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Studies on Alluvial Sediments in Hiroshima Prefecture, No. 1.

By

Toshiyuki HABARA

With 4 Tables and 24 Text-figures

ABSTRACT: Stratigraphical and mineralogical inspections for alluvial sediments obtained from core borings at several localities along the Seto Inland Sea have for some years been carried into effect. A part of the results and a few reference to the relation of mineralic constituents to plasticity have been presented.

CONTENTS

I. INTRODUCTION

Alluvial sediments, of marine origin, developed in the coastal plains in various regions have so far been researched through mechanical treatments mainly from a standpoint of soil engineering, whereas it seems the fact that few of the studies have, though be subjected to severe interests for a long time, been referred to their relationship with geological factors such as the sources, mineralic constituents, environments of deposition and so forth. In view of this, the present author will, as a part of mineralogical investigations concerning the problem in question, hereunder allude principally either to the stratigraphies of alluvial deposits developed along the coastal regions of Seto Inland Sea within Hiroshima Prefecture or to the relations of cohesive sediments to their mechanical characteristics and compositions of clayey minerals.

Much thanks have to be dedicated to Professor Yoshiharu UMEGAKI, Institute of Geology and Mineralogy, Hiroshima University, who gave the author valuable instructions throughout this works, as well as to other members of the same institute, Assistant Professor A. HASE, Assistants M. NAKANO, A. SOEDA, and S. NAGATOMI, and to Messrs. K. MATSUMURA, President of Chūgoku and Shikoku Reconstruction Co., Y. SEGAWA, S. ASHIBA, K. MIYAHARA and other staffs of the same company.

II. STRATIGRAPHICAL ASPECT

The sediments considered to be included in alluvium in various regions plotted in Fig. 1 are composed of the marine materials transported respectively by each river running across the back lands, revealing varieties of facies ascribable to difference of riverine and sea agencies appeared in the neighborhood of estuaries, as are stratigraphically listed in Table 1.

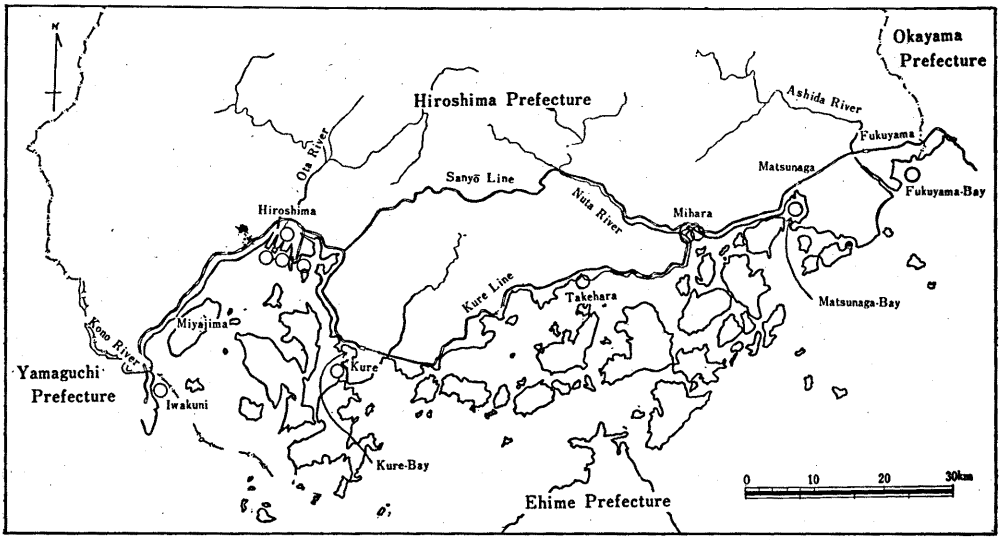


FIG. 1. Locality map

(1) *Iwakuni Bay*

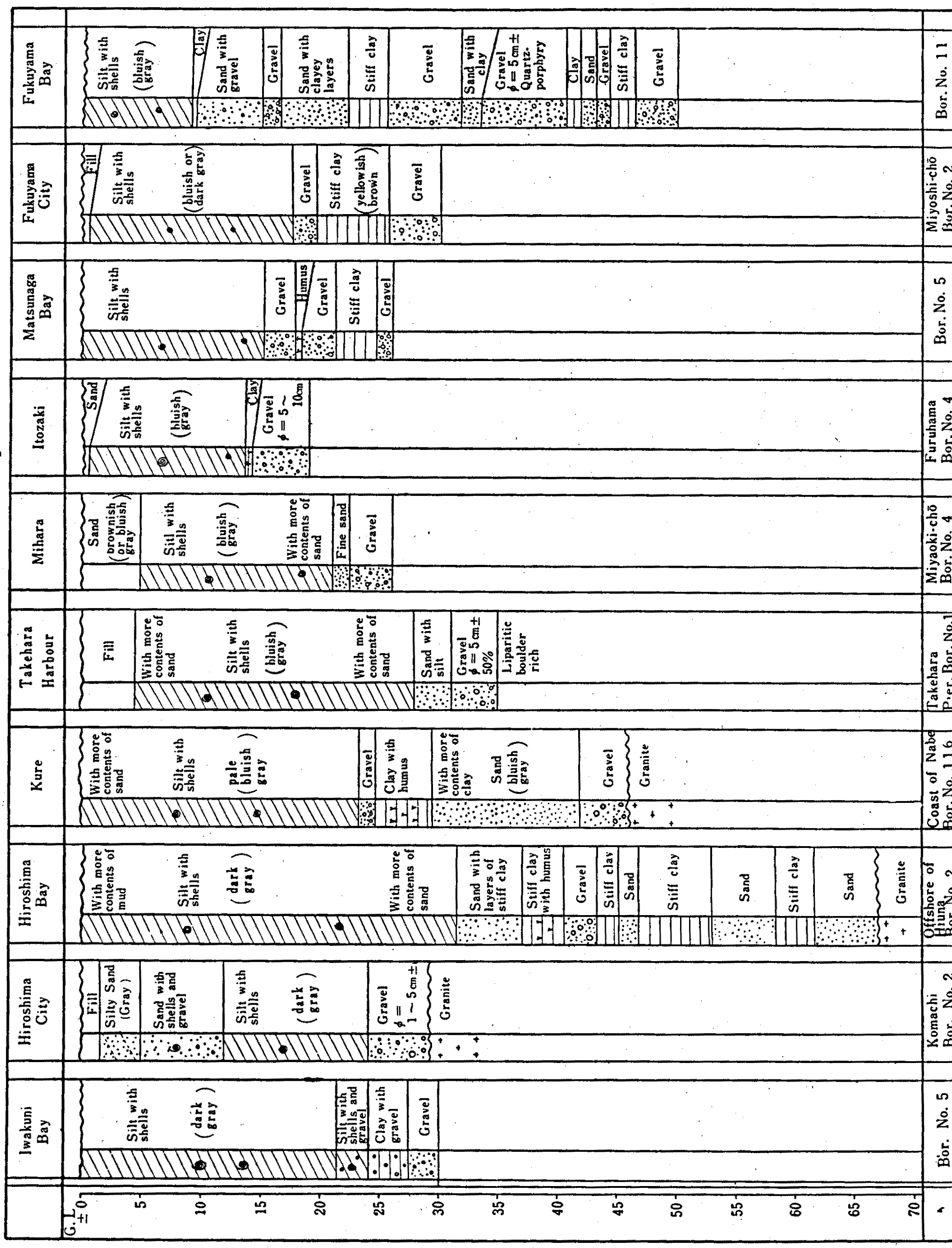
The sediments deposited in the Iwakuni Bay seem to have not been influenced directly by the Kono River, and consisted mainly of the upper silty, and lower clayey beds mingled with gravels. The former is generally predominant in silty materials, classified into sandy silt or clayey silt, and becomes thicker with remoting from the coast (for instance, from 5.0 m to 21.2 m in thickness in this case) and more rich in organic matters with approaching to the land, while the latter shows a gentle slope toward the offshore.

(2) *Hiroshima*

Street terrain of Hiroshima City is situated within the compound constructed by several times repetition of reclamation on the typical composite delta of the Ôta River. Inspection of the data obtained from core borings indicates that composition of the related underground is commonly represented by the upper sandy bed, the silty bed, and the lower gravelly bed lying on the basement.

The basement rock composed of granite is used to displaying the irregular surface lying in depth and, especially in the vicinity of Hiji-yama, Shirakamisha, Eba-yama, and Ôgon-zan etc., soars above the landsurface as islets in the old

TABLE 1. Columnar Section of the Alluvial Sediments Developed in the Coastal Plains



Hiroshima Bay.

The lowermost gravelly bed composed of quartz porphyry, chert, slaty hornfels, granite and so on is found lying unconformably over the basement and rich in variation of width, while its upper part includes a considerable amount of silt and is gradually transitional into the upper silty bed.

The bed composed of silt grouped into clayey silt and silty clay according to soil classification contains the fragments of shells together with organic matters and is likely to reveal either less width (for example, ca. 20 m in the central part and ca. 30 m in the offshore) culminating in pinching-out or more increase of sandy components with approaching to the northern side.

The upper sandy bed is coarser in grain-size on the northern side and more rich in silty components on the opposite side. The very bed is, in parts, disappeared in the offshore but reveals a local thickening at the estuary of the Enkō River.

Hase (1951) was of opinion that the alluvial deposit developed in the Hiroshima plain is divided into A (the upper) and B (the lower) beds comprising several layers respectively, and certain kinds of shelly fossils are contained in the latter composed mainly of clayey materials. In relation to this, Takahashi (1961) established a view concerning the stratigraphy of alluvial deposit in the Hôfu plain, indicating the possibility of division into the burying and deposition period corresponding to that related to deposition of the A-bed, the Yūraku-chô period (Jômon) connected with that of Flandrian transgression causing formation of the B-bed in the middle of alluvial stage, and the swamp period.

Interesting is that on the basis of the results obtained from test borings at the offshore of Hiuna in Kaita Bay, the bed, corresponding to the lowermost one, found covering unconformably over the basement is conspicuously thick and intercalated with hard clay without shells. The bed under consideration is reasonably believed to have not any direct relation to the silty bed mentioned above and rather to represent another cycle of deposition. Both plan and profiles traversing some localities are shown in Fig. 2 and in Figs. 3 and 4.

(*3*) *Kure*

The area locating at the southernmost end surrounding the Kure Harbor is the sole one with no regard to pouring of any streems. Accordingly, the products are considered to have been affected only by coastal current of sea water. The relief of the basement in this area is specifically irregular and related to the land topography cropped out in its neighborhood.

The sediments covering the basement reveal considerably different order of deposition respectively on the western side, as is shown in Table 1, and on the eastern side, as is illustrated in Fig. 5, but are generally composed of the upper gravelly bed, the silty layer and the lower gravelly bed. Of three, the silty bed is greyish blue in color and contains the fragments of shells, bearing a tendency of decreasing its thickness toward the land and eastern side, and *vice versa*. The very bed is

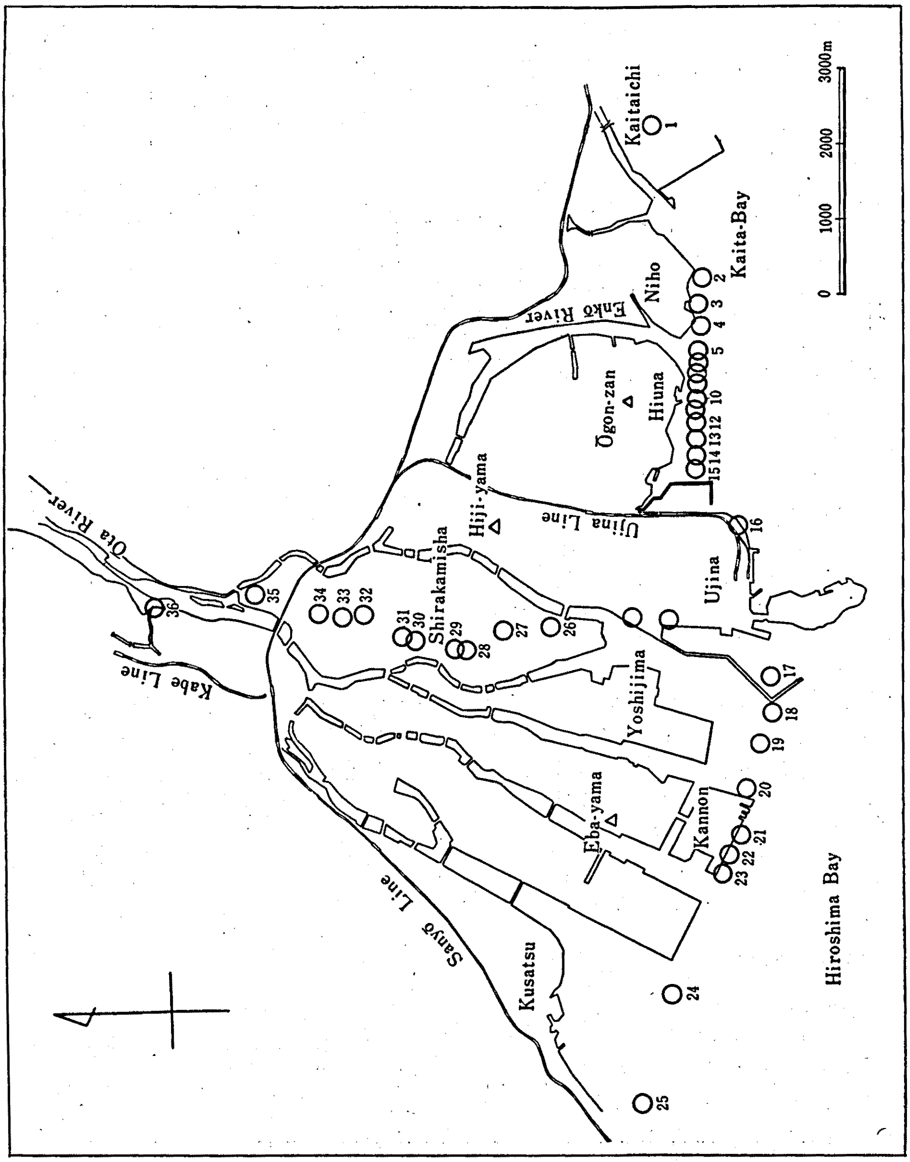


FIG. 2. Locality map concerning Hiroshima area.

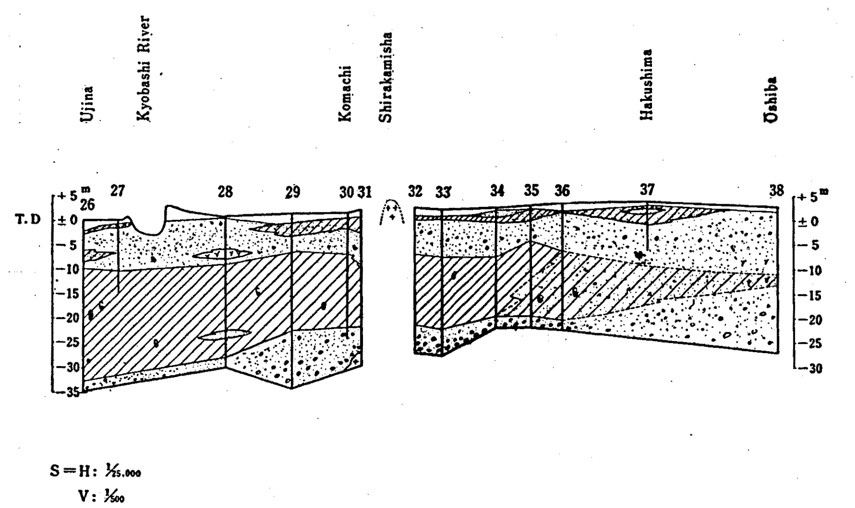


Fig. 4. N–S profile obtained from the data of core borings.

grouped into that composed of silty clay and clayey silt, revealing an increase of sandy components in its upper and lower parts or in the thinner parts. The upper and lower gravelly beds are mainly consisted of granitic materials in their various ratio and apt to disclosing lack in one or in the other. The lower bed happens to be sporadically intercalated with clayey parts predominant in organic matters. Panel diagram and contour map of basement relating to this region are illustrated respectively in Figs. 5 and in 6.

(*4*) *Takehara Harbor*

The sediments in this region are of the estuarine deposits transported by the Kamo River and, in the vicinity of the pier, composed of the upper silty bed, the gravelly bed and the lower sandy bed. Of all, the silty bed grouped into that of clayey silt and silty clay is used to bearing a homogeneous composition in grain-size excepting its upper and lower parts with abundance of sandy components. Gravels in the related bed are commonly consisted of rhyolitic ones including about 50% of those with diameter of 5 cm±.

(*5*) *Mihara and Itozaki Harbor*

Both the sediments distributed at the estuary of the Nuta River, Miyaoki-chô,

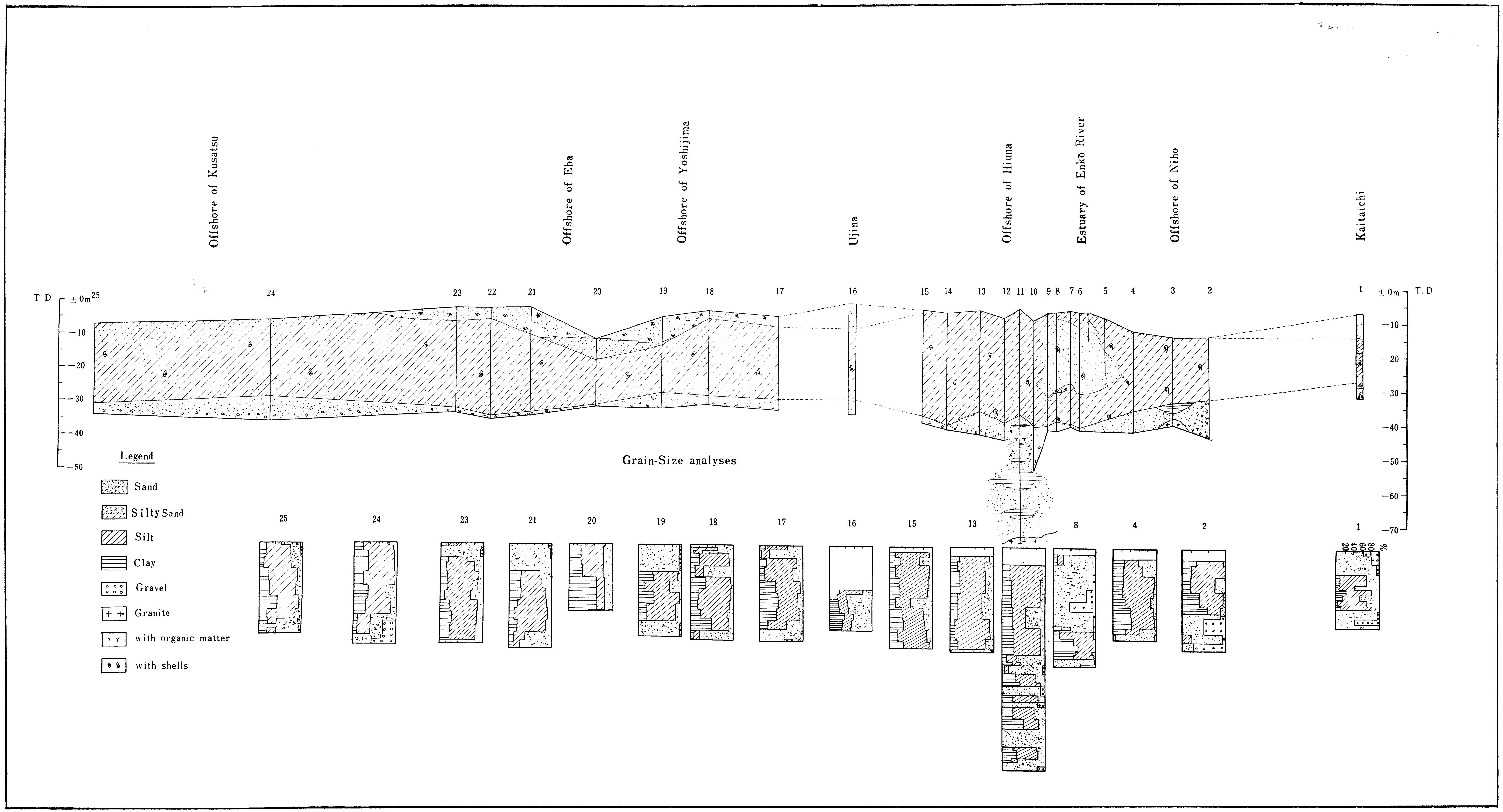


Fig. 3. E–W profile obtained from the data of core borings

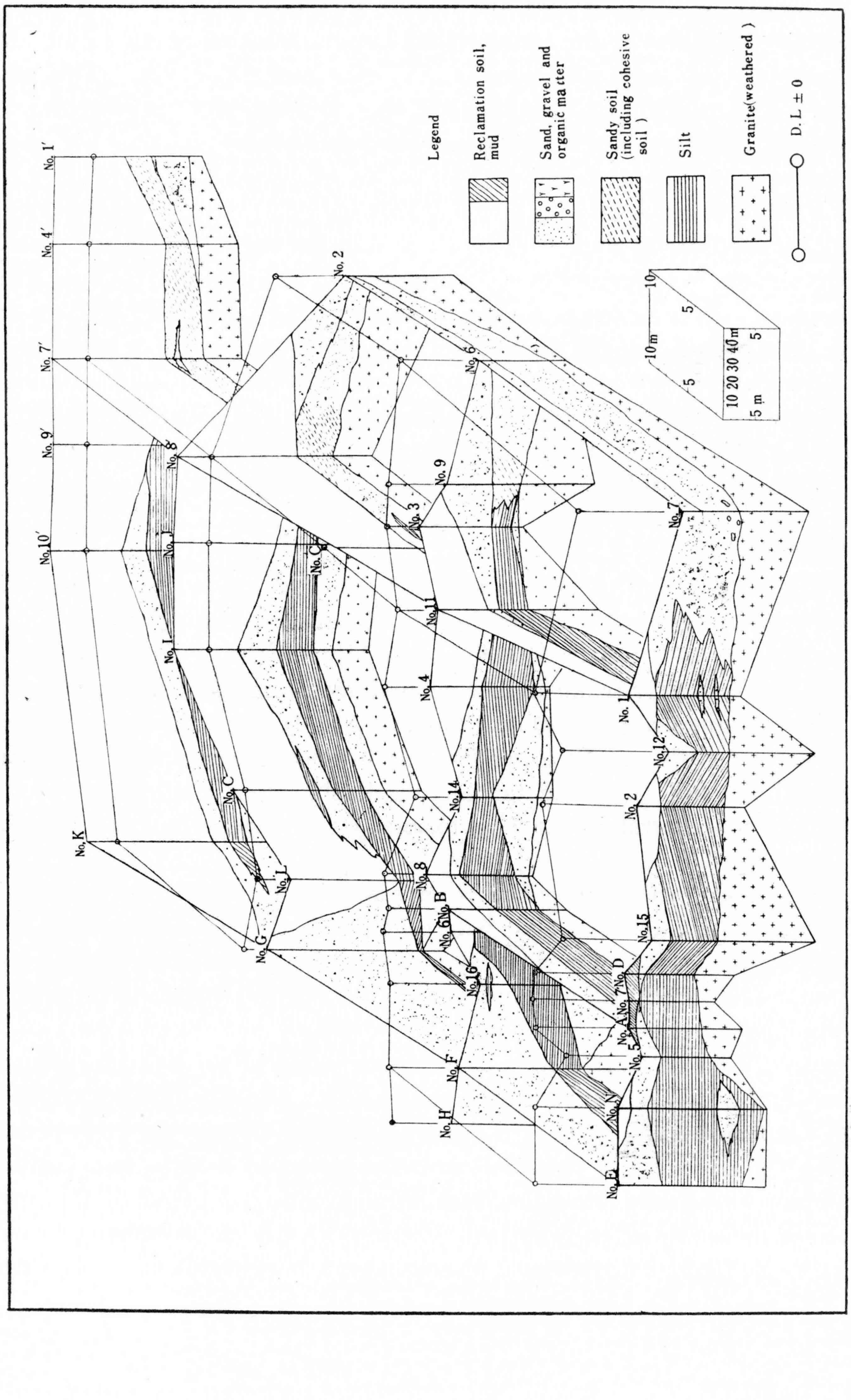


FIG. 5. Panel diagram of Kure (coast of Nabe)

Mihara City and those developed at the estuary of the Wakihara River are represented by the upper sandy bed, the middle silty bed, and the lower gravelly bed, respective thickness of the former being larger than that of the latter. Most of silty parts are dividable into those of silty clay and clayey silt. Thin layers (less than 1 m in width) of somewhat hard clays containing organic matters are found intercalated between the middle and the lower beds.

(6) *Matsunaga Bay*

Taking into account of some data resulted from test borings at several localities in the Matsunaga Bay situated at the estuaries of the Fujii and Habara Rivers, the sediments in the area concerned are divided into the upper silty bed, 13–15 m ± in thickness, containing the shelly fragments, the middle sandy or gravelly beds accompanying clayey layers and the lower gravelly bed intercalated sporadically with stiff clays. The first bed is almost homogeneously composed of clay and silty clay in soil classification. The third bed may be correlative to the similar one cropped out on the hilly lands surrounding the Matsunaga Bay.

(7) *Fukuyama*

The materials covering the Fukuyama delta constructed by the Ashida River seem to represent a gradual variation in facies from sand, through sandy silt, and to clay. Scrutiny of the data obtained from Miyoshi-chô, Fukuyama City and Fukuyama Bay evidently points to that the sediments composing the delta are classifiable into the upper silty bed of soft property, 10–18 m in thickness, involving the fragments of shells and the lower gravelly bed accompanied with clayey parts of comparatively stiff characteristics in considerably good continuity, the latter being assumed to be correlative to those exposed on the landsurface in the environs of Fukuyama City.

The silt included in the upper bed is dark greyish in color and classified into sandy silt, clayey silt, and silty clay, whereas the stiff clay in the lower bed is pale bluish grey to greenish grey in color, almost less than 3 m in width and, in severe sense, grouped into sandy silt associating abundance of the fragments of wood and fibrous organic matters.

As a result, most noticeable may, as are observable in the eastern districts of Hiroshima Prefecture, be the existence of the lower gravelly bed accompanying the clayey layer of stiff property, the latter being for the present regarded as a part of diluvial deposits but remained to be inspected in more details basing on the determination of absolute age. Furthermore, clays of the similar property, comprised in the sandy or gravelly bed covering directly the basement, are to be correlated to that mentioned above. Panel diagram within this region is given in Fig. 7.

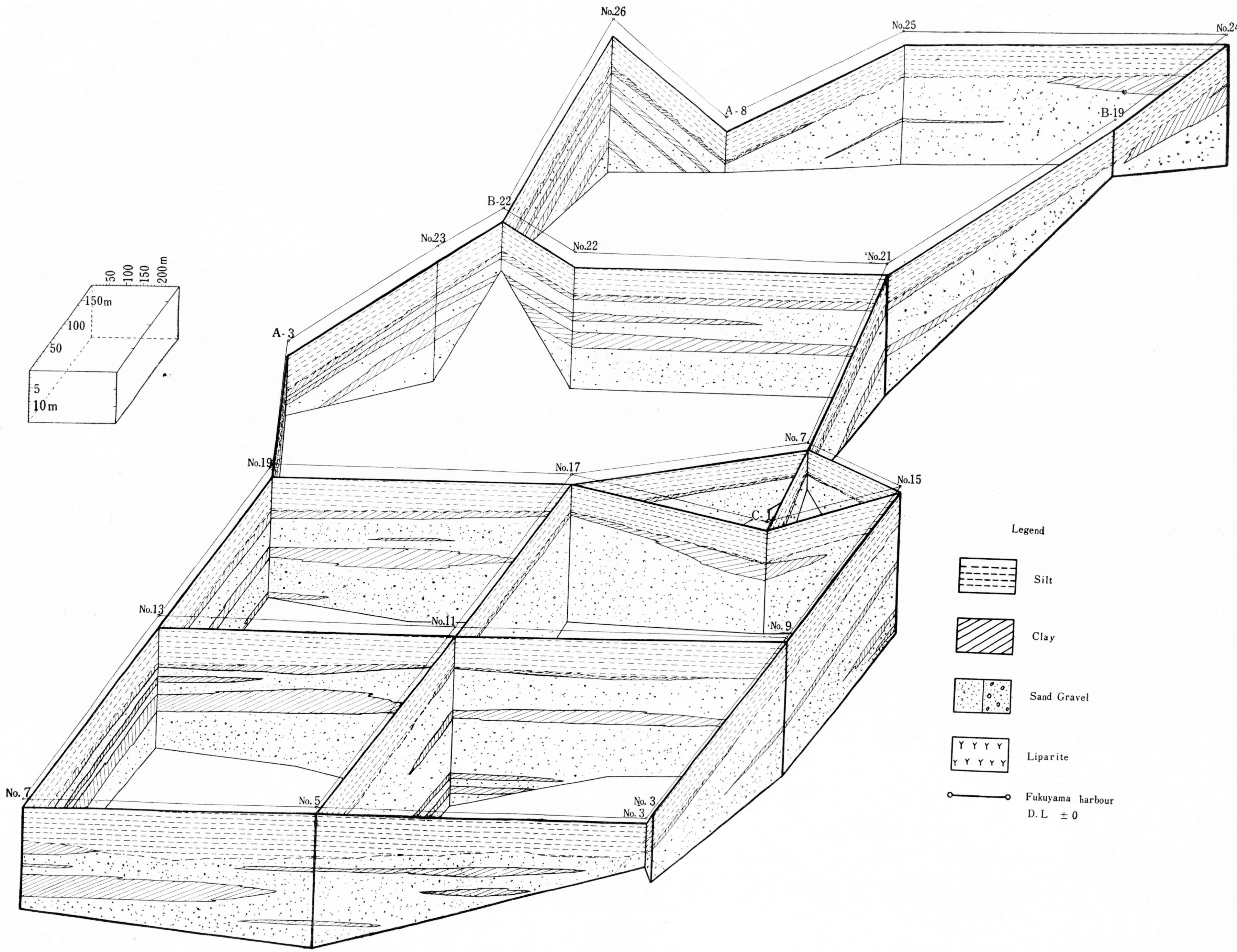


Fig. 7. Panel diagram of Fukuyama Bay

FIG. 6. Contour map of basement

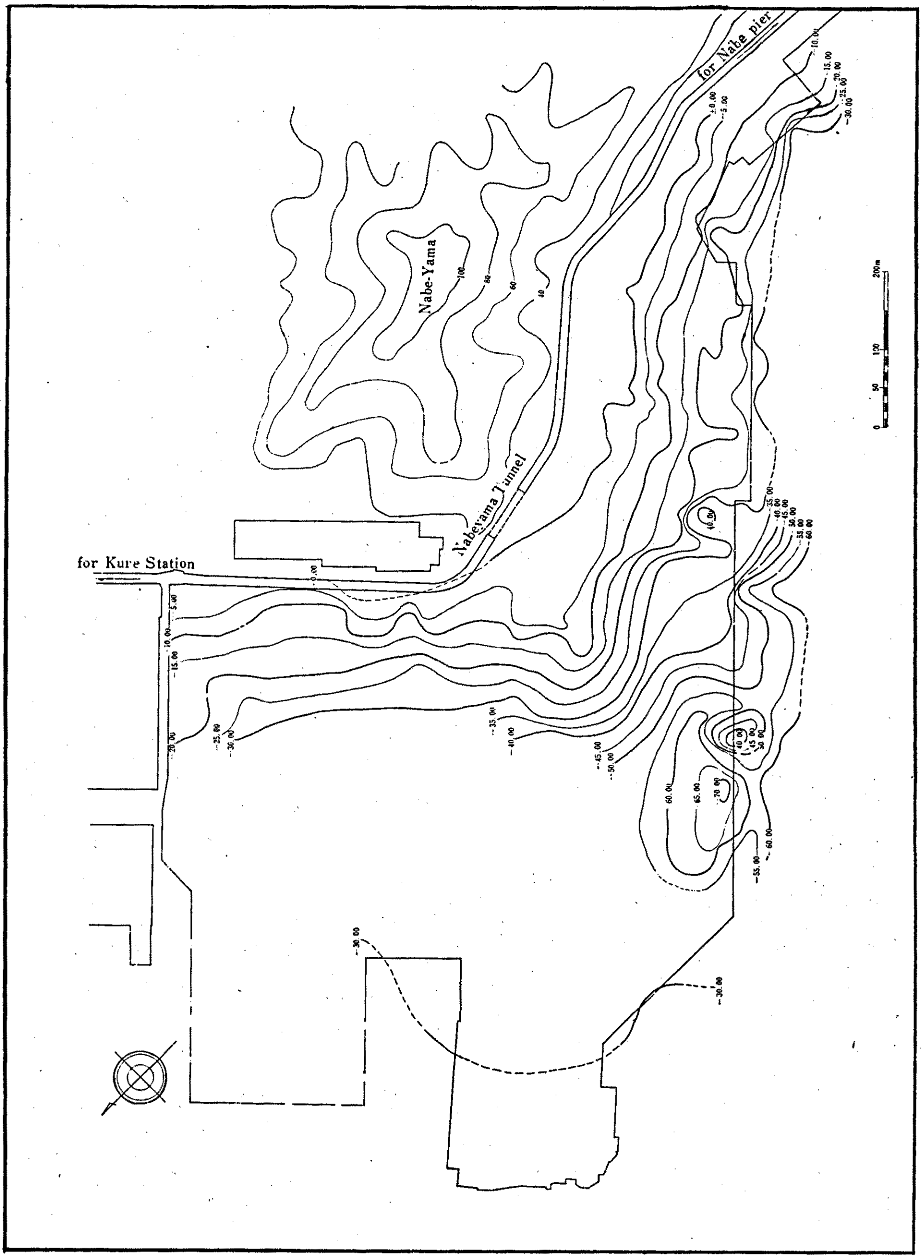


TABLE 2. LOCALITY AND CLASSIFICATION OF THE SPECIMENS

No. of specimen	Locality	Depth below the sea bottom (m)	Proportion (%) of			Classification	Density g/cc	Liquid limit (%)	Plasticity Index (%)
			Sand	Silt	Clay				
I	Iwakuni Bay	14.00–14.70	23.0	63.5	13.5	Sandy Silt	2.65	76.6	41.8
H	Hiroshima Bay	4.00– 4.50	9.0	68.0	23.0	Clayey Silt	2.71	95.8	35.2
K	Kure	7.00– 7.65	16.0	60.0	24.0	Clayey Silt	2.73	89.1	50.9
T	Takehara	15.00–15.74							
M	Mihara	7.60– 8.20	5.0	50.0	45.0	Silty Clay	2.70	99.9	57.5
F-1	Fukuyama Bay	3.50– 4.35	17.0	69.0	14.0	Sandy Silt	2.76	119.8	80.1
F-2	Fukuyama Bay	9.60–10.40	26.0	37.0	37.0	Silty Clay	2.75	66.1	40.2

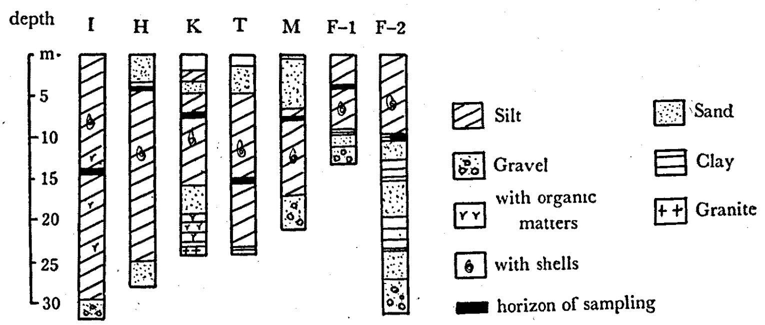


FIG. 8.

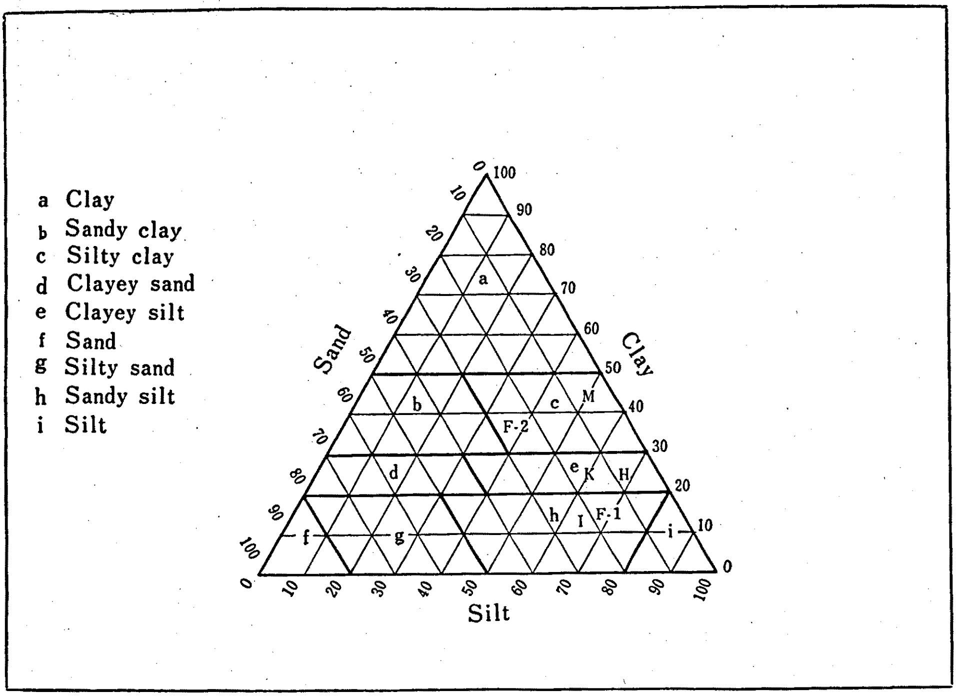


FIG. 9. Diagram for grain-size classification defined by Mississippian Committee

III. Mineralic Constituents

(1) Specimens provided for research

All the specimens were sampled by means of thin-wall tube from boring holes at undisturbed state. The locations, the depth of sampling, the grain-size of the specimens and so on are show in Table 2 and Fig. 8.

For reference, classification diagram based on the rule given by the Mississippian Committee of Soil Engineering is indicated in Fig. 9.

(2) Differential thermal analysis

As are evident in Fig. 10, preliminary tests for both specimens with respective grain-size of less than 4 μ and 70 mesh reveals almost the similar results in the case of F-T. In consequence, experiments were carried out for the specimens with grain-size same as the latter in the heating rate of 10°C/min. It is deducible from the data obtained for all specimens that the endotherm at 150°C is related to dehydration, the broad exotherm at 200°–500°C, as are conspicuously appeared especially in the cases of I, H, K, and M, to ignition of organic matters or to content of iron oxide, the endotherm at 550°–600°C to conversion of quartz and to content of kaolinite, that at ca. 700°C to 2:1 structures of montmorillonite or mica group and the exotherm at 900°–1000°C to coexistence of the latters.

(3) X-ray diffraction

The air-dried specimens, generally less than 70 mesh and partly less than 4 μ in grain-size, were subjected to X-ray diffraction at various states. The apparatus and experimental conditions are

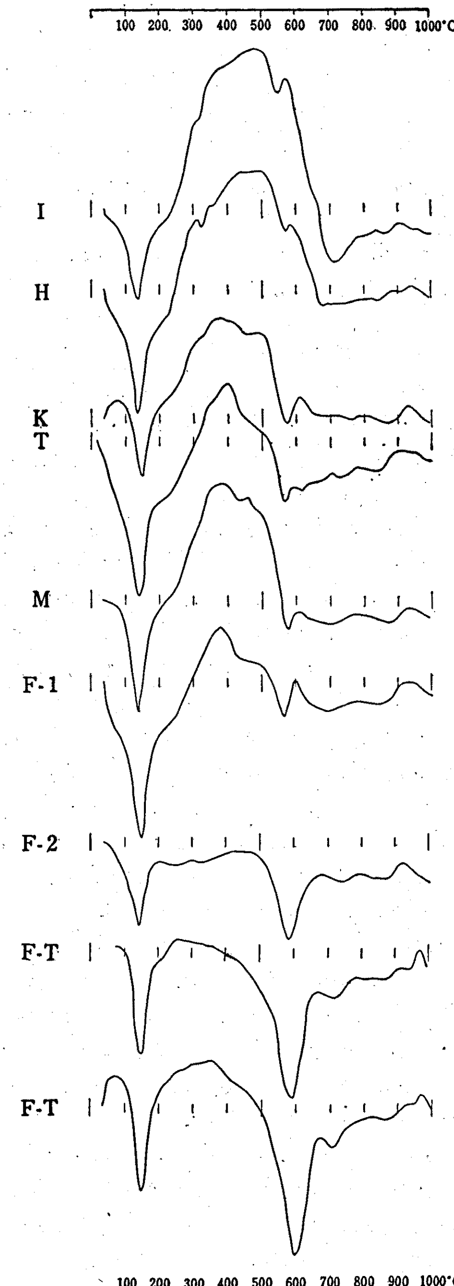


Fig. 10. DTA diagrams of some clayey materials obtained from several regions.

I. Quartz, illite, kaolinite group and chlorite with bulk of organic matter. H. ditto without montmorillonite. K, T, M, F-1. ditto. F-2 Quartz, illite, kaolinite group and trace of chlorite. F-T. Quartz, montmorillonite, illite and kaolinite group.

as follows:
X-ray diffractometer: GX-2B type of Shimazu Man. Co.
X-ray: Cu Kα, Filter: Ni, EMF and current intensity of X-ray tube: 30 KV, 15 mA, time constant: 2.5 sec for 1000 cps and 5 sec for 500 cps, scanning speed: 1° (2θ)/min, rotating speed: 1 cm/min, divergent slit: 1.5 mm, receiving slit: 0.2 mm.
X-ray diffraction data obtained at room temperature in all regions concerned are listed in Table 3.

Specimen I from Iwakuni:

At an ordinary state without any treatment, diffractions at 14.6 Å, 10.0 Å, 7.1 Å, 5.0 Å, 4.48 Å, 3.55 Å, 2.95–2.94 Å, 2.57 Å, and 2.40 Å etc., suggesting the co-existence of quartz, feldspars and clayey minerals, are characteristically conspicuous in their intensity.

With heating of the specimen for an hour, diffraction at 14.6 Å indicates a gradual decrease both in intensity and in 2θ at 150°C and 300°C and almost disappears at 450°C but restores its intensity in somewhat deviated position (13.9 Å) at 600°C, the behavior being congruent with that of chlorite. That at 10.0 Å is nearly invariable with the same treatment, suggesting the content of illite without halloysite. That at 7.1 Å discloses a variation in intensity at the temperature through 450°C to 600°C and culminates in conspicuous diminution and broadening, pointing to mingling of kaolinite group. With heating at 750°C, spacings corresponding to illite are remained not disappeared.

Basing on that swelling of the spacing from 14 Å to 17–18 Å is not ascertainable even through immersion of the specimen in ethylene glycol, content of montmorillonite is hardly expected. Treating the specimen with hydrochloric acid, diffraction pattern at 14 Å completely disappears probably on account of destruction of chlorite structure, while those at 10 Å and 7 Å remains though to a slight extent and seem to imply a small amount of kaolinite group. The result obtained through heating of the specimen in 1 N-ammonium nitrate for 10 min. is negatively reflected on diffraction for inspection of vermiculite. X-ray diffraction patterns are presented in Fig. 11.

From the data mentioned above it is concluded that the clayey specimens sampled in this region are composed of illite, kaolinite and chlorite, among which the last is regarded as a sort of so-called clay chlorite because of its destructibility at lower temperature.

Specimen H from Hiroshima:

Ordinary procedure at room temperature gives the spacings representing clayey minerals at 14.4 Å, 10.1 Å, 7.2 Å, 4.48 Å, 3.57–3.56 Å, 2.93 Å, and 2.57 Å etc. together with remarkable ones of quartz and feldspars.

Heat treatment causes the contraction, and rapid decrease of intensity, of the

TABLE 3. X-RAY DIFFRACTION DATA

Iwakuni		Hiroshima		Kure		Takehara		Mihara		Fukuyama (F-1)		Fukuyama (F-2)		Fukuyama* (F-T)		Minerals identified
d(Å)	I	d(Å)	I	d(Å)	I	d(Å)	I	d(Å)	I	d(Å)	I	d(Å)	I	d(Å)	I	
														26.0	2	
														17.1	7	
										16.1(?)	2			15.5	10	M (Montmorillonite)
14.6	7	14.4	6	14.3	3	14.4	2.5	14.3	3			14.5	2			C (Chlorite)
						10.2				10.4						
10.0	13	10.1	7	10.1	5	10.1	5	10.0	3	10.1	2	10.2	3	10.1	2	I (Illite)
8.5	3	8.4	3					8.6	2.5			8.5	3			
														7.3		
7.1	14	7.2	8	7.2	5b	7.1	7	7.2	3	7.2	3b	7.2	5b	7.2	3	K (Kaolinite)
6.5	5	6.6	2	6.4	4	6.4	3	6.4	2	6.5	2	6.4	2			F (Feldspar)
5.0	5													5.1	3	I
								4.52								
4.48	6	4.48	3	4.46	7	4.46	4	4.48	5	4.49	5	4.46	5	4.48	12	I, C, K, M
4.26	26	4.30	24	4.26	16	4.25	18	4.26	14	4.25	13	4.26	16	4.26	22	Q (Quartz)
4.03	12	4.06	11	4.04	15	4.03	8	4.04	8	4.04	5	4.04	5			F
3.79	6	3.78	9	3.78	8	3.77	5	3.79	5	3.78	5	3.78	4	3.78	3	F
3.67	8	3.67	8	3.67	8	3.67	6	3.68	4	3.68	4	3.67	3	3.70	4	F
		3.57														
3.55	11	3.56	9	3.55	4b	3.56	4b	3.54	4	3.53	4b	3.55	5b	3.58	2	K
				3.48	5	3.47	3									F
3.34	80+	3.34	80+	3.34	54	3.34	67	3.34	52	3.34	55	3.34	78	3.34	75	Q, I
		3.24	12													
3.24	19	3.19	30					3.20	12							
3.20	37	3.14	10	3.20	25	3.20	35	3.15	10	3.20	11	3.20	18	3.25	7	F
3.00	4	3.00	6	3.03	9					3.00	3	3.00	2	3.00	3	
2.94	4															
2.95	5	2.93	2	2.93	5					2.90	2	2.96	3			F, C, I
		2.71	3					2.71	3.5	2.71	3					
				2.58		2.60		2.57	4					2.56	7	
2.57	5	2.57	5	2.56	5b	2.56	4b	2.55	3	2.56	4b	2.56	5	2.55	6	I, C, K, M
2.46	10	2.46	8	2.46	5	2.46	7	2.46	4	2.46	6	2.46	7	2.46	9	Q, I
2.40	2															
2.32	3			2.37	4b	2.38	3									K, I
2.28	7	2.28	7	2.28	5	2.28	4	2.28	2.5	2.29	4	2.29	5	2.28	6	Q

* Shale from the ground of Iyō High School, Fukuyama City, taken for comparison with marine sediments. According to oral publication of IMAMURA (1962), it has been determined as a part of the Miocene formation because of occurrence of *salvinia natans*.

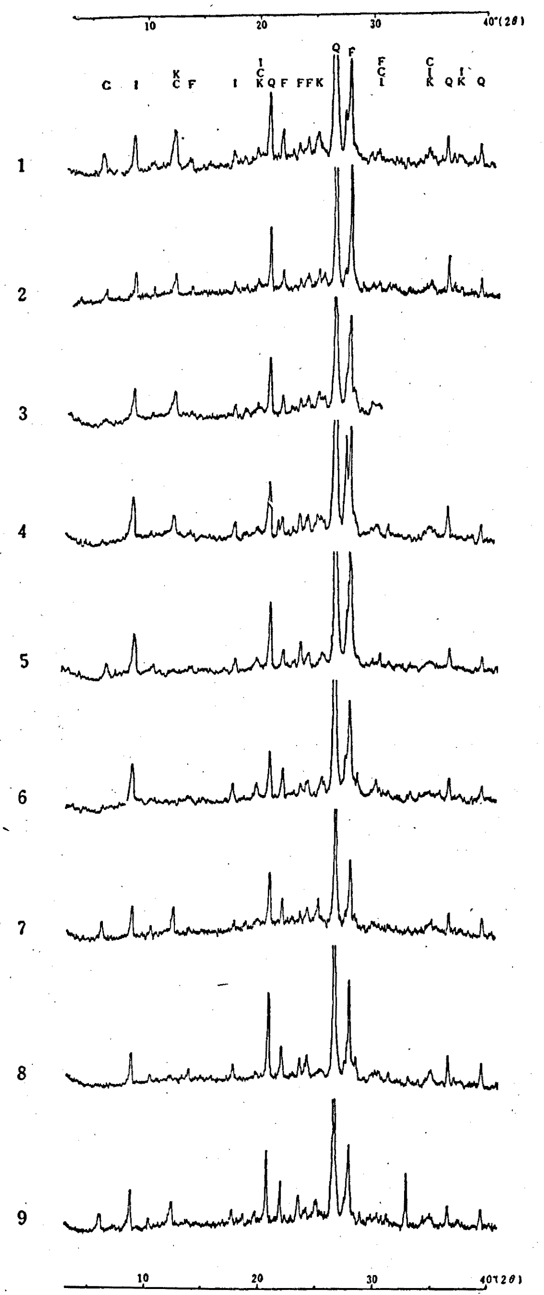


FIG. 11. X-ray diffraction patterns for the specimens I
C: Chlorite (clay chlorite) I: Illite K: Kaolinite group. F: Feldspar Q: Quartz
1. untreated 2. 150°C 3. 300°C 4. 450°C 5. 600°C 6. 750°C 7. E. G 8. HCl 9. NH_4NO_3
1. 3. 4. 5. 6. 500 c.p.s. 5 Sec.
2. 7. 8. 9. 1,000 c.p.s. 2.5 Sec.

spacing of 14.4 Å at 150°C, its vanishing at 300°C, and reappearance of 14.1 Å to an extremely slight extent at 600°C. In this case, diffraction at 10.1 Å becomes somewhat stronger and remains even at 750°C, associating appearance of 5.0 Å related to the secondary diffraction. That at 7.2 Å completely disappears at 600°C.

No variation of spacings and no expansion from 14 Å to 17 Å in the procedure with ethylene glycol seem to suggest the absence of montmorillonite. Treatment with hydrochloric acid results in disappearance of 14 Å and broadening of 7 Å. The effects of ammonium nitrate are not confirmable on all spacings but for weakening of 14 Å to a certain extent.

Scrutiny of the results makes it clear that the specimens under consideration comprise kaolinite, illite, and chlorite considered to be grouped into clay chlorite or vermiculitic chlorite. X-ray diffraction patterns are shown in Fig. 12.

Specimen K from Kure

Feeble diffractions manifesting the presence of clayey minerals at 14.3 Å, 10.1 Å, 7.2 Å, 4.46 Å, 3.55 Å, 2.58–2.56 Å, and 2.37 Å etc. together with characteristic ones of quartz and feldspars are discernible through ordinary process at room temperature.

Thermal effects on 14 Å yield

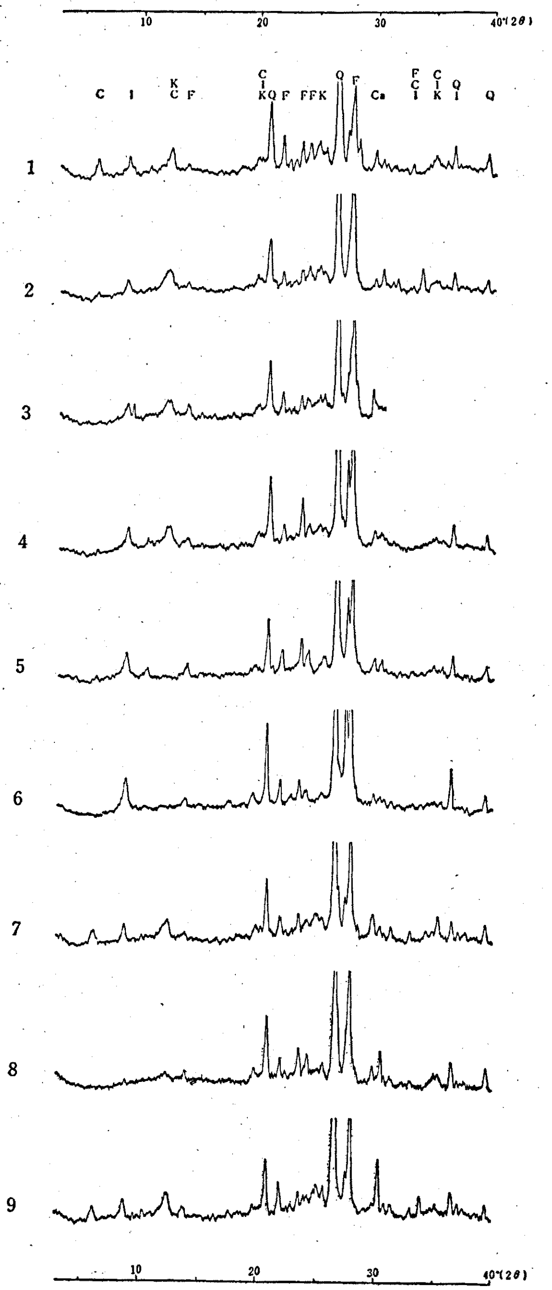


Fig. 12. X-ray diffraction paterns for the specimen H.
1. untreated 2. 150°C 3. 300°C 4. 450°C 5. 600°C
6. 750°C 7. E. G 8. HCl 9. NH_4NO_3
1. 2. 3. 4. 5. 6. 500 c.p.s. 5 Sec.
7. 8. 9. 1,000 c.p.s. 10 Sec.

an extreme decrease in its intensity at 150°C and are of almost no use for recovery of intensity even at higher temperature up to 600°C. Diffraction at 10 Å reveals a striking increase in its intensity at 600°C and becomes more stronger at 750°C. That at 7 Å remains at the temperature up to 450°C but disappears at 600°C. Test with ethylene glycol concerning the swelling of 14.3 Å clearly denies the presence of montmorillonite. With hydrochloric acid, the spacing of 14 Å disappears, that of 10 Å markedly weakens and that of 7 Å remains to be not disappeared. With ammonium nitrate all spacings are invariable. X-ray diffraction patterns are indicated in Fig. 13.

These data suggests the content of kaolinite group, illite and chlorite of the same property as are mentioned in the precedings.

Specimen T from Takehara:

Diffractions of the spacings recognized commonly in clayey minerals are appeared through ordinary procedures. Heating of the specimens contributes to remarkable weakening of 14.4 Å as well as to new formation of 8.5 Å at 150°C, to nearly complete vanishing of the former as well as to strenghening the intensity of 10.1–10.2 Å at 300°C, and to development of 10.1 Å accompanied with fading of 8.5 Å and 7.1 Å at 450°C while, at

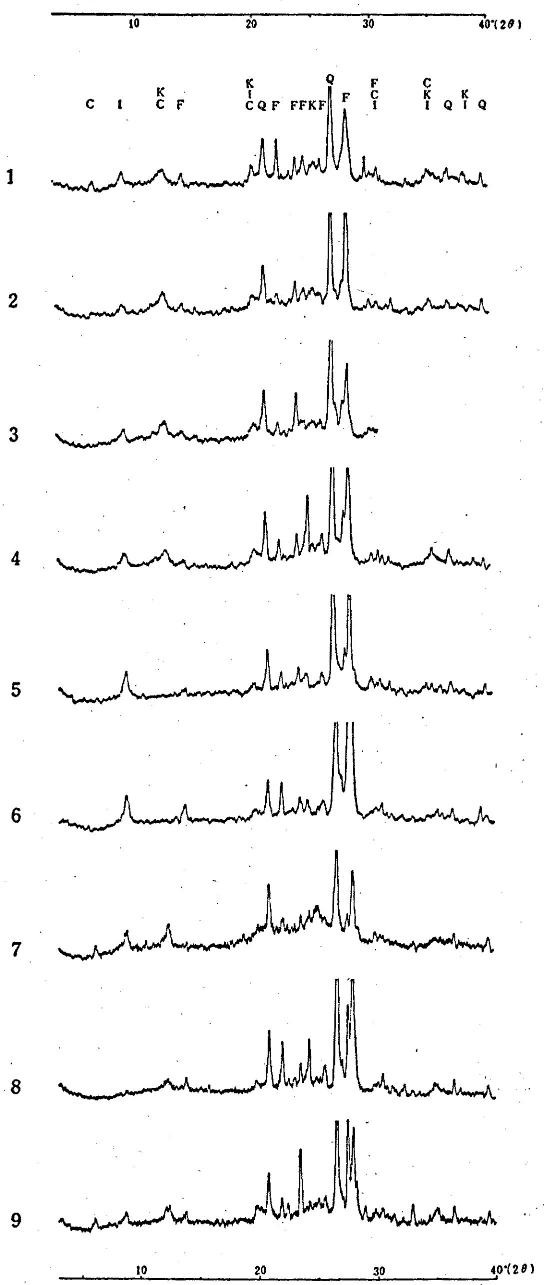


FIG. 13. X-ray diffraction patterns for the specimen K.
1. untreated 2. 150°C 3. 300°C 4. 450°C 5. 600°C 6. 750°C 7. E. G. 8. HCl 9. NH_4NO_3
1. 2. 3. 4. 5. 6. 500 c.p.s. 5 Sec.
7. 8. 9. 1,000 c.p.s. 2.5 Sec.

600°C, diffraction at 10.1 Å only is distinct, that at 8.5 Å is very weak and those at 7.1 Å and 3.56 Å disappear.

That the immersion in ethylene glycol results in the weakening of diffraction to more or less extent but does not in expansion of 14 Å to 17 Å evidently signifies the absence of montmorillonite. Treating with hydrochloric acid, diffraction at 14.3 Å disappears, and those at 10.0 Å and 8.5 Å together with broad one at 7.1 Å remains. Treatment with ammonium nitrate brings about the decay of 14.3 Å and the faint emergency of 10.5 Å and 9.1 Å probably due to intercalation of ammonium radicals between interlayers. The spacings corresponding to the latter two and to 8.5 Å appeared with heating at higher temperature are to be scrutinized in more details. X-ray diffraction patterns are manifested in Fig. 14.

These results are not so much different from those obtained in the precedings concerning other specimens.

Specimen M from Mihara:

The specimens in question give nothing other than feeble diffractions pointing to ill crystallinity at ordinary state.

Heating of the specimens at 150°C manifests almost no variation of diffractions in their intensity and position and that at 300 °C causes the fading and broad-

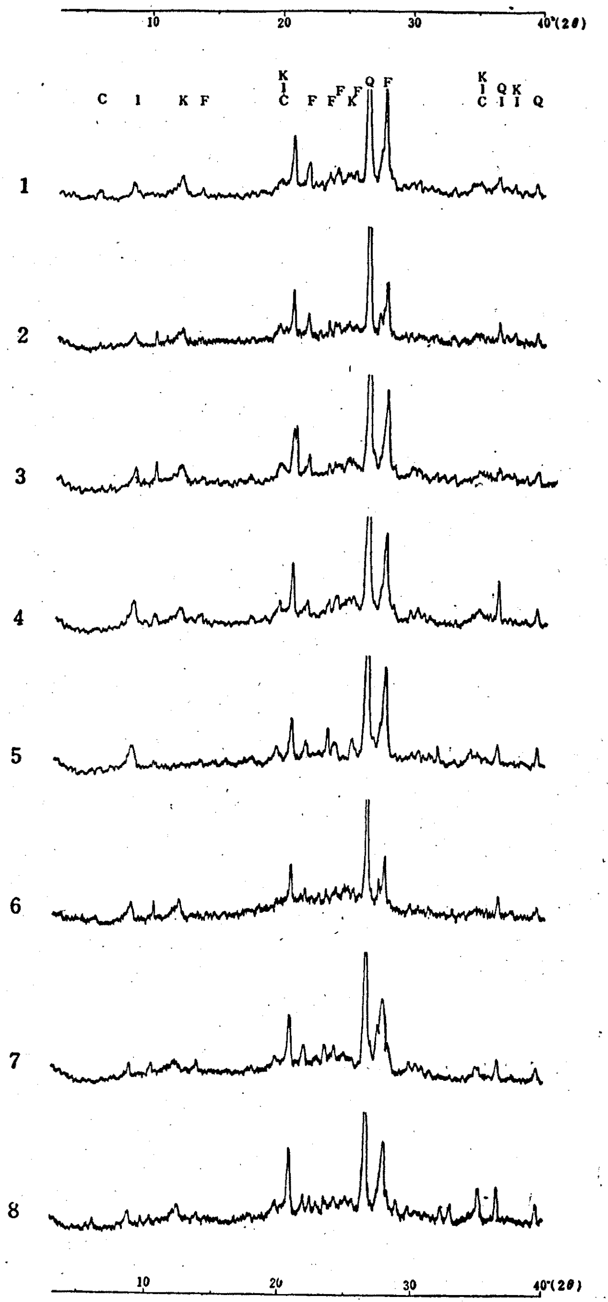


FIG. 14. X-ray diffraction patterns for the specimen T
1. untreated 2. 150°C 3. 300°C 4. 450°C
5. 600°C 6. E. G 7. HCl 8. NH_4NO_3
1. 3. 4. 5. 500 c.p.s. 5 Sec.
2. 6. 7. 8. 1,000 c.p.s. 2.5 Sec.

ening of 14.3 Å as well as somewhat stronger diffraction at 10 A and the settling of 8.4 Å, 7.9 Å and 7.3 Å–7.2 Å in the past larger than 7.2 Å, while the similar treatment at 450°C does almost perfect lack of 14.3 Å, the prosperity of 10.0 Å and 8.4 Å, and the broadening of 7.2 Å toward larger side in Å.

Only noticeable variation of diffractions can not be confirmed due to the effect of ethylene glycol. That the agency of hydrochloric acid is effective for complete disappearance of 14.3 Å but indifferent to the presence of 10.0 Å, 8.4 Å and 7.2 Å seems to give a clue to mingling of kaolinite group. Treatment with ammonium nitrate is of use only for weakening of all spacings. X-ray diffraction patterns are shown in Fig. 15.

The results thus obtained are almost similar to those in the foregoing cases.

Sample F-1 from Fukuyama:

Diffractions for the specimens at ordinary temperature are too faint to distinguish one from another. Behavior of the spacing at 14 Å is of obscurity at higher temperature. The spacing of 10 Å becomes stronger in intensity with heating at 600°C and 750°C, while that of 7.0 Å remains at the temperature up to 450°C but

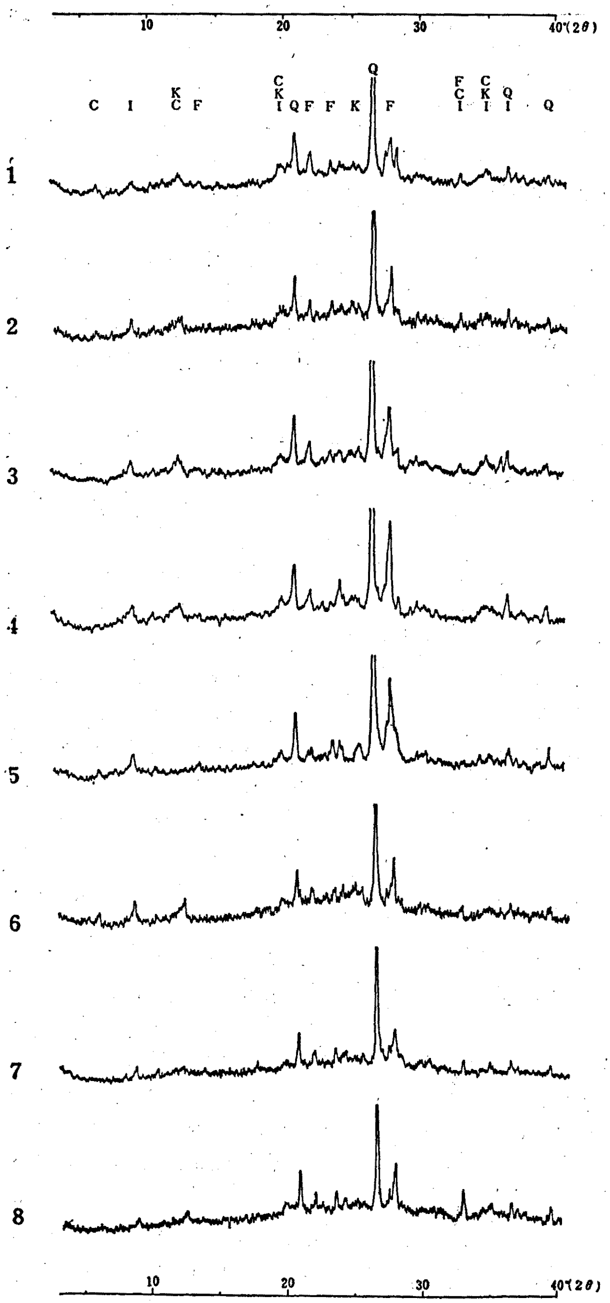


FIG. 15. X-ray diffraction patterns for the specimen M
1. untreated 2. 150°C 3. 300°C 4. 450°C
5. 600°C 6. E. G 7. HCl 8. NH_4NO_3
1. 3. 4. 5. 500 c.p.s. 5 Sec.
2. 6. 7. 8. 1,000 c.p.s. 2.5 Sec.

disappears at 600°C.

Effects of ethylene glycol on the spacings in the range larger than 14 Å are ambiguous in spite of apparent diffractions at 10.1 Å and 7.2 Å. Diffractions at the latter two together with 4.5 Å display the decrease in intensity in the case of being treated with hydrochloric acid. The spacings at 14.1 Å, 10.1 Å, 7.2 Å and 4.5 Å evidently remain even with use of ammonium nitrate. X-ray diffraction patterns are displayed in Fig. 16.

The fact referred to already clarifies the mingling of kaolinite group and illite into the specimens but there is a room for further inspection of diffraction at 14 Å.

Specimen F-2 from Fukuyama:

Of all spacings emerged at ordinary state, that of 14.5 Å disappears almost completely with heating at 150°C and the others increase their intensity at 300°C to 450°C, whereas that of 7.2 Å decays almost thoroughly at 600°C but that of 10.2 Å remains at 750°C.

Invariability of diffractions with use of ethylene glycol seems to imply the absence of montmorillonite. Basing on that nothing other than slight broadening of 7.2 Å and weakening of 3.51 Å is not ascertainable as effect of hydrochloric acid, the specimens are

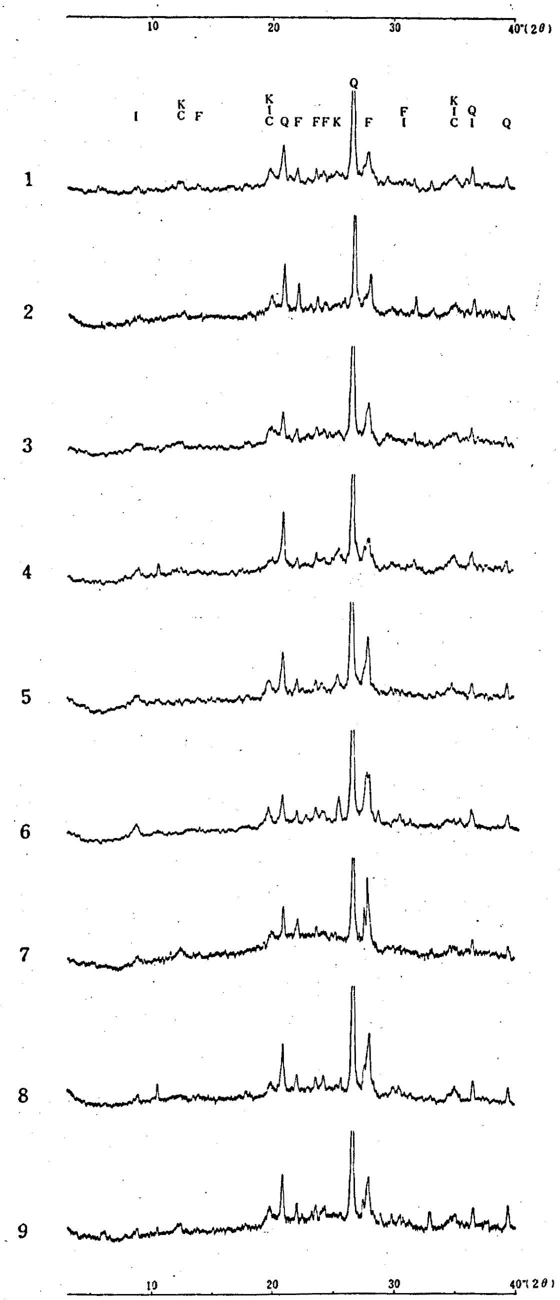


FIG. 16. X-ray diffraction patterns for the specimen F-1.
1. untreated 2. 150°C 3. 300°C 4. 450°C 5. 600°C
6. 750°C 7. E. G 8. HCl 9. NH_4NO_3
1. 3. 4. 5. 6. 500 c.p.s. 5 Sec.
2. 7. 8. 9. 1,000 c.p.s. 2.5 Sec.

considered to involve mainly kaolinite group associated with scarce amount of chloritic mineral. Treatments with ammonium nitrate result in a general increase of diffractions, broadening of 10.2 Å, emergency of 4.93 Å regarded as a sort of secondary diffraction, and appearance of 3.96 Å, 3.77 Å, 3.69 Å, 3.52 Å and some others probably due to intercalation of ammonium radicals between the interlayers of illite or hydrous mica. X-ray diffraction patterns are revealed in Fig. 17.

It thus follows that exclusive of allusion to quartz and feldspars, the specimens in question are composed mainly of illite and kaolinite group accompanying an extremely little amount of clay chlorite.

Specimen F-T from Fukuyama:

With heating at 150°C, feeble diffraction at 26 Å and broad ones at 17.1 Å to 15.5 Å almost disappear, those at 10.5 Å to 10.1 Å converge on the sharp one at 10.1 Å, and those at 7.2 Å and 3.77 Å increase their intensity. At 300°C and 450°C, diffractions at 10.1 Å, 7.2 Å and some others indicate the increase of intensity, while at 600°C, those at 7.2 Å and 3.58 Å disappear and at 750 °C, that at 10.1 Å remains not disappeared. As far as the heat treatment is concerned, diffractions at 26 Å may be ascribed to a sort of mixed layer structure

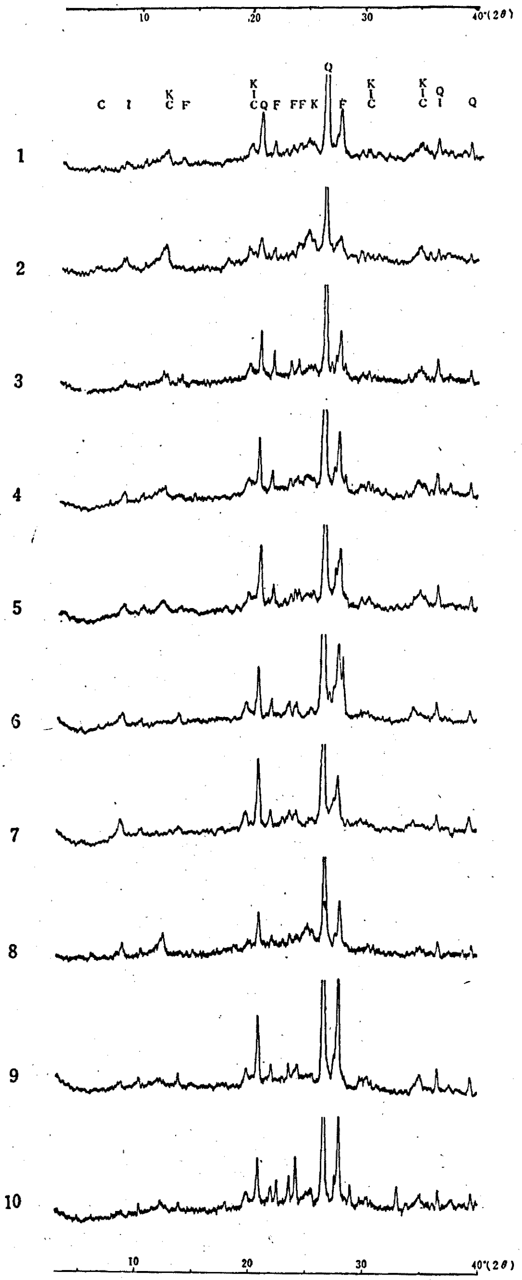


FIG. 17. X-ray diffraction patterns for the specimen F–2

1. untreated (−70 mesh) 2. ditto (−4μ) 3. 150°C
4. 300°C 5. 450°C 6. 600°C 7. 750°C 8. E. G
9. HCl 10. NH_4NO_3

1. 2. 3. 4. 5. 6. 7. 500 c.p.s 5 Sec.
3. 8. 9. 10. 1,000 c.p.s 2.5 Sec.

of 17.1 Å–15.5 Å with 10.5 Å–10.1 Å, easier destruction of 15.5 Å at lower temperature to the presence of montmorillonite, diffractions at 10.5 Å–10.1 Å to hydrated complex of illite, and that at 7.2 Å to kaolinite group.

Of due significance is the marked swelling of spacings represented by 17.1 Å–15.5 Å in some per cent through effect of ethylene glycol due to the remarkable content of montmorillonite. Acid treatment is effective for fading of the conspicuous spacings of 17.1 Å–15.5 Å, while diffractions at 10.1 Å and 7.2 Å remain though to a slight extent. Treating with ammonium nitrate, emergency of broad and weak diffraction in the range surrounding 13.1 Å, due to inclusion of ammonium radicals between interlayers of montmorillonite, and feeble diffractions at 10.2 Å and 7.3 Å are surely observed. X-ray diffraction patterns are given in Fig. 18.

It thus results in that the specimens under consideration are characterized with contents of quartz, feldspars and clayey minerals such as montmorillonite, illite, hydrous complex of illite, kaolinite group and mixed-layer minerals composed between montmorillonite and illite.

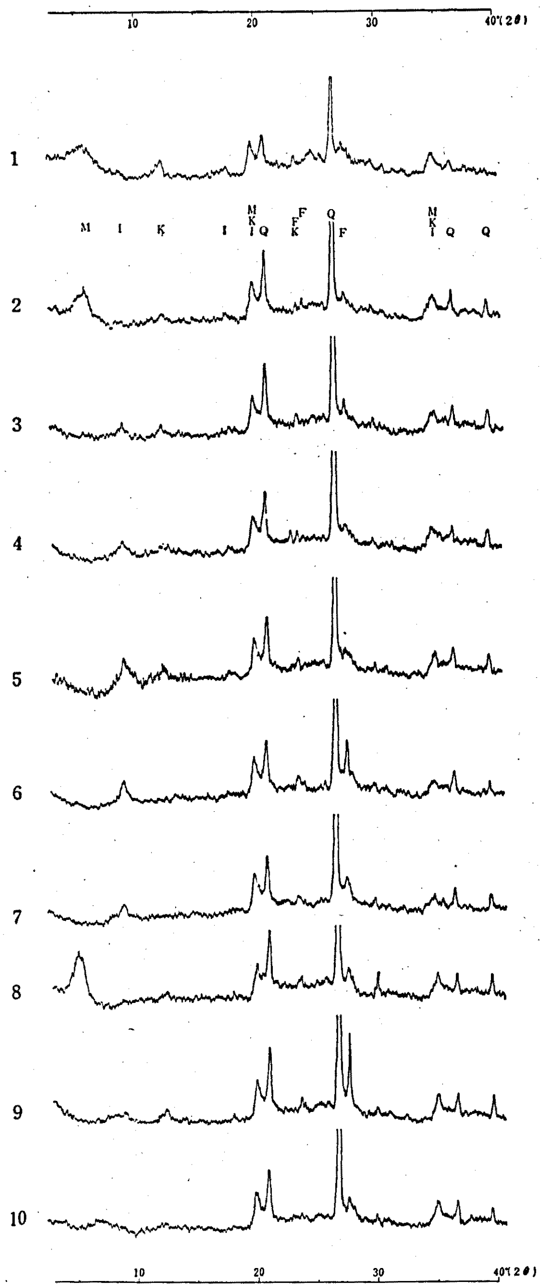


FIG. 18. X-ray diffraction patterns for the specimen F–T
M: Montmorillonite
1. untreated (-4μ) 2. ditto (-70 mesh) 3. 150°C 4. 300°C
5. 450°C 6. 600°C 7. 750°C 8. E. G 9. HCl 10. NH_4NO_3
1.∼7. 500 c.p.s 5 Sec.
8.∼10. 1,000 c.p.s 2.5 Sec.

IV. PLASTICITY OF COHESIVE SEDIMENTS

As an initial step of finding out the factors controlling the mechanical property of alluvial deposits, characteristics of cohesive materials such as silty or clayey sediments obtained in respective regions were subjected to scrutiny specifically on the basis of liquid limit (Lw) and plastic limit (Pw) or plasticity index (PI). The relationships between Lw and PI regarding the specimens in question are, as are plotted in Figs. 19–24, nearly linear, whereas establishment of this relation in the soils contained within the single drainage region was previously pointed out.

The relation is generally formulated as follows:

$$PI = m(Lw - a),$$

where m represents tangent of the angle between PI and Lw, and a the distance of the line intersecting at $PI = 0$ from the origin, both being the constants defined due to the conditions of respective localities. As are listed in Table 4, similar ten-

TABLE 4. m AND a FOR EACH LOCALITY

Locality	m	a
Iwakuni	0.80	28
Hiroshima	0.66	20
Kure	0.67	17.5
Mihara	0.93	33
Fukuyama	0.84	25
ditto (stiff clay)	0.76	20

dencies situating near the Casagrande's line 'A' are confirmable in all cases and, in consequence, seem to imply after mechanical classification that the cohesive materials in question are enclosed within the area representing inorganic silt under high compression, organic silt to inorganic silt under medial compression, and organic silt. It is of course that concentration areas are really different one from another for respective localities and sampling horizons even at the same locality, as are surely observable in the examples obtained from Fukuyama concerning the upper alluvial silt and the lower clay of stiff property.

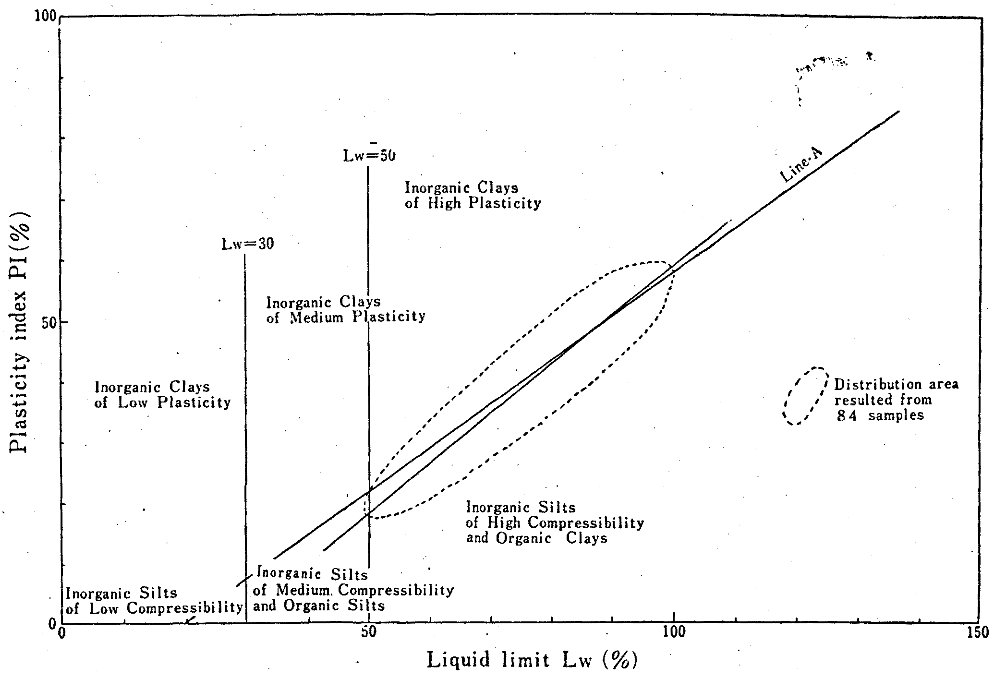


FIG. 19. Plasticity diagram for the specimens of Iwakuni

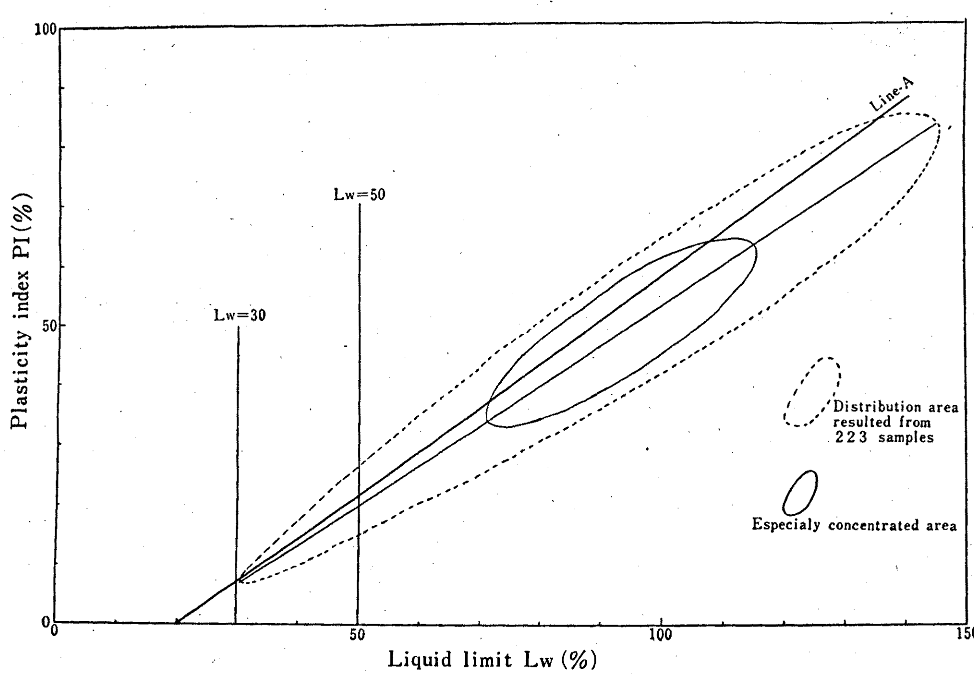


FIG. 20. Plasticity diagram for the specimens of Hiroshima

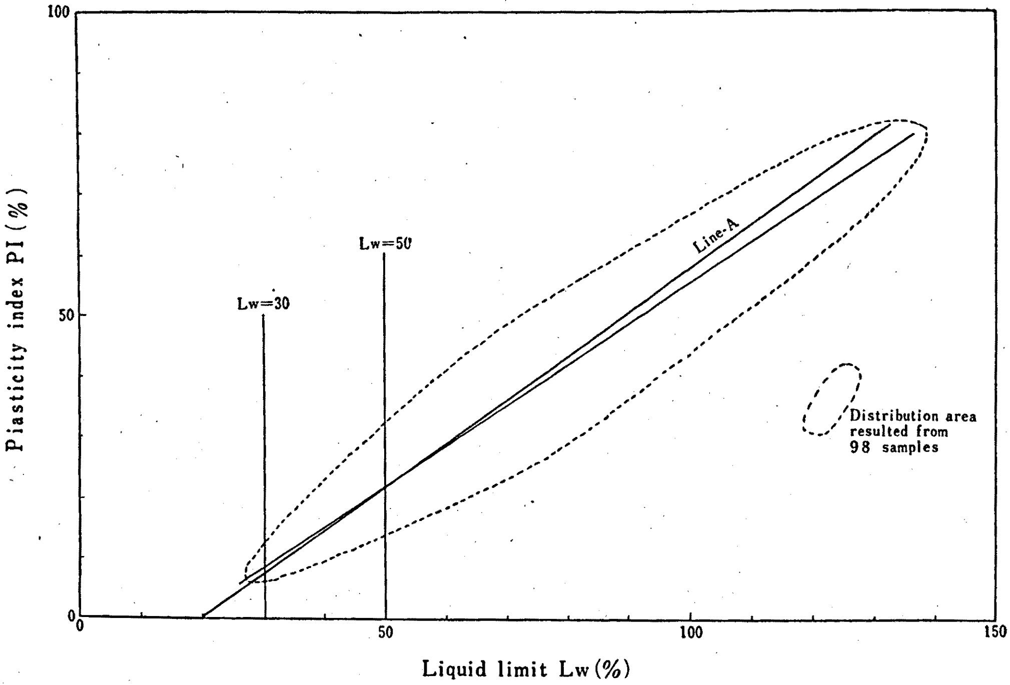


FIG. 21. Plasticity diagram for the specimens of Kure

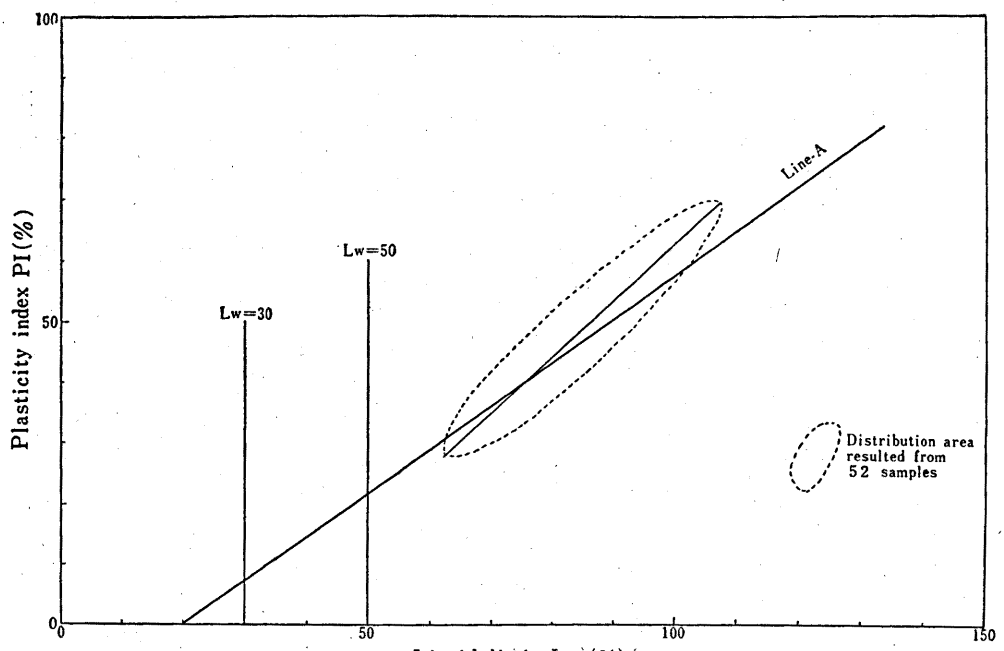


FIG. 22. Plasticity diagram for the specimens of Mihara

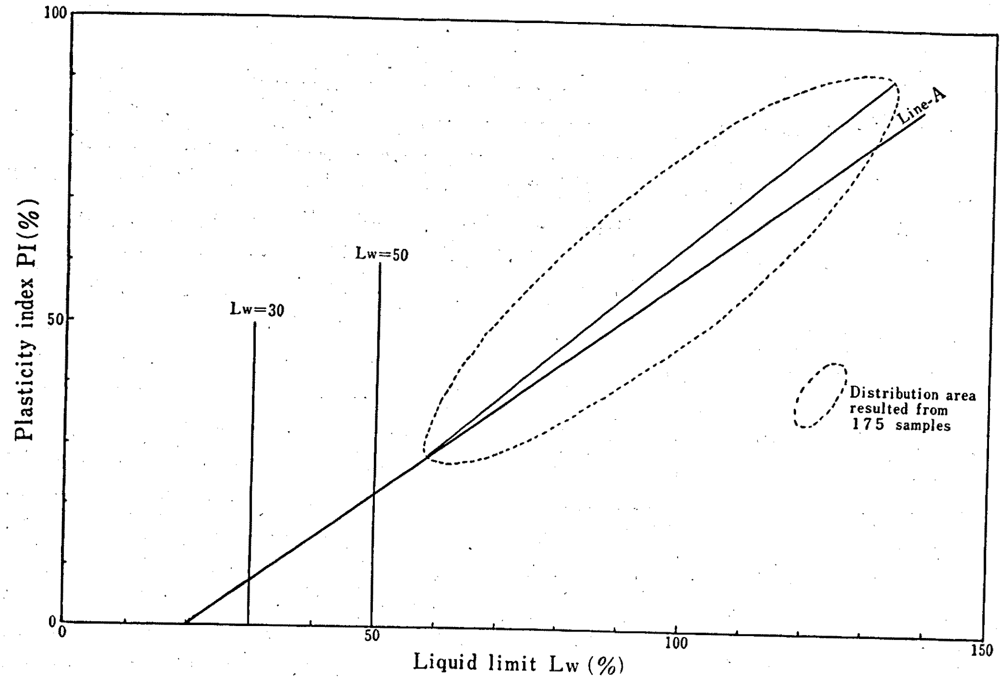


FIG. 23. Plasticity diagram for the specimens (soft silt) of Fukuyama

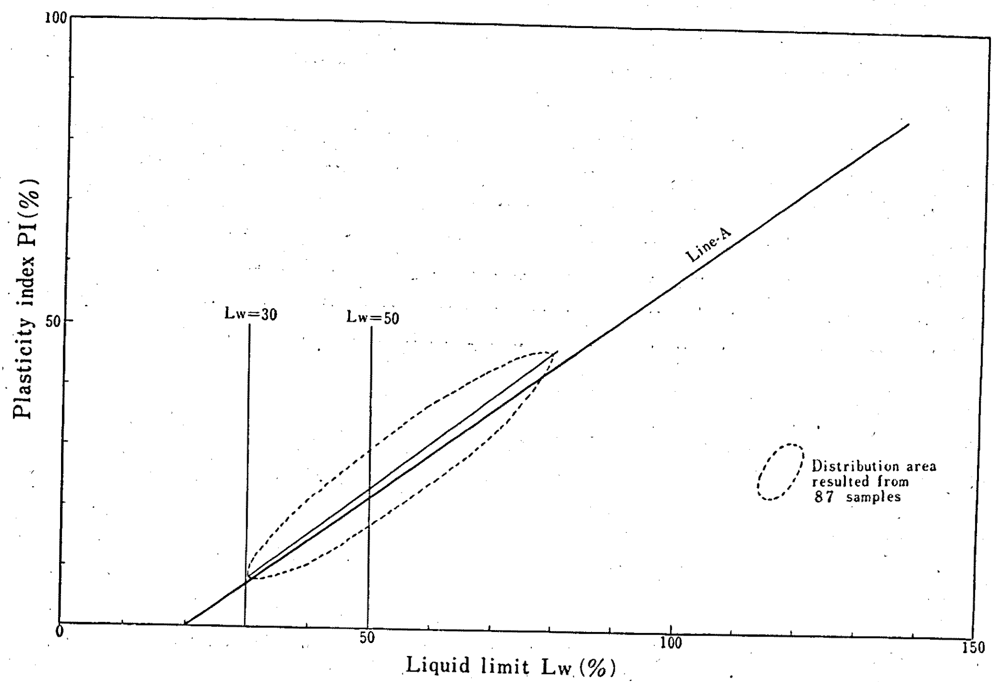


FIG. 24. Plasticity diagram for the specimens (stiff clay) of Fukuyama

V. SUMMARY

(1) Typical stratigraphy of the sediments dealt with in this investigation is composed of the upper sandy bed, the middle silty bed and the lower gravelly bed covering unconformably the basement but, with remoting from the estuaries the second becomes predominant without, or in stead of, the first. In the cases of certain localities such as Hiroshima, Hiuna, Matsunaga and Fukuyama, the clayey layers of stiff property are often intercalated within the lowest beds without the fragmental shells and distinguished from overlying silty beds in their environment and stage of deposition.

(2) Inspection of the data obtained through heat treatment and procedures with certain reagents clearly indicates that quartz and feldspars are most common as mineralic constituent composing the silts, and illite, kaolinite group, and clay chlorite or vermiculite-like chlorite destructed easily through thermal effect follow as clayey minerals. It seems general that clayey minerals from Iwakuni and Hiroshima are better in their crystallinity than those from other localities. Special allusion to montmorillonite is considered indispensable, since the samples of shale, a part of the Miocene formation, constructing the hilly lands situated at Fukuyama City are characterized by the presence of montmorillonite, illite, hydrous derivatives of illite, kaolinite group and mixed-layer minerals between montmorillonite and illite, and seem to play an important role in deposition of the alluvial silty beds as their sources.

(3) To be remarked is that plasticity diagrams representing silts and stiff clays obviously illustrate either local features or vertical difference in mineralic components due to each horizon at the same locality.

(4) As the problems necessiating further researches, the relations of chemical and physical properties of solid particles consisting cohesive sediments, their secondarily obtained characters such as absorbability and exchangeability for ions and soluble salts, variation of their structures, ratios and kinds of mineralic constituents in the sediment concerned, proportion of grain-size distribution and so forth to plasticity as well as to other mechanical factors connecting closely with strength of the sediments still now remain to be solved.

LITERATURES

Clay Research Group of Japan (1957, 1960, 1962): Advances in clay science (in Japanese), (1), (2), (3), Gihodo Press.

GIRM, R. E., DIETZ, R. S. and BRADLEY, W. S. (1949): Clay mineral composition of some sediments from the Pacific Ocean off the California coast and the Gulf of California, Geol. Soc. Amer. Bull., **60**, 1785–1808.

HASE, A. (1951): Geology of Hiroshima Plain (in Japanese), Rep. Hiroshima Geol. Ass., 2, 2–3.

ISHII, Y., KURATA, S. and FUJISHITA, T. (1955): Researches on the engineering properties of alluvial clays (in Japanese), Trans. Japan Soc. Civ. Eng., (30), 1–92.

ITIHARA, Y. (1960): Weathering of clay minerals in marine sediments (in Japanese), Jour. Geol.

Soc. Japan, **66**, 812–819.

KUMAGAI, T., ABE, E. and YOSHIMURA, Y. (1957): Depth of granite basement beneath the alluvial deposit of Hiroshima City basing on gravity measurement (in Japanese), Rep. Hiroshima Geol. Ass., 10, 5–16.

OINUMA, K., KOBAYASHI, K. and SUDO, T. (1959): Clay mineral composition of some recent marine sediments, Jour. Sed. Petrol., **29**, 56–63.

PARKER, D. T. and ROLSTON, W. J. (1951): Engineering geology of San Francisco Bay, California, Bull. Geol. Soc. Amer., **62**, 1079–1110.

TAKAHASHI, E. (1960): Stratigraphy of alluvial deposits of the Hofu plain (in Japanese), Jour. Fac. Sic. Yamaguchi Univ., **11**, 171–172.

TERZAGHI, K. (1955): Influence of geological factors on the engineering properties of sediments, Econ. Geol. 50th Anniv. Vol., 557–618.

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