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GROUND MOTION AND SITE EFFECT IN SOUTHWESTERN AREA OF HOKKAIDO, JAPAN

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ABSTRACT

The present paper aims to get the regional distributions of maximum acceleration on the ground for a few cities and towns around and near the Bay of Uchiura in southwestern area of Hokkaido, Japan. The fault model of 1968 Tokachi-oki(offshore) earthguake was used as one of future coming earthguake and the upper and lower underground structures were estimated by means of boring survey data and others. The regional distributions of maximum acceleration were consistent with the intensity distributions due to 1968 Tokachi-oki earthquake and 1993 Hokkaido-nanseioki(southwestern-offshore) earthquake. From the above fact, we can say that the shaking characteristics of ground depend chiefly on the upper ground structure for the case of intermediate or long distance earthquakes. The present result is expected to be useful for making countermeasures against earthquake disasters due to coming earthquakes.

KEYWORDS

Microzonation, Maximum acceleration, Intensity, Earthquake disasters
Maximum earthquake motiom, Zoning map, Seismic risk, Hazard map

1. Introduction

In order to mitigate and prevent earthquake disasters, it is essential to evaluate earthquake motions due to a future coming earthquake and the accompanying damages and to make the countermeasures. Uchiura bay area(Fig. 1), which is located at southwestern part of Hokkaido, is regarded as the kernel area for maritime, high technolgy and travel industry in 21 century, and a few feasibility studies for possibility of future growth have been started(Fig. 2). There are a few active volcanoes in the area and it is located at the intermediate distance from subduction zones in Pacific ocean and Japan sea(Fig. 3). In the past, Uchiura bay area has experienced a little severe intentity and damages by 1952 Tokachi-oki eq., 1968 Tokachi-oki eq. and 1993 Hokkaido-nanseioki eq..

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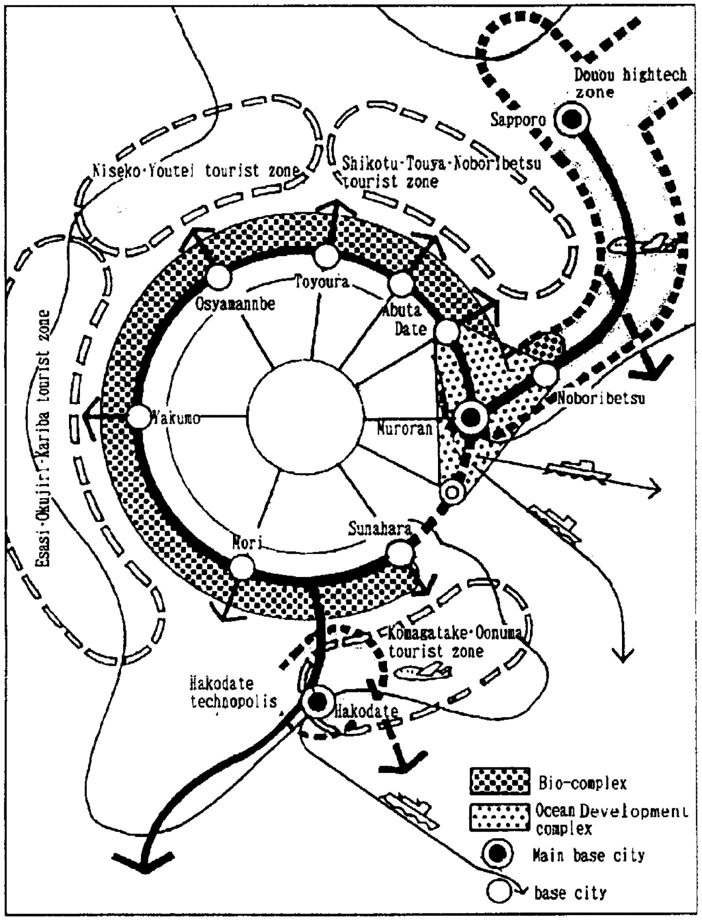

Fig. 2 Development of Uchiura bay area in 21 century.

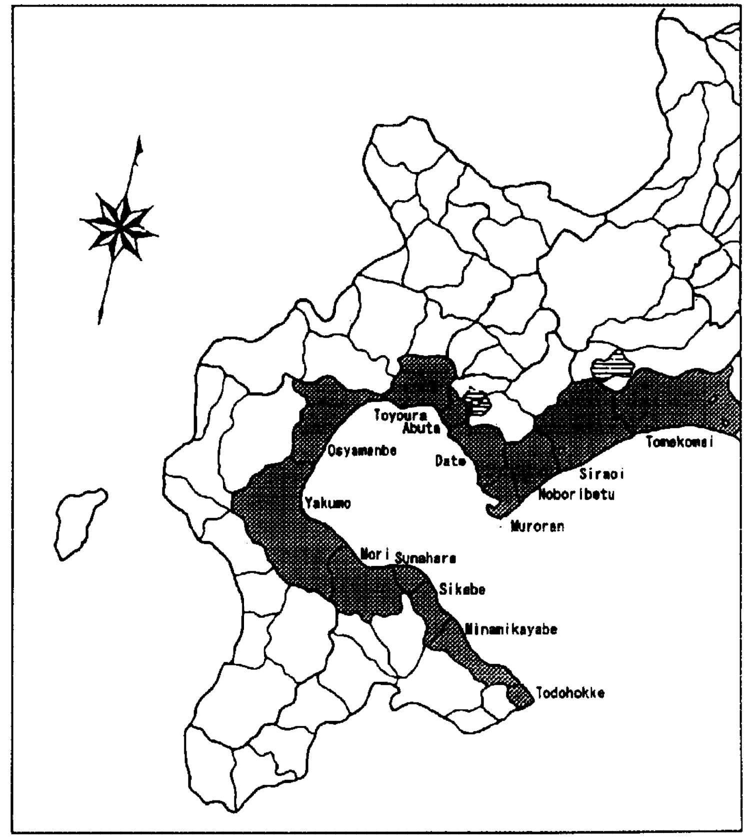

Fig. 1 Location of Uchiura bay area.

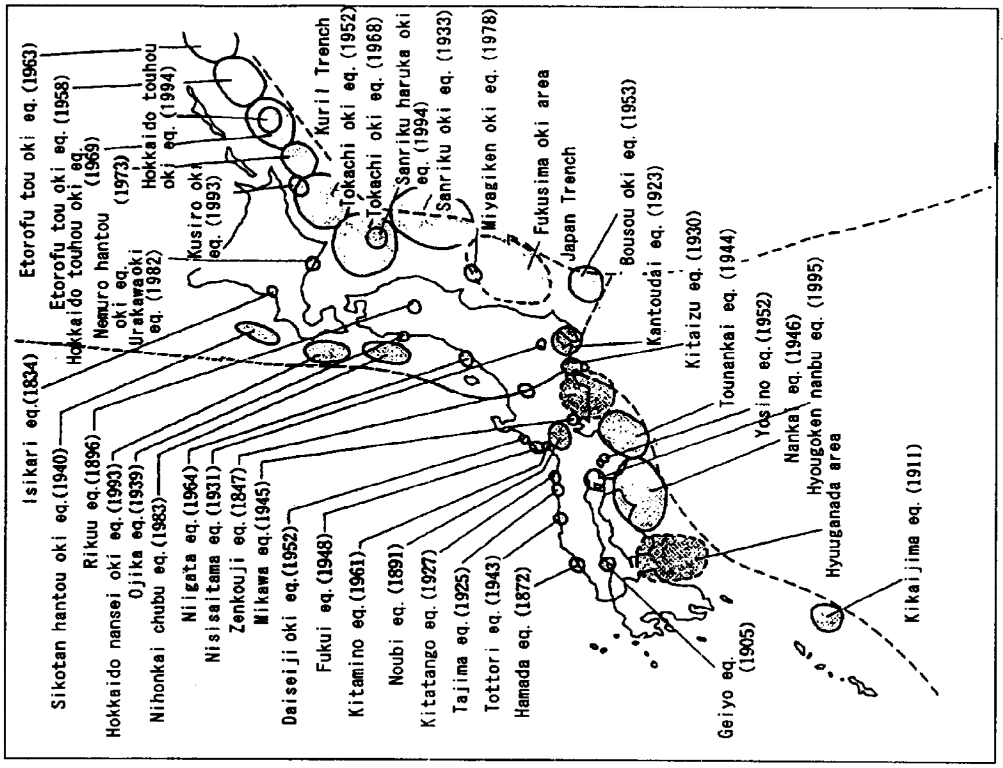

Fig. 3 Seismic activity in and around Hokkaido and Japan.

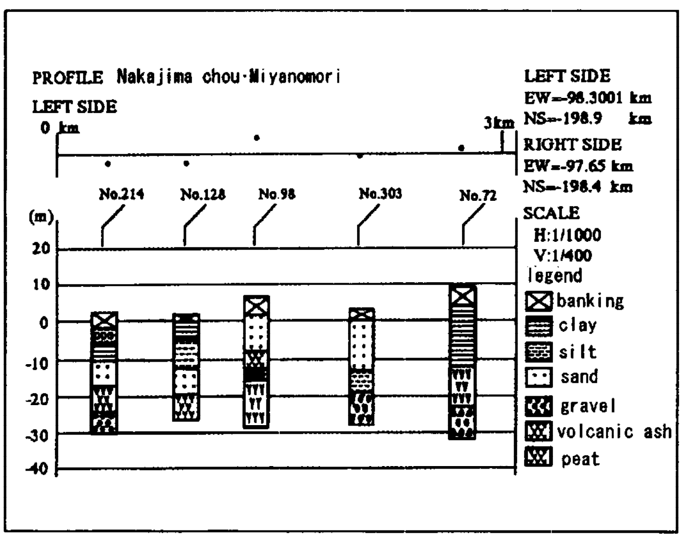

FIg. 4 An example of geological section of soft ground.

The purpose of this report is to obtain the regional distribution of maximum acceleration or intensity depending on upper and lower underground structures and a future coming eq.. The number of sites for which analysis could be made was not alway sufficient large because of lack of boring survey data for estimating the upper underground structure. Therefore, a new way to assume the upper underground structure has been devised.

2. SEISMIC ENVIRONMENT OF HOKKAIDO AREA

2-1. Seismic activity

The seismic activity in and around Hokkaido is, in the frist place, due to huge earthquakes along the subduction zone (Kuril and Japan trenches) between North American plate and Pacific Ocean plate. In this region, we have 1952 Tokachi-oki eq. (M8.2), 1968 Tokachi-oki eq. (M7.9), 1973 Nemuro-hantooki(peninsula offshore) eq. (M7.4), 1993 Kushiro-oki(offshore) eq. (M7.8), 1993 Hokkaido-tohooki(eastern offshore) eq. (M7.5) and 1994 Sanriku-harukaoki(far offshore) eq. (M7.5). The second active seismic zone is along the boundary between Eurasian plate and North American plate in Japan sea, where 1940 Shakotan -hantooki(peninsula offshore) eq., 1964 Oga hantooki(peninsula offshore) eq., 1983 Nihonkai-chubu(central part) eq. (M7.7) and 1993 Hokkaido-nanseioki eq. (M7.8) were occurred.

Moreover, in the land area of Hokkaido and in the Sea of Okhotsk, big and small earthquakes have been occurred and various damages were given to many cities. Fig. 3 shows seismic activity in and around Hokkaido and Japan.

2-2 Examples of earthquake damages in southwestern area of Hokkaido

(1)Damages due to 1968 Tokachi-oki eq. (May 16, 1968, M7.9, 40.7° N, 143.6° E): heavy damages in southern part of Hokkaido and Tohoku district, the killed 52, the injured 330, completely destructed buildings 673, partially destructed buildings 3004, height of Tsunami, 3-5m at Sanriku coast and 3m at Erimo cape of Hokkaido, JMA intensidy from Ⅲ to Ⅴ. (2)Damages due to 1993 Hokkaido-nanseioki eq. (July 12, 1993, M7.8, 42.8° N, 139.2° E):heavy damages in Tsunami in Okujiri island, southern part of Hokkaido and northern part of Tohoku district, the killed 201, the missing 29, the seriously injured 66, the slightly injured 239, completely destructed buildings 590, half and partially destructed buildings 3811, heavy damages of road, harbor facilities and life system, height of Tsunami, 21-3m at Okujiri island and 7.5-0.8 m at western coast of Hokkaido, JMA intensity from Ⅲ to Ⅴ.

3. COMING EARTHQUAKE AND GROUND STRUCTURE

3-1. Assumpsion of a coming earthquake.

The author proposed the following attenuation relation which was made by using strong motion records of 40 earthquakes (M5.3-7.9) observed at Muroran harbor during period 1968-1987.

$$\log A = 0.54M - 2.33\log(R+30) + 3.33 \qquad (1)$$

(A:maximum acceleration (cm/sec^2), R:epicentral distance(km), M:magnitade)

We can estimate the maximum acceleration to be 145 cm/sec^2 in Muroran harbor by the above equation for the assumed Hidaka-chubu(central part) eq., which is one of assumed eq. by Hokkaido. On the other hand, the earthquake which brought the southwestern area of Hokaido fairly huge damages in the past is 1968 Tokachi -oki eq. and it's maximum acceleration on the ground surface was 251 cm/sec^2. In the present report, therefore, 1968 Tokachi-oki eq. is assumed as a coming earthguake in the future. The source parameters of Tokachi-oki eq. are as follows(Kanamori(1971), Kikuchi and Fukao(1985)): length of fault 150 km, width of fault 100km, slip 4.1m, inclination of fault plane 20°, rise time 1.0 sec, rupture veloaity 2.5km/sec, S wave velocity on the wave path 3.5 km/sec and starting point of rupture: center of the upper edge of the fault.

3-2. Lower underground structure

The underground structure is divided into the upper part, what is called soft ground and the lower part, the part of ground between the bottom of upper ground and the base rock, the S wave velocity of which is 3 km/sec. The lower underground structure is assumed being based on deep boring survey implemented at hot spring areas, which gives thickness of layers, kind of rocks of each layer, density of each depth and the volume percent of rocks, and P and S wave velocities of rocks measared by geophysical way (Society of Exploration Geophysicists of Japan, 1989). Table 1 is an example of lower underground structure at one site.

3-3. Upper underground structure

The S wave velocity and density of soft ground were estimated by the following equations (Taniguchi(1989) and Maruyama(1986)):

$$V_s=64.964H^{0.228}N^{0.193}(1.000 \text{ for silt, } 1.134 \text{ for sand, } 1.221 \text{ for sandy gravel})(1.000 \text{ for Alluvium, } 1.221 \text{ for Diluvium}) \tag{2}$$

$$\rho=1.685N^{0.027}H^{-0.018}(1.000 \text{ for clay, } 1.014 \text{ for silty sand, } 1.064 \text{ for fine sand and } 1.122 \text{ for gravel})(1.000 \text{ for Alluvium, } 1.041 \text{ for Diluvium}) \tag{3}$$

where V_s :S wave velocity(m/s) , ρ :density(g/cm ^{3}), H:depth(m), N:N value , kind of soil and age at each depth .

Fig. 4 shows an example of geological section of soft ground. The area was divided into lots of segments of 500m × 500m, to each of which one model of the upper underground structure was given. However, the model of underground structure can not always be given to all segments because of lack of boring data. We asked to ten cities and towns which are located around and near Uchiura bay whether or not they have collected and compiled boring data in their jurisdiction and wished to allow for us to utilize the data . Unfortunately, only a few cities sent the data to us.

4. EVALUATION OF MAXIMUM ACCELERATION ON THE GROUND SURFACE

The maximum acceleration on the ground were calculated by the way of Kobayashi and Midorikawa(1982) being based on source parameters of the coming earthquake and upper and lower underground structure of the site . Firstly, the earthguake motion on the base rock is obtained by synthesizing seismic waves on a lot of small elements on the fault plane and secondly, the maximum acceleration on the ground are calculated by multiplying earthquake motion on the base rock and amplification characteristic of the underground structure.

Two controversial points must be investigated. The first point at issue is whether or not the size of 500m × 500m segment has such sufficient resolution as to show detailed regional distribution of maximum earthquake motion for a city area . Fig. 5 shows examples of variations of maximum acceleration within a 500m × 500m segment. The variations of accelerations within one segment are 110-146 gal in the example of Abuta area and 103-209gal in Muroran area. From the above examples, we have to recognize that to describe shaking level of 500m × 500m segment by only one maximum acceleration is not alway sufficient from the viewpoint of ideal microzonation. The second point at issue is that even when we have divided the area into 500m × 500m segments , we can not always get boring data for all of segments.

In order to solve the above points, we devised a way to estimate the upper underground structure for one site which is unknown but essential for calculating maximum acceleration because the site is a critical point

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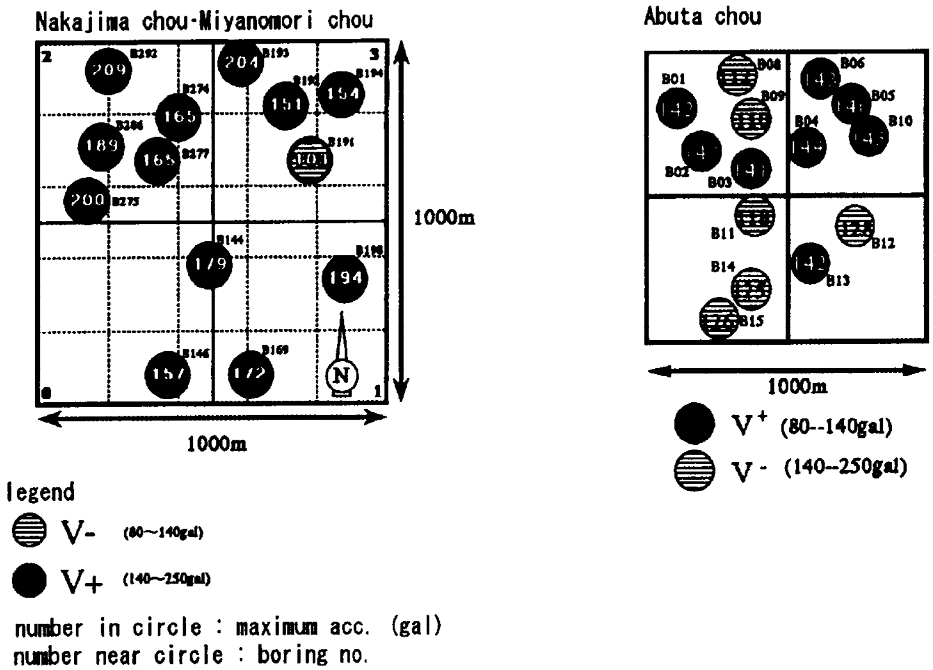

Fig. 5 Variations of maximum acceleration within 500m × 500m segment. (a) Abuta area and (b) Muroran area.

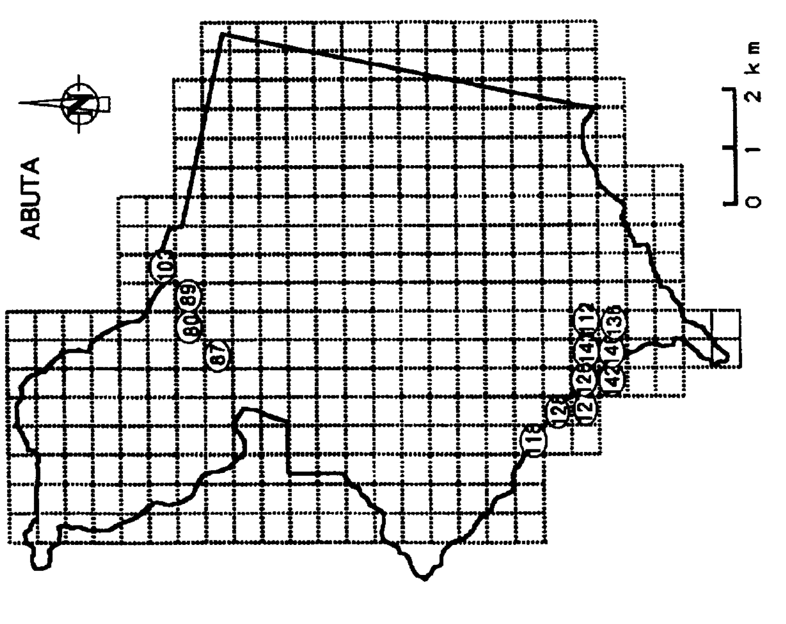

Fig. 6 An example of regional distribution of maximum acceleration for Abuta area.

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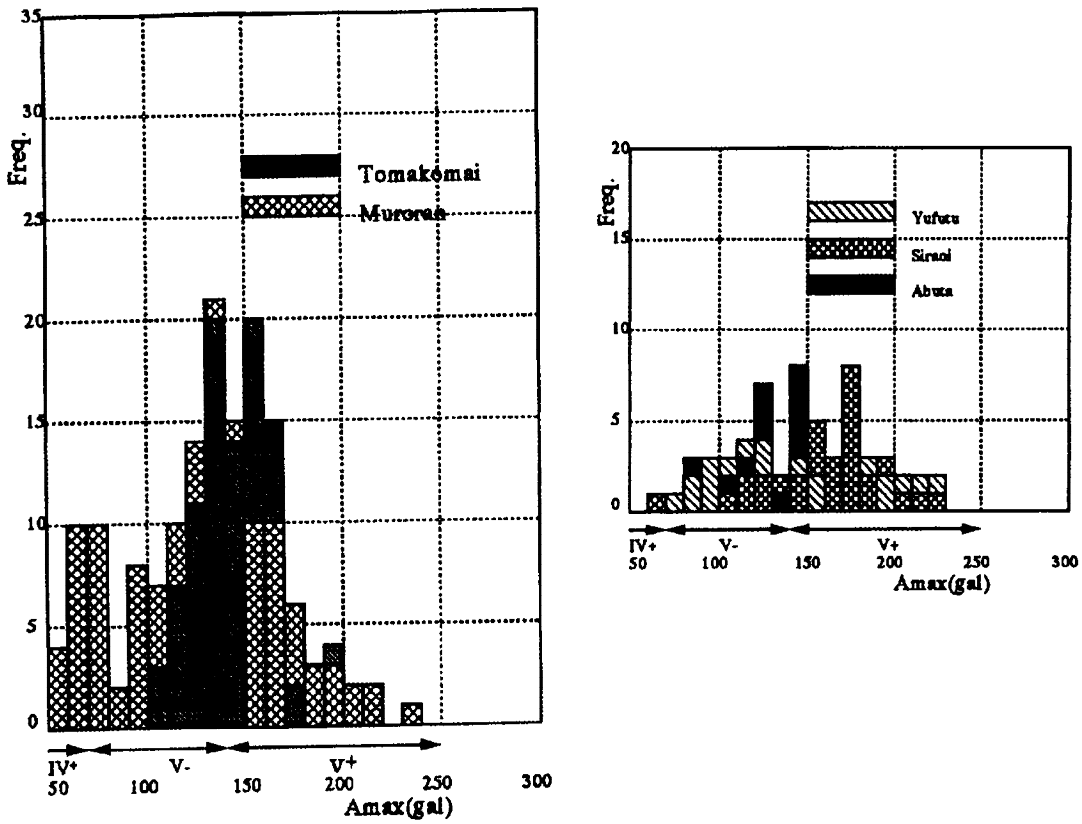

Fig. 7 Frequencies of maximum acceleration in a few areas of southwestern Hokkaido.
(a) Tomakomai and Muroran areas. (b) Abuta , Yufutu and Siraoi areas.

Age	Layer	Density (g/cm³)	S wave vel. (m/s)	Thickness of layer(m)
Pleisocene	Kamichowa	1.85	450	20
	Soukaishu	1.95	520	70
	Fresh andesite	2.34	1610	50
	Rerukomabecu	2.17	1600	120
Neogene	Kitayuzawa (Pliocene)	2.00	1600	400
	Soushunaigawa (Miocene)	2.55	1840	350
	Osarugawa (Miocene)	2.59	1840	850
Paleogene	Base rock	2.79	2300	∞

Table. 1 An example of lower underground structure (density(g/cm ^{3}), S wave velocity(m/sec) and thickness of layess (m)).

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for detailed zoning, by interpolating boring data of adjacent sites. This procedure have been done by a computer software for geological analyses. Fig. 6 is an example of regional distribution of maximum acceleration for Abuta area and Figs. 7 show frequenccy distributions of maximum acceleration in a few areas of southwestern Hokkaido.

5. RESULTS AND DISCUSSIONS

The reqional distributions of maximum acceleration on the ground were obtained for a few areas around and near Uchiura bay of Hokkaido on the basis of focal parameters and upper and lower underground structure. This must be very important data for mitigation and prevention of earthquake disarters. In this report, especially, considerations were given how to utilize deep boring survey data and data base of elastic wave velocities of rock for estimating the lower underground structure and how to use boring data of soft ground for the upper underground structure. More considerations were given to differences of maximum acceleration among close points. The followings are results and comments from the present analyses . (1) It is recommended that in order to estimate lower underground structure, deep boring survey data , geological data and data base of elastic wave velocity of rock are taken into considerations. (2) Differences among maximum acceleration in 500m × 500m segments are large in one time and small in other time. Some examples concerning to this fact have been shown in this report. We have to learn that it is very important for ideal microzonation how to establish the size of segment, that is, the size must be determined from area to area. (3) In order to make exact microzonation , it is essential to collect and compile more and exact boring survey data , and cooperation among research institutes and administrative agencies are recommended. (4) Uchiura bay area is expected to develop very much in 21 century and the level of seismic hazard seems to be fairly high. The countermeasure for the area , therefore, must be made as soon as possible.

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