EARTHQUAKE DAMAGE AND SUBSOIL CONDITIONS AS OBSERVED IN CERTAIN DISTRICTS OF JAPAN

by

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In the past earthquakes, there has been recognized the considerable difference in the extent of the seismic hazard according to the subsoil conditions. Recently, in Japan, the studies are being made on the seismic damage from various standpoints, such as, (a) the geological study in the seismic area with the purpose of making clear the dependence of the seismic damage upon the geologic formation, and on the other hand, (b) studies are being continued in the characteristics of the seismic waves which relate directly to the response of the structures built on various kinds of ground. The characteristics of the waves are strongly influenced by the superficial soil layers. Therefore, the seismic (or dynamical) character of the ground is essentially needed in the study of the seismic damage.

Extensive studies have been made by the Subsoil Research Team of the Earthquake Research Institute of the Tokyo University in the cities of Tokyo, Osaka, Yokohama, Kawasaki Nagoya, Ichinomiya, Sakata and in the district of Totomi. Results of these studies have been already published elsewhere.

In this paper, introductions will be made of the recent studies made by the Research Team, mostly of the distribution of the seismic damage of the wooden dwelling houses which was caused by the earthquake that occurred in 1944, that is the Tonankai earthquake.

Another problem in this paper is the seismic zoning map which was constructed by the Research Team recently for the city area of Osaka.

(A) Relation between the subsoil conditions and the distribution of the seismic damage percentages of the wooden dwelling houses in the district of Totomi.

As mentioned above, the earthquake occurred on December 7, 1944 ,centering in the Kumanonada , the southeastern Pacific side of Japan. The damage was mostly limited in three Prefectures, Shizuoka, Aichi and Miye.

The present study was carried out by Mr. S. Ooba under the guidance of Professor H.Kawasumi and other members of the Subsoil Research Team mentioned above and the result has been already made public[1].

In the following paragraphs the results of this study will be described briefly.

For convenience, the sub-village (Koaza) and sub-town (Ku) were divided into several groups such that each group has 20-30 or 60-70 houses. We have experienced fortunately that in each group thus divided, the geological condition of the ground is practically uniform. The sub-towns and sub-villages in such conditions are about 98 % of the total number of 1,150 which belong to one city (Hamamatsu) and other 116 towns and villages.

Relative intensity of the earthquake can be inferred from the difference of the dynamical effect on the same kind of the structure. As the area is fairly densely populated, the dwelling house is one of the most prevalent structure of which construction is of no much difference within a certain limited area. Therefore, it may be natural that the percentage of the damaged houses shows the relative intensity of the earthquake . If we take, therefore, the area properly as the group mentioned above, we can obtain mean intensity of the earthquake for known subsoil condition.

As the certain ambiguity might occur between the definitions of totally collapsed housed and half-collapsed housed, only the totally collapsed houses were referred in this study.

In Totomi ,the damage due to the earthquake was severest, notwithstanding the fact that the epicentral distance there was not shortest. The distance was between 150 and 220 km according to the Central Meteorological Observatory. The total number of totally destroyed houses in the whole disturbed area was reported to be 26,130, of which the Province of Totomi shared 5,183 amounting to nearly one-third of the total.

The percentage of totally collapsed housed is shown in Fig.1, in which contours (isoseismals) of 80, 60, 40 20 % are drawn. We can see from this figure,, marked clustering of the places of high percentage of damage such as up to 100 % in the drainage basins of the Rivers Ootagawa and Kikukawa, while along the river courses of Tenryu and Ooi, the circumstances are quite different. From these intensity-distributions we cannot find out any direct relation between the intensity of the earthquake and the epicentral distance. Further,we cannot expect such a particular pattern of energy radiation from the seismic origin. Therefore, another causes of distribution of the seismic damage must be considered. As there can be seen a close relation between the shapes of the distribution curves and the geological features , we may conclude that such distributions as shown in the figure is mainly due to the subsoil conditions existing there.

From these points of view, the area in question was divided into 10 regions as in the following.

(1) Ootagawa Basin (C_o, G_o)
(2) Kikugawa Basin (C_k)
(3) Alluvial area at the Foot of the Makinohara Plateau (C_m)

(4) Alluvium near the Lake Hamana (C_h , S_h)
(5) Tenryu Plain (G_t)
(6) Ooigawa Fan (G_i)
(7) Gravel deposit are around the Mt.Ogasa (G_g)
(8) Coastal Sand -dune area (S_c)
(9) Diluvial Plateau (D)
(10) Rocky Foundation (R)

The symbols C, S, G and R indicate clay, sand, gravel and rock foundations respectively, while the subscripts o, k, m, h, t, i and g denote the regions mentioned above respectively.

Markedly high damage was experienced in the basin where clayey marsh deposits extended near the low grade river course, while on the diluvial plateau with a gravel layer or along high grade river courses with gravel beds, the damage was decidedly slight as in the Tenryu and Ooigawa regions.

In the coastal sand-dune area, the damage was intermediate, and on the rocky ground, the damage was negligible.

The mean percentages of damage of dwelling wooden houses for various geological formations are as follows :

For C,	percentage	= 26.1
G,	"" ""	= 1.4
S,	"" ""	= 3.5
(D+R),	"" ""	= 0.2

(A') Further studies of the subsoil conditions in the district of Totomi

More precise studies were made by the Subsoil Research Team, of the seismic damage in the district of Totomi by the methods of seismic prospecting, geological surveys by using the data for borings and the mechanical analyses of the soil-samples,etc.,especially for the Kikukawa and Ootagawa areas.

The classification of the ground was tried from the results of observation of the micro-tremors at various places in these areas, but it is not the time to make public the results of this observation.

The seismic prospecting was carried out in five villages,of which the Villages Nishigasaki and Tsuchihashi had percentages of the damaged houses of more than 80, in Ikemura the percentage was 40 -60, in Village Chihama it was 20 % and in Kikukawa Town it was practically zero.

Through the seismic prospecting, the underground formation at these places were made clear as shown in Fig.2.

Generally speaking, the superficial layer has a velocity of 500 m/sec., and the second layer has a velocity of 1,200 - 1,400 m/sec., and the third layer has a velocity of 1,900 - 2,050 m/sec.

It will be seen that the formation of the ground near the surface is never simple and there exist some irregular boundaries between the second and the third layers. This is the tendency which can be seen generally at all places where the seismic prospecting was made.

In Nishigasaki, for example, the second layer of a velocity of 1,260 m/sec. is acculumated in a shape of basin, with depths varying from 2 to 25 m. In such places as Nishigasaki, the damage was considerably different in its extent, if the damage were investigated more precisely. It may be thought that the thickness of the layer influences the extent of the damage.

It has been already found in the 1923 earthquake, the rate of damage of wooden houses in Yokohama became greater as the thickness of the alluvium increased. Very large rate of damage was found at the places where the thickness of the alluvium was, thirty metres or more. This will be a similar fact also prevailing in the Totomi district.

In Chihama Village, discontinuity may be deducible in the underground formation, while in other places, that is, Ikemura, Tsuchihashi and Kikukawa, the change in the thickness of the stratum is comparatively small.

Soils in the Kikukawa and other areas were carefully investigated mostly on the following points.

1) Vertical distribution of soils in boring-holes
2) Water content
3) Mechanical analysis by means of sieves.

Among these items, a great deal of effort was made in the mechanical analysis. Eighty-four samples of soils were taken up at thirty-five places ; nine samples were taken at one place in the maximum (Nishigasaki).

Automatically moving sieves were used of which meshes are 4, 9, 20, 35, 60, 140 and 200 corresponding to the apertures of 4.760, 2.000, 0.840, 0.420, 0.250, 0.105 and 0.074 mm respectively.

Accumulation curves were constructed for the samples of soils and are shown in Fig.3.

In this figure, we can divide the curves approximately into two kinds, that is, the curve showing a comparatively large percentage of grain size of about 250 microns and that showing a large percentage of grain size of about 100 microns. The former corresponds to the soil which is rather sandy and the latter to the soil which is rather silty.

Roughly speaking, at the place where the sample of soil was silty, the seismic damage was comparatively large, whilst at the place where the sandy sample was taken, the damage was slight.

(B) Classification of ground in the City of Osaka

For these years, efforts have been made to apply the micro-tremor method to the judgement of the kind of the ground. Typical records and the frequency curves of the micro-tremors are shown in Fig.4.

In the following paragraphs, a brief explanation will be given about the method of classification of the ground from the results of the observation of micro-tremors.

It has been known that the predominant period, the mean period and the largest (maximum) period of the micro-tremor do not change their values whenever they are measured. Here, we mean by the largest period the period which is largest among those of the waves registered at a certain point by our seismograph having a natural period of oscillation of 1.0 second. The physical meaning of this largest period is not yet made clear, but it is convenient to use this period practically in the classification of the ground.

It is also known that the value of mean period agrees with that of the predominant period. Therefore, we may use the mean period instead of the predominant period.

In the classification of the ground, a diagram as shown in Fig.5 is proposed to be used. As can be seen in this figure, the value of the maximum period is plotted against the average period determined at various points. Border-lines are drawn in parallel to the ordinate and the abscissa of this diagram to divide the space into four kinds, 1, 2, 3 and 4 . If a point drops in a space corresponding to kind 2, the ground represented by this point may be classified as kind 2. If a point lies in an intermediate space between 2 and 3 , the ground represented by this point belongs to kind 2 - 3.

Observation of the micro-tremors was carried out by the Subsoil Research Team in the City of Osaka, selecting the points of observation as shown in Fig. 6.

The classification of the ground so far made for these points are shown in Fig. 7.

It will be seen in this figure, the most of the designated kinds of the ground is higher than 3, that is to say, the ground is generally soft.

In the approximate centre of this figure, there can be seen a region of kind 2 - 3. The ground in this region is comparatively hard in Osaka. This region lies near Oogimachi,Sakai-suzi and Tanimachi and Abeno.

It has been found that the up-town of Osaka which extends from the Osaka castle to the Tennoji was found to be necessarily of the good or hard ground. The ground designated in this region was mostly 3 or 3 -4 .

Very soft ground which corresponds to kind 4 can be seen near the Bay of Osaka. and others. The places were once marshy and reclaimed.

The contours in full lines indicate the elevations of the ground and those in broken lines the depths of the gravel layer which is so hard that the foundations of most of the buildings are rested upon it.

It is clear that where the ground is good, the depth of this gravel layer is small. In the region of kind 2 - 3 mentioned previously, the depth is about 5 m, while in the region of kind 4, it is larger than 25 m.

As a reference, the standard for designation of the districts where the ground is soft and bad will be given in the following. — Ministry of Construction Notification No.1074, July, 1952.

1) Alluvium consisting of soft delta deposits, top-soil, mud, or the like(including heaping up, if any0, whose depth is about 30 m or more.

2) Land obtained by reclamation of a marsh, muddy sea bottom etc., of which the depth of the reclaimed ground is about three meters or more and where thirty years have not yet elapsed since the time of reclamation.

Coefficient of design (horizontal) seismic force acting on the wooden buildings which stand on soft and bad ground, shall be not less than 0.3. (Building Standard Law Enforcement Order, Article 88, November, 1950)

Comparative observations of earthquake and microseism in Osaka

Comparative observations of earthquakes and microseisms were made at various places in Osaka.

We mean by the microseism the pulsatory motion of the ground of which periods are usually longer than those of the micro-tremors. The period has a value of several seconds.

In Fig.8, the results of the observations are shown.

The ratio of amplitudes increases with increasing thickness of the superficial soil layer. It is of interest that the same tendency can be seen in the cases of the earthquake and the microseisms. Therefore, in the classification of the ground, the observation of the microseisms is also useful as the micro-tremors above cited.

Bibliography

1) S. Ooba : Study of the relation between the subsoil conditions and the distribution of the damage percentage of wooden dwelling houses in the Province of Totomi in the case of the Tonankai earthquake of December 7th, 1944. Bull.Earthq.Res.Inst., No.1, Vol.35, 1957.

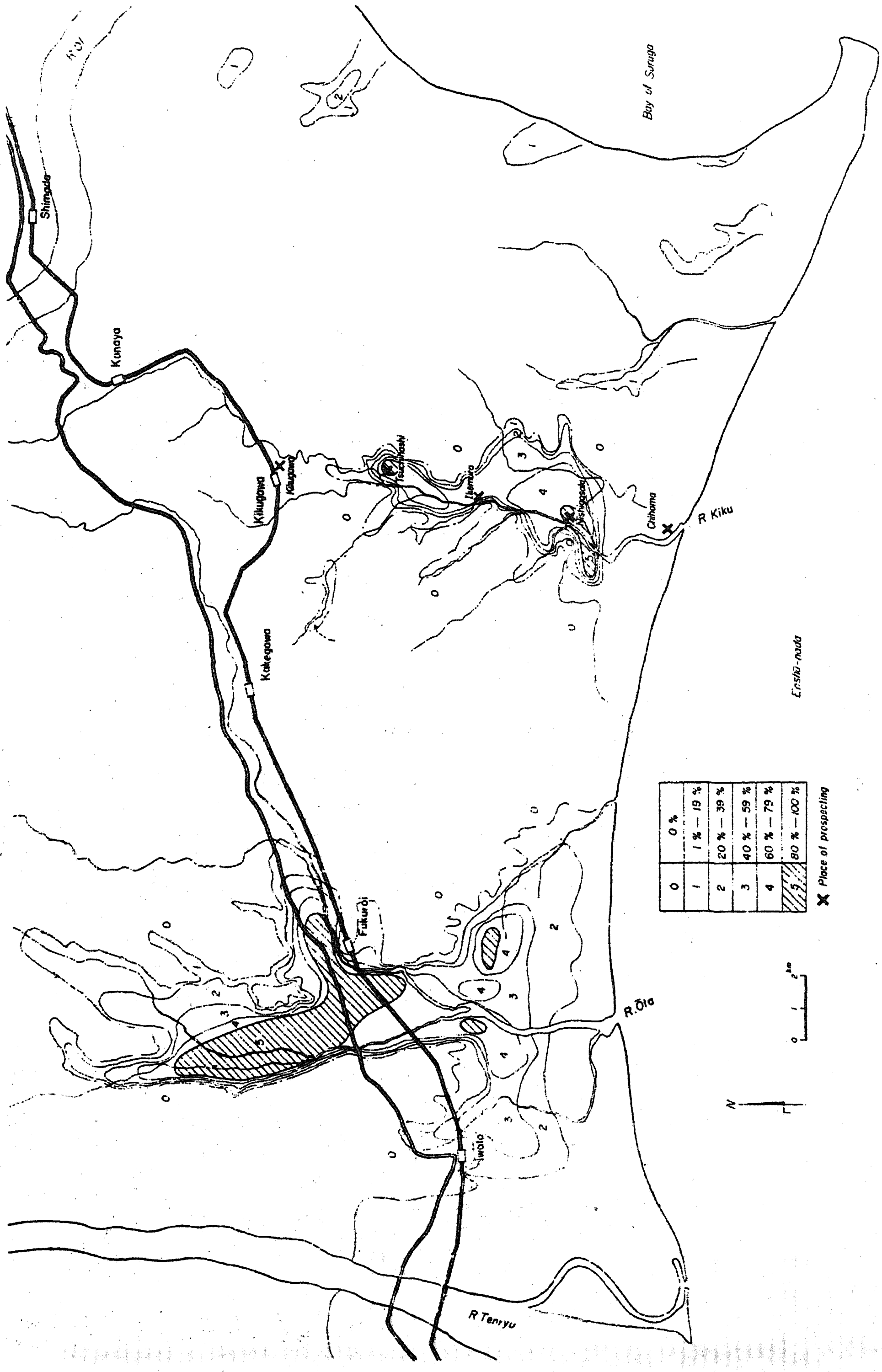


Fig.1. Distribution of damage of dwelling houses in the District of Totomi.

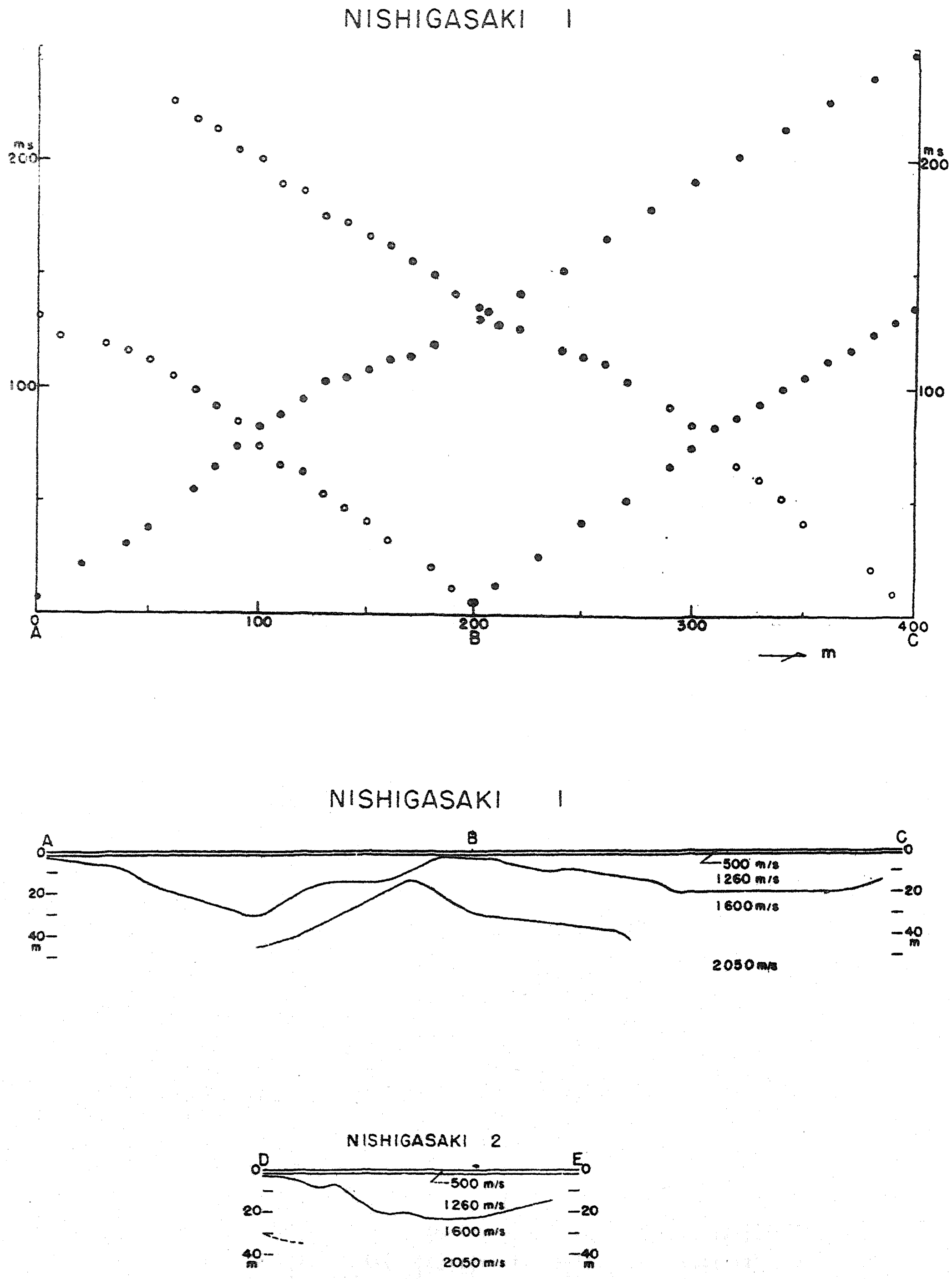
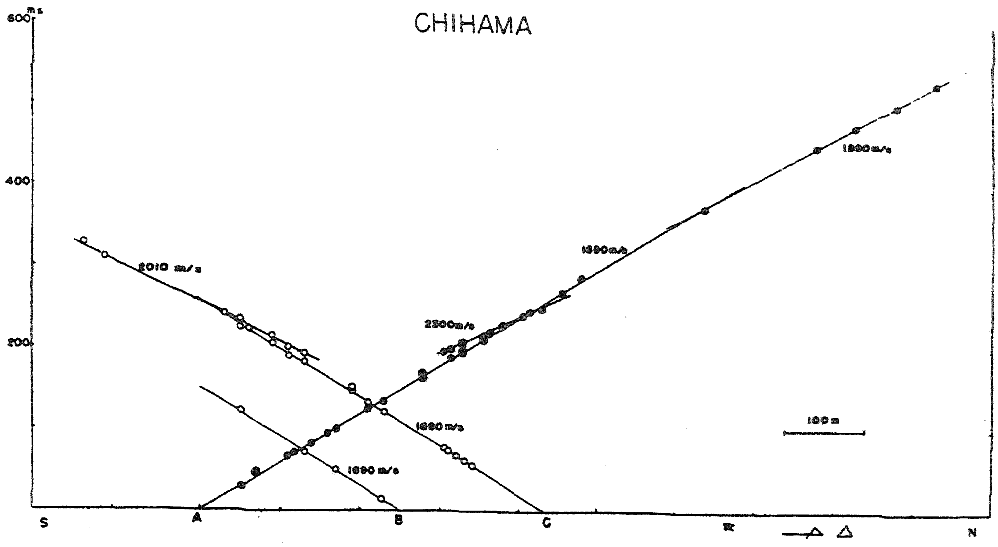


Fig. 2-(1). Travel-time curves and profils obtained by seismic prospecting.



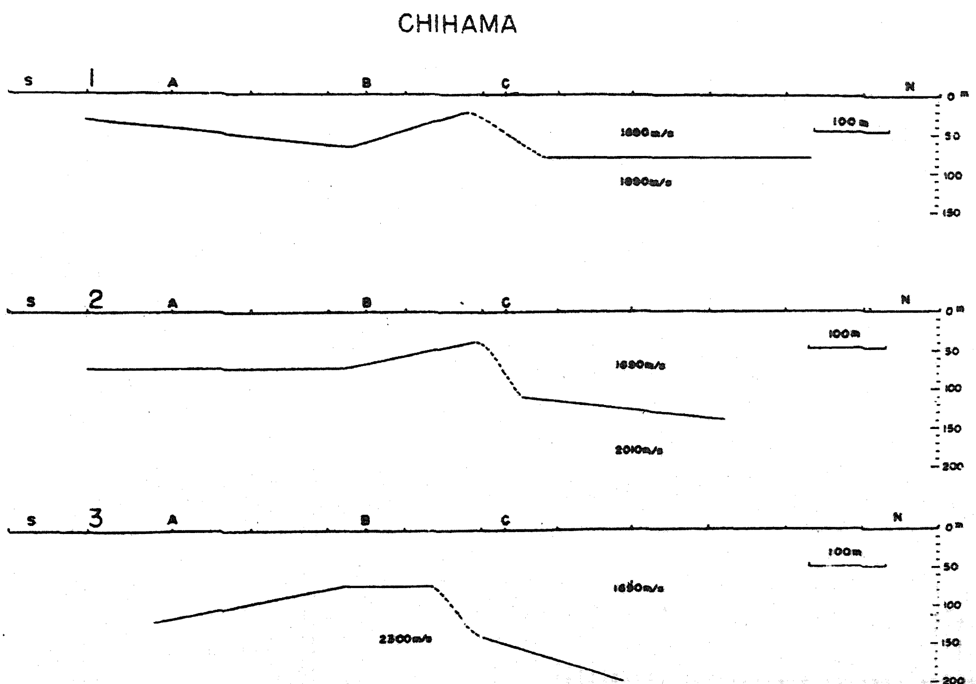


Fig. 2-(2). Travel-time curves and profils obtained by seismic prospecting.

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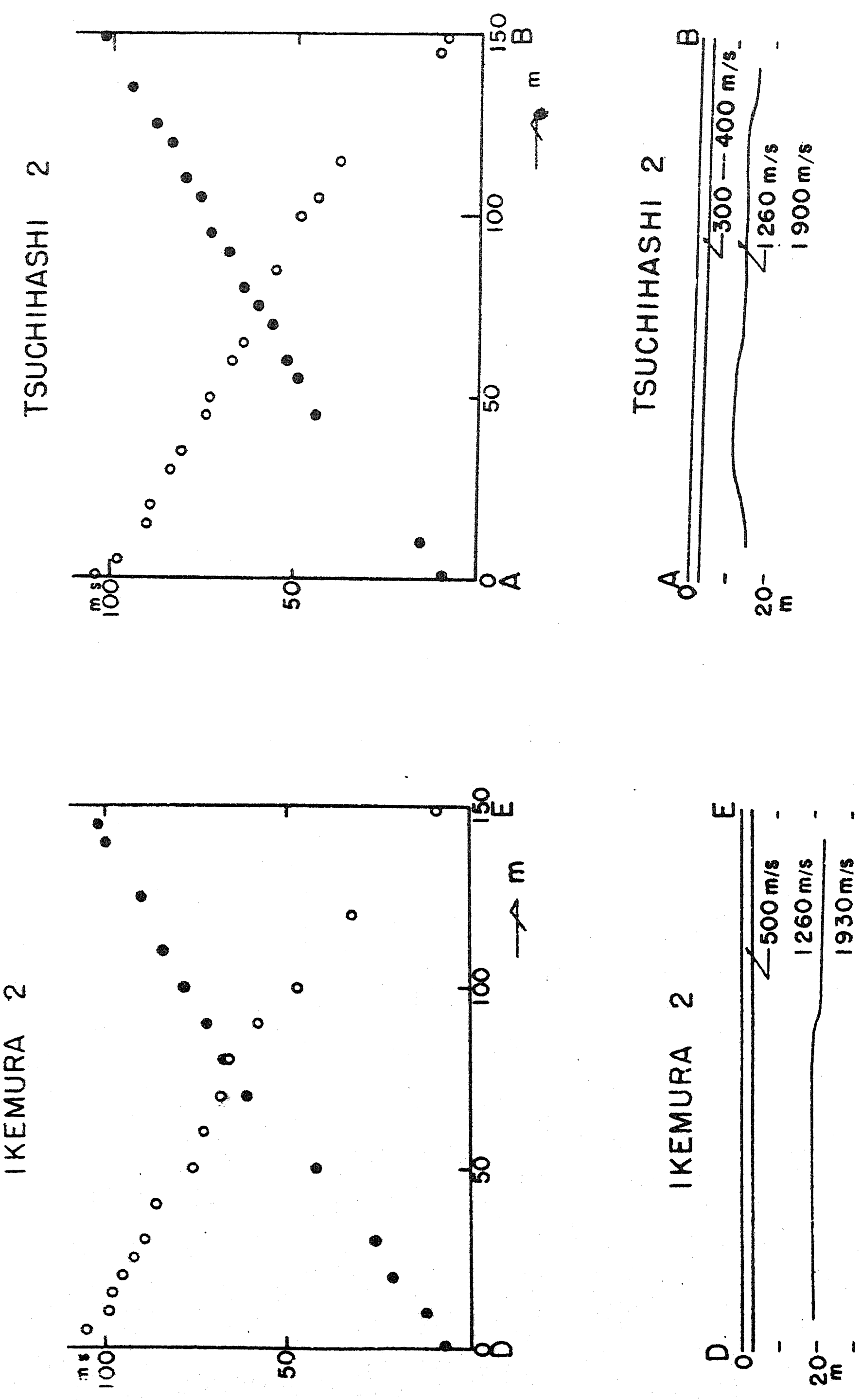

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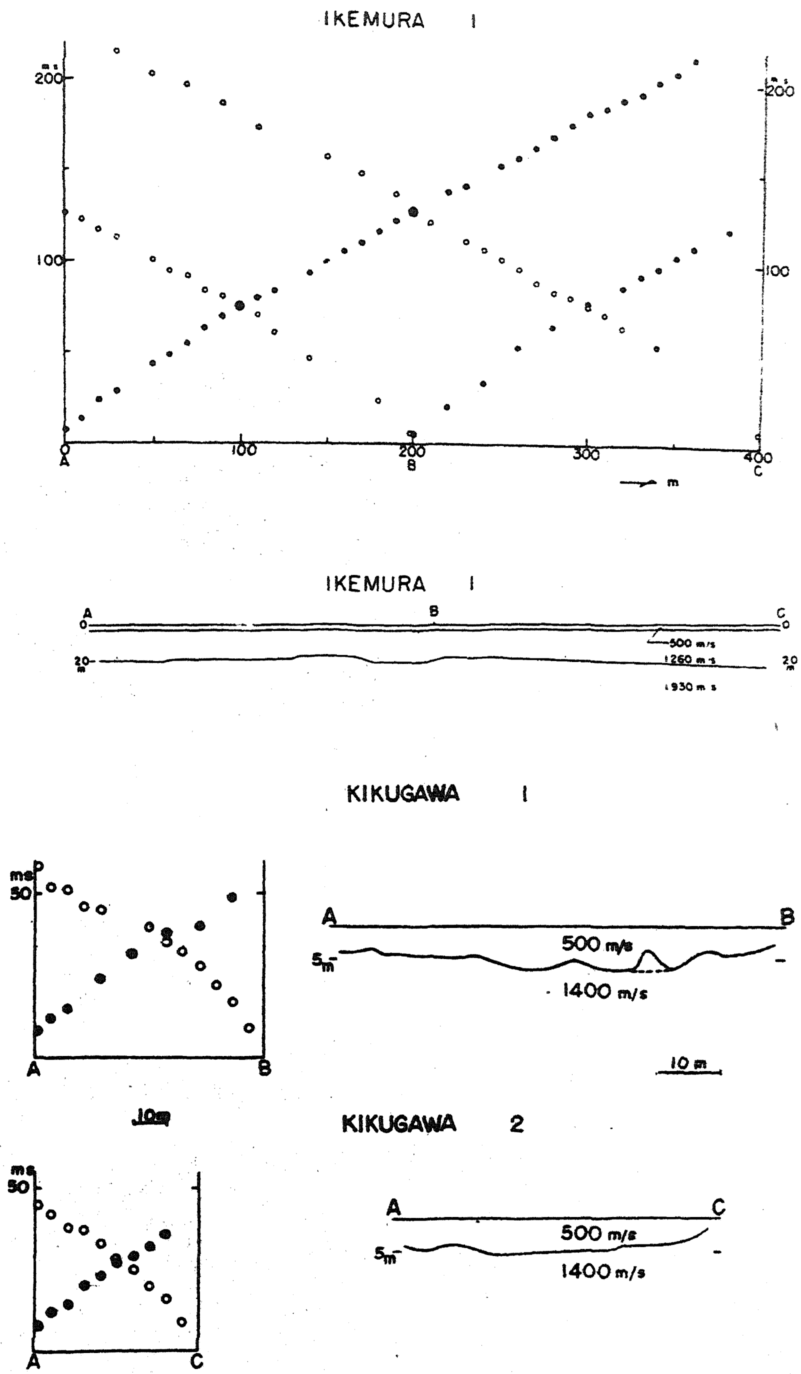

Fig. 2-(4). Travel-time curves and profils obtained by seismic prospecting.

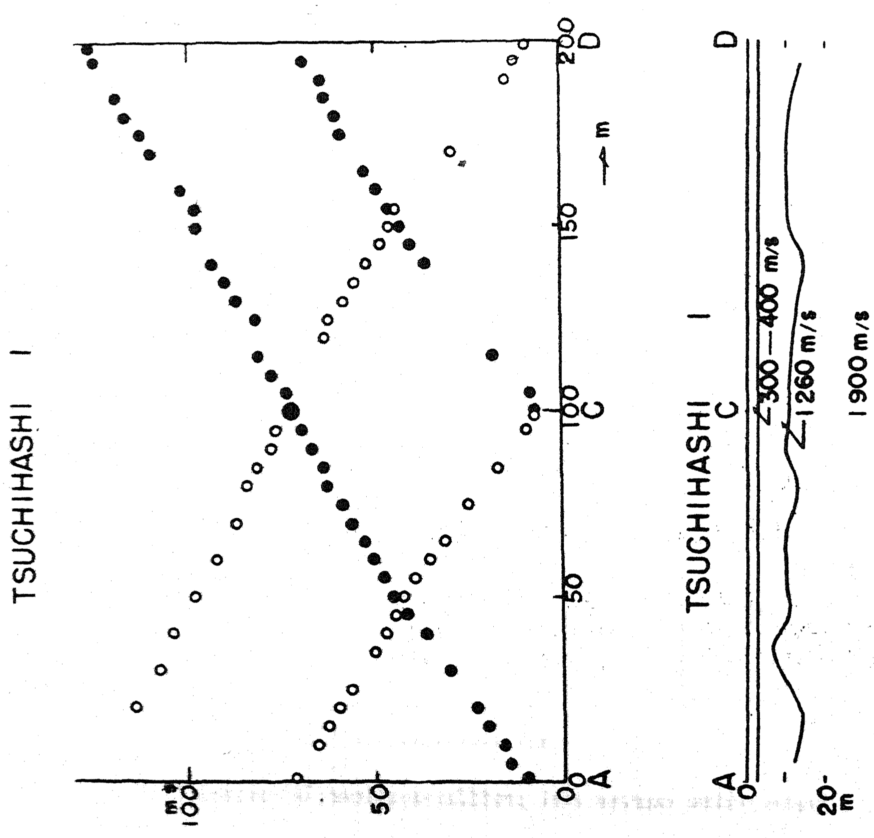

Fig. 2-(5). Travel-time curves and profiles obtained by seismic prospecting.

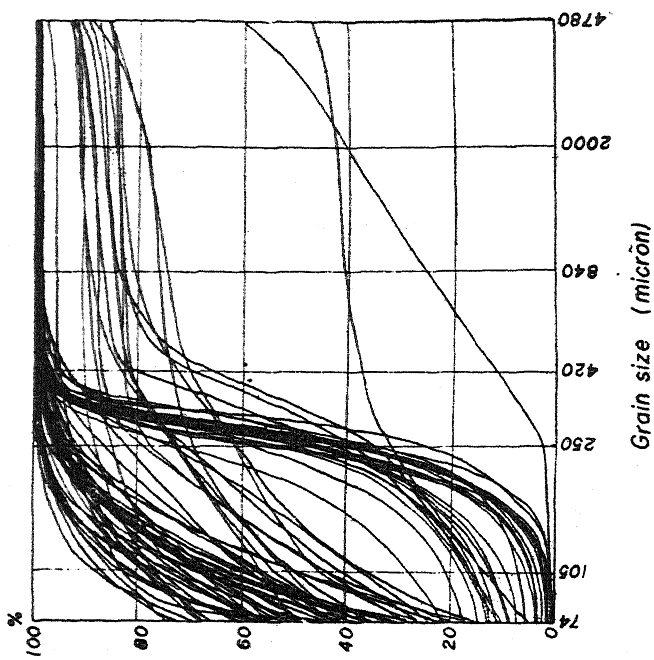

Fig. 3. Accumulation curves.

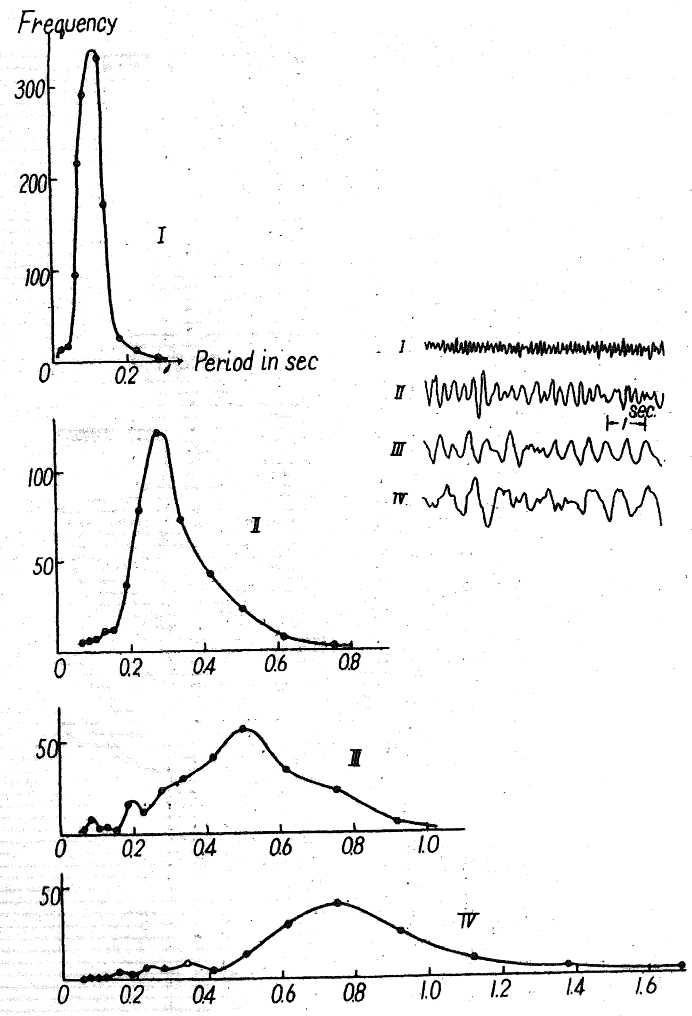

Fig. 4. Typical records and frequency curves of micro-tremors.

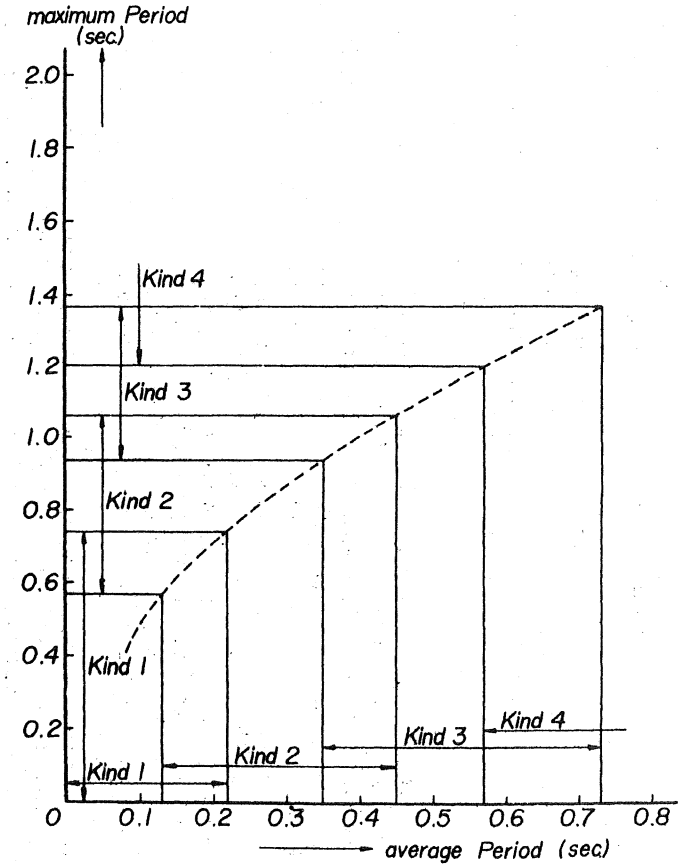

Fig. 5. Diagram proposed in the classification of the ground. (After K. Kanai.)

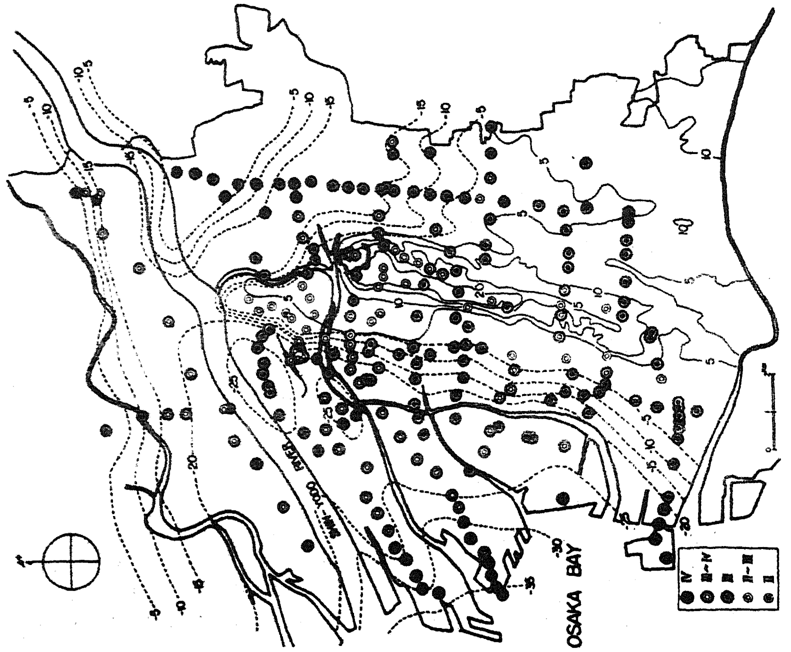

Fig. 7. Kinds of ground designated in Osaka.

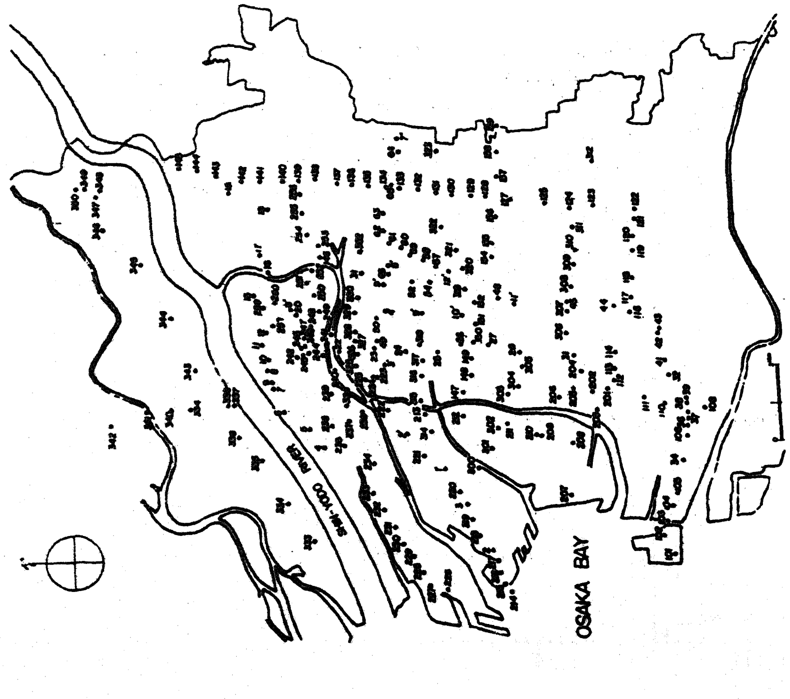

Fig. 6. Points of observation of micro-tremor in Osaka.

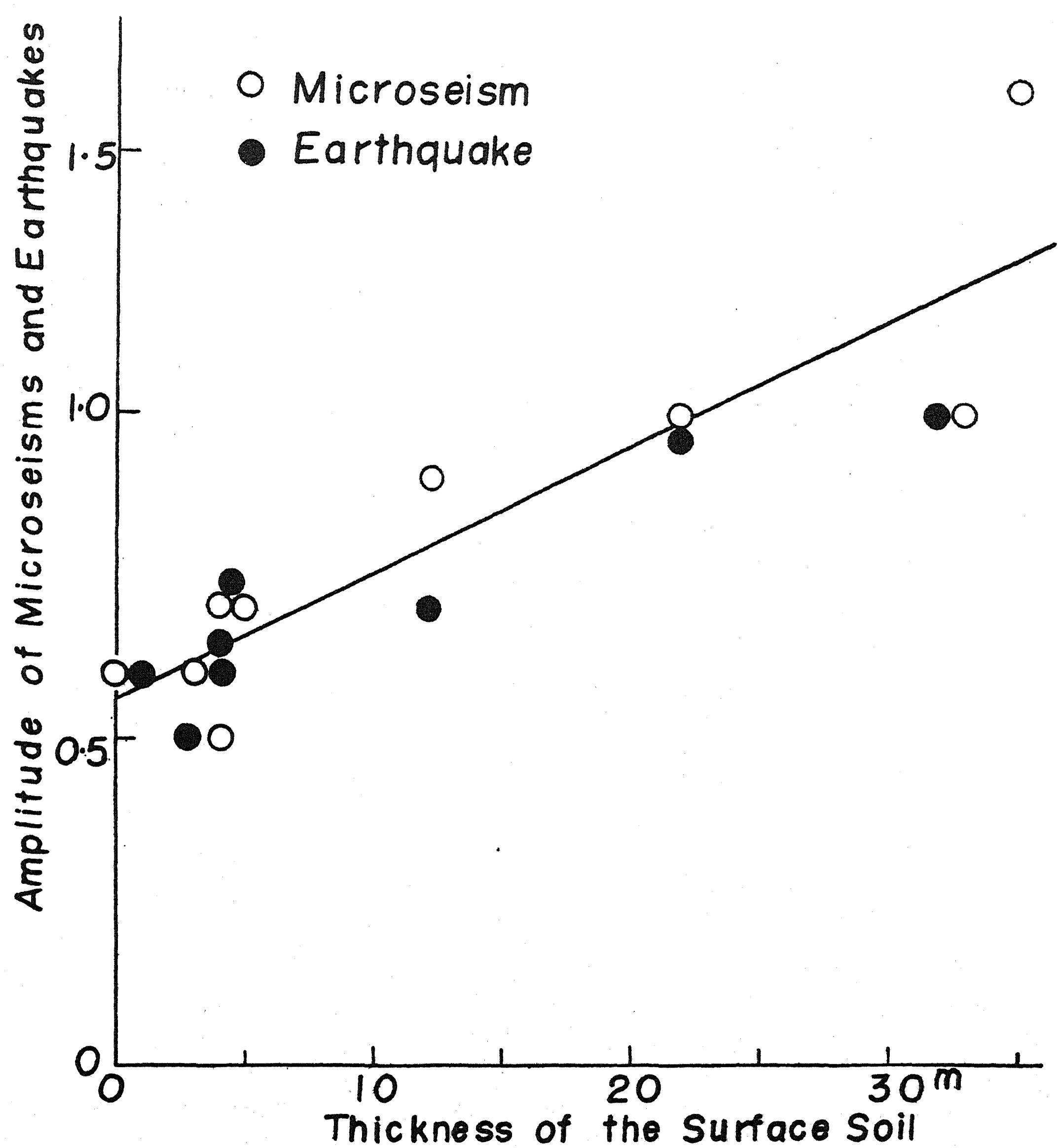

Fig. 8. Relation between the thickness of Surface Soil at Various Stations in Osaka and the Amplitudes of Microseisms and Earthquakes observed there. (Values at Kowan Station have been taken to be unity).