider that the value of the equation (2.4) is an index to evaluate an amplification effect. The calculation results of the equations (2.4), (2.5) at each observation point are shown in Figure2. In Figure 2, the indexes of the amplification effect including the standard deviation are shown on a vertical axis and are displayed in order of the size.

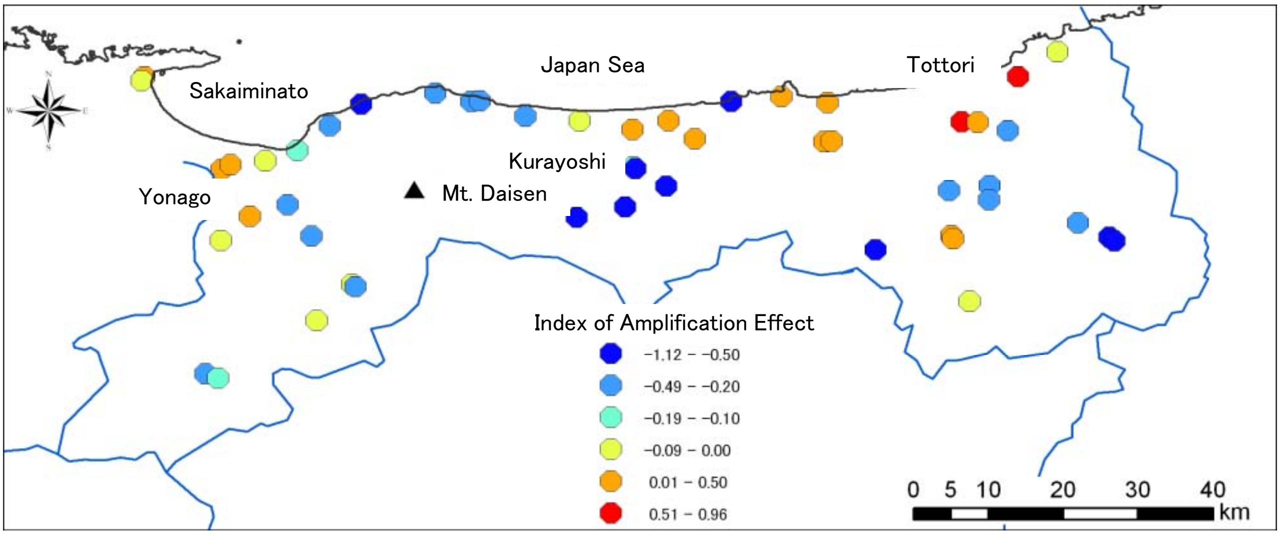

Figure 3 Distribution map of the index of amplification effect

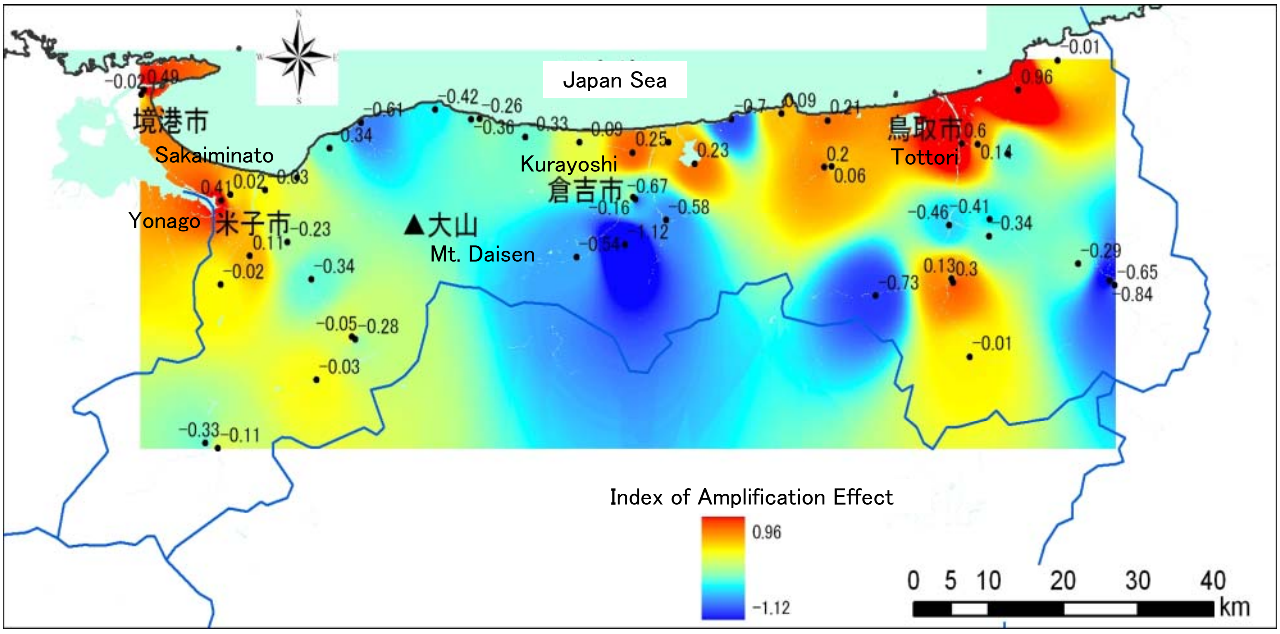

Figure 4 Zoning map of the index of amplification effect

3. THE INDEX DISTRIBUTION OF AMPLIFICATION EFFECT IN TOTTORI PREFECTURE

The result of chapter 2 is shown in Figure 3 to survey the index distribution of amplification effect in Tottori prefecture. The areas where amplification effect is high are shown by a warm color, and concentrate in Tottori City, Yonago City, Sakaiminato City and Kurayoshi City. The areas with a low amplification effect concentrate in the inland part and the coast part between Kurayoshi and Yonago City. The zoning map using a space processing of GIS is shown in Figure 4 to define the region more clearly. The areas with higher index clearly spread in the western area (Yonago City and Sakaiminato City), in the central area (Kurayoshi City) and in the eastern area (Tottori City). These areas are located on the sedimentary ground of the plains. The areas with lower index are located around Mt. Daisen, a Quaternary volcano and in the area surrounded by Kurayoshi City and Yonago City. The areas with lower index in the inland are in the mountainous district and have a geological feature of the basement rock before the Tertiary. About the relations with the ground structure, we mention in next chapters in detail.

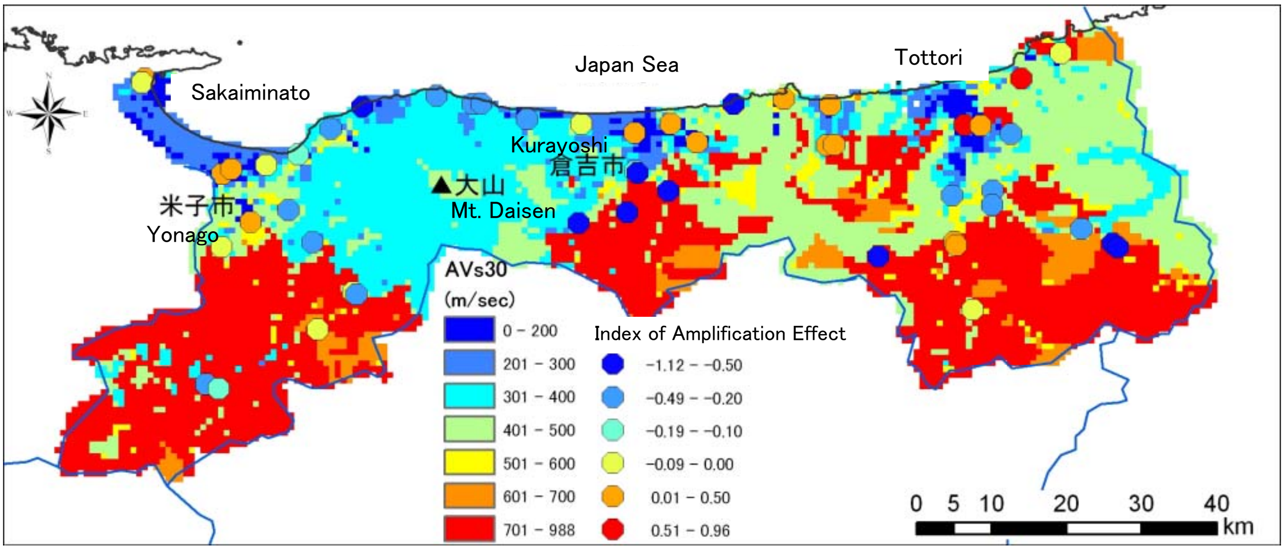

Figure 5 Distribution map of index and AVS30 of the amplification effect

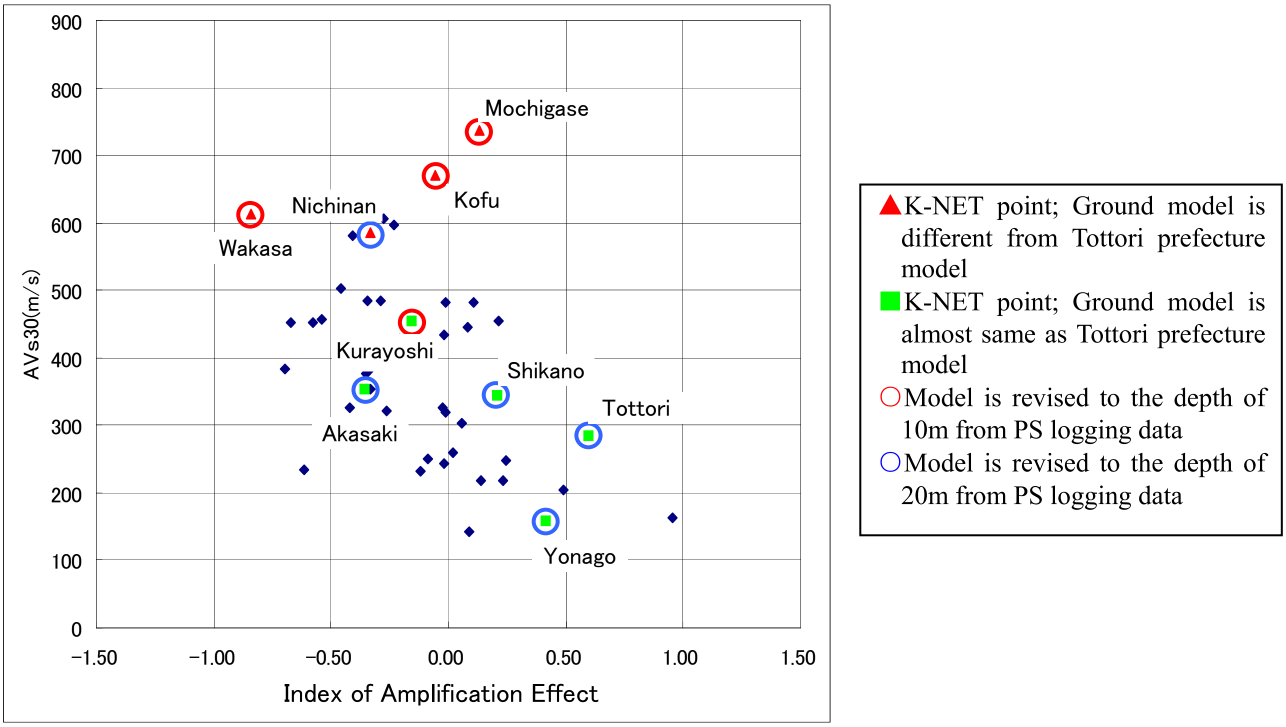

Figure 6 Comparison between the index of amplification effect and AVS30

4. COMPARISON BETWEEN AMPLIFICATION EFFECT AND SUBSURFACE GROUND STRUCTURE

4-1. Subsurface ground structure data

To examine how the index of amplification effect is related with the subsurface structure, the distribution map of the gravity anomalies reflecting the deep structures and AVS30 showing the average S-wave velocity of the subsurface structure in the area was made. The gravity database (Geological Survey of Japan, 2004), (The Gravity Research Group in Southwest Japan, 2001) was used for data of the gravity anomalies, and the

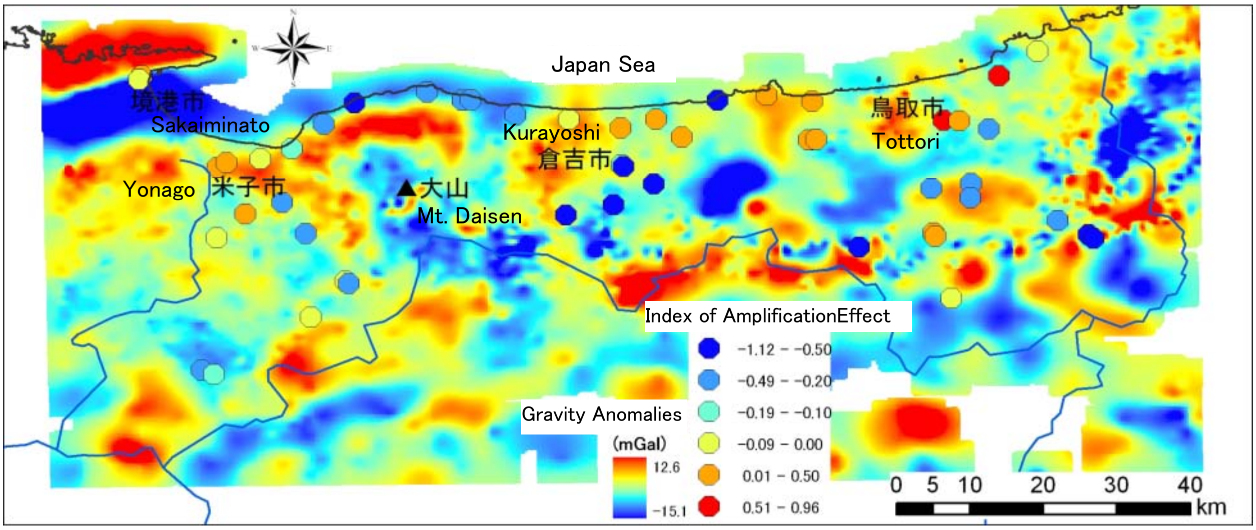

Figure 7 Distribution map of the index of the amplification effect and the gravity anomalies

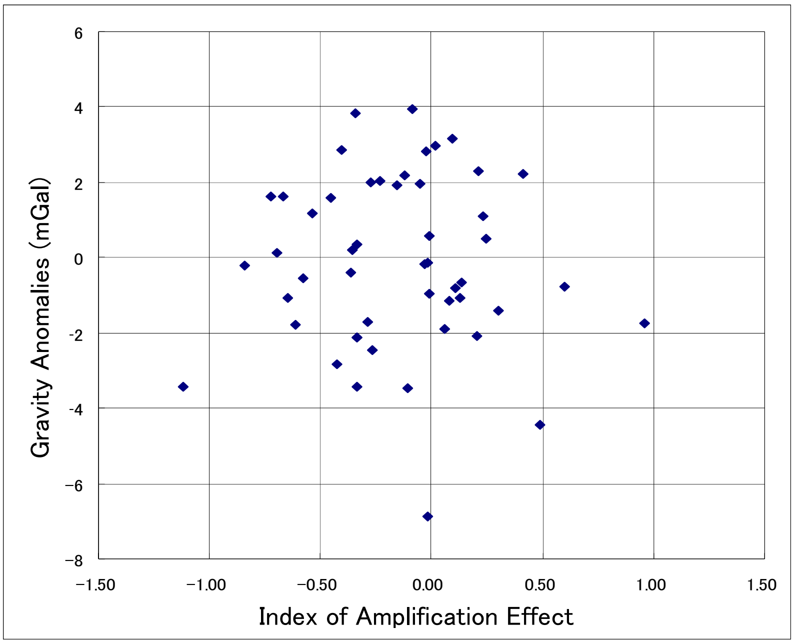

Figure 8 Comparison between index and gravity anomaly of the amplification effect

subsurface structure data with a grid size 500m obtained from Tottori prefecture database was used for the AVS30. AVS30 of K-NET points were calculated by using a model of PS logging data to the depth of 10m or 20m.

2.5(t/m^3) that is the average density of basement rock (a mountainous district) in Tottori prefecture was used as the assumed density of the gravity anomalies. In addition, a 5km upward filter processing was used to reduce a trend of the gravity anomalies that reflected the information to a crustal structure. It is thought that the gravity anomalies after this filtering process reflect heterogeneous distribution of the density in the shallower part than seismic bedrock.

4-2. Comparison with subsurface structures

The distribution of AVS30 and the index of amplification effect of each observation point are shown in figure 5. The areas with lower AVS30 (cold color) are distributed in Tottori City, Kurayoshi City, Yonago City and

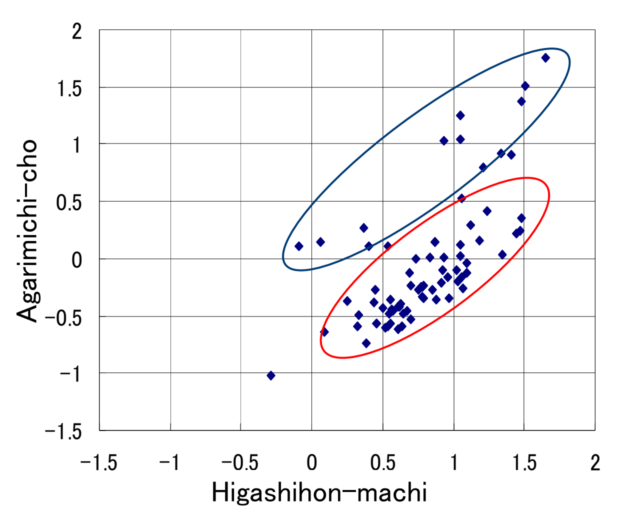

Figure 9 Comparison of the difference between the estimated instrumental seismic intensity and the observed value in the closed two sites in Sakaiminato City

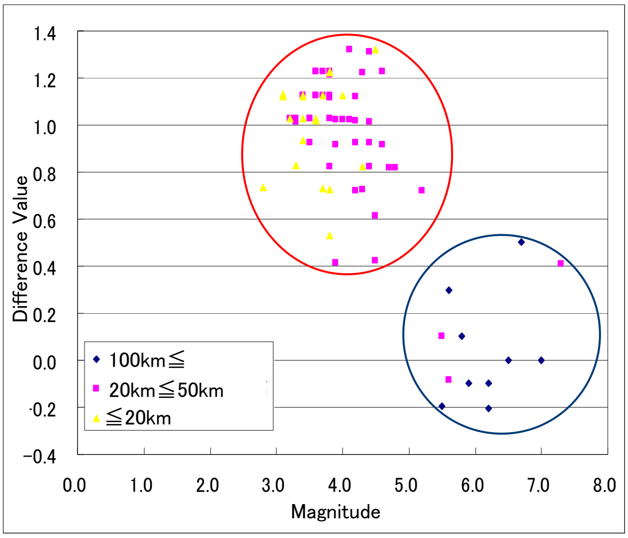

Figure 10 Difference of the instrumental seismic intensity estimated and the observed value in the closed two sites in Sakaiminato City. The relation of magnitude and the hypocentral distance.

Sakaiminato City and the index of the local amplification effect shows a tendency to become high. In other words, the index of amplification effect is high in the areas with lower AVS30. Therefore, an amplification tendency of the subsurface structure will be correlated with the index. Here, the index of amplification effect is compared with AVS30 (Figure 6). The tendency that the higher the index of the amplification effect becomes, the lower AVS30 becomes, can be clearly seen..

The index of amplification effect is compared with a gravity anomaly to examine the relation with a deeper structure (Figure 7, 8). From Figure 7, if the base density does not change, it can be judged the density of subsurface structure is low or the layer is .thick. However, the correlation with the amplification effect is not clear. In other words, the relation between a gravity anomaly and the index (the lower a gravity anomaly is, the higher an index is) can not be seen.. Also, any correlations cannot be found in Figure 8. It is thought that the influence to the deep subsurface structure is not given to the index of amplification effect.

From these comparisons, it was found that there was a clear correlation between the amplification effect and subsurface structure (AVS30) in Tottori prefecture. Therefore, the detailed zoning map of the amplification effect can be made in Tottori prefecture by using a distribution of AVS30.

5. CHARACTERISTICS OF CLOSED TWO SITES OF SAKAIMINATO CITY

The instrumental seismic intensity of Higashihon-machi (Sakaiminato meteorological observatory) was higher than that of Agarimichi-cho (Sakaiminato City Office) by 0.6 in the case of the 2000 western Tottori Prefecture earthquake, though the distance between the two sites is only 600m. It was reported that Higashihon-machi had a higher value than that of Agarimichi-cho in the comparison data of the questionnaire's seismic intensity, the strong ground motion record and the seismic intensity. Therefore, the comparison between the two sites is done according to the analysis result mentioned in the previous chapter. In addition, as for the amplification effect, the data of the closed two sites is compared with that of K-NET Mihonoseki, and the relation with the subsurface structure is also considered.

5-1. Difference of the instrumental seismic intensity

At first, as for the times that the instrumental seismic intensity more than 1 was observed, Higashihon-machi had 284 times and Agarimichi-cho, only once. There were 75 cases where it was observed in the two sites at the same time. In these cases, the Higashihoncho had the larger value than the other by 0.8 in the average. The difference between the estimate of instrumental seismic intensity and the observed value were 0.49 at Higashihon-machi (76 times of observation) and -0.02 at Agarimichi-cho (359 times of observation) ;the difference between the two sites was 0.51. From the analysis in this study, it was found that Higashihon-machi had a large seismic ground motion. The index of amplification effect of K-NET Mihonoseki was 0.14. From these relations, Agarimichi-cho can be judged to have a very small seismic ground motion. The differences between the estimate instrumental seismic intensity and the observed value were compared on the two points by using the data observed at same time (Figure 9). The result from the figure can be divided into two plot groups, one is surrounded with red (Higashihon-machi is larger by about 1) and the other is surrounded with blue (approximately 1:1). In the Figure 10, hypocentral distances are shown by changing the colors to examine relations of the plot group about an earthquake shown in Figure 9 in detail. From this figure, it is found that the difference is large when the magnitude is more than 5 and the epicentral distance is more than 100km, and is small when the magnitude is less than 5 and the epicentral distance is 50km. In other words, the difference in the two sites becomes small when the magnitude is large and the epicenter is far.

5-1. Relations with the subsurface structure

AVS30 is 243m/sec in Agarimichi-cho and 204m/sec in Higashihon-machi, and it is thought that the difference in AVS30s is not a cause of a difference of the seismic intensity. Noguchi has investigated a subsurface structure in detail in this area, but the clear difference in S-wave velocity structure was not found from the result. According to the PS logging data to the depth of 10m, AVS10 is 264m/sec at K-NET Mihonoseki. Because the basement rock of Tertiary was outcropped near the site, it is expected that AVS30 becomes larger than AVS10. Therefore, K-NET Mihonoseki seems to have a harder ground than that of 2 sites in Sakaiminato. It is necessary to examine the cause why the seismic ground motion of the Agarimichi-cho was small from relations of the subsurface structure in future.

6. CONCLUSION

Using the instrumental seismic intensity data from 1997 to 2006 of Tottori prefecture, the characteristics of ground strong motion were analyzed and the relationship between seismic ground motions and subsurface structures were examined. The results are as follows.

1) The large index distribution of amplification effect spreads widely in Tottori City, the northern part of Kurayoshi City, Yonago City and an urban area of Sakaiminato City, and has a tendency to become small in mountains areas and around Mt. Daisen.
2) From the relations of subsurface structure, the index of the amplification effect has a tendency to become large in the areas with small AVS30 in plains. It was found that there was a clear correlation between the amplification of the subsurface structure and the index of the amplification effect.
3) There was not a correlation between the gravity anomaly and the index of the amplification effect. Therefore, it thought that there were not any clear relations between the deep subsurface structure to seismic bedrock and an amplification effect by the seismic intensity.
4) The amplification effect was compared by using the results of analysis on the closed two sites in Sakaiminato City. The amplification effect of Agarimichi-cho showed an extraordinary small value. In addition, the value of Agarimichi-cho was smaller than that of the K-NET Mihonoseki.
5) It was found that the difference in the index of amplification effect between the two sites in Sakaiminato City was small when the magnitude was large and the epicenter was far.

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