

# *Epitome of Quaternary History of Hamamatsu and Its Environs in Central Japan.*

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We have watched the waves changing the  
pre-Glacial banks and shelves, when the surface  
of the ocean slowly sank and rose, as if Neptune  
were breathing with the august dignity of a god.

..... R. A. DALY

## 1 Preface

I am to dedicate this paper with sincere thanks to my respected teacher Kenzo SAITOH who has long from my childhood encouraged my studies in geological science.

This is a short report on the Late Quaternary history of coastal district about Hamamatsu on the Pacific coast of Central Japan. Through Late Quaternary time, the district must have been inevitably influenced by the eustatic swing of sea level. In the area of unstable crust, however, it is difficult to detect in some kinds of phenomenon the direct influences given by the eustatic change in sea level.

The district of Hamamatsu (34°40'N; 137°42'E) is consisted of uplands and lowlands near the mouth of the Tenryu River which has since remote geologic past transported and deposited large quantities of detritus. As the result of rather rapid accumulation, deposits of younger geologic ages bear a high degree of estuarine aspect in this district.

Two stages of marine transgression are recognized since possibly the Riss-Würmian Interglacial stage, of which the younger denotes the stage of deposition of the so-called Alluvial bed whose front is still under progradation.

Between both plains of deltaic deposition are displayed several steps of fluvial terraces with various altitudes, which seem to suggest the mode of terracing having taken places under the influence of change in sea level.

The study was commenced in 1961 immediately after arrival from my trip in Europe and two years were spent for geological and geomorphological investigations in this environ. This line of study together with micropalaeontological and palaeontological studies carried out by Prof. M. SHIMAKURA, Dr. M. CHIH and Mr. S. KOKAWA, were made possible under the financial

aid from the Hamamatsu Municipal Office. A part of my field work was supported by many students of geology, for instance, Mr. J. SAKAI of Kyoto University, Mr. T. OKAMOTO, Mr. T. NASU and Mr. H. KAGAMI of Shinshu University. Dr. Y. KATO of Shizuoka University gave me kind helps and valuable instructions. I have also benefited by discussions with Dr. M. HOSHINO of the Japanese Hydrographic Office in Tokyo. Dr. K. MOMOSE of our Laboratory of Geomagnetism and Mrs. Tamura helped prepare some of illustrations. I wish to extend my thanks to these persons.

A monograph on geology and palaeontology of the Quaternary deposits in the district of Hamamatsu will be printed in a volume to be published by the Municipal Office of Hamamatsu. The problems that I can not deal with in the present paper will be discussed in the monograph in some details. A coloured geologic map on a scale 1:30,000 was already published, therefore, numbers of localities cited in this paper will be found in that geologic map (HAMAMATSU MUNICIPAL OFFICE, 1963).

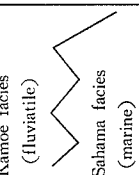
| Geologic age        | Topographic surface (altitude in m.) | Deposit (thickness in m.) |   | Notes   |
|---------------------|--------------------------------------|---------------------------|---|---|
| LATE<br>PLEISTOCENE | Nakaze flood plain (40-0)            | Shitamachi<br>Formation   | Top sand & gravel (20-)   | Later substage  |
|                     | Hamakita terrace (50-22)             |                           | Middle silt zone (40-)  | Mollusk shells  |
|                     |                                      |                           | Hamakita Fm. (?)  | Hamakita subst.   |
|                     |                                      |                           | Basal gravel (20)   |   |
|                     |                                      | Settai terrace (53)       | Settai gravel Fm. (10)  | Early substage<br>Maximum drop of sea level ?   |
|                     |                                      | Ubagaya terrace (65-30)   | Ubagaya gravel Fm. (10)   |   |
|                     |                                      | Tomioka terrace (60-10)   | Tomioka gravel Fm. (10)   | comparable to Komakian stage of terracing ?   |
| EEMIAN              | Mikatagahara upland (115-25)         |                           | Mikatagahara gravel Fm. (20-3)  |   |
|                     | Kamoe upland (150-30)                | Hamamatsu Formation (30)  |  | <i>Palaeoloxodon namadicus naumanni</i> ,<br><i>Anadara granosa bisenensis</i> ,<br><i>Sapium sebiferum</i> ,<br><i>Paliurus nipponica</i> ,<br><i>Styrax japonica</i> ,<br><i>Alnus japonica</i> |
|                     |                                      | Infra-Hamamatsu Formation |   | sand, gravel and silt   |

Table 1. Chronologic situations of Quaternary deposits and associated topographic surfaces in the Hamamatsu district.

Abbreviations: Fm: Formation

## 2 Hamamatsu Stage

### 2-1 Hamamatsu formation

The Hamamatsu formation builds the Horiya Hill on the north and the Kamoe upland occupying very small area southeast of the Mikatagahara upland. The Hamamatsu formation proper has also been confirmed from the present study to lie disconformably under the Mikatagahara gravel bed.

The Hamamatsu formation consists of two lithologic facies differing from one another, of which one bears a terrigenous facies characterized by fluvialite gravel, whereas another bears marine facies characterized by the dominance of dark blue silt containing remains of molluscs, foraminifers, often elephants, plants and other organisms.

Terrigenous or fluvialite facies that I am to call the "Kamoe facies" occupies the eastern part close by the Tenryu River which has long supplied vast amount of materials into the estuarine sea near the mouth, whereas marine facies named as the "Sahama facies" is typically developed to the west of Hamamatsu.

Although both facies are characterized respectively by terrigenous or marine sediments, even within the typical Kamoe facies are often recognized seams of marine blue silt bearing sometimes molluscs and other marks or traces of marine organisms. On the other hand, typical blue silt layers belonging to the Sahama facies are usually overlain by gravel bed with the lithological feature of the Kamoe facies.

The sediments that are assigned to the Sahama facies have been studied by many researchers such as WAKIMIZU (1918), MAKIYAMA (1924, ab), OINOMIKADO (1934), KOBAYASHI (1942), GOHARA and SASAKI (1951), TSUCHI and ITO (TSUCHI, 1960; ITO and TSUCHI, 1960; TSUCHI, 1961).

Among these authors, TSUCHI and ITO expressed in 1960 a peculiar opinion that their "Higashi-Kamoe formation" was understood as underlying the "Sahama mud formation" in an unconformable relation. According to the present study conducted for these facies, I came to a conclusion that at type locality the Higashi-Kamoe formation which is the same as the Kamoe facies, should be synchronous with the sediments of the Sahama facies, namely both Kamoe and Sahama facies form a single stratigraphic unit—the Hamamatsu formation. Stratigraphic evidences for this conclusion can readily be mentioned in the succeeding paragraphs.

Apart from this problem, another matter of importance must be discussed. The thickness of the Hamamatsu formation is unknown as the information from borings indicates that a thick deposit featured by the similar lithology with those of the Hamamatsu formation, lies down to the depth of at least 300m. Several uneven surfaces of erosion, which are seemingly intraformational ones are observed at a low altitude in exposures existing between both areas of the Sahama and the Kamoe facies. Though the indication of such stratigraphic break is recognized at only a few places, I should like to separate tentatively the Hamamatsu formation in strict sense from the thick formation below the ground. The name "Infra-Hamamatsu

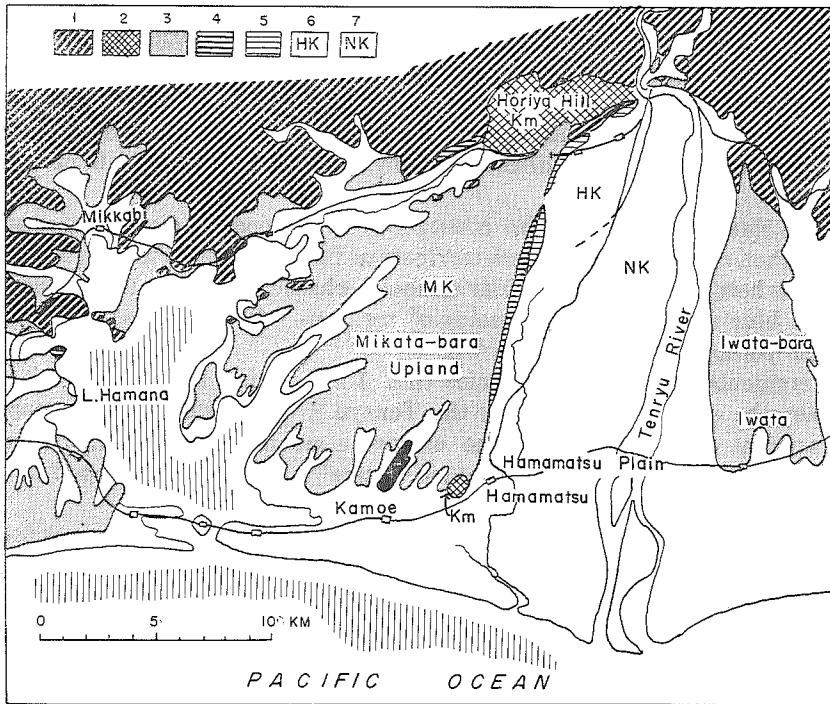


Fig. 1. Index map of the Quaternary deposits and associated topographic features of Hamamatsu and its environs.

- 1: Mountains consisting of Palaeozoic rocks, 2: Fill top of the Hamamatsu formation, 3: Mikatagahara formation and its equivalent. 4: Tomioka (Higher) terrace, 5: Ubagaya (Middle) terrace, 6: Hk Hamakita (Lower) terrace 7: Nk Nakaze flood plain

formation" is to be given for the latter which has been known as being an excellent reservoir of artesian water (MURASHITA, et al, 1962).

The Infra-Hamamatsu formation raises of course a difficult problem on its geologic age of deposition.

a) Kamoe facies

The type section of the Kamoe facies of the Hamamatsu formation is adopted from an exposure at Loc. 645 (Fig. 2) in Iba southwest of the city of Hamamatsu. The deposits consist principally of gravels from 7 to 3 cm in diameter. The graveliferous facies are rather worse sorted compared with that of the Mikatagahara formation. The gravel bed of the Kamoe facies consists of pebbles of sandstone, chert, slate, diabase, quartz, granite, quartz-porphry and others. Pebbles of sandstone, granite, quartz porphyry and diabase are usually decayed through weathering. Pebbles of granite are

often mechanically disintegrated. Near Miyaguchi and Hainoki (Pl. 3; Fig. 6) in the northern part of distribution, gravels are larger in size, sometimes they attain to the grain size up to 18 cm and are intensively weathered, so that they are variegated owing to discoloration through weathering. The matrix cementing gravels of the Kamoe facies is usually more clayey and a little more compact than that of the Mikatagahara formation.

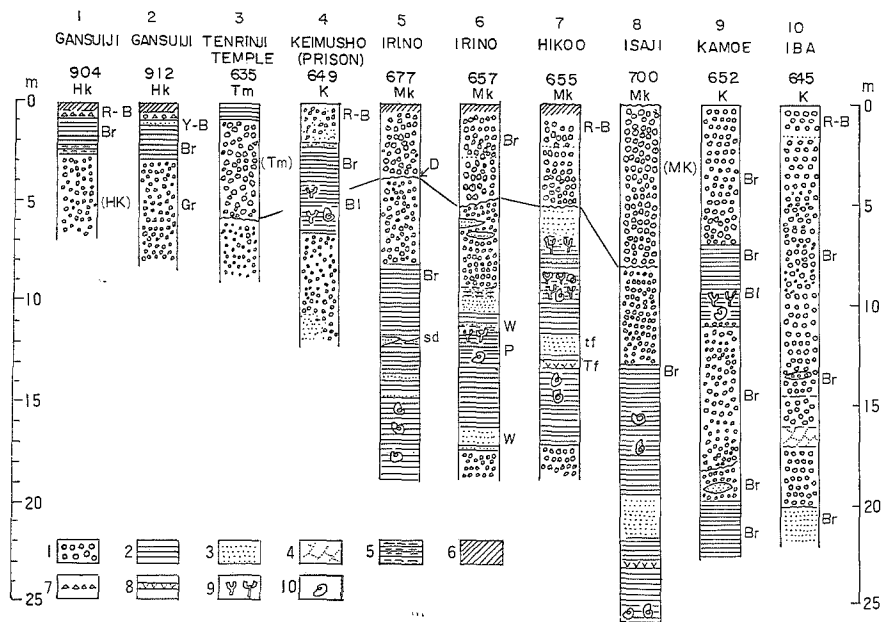


Fig. 2: Columnar sections of the Quaternary deposits in the Hamamatsu and its environs.

Abbreviations:

Lithology: 1: gravel, 2: silt, 3: sand, 4: cross-lamination, 5: alternation of silt and sand, 6: humus, 7: breccia, 8: tuff, 9: sand pipe, 10: fossil mollusk

K: Kamoe terrace, Mk: Mikatagahara terrace, Tm: Tomioka terrace, Hk: Hamakita terrace, (Mk): Mikatagahara formation, (Tm): Tomioka formation, (Hk): Hamakita formation.

R-B: reddish brown, Br: brown, Bl: blue, tf: tuffaceous, sd: sandy, D: disconformity, P: *Palaeoloxodon namadicus naumanni*

Localities:

904, 912: near Gansuiji (Fig. 6), 649: (Pl.3), 677: (Pl.4), 657: on the southwestern coast of Lake Sanaru (-ko), 655: immediately east of Loc. 657, 700: the same as Loc. 19 in KOBAYASHI'S paper of 1942 (p.328), behind the kindergarten at Isaji (type locality of the Sahama facies), 652: immediately west of Loc. 649 close to the prison of Hamamatsu, 645: north of Midorigaoka Kindergarten in Iba (type locality of the Kamoe facies).

The Kamoe facies consists, as a whole, of an alternation of gravel, sand, and silt. Dark blue or grey silt seams of marine or non-marine water deposition are traced extensively within the graveliferous deposits that can be assigned to the Kamoe facies.

Silt seams within the graveliferous facies developed typically in the Kamoe facies, thicken westward and change into the leading members of the Sahama facies. To the east of Lake Sanaru (-ko), is recognized transitional facies characterized by the dominant occurrence of sand and by the intercalation of blue silt seams. Within a typical section of the Kamoe facies exposed near the prison of Hamamatsu (Loc. 649) is embedded a fossiliferous marine silt seam whose upper limit is only 4.3 m below the level of depositional surface of the Hamamatsu formation, namely 25m above sea level. This fossil bed with an estuarine aspect seems to indicate the sediments deposited during the last subphase of transgression which took place through the Hamamatsu stage.

Fossil molluscs from Loc. 649 are *Anadara inflata*, *A. granosa bisenensis*, *Theora lubrica*, *Raeta yokohamensis*, *Barnea japonica*, *Dosinia angulosa* etc. Among these, *Anadara granosa bisenensis* is a noteworthy warm water species which lives now along the Pacific coasts of Southwest Japan.

In the northern part of distribution, the Hamamatsu formation whose depositional surface is as high as 150m near the deltaic apex is represented by the deposit of graveliferous facies inserting sometimes water-laid grey silt seams, one of which is at the level not less than 100m above sea level. The fact is likely to suggest that certain kind of upheaval amounting at least up to 60 m have taken place in this part of the delta.

From the water-laid silt at Loc. 632 near Handa on the northern outskirts of the city, KOKAWA collected the following 14 plant species: *Alnus japonica*, *Carpinus tschonoskii*, *Cyclobalanopsis gilva\**, *Euryale ferox*, *Ceratophyllum demersum*, *Sapium sebiferum* var. *pleistoceaca*, \**Sapindus mukurosii\**, *Euscaphis japonica\**, *Camellia sasanqua\**, *Lagerstroemia* sp\*. *Trapa macropoda*, *T. mammilifera*, *Styrax japonica* and *Ehretia ovalifolia\**.

An asterisk at the end of each specific name denotes that it grows now in a region under the subtropical climate. Thus the floral assemblage of the Kamoe facies of the Hamamatsu formation indicates the climate having been similar to or otherwise a little warmer than now.

#### b) Sahama facies

On the northern and eastern coasts of Lake Hamana are observed many exposures of the deposits of the Sahama facies which is characterized by domination of silty facies containing rich molluscs and often numerous sand pipes. The type locality of the Sahama facies is employed from the exposure at Loc. 700 near Isaji (Loc. 19 in KOBAYASHI'S previous paper of 1942) 1km east of Sahama. In exposures, the Sahama facies usually consists of blue or grey silt but the silty facies is not always so thick as expected. For instance, the boring log obtained from well-drilling at Ubumi in Yuto-cho indicates that the beds below the Sahama facies is consisted of an alternation of gravel, sand and silt.

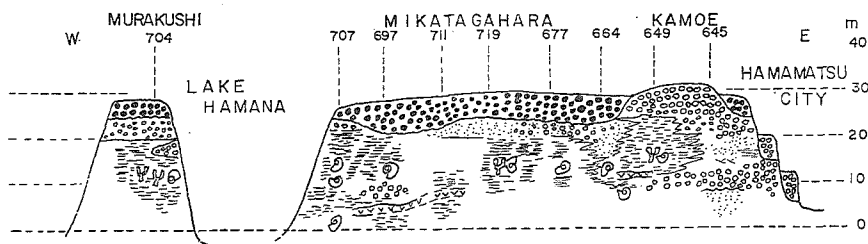


Fig. 3. Schematic illustration of the Hamamatsu formation.

The depositional surface of the Kamoe facies is indicated at the highest level. Wide surface of the Mikatagahara is underlain by the gravel lying unconformably upon the Hamamatsu formation. The Kamoe facies interfingers with the Sahama facies on the west. Molluscs, sand pipes and tuff seams are indicated.

The Sahama facies is in many cases characterized by occurrence of graveliferous facies in the upper part. This graveliferous part is then covered disconformably by the Mikatagahara formation which consists wholly of gravels. Many authors mistook this graveliferous part of the Sahama facies for a part of the Mikatagahara formation, because it was hard for these authors to detect the intervention of stratigraphic break between both graveliferous facies. (Pl. 4, Fig. 8; Pl. 5). One or two white seams of tuff sometimes intermingled with pumice grains are at many exposures recognized at the height of some 10 m above sea level. Some samples have been collected to analyse the heavy mineral compositions, from exposures at Loc. 680-1 (P) near Araya southeast of Kega, at 655 Loc. near Nishi-Hikoo and at other places pumice grains from Loc. 680-1 consist of roughly 50 % of magnetite, some 20 % of hornblende and a little less amount of hypersthene, whereas tuff from 655-3 (T) is characterized by the excess of hornblende, about 20 % of hypersthene and a small amount of magnetite (KOBAYASHI, 1963). Below tuff seams is a distinguished bed of fossil molluscs shown in the following.

*Anadara subcrenata*, *A. granosa bisenensis*, *A. broughtonii*, *Ostrea gigas*, *Dosinia angulosa*, *Lucina pisidium*, *Corbicula japonica*, *Paphia undulata*, *Raeta yokohamensis*, *Theola lubrica*, *Trapezium japonicum*, *Brachidontes senhausia*, *Batillaria multiformis*, *Cerithidea djadjariensis*, *Polinices dydima*, *Barnea japonica*, *Ringicula arctata*, *Dentalium octangulatum* etc.

Besides, TSUCHI (1960) reported an existence of *Soletellina rostrata* now living around or south of Formosa. The water temperature implied by these fossil molluscs together with foraminifers studied by CHII is similar to or a little warmer than at present.

As a rare instance, at an exposure (Loc. 696) close by Yamasaki, the lamination of brown coarser sediments overlying the marine silt, slopes at a high angle (Plate 5). As illustrated in Plate 5, the bed is truncated at its top disconformably by the gravel bed of the Mikatagahara formation.

First, the Mikatagahara formation at the top of the cliff is said by no means to be the so-called "topset bed" of the delta, possibly some authors have mistaken such an overlying horizontal bed for the "topset bed".

Secondly, is it possible whether we are to identify the bed whose lamination dips at a high angle to the "foreset bed" or not? The bed is only 10 m thick and forms, as it were, a topset bed for the underlying thick deltaic sediments.

In many famous textbooks of geology and geomorphology, for instance a schematic profile of delta illustrates three components of delta. But a bed with steep lamination may be a depositional feature peculiar to a sheet of deposit or stratum of progradation. In nature, it is believed that very few deltas bear the structure in which three sets of deltaic components are coexisted.

#### *2-2 Sedimentary environment of the Hamamatsu formation*

The depositional surface of the Hamamatsu formation stands at the highest level of 150 m in the northernmost part near Futamata. That place is judged by its location to be the apical area of deltaic accumulation constituting the Hamamatsu formation.

Gravels in this part near the apex are coarser and often are as large as 20 cm in diameter, but they diminish their sizes southward until they become, at the southern margin of the upland, down to 7 to 3 cm in diameter.

Fluvial facies designated as the Kamoe facies predominates in the eastern part of distribution of the Hamamatsu formation, whereas marine facies designated as Sahama facies predominates west of the Kamoe facies. This may be due to the fact that as the area where the Kamoe facies predominates is nearer to the former vomitory of the Tenryu River than the area on the west, more amount of coarser materials, therefore, were forced to have laid down in the eastern part near to the former vomitory of the Tenryu River.

As seen in the topographic features indicated by the occurrence of several bed rock islands surrounded by younger deposits, strong relief of subsurface bed rocks is indicated beneath the Hamamatsu formation in the northern part close to mountains.

The Horiya Hill occupying the northernmost extent of distribution of the Hamamatsu formation is more strongly dissected than the Kamoe upland close to the city of Hamamatsu. This is mainly due to the dissection accelerated, after the Hamamatsu stage, by the extension of pre-existing river valleys cut in the mountains of solid geology.

Strong relief produced before the deposition of the Hamamatsu formation is likely to demonstrate that the relatively lower stand of sea level lasted for a considerably long period. May I consider the strong relief produced before the Hamamatsu stage as suggesting the Rissian lower sea level?

Apart from this kind of hard problem, high stand of sea level during the Hamamatsu stage is clearly indicated. Near Hainoki (Loc. 649), silt layer of water-deposition is situated at the level of about 100 m above sea level;



and at the road-cut (Loc. 753) of Hoda slope, estuarine mollusc *Brachidontes senhausia* is obtained from blue silt at the height of some 30 m above sea level. Just below this fossil bed, was recovered *Palaeoloxodon namadicus naumanni*—a characteristic elephant which is said to have thrived during the Shimosueyoshi stage (maybe the Riss-Würmian Interglacial). The fossil elephants which have often been found from many localities in this district indicate the horizons near sea levels as they have been found from blue silt or blue graveliferous silt of water-deposition.

Whether or not I am to ascribe the marine transgression which took place during the Hamamatsu stage to the eustatic uprise of sea level, following lines of discussion will possibly be made.

(1) Considering the climate of the Hamamatsu stage, I may conclude that the Hamamatsu stage is characterized by an interglacial climate which was not so warm as that suggested by the *Syzygium* flora at Uegahara near Osaka (MIKI, HUZITA and KOKAWA, 1957). The Uegahara flora consisting exclusively of many broad-leaved evergreen trees, of which many grow now in the southern part of Japan. According to its stratigraphic situation and to the remarkable warmth implied, many authors are of opinion that the flora is to be referred to Mindel-Rissian Interglacial stage.

(2) The marine transgression of the Hamamatsu stage is supposed, based upon these informations, to have taken place during the Riss-Würmian Interglacial. Such a coincidence of both times of mildness of climate and marine transgression may lead us to expect that the Hamamatsu transgression may have occurred caused by the ablation of continental ices.

(3) The highest mark of sea level during this stage is indicated at 25 m above sea level at Loc. 649 near the prison of Hamamatsu. In the northern part of the Hamamatsu formation water-laid silt, as mentioned previously, is at the level of 100 m above sea level.

Anyhow, these heights of sea level seem to be a little too high to accept any of them as the actual sea level which stood during the Riss-Würmian Interglacial, if we approve a general opinion as to the sea level of the Monastrian stage (PFANNENSTIEL, 1944, 1956; AUER, 1959; FAIRBRIDGE, 1961; ZEUNER, 1962, p. 128)

### 3 Mikatagahara Stage

#### 3-1 Mikatagahara formation ...A fan-like deposit upon delta

The upland of Mikatagahara exhibits an outstanding flatness over the whole extent of its surface, which slopes southward at an average gradient of 5.89 per mill. The upland is as a whole twofold in structure, namely the lower part made up of the Hamamatsu formation is covered disconformably by gravel bed of the Mikatagahara formation. It consists wholly of fluvial graveliferous deposit that can possibly be assigned to the deposit like fan.

The thickness is surprisingly uniform ranging from 20 to 3 m over the whole extent of distribution, so that the deposit of the Mikatagahara formation is to be, in a sense, a kind of gravel veneer. The deposit lessens its

thickness toward the south. The grain-sizes of gravels in the southern part near the city are 10 to 5 cm, but in the northern part near the apex of the fan they are as large as 30 cm in diameter.

Stratigraphic relation between the Mikatagahara formation and the underlying deposits of the Sahama facies (s. str.), has long been believed as being in a conformable relation (MAKIYAMA, 1924 a, b; KOBAYASHI, 1942; TSUCHI, 1960; ITO and TSUCHI, 1960). TSUCHI supposed (1960) that the Mikatagahara formation and his Higashi-Kamoe formation were in a disconformable relation but he concluded that the former lies upon the Sahama mud with no stratigraphic break. GOHARA and SASAKI (1951) recognized uneven surfaces below the Mikatagahara formation but they did not regard the disconformable relation being placed between the both formations.

Both Sahama mud and the gravel bed of the Kamoe facies which TSUCHI and his coworker called the "Higashi-Kamoe formation" are believed to form a single stratigraphic unit, accordingly the Mikatagahara formation should be observed to lie disconformably upon the both facies of the Hamamatsu formation. In reality, the disconformable relations are observed at many exposures as shown, for instance, in Plate 1, 2, 4, 5 and 6. As both formations are graveliferous, recognition of disconformity is not always easily made. The underlying gravel beds of the Hamamatsu formation contain, however, much more clayey materials in the matrix and gravels of smaller size than those of the Mikatagahara formation.

As shown in the uniform thickness of the Mikatagahara formation, surface of the basement is so even that it is impossible to recognize any signs of marked dissection which progressed before the deposition of the Mikatagahara formation. As illustrated in Fig. 4 in Plate 2, a peculiar instance of disconformable feature in the form of narrow and shallow depression which is only 5 m deep, is observed in an exposure at Shijimizuka. *The disconformable feature as such seems to merit the conception that any marked lowering of sea level or otherwise any marked retreat of sea could not have taken place before the deposition of the Mikatagahara formation.*

### 3-2 Delta or fan?

The Mikatagahara upland on the west of the Tenryu River slopes southward at a gradient of some 5 per mill and exhibits a fan-like appearance. Genetical significance of the upland has long been discussed by many authors but there has not always been a unanimity of opinion whether the upland might be a fan or a delta.

In 1919, TSUJIMURA (p. 547-553) assigned genetically the upland to an old fan. In opposition to this opinion, WATANABE later in 1930 (p. 3) and in 1931, (p. 738-744) stated that the Mikatagahara upland should be considered as the upheaved delta built by the accumulation of the Tenryu River. But he changed his former opinion later (1942, p. 207), and concluded that the upland might be a "dissected fan", further he considered the occurrence of marine silt as an evidence that the delta changes lithologically into fan. I (KOBAYASHI, 1942) thought the upland might be a type of delta whose top facies changes transitionally, without any hiatus, into fluvial facies. As has been discussed

in the foregoing paragraphs, all of these interpretations are not correct in the true meaning, so that they need certain revisions.

Geological structure of the Mikatagahara upland should therefore be expressed genetically as it were a "fan upon delta" structure. The similar structure is also recognized in the case of the Musashino upland in Tokyo, but the structure as such, I expect, will be found in other deltaic regions of the world.

In reality, sea level may have been in a state of still stand of relatively short duration soon after the deposition of the Hamamatsu formation. This period which followed the Hamamatsu stage is to be designated as the Mikatagahara stage which seems to represent a short period of still stand of sea level.

#### 4 Early Stage of Late Quaternary Marine Regression

After the deposition of the Mikatagahara gravel bed, remarkable tendency of marine regression is indicated. Below the surface of Mikatagahara are shown three steps of fluvial terraces which are named as the "Tomioka", or the "Higher terrace", the "Ubagaya" or the "Middle terrace" and the "Hamakita" or the "Lower terrace" in descending order. This group of terraces is undoubtedly carved out by the erosion and accumulation of the Tenryu River. At the base of cliff below every terrace is exposed the gravel bed of the Hamamatsu formation. The upper two terraces are somewhat like erosion terrace as they are covered by veneer-like gravel beds of about 10 m in thickness.

##### 4-1 Tomioka stage

The Tomioka terrace stretches from the northern part near Miyaguchi to the city of Hamamatsu. Low hills on which Tenrinji Temple and Toshogu Shrine stand are classed as the Higher or the Tomioka terrace. It slopes

Table 2. Gradients of terraces on the eastern slope of the Mikatagahara upland (%)

| Terrace          | B       | C         | D        | E        | F        | Average   |
|------------------|---------|-----------|----------|----------|----------|-----------|
| Mikatagahara     | ← 6.85  |           | → ← 4 →  |          | ← 4.35 → | 5.89 % a) |
| Tomioka terrace  |         | ← 5.47 →  | ← 3.77 → |          |          | 4.22 b)   |
| Ubagaya terrace  | ← 5.4 → |           |          |          |          | 5.04 c)   |
| Hamakita terrace |         | ← 4ca →   |          |          |          | 4 d)      |
| Alluvial plain   |         | ← 1.025 → |          | ← 0.85 → |          | 1         |

B: west of Tsuttori, C: west of Ubagaya, D: west of Handa, E: near the Municipal Playground F: Kosei Commercial Senior High School. G: Iba

Average a) From the apex of fan to southern terminal, b) From site B to south of F, c) From north of site B to south of site C, d) From Nishi-Kajima to Kobayashi.

seaward at a gradient of 4.22 per mill, which is a little less stronger than that of the Mikatagahara upland but is a little stronger than that of the Middle or the Ubagaya terrace (Table 2, Fig. 4.).

The gravel bed which considerably resembles in lithology to the Mikatagahara gravel bed underlies the Tomioka terrace and is to be called the "Tomioka formation" or the "Tomioka gravel bed". The top horizon of the Tomioka gravel bed indicates the similar degree of weathering to that indicated in the top horizon of the Mikatagahara gravel bed.

#### 4-2 *Ubagaya stage*

Among these terraces, the Ubagaya terrace (Middle terrace) indicates rather high gradient of 5.0 per mill in the seaward direction. Owing to its high gradient, the Ubagaya terrace dips in its extension under the Alluvial beds. Several fragments of the Middle terrace are recognized to flank on the southern slopes of mountains of Palaeozoic rocks north of a line from Miyaguchi to Nishi-Kajima. The gravel bed which forms the terrace surface of the Ubagaya terrace is some 10 m thick and is observed at several exposures in which moderate degree of weathering is also recognized in the top horizon. Anyhow the Ubagaya terrace seems to suggest that at this stage sea level was considerably lower than the present sea level.

TSUCHI gave in 1960 a collective name the "Onoguchi gravel bed" for my both Tomioka and Ubagaya formations as he believed that both bases of the two terraces were at the same height. At least in the southern part of the Ubagaya terrace, the base of the Ubagaya gravel is certainly lower than that of the former. In contrast to the relatively low gradient of the Tomioka terrace, the steeper gradient of the Ubagaya terrace indicates, anyhow, that the rapid lowering of sea level was in progress.

#### 4-3 *Hamamatsu Shitamachi (Downtown Hamamatsu) formation*

More than 200 geologic columns have been obtained from borings conducted in the Alluvial plain for prospecting water resources and for examination of geologic structures below the ground. Some of well-drillings hitherto carried out disclose a maximum depth of nearly 300 m below the ground. Some 90 test borings have been carried out to obtain geologic informations and the standard penetration resistances. The data obtained are used for the generalization of geologic structures of the Hamamatsu Shitamachi formation.

The "Hamamatsu Shitamachi" or shortly the "Shitamachi" formation is presumably considered as the river-mouth deposits which have filled up the valley cut down during the lowering of sea level and ranging from the latest Pleistocene to the middle part of Holocene time. The deposits as such are usually called in Japan "the Alluvial deposit" which roughly denotes the deposits of the Holocene age. But it does not represent the Holocene age strictly, if we accept the term "Holocene" as a synonym of the term "postglacial" or as the term "Recent" in general usage (MORRISON, GILLULY, RICHMOND and HUNT, 1957).

##### a) Top horizon of the Shitamachi formation

The Shitamachi formation forms essentially a kind of stratigraphic unit

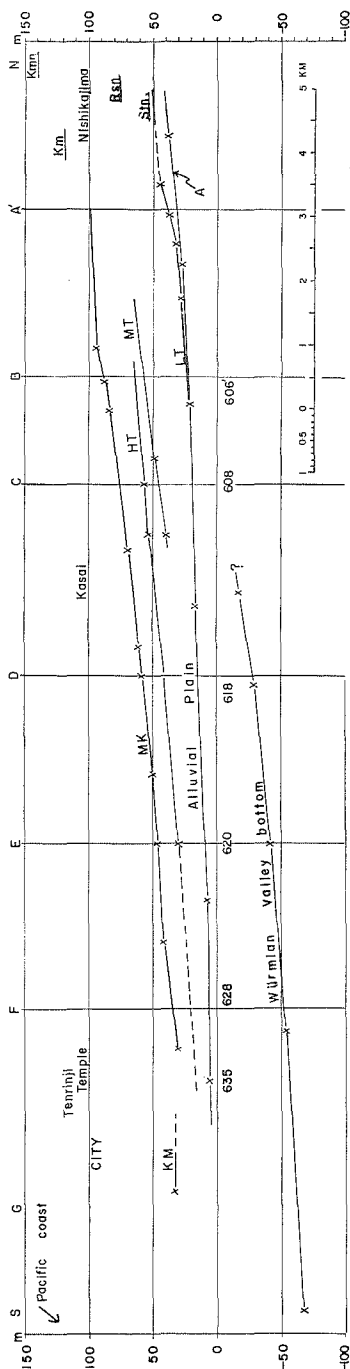


Fig. 4. Profiles of terraces in NS direction, from the apical area of the Mikatagahara fan southward to the city of Hamamatsu.

Abbreviations: Km: The Kamoe depositional surface, Mk: The Mikatagahara Upland surface  
 HT: Higher or the Tomioka terrace, MT: Middle or the Ubagaya terrace, LT: Lower or the  
 Hamakita terrace, A: Older floodplain or the so-called Alluvial plain, Km: The Kamoe  
 depositional surface near Nishi-Kajima, Rsn: Ringyo Shikenjo terrace near Nishi-Kajima, STN:  
 the Settai terrace, Würmian valley bottom: the same as that indicated in Fig. 5.

with an estuarine aspect and contains sometimes mullusk shells. The deposit bears in particular a river-mouth facies as indicated by the dominance of gravels.

At the top of the Shitamachi formation is a horizontally continuous gravel bed with the maximum thickness of about 15 m. In the environs close to the southeastern margin of the Kamoe upland, the top gravel on the east abruptly changes into sand facies to the west. This may be due to the fact that the upland have hindered the stream course of the Tenryu River from its westward shifting, in consequence the graveliferous facies was restricted to be existed east of the marginal cliff of the upland.

In places upon these sand and gravel horizon, are developed sand dunes, peat seams and silt layers, all of which are very thin perhaps less than 5m thick.

b) Middle silt zone

Below the top member consisting of sand and gravel is the "Middle silt zone" in which horizontally discontinuous and lenticular silt layers are scattered in various horizons. The Middle silt zone occupies as a whole

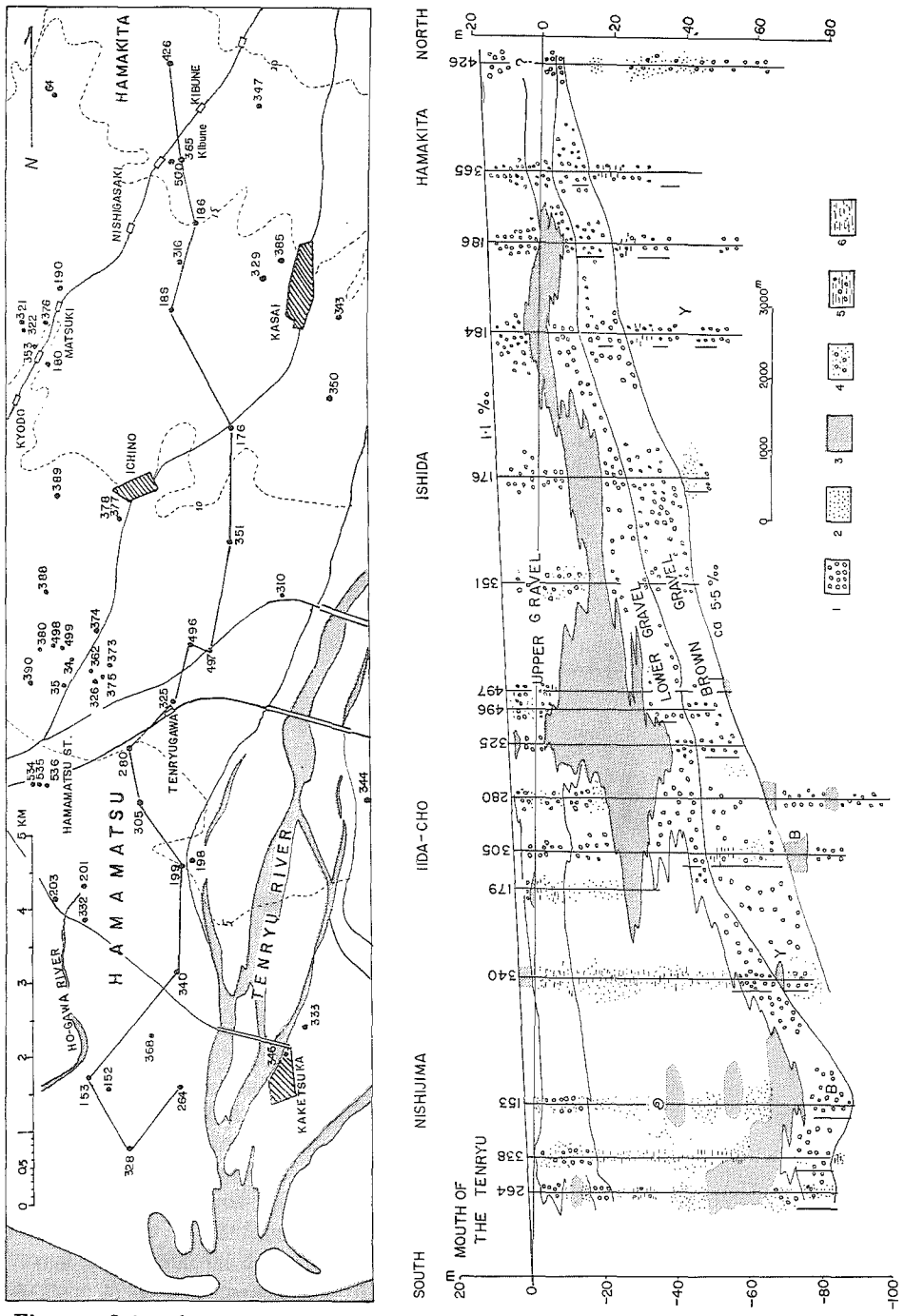


Fig. 5. Subsurface geologic structure in the direction along the Tenryu River, drawn based upon 16 boring logs.  
 Abbreviation: 1: gravel, 2: sand, 3: silt, 4: sand intermingled with pebbles, 5: silt with pebbles, 6: sandy silt

the space ranging from 15 to 40 m in depth. It is composed of rather finer materials, such as silt, sandy silt and finer sand which contain sometimes molluscan remains (Fig. 5).

c) *Base of the Shitamachi formation*

Under the Shitamachi formation is supposed, according to boring logs, to lie a thick deposit which measures at least 200m in thickness and consists mainly of brown or yellowish sand and gravel, and less amount of blue silt besides.

One of the most difficult problems is to identify the very base of the Shitamachi formation or otherwise the top of basement underlying the formation, because both formations bear a quite similar assemblage of lithology and are varying in facies.

Below the Middle silt zone is grey or bluish gravel with the average thickness less than 10m and the latter is again underlain by brown or yellow bed of gravel, sand or silt. On the right bank of the Tenryu River, the total thickness of the middle silt zone increases from north to south, for instance, from some 5 m near Ishida to 20 m near Tenryugawa-cho. On the southernmost part near sea shore, the Middle silt zone intercalating sometimes gravel seams is measured as thick as 50 m. Here, we face the two different interpretations as to the generation of the gravel bed below this silt zone. Grey or blue gravel bed below the Middle silt zone might indicate, based upon one standpoint of interpretation, the existence of former alluvial fan developed during the lower sea level of Late Quaternary time. In another interpretation, this gravel bed might be inferred as the deposit which settled down as the site of deposition shifted up the Würmian trench or the valley of the Palaeo-Tenryu River through the period when sea level rose.

For the former anticipation, several instances may be added in the following.

As quoted by DALY (1934, p. 186-188), when the supply of the amount of debris by the Durance River flowing out of the Western Alps was great owing to the increase of debris accelerated by the Würmian glaciation of the Alps, a deposit that can be called in the name of the "fan-delta" was formed near the lower course of the Rhone River. The surface of that deposit in the inland part is more than 100 m above the present sea level, whereas the lower part of the "fan delta" underlies the Alluvium of the Camargue.

ISEKI interpreted that a fan perhaps in the similar sense to the fan-delta was formed by the extension of river during the period of the lowest sea level and he named it the "Gravel bed No. 1" (ISEKI, 1957, p. 88). According to this standpoint it must be admitted that the ISEKI's Gravel bed No. 1 should be covered with a stratigraphic hiatus by the overlying member—the Alluvial formation, because the Alluvial formation in the sense which I quoted here may be a deposit which represent the stage when sea level was rising.

As to another anticipation, the discussion made by FISK and Mc FARLAN (1955) is particularly, I suppose, important for the present consideration. In

the middle phase of the construction of the Mississippi delta, valley system (Mississippi Trench) cut into the older formation were buried with sediments of aggradation series. Coarser materials have settled down as the site of deposition shifted back inland caused by the uprise of sea level.

In principle, it is inferred from this standpoint that flood plain was formed when sea level stood at a low level, accordingly the river extended. During this period, materials constituting the flood plain may have been subjected to a subaerial weathering. Therefore I should like to discard the interpretation that blue or grey gravel bed directly underlying the Middle silt zone should be assigned to the fan which filled the Würmian valley bottom of the Palaeo-Tenryu River before the deposition of the Shitamachi formation, because it seems rather hard to understand the necessity that remarkable fluvial deposition could have taken place along the upstream from the present river-mouth, and because it seems also hard to recognize a marked sign of weathering within the grey gravel bed (Fig. 6).

Based upon the assumption that I mentioned above, I am to place tentatively the lowest demarcation of the Shitamachi formation between the upper gravel bed (grey) and Lower (brown or yellow) gravel bed. The gravel bed in brown may, I suppose, be a deposit weathered when it was exposed under subaerial condition during the period of low stand of sea level. The gravel bed in grey should naturally be considered as the deposit having settled down as the site of accumulation shifted back inland through the period of rising of sea level.

Nevertheless, valley system beneath the Shitamachi formation is hard to restore, because both lithological features of the Shitamachi and underlying formations are too alike to separate one from another. The profile illustrated in NS direction along the right bank of the Tenryu River indicates an interpretation as to the Würmian valley bottom cut down by the former stream of the Palaeo-Tenryu River, during the period when sea level dropped to the lowest level. The maximum depth of the valley bottom is indicated in Fig. 6 to be at the depth of some 90 m below sea level. The longitudinal profile of the bottom is indicated to bear a gradient of 5.5 per mill, which is stronger than the Hamakita terrace to be discussed in the later. According to the informations supplied by many well-drillings, the bottom of the Würmian trench produced during the maximum drop of sea level seems likely to have attained the width less than 10 km near the present mouth of the Tenryu River.

## 5 Submarine Topography off the Mouth of the Tenryu River

### 5-1 Submarine and subterranean terraces

Beneath the Shitamachi formation are recognized four even surfaces that may be due to terraces and valley bottom.

(1) Among these, a terrace at 10 m below the ground may be originated from wave-cut erosion in the end of the Jomon transgression or the postglacial uprise of sea level, because it seems to border the southern marginal slope of the Kamoe upland.



(2) Outside of the  $-10$  m terrace is a terrace 30 m or less in depth, which with a narrow extent seems also to fringe the  $-10$  m terrace mentioned above. I encounter a problem as to the age of origination of the  $-30$  m terrace, then I leave it untouched for a little while.

(3) Furthermore there is a wide and gentle slope ranging from 30 to 50 m in depth on the west of the Tenryu River. Although about 100 boring logs are available for this consideration, informations from the underground are still meagre for introducing a conclusion on this gentle slope with the depth 30 to 50 m. Under the present status of knowledges on the subsurface geology it is doubtful if there is a scarpline separating the  $-50$  m terrace from the  $-90$  m bottom of the Palaeo-Tenryu River.

In this connection submarine topography off the coast of Hamamatsu district will supplement the ambiguity of knowledges with more logical inferences.

**Table 3.** Tentative correlation between the submarine terraces of the continental shelf and the terraces and bottoms of the Würmian valley system in the Hamamatsu district.

| Fluviatile terraces                  | Subsurface terraces    |   | Submarine terraces  |
|--------------------------------------|------------------------|---|---|
|                                      | depth                  | area of distribution  |   |
| Tomioka terrace<br>(well-developed)  | $-30$ m<br>(max.)      | Either of the<br>two terraces: outside<br>of the $-10$ m terrace        |   |
| Ubagaya terrace<br>(well-developed)  |                        |   |   |
| Settai terrace<br>(worse-developed)  | $-90$ m<br>(max.)      | Valley bottom of the<br>Palaeo-Tenryu River.<br>Near to the river-mouth | A terrace of the<br>continental shelf.<br>$-120$ m or more. |
| Hamakita terrace<br>(well-developed) | $-30$<br>to<br>$-50$ m | Nor theast of<br>Hamamatsu city   | $-50$ to $-60$ m at<br>the edge of the terrace              |
|                                      | $-10$ m                | Terrace fringing the<br>cliff of the upland                             |   |

According to the bathymetric chart off the mouth of the Tenryu River (SATO and HOSHINO, 1962), the continental shelf proper in this district is 9 km wide and 120 to 160 m deep. However, a terrace with the width of some 3.5 km and the depth of 50 to 60 m at its edge is recognized just off the river-mouth and it occupies the valley head of submarine valley system called the "Tenryu Submarine Canyon" which is traced southward over more than 100 km and down to the depth at least 4,000m and which accordingly considered as a part of the sunken valley system of the former Tenryu River.

The even surface at  $-50$  to  $-60$  m deepens toward the west gradually

down to the continental shelf at  $-120$  to  $-300$  m.

According to HOSHINO (oral communication) and another author (HOSHINO and IWABUCHI, 1963), the submarine terrace at  $-50$  to  $-60$  m off the mouth of the Tenryu River seems to be the depositional surface which may have formed after the maximal phase of dropping of sea level, and which is called by both authors the "Middle terrace of the continental shelf".

Correlation of terraces under the Shitamachi formation with the even sea bottom will be tried in the following.

(1) There has been a general consensus of opinion that the even bottom at  $-120$  or so is a product during the period of lowest sea level. The bottom of the Palaeo-Tenryu River at 90 m below the ground may be correlated with the  $-120$  m surface of the continental shelf.

(2) Although the problem concerned with the Hamakita terrace that I shall take up in the next chapter, it has an average gradient 4‰ which is much lower in gradient than that 5.5‰ of the valley bottom of the Palaeo-Tenryu River, so that the Hamakita terrace can not be traced to the lowest sea level. Much tentatively, I should like to correlate the terrace with the middle terrace at  $-50$  to  $-60$  m of the continental shelf.

(3) The Ubagaya terrace dips under the Alluvial deposit perhaps in the northern part of the city. A narrow strip of subterranean terrace at  $-30$  m or shallower is recognized in Iba district south of the city hence it is not impossible to identify this terrace to the extension of an either of the Ubagaya or otherwise the Tomioka terrace.

(4) As seen in Fig. 5, the valley bottom of the Palaeo-Tenryu River may have been entrenched after the terracing of the Ubagaya terrace. Therefore the time of the lowest sea level should naturally be close to the time of the formation of the Settai terrace, though it is quite doubtful whether the fluvial terracing could have taken place markedly during the period of the lowest sea level.

Gradients of several terraces are illustrated in Fig. 5 which will serve as a guide to discuss the correlation of terraces with submarine even surfaces. However, I would like to discuss more fully the nature and significance of the Hamakita terrace.

#### 5-2 *Hamakita substage*

The Hamakita substage is established for special purpose to stress the Late Quaternary eustatic history, as it is supposed that the substage might possibly represent the time after the period of maximum drop of sea level. The term Hamakita substage is therefore employed for a short period of the Shitamachi stage.

The lowest terrace designated as the "Hamakita terrace" after the name of Hamakita city, occupies a broad area between the eastern slope and of the Mikatagahara upland and the present flood plain of the Tenryu River.

In the northern part, it is 9.5 m above the Nakaze plain—former flood plain of the Tenryu River, but it decreases its height southward down to 0 m in the neighbourhood of Enshu-Kobayashi tram-stop. (Fig. 6).

In appearance, the terrace is fan-shaped and its center is some 15 km

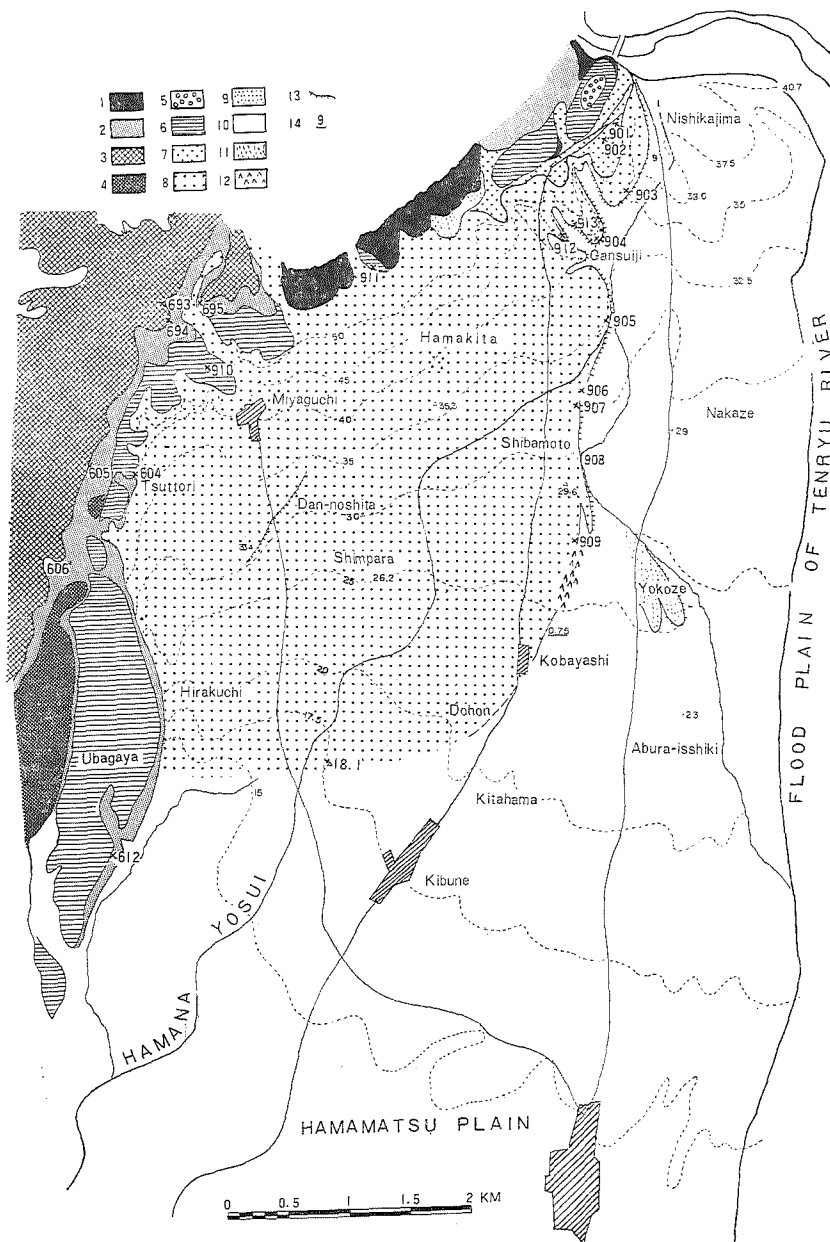


Fig. 6. Geomorphological map of the neighbourhood of Hamakita city immediately north of Hamamatsu.  
 Abbreviations: 1: Mountains consisting of Palaeozoic rocks, 2: deposits of the Kamoe facies of the Hamamatsu formation, 3: The Mikatagahara surface and associated deposit—the Mikatagahara formation, 4: The Tomioka terrace and associated deposit—the Tomioka formation, 5: The Ringyo Shikenjo terrace (the equivalent of the Tomioka terrace ?), 6: The Ubagaya terrace and associated deposit the Ubagaya formation, 7: The Settai terrace and associated deposit, 8: Hamakita terrace and associated deposits —the Hamakita formation, 9: Upper surface of the Nakaze flood plain 10: the Nakaze flood plain, 11: Piedmont debris, 12: Pine woods, 13: Scarlet, 14: Height of cliff.

distant from the adjacent sea shore. Parts of the Hamakita terrace are covered by brecciated debris supplied from valleys descending adjacent mountains of solid geology (Fig. 2 and 6; Loc. 904, 912 and 913). At the top of the section of the Hamakita formation is a kind of black humic soil popularly called "Kuroboku" soil in Japan. As the chronologic situation of the terrace is rather problematic, pedological knowledges concerned with the surface soil of the terrace seems likely to offer some hints for this purpose. (Pl. 6; Fig. 11).

The Hamakita formation building the Hamakita terrace consists of rounded gravels 20 to 10 cm in diameter. Its lithology resembles, within reach of our observation, very much to that of the Middle terrace. Its surface slopes at a gradient of 4 per mill which is steeper than that of the flood plain, hence the terrace dips under the Alluvial deposits roughly in the environs near the border of both Hamamatsu and Hamakita cities.

Under the present status of knowledges, as tentatively shown in Table 3, the subsurface slope with depths 30 to 50 m and with a gradient 2.86 per mill might be corresponding to the extension of the Hamakita terrace.

To identify the age of the terrace is difficult unless we obtain more informations about the subsurface geology particularly in the area north of the city of Hamamatsu.

In principle, we face two interpretations as to the age of the terrace, as it might be placed at some time during the period when sea level was lowering after the Riss-Würmian Interglacial stage, otherwise it might be placed at some time during the period of postglacial uprising of sea level. If the latter interpretation is nearer to the truth, the Hamakita terrace may represent the time close to the Pleisto-Holocene boundary, because there is a ground for considering the sea level at that time being considerably higher than that of the lowest situation at some 20,000 years ago.

## 6 Conclusion on Late Quaternary History of Hamamatsu and Its Environs

For all the discussion hitherto made in this paper, I did not give accounts as to the crustal movement which may have tilted or uplifted the land surfaces in the neighbourhood of Hamamatsu. To be sure, the gradient (36.3‰ in the average) indicated along the course of the "Tenryu submarine canyon" is so high that it is impossible to explain the origination of such a high gradient without assuming certain kind of tilting having taken place off the mouth of the Tenryu River. To take, if possible, such influences due to crustal movement into consideration, is certainly a necessary trial for the study of the eustatic change in sea level. Such a trial is, however, apt to form a vicious circle. For this reason, I gave up to refer to the effects of crustal deformation, because there seems to be no plausible objections for introducing the present conclusion except for a long and continuous tilting which may have more or less increased the seaward gradients of many terraces.

(1) The conclusion on the age of the Hamamatsu stage is based on several lines of evidence as discussed on page 26, 29, and 42. Above all,

the eustatic history since the high stand of sea level during the Hamamatsu stage offers a reliable basis of inference for this conclusion. In Fig. 8 the eustatic curve is depicted based on the data obtained from the present study made in the Hamamatsu district. It should be emphasized that since the Mikatagahara stage sea level has never stood at higher level than at present. Probability is not so small in considering the Mikatagahara stage as being the later phase of the Riss-Würmian Interglacial, because my search for an evidence of readvance of the sea has failed to obtain anything within the Mikatagahara formation.

(2) Historical arrangement of the Late Quaternary events which have occurred in the Hamamatsu district is put in Table 4. Correlation of the events with the Late Quaternary division propounded by GROSS (1958) is quite tentative.

(3) The chronologic situation of the Tomioka stage is very important for the present correlation. I placed the Tomioka stage tentatively at the interstadial phase of the Würmian glacial chronology. This interstadial interval is significantly known in Europe as the "Paudorf Interstadial", in North America as the "Farmdalian Interstadial" (FRYE and WILLMAN, 1960) and the "Plum Point Interstadial" (FLINT, 1963), and in Japan the equivalent seems likely to be demonstrated as the phase of terracing of the Komaki terrace in the Nobi Plain. The date of this period of terracing is at some 27,000 C<sup>14</sup> years ago (QUAT. RES. GROUP KISO VALLEY and KIGOSHI, 1964).

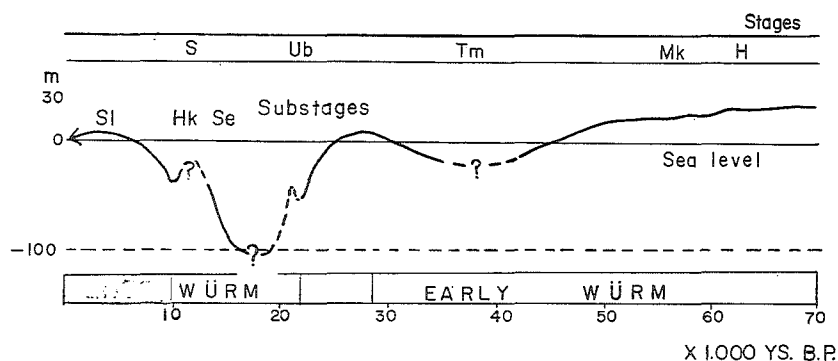


Fig. 7. The eustatic curve based upon the informations obtained from the study made in the Hamamatsu region.

Abbreviations: [Stages] H: Hamamatsu stage, Mk: Mikatagahara stage, Tm: Tomioka stage, Ub: Ubagaya stage, S: Shitamachi stage; [Substages]: Se: Early substage of the Shitamachi stage, Hk: Hamakita substage of the same, Sl: Later substage of the same

The reason why I have placed it at this interstadial phase is in that:

(a) As we have seen, the Tomioka terrace slopes less steeply than both the Mikatagahara upland and the Ubagaya terrace which

forms a step immediately below the Tomioka terrace. The fact signifies that sea level did not drop before the formation of the Tomioka terrace to the depth comparable to that of the late Würmian lowest sea level.

(b) Considering the comparison with other sets of terrace in Japan, I have tried to depict the eustatic curve together with the correlation chart of the Quaternary events of the Hamamatsu district. (KOBAYASHI, 1962).

(4) In parallel with the shoreline are displayed several sand ridges upon which sand dunes are developed. These sand ridges may have formed by the emergence of longshore bars. In the later substage of the Shitamachi stage, sea level became higher by about 2 m or more than the present sea level. This is inferred from the fact that most sand dunes which are extensively developed in EW direction along the Pacific coastline are about 2 m above sea level. The height of 2 m seems to be critical for the discrimination of sand dunes that are not covered by peat layers.

Table. 4. Late Quaternary History of the Hamamatsu region

| Division by<br>GROSS (1958)  |                               | Late Quaternary History of the Hamamatsu region<br>(KOBAYASHI, 1963) |  |   |
|------------------------------|-------------------------------|--|--|---|
| Klimaoptimum                 |                               | Holo-<br>cene  | Later substage   | Jomon transgression (slight regression after the maximum transgression -2m) |
| Hauptwürm                    | Wh 3                          | Late Würmian   | Shitamachi stage   | Younger delta   |
|                              | Wh 3/2                        |  | Hamakita substage  | Oscillation in sea level, perhaps equivalent to the Valderan phase          |
|                              | Wh 2                          |  | Early substage   | Beginning of the postglacial transgression                                  |
|                              | Paudorfer Interstadial Wh 1/2 | Ubagaya stage  | Remarkable regression. In the end of this stage sea level lowered at least to -90 m                                    |   |
|                              | Wh 1                          | Tomioka stage  | Fluviatile terracing. Still stand of sea level   |   |
| Göttweiger Interstadial Wv/h | Early Würmian                 | Mikatagahara stage   | Regression of sea level. Lowering of sea level by about 20 m   |   |
| Alt-würm Wv                  |                               |  | Formation of fan upon delta. Still stand of sea level soon after the Riss-Würmian Inter-glacial stage.                 |   |
| Riss/Würm Interglazial       |                               | Hamamatsu stage (a little warmer than now)                           | Very slight regression. Lowering of sea level by about 15 m. No remarkable vertical erosion                            |   |
|                              |                               |  | Deposition of the Hamamatsu deltaic formation. Stage of higher sea level <i>Palaeoloxodon</i> , <i>Anadara granosa</i> |   |

(5) Peat bogs or back swamps may have occupied the interdunal belt of depression perhaps since the maximum uprise of sea level. Rather big tarns called Numata-ike and Hasu-ike are the relics of a kind of back marsh which was once far wider in areal extent.

(6) Until the early part of the Holocene period, the sea penetrated northward into the land and Lake Sanaru (-ko) was at that time a part of an inlet embraced by arms of the Mikatagahara upland. Perhaps before the settlement of the early Jomon people in the environs of the Shijimizuka site, the inlet was nearly bridged across by a kind of bay bar developed at the mouth. Thus the inlet first converted into a tidal inlet then into a lake of freshwater.

The environs of the Shijimizuka site has been inhabited by the people whose cultural features indicate their age having lasted roughly from 4,500 to 3,000 years B.P. According to KATO et al. (1957), the change from inlet to lake was nearly finished before the period during which the Shijimizuka culture prospered.

About the last phase of the Quaternary history, I wish to discuss fully in another paper that follows the present one.

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#### Explanation of Plates

- Pl. 1; Fig. 1 The Mikatagahara upland as seen northward from the center of the city of Hamamatsu. The outstanding flatness of the upland is indicated. In the foreground of the picture are shown marginal cliffs and incipient valleys.
- Fig. 2 An exposure (Loc. 630) of the disconformity between the Hamamatsu formation (Kamoe facies) and the overlying Mikatagahara formation. Here the Mikatagahara formation is 6.5 m thick and the upper 1.55 m become reddish brown through weathering. Gravels of the Mikatagahara formation are better-sorted and less weathered than those of the Hamamatsu formation which is composed of much clay content and tinted in brown.
- Pl. 2; Fig. 3 Terrace scarp (22 m high above the Tomioka terrace) of the Mikatagahara upland as seen from north of Tomioka upon the Tomioka terrace. A tea-plantation is widely developed upon the gravel bed of the Tomioka terrace as shown in the picture.
- Fig. 4 A marked disconformity exposed at Loc. 851-b near the Shijimizuka Neolithic site on the northwestern outskirts of the city. The gravel bed with torrent-bedded facies is assigned to the Mikatagahara formation. The one side of a narrow trench only 5 m deep is indicated. A block of basal gravel bed was broken off and buried within the lower part of the Mikatagahara formation. The disconformity seems to indicate that the lowering of sea level was too slight and insignificant to assume a marked decrease of marine water through glaciation.
- Pl. 3; Fig. 5 An exposure of the typical Kamoe facies at Loc. 649 near the prison (Keimu-sho) of Hamamatsu (see also Textfig. 2). The edge of the depositional surface of the Hamamatsu formation is at the top of the cliff. From 4.3 to 6.5 m below the top is a marine silt layer which contains many mollusk shells and sand pipes.
- Fig. 6 Decayed gravels of the Kamoe facies. Loc. 694 1 km northwest of Miyaguchi. The gravels of fluvial deposition are more intensely weathered than the gravels of marine-water deposition. In the northern part of the Kamoe facies gravels are usually decayed to a higher degree.
- Pl. 4; Fig. 7 A scarp along the eastern margin of the Hamakita terrace. At Loc. 907 south of Hamakita Hokubu Junior High School at Oro. Here the cliff is only 4 m high above the flood plain of the Tenryu River.
- Fig. 8 A Cliff (Loc. 677) near clay mine of a brickyard near Irino. Typical Sahama facies with gravel bed at the top. A faint sign of disconformity is indicated 3 m below the top of cliff. See Textfig. 2.
- Pl. 5; Fig. 9 An exposure at Loc. 696 near Yamasaki on the eastern coast of Lake Hamana. The Mikatagahara formation truncates the graveliferous bed with steeply dipping laminations and with the thickness of ca. 10 m. Explanations in some detail will be found on page 27 to 28 of the text.
- Pl. 6; Fig. 10 Disconformable relation exposed at Loc. 847 north of Murakushi in the southwesternmost part of distribution of the Mikatagahara formation.

In the lowest part of the Mikatagahara formation or immediately above the disconformity are blocks of silt broken off the underlying Hamamatsu formation.

- Fig. 11 Profile of the top horizon of the Hamakita terrace near Gansui (-ji) Temple (Loc. 913). Breccias of chert are embedded below black humic soil at the top.
- Pl. 7; Fig. 12 Marsh or peat bog occupying the interdunal belt of depression near Takatsuka southwest of Hamamatsu.
- Fig. 13 Restored Neolithic dwelling houses at Shijimizuka Jomon cultural site. The age of the shell mounds ranges from the middle stage to the latest stage of Jomon culture. The shell mounds comprises extremely abundant shells of *Corbicula japonica*.

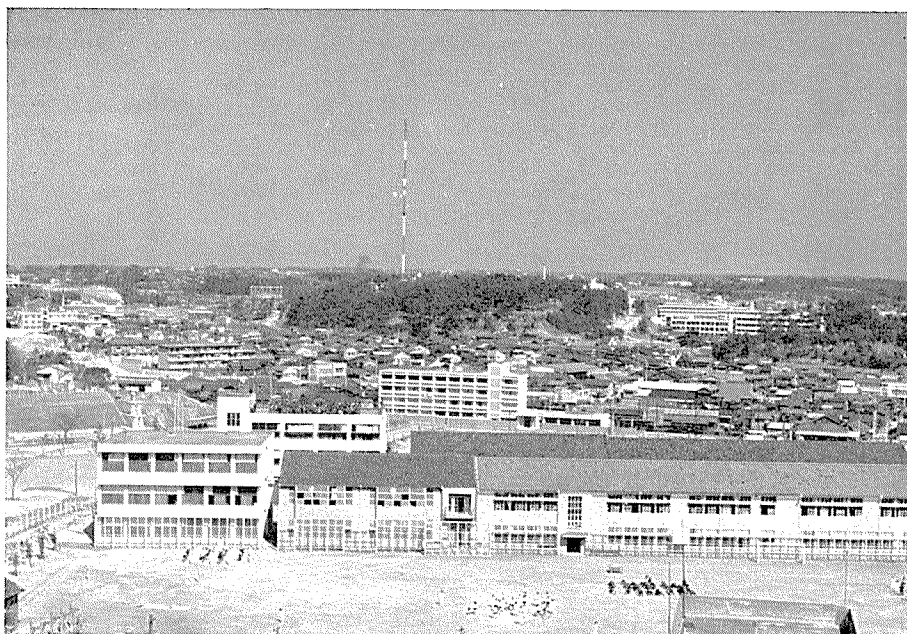


Fig. 1



Fig. 2



Fig. 3

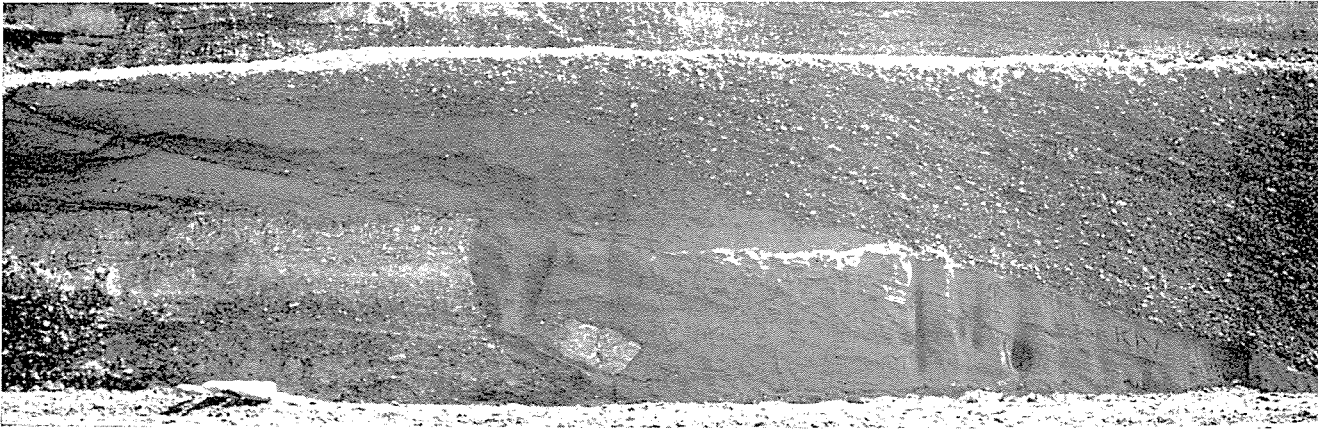


Fig. 4



Fig. 5



Fig. 6



Fig. 7



Fig. 8



Fig. 9 a

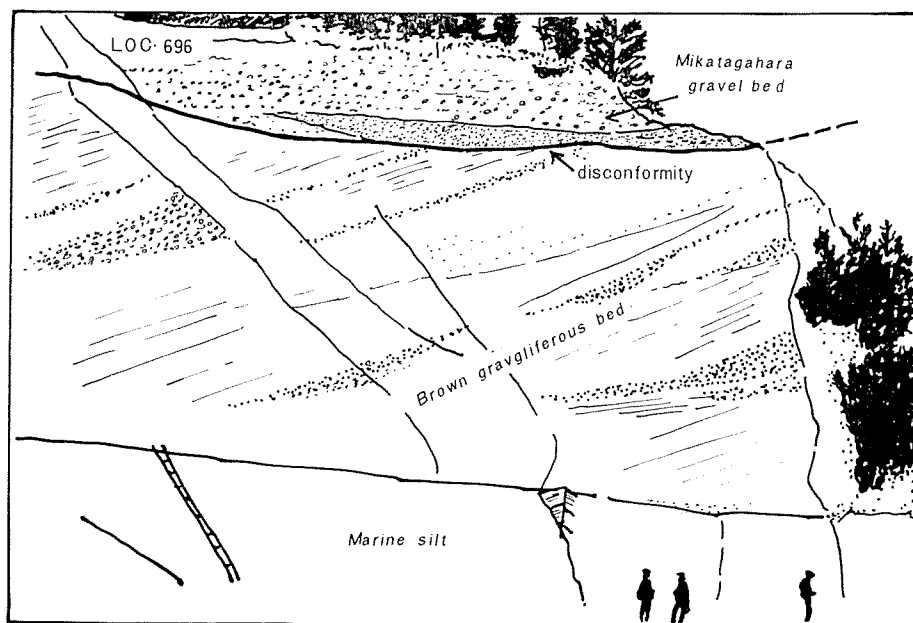


Fig. 9 b

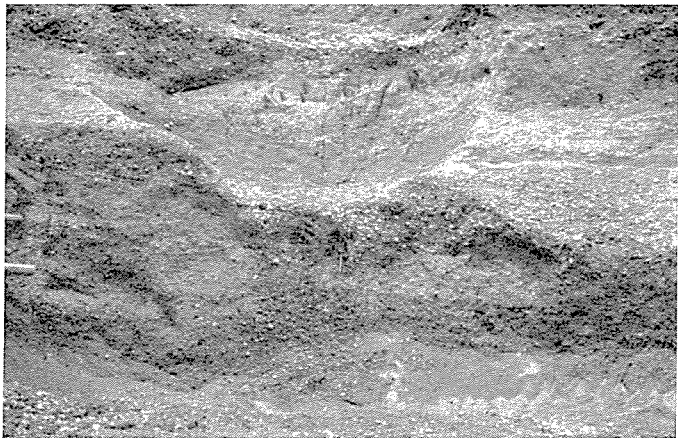


Fig. 10 a.

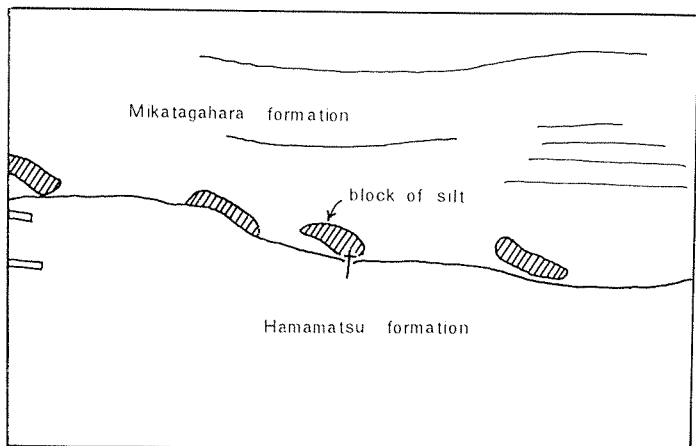
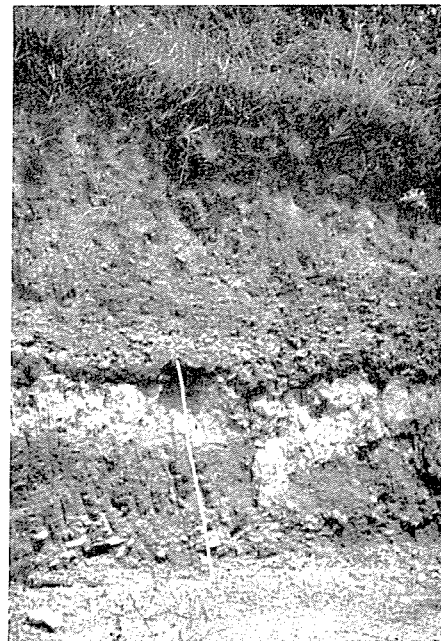


Fig. 10 b.



- humus
- rounded gravels
- breccias
- rounded gravels
- sand (limonitized)
- sandy silt & pebble
- sandy clay & pebble
- rounded pebble

Fig. 11.





Fig. 12



Fig. 13