New Strong Motion Array Observation System of the Public Works Research Institute

by

Koichi Yokoyama [1], Keiichi Tamura [2], Hideki Sugita [3], Riki Honda [4] and Akira Chiba [4]

ABSTRACT

Strong motion records obtained by dense instrument array are essential for research of ground motion, including propagation characteristics of seismic wave, effect of the ground condition, etc.

The Public Works Research Institute (PWRI), Ministry of Construction, has been conducting array observation since 1980 in four areas around Suruga Bay: Sagara, Yaizu, Numazu and Matsuzaki. In 1996, these arrays were replaced with a new system and in 1997, new arrays were additionally installed in five areas. Two arrays were deployed in Kobe (Hyogo Prefecture), and one in each of Odawara (Kanagawa Prefecture), Makuhari-Narashino (Chiba Prefecture) and Tateyama (Chiba Prefecture).

In the new system, all accelerographs are connected with the workstation in PWRI by digital telephone (ISDN) line. All accelerographs are under the control of this workstation, and various functions such as acquisition of strong motion data, check of the status of the accelerographs are operable on-line from PWRI.

This paper describes the new array observation system, including major functions of the system, site condition of the arrays, configuration of accelerometer deployments.

Key Words : Strong Motion,
Array Observation

1. INTRODUCTION

Rationalization of seismic design method requires accurate estimation of the earthquake ground motion. Research of the ground motion characteristics has progressed widely in the last several decades. In spite of such achievements, research of earthquake ground motion still has many unsolved topics.

One of such topics is the spatial variation of ground motion, especially that in the space with the order of several kilometers or less. Investigation of the damage of the past earthquakes or analyses of the strong motion records revealed that ground motion is considerably different at different points. In the 1995 Hyogoken Nanbu Earthquake, it was also observed that there were cases in which structures near the severely damaged structure were little damaged and that difference of the ground motion is considered as one of major reasons. Such spatial variation of ground motion is essential for rational seismic design because it determines the difference of the ground motion that should be considered in the seismic design of large scale civil engineering structures, such as long span bridges, tunnels, pipelines, etc.

As is widely recognized, for the research of the ground motion characteristics, strong motion records are indispensable, and for the research of spatial variation of ground motion, strong motion records obtained by instrument arrays are essential.

The importance of the dense array for strong motion monitoring is widely recognized. The Executive Committee of the International Association for Earthquake Engineering decided in 1977, to hold the International Workshop on Strong Motion Earthquake Instrument Arrays, which was

---

1) Director, Earthquake Disaster Prevention Research Center, Public Works Research Institute, Ministry of Construction, Asahi 1, Tsukuba-shi, Ibaraki-ken, 305 Japan,

2) Head, Ground Vibration Division, ditto.

3) Head, Earthquake Disaster Prevention Technology Division, ditto.

4) Research Engineer, Ground Vibration Division, ditto.

also consented by the International Association of Seismology and Physics of the Earth's Interior (IASPEI). The workshop was held in 1978 in Hawaii[1], and in advance of that workshop, the Steering Committee of Earthquake Engineering of Japan Science Council organized the Workshop on Strong Motion Earthquake Instrument Arrays to prepare the master plan of array observation.

After the 1995 Hyogoken Nanbu Earthquake, importance of array observation of strong motion is reaffirmed. Necessity of array observation is mentioned in the reports such as, Proposal on Earthquake Resistance for Civil Engineering Structures (Vol.1) by the Japan Society of Civil Engineers[2], the first report of the Special Committee for Investigation of Hanshin-Awaji Great Earthquake Disaster, Japan Science Council[3], etc.

Considering such situation, the Public Works Research Institute started the installation program of dense accelerograph array for strong motion observation, and during the period of 1981 to 1985, PWRI deployed four arrays in Shizuoka Prefecture (Sagara, Yaizu, Numazu and Matsuzaki)[4][5]. Since then PWRI has been conducting the strong motion observation by those dense arrays.

In 1996, PWRI renewed those existing four arrays, and in 1997 it additionally installed five new arrays: two Kobe Arrays (West and East) in Hyogo Prefecture, Odawara array in Kanagawa Prefecture, Makuhari-Narashino Array and Tateyama Array in Chiba Prefecture.

Locations of nine arrays are shown in Fig.1. Each array consists from about ten observation stations and there are 97 stations in total. (Some stations have more than one observation point and, therefore the total number of observation points is 103.) All accelerographs are connected to the workstation installed at PWRI with a digital telephone line and they are under the control of the workstation.

2. NEW ARRAY OBSERVATION SYSTEM

Fig.2 illustrates the typical equipment of an observation station. One station has an observation house, which contains the data transmission controller, and one to six accelerometers (acceleration sensors). The data transmission controller conducts time calibration every second using the information of time received through the GPS antenna. All accelerometers are set underground at various depths and, in general, one of the accelerometers of each observation point is set at the depth of 2m. The data transmission controller is connected to the workstation with the digital telephone (ISDN: Integrated Services Digital Network) line.

When accelerometers detect ground motion, the data transmission controller stores the strong motion data on the non-volatile memory, and sends alarm signal and the data to the workstation at PWRI. On the workstation, addition of the data to the database, plot of distribution of the recorded peak accelerations on the map, and calculation of acceleration response spectra and Fourier spectra, etc. are performed.

Maintenance of the observation system is also automatically conducted, as is scheduled, under the control of the workstation. The workstation can check the status of accelerometers by sending test signals through the data transmission controller. It also can check the condition of the data transmission controller, such as backup battery, available memory capacity, accuracy of clock etc.

3. SITE CONDITION OF ARRAYS

In this section, site condition of each array is described briefly.

3.1 Sagara Array[6]

Sagara Array is located in Shizuoka Prefecture and in the west of the Suruga Bay. The area around the Suruga Bay, which was severely damaged in the 1854 (Ansei era) Tokai Earthquake (Inferred magnitude is 8.4), is alluded to have a high possibility to be hit by a large earthquake. This is because in the Suruga Bay runs the Suruga Trough, which is shown in Fig.1. The Suruga Trough is considered to be seismically active because the

Philippine Sea Plate and the North America Plate collide there.

Configuration of observation points is shown in Fig.3(a) and the cross section of the ground along the line A-A' is shown in Fig.3(b). (In the figure of the ground cross section, the accelerometers installed at the depth of 2m are not explicitly shown to make the figure simple. It is also the same with the following figures of other arrays except Tateyama Array.) The installation depths of the accelerometers are listed in Table1.

Most of the area is covered with soft alluvial layers and the bedrock is Sagara Group. The surface layers consist mainly from the deposits of the Hagima River. They are soft and their shear wave velocity is about 100m/sec. The bedrock has the shear wave velocity of about 400m/sec. Depth of the bedrock varies gradually along the section A-A' and therefore it is expected that the effect of the variation of ground condition is observed.

There are ten observation points and the distance between observation points is less than a few hundred meters. Additional accelerometers (hereinafter, accelerometer installed at the depth deeper than 2m will be referred to "additional accelerometer".) are installed at observation points Nos.4, 5, 8 and 10. The deepest accelerometers at observation points Nos.4, 5, 8 and 10 are all installed in the bedrock layer.

3.2 Yaizu Array [7]

Yaizu Array is located in the northeast of Sagara Array and it also faces the Suruga Bay. Configuration of observation points is shown in Fig.4(a), and the cross section of the ground along the line A-A' is shown in Fig.4(b). The installation depths of the accelerometers are listed in Table 2.

The surface layer consists mainly from deltaic sediment and back-marsh sediment. It is soft and its shear wave velocity ranges from 100 to 200m/sec. The layer deeper than 25m is the alternation of sand and clay. Shear wave velocity increases gradually and reaches 600m/sec at the bedrock, basaltic layer. The bedrock layer is found at the depth of 10m at the observation point No.1, which indicates the variation of the depth of the bedrock layer.

In this array, the accelerometers are mainly installed at the shallow layer and additional accelerometers are installed at observation points Nos.5 and 9. The deepest accelerometer at No.9 is at the depth of 113m and reaches the bedrock. Observation point No.1 has one accelerometer at the depth of 10m, in the bedrock, and not equipped with the accelerometer at 2m deep.

3.3 Numazu Array [8]

Numazu Array also faces the Suruga Bay on its south end. Configuration of observation points and the cross section of the ground along the line A-A' are shown in Figs.5(a) and (b) respectively and the installation depths of the accelerometers are listed in Table 3.

The Numazu array ranges from the foot of Mt. Ashitaka to the coastal line facing the Suruga Bay. The mountainous area is covered with a soft loam layer and a stiff gravelly layer exists underneath. The area between the Tokaido Shinkansen Line and The Tokaido Line is covered with an alluvial layer, which is about 10-15m thick and consists of the organic soil with shear wave velocity of less than 100m/sec. It is underlain by relatively stiff alluvial layers with shear wave velocity of 200m/sec or larger. Under these alluvial layers exists a stiff diluvial gravelly layer whose shear wave velocity is about 500m/sec.

There are 14 observation points in Numazu Array. Observation points Nos.2, 7, 8 and 9, for example, are about only 100m apart. Observation points Nos.3, 10, 11 and 13 are equipped with additional accelerometers and the deepest accelerometers at these observation points are all installed in the diluvial gravel layer. Accelerometer of the observation point No.14, which does not have a accelerometer at the depth of 2m, is set in the gravel layer.

3.4 Matsuzaki Array [9]

Matsuzaki Array is located in the west coastal area of the Izu Peninsula, facing the Suruga Bay. Configuration of observation points and the cross section of the ground along the line A-A' are shown in Figs.6(a) and (b) respectively and the installation depths of the accelerometers are listed in Table 4.

Matsuzaki Array spreads from the top of Mt. Ushibara to the north end of the plain area. The observation points Nos.1 to 5 are deployed on the steep slope of Mt. Ushibara. The difference of the elevation between points Nos.1 and 5 is about 150m. It is expected the effect of the topographical condition will be observed. The slope is covered with relatively soft alluvial soil, and the accelerometers are installed both at the depth of 2m and in the stiff layer underneath.

The plain area is mainly covered with the alluvial soil, that is, stream deposits of the Naka River and marine deposits. Shear wave velocity of the alluvial soil is about 150m/sec.

There are 11 observation points in this array. The additional accelerometers are installed at observation points except Nos.7, 10 and 11. Most additional accelerometers are mainly in the bedrock or stiff gravel layer. Exception is one of the accelerometers of the observation point No.6, which is installed 10m deep. The other is located at the depth of 40m in the bedrock at this observation point. Point No.6 is located near the foot of Mt. Ushibara where depth of the bedrock layer varies, and therefore it is an important point to observe the effect of the depth variation of a base layer.

3.5 Kobe Arrays (West and East)

Kobe Arrays are both located in the east part of the Kobe City, facing the Osaka Bay. This is part of the area, which suffered severe damage in the 1995 Hyogoken Nanbu Earthquake. The arrays cross the band where the highest seismic intensity 7 was declared by the Japan Meteorological Agency.

It is known that the area including Kobe and Osaka has many active faults and in the array area there are active fault trace and fault scarp, which are presumed to be a part of the Gosukebashi Fault and a part of the Ashiya Fault, respectively[10]. Their locations are shown in Fig.7(a) with the configuration of the observation points.

It is not expected that such a large earthquake will hit this area soon after the 1995 Hyogoken Nanbu Earthquake. But it is meaningful to record the strong motion at the area where once unprecedentedly strong ground motion was observed, because comparison of the ground motion characteristics would lead to various finding.

Figs.7(a) and (b) show the configuration of observation points and the cross section of the ground along the line A-A' respectively, and the installation depths of the accelerometers are listed in Table 5.

The Kobe Arrays range from the mountainous area belonging to the Rokko mountains, to the artificially reclaimed islands in the coastal area. Bedrock is granite and its shear wave velocity is about 2km/sec. The bedrock layer lies at a shallow depth in the northern mountainous area around the observation points Nos.10 and 11 of the West Array. It is said, however, that the bedrock is at more than 1km depth in the coastal area. The area between the south of Hankyu Kobe Line and National Highway Route No.43 is covered with thin alluvial layers. In the southern area of Route No.43 is mainly an artificially reclaimed land covered with about 20m thick soft soil, which is underlain by alluvial and diluvial layers. Some of the strong motion records of the 1995 Hyogoken Nanbu Earthquake showed that the ground motion of the reclaimed land was damped because of the inelastic behavior of the ground and, to the contrary of what was widely admitted, its peak acceleration at the ground surface was smaller than that of underground records. It is expected that strong motion records by Kobe Arrays, whose ground condition varies from the bedrock of granite to the relatively new reclaimed land, may contribute to the research about such phenomena.

Kobe West Array consists of twelve observation points and it has additional accelerometers at observation points Nos.2, 4, 6, 7, 8 and 11. One of the accelerometers of the observation point No.11 is set in the granite bedrock. At the observation points Nos.2 and 4, six and five accelerometers respectively are installed in various layers including the soft surface layer whose shear wave velocity is less than 150m/sec, and the diluvial layer at the depth of 80 - 100m whose shear wave velocity is about 500m/sec.

In Kobe East Array there are nine observation points and additional accelerometers are installed at observation points Nos.2, 3 and 6-9. The observation point No.2, which is located on the artificially reclaimed soft ground of the Fukae Hama, has five accelerometers and the deepest accelerometer is installed at 100m deep in the silty layer whose shear wave velocity is about 300m/sec. The deepest accelerometers of the observation points Nos.3 and 7 are at the depths of 40m and 32m respectively and both are in the gravelly layer with shear wave velocity of about 400m/sec or more.

3.6 Odawara Array

Odawara Array is located in the east of the center of Odawara City, facing the Sagami Bay. It expands along the coastal line and it crosses the Kozu-Matsuda Fault. Kozu-Matsuda Fault[10], which is shown in Fig.8(a) with the configuration of the observation points, is considered to be a part of the Sagami Trough. The Sagami Trough is the boundary of the Philippine Sea Plate and the North America Plate (or the Okhotsk Plate) and several huge earthquakes occurred on the trough, such as the 1923 Kanto Earthquake (M=7.9) and the 1703 (Genroku era) Kanto Earthquake (M=7.9-8.2). The Kozu-Matsuda Fault is estimated to accumulate dislocation at the ratio of about 3.5mm/year and it is considered seismically active.

The cross section of the ground along the line A-A'(Fig.8(a)) are shown in Fig.8(b) and the installation depths of the accelerometers are listed in Table 6.

Odawara Array expands crossing the Kozu-Matsuda Fault, including the mountainous area (observation point No.4) to the Sakawa River. Discontinuity of the ground condition between the observation points Nos.1 and 2, shown in Fig.8(b), corresponds to the Kozu-Matsuda Fault. In the east area of the fault, bedrock with a shear wave velocity of about 700-1000m/sec exists at a small depth and the deepest accelerographs of Nos.2-4 are installed in this layer. The ground condition changes drastically in the west area of the fault. It consists mainly from the alternation of sandy and clayey layers whose shear wave velocity is about 200-400m/sec, and the diluvial gravelly layer with the shear wave velocity of 600-1000m/sec underlies them. Ground under the observation point No.8 was judged to be diluvial from the boring data, but further investigation is required to confirm it.

Odawara Array consists of 11 observation points. This array is equipped with large number of deeply installed accelerometers and additional seismometers are installed at all observation points except Nos.6 and 11. The deepest accelerometer of the observation point No.9 is installed at the depth of 88m; in the gravel rock layer underling the gravelly diluvial layer. The shear wave velocity of the rock is about 700m/sec.

3.7 Makuhari-Narashino Array

Makuhari-Narashino Array is located on the coastal line facing the Tokyo Bay on its southwest end. Configuration of observation points and the cross section of the ground along the line A-A' are shown in Fig.9(a) and (b) respectively and the installation depths of the accelerometers are listed in Table 7. Northeast part of this array (observation points Nos.1 and 2.) is in Narashino City and the rest is in Makuhari district of Chiba City.

The area around Tokyo Bay is seismically active. Coastal area of Narashino district is newly reclaimed land and therefore it is expected the ground motion of the newly reclaimed soft ground will be recorded.

The Makuhari-Narashino Array consists of 11 observation points and additional accelerometers are installed at observation points Nos. 1, 3, 5, 8, 10 and 11. The array site can be divided into three parts.

The northeast part including observation points Nos.1 and 2 is located on the lowland in the plateau, which is filled with the soft deposit. That deposit is about 13m thick and its shear wave velocity is less than 100m/sec. The soft deposit consists of three layers; superficial sandy filling, organic soil and silty sand. The underlying diluvial sandy layer has shear wave velocity of about

300m/sec. Three of the four accelerometers of observation point No.1 are installed in the three layers of soft deposit and the deepest one is in the diluvial layer.

The area between observation point No.3 and National Highway Route No.14 is a plateau, which is covered with 4-5 meter thick loam layer and the diluvial sandy layer exists under the loam layer. Shear wave velocity of the loam layer is 100-200m/sec and that of the underlying diluvial layer is more than 300m/sec. Additional accelerometers of the observation points Nos.3 and 5 are installed at the shallow depth (at the depth of 10 and 6m respectively) and at the depth of 30m in the diluvial layer.

The area between Route No.43 and the seashore is artificially reclaimed land and it is covered with 10-30m thick soft layer with the shear wave velocity of less than 200m/sec. The sandy diluvial layer underneath has the shear wave velocity of 300m/sec. The deepest accelerometer is installed at the observation point No.8, which has three additional accelerometers at the depths of 8, 30 and 100m.

3.8 Tateyama Array

Tateyama Array is located in the southern part of the Boso Peninsula, facing the Tateyama Bay. Tateyama City, which is located close to the Sagami Trough, suffered severe damage in the 1703 Kanto Earthquake and the 1923 Kanto Earthquake. Many fault models[11] proposed as the causative faults of these earthquakes, lie under Tateyama City. It can be said, therefore, that Tateyama Array is located also seismically active area.

Configuration of observation points, cross section of the ground along the line A-A' and the installation depths of the accelerometers are shown in Fig.10(a), (b) and Table 8, respectively. In Fig.10(b), accelerometers at the depth of 2m are also shown. There are 11 observation points and observation points Nos.4, 6 and 10-12 are equipped with additional accelerometers.

There is a small hill in the Shiroyama Park and observation points Nos.1-3 are installed on its slope. Thin soft clayey soil covers the hill and its thickness is large at the bottom of the hill. Therefore the accelerometer of the observation point No.3 is installed at the depth of 7m while those of observation points Nos.1 and 2 are at the depth of 2m.

The other observation points are deployed in the plain area. The plain area is uniformly covered with an about 10m thick alluvial sand layer and an about 10m thick alluvial clayey layer. Beneath them lies a rock stratum, whose depth varies steeply. Therefore in this array, it is expected that the effect of the spatial variation of the depth of base layer will be observed.

3. CONCLUDING REMARKS

The new strong motion array observation system of the Public Works Research Institute is introduced. The arrays that had been deployed around the Suruga Bay between 1981 and 1984 were renewed and five new arrays were additionally installed; Kobe West Arrays, Kobe East Arrays, Odawara Array, Makuhari-Narashino Array and Tateyama Array. Strong motion observation at these sites are considered important from the view point of earthquake engineering for reasons such as that they are located in seismically active areas or near active faults, and that the ground conditions of these arrays vary spatially.

Authors hope the strong motion records that will be obtained by these arrays attribute to the progress of earthquake engineering technology, earthquake disaster prevention technology and so on.

ACKNOWLEDGMENT

The observation stations of the arrays are installed in the places such as parks, school grounds and other various facilities with the permission of the owners, the administrators, the municipal corporation etc. Installation of these arrays could not have been done without their understanding and cooperation. Authors would like to express their sincere gratitude to everybody and every

organization concerned.

REFERENCES

1) Proceedings of the International Workshop on Strong Motion Earthquake Instrument Arrays, International Association for Earthquake Engineering, May 1978
2) Proposal on Earthquake Resistance for Civil Engineering Structures (Vol.1), Japan Society of Civil Engineers, May 1995. (in Japanese)
3) First Report of the Special Committee for Investigation of Hanshin-Awaji Great Earthquake Disaster, Japan Science Council, October 1995. (in Japanese)
4) T. Okubo, T. Arakawa et al., Dense Instrument Array Program of the Public Works Research Instiute and Preliminary Analysis of the Records, Proceedings of 8th World Conference on Earthquake Engineering, 1984
5) T. Iwasaki, Y. Sasaki, et al., Dense Instrument Array System by PWRI for Observing Strong Earthquake Motion, Proceedings of the 18th Joint Meeting, U.S.-Japan Panel on Wind and Seismic Effects, UJNR, May 1986
6) T. Arakawa, K. Kawashima, et al., Dense Instrument Array Observation by Public Works Research Institute, -(1) Observation System at Sagara Area -, Technical Memorandum of PWRI, No.1847, July 1982. (in Japanese)
7) T. Arakawa, K. Kawashima, et al., Dense Instrument Array Observation by Public Works Research Institute, -(2) Observation System at Yaizu Area -, Technical Memorandum of PWRI, No.1994, March 1983. (in Japanese)
8) T. Arakawa, Y. Sasaki, et al., Dense Instrument Array Observation by Public Works Research Institute, -(3) Observation System at Numazu Area-, Technical Memorandum of PWRI, No.2140, September 1984. (in Japanese)
9) Y. Sasaki, K. Tamura et al., Dense Instrument Array Observation by Public Works Research Institute, -(4) Observation System at Matsuzaki Area -, Technical Memorandum of PWRI, No.2238, May 1985. (in Japanese)
10) Active Fault Map in Urban Area, Geographical Survey Institute, September 1996.
11) R. Sato et al., Japan Earthquake Fault Parameter Handbook, March 1989, Kajima Institute Publishing Co., Ltd. (in Japanese)

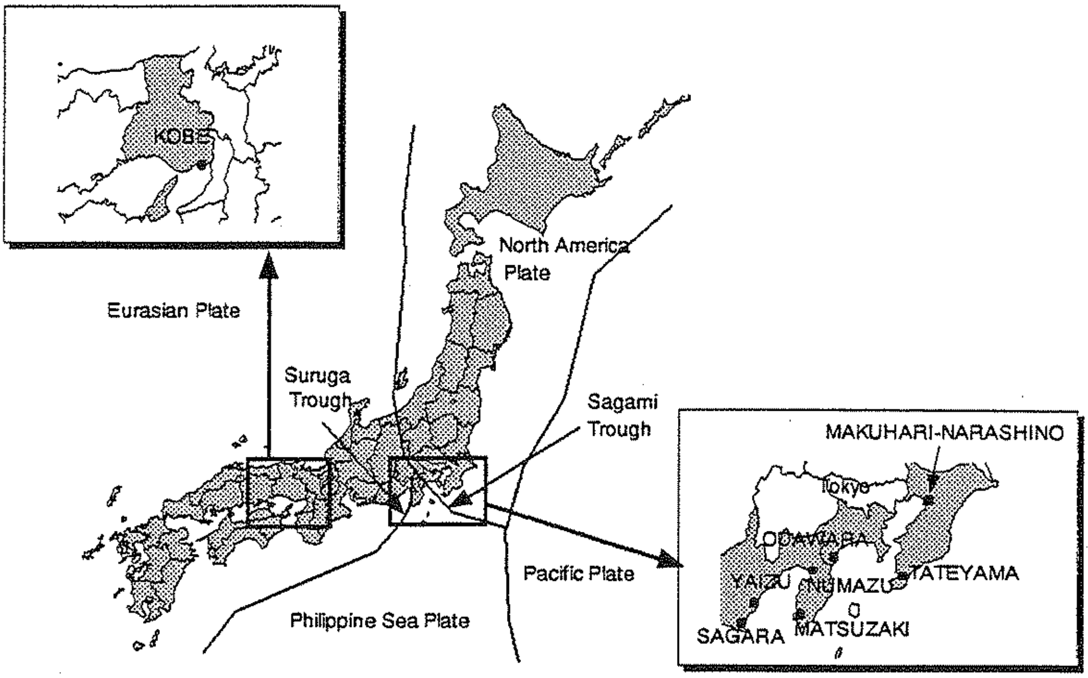


Fig.1 Locations of Arrays

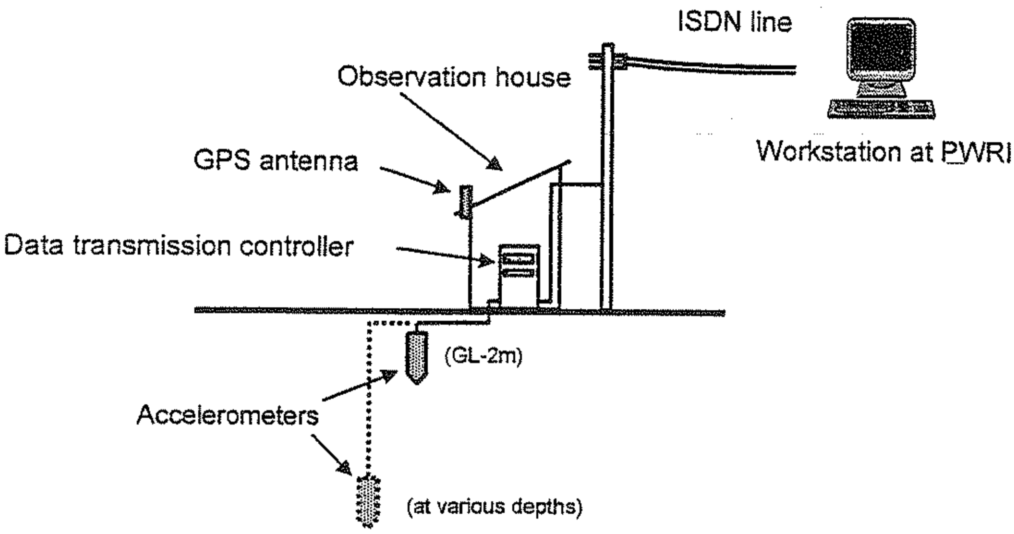
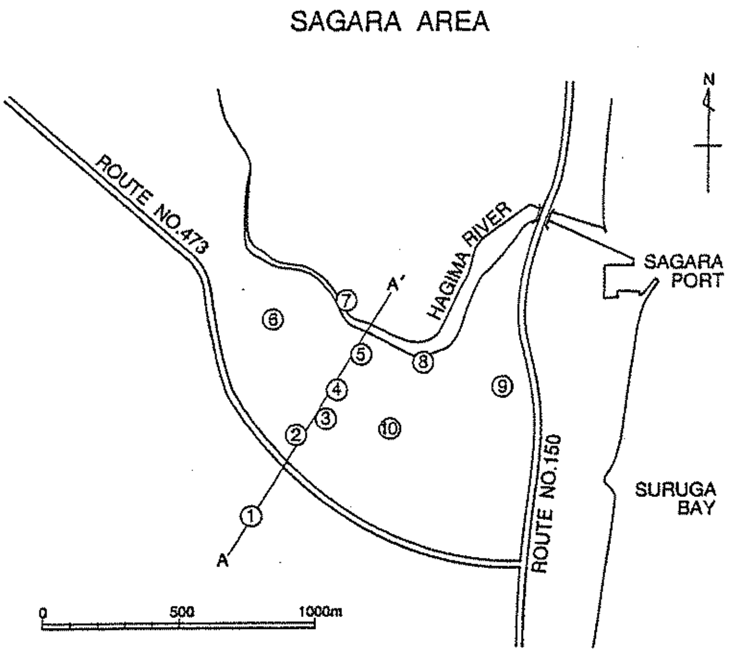


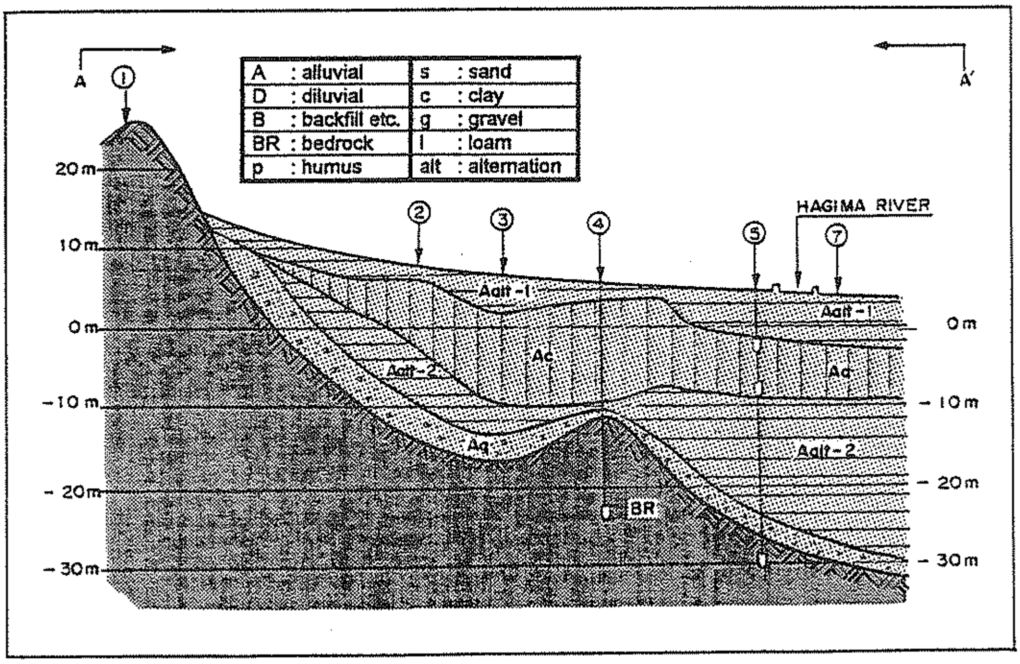
Fig.2 Illustration of devices installed in each observation station



(a) Configuration of Observation Points

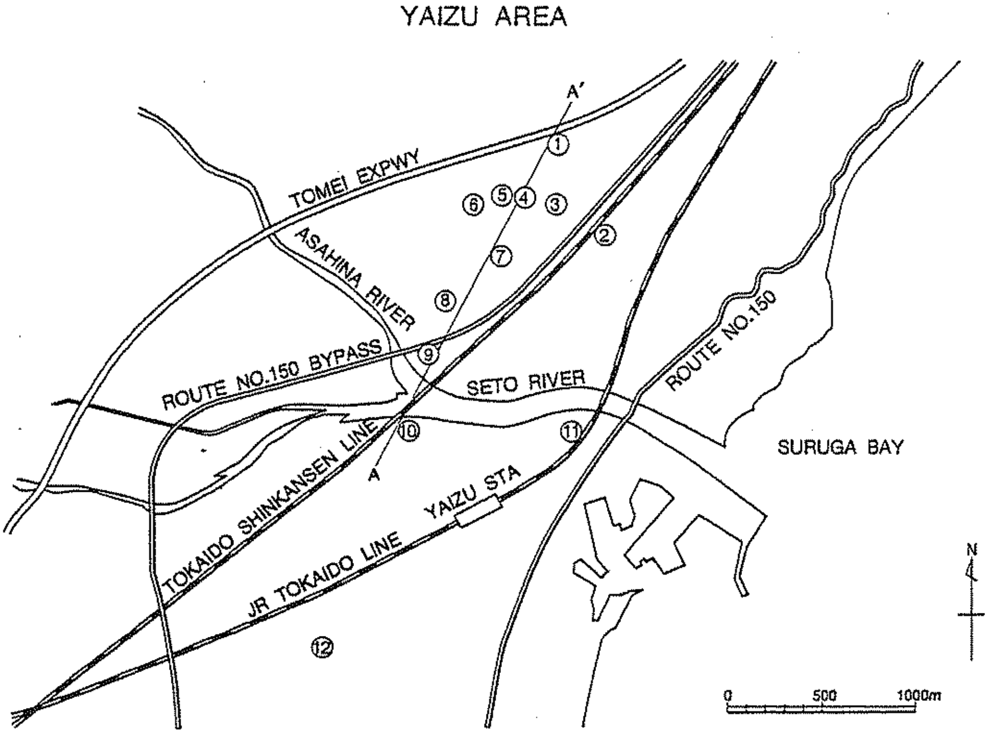
Table 1 Accelerometer Installation Depth of Sagara Array

Observation Point No.	Accelerometer Installation Depth [m]
1	2
2	2
3	2
4	2, 30
5	2, 8, 12, 32
6	2
7	2
8	2, 36
9	2
10	2, 30

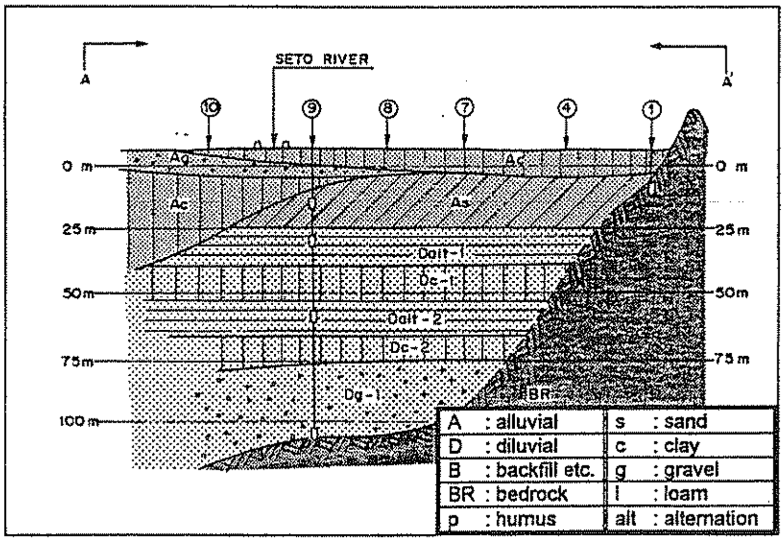


(b) Section of the Ground along A-A' line

Fig.3 Site Condition of Sagara Array



(a) Configuration of Observation Points

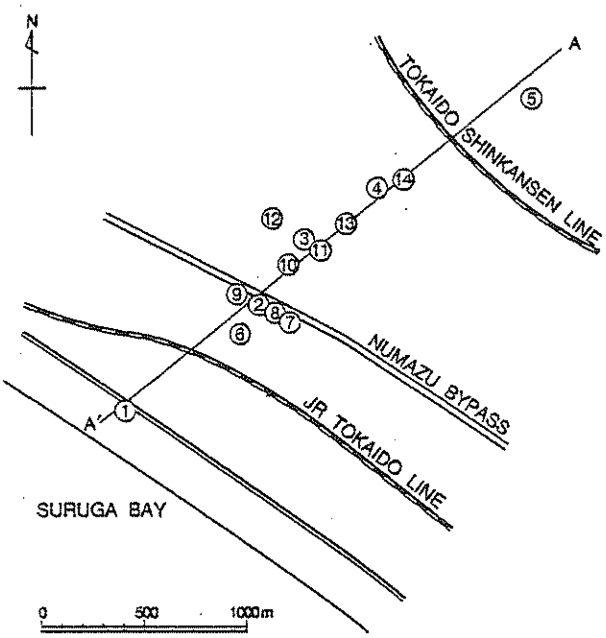


(b) Section of the Ground along A-A' line

Table 2 Accelerometer Installation Depth of Yaizu Array

Observation Point No.	Accelerometer Installation Depth [m]
1	10
2	2
3	2—
4	2
5	2, 15
6	2
7	2
8	2
9	2, 20, 30, 63, 113
10	2
11	2
12	2

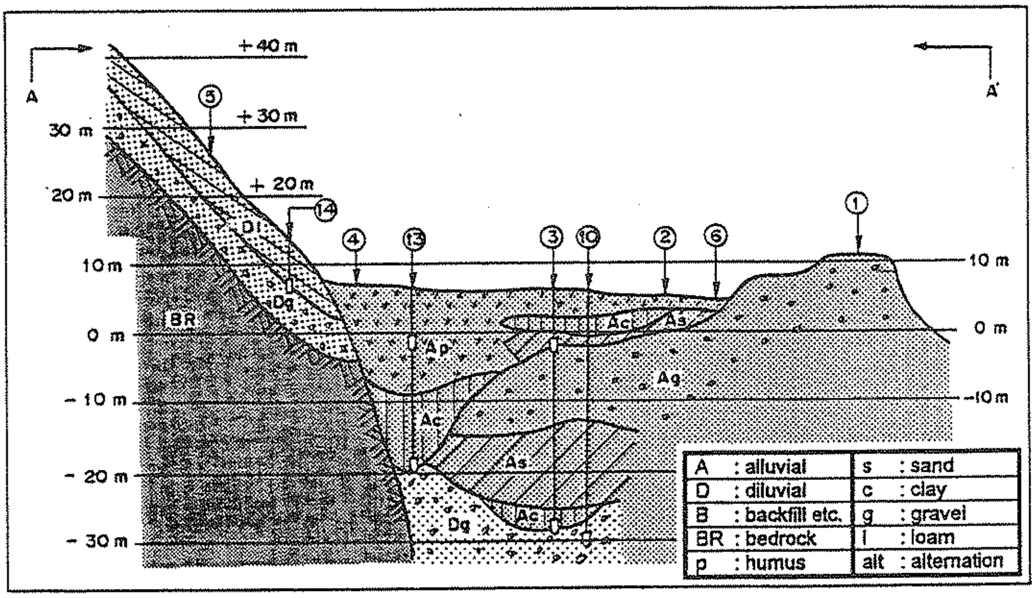
Fig.4 Site Condition of Yaizu Array



(a) Configuration of Observation Points

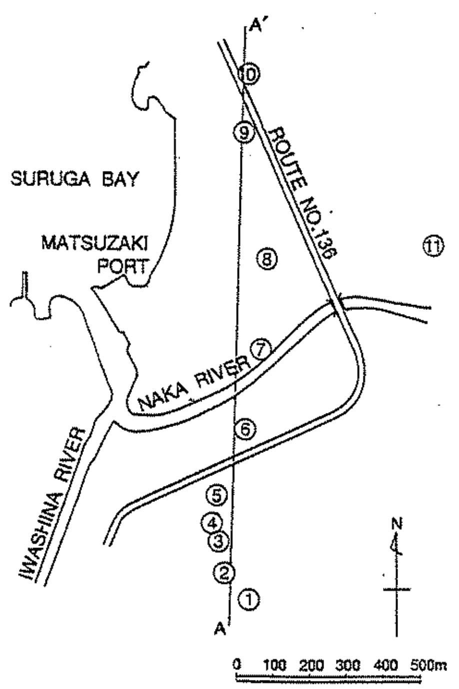
Table 3 Accelerometer Installation Depth of Numazu Array

Observation Point No.	Accelerometer Installation Depth [m]
1	2
2	2
3	2, 10, 32
4	2
5	2
6	2
7	2
8	2
9	2
10	2, 35
11	2, 32
12	2
13	2, 9, 27
14	11



(b) Section of the Ground along A-A' line

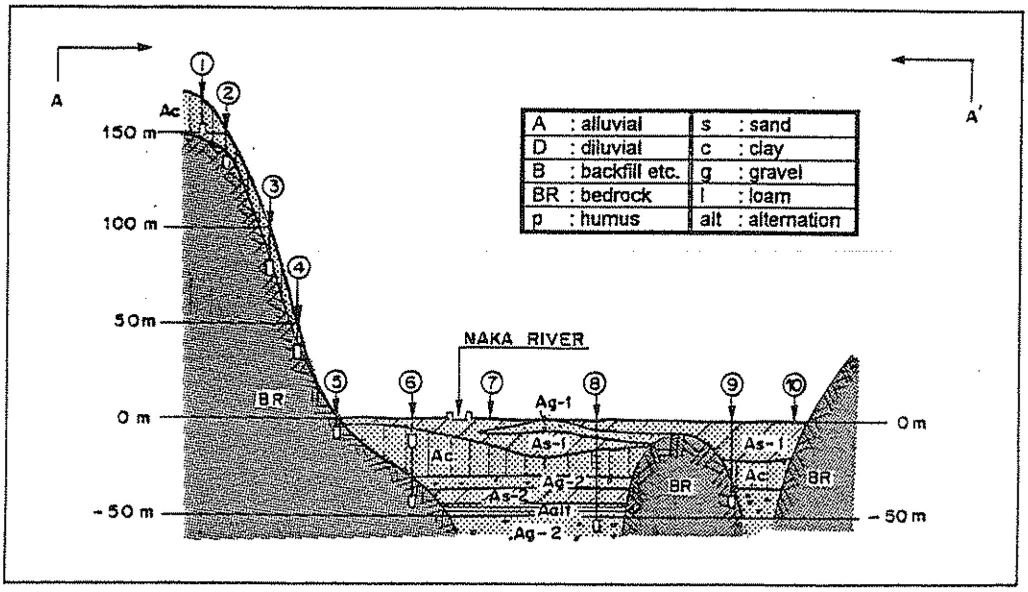
Fig.5 Site Condition of Numazu Array



(a) Configuration of Observation Points

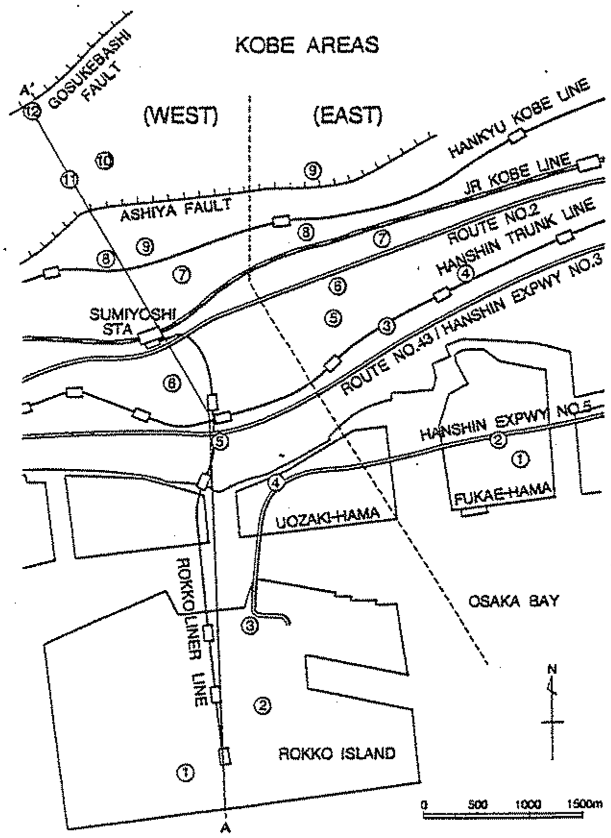
Table 4 Accelerometer Installation Depth of Matsuzaki Array

Observation Point No.	Accelerometer Installation Depth [m]
1	2, 24
2	2, 13
3	2, 11
4	2, 9
5	2, 5
6	2, 10, 40
7	2
8	2, 52
9	2, 38
10	2
11	2

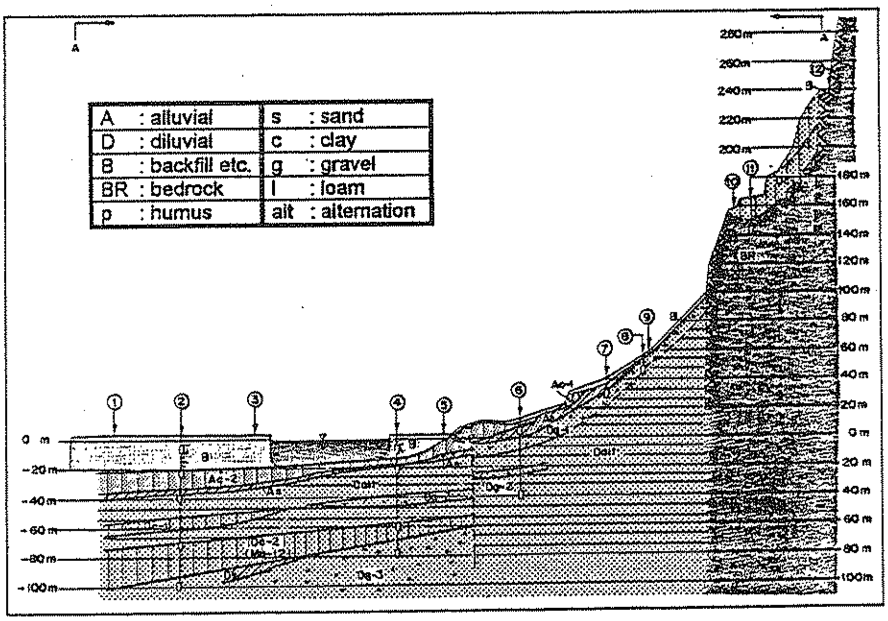


(b) Section of the Ground along A-A' line

Fig.6 Site Condition of Matsuzaki Array



(a) Configuration of Observation Points



(b) Section of the Ground along A-A' line

Fig.7 Site Condition of Kobe Arrays

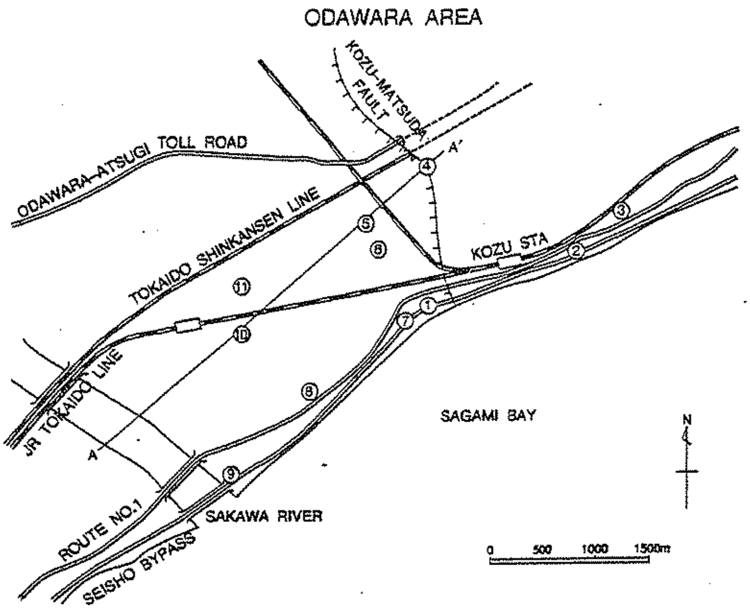
Table.5 Accelerometer Installation Depth of Kobe Arrays

(West)

Observation Point No.	Accelerometer Installation Depth [m]
1	2
2	2, 10, 25, 43, 75, 102
3	2
4	2, 10, 23, 61, 80
5	2
6	2, 7, 50
7	2, 10
8	2, 10
9	2
10	2
11	2, 20
12	2

(East)

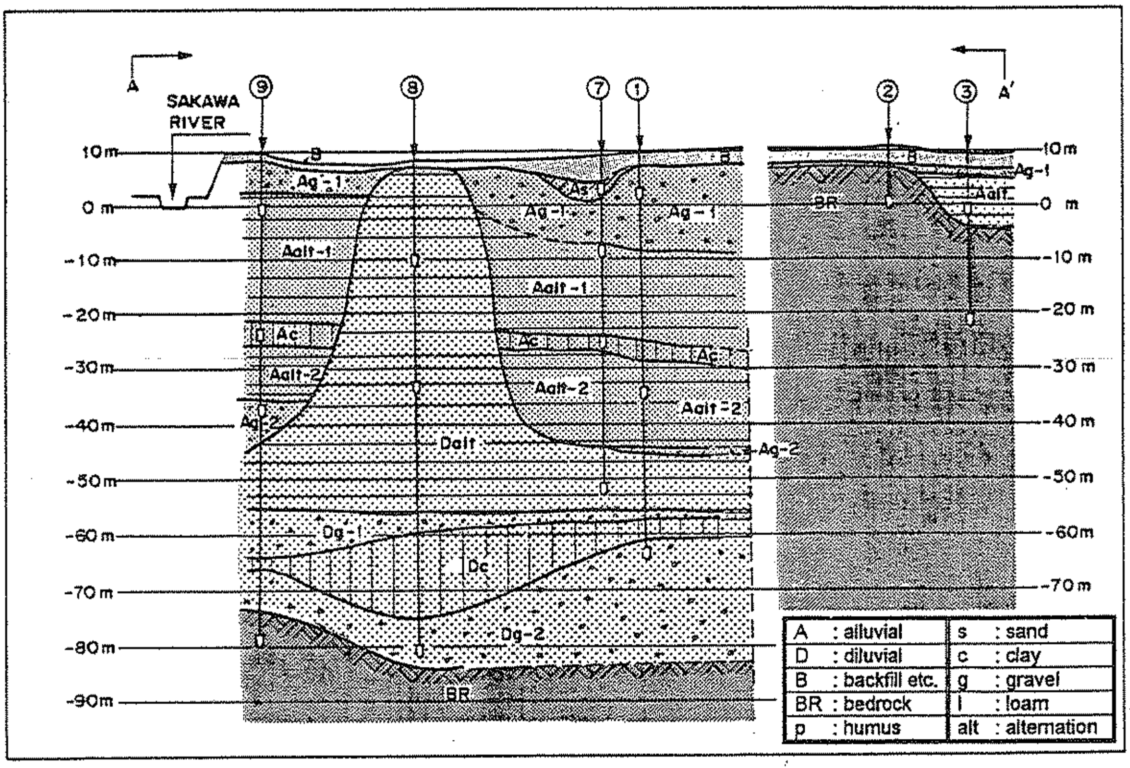
Observation Point No.	Accelerometer Installation Depth [m]
1	2
2	2, 8, 26, 54, 100
3	2, 14, 40
4	2
5	2
6	2, 16
7	2, 13, 32
8	2, 15
9	2, 12



(a) Configuration of Observation Points

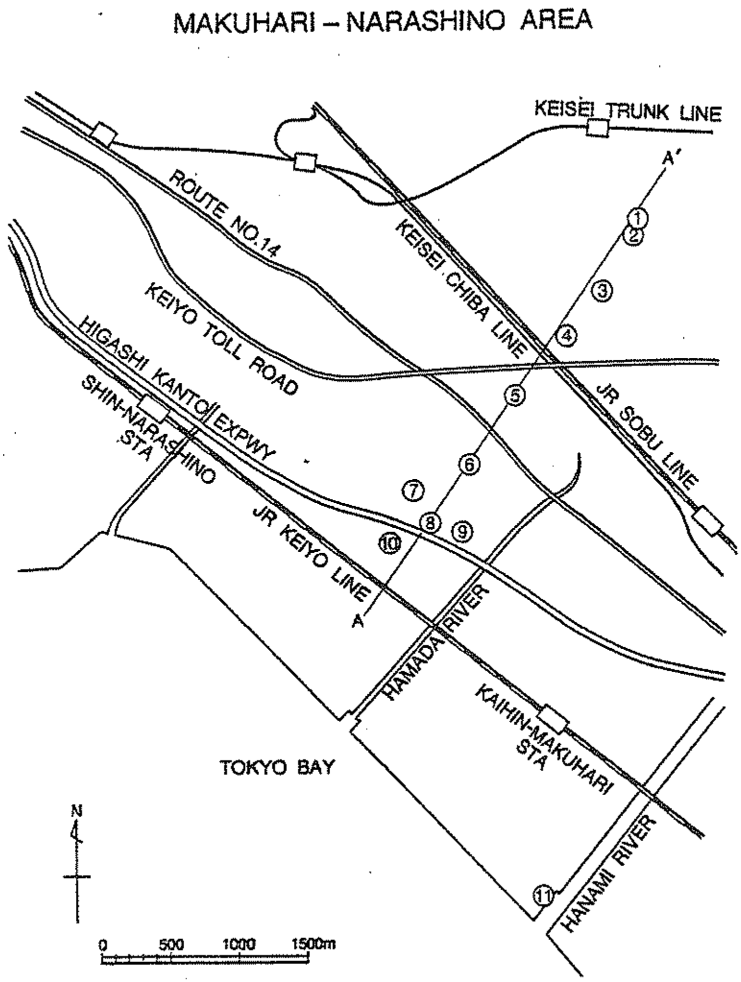
Table 6 Accelerometer Installation Depth of Odawara Array

Observation Point No.	Accelerometer Installation Depth [m]
1	2, 7, 44, 73
2	2, 10
3	2, 10, 30
4	2, 30
5	2, 12, 20, 51
6	2
7	2, 7, 17, 34, 60
8	2, 18, 41, 90
9	2, 10, 34, 46, 88
10	2, 14, 24, 50, 90
11	2



(b) Section of the Ground along A-A' line

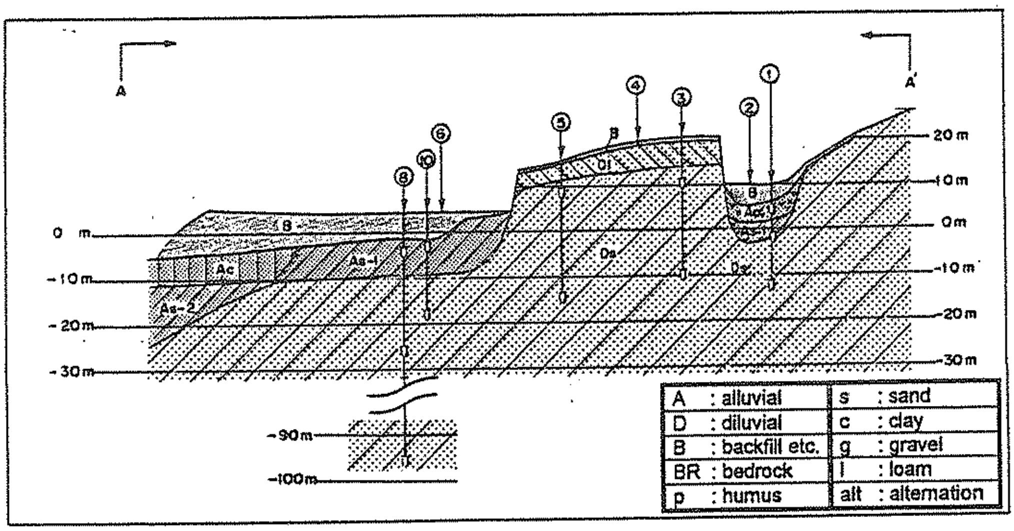
Fig.8 Site Condition of Odawara Array



(a) Configuration of Observation Points

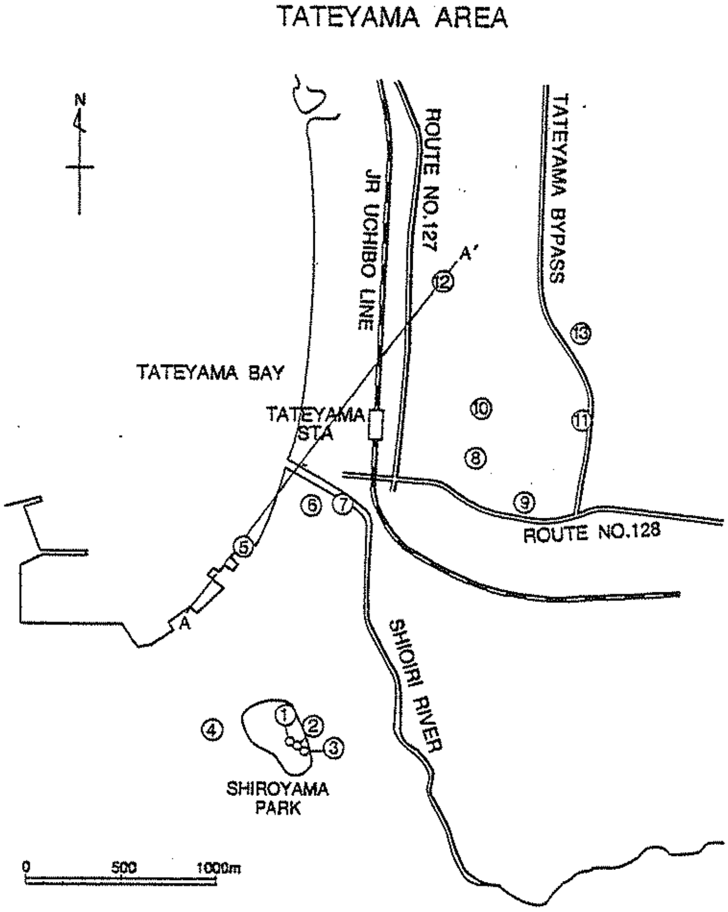
Table 7 Accelerometer Installation Depth of Makuhari-Narashino Array

Observation Point No.	Accelerometer Installation Depth [m]
1	2, 6, 12, 22
2	2
3	2, 10, 30
4	2
5	2, 6, 30
6	2
7	2
8	2, 8, 30, 100
9	2
10	2, 7, 22
11	2, 9, 19, 45



(a) Configuration of Observation Points

Fig.9 Site Condition of Makuhari-Narashino Array

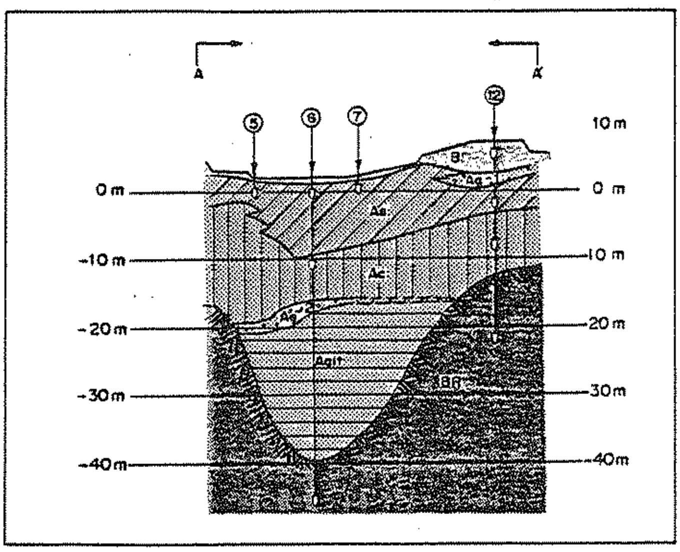


(a) Configuration of Observation Points

Table 8 Accelerometer Installation Depth of Tateyama Array

Observation Point No.	Accelerometer Installation Depth [m]
1	2
2	2
3	7
4	2, 21
5	2
6	2, 13, 47
7	2
8	2
9	2
10	2, 8, 41
11	2, 13
12	2, 9, 15, 29
13	2

A : alluvial	s : sand
D : diluvial	c : clay
B : backfill etc.	g : gravel
BR : bedrock	l : loam
p : humus	alt : alternation



(b) Section of the Ground along A-A' line

Fig.10 Site Condition of Tateyama Array