ESTIMATION OF SITE AMPLIFICATION FACTORS USING STRONG MOTION RECORDS OF HOKKAIDO

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ABSTRACT :
Site amplification factors at subsurface layers are often used as one of the parameters for estimation of strong ground motion. The site amplification factors influence strongly the ground motion at subsurface layers. For example, waveforms obtained from observation sites are sometimes clearly different even if the observation sites are situated in the vicinity of each other. Therefore, it is assumed that the consideration for the influence of site amplification factors on the ground motion at subsurface layers is important, and improving the accuracy of the site amplification factors contributes towards the technology of earthquake disaster mitigation. The authors investigated the site amplification factors at subsurface layers using strong motion records of Hokkaido. The site amplification factors were estimated by adopting microtopography classification based on the Digital National Land Information. It was found that there were areas which did not show similar tendency of site amplification factors when compared to that obtained by strong motion records of Hokkaido. A more detailed investigation of this issue revealed that the tendency was influenced by regional characteristics, such as alluvial fan. Therefore, detailed areas within the microtopography concentrated were selected, and the regression coefficients for estimation of the site amplification factors were re-determined. The tendency of the site amplification factors estimated by detailed area of the microtopography classification became approximately similar to the site amplification factors obtained by the strong motion records. And the site amplification factor was estimated more precisely by determining regression coefficients in consideration of the regional characteristics.

KEYWORDS:
site amplification factor, strong motion record, digital national land information, microtopography classification

1. INTRODUCTIONS

The site amplification factor at subsurface layer for the maximum ground velocity (ARV) is an important parameter that provides essential information on ground characteristics and the factor of the maximum velocities from the base by engineering practice to the ground surface, in addition to its adoption in earthquake disaster maps. The seismic wave propagates from the underground to the ground surface. There are cases in which the characteristics of waves adjacent to observation sites are different from each other due to different subsurface layer's properties. Thus, the estimation of the ARV is important for effective earthquake disaster mitigation. There are two main methods to estimate the ARVs, namely by boring data, and by topography classification. In this paper, the method by topography classification is investigated because it is simple and possible to be applied in all parts of Japan. Methods that were proposed to estimate the ARV are discussed in brief as follows: Matsuoka and Midorikawa used microtopography classification based on the Digital National Land Information for estimation of the ARVs, of which the distribution was obtained by interpolation. In this method, the time-weighted average shear-wave velocity in a 30m-deep surface layer (AVS30) was determined by referring to the geographic classification based on the Digital National Land Information. Besides, the ARV was obtained from AVS by using an regression formula. The regression formula for the relationship between AVS30 and ARV was derived from strong motion records obtained in the Kanto region; Hisada et al. came out with a more detailed distribution map of the ARVs by preparing the topography classification with a mesh size of 500m; Fujimoto and Midorikawa proposed a method to estimate the AVS30 with a higher accuracy by dividing Japan into 3 sections; Wakamatsu et al. suggested that the conventional topography classification was not uniform, and proposed a new topography classification. The authors of this paper focused on the method by

Fujimoto and Midorikawa, by dividing Japan into 3 sections. In this paper, the authors investigated the ARVs at subsurface layers using strong motion records of Hokkaido. Next, the ARVs were estimated by adopting microtopography classification based on the Digital National Land Information due to increase the density of the ARVs. As the investigation of the issue, the regression coefficients were determined by selecting the detailed areas. The characteristic of the method in this paper is to estimate the ARVs by the microtopgraphy classification of Hokkaido in the consideration for the regional characteristics. As the result, the ARVs estimate by the method is more similar to the ARVs using strong motion record than the ARV estimated by the method of Matsuoka and Midorikawa.

2. SITE AMPLIFICATION FACTORS (ARV) USING STRONG MOTION RECORDS

The ARV are calculated by the factor of peak ground velocity (PGV) of the observation records. The PGV components of two horizontal observation records are used in the calculation of the ARV. Sato et al. established the Warning Information System of Earthquake (WISE) for observation network of strong motion records in Hokkaido originally. In this study, strong motion records of WISE, KiK-net, K-NET, JMA (Japan Meteorological Agency) were utilized. The strong motion records of KiK-net were used as the record obtained at the base by engineering practice where the shear wave velocity is equal to 400 m/sec. The PGV at the base by engineering practice of the observation site of others (K-NET, WISE, JMA) were estimated by interpolation of the records of KiK-net. Equation (1) is used for calculating the ARVs using the strong motion records.

$$ARV = \frac{PGV \quad at \quad the \quad ground \quad surface\,(KiK-net, K-NET, WISE, JMA)}{PGV \quad at \quad the \quad base\,(Interpolation \quad of \quad the \quad record \quad of \quad KiK-net)} \tag{1}$$

Accelerations given by the observation records were converted into velocity data by integration, with frequency ranging from 0.1Hz to 10.0Hz. The strong motion records of the 2003 Tokachi-Oki earthquake were selected for the calculation of the ARV. Figure 1 shows the distribution of observation sites that hold strong motion records of the 2003 Tokachi-Oki earthquake. The ARV calculated by Equation (1) is the value on the observation site, but by calculating the interpolated values, the distribution of the ARVs obtained by strong motion records. Figure 2 shows the distribution of the ARV using the strong motion records of the 2003 Tokachi-Oki earthquake.

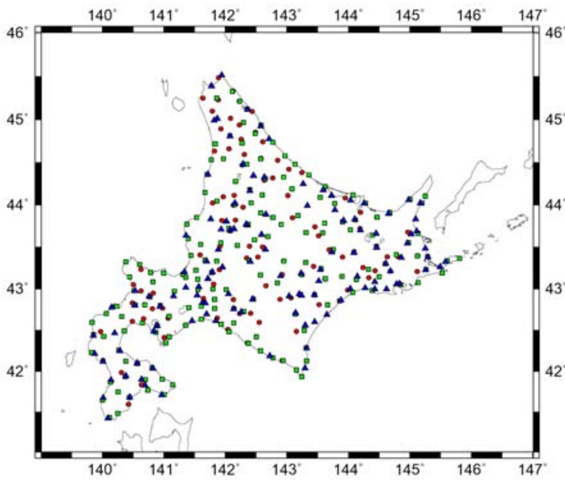

Figure 1 The distribution of observation sites that hold strong motion records of the 2003 Tokachi-Oki earthquake

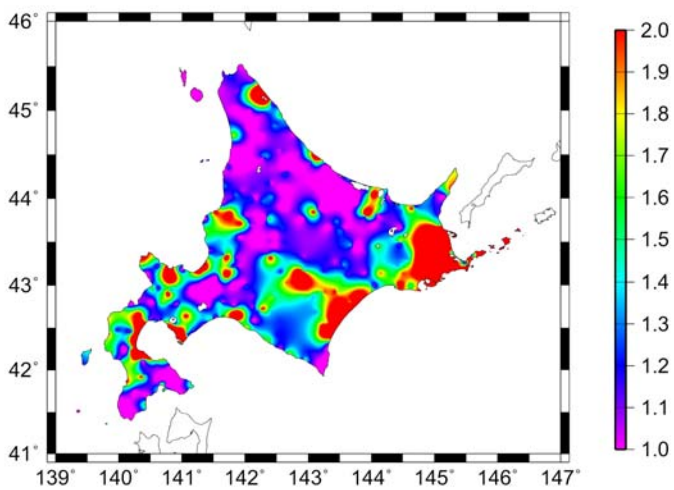

Figure 2 The distribution of ARV using the strong motion records of the 2003 Tokachi-Oki earthquake

3. ESTIMATION OF SITE AMPLIFICATION FACTORS (ARVs) BY MICROTOPOGRAPHY CLASSIFICATION BASED ON THE DIGITAL NATIONAL LAND INFORMATION

The ARVs were estimated by microtopography classification based on the Digital National Land Information. In this paper, the estimated results were compared with those yielded from the method of Matsuoka and Midorikawa. The first step of this investigation is to determine the regression coefficient to estimate the ARV from AVS30. The next step is to determine the regression coefficient to estimate AVS30 from the altitude corresponding to the microtopography of Hokkaido and the distance from river. It is considered that the sizes of ARVs depend on the extent of earthquake. By considering that the ARVs are used for damage prediction of civil structures, the 2003 Tokachi-Oki earthquake was selected. Equation (2) is used for calculating the AVS30.

$$AVS30 = \frac{D}{\sum \frac{D_i}{Vs_i}} \qquad (2)$$

In which, D is the depth of 30 m, and Di is the depth of each layer, Vsi is shear-wave velocity of each layer. The relationship between AVS30 and ARV using strong motion records of the subsurface layer are given in Equation (3).

$$\log ARV = a + b \log AVS30 \qquad (3)$$

The relation between AVS30 and ARV of the 2003 Tokachi-Oki earthquake are given Equation (4).

$$\log ARV = 1.08 - 0.38 \log AVS30 \qquad (4)$$

The regression coefficients of each microtopography classification of Hokkaido were determined in Equation (5).

$$Log AVS30 = a + b \log H + c \log D \qquad (5)$$

In which, H is altitude above the sea level (m); D is distance from river (km). The microtopography classification is determined by referring to the Digital National Land Information. There are land classifications in the Digital Land Information. The land classification in the Digital National Land Information is based on a land classification map with a scale of 1 to 100,000 - 200,000, in which the unit mesh size is 30 seconds latitudinally and 45 seconds longitudinally (third order mesh, approximately 1 x 1 km.). The microtopography classification is determined from the land classification of third order mesh based on the method of Matsuoka and Midorikawa. Table 1 shows the microtopography classifications based on Digital National Land Information. Figure 3 shows the distribution of microtopography classification in Hokkaido. In some microtopography classifications, there are no observation sites, or the observation sites in those classifications do not posses AVS30 data. The observation data is obtained from interpolation of third order mesh for AVS30 and the regression coefficients are acquired by one of the following procedures.

(1) When an observation site having AVS30 is found, regression coefficients are acquired by using the AVS30 of that observation site.

(2) When observation sites having no AVS30 values but having strong motion records, the regression coefficients are acquired by using as the AVS30 values from the strong motion records.

(3) When observation sites of the classification having no AVS30 values and no strong motion records, the regression coefficients are acquired by using interpolated values of third order mesh for AVS30 and ARV obtained by the strong motion records of all classification.

In addition to the above mentioned, when it is impossible to determine the effective regression coefficients from the distribution pattern of the relationship between H or C and AVS30, when the almost zero gradient is obtained from the pattern of distribution, the average value is calculated and regression coefficients with a zero gradient is obtained.

Table 2 shows the coefficient list by microtopography classification. Figure 4 gives the distribution of ARVs estimated by microtopography classification of Hokkaido. The purpose of this paper is to improve the estimating accuracy of the ARV due to use for damage prevention of civil structures. But, the distribution of figure 4 is not similar to the distribution of figure 2 when the evaluation is in absolute value. and when the evaluation is in the relative tendency of those distributions, the distribution of figure 4 is approximately similar to the distribution of figure 2. In this paper, at first it is confirmed that the relative tendency is similar, and it is decided that next step is to investigate improving the ARVs on alluvial fan by microtopography classification. On alluvial fan classification in the vicinity of Tokachi-Shicho, the issues are found because the characteristics do not seem to suggest the tendency that the ARV increases with the reduction of distance from river by taking into consideration of the ground conditions. As the investigation of this issue, the ARV by the microtopography classification were segmented the more detailed area were re-determined. In addition, this issue occured in the classification of alluvial fan, but by the consideration for the possibility to become different tendency in the other microtpography classification, it became to investigate in the all microtopography classification.

Table 1 The microtopography classifications based on the Digital National Land Information

Geomorphplogical unit or Geology	classification main	sub	geological features age
①Reclaimed land		6	
②Artificial transformed Land			
③Delta, Back Marsh (D≦0.5)	20,21		
④Delta, Back Marsh (D>0.5)	20,21		
⑤Natural Levee	22		
⑥Valley Plain		7	
⑦Sand Bar, Dune	23	8	
⑧Fan	12,19		
⑨Loam Plateau	14,31-33		
⑩Gravel Plateau	10,16,17,237-39		
⑪Hill	00,09-11		
⑫Other Geom. Units	01-08,15,18,24,25		
⑬Pre-Tertiary			1-4,7-9

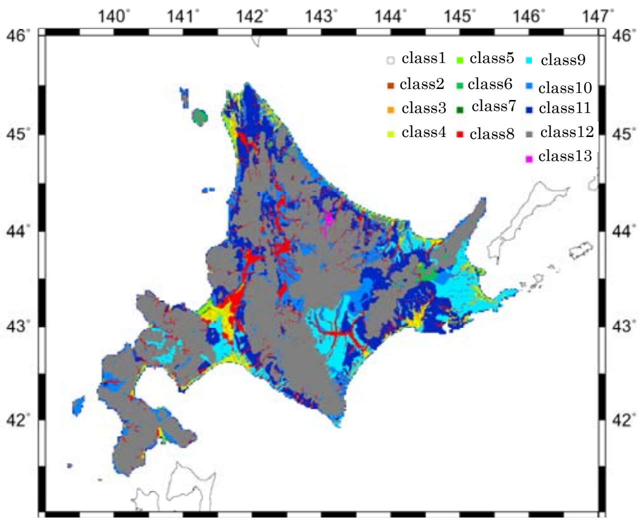

Figure 3 The distribution of microtopography classification of Hokkaido

Table 2 The coefficient list by microtopography classification

microtopography classificatipn	a	b	c	observation sites	N	N (by inverse of equation 4)	N (by interpolation)	By the way
①Reclaimed land	2.6	0	0	0	0	0	**1**	5
②Artificial transformed Land	-2.26	0	0	0	0	0	0	5
③Delta, Back Marsh (D≦0.5)	2.36	0	0	8	7	**28**		4
④Delta, Back Marsh (D>0.5)	1.87	0	0	10	**3**	20		4
⑤Natural Levee	2.1	0	0	7	1	**10**		4
⑥Valley Plain	2.57	-0.03	0	0	0	4	**528**	3
⑦Sand Bar, Dune	2.35	0	0	0	0	2	**16**	4
⑧Fan	2.31	0.17	0	27	21	**40**		2
⑨Loam Plateau	2.04	0.21	0	14	10	42	**8191**	3
⑩Gravel Plateau	2.66	0	0	23	0	**14**		3
⑪Hill	2.25	0.24	0	19	6	**33**		3
⑫Other Geom. Units	2.39	0.1	0	26	14	51	**42751**	3
⑬Pre-Tertiary	2.84	0	0	0	0	2	**148**	4

way 1 ･･･deciding regression coefficients by AVS30
way 2 ･･･deciding regression coefficients by AVS30 data of inverse equation 4
way 3 ･･･deciding regression coefficients by interpolation data
way 4 ･･･average data、slope is zelo
way 5 ･･･the other

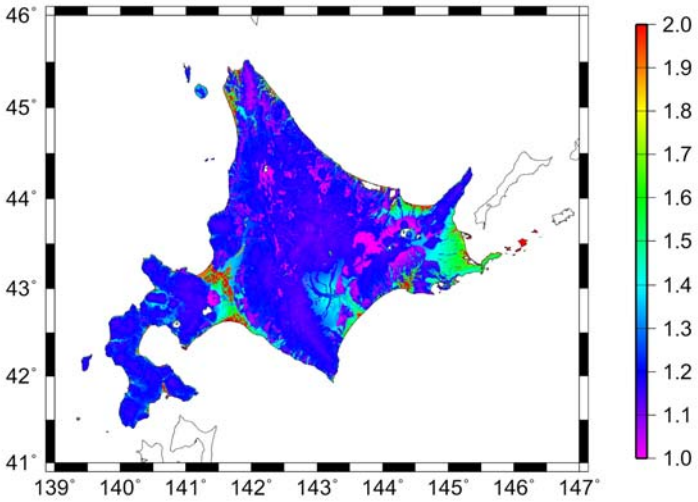

Figure 4 The distribution of ARV estimated by microtopography classification of Hokkaido

4. SITE AMPLIFICATION FACTOR (ARV) BY DETAILED AREA OF MICROTOPOGRAPHY CLASSIFICATION

Figure 5 shows detailed area of each microtopography classification. Detailed area is where each microtopography classification is concentrated. It was used to determine the regression coefficients to estimate AVS30 from the altitude corresponding to the microtopography classification of Hokkaido and the distance from river. Figure 6 shows the relationship between the altitude corresponding to the microtopography classification of Hokkaido or the distance from river, and AVS30. It shows observation sites data of AVS30, the interpolation value of AVS30 in the third order mesh, the regression line under previous condition in which the detailed area has not been selected. By confirming the change of the gradient of regression line, the regression coefficients were re-determined in the classification 3 (delta back marsh (D <= 0.5 km)), classification 4 (delta back marsh (D > 0.5 km)), classification 5 (natural levee), classification 8 (fan), classification 9 (loam plateau).

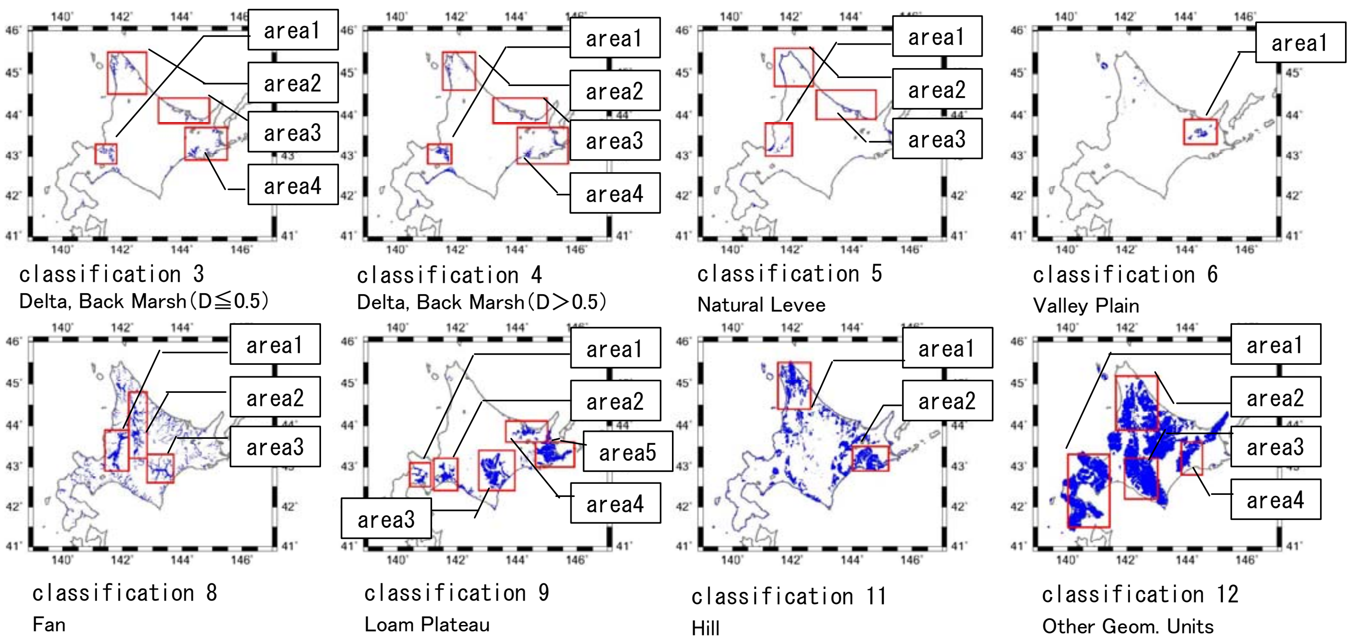

Figure 5 Detailed area of each microtopography classification

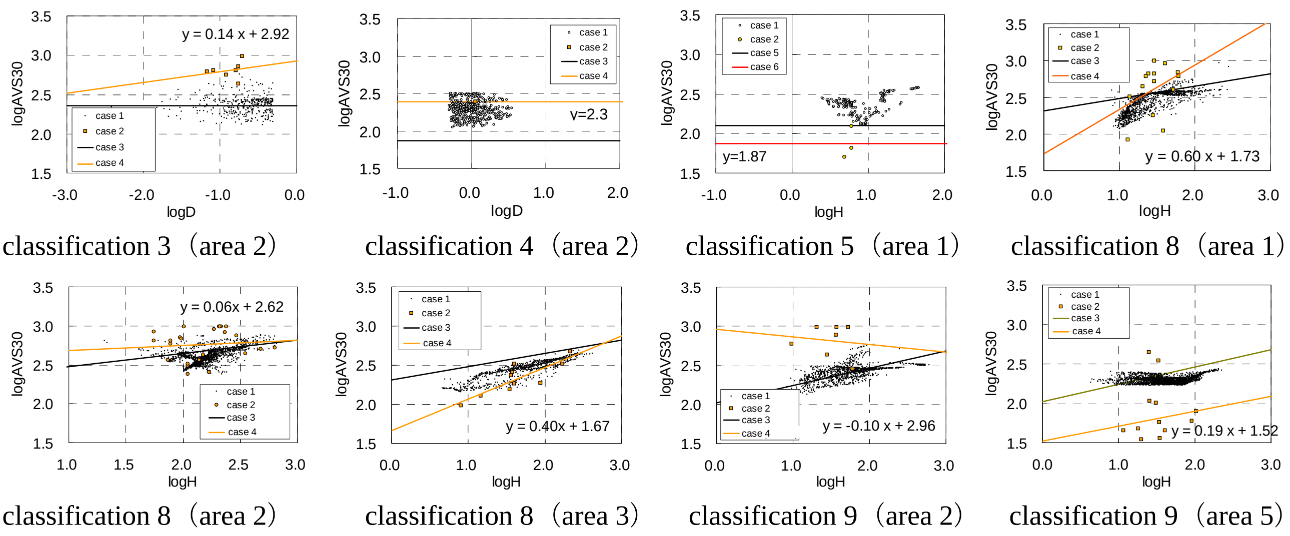

Figure 6 The relationship between the altitude corresponding to the microtopography classification of Hokkaido or the distance from river and AVS30. Case 1 is AVS30 of interpolation points, case 2 is AVS30 of observation sites, case 3 is regression line of each microtopograpy classification on table 2, case 4 is regression line of each area in microtopography classification, case 5 is average of AVS30 of observation sites of each microtopography classification, case 6 is average of AVS30 of observation sites of each area in microtopography classification.

Table 3 The re-determined coefficient list of microtopography classification

microtopography classification	a	b	c	N	N (by inverse of equation 4)	N (by interpolation)	By the way
1)Reclaimed land	2.60	0	0	0	0	**1**	5
2)Artificial transformed Land	-2.26	0	0	0	0	0	5
3)Delta, Back Marsh(D≦0.5)	2.36	0	0	7	**28**		4
Area 2	2.92	0	0.14		**7**		2
4)Delta, Back Marsh(D＞0.5)	1.87	0	0	**3**	20		4
Area 2	2.39	0	0		**1**		4
5)Natural Levee	2.10	0	0	1	**10**		4
Area 1	1.87	0	0		**3**		4
6)Valley Plain	2.57	-0.03	0	0	4	**528**	3
7)Sand Bar, Dune	2.35	0	0	0	2	**16**	4
8)Fan	2.31	0.17	0	21	**40**		2
Area 1	1.73	0.60	0		**14**		2
Area 2	2.62	0.06	0		**23**		2
Area 3	1.67	0.40	0		**9**		2
9)Loam Plateau	2.04	0.21	0	10	42	**8191**	3
Area 2	2.96	-0.10	0		7		2
Area 5	1.52	0.19	0		13		2
10)Gravel Plateau	2.66	0	0	0	**14**		3
11)Hill	2.25	0.24	0	6	**33**		3
12)Other Geom. Units	2.39	0.10	0	14	51	**42751**	3
13)Pre-Tertiary	2.84	0	0	0	2	**148**	4

way 1･･･deciding regression coefficients by AVS30
way 2･･･deciding regression coefficients by AVS30 data of inverse equation 4
way 3･･･deciding regression coefficients by interpolation data
way 4･･･average data、slope is zelo
way 5･･･the other

Table 3 shows the re-determined coefficient list of microtopography classification. At classification 8, in the case of determining the regression coefficients from all observation sites data of Hokkaido, the regression coefficient b was 0.17. However, in the case of determining the regression coefficients from the observation site data in area 3, 0.4 of the gradient can be obtained by the distribution of the relationship between the altitude and AVS30. Therefore, it was considered the appearance of the tendency that the area has by selecting appropriate area, the influence of regional characteristics is being represented. The distribution of the ARV was constructed by the re-determined regression coefficients. Figure 7 shows the distribution of the re-determined ARV. As the result, it is seen that the tendency of the distribution of the ARVs became approximately similar to that of the ARV obtained by the strong motion records shown in Figure 2 on the alluvial fan classification in the vicinity of Tokachi-Shicho. As the other area, it seemed that the change of the tendency of the distribution of the ARV in the vicinity of Nemuro-Shicho, and it became more similar to that of the ARVs obtained by the strong motion records. But there are also other areas that are not similar, more detailed investigation issue is being left.
Figure 8 shows the ARV on the alluvial fan classification in the vicinity of Tokachi-Shicho. The ARVs considering microtopography classification are lower compared with the ARVs using strong motion records. But the ARV re-determined regression coefficients by detailed area became similar to the ARV using the strong motion records. The ARV obtained by the method of Matsuoka and Midorikawa is within the range of the standard deviation of estimated scattering, but when the median of the ARV was compared with the ARV estimated by the proposed method, the ARVs estimated by the proposed method are closer to the ARV obtained by the strong motion records.

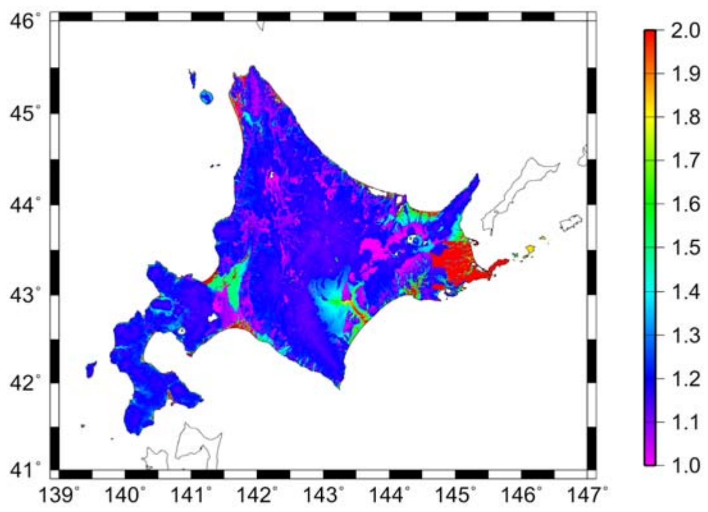

Figure 7 The distribution of re-determined ARV

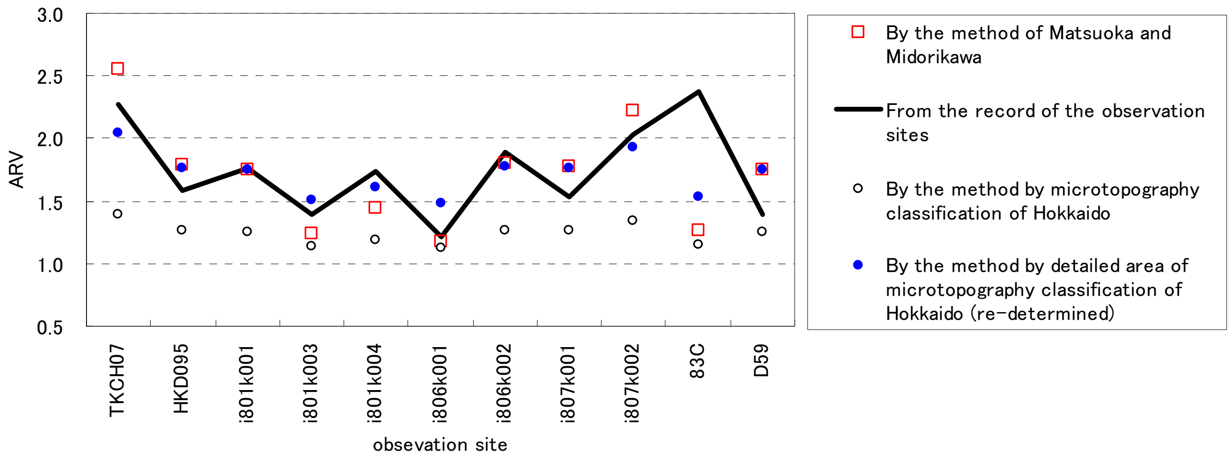

Figure 8 The ARV on the alluvial fan classification in the vicinity of Tokachi-Shicho

5. CONCLUSIONS

(1) Coefficients used for estimating the ARV considering microtopography classification of Hokkaido were determined. Using strong motion record of 2003 Tokachi-Oki earthquake, the regression coefficients used for estimating the ARV were determined. In addition, the method of Matsuoka and Midorikawa was employed to determine regression coefficients of ARV of Hokkaido by microtopography classifications based on the Digital National Land Information. The results were obtained to have similar tendency when compared to the distribution of the ARV previously acquired from strong motion records of Hokkaido. However, issue was found that the ARVs on the alluvial fan in the vicinity of Tokachi-Shicho were lower than expected.

(2) In order to consider the regional characteristics to influence the regression coefficients, detailed area within the microtopography concentrated were selected, and the regression coefficients for estimation of ARV were re-determined. As the result, the distribution of relationship between the altitude and AVS30 in the selected alluvial fan area can be clearly identified, and the distribution of the re-determined ARVs gave similar tendency to the distribution of the ARVs by the strong motion records on the alluvial fan in the vicinity of the Tokachi-Shicho . Furthermore, when comparing the ARV of the observation sites with the ARVs estimated by detailed area of the microtopography classification on alluvial fan in the vicinity of Tokachi-Shicho, similar results were observed.

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