MEMOIRS OF THE FACULTY OF SCIENCE, KYOTO UNIVERSITY, SERIES OF GEOL. & MINERAL.,
Vol. XLVI, No. 1, pp. 61–106, 1979

Chita Movements, the Tectonic Movements Preceding the Quaternary Rokko and Sanage Movements*

By

Takeshi MAKINOUCHI**

(Received February 1, 1979)

Abstract

Neotectonics in Southwest Japan had been hitherto exemplified by "Rokko Movements" and "Sanage Movements". Recently, it has been recognized that the Rokko and Sanage Movements are the Quaternary tectonic movements under the stress field with latitudinal compression.

In the Chita Peninsula, gently undulated hilly lands are widely distributed over the whole area. The hilly lands are composed of two kinds of geologic series. Thus, the upper constituents of the hill are of the middle Pleistocene Taketoyo Formation, and the lower constituents are of the Pliocene Tokoname Group. The Tokoname Group is a partial component of the Tokai Group, the name of which is given to the fillings of Lake Tokai of the Pliocene to early Pleistocene time. Relationship between the Taketoyo Formation and the Tokoname Group is represented by clino-unconformity. This unconformity is recognized everywhere in and around the Ise Bay, between the Tokai Group and the correlatives of the Taketoyo Formation.

Differences observed between the upper and lower constituents of the hill are distinctly recognized in lithology, rate of sedimentation, size and structure of the sedimentary basins and geological ages. As for the mode of tectonic movement, it is also recognized clear differences between depositional stages of both constituents. Accordingly, both geological series have different backgrounds from a geological point of view.

Hereupon, two kinds of tectonic movement can be distinguished from each other, the "older movement" which deposited the Tokai Group, and the "younger movement" which deposited the Taketoyo and correlative Formations. The "older movement" does not fall in the category of Rokko and Sanage Movements. This is the reason why the "older movement" must be distinguished from the Quaternary tectonic movements.

The name of **Chita Movements** is given to the "older movement". The Chita Movement is defined as the tectonic movement which caused the Tokai Group to deposit, deform and dislocate mainly during the Pliocene time. Regime of the Movement covers the Ise Bay and the surrounding area. Duration of the Movement is designated as the Pliocene and the former half of the early Pleistocene. The chief characteristic of tectonic movement is down-warping.

It is suspected that the Chita Movement was generated under other stress condition which is different from the horizontal compressive one with latitudinal trend in the Quaternary Movement. The Chita Movement had emerged in the Lake Biwa and Osaka Bay districts.

---

* Read at the 84th Annual Meeting of Geological Society of Japan, held in Kochi Univ., Kochi on April, 1977.

** Department of Earth Science, Faculty of Science and Technology, Meijo University, Nagoya, 468, Japan.

I. Introduction

Defining Neotectonics in Southwest Japan, IKEBE (1956, 1957) designated "Rokko Movements" as a sum of the whole displacement which took place in the Setouchi Geologic Province during the Pliocene and Pleistocene Periods. Following him, HUZITA (1962) compiled the tectonic development of the Setouchi Province, and clarified characteristics of the Rokko Movement.

Since the later half of the 1960's, studies on the Movement have been pushed forward by many investigators; IKEBE and HUZITA (1966), HUZITA and KISHIMOTO (1972), HUZITA (1976) and so on. Through these works, the Rokko Movement has come to a recognition as the Quaternary tectonic movement generated under the horizontal compressive stress field with E–W trend.

The author has engaged in geological survey of the Chita Peninsula since 1968. As a result of this investigation, he has established the stratigraphy of the Pliocene series (Tokoname Group), and has revealed the geologic structure, in the southern part of the peninsula (MAKINOUCHI, 1975a). In this way, the stratigraphic situation of the Tokoname Group becomes clear among Plio-Pleistocene series in the Setouchi Province (MAKINOUCHI, 1975a). In addition, the Taketoyo Formation, which occupies the upper part of hills in this area, was proved to be constituents of the hill, covering the Tokoname Group with unconfomity (MAKINOUCHI, 1975b). Furthermore, the mode of tectonic movement in each stage has become distinct (MAKINOUCHI, 1976). As a result, the author has arrived at the standpoint that Pliocene tectonic movements must be distinguished from those of the Quaternary (MAKINOUCHI, 1976).

Consequently, the term of **Chita Movements** is newly given for the older tectonic movements preceding the Quaternary Movement.

In this paper, the author intends to discuss the characteristics of Chita Movements.

II. Summary of the Pliocene and Pleistocene Sediments in the Chita Peninsula and the Surrounding Area

A. Geological Outline

The Japanese Islands are usually divided into two parts, "Northeast Japan" and "Southwest Japan", by the Itoigawa-Shizuoka Tectonic Line (Figs. 1 and 2).

Southwest Japan is further subdivided into the Inner and Outer Belts by the Median Tectonic Line. In Southwest Japan, Neogene and Quaternary sedimentary and volcanic blankets occupy three zones, the inner zone along the Japan Sea, the median zone including the inland sea (Seto-Naikai), and the outer zone facing the

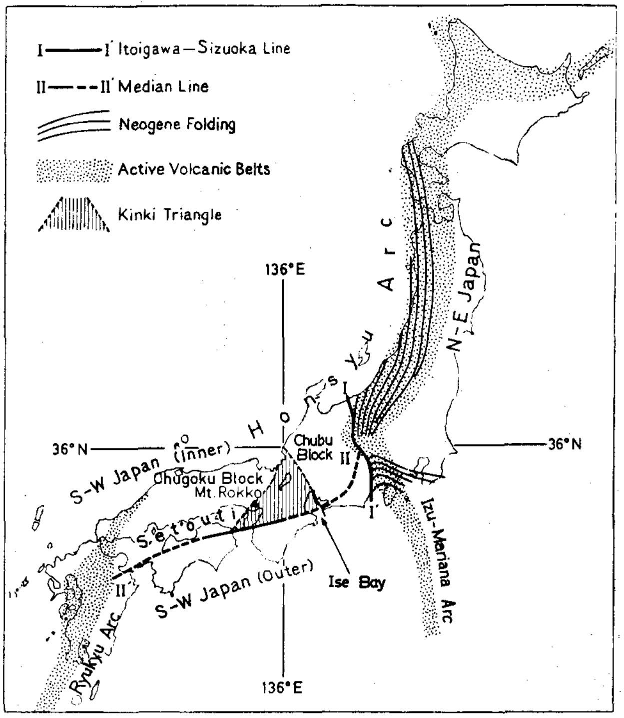


Fig. 1. Index map showing the neotectonic elements of the Japanese Islands (based on MATSUDA, 1964; HUZITA, 1969, slightly modified).

Pacific Ocean.

For such distribution pattern of those blankets, MAKIYAMA (1939) designated the Miocene paleogeographic provinces as "North inside area", "West outside area" and "West inland sea". The last being inland sea covered a narrow belt stretching from the southern Shinshu to Shodo Island. Clarifying MAKIYAMA's conception, IKEBE (1957) introduced the term of "Sedimentary province", namely "Hokuriku-San'in", "Nankai" and "Setouchi" provinces, respectively.

At the same time, he also proposed conceptions of the "First Setouchi Series" in the Miocene and the "Second Setouchi Series" in the Pliocene to Pleistocene in order to classify the evolutional stage of late Cenozoic geohistory in the Setouchi Geologic (Sedimentary) Province.

From the structural view point, depression of the Ise Bay and its surrounding area is situated in the Inner Belt of Southwest Japan. Mino massif lies to the north of the depression. In the western margin, Suzuka Mountain Range runs meridionally interposing the Ichishi Fault in the eastern foot. The eastern border is confined by

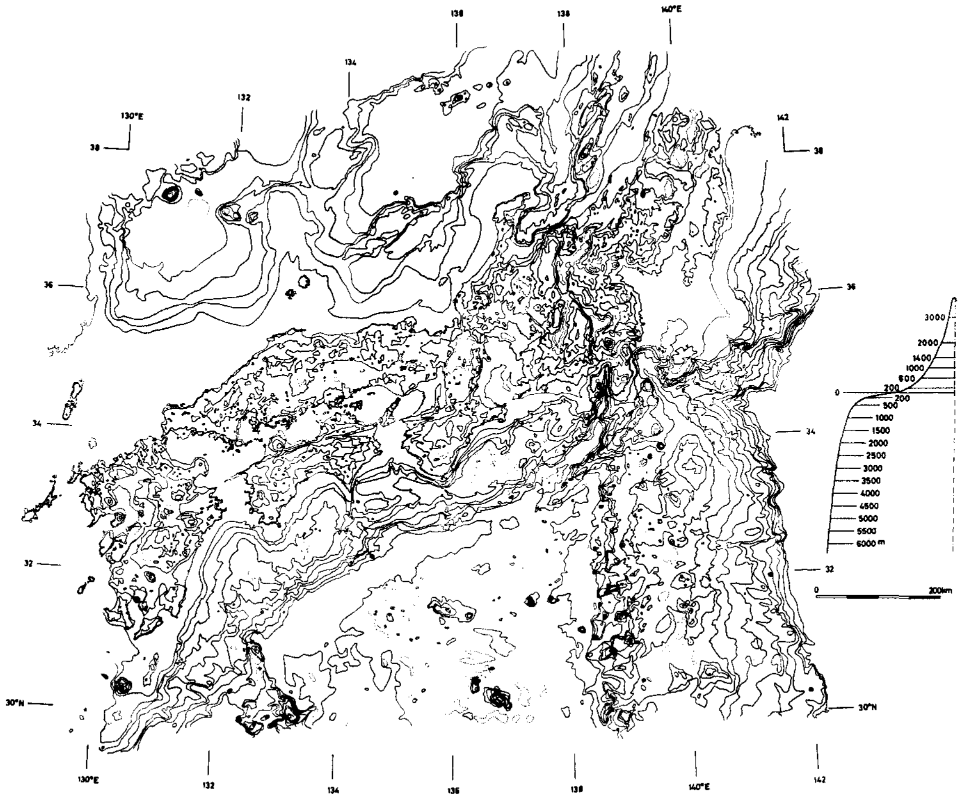


Fig. 2. Major relief in and around Southwest Japan based on the Summit level map of OKAYAMA (1969) and the Bathymetric chart of HYDROGRAPHIC OFFICE (1965).

the Mikawa Highland.

In the southern half of the depression, the Ryoke metamorphic and granitic rocks lie under the Cenozoic blankets, and the Mino Paleozoic rocks lie under the northern half.

Miocene sediments of the First Setouchi Series are partly exposed in the peripheral zone of the depression, namely, the Ichishi and Suzuka Groups in the southwest, the Chikusa Group in the eastern foot of Suzuka Range, the Mizunami Group in the northeast, and the Morozaki Group in the southern extremity of the Chita Peninsula (Fig. 3). Miocene sediments are discovered by drillings deeper than about 500 and 1,000 m below the surface of northern Chita and Nohbi Plain, respectively (KUWAHARA, 1968).

In the northeastern margin of the depression, "porcelain clay deposits" are exposed dispersedly at the basal part of hills. Among them, the Seto Porcelain Clay Formation is a representative one (Fig. 3).

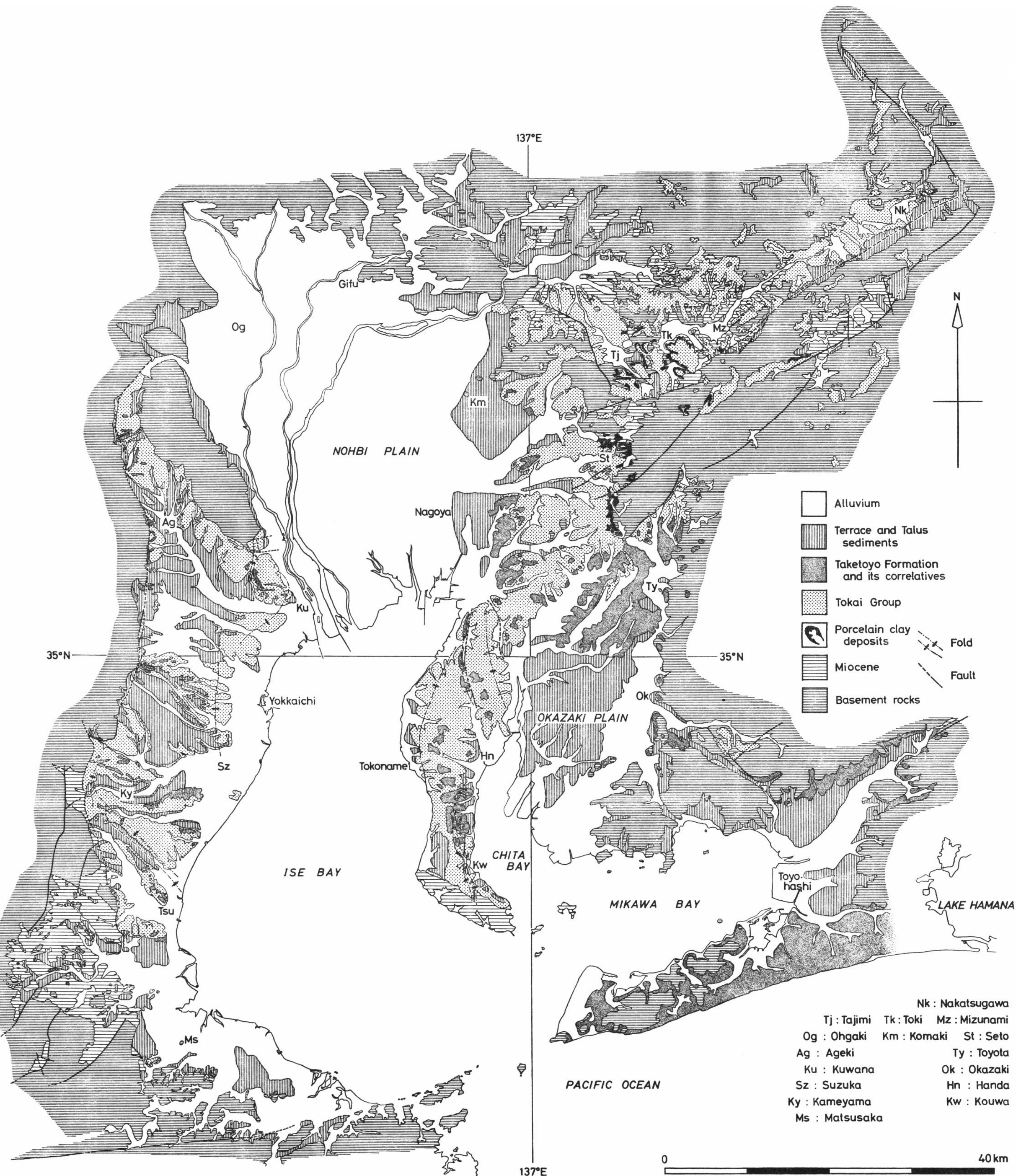


Fig. 3. Geologic map around the Ise Bay.

Pliocene sediments form extensively hilly lands around the Ise Bay, and those are variously called the Agĕ Group in Ise, the Seto Group in Nagoya and the Tokoname Group in the Chita Peninsula (Fig. 3). These groups are sediments in Lake Tokai (TAKEHARA *et al.*, 1961 and 1964) which is assumed to have existed in the Pliocene to early Pleistocene. Based on this assumption, the general term of "Tokai Group" (ISHIDA and YOKOYAMA, 1969) is applied to the fillings of this lacustrine sedimentary basin. The Tokai Group, the Osaka Group in the Osaka district and the Kobiwako Group in the Oomi and Iga Basins belong to the major member of the Second Setouchi Series.

Apart from the Tokai Group, the middle Pleistocene gravelly sediments are scattered sporadically around the Ise Bay, occupying the upper part of hills (Fig. 3).

Terrace deposits are classified as the Higher, Middle and Lower Terrace Deposits. Generally speaking, the Higher Terrace Deposits are thin gravelly sediments of veneer, resting on the hill surface. The Middle Terrace Deposits are well developed along the present rivers, and sometimes have intercalations of marine sediments in the lower reaches. The Lower Terrace Deposits are represented by gravelly beds along the present river courses.

The Chita Peninsula is located in the south of Nagoya, elongating southwards between the Ise Bay on the west and the Chita Bay on the east. In the south, the Atsumi Peninsula elongates from the east, separating both bays from the Pacific Ocean.

The Ryoke metamorphic and granitic rocks construct the basement of the Chita Peninsula. The Miocene Morozaki Group is of marine sediments consisting chiefly of mudstone, more than 1,200 m thick. The Morozaki Group forms a syncline plunging northwestwards.

Table 1. Geologic systems in the southern part of the Chita Peninsula (MAKINOUCHI, 1975a).

GEOL. AGE	STRATIGRAPHY		THICKNESS	LITHOLOGY
HOLOCENE	Alluvium			
PLEISTOCENE	Lower & Middle Terrace Deposits		30m-	gravel, sand & mud (marine)
	Higher Terrace Deposits		10m-	gravel
	Taketoyo Formation		20m	gravel, sand & mud (marine)
PLIOCENE	Tokoname Group	Futto Formation	280m+	alternation of sand & mud
		Kouwa Formation	180m	alternation of sand & mud
		Toyooka Formation	85m	sand & gravel
MIOCENE	Morozaki Group		1200m	mud dominant marine sediments
BASEMENT	Ryoke Granitic Rocks			

The Pliocene Tokoname Group (Tokai Group) covers the Morozaki Group with unconformity, and constitutes gently undulated hills with altitude ranging from 60 to 80 m over the whole peninsula, and extends its exposure continuously to the Seto Group in the southeast of Nagoya. The Tokoname Group is composed mainly of irregular alternations of sand and mud beds, with intercalations of volcanic ash and lignite beds. The total thickness is about 550 m (Fig. 8).

The middle Pleistocene Taketoyo Formation comprises the upper part of hills in the Fuki and Taketoyo areas, covering the Tokoname Group with unconformity. The thickness is about 30 m. The Taketoyo Formation presents the highest topographic surface with rather constant summit level. Geologic structure of the Taketoyo Formation is harmonic with that of the Tokoname Group.

The Higher and Middle Terraces are distinguishable in the southern part of the peninsula. The Higher Terrace Deposits (Fuki Formation*) are represented by a thin (2 m–) gravelly bed, resting on the Taketoyo Formation with unconformable indication (Fig. 18). The Middle Terrace Deposits are developed in the Noma (west coast), Kouwa, Fuki and Taketoyo (east coast) areas. The Shinden Formation* is the term used for the terrace deposits with surface altitude of 10 to 20 m. a.s.l., in the east coast, and intercalates marine sediments (Fig. 19). The Noma Formation comprising of marine sediments is developed in the west coast, 30 to 40 m in surface altitude (Fig. 20).

B. Porcelain Clay Deposits

Clay deposits being mined as the raw materials for pottery are exposed in Seto, Tajimi, Toki and their adjacent areas (Fig. 3). These deposits are called "porcelain clay deposits", and consist mainly of quartz sand, micaceous sandy clay (the so-called "Kira" in Japanese), quartz grain bearing clay ("Gairome"), pale grey to bluish grey clay and lignitic clay ("Kibushi"). According to KUWAHARA (1971a), the Seto Porcelain Clay Formation does not exceed 30 m in thickness, and indicates high grade of maturity. Basement rocks beneath the formation generally suffer deep weathering. And, he concluded that the formation was deposited in small depressions of low-relief basement through alternating cut and fill sedimentation of weathered materials derived from the surrounding granitic basement in the process of long time weathering. "Porcelain clay deposits" in other areas also show similar lithology to that of the Seto Porcelain Clay Formation. In the eastern foot of Suzuka Range near Kameyama, the western margin of the Ise Bay depression, a similar clay bed is exposed (AKAMINE *et al.*, 1951; WADA, 1976). Abundant occurrence of fossil corn of *Pinus trifolia* suggests the geological age of the Seto Porcelain Clay Formation, however, some of the other "porcelain clay deposits" may not be formed contemporaneously.

In lithology, these "porcelain clay deposits" are clearly different from the following Tokai Group, and the horizon of these deposits is stratigraphically lower than the Tokai Group. In this way, the "porcelain clay deposits" should be antecedent to the generation of Lake Tokai (MAKINOUCHI, 1976).

C. Tokai Group

The Tokai Group is subdivided into three groups according to exposed areas, namely, the Agĕ Group in Ise, the Yadagawa Formation of the Seto Group in Nagoya

---

* newly defined term

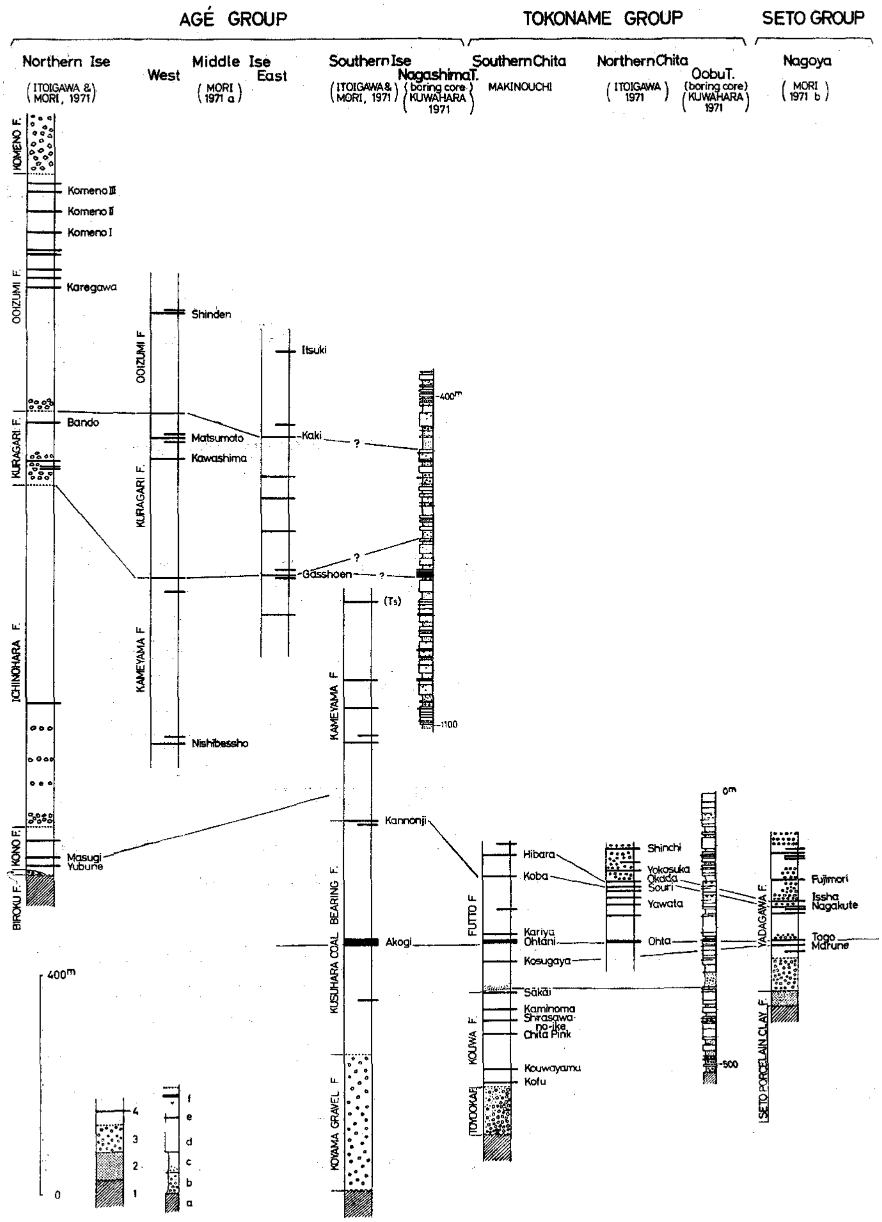


Fig. 4. Correlation chart of the Seto, Agě and Tokoname Groups (MAKINOUCHI, 1975a).
1; basement, 2; porcelain clay, 3; gravel, 4; volcanic ash,
a; basement, b; gravel, c; medium to coarse sand, d; fine sand, silt and clay,
e; lignite and peat, f; volcanic ash

The deepest horizon of the Nagashima T. boring core is not 1100 m but 1000 m.

and the Tokoname Group in Chita (Fig. 3). The lower and middle parts of the Agĕ Group and the Yadagawa Formation are approximately correlated with the Tokoname Group, and Pliocene in age. The upper part of the Agĕ Group belongs to the early Pleistocene (MAKINOUCHI, 1975a) (Fig. 4).

In the southern part of the Chita Peninsula, the **Tokoname Group** is divided into three formations, the Toyooka, Kouwa and Futto Formations, in ascending order (Figs. 6, 7 and 8). Generally, three formations imbricate conformably toward the northeast with NW–SE strike.

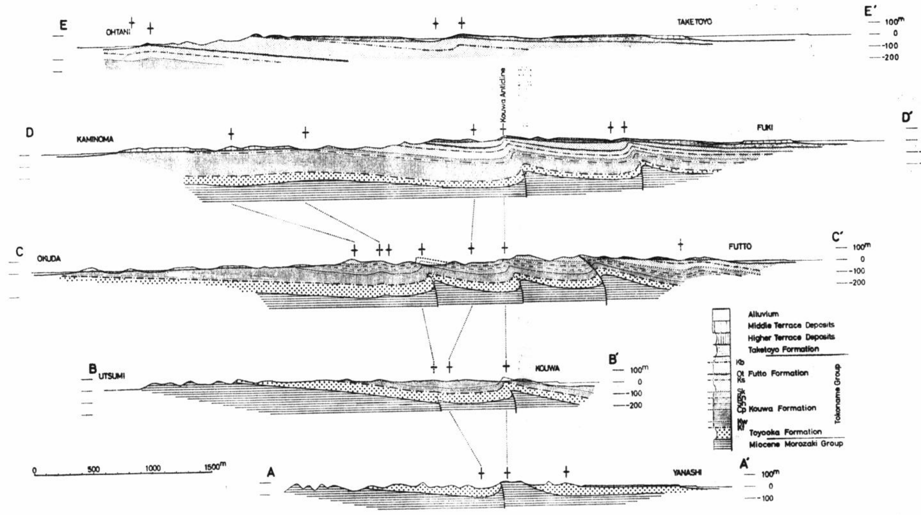


Fig. 5. Geologic profiles of the southern part of the Chita Peninsula (MAKINOUCHI, 1975a). A–A′, B–B′, C–C′, D–D′ and E–E′ are shown in the geologic map.

The Toyooka Formation consists of gravel beds with intercalations of mud seams, and is 70 to 100 m thick. The Kouwa Formation is composed of irregular alternations of sand and mud beds, and intercalates lignite and volcanic ash seams. The formation is about 180 m in thickness. Each of the sand and mud beds ranges from several tens of centimeters to 10 m in thickness. Sand beds are poor in continuity, thinnig out or interfingering with mud beds. The Futto Formation is more than 280 m thick, and resembles lithologically the Kouwa Formation. At the base, the formation contains coarser sediments.

In the northern part of the peninsula, strata which are correlated with the upper part of the Futto Formation are exposed (Figs. 9 and 10), and are about 150 m thick (ITOIGAWA, 1971; MAKINOUCHI, 1973). The strata show similar lithology to that of the Futto Formation (Figs. 11, 12 and 13).

According to NASU (1972), *Carya* pollens (less than 1% for the total pollen) are

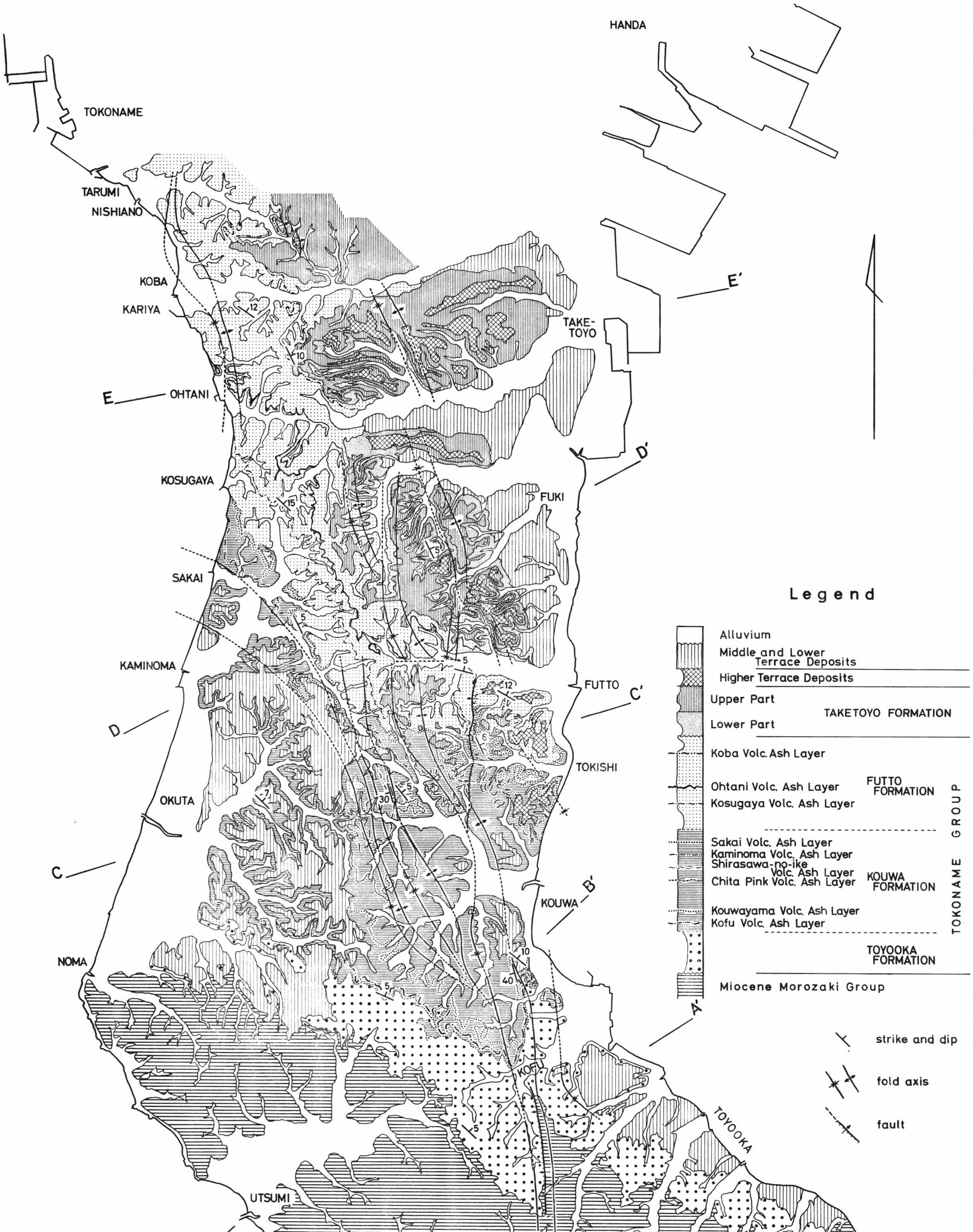


Fig. 6. Geologic map of the southern part of the Chita Peninsula (MAKINOUCHI, 1975a).

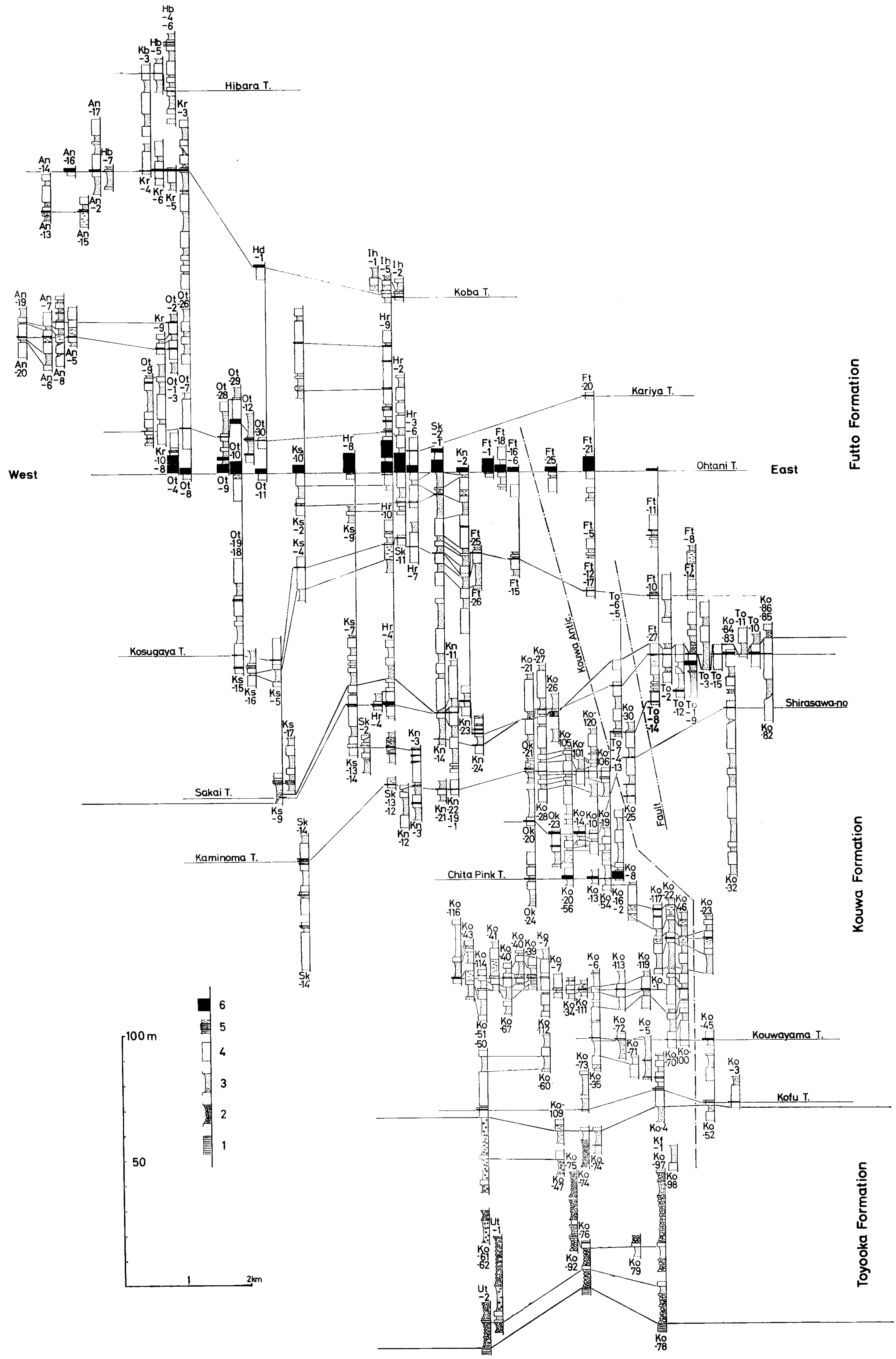


Fig. 7. Columnar sections of the Tokoname Group (Makinouchi, 1975a).

1; Morozaki Group, 2; gravel, 3; medium to coarse sand, 4; fine sand, silt and clay, 5; lignite and peat, 6; volcanic ash detected from horizons below the Ohtani Volcanic Ash Layer of the Futto Formation. He has also stated that the horizons above this ash layer indicate similar pollen composition to that of the Shimagahara Flora of the Iga and Nabari areas.

The **Agĕ Group** (TAKEHARA, 1961) constitutes hilly land over the whole Ise district, and its total thickness is about 1,500 m. Younger Quaternary blankets divide exposures of the Agĕ Group into two parts, the south and the north. Roughly speaking, the lower part of the Agĕ Group is exposed in the south, while the upper part is in the north.

In the south (Tsu and Kameyama areas), the Koyama (Saigyodani) Gravel, Kusuhara Coal-bearing and Kameyama Formations are exposed, in ascending order (AKAMINE *et al.*, 1951; WADA, 1976). These formations imbricate toward the north and east. The Koyama Gravel Formation comprises mainly pebble and cobble gravels. The Kusuhara Coal-bearing Formation is characterized by alternations of sand and mud beds with intercalations of lignite beds, and is about 400 m thick. The Kameyama Formation is composed mainly of alternations of sand and mud beds. Sand beds are dominant in this formation, compared with the Kusuhara Coal-bearing Formation. The thickness is about 350 m.

In the north (Yokkaichi, Kuwana and Inabe areas), the Agĕ Group is subdivided into six formations; the Biroku, Kono, Ichinohara, Kuragari, Oh'izumi and Komeno Formations, in ascending order (KATO, 1957; YOKOYAMA, 1971). Generally speaking, these formations show a basin structure with the center in the Komono area, west of Yokkaichi. Among them, the Biroku Formation occupies the position of basal conglomerate. The overlying

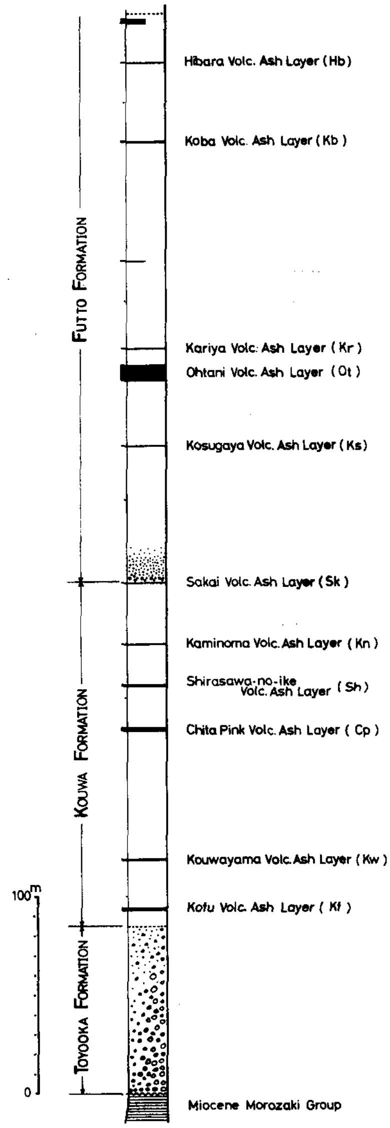


Fig. 8. Compiled columnar section of the Tokoname Group (MAKINOUCHI, 1975a).

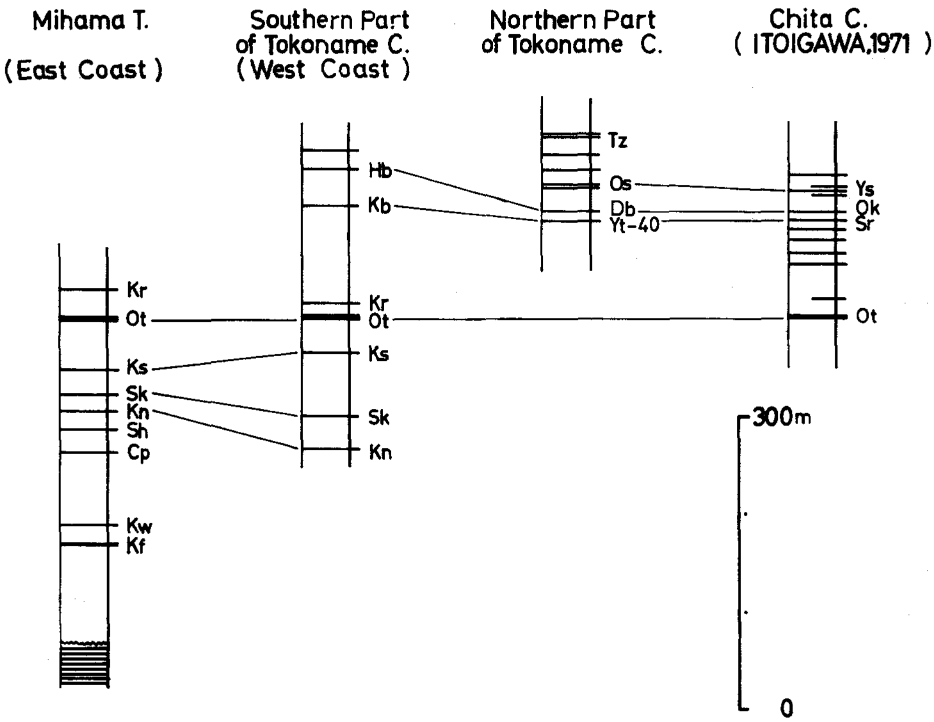


Fig. 9. Correlation of the Tokoname Group in the south and the north areas (MAKINOUCHI, 1973).

Kono Formation is about 100 m thick, and consists of bluish green mud. Next, the Ichinohara Formation comprises alternations of gravel and mud beds, and the Kuragari Formation is characterized by thick gravel beds (100 to 200 m). The Oh'izumi Formation is 300 to 350 m in thicknesss, and is made chiefly of alternations of sand and mud beds. And lastly, the Komeno Formation is about 100 m thick, and is composed of gravels.

The **Seto Group** (MAKIYAMA, 1950) consists of gravel, sand and mud beds with intercalations of lignite and volcanic ash beds, and constitutes hilly land in the eastern periphery of Nohbi Plain. MATSUZAWA *et al.* (1960) classified the Seto Group into two formations, the Seto Porcelain Caly Formation (lower, already stated in the previous section) and the Yadagawa Formation (upper). They pointed out the presence of unconformity between both formations. According to tephrostratigraphy (MORI, 1971b), the Yadagawa Formation is divided into three members, namely, the Mizuno, Takahari and Idaka Members, in ascending order. Since the Yadagawa Formation shows homoclinal structure inclined gently to the west or southwest, upper member crops out further west. This formation is about 250 m in thickness.

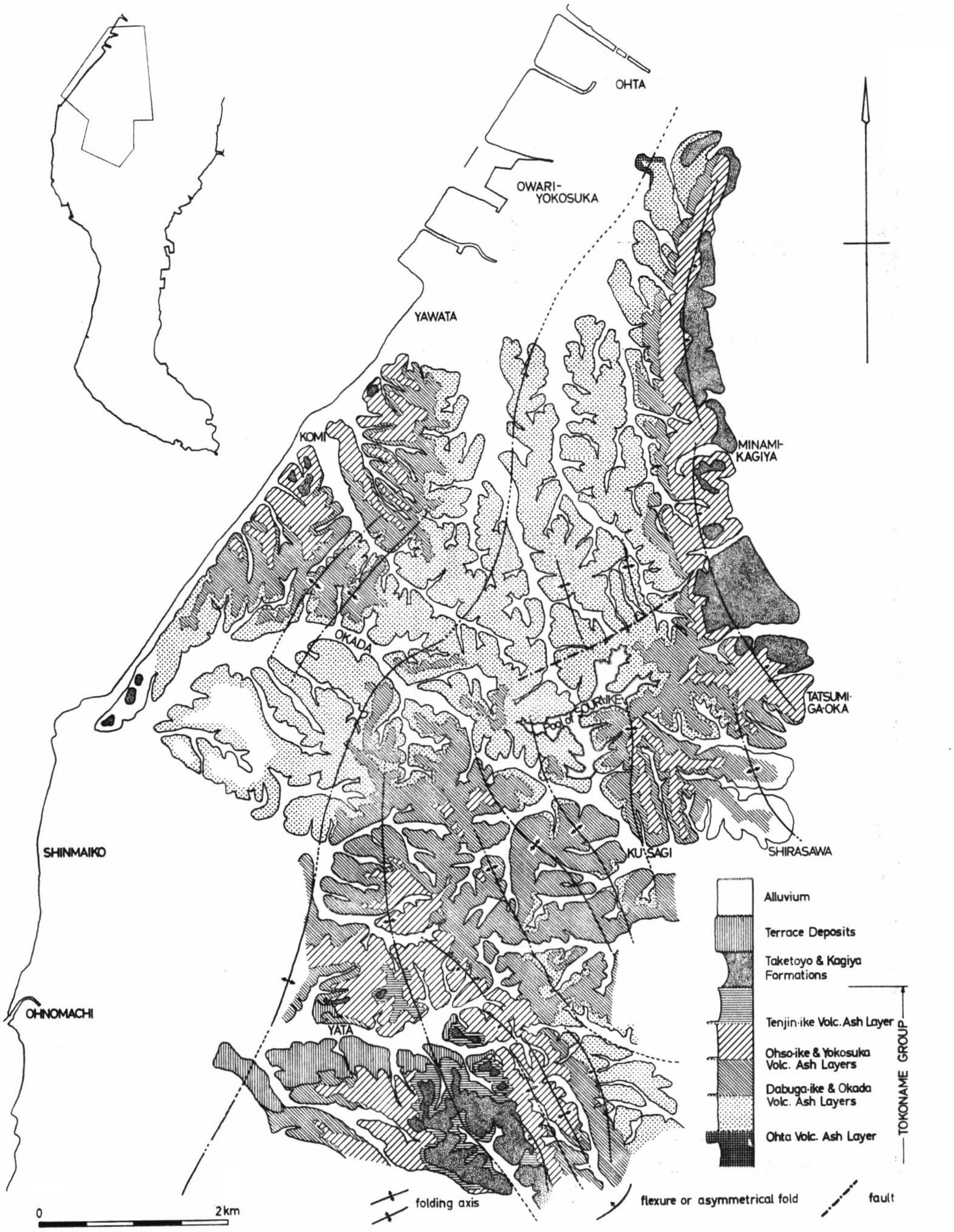


Fig. 10. Geologic map of the northern part of the Chita Peninsula based on ITOIGAWA (1971) and MAKINOUCHI (1973).

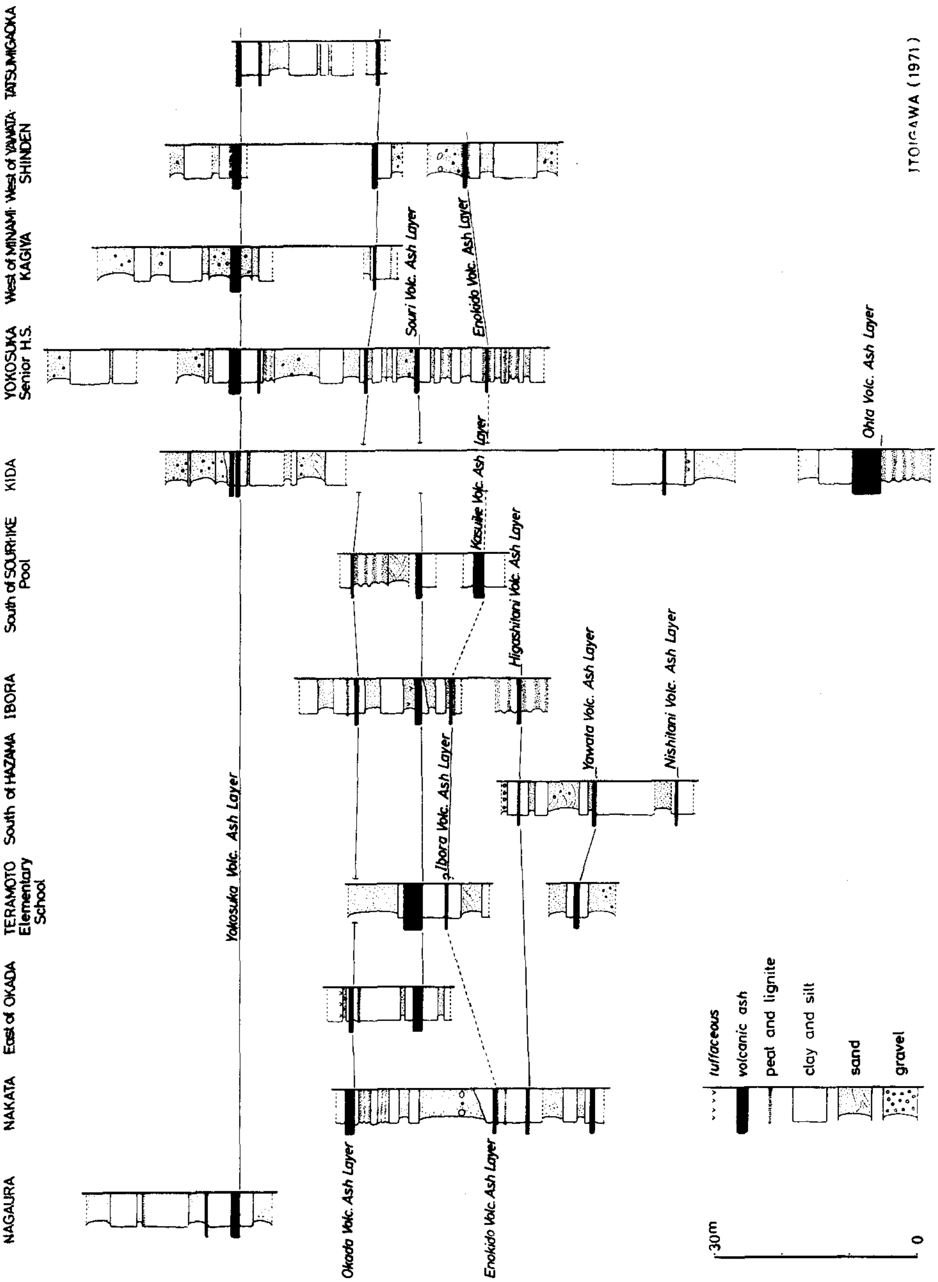


Fig. 11. Columnar sections of the Tokoname Group in the Chita City area (ITOIGAWA, 1971).

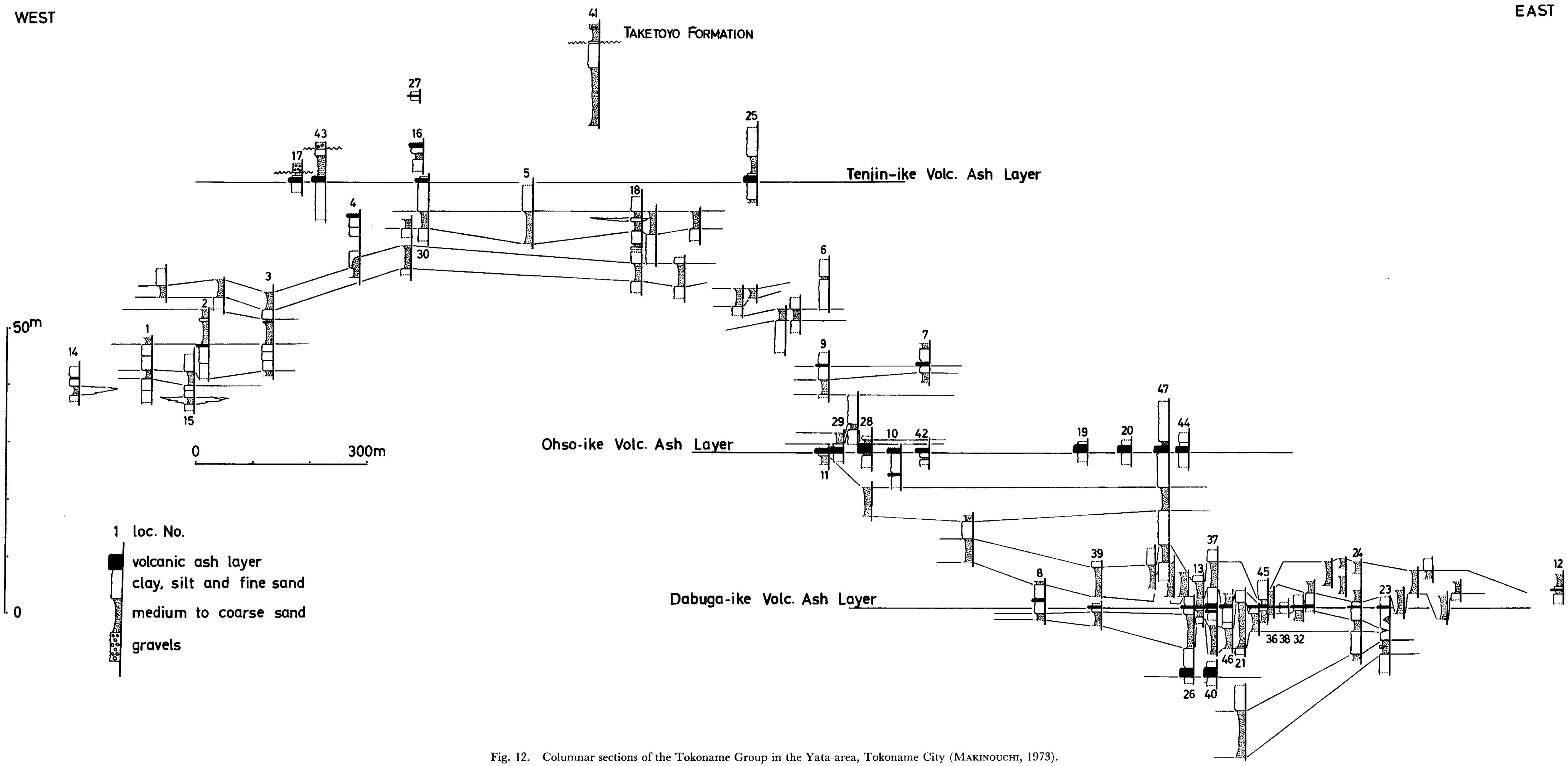


Fig. 12. Columnar sections of the Tokoname Group in the Yata area, Tokoname City (MAKINOUCHI, 1973).

The **Toki Sand and Gravel Formation** is of gravelly sediments forming hills in the Tajimi, Toki, Mizunami and Ena Basins and the surrounding area. This formation covers unconformably the porcelain clay deposits, the Mizunami Group and the basement rocks, and is generally subject to intense weathering. The thickness is less than 100 m. Corns of *Metasequoia* and *Pinus koraiensis* were found in a clay bed of the formation at Magome (KUWAHARA, 1973).

In the Osaka Group, the same plant fossils coexist in horizons from the Shinden to Azuki Volcanic Ash Layers (NASU, 1972). As age of the coexisting horizons is the early Pleistocene, a part of the Toki Sand and Gravel Formation should be also the same geological age.

D. Taketoyo Formation and its Correlatives

Though precise stratigraphic situations have not yet been settled, the Taketoyo Formation and its equivalents around the Ise Bay are correlated with the Osaka Group, especially with the upper part of the group. These are identified by various names thus; the Matsusaka, Kentoyama, Honjiromatsu, Ohtaniike, Kitashiraki, Tozenji, Rengeji, Kamisue, Karayama, Yagoto, Kagiya and Taketoyo Formations (Fig. 3).

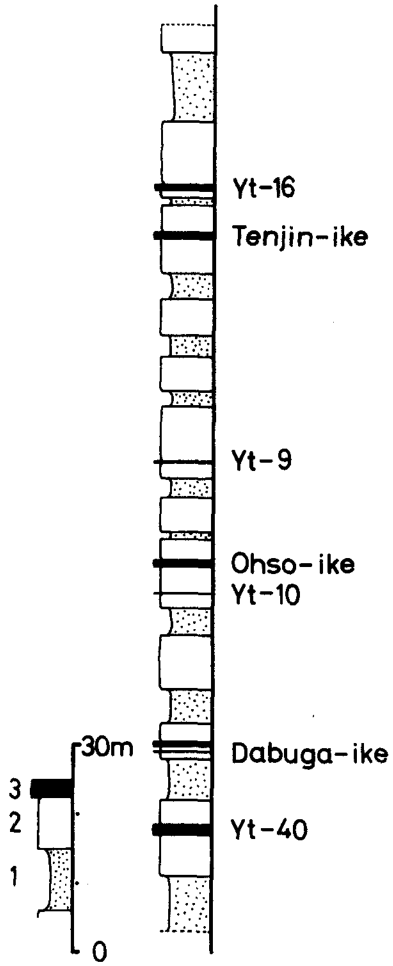


Fig. 13. Compiled columnar section of the Tokoname Group in the Yata area, Tokoname City (MAKINOUCHI, 1973).
1; medium to coarse sand, 2; fine sand, silt and clay, 3; volcanic ash

These formations are commonly characterized as follows;

i) These formations cover the Tokai Group with unconfomity, and occupy the upper part of hills.
ii) Geologic structures of these formations are concordant with those of the Tokai Group.
iii) These formations form the erosion surface of hills with constant altitude,

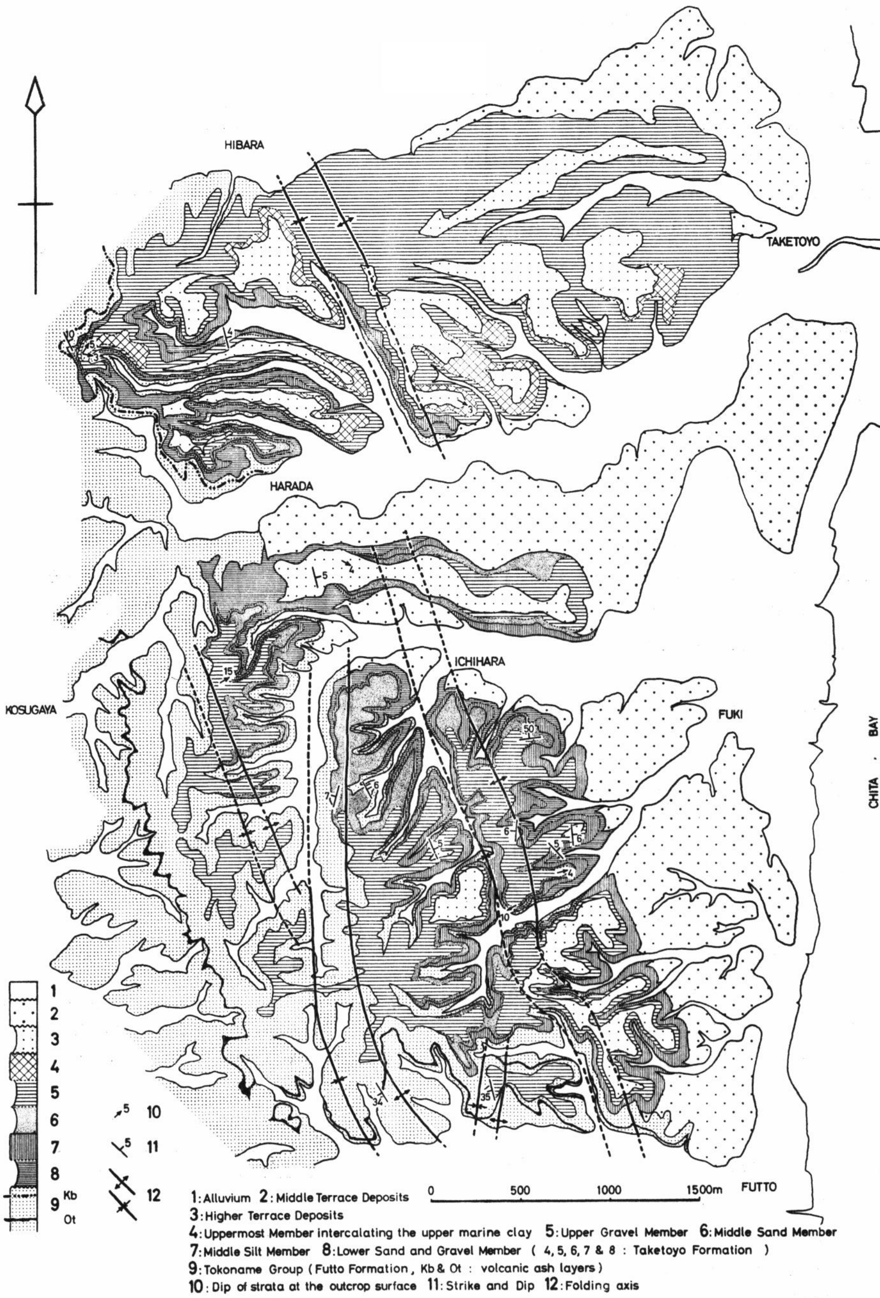


Fig. 14. Geologic map of the Fuki and Taketoyo areas in the Chita Peninsula (MAKINOUCHI, 1975b).

which is higher than the Higher Terrace Plain.

iv) These formations have undergone intense weathering, and are reddish in color, containing decayed gravels.

In the Chita area, the **Taketoyo Formation** (MAKINOUCHI, 1975b) is developed in the Taketoyo and Fuki areas (Figs. 14, 15 and 16). The formation is divided into five members, the Lower Sand and Gravel, Middle Silt, Middle Sand, Upper Gravel

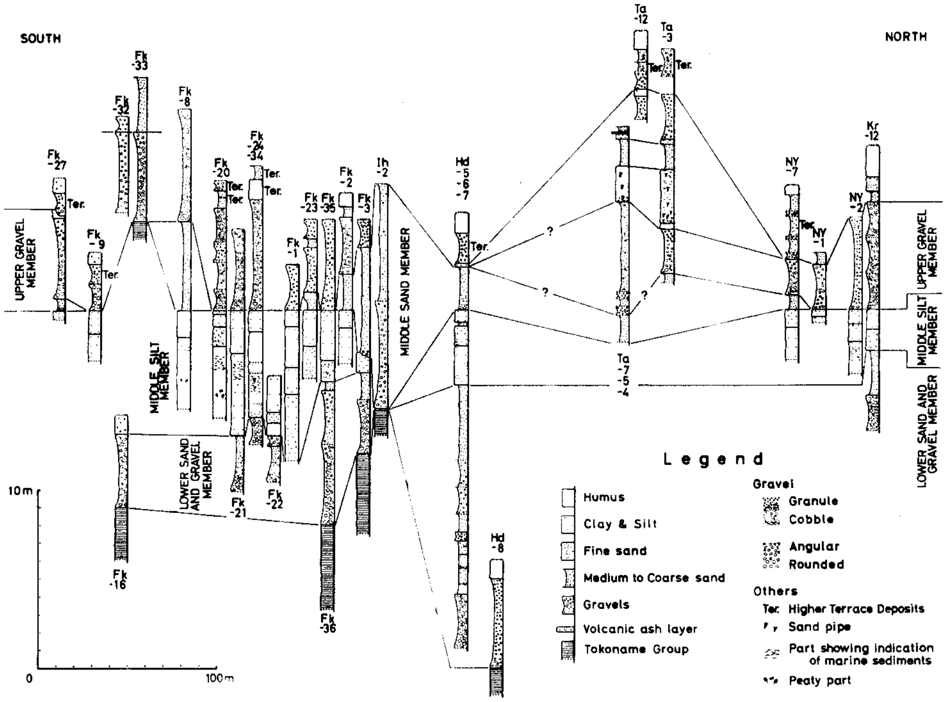


Fig. 15. Columnar sections of the Taketoyo Formation. Horizontal scale is not 100 m but 1,000 m. (MAKINOUCHI, 1975b).

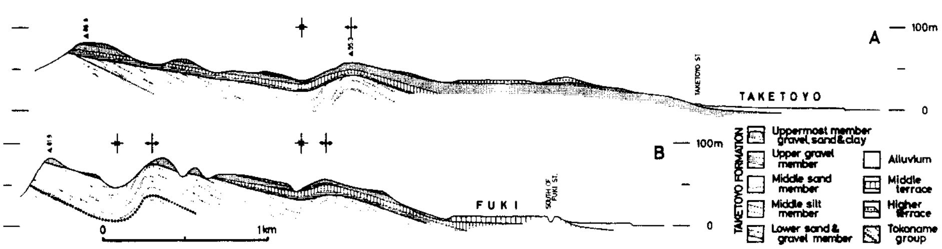


Fig. 16. E–W geologic profiles of the Fuki and Taketoyo areas in the Chita Peninsula (MAKINOUCHI, 1975b).

A; Taketoyo area, B; Fuki area

and Uppermost Gravel-Sand-Clay Members, in ascending order. The Middle Sand Member forms scooping and/or abutting structure against the Middle Silt Member, indicating unconformity. The Middle Silt and Uppermost Members have intercalations of marine facies. The formation is about 30 m thick. The **Kagiya Formation** (ITOIGAWA, 1971), the equivalent in the northern Chita, is composed of gravels with less than 20 m thickness.

On the west coast of the Ise Bay, the correlatives of the Taketoyo Formation are gravelly sediments preserved in the upper parts of hills. According to KIMURA and TAKEHARA (1969), these deposits are represented by three types of sedimentary facies. The first is valley-filling deposits represented by the Kentoyama Formation. The second is gravel veneer which seems to be sediments covering flood plain. The Ohtaniike and Rengeji Formations belong to this type. The third, talus and fan deposits, are exemplified by the Tozenji Formation.

The **Kentoyama Formation** (ARAKI and KITAMURA, 1971) is developed in the Tsu area. The thickness ranges from 15 to 20 m. The formation is made of the Lower Gravel, Middle Sand, Middle Silt and Upper Gravel Members, showing one sedimentary cycle (ARAKI and KITAMURA, 1971). NISHIYAMA *et al.* (1975) have correlated the formation with the upper part of the Osaka Group, based upon the occurrence of *Liquidambar* pollen and plant fossil of *Juglans mandshurica* var. *sieboldiana* (ARAKI and KITAMURA, 1971).

The **Ohtaniike Formation** (KIMURA and TAKEHARA, 1969; KIMURA, 1971) is of thin gravelly sediments which is developed in Dohaku hill on the southern bank of River Suzuka. The formation consists of subangular gravels of boulder and pebble, and the thickness is about 10 m.

The **Rengeji Formation** (KATO, 1957) is developed in the west of Kuwana, and is chiefly composed of gravels with less than 20 m thickness.

The **Tozenji Formation** (KIMURA, 1971) is scattered at the eastern foot of Suzuka Range, west of Ageki, and represents the facies of the third type. The thickness is more than 10 m.

In Nagoya and the suburban area, correlatives of the Taketoyo Formation are the Karayama and Yagoto Formations.

The **Karayama Formation** is characterized by gravels rich in quartz-porphyry, and is found mainly in the eastern part of Nagoya City. The thickness is about 10 m. The formation intercalates silt and sand beds in the upper part (Fig. 17). The formation does not yield such fossil pollens as *Cunninghamia, Metasequoia, Glyptostrobus, Liquidambar, Nyssa, Sciadopitys, Jnglaus, Rhus* and *Ericacea,* which are common in the Seto Group (SOHMA, 1958).

The **Yagoto Formation** forms the summit surface of hills, and is about 50 m in thickness. The formation consists of alternations of gravelly (5 to 7 m thick) and muddy (2 to 4 m thick) beds (Fig. 17). Generally, gravels of the formation are

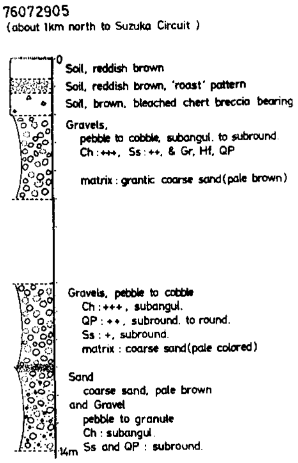


Fig. 17a. Columnar section of the Ohtaniike Formation.

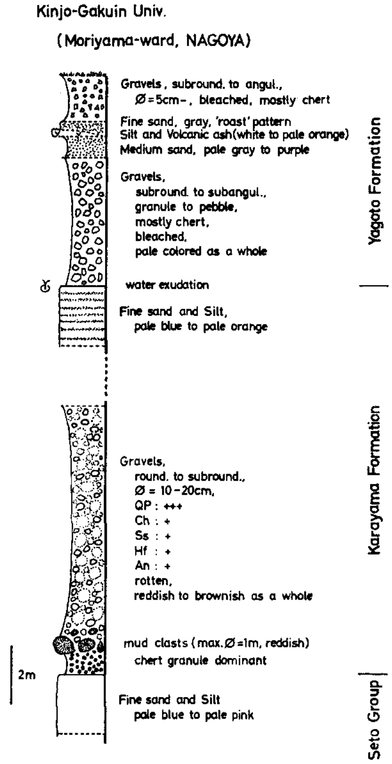


Fig. 17b. Columnar section of the Karayama and Yagoto Formations.

bleached to a pale color.

E. Younger Quaternary Deposits

1. *Land Area*

In the Chita Peninsula, the Fuki Formation which is nominated to the Higher Terrace Deposits is developed in the Taketoyo and Fuki areas. The thickness of this formation ranges from several tens of centimeters to a few meters, and the formation is composed mainly of angular to subangular chert gravels (Fig. 18). These gravels are characteristic of finer (7 cm–) than those of the Taketoyo Formation, and of bleached in many cases. Generally, the uppermost section consists of soil-like fine materials in the upper half showing brown to red (5 to 2.5 YR in color index), and of fine-grained sediments in the lower half showing spotted pattern of pale gray and brown to red (the so-called "roast" pattern).

According to KIMURA (1971, 1972 and 1973), the Higher, Middle and Lower Terrace Deposits are distinguished in the west coast of the Ise Bay.

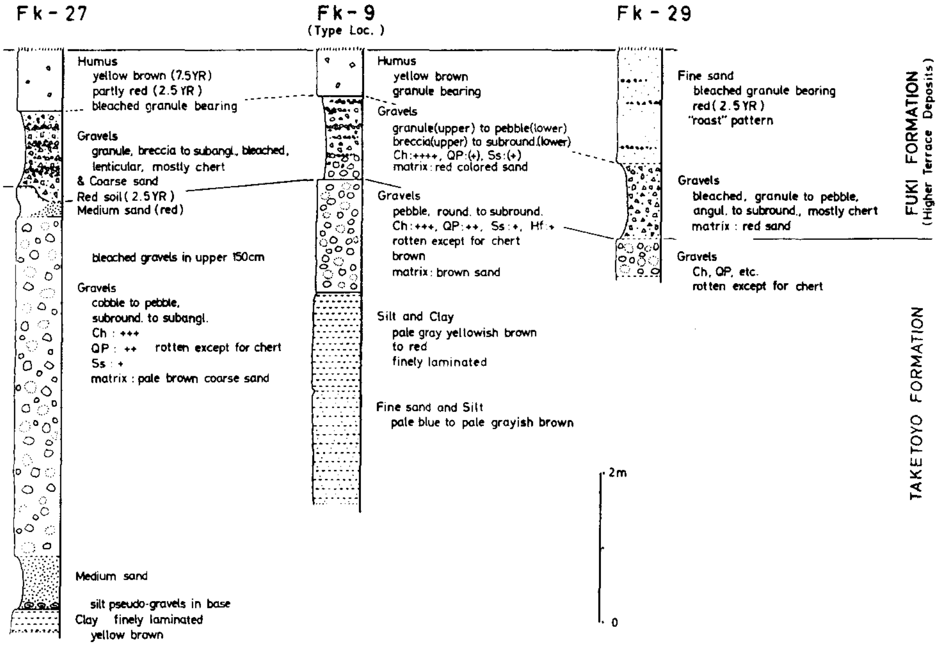


Fig. 18. Columnar sections of the Fuki Formation (Higher Terrace Deposits).

The author has observed the Aokigawa Formation (Higher Terrace Deposits in the west of Yokkaichi) in 1976. According to him, only the uppermost part, which is composed of bleached finer rubbles and humus-like reddish materials, qualifies for the category of Higher Terrace Deposits (Fig. 21). The main part having decayed gravels is thought to be correlative to the Ohtaniike Formation. The similar case is also observed in the Higher Terrace Deposits of Dohaku hill. Accordingly, the main part of KIMURA's "Higher Terrace Deposits" may be correlated with the Ohtaniike Formation, and usage of the Higher Terrace Deposits should be limited to the uppermost part only. However, the unconformity between the uppermost and main parts of those sediments is not always

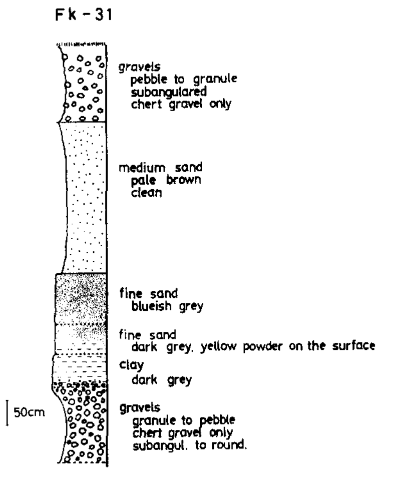


Fig. 19. Columnar section of the Shinden Formation (Middle Terrace Deposits) at the locality just south of Fuki Station, Meitetsu Railway.

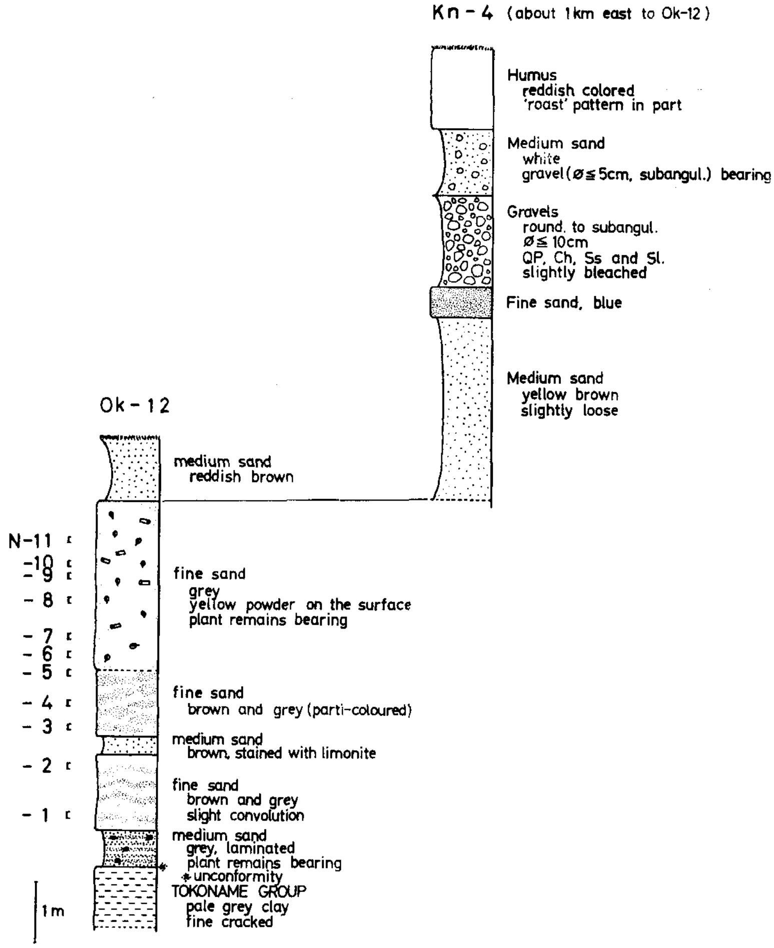


Fig. 20. Columnar sections of the Noma Formation.

distinct, but is rather ambiguous in many cases. Therefore, it is important to clarify what are the Higher Terrace Deposits. The criterion as to whether it is the Higher Terrace Deposits or not should depend upon the inclusion of bleached finer rubble. In other words, sediments which contain weathered decayed gravels must be correlated with the Ohtaniike and/or Kentoyama Formations.

In Nagoya and the suburban area, the Middle and Lower Terrace Deposits are represented by the Atsuta and Ohzone Formations, respectively.

2. *Subsurface Deposits beneath Nohbi Plain*

The sediments beneath Nohbi Plain are called, in decending order, the Nanyo, Nohbi, First Gravel (G1), Atsuta, Second Gravel (G2), Ama, Third Gravel (G3), and

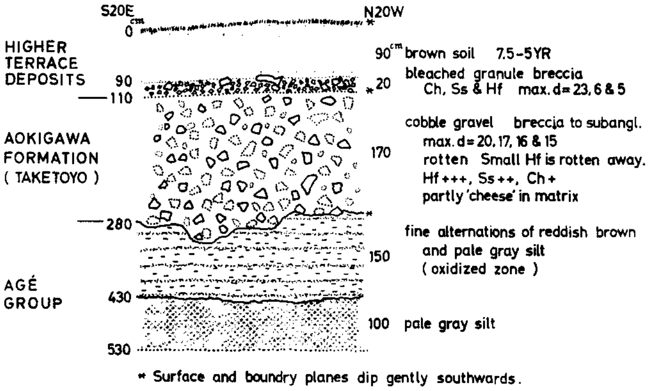


Fig. 21. Sketch showing the Higher Terrace Deposits above the Aokigawa Formation at the west of Kobayashicho, Yokkaichi City.

Infra-Ama* Formations, and the Tokai Group in the foundation (KUWAHARA, 1975; NOBI PLAIN QUATERNARY RESEARCH GROUP, 1977).

The Ama and Infra-Ama Formations are correlatives of the Karayama and/or Yagoto Formations. Generally, these are composed of alternations of muddy and gravelly sediments, and the total thickness is about 100 m in Tobishima, west of Nagoya Harbour, and about 200 m in the Nagashima bore hole. The Infra-Ama Formation is terrestrial, while the Ama Formation intercalates two horizons of marine facies which contain marine fossils of diatom, foraminifer and mollusk.

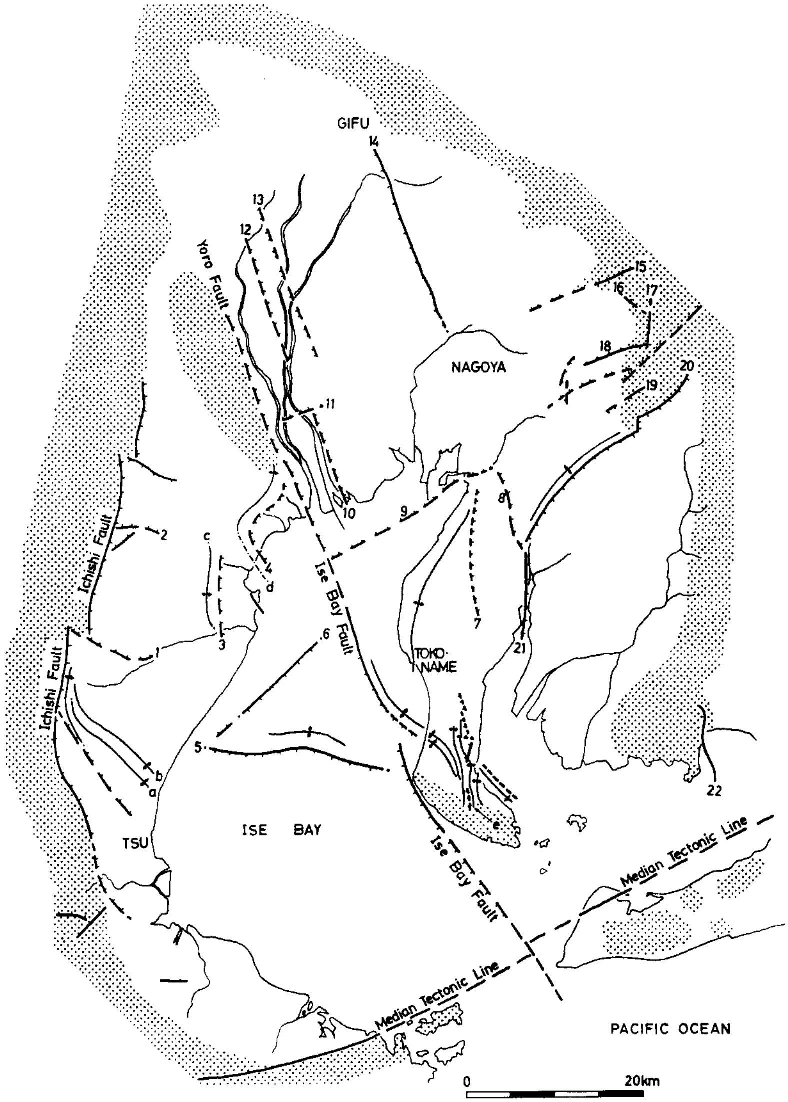
The Atsuta Formation is subdivided into the upper and lower parts. Marine clay constitutes the upper half of the lower part, while the upper part is made of sand and gravel. Pumice grains are also contained. The thickness is more than 60 m. The First Gravel Formation is correlated with the Lower Terrace Deposits in land area.

III. Geologic Structures

A. Structural Outline

The eastern part of the Inner Belt of Southwest Japan is divided into three neotectonic provinces, namely, the Chubu, Kinki and Chugoku Blocks, which are bordered by active faults. Boundary between the Kinki and Chugoku Blocks is represented by the fault zone which connects the Osaka and Tsuruga Bays including the Hanaore Fault, fault system of the Rokko area and so on. The Yanagase and

* The "Post-Yagoto Stage" and "Yagoto Stage" Formations have been used, but these names are apt to bring some confusions. Therefore, the author uses here the term of "Infra-Ama" Formation.



dotted parts : areas where the basement rocks are exposed (including the Miocene)

1 : Oota Fault 2 : Komono F. 3 : Yokkaichi F. 4 : Kuwana F. 5 : Shirako-Noma F. 6 : Suzuka-oki F.
7 : Nawa-Kagiya F. 8 : Oobu-Ootaka F. 9 : Tenpaku-kako F. 10 : Kisozaki F. 11 : Yatomi F. 12 : Oogaki-Imao F.
13 : Ooyabu-Tsushima F. 14 : Gifu-Ichinomiya F. 15 : Kasahara F. 16 : Shinano F. 17 : Akazu F. 18 : Hatayama F.
19 : Sasahara F. 20 : Sanage-Sakaigawa F. 21 : Kinuura F. 22 : Fukouzu F.

a : Shitomo Syncline b : Ohmitsu Anticline c : Yokkaichi A. d : Kuwana A. e : Kouwa A.

Fig. 22. Tectonic framework in and around the Ise Bay (KUWAHARA *et al.*, 1972, slightly modified).

Yoro-Ise Bay Faults separate the Kinki Block from the Chubu Block. The boundary between the Chubu and Kinki Blocks is also the most coarctate zone in Honshu Island (Figs. 1 and 2). In lay-out, the Kinki Block forms a triangular shape enclosed with the Tsuruga, Osaka and Ise Bays, and is called "Kinki Triangle" (HUZITA, 1962). This block is characterized by the arrangement of ellipsoidal basins bordered by narrow moutain ranges running meridionally.

The Chubu Block is called "Chubu Tilting Block" (KUWAHARA, 1968). This is westward tilting block with active faults of NW–SE trend such as the Atera and Neodani.

Depression of the Ise Bay and the surrounding area was a part of the Setouchi Depression during the Pliocene and early Pleistocene periods, and was also the territory of Lake Tokai in that time. The dpression has been situated in the southern boundary zone between the Chubu and Kinki Blocks since the early Pleistocene.

As mentioned above, the Yoro-Ise Bay Fault divides the depression into two parts (Fig. 22), the eastern half of which belongs to the Chubu Block and the western half to the Kinki Block. The western margin of the depression is bounded by the Ichishi Fault, and the southern boundary is limited by the Median Tectonic Line.

In the western half, the Tokai Group forms a basin structure with the center in the Komono area, west of Yokkaichi. On the other hand, the eastern half is subdivided further into two portions. The northern portion is called "Nohbi Tilting Block" (MATSUZAWA and KUWAHARA, 1964; MATSUZAWA, 1968), in which the Tokai Group dips gently westwards. The southern portion is the Sanage-Hekikai Basin, and the Sanage-Chita upheaving belt separates the southern portion from the north.

The Chita Peninsula is situated in the southwestern corner of the Chubu Block. The Ise Bay Fault (KUWAHARA, 1969; CHUJO and SUDA, 1971; KUWAHARA *et al.*, 1972) can be traced toward the SSE from the exit of River Nagara. Near the base of the peninsula, two linear valleys elongate from Handa to Kagiya and from Ohbu to Ohtaka, and such topography is thought to be a result of faulting. These faults are called "Nawa-Kagiya" and "Ohbu-Ohtaka Tectonic Lines", respectively (MATSUZAWA and UEMURA, 1957).

Fig. 23. Structural map of the southern part of the Chita Peninsula and the surrounding area (MAKINOUCHI, 1976).

The geologic structure of the Morozaki Group is followed after TERASHIMA (1965 MS), and those of the Ise and Chita Bays are followed after CHUJO and TAKADA (1970) and CHUJO and SUDA (1971).

Horizontal plain is situated at the level of about 20 m a.s.l.

1; strike and dip, 2; folding axis, 3; fault, 4; trace of volcanic ash layer, 5; unconformity

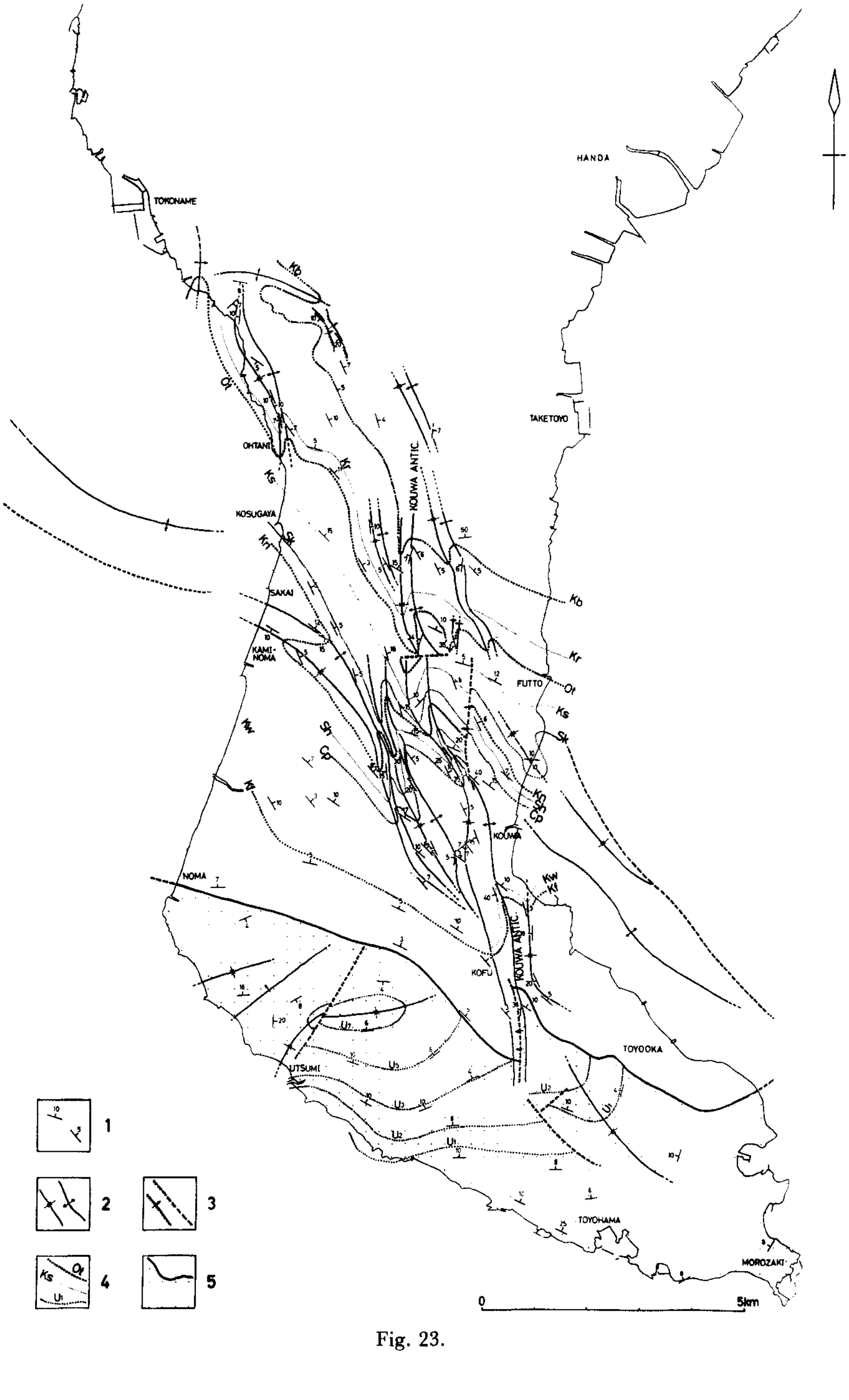

HANDA
TOKONAME
TAKETOYO
OHTANI
KOSUGAYA
SAKAI
KAMI-NOMA
FUTTO
KOUWA
NOMA
KOFU
UTSUMI
TOYOOKA
TOYOHAMA
MOROZAKI
KOUWA ANTIC.
KOUWA ANTIC.
1
2
3
4
5
0
5km

Fig. 23.

B. Geologic Structures of the Southern Part of the Chita Peninsula

In this area, the Tokoname (Tokai) Group dips gently northeastwards with strike of NW–SE trend (Fig. 23). In the case of the Taketoyo Formation, the strike is shifted slightly northwards, and the dip becomes more gentle, although the structure, as a whole, is concordant with that of the Tokoname Group.

The Kouwa Anticline (MAKINOUCHI, 1975a) is the most distinct structure in this area. The Morozaki and Tokoname Groups and the Taketoyo Formation are subject to the folding deformation. The anticline shows asymmetrical shape with steep (30°—70°) west wing and gentle (10°—20°) east wing. On the other hand, anticlines (or warpings) in the northern part of the peninsula (ITOIGAWA, 1971) reveal the inverse figure compared with those of the southern part.

A reverse fault trending meridionally exists in the west of Futto. Reverse faults are also observed in the northwest of Hibara (Fig. 27).

Recently, geologic structures below the Ise and Chita Bays have been clarified considerably by means of continuous seismic profilings and gravitational surveys (CHUJO and TAKADA, 1970; CHUJO and SUDA, 1971, 1972). These data indicate that geologic structures below the sea-floor around the peninsula are continuous with those of hilly land in the peninsula (MAKINOUCHI, 1976). However, these features do not accord with general trend of the Morozaki Group and the present coastal lines (Fig. 23).

The Morozaki Group generally shows latitudinal trend in structure. General trend of the Tokoname Group is NW–SE direction. And, the Taketoyo Formation has a general trend of NNW–SSE direction. Further, the present coastal lines of the peninsula extend nearly meridionally. It is very interesting that the general trends of those geologic structures have shifted clockwise, apparently, from older to younger.

C. Difference in the Mode of Tectonic Movements

With regard to the tectonic development of the Chita Peninsula and the surrounding area, it is very fruitful to discuss the sequence of tectonic movements. For this purpose, it is necessary to analyze structure of each geologic series, and to examine the meanings of those unconformities.

1. *Unconformities between the Tokoname Group and Taketoyo Formation, and between the Taketoyo Formation and Higher Terrace Deposits*

By comparing lithology, grade of compaction and distribution pattern, some distinctions can be clarified between the Tokoname Group and the Taketoyo Formation.

i) Gravel composition of the Taketoyo Formation is clearly different from that of the Tokoname Group (Figs. 5 and 6 in MAKINOUCHI, 1975b).

ii) Such fine-grained sediments of the Taketoyo Formation as clay, silt and fine sand are more loosely compacted than those of the Tokoname Group.

iii) The Taketoyo Formation rests on higher and higher horizons of the Tokoname Group toward the north (Fig. 7 in MAKINOUCHI, 1975b).

Based on these facts, the conclusion of unconformity is drawn. Actually, clino-unconformity is observed in several outcrops.

In the second, difference between the Taketoyo Formation and the Higher Terrace Deposits (Fuki Formation) is clarified as follows.

The Higher Terrace Deposits are composed mostly of fine-grained rubble of bleached chert without decayed gravels, while the Taketoyo Formation is made of not only round gravels of chert but also round gravels of decayed quartz-porphyry (Figs. 5, 6 and 8 in MAKINOUCHI, 1975b). Such difference allows us to suppose a distinct change between both sedimentary environments. Therefore, it is expected that the relationship is unconformable.

However, the author has thought that time interval between depositions of both sediments is not so long, because the sediments making the Higher Terrace seem to be derived mostly from the Taketoyo Formation.

When the Taketoyo Formation had grown into hilly land, chert gravels were bleached and fractured into finer pieces of rubble, and other less durable gravels decayed, owing to weathering. These weathered materials were derived as terrace deposits, and rested as veneer on the hilly Taketoyo Formation. This is the reason why the Higher Terrace Deposits are made mostly of bleached chert rubbles.

2. *Change of the Mode of Tectonic Movements*

In the outcrop of Ft–30 being situated in the immediate south of the triangulation station 81.9 m a.s.l., 3 km west of Fuki, we can observe the clino-unconformity as shown in Fig. 24. In this outcrop, a tectonic movement taken place before and during deposition of the Taketoyo Formation is distinguishable from that which occurred after the deposition.

On the Kouwa Anticline, such outcrop (Fk–6) as shown in Fig. 25 has once been exposed at 0.6 km northeast of the triangulation station stated above. In this outcrop, a movement preceding deposition of the Taketoyo Formation can be dis-

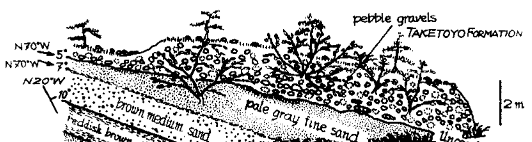


Fig. 24. Unconformity between the Taketoyo Formation and the Tokoname Group at Ft–30, just south at the triangulation station 81.9 m a.s.l., 3 km west of Fuki (MAKINOUCHI, 1976).

tinguished from the folding which forms the Kouwa Anticline. Accordingly, it is concluded that the severe folding has occurred after the deposition of the Taketoyo Formation. Moreover, the Taketoyo Formation dips more steeply in the west wing of an anticline, as shown in Fig. 26. This folding indicates also severe deformation after the deposition.

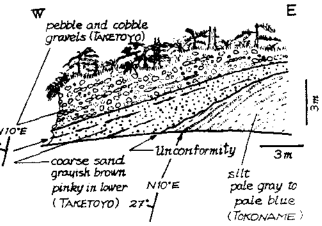


Fig. 25. Taketoyo Formation at the west wing of the Kouwa Anticline (Makinouchi, 1976).

This outcrop (Fk-6) is situated at 0.6 km northeast of the triangulation station 81.9 m a.s.l.

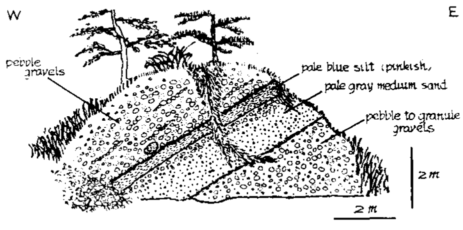


Fig. 26. Steep dip of the Taketoyo Formation at the west wing on an anticline (strike; N20°W, dip; 35°W) (Makinouchi, 1976).

This outcrop (Ft-22) is situated at about 1.5 km west of Futto.

In hills of Fuki and Taketoyo, the Taketoyo Formation has strikes of N 10°—20° W and dips of 5° E. In many cases, the underlying Tokoname Group below the Taketoyo Formation shows strikes of N 20°—30° W and dips of 5°—10° NE (Fig. 28). Accordingly, the Tokoname Group dips more steeply than the Taketoyo Formation, and structural trend of the Taketoyo Formation intersects obliquely that of the Tokoname Group. When the Taketoyo Formation is restored to horizontal state, the bedding plane of the Tokoname Group is brought into nearly horizontal or dips of 5° NE with strikes of N 20°—56° W (Table 2). Accordingly, structural trend of the folding before and during deposition of the Taketoyo Formation is considered to be nearly NW–SE in direction, and that after the deposition is NNW–SSE trend.

Based on the above discussions, two phases of folding deformation can be detected, namely, the older folding before deposition of the Taketoyo Formation and the

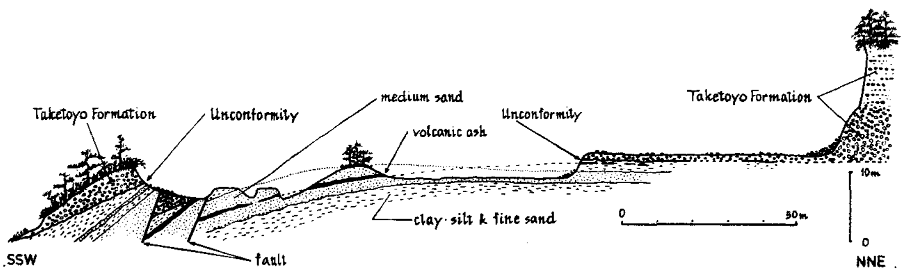


Fig. 27. Geologic profile of Hb-9, about 1 km northwest of Hibara (Makinouchi, 1976).

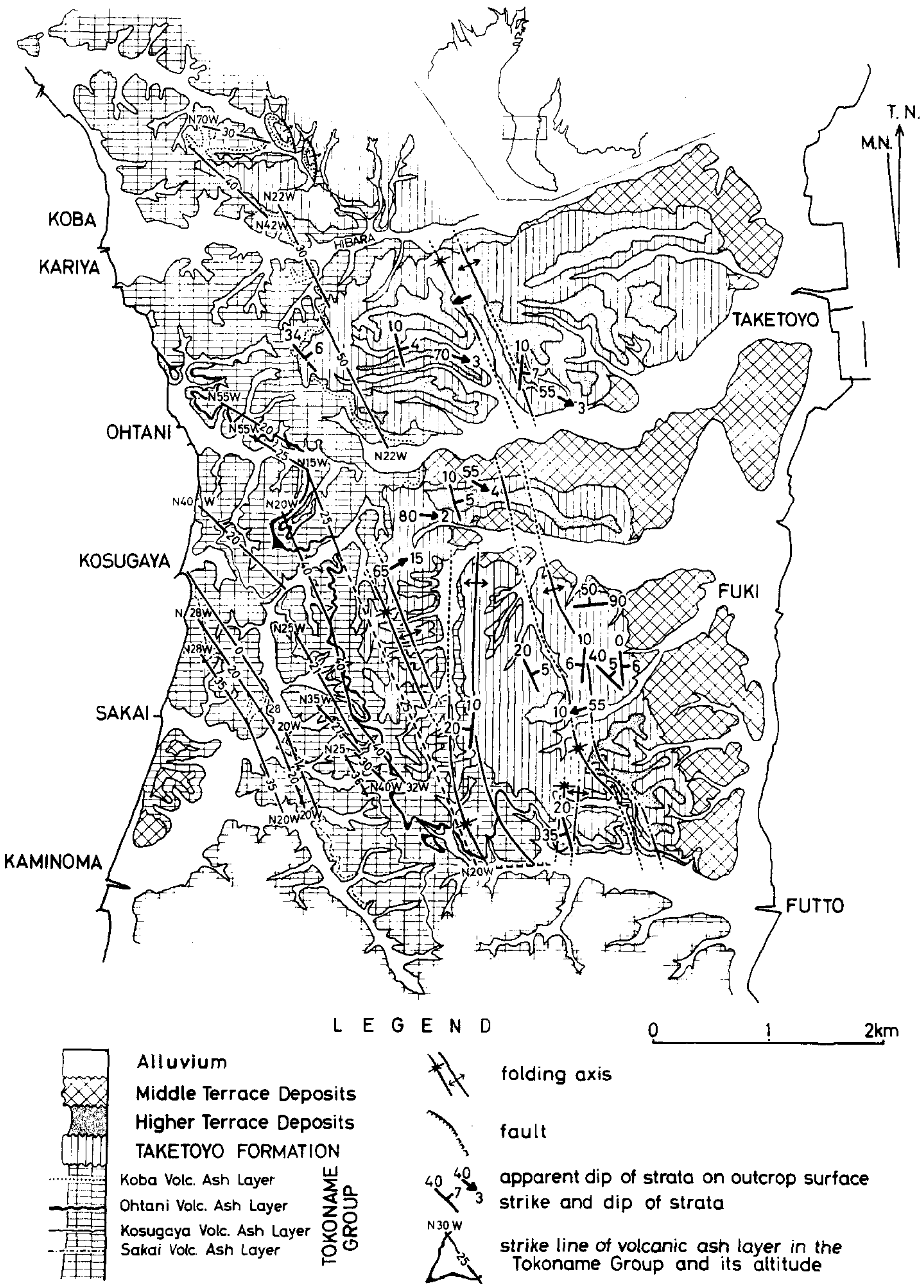


Fig. 28. Geologic map showing the difference of structural trend between the Tokoname Group and the Taketoyo Formation (MAKINOUCHI, 1976).

Table 2. Strike and dip of the Tokoname Group when restored the Taketoyo Formation to horizontal (MAKINOUCHI, 1976).

STRIKE & DIP OF THE TAKETOYO FORMATION	STRIKE & DIP OF THE TOKONAME GROUP	STRIKE & DIP OF THE TOKONAME GROUP when the Taketoyo Formation is restored to the horizontal state
N 10° W, 5° E	N 20° W, 5° E	N 56° E, 1° NW (nearly horizontal)
〃	N 20° W, 10° E	N 32° W, 5° NE
〃	N 30° W, 5° E	N 50° E, 2° NW (nearly horizontal)
〃	N 30° W, 10° E	N 56° W, 5° NE
N 20° W, 5° E	N 20° W, 5° E	horizontal
〃	N 20° W, 10° E	N 20° W, 5° E
〃	N 30° W, 5° E	N 83° W, 1° N (nearly horizontal)
〃	N 30° W, 10° E	N 40° W, 5° NE

younger one after the deposition. The former is characterized by gentle folding with NW–SE trend, and the latter is represented by severe folding with NNW–SSE trend. It is thought that the latter movement is responsible for major geologic structures in the southern part of the peninsula.

Furthermore, a geological section as shown in Fig. 27 is observed in the northwest of Hibara. In this section, the folded or warped Taketoyo Formation is cut by reverse faults, which indicate that the Tokoname Group has thrust up against the Taketoyo Formation.

In Taketoyo hill, the top surface of the Higher Terrace Deposits have altitude discontinuity with about 15 m in both sides of folding axis of the Taketoyo Formation, higher in the east side and lower in the west side (Fig. 16). And, altitudes of the

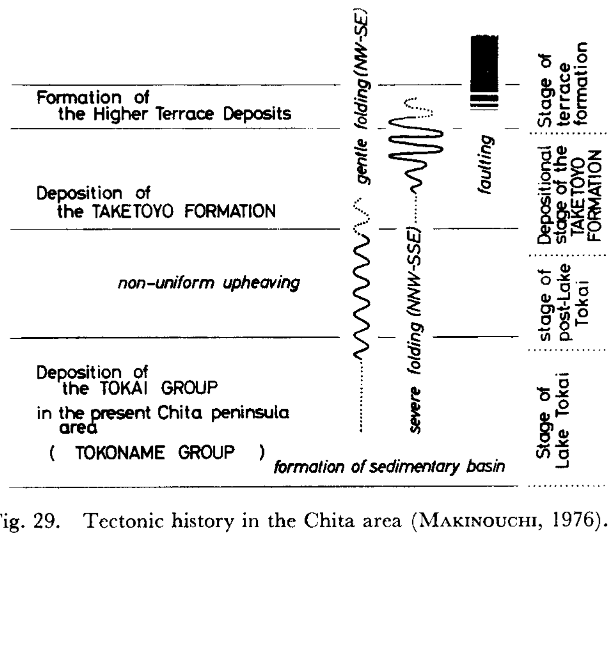


Fig. 29. Tectonic history in the Chita area (MAKINOUCHI, 1976).

Middle Terrace Plains are 30–40, 30–40 and 15–20 meters in the Noma (west coast), Kouwa and Fuki-Taketoyo (east coast) areas, respectively. This fact shows that topographic surfaces have intimate relations with structures of the underlying formations, namely, higher plain to structural high area and lower plain to structural low area. Such altitude discontinuity of terrace plain seems to be caused by faulting.

From the above descriptions, it is concluded that faulting movements have followed after the severe folding.

Based on the discussions mentioned above, modes of tectonic movements and their geological stages in the southern part of the peninsula are summarized in Fig. 29.

IV. Unconformities between the Tokai Group and the Correlatives of the Taketoyo Formation

1. *Unconformity between the Kentoyama Formation and the Agĕ Group*

ARAKI (1953) first settled the Kentoyama Formation to the uppermost part of the Kagei (Agĕ) Group. TAKEHARA (1955, 1968) thought the relationship to be unconformable, and KIMURA and TAKEHARA (1969) ascertained the unconformity, based on the fact that a volcanic ash layer in the Agĕ Group is cut by the Kentoyama Formation. NISHIYAMA *et al.* (1975) have mentioned that the relationship is represented by parallel-unconformity in most localities.

In hills northwest of Tsu, the Kentoyama Formation inclines gently toward the southeast, while the underlying Agĕ Group dips to the northeast (Fig. 30). Therefore, it is acceptable that the relationship is clino-unconformity. Actually, NISHIYAMA *et al.* (1975) has described the clino-unconformity at Ohtani of Tsu City.

2. *Unconformity between the Rengeji Formation and the Agĕ Group*

KATO (1957) stated that the Rengeji Formation covered the folded Kuwana (Agĕ) Group with unconformity, but had similar structure to that of the Agĕ Group. He also mentioned that the top surface of the Rengeji Formation had the highest altitude near the axis of anticline, and lowered toward both sides. And, he concluded that the Rengeji Formation was deformed by similar movement to that forming geologic structure of the Agĕ Group.

In Karegawa, northwest of Kuwana, the author and his co-workers have also observed such clino-unconformity (Fig. 31). Accordingly, two phases of deformation can be recognized by different inclinations of both sediments. And some reverse faultings have occurred subsequent to the folding.

3. *Unconformity between the Karayama and Yagoto Formations and the Seto Group*

According to MATSUZAWA *et al.* (1960), the unconformity between the Seto Group and the Karayama Formation can be clearly observed in many localities. Though the structural difference is not always clear, in geologic profiles, the Karayama

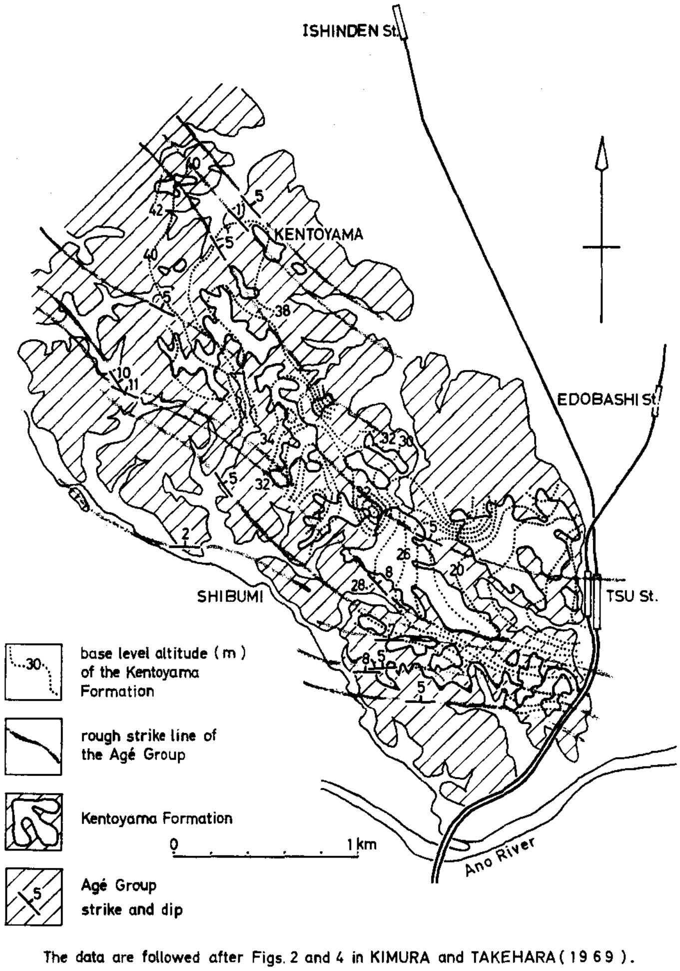


Fig. 30. Geologic map showing the relation of clino-unconformity between the Agĕ Group and the Kentoyama Formation.

Formation scrapes off gently dipping Seto Group with a low angle (MATSUZAWA and KUWAHARA, 1964). The Yagoto Formation covers not only the Karayama Formation but also the Seto Group with unconformity.

4. *Evaluation of the Unconformity between the Tokai Group and the Taketoyo and its Correlative Formations*

In the previous discussions, the relationship between the Tokai Group and the Taketoyo and its corresponding Formations can be concluded as clino-unconformity in land areas. In the next, it is discussed whether this clino-unconformity is traceable into subsurface of the Ise Bay and Nohbi Plain, or not.

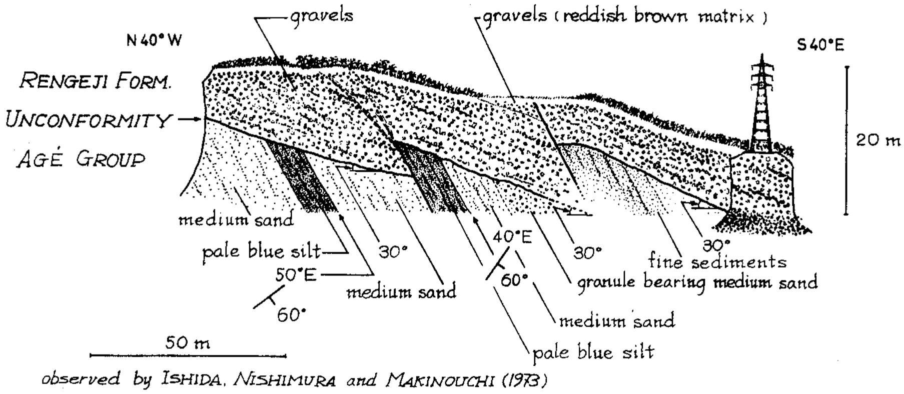


Fig. 31. Sketch showing clino-unconformity between the Agĕ Group and the Rengeji Formation.

This cliff is situated in about 1 km north of Karegawa, Kuwana City.

Based on gravitational surveys and continuous seismic profilings (CHUJO and SUDA, 1971, 1972; KUWAHARA *et al.*, 1972), the corresponding sediments of the Taketoyo Formation seems to be deficient in the Ise Bay.

On the other hand, thick sediments correlated with the Taketoyo Formation (Ama and Infra-Ama Formations) are laid in the subsurface of the western part of Nohbi Plain and probably beneath the northern recess of the Ise Bay.

As it is known that the basal parts of the Ama and Infra-Ama Formations are composed of gravelly sediments (KUWAHARA, 1968, 1971a; NOBI PLAIN QUATERNARY RESEARCH GROUP, 1977), the initial sedimentary environment is regarded as a terrestrial and/or denuded area. And, it is probable that these sediments directly cover the middle part of the Tokai Group, eroding the upper part of the group.

Based on the above discussions, relationship between the Tokai Group and the overlying formations also seems to be unconformable in the Ise Bay and the western part of Nohbi Plain.

Accordingly, the unconformity between the Tokai Group and the Taketoyo and its corresponding Formations is recognized not only in the surrounding area but also in the center of the Ise Bay depression.

V. Chita Movements – A New Proposal

As already stated, the relationship between the Tokai Group and the Taketoyo and its corresponding Formations is (clino-)unconformity in every place, although both of the sediments are subject to folding or tilting deformation, and constitute together hilly lands around the Ise Bay. The clino-unconformity evidences the process that the Tokai Group underwent upheaving and folding or tilting, and then the younger sediments were formed on denuded surfaces of the Tokai Group. Based on this account, the tectonic movements which caused the Tokai Group to upheave and deform can be recognized before deposition of the Taketoyo and the correlative Formations over the entire areas in and around the Ise Bay. So, it is necessary to compare both constituents of the hill.

A. Differences in Sediments and Sedimentary Basins between the Tokai Group and the Taketoyo and Corresponding Formations and in Tectonic Movements

1. *Lithological Difference*

Generally speaking, lithology of the underlying Tokoname Group is represented by limnic alternations of sand and mud beds (Fig. 7). On the other hand, the covering Taketoyo Formation is characterized by alternations of gravel and mud beds (Fig. 15), with intercalations of marine facies. Therefore, the lithology of both sedimentary sequences is certainly different from each other. Concerning thickness, the lower sediment is thicker (about 550 m), and the upper is thinner (about 30 m).

In the west coast of the Ise Bay, the underlying Agĕ Group is composed mainly of alternations of sand and mud beds, although gravel beds are intercalated in the middle part (Fig. 2 in AKAMINE *et al.*, 1951; Fig. 1 in KATO, 1957 and Fig. 2 in YOKOYAMA, 1971). In contrast with the Agĕ Group, the covering Kentoyama, Ohtaniike, Rengeji and other Formations are made of gravels and/or alternations of gravel and mud beds (Fig. 3 in ARAKI and KITAMURA, 1971 and Fig. 17). Lithologically, the upper sediments are considerably different from the lower. The lower sediment is several hundreds of meters thick in each area, but the upper ones are only a few tens of meters in thickness.

In Nagoya and suburban areas, the lithology of the underlying Yadagawa Formation is characterized by alternating sand and mud beds, although sand beds are commonly coarser with gravels (Fig. 4 in MORI, 1971b). The covering Karayama and Yagoto Formations consist of alternations of gravel and mud beds (Fig. 17). Lithologically speaking, it can also be said that the upper sediments are significantly different from the lower. The lower sediment exceeds 200 m in thickness and the upper is about 60 m in total.

In the subsurface of Nohbi Plain, the underlying Tokai Group is chiefly made of alternations of sands and muds (Fig. 4 in KUWAHARA, 1968; Fig. 2 in KUWAHARA, 1971a; Fig. 9 in NOBI PLAIN QUATERNARY RESEARCH GROUP, 1977). In contrast with the Tokai Group, the overlying Ama and Infra-Ama Formations consist of alternations of muddy and gravelly sediments. Furthermore, mud beds of the Ama Formation indicate marine facies. Lithology of the lower and upper sediments also differs from each other. The lower sediment attains to 1,000 m thick, while the upper ones are 100 to 200 m.

2. *Difference in Sedimentary Basin*

As the alternation shows very irregular features, it is supposed that the Tokoname Group was deposited in an unstable water regime of Lake Tokai. So, in the Lake Tokai sedimentary basin, it is probable that the Chita area had occupied a situation where is not the central part, and wherein coarser materials are not supplied.

The Yadagawa Formation of the Seto Group is composed of coarser sediments than the Tokoname Group. Therefore, the eastern margin of Nohbi Plain should be situated in a more peripheral area of the lake.

On the other hand, the Agĕ Group has many intercalations of thick mud beds in various horizons, and is thicker than the corresponding horizon of the Tokoname Group. So, the Ise district is supposed to have maintained the main part of the lake. It is a future problem to discuss severely the probability that the Tokai Group was formed either in a single continuous basin or in several separate basins.

Among the upper sediments, the Ama and Infra-Ama Formations reach a thickness of 100 m, respectively, while other formations are only a few tens of meters thick. Accordingly the main depositional part of the basin was located in the area where the Ama and Infra-Ama Formations were formed. But, the sedimentary basin might not be a single wide basin, because the intercalation of marine facies is limited in distribution. Probably, the basin was composed of several smaller basins, a few of which were connected with the Pacific Ocean.

Taking account of the above discussion, the size and shape of both sedimentary basins are illustrated in Fig. 32. The territory of Lake Tokai had covered the whole Ise Bay depression, although the expanse in each stage might vary somewhat in width.

On the other hand, basin territory of the upper sediments coincides mainly in the present depressions, namely, the Ise and Chita Bays and Nohbi and Okazaki Plains. The main part of subsidence must be restricted within Nohbi Plain and the northern recess of Ise Bay. In any case, it can be said that the basin territory of the upper sediments is confined within a smaller part of the earlier basin. Therefore, the basin territory of the upper sediments differs distinctly from that of the lower sediments in its expanse.

In the next portion, structures of sedimentary bodies filling both sedimentary basins are discussed (Fig. 33).

As upper horizons of the Tokai Group tend to develop toward the north and/or west, the structure of sedimentary bodies can be termed "sedimentary imbricate structure". In contrast with the lower, the upper and younger Quaternary sediments, which are typically developed in the subsurface of Nohbi Plain, show a superposing structure of asymmetrical lenticular sedimentary bodies.

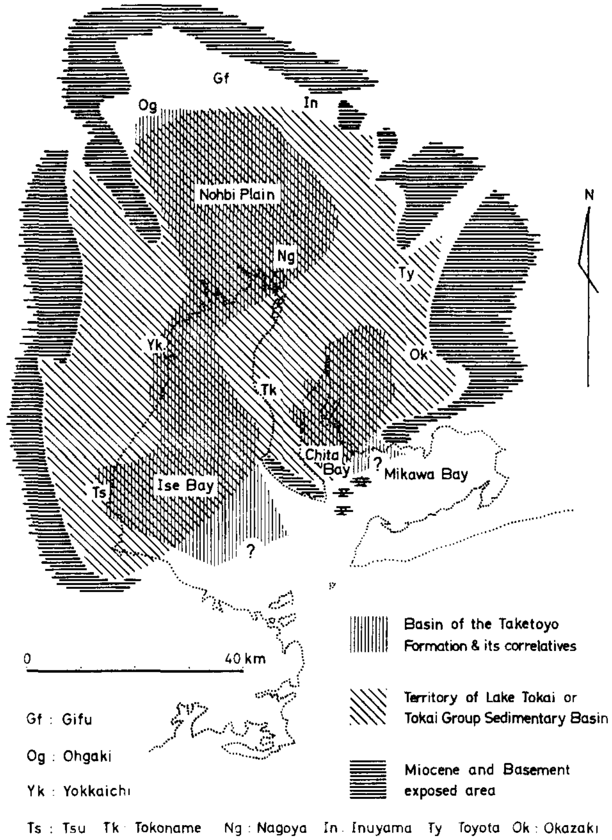


Fig. 32. Generalized map showing the territories of the Lake Tokai and the younger (Quaternary) sedimentary basins.

3. *Geological Age of the Boundary between the Lower and Upper Sediments*

In this section, geological age bounding the lower and upper sediments is probed (Fig. 34).

Firstly, the younger limit of the lower sediments is discussed. Among the sediments of Lake Tokai's stagnant water, the uppermost is the Oh'izumi Formation of the Agĕ Group. Based on tephrostratigraphy (YOKOYAMA, 1969; ISHIDA *et al.*, 1969), the Oh'izumi Formation has been correlated with the Lowest and Lower (especially lower half) Osaka Group. The upper part of the Oh'izumi Formation has yielded fossil elephant, *Stegodon akashiensis*. In the Kobiwako and Osaka Groups, this elephant fossil ranges from the Kaigake (ISHIDA *et al.*, 1969) or Senriyama (KAMEI and SETOGUCHI, 1970) to Yellow Volcanic Ash Layers. Accordingly, the Oh'izumi Formation is not higher than the horizon of Yellow Volcanic Ash Layer

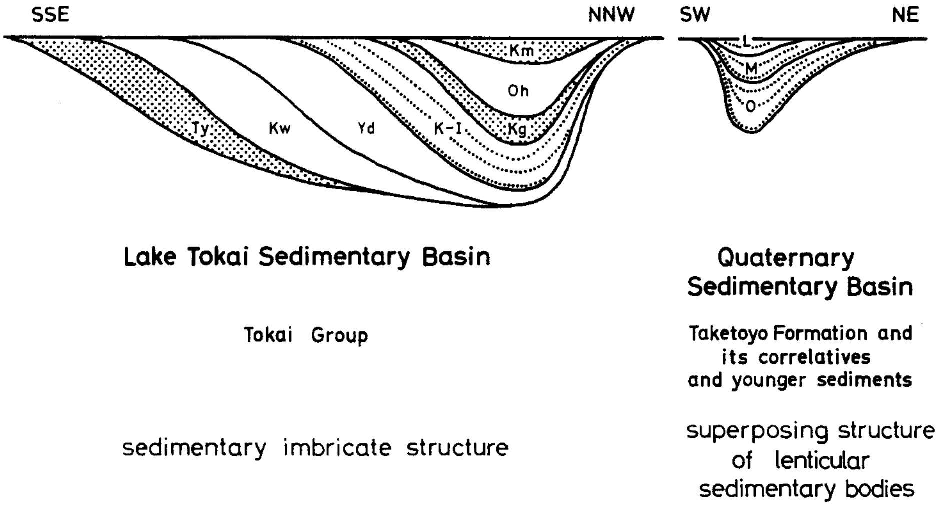
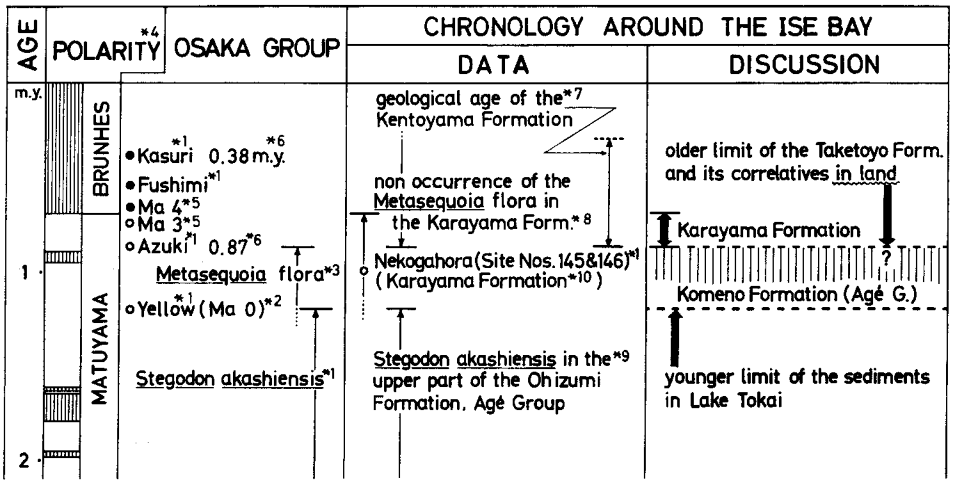


Fig. 33. Generalized structures of sedimentary bodies within sedimentary basins.



*References

1 ISHIDA et al. (1969)
2 ISHIDA (1970)
3 ITIHARA (1960)
4 McELHINNY (1973)
5 NISHIDA and ISHIDA (1975)
6 NISHIMURA and SASAJIMA (1970)
7 NISHIYAMA et al. (1975)
8 SOHMA (1958)
9 YOKOYAMA (1967)
10 YOKOYAMA (1977, personal communication) and NOBI PLAIN QUAT. RES. GROUP (1977)

Fig. 34. Geochronological chart of the Tokai Group and the correlatives of the Taketoyo Formation.

(Ma 0). Therefore, the sediments of stagnant waters are not younger than the depositional age of Ma 0 horizon in the Osaka Group.

Secondly, the older limit of the upper sediments is discussed. Many investigators agree with the opinion that the Karayama Formation is the oldest among the upper sediments in land areas. The Karayama Formation indicates reverse polarity in paleomagnetic measurement (ISHIDA *et al.*, 1969; NOBI PLAIN QUATERNARY RESEARCH GROUP, 1977). This fact suggests that the Karayama Formation was deposited during the Matuyama Reversed Epoch.

On the other hand, pollen analysis of the Karayama Formation (SOHMA, 1958) suggests the absence of components of the so-called *Metasequoia* Flora, although the Kentoyama and Infra-Ama Formations yield *Liquidambar* pollen (NISHIYAMA *et al.*, 1975; NOBI PLAIN QUATERNARY RESEARCH GROUP, 1977). The *Metasequoia* Flora has occurred in horizons lower than the Azuki Volcanic Ash Layer (within Ma 3) in the Osaka Group (ITIHARA, 1960). Accordingly, the Karayama Formation is assumed to be not older than depositional age of the horizon of the Azuki Volcanic Ash Layer, and to be not younger than 0.69 m.y. B.P.

Therefore, the upper sediments in land are not older than the age of the Azuki Volcanic Ash Layer. However, it is probable that horizons lower than the Azuki Volcanic Ash Layer are buried below Nohbi Plain.

Based on the above discussions, a significant time interval is intervened between depositions of the upper and lower sediments.

4. *Difference in Tectonic Movement*

As shown in Fig. 29, the tectonic movement is considered to have intensified since the depositional stage of the Taketoyo Formation in Chita. The same mode of tectonism has been observed in other areas (KUWAHARA, 1968).

Accordingly, the tectonic movement is inferred to have intensified since the stage of the upper sediments over the whole Ise Bay depression. It is probable that the severe tectonic movements of the younger stage is caused by fault block-movement, and warping made the movement of the older stage gentle.

5. *Conclusion*

Based on the previous discussions, differences between the upper and lower constituents of the hill are summarized in Table 3. As shown in this table, it is concluded that the upper and lower sediments differ considerably from each other from a geological point of view.

Hereupon, two phases of tectonic movements can be distinguished, namely, the "older movement" which caused the Tokai Group to construct and deform, and the "younger movement" which caused the Taketoyo and the correlative Formations to deposit and deform.

Table 3. Comparison of various characters between the Tokai Group and the Taketoyo and correlative Formations.

	TOKAI GROUP	TAKETOYO FORMATION AND ITS CORRELATIVES
LITHOLOGY	Alternations of sand bed and mud bed (limnic facies)	Alternations of sand and gravel bed and mud bed (marine facies intercalation)
THICKNESS (m)	several hundreds (10^2)	few decades (hill) to a hundred (subsurface below the Nohbi Plain) (10^2)
DURATION and GEOLOGICAL AGE	1 m.y. mainly Pliocene	10^{-1} m.y. Pleistocene
RATE OF SEDIMENTATION	$<$	
SEDIMENTARY BASIN	vast expanse sedimentary imbricated structure	a part of former basin piling structure of lenticular sedimentary bodies
TECTONIC MOVEMENT	gentle warping	severe fault block movement

B. Chita Movements

1. *Brief History of Studies on the Rokko and Sanage Movements*

The Rokko Movement was proposed by Ikebe (1956, 1957) to typify all crustal movements throughout the Pliocene and Pleistocene Periods in the Setouchi Depression. It is mainly characterized by fault-foldings with thrusting and upwarping. Itihara (1960) proposed the conception of "climax of the Rokko Movement". Huzita (1962) distinguished two types of structural trend, namely, the older latitudinal trend and the younger meridional trend. Consequently, Ikebe and Huzita (1966) re-defined the Rokko Movement only to younger crustal movements of the almost meridional trend. Itihara (1966) proposed classifying the Quaternary sediments into two types, sediments which have the fill top surface (terrace deposits) and those without fill top surface (constituents of hill).

After Ikebe and Huzita's proposal, the term of Rokko Movements has been used as the re-defined term. Huzita and his co-workers have greatly advanced investigations on the cause and development of the Rokko Movement (Huzita, 1968;

HUZITA *et al.*, 1971, 1973; HUZITA and KISHIMOTO, 1972; HUZITA, 1976; and so on).

And KUWAHARA (1968) proposed "Sanage Movements" for the tectonic movement around the Ise Bay. This is characterized mainly by mass blocking due to thrusting, and is contemporaneous with the Rokko Movement.

In this currency, the Rokko and Sanage Movements have come to be recognized as tectonic movements occurring in the Quaternary Period, namely the Quaternary Movement.

Therefore, it is necessary to define another tectonic movement which caused the Tokai Group to deposit and deform in the Pliocene time. The author introduces here the Pliocene tectonic movements, Chita Movements.

2. **Chita Movements** (*newly defined term*)

The Chita Movement is defined, in a strict sense, as the tectonic movement which caused the Tokoname Group to deposit, deform and dislocate during the sedimentary process, mainly of Pliocene age.

i) *Regime of the Movement*

Regime of the Movement is areas where the Tokoname Group was deposited. Strictly speaking, the regime is confined in the Chita Peninsula. However, as the Tokoname Group is a partial component of the Tokai Group, the regime may cover the Ise Bay and the surrounding area.

ii) *Geological Age of the Movement*

Duration of the Movement is designated as the Pliocene to former half of the early Pleistocene.

iii) *Mode of Tectonic Movement*

The Movement can be also defined as tectonic movements occurring throughout the evolutional process of Lake Tokai. So, the mode of tectonic movement is chiefly defined as the basin-forming movement of Lake Tokai.

Lake Tokai generated in the northern side of the Median Tectonic Line was stretched from the Tsu area to southern Chita in the embryonic stage. In the early stage, the depression was expanded further north, and the lake extended its territory into vast expanse. In the middle stage, the lake tended to retrench the territory. Moreover, the center of deposition migrated toward the north and west, being accompanied by subsequent swell of the lake floor. And, the lake began to dry up from the southern and eastern parts by non-uniform upheaving and gentle folding in the late stage. In the last stage, the lake was left in the western part of Nohbi Plain and in the area between Suzuka and Yoro Ranges (MAKINOUCHI, 1976).

Based upon the above mentionings, the mode of tectonic movement is characterized by down-warping. The sedimentary basin formed by the Movement occupied a vast expanse, although the velocity of subsidence was not so large. And, the center of subsidence (or deposition) tended to migrate toward the north and west. The migration of subsidence center and the gentle folding followed after the non-uniform upheaving (up-warping) from the south and east.

3. *Significance of the Movement*

Comparison of geological characteristics between the Chita and Quaternary Movements is summarized in Table 4. Based on differences displayed in this table, it becomes certain that the Chita Movement is another type of tectonic movement different from the Quaternary Movement.

Table 4. Comparison between the Chita Movement and the Rokko and Sanage Movements.

		Older Movement	Younger Movement
Intensity		*gentle*	*severe*
Mode of Movement		*warping*	*block movement*
Sedimentary Basin	water basin	*vast expanse*	*small expanse*
	velosity of subsidence	*slow*	*fast*
	depression	*not so deep*	*deep*
	center of subsidence	*mobile, directive shifting*	*fixed*
Geological Age		*mainly Pliocene*	*Pleistocene*
Topography		*low-relief*	*high-relief* *responsible for the present high-relief topography*
		"Chita Movements"	*Rokko Movements* *Sanage Movements*

The difference between both movements suggests a difference in stress condition acting in the eastern part of Southwest Japan.

About the stress field during the Quaternary Movement, many investigators have concluded the stable tectonic compression acting in horizontal and E–W trend, based upon analyses of earthquake mechanisms, horizontal displacement of triangulation and active faults (HUZITA, 1968, 1969; MATSUDA, 1969; HUZITA *et al.*, 1971, 1973; HUZITA and KISHIMOTO, 1972; HUZITA, 1976; and so on).

On the other hand, the stress field during the Chita Movement has not yet been noticed. However, the shift of structural trend in Chita gives a suggestion regarding the mode of stress condition (Fig. 35). Probably, the Chita Movement may be generated under other stress condition which is different from that of the Quaternary Movement, although more strict discussions will be required.

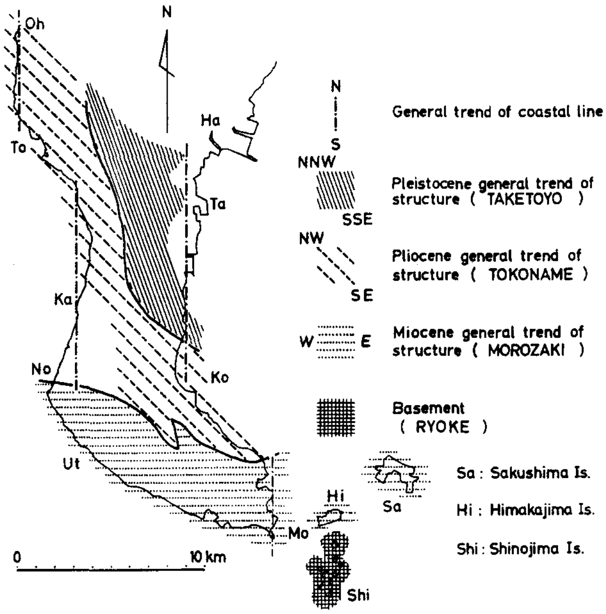


Fig. 35. Clockwise shift of structural trends in the southern part of the Chita Peninsula.

HUZITA (1968) has already drawn a compressive stress field with meridional trend.

C. Chita Movements in the Setouchi Geologic Province

In the Lake Biwa district, the Plio-Pleistocene Kobiwako Group is developed mainly in the southeastern and northwestern sides of the lake. According to YOKOYAMA (1969), in the southeastern side of the lake, the uppermost part of the group is composed of gravels (Yokaichi Formation), which are exposed in the nearest zone of the present lake basin. He correlated the group in the northwestern side of the lake with horizons above the Yokaichi Formation of the southeast. In Katata hill, HAYASHI (1973) ascertained YOKOYAMA's opinion, correcting the tephrostratigraphy.

This gravel bed is intervened in the middle horizon of the group, and divides finer sediments into two parts, the lower horizon in the south and the higher horizon in the north. In this sense, YOKOYAMA called "Middle Gravel" (the earliest Pleistocene in age). And, YOKOYAMA (1973) concluded that subsidence of the younger lake basin (present Lake Biwa) began to accelerate in the Middle Gravel Stage, and further, he stated that the Middle Gravel was sediments left during transition of lake basin from the south to the north.

It is understandable that there have existed two sedimentary basins, namely, the older one in the south, and the younger one in the north, which has lasted up to the present as Lake Biwa. Therefore, two phases of the basin-forming movement can be detected. The older basin-forming movement accumulated the Iga-Aburahi, Sayama and Gamo Formations, in ascending order. Among them, upper formation tends to be exposed in further north. This fact indicates the northward migration of the subsidence center. These formations are correlated approximately with the main part of the Tokai Group. Accordingly, the older basin-forming movement almost coincides with the category of Chita Movements.

In the Osaka Bay district, the Plio-Pleistocene Osaka Group is widely exposed. The Osaka Group is divided into three parts, the Lowest, Lower and Upper parts (ITIHARA and KAMEI, 1970). The Lower and Upper parts are characterized by cyclic alternations of marine and non-marine facies. But, the Lowest part displays non-marine facies.

As differences can be almost clearly recognized between the Lowest and the other parts in lithology, grade of compaction and sedimentary environment, the Lowest part is distinguished from the Osaka Group proper. And, it is probable that the sedimentary basin which deposited the Lowest part is different from that of the Osaka Group proper. So, the older basin-forming movement seems to have existed in the Osaka Bay district too, during the Pliocene to early Pleistocene.

Based on the above consideration, it can be concluded that the Chita Movement has emerged not only in the Lake Biwa district but also in the Osaka Bay district.

VI. Summary

1. The Chita Peninsula is composed of such geologic series as the Miocene Morozaki Group, the Pliocene Tokoname Group, the middle Pleistocene Taketoyo Formation and terrace deposits, and the Ryoke metamorphic and granitic rocks in the basement (Fig. 5).

2. The "porcelain clay deposits" are antecedent to the sediments of Lake Tokai. The Tokai Group is used as the general term for the fillings of Lake Tokai, and is subdivided into three, namely, the Agĕ Group in Ise, the Seto Group in Nagoya and the Tokoname Group in Chita. The Tokai Group is characterized by limnic alternations of sand and mud beds. The Tokai Group is the lower constituents of the hill. On the other hand, the Taketoyo, Kentoyama, Rengeji, Karayama, Yagoto and other Formations are characterized by alternations of mud and gravel beds intercalating marine facies in parts, and these formations are the upper constituents of the hill (Fig. 3).

3. In the southern Chita, the Tokoname Group and the Taketoyo Formation show geologic structure dipping northeastwards, in general (Fig. 23). Each structural trend has apparently shifted clockwise from latitudinal in the older to meridional in the younger (Fig. 35).

4. The Taketoyo Formation covers the Tokoname Group with clino-unconformity (Figs. 24, 25, 27 and 28). The boundary between the Taketoyo Formation and the Higher Terrace Deposits presents unconformable indication. History of the mode of tectonic movement is summarized in Fig. 29, namely, gentle folding with NW–SE trend before the deposition of the Taketoyo Formation, severe folding with NNW–SSE trend after the deposition, and faulting during formational stage of terrace deposits. The (clino-)unconformity between the Tokai Group and the correlatives of the Taketoyo Formation can be recognized everywhere in the Ise Bay district.

5. Differences between the Tokai Group and the Taketoyo and the correlative Formations are clearly recognized in lithology, rate of sedimentation, magnitude of sedimentary basin, geologic age, character of geologic structure, etc. (Table 3). Therefore, two different phases of the tectonic movement can be detected, the "older movement" and the "younger movement".

6. The **Chita Movement** is a newly proposed term for the "older movement". It is defined as the tectonic movement which caused the Tokai Group to deposit, deform and dislocate, mainly Pliocene in age. Regime of the Movement covers the Ise Bay and the surrounding area. Duration of the Movement is designated as the Pliocene to former half of the early Pleistocene. And, the mode of tectonic movement is characterized mainly by down-warping (Table 4).

7. It is suspected that the Chita Movement was generated under other stress condition which is different from the horizontal compressive stress field trending in latitudinal direction during the Rokko and Sanage Movements. Moreover, it is inferred that the Chita Movement had influence on the Lake Biwa and the Osaka Bay districts.

Acknowledgements

First, the author expresses his sincere thanks to Prof. T. KAMEI, Prof. K. NAKAZAWA and Dr. S. ISHIDA of Kyoto University, who gave constant instructions on field surveys, many discussions on the tectonic development of the Setouchi Province and leads on preparing this manuscript.

He must express his heartfelt appreciations to Prof. K. HUZITA of Osaka City University, Dr. J. ITOIGAWA of Nagoya University and Prof. T. KUWAHARA of Meijo University, who gave him kind and successive directions about field survey and useful suggestions on the neotectonics in Southwest Japan.

Many thanks are due to Mr. T. YOKOYAMA and Mr. Y. NAKAGAWA of Doshisha University, Mr. S. MORI of Nagoya University and Mr. T. NASU of Osaka City Museum of Natural History, who gave him useful suggestions and discussions on the Osaka, Kobiwako and Tokai Groups, on tectonic development of sedimentary basin and on fossil pollen, and they gave him kind encouragements.

Thanks are also due to Mr. M. HATA of Tokai City for his convenience to lodging in surveyed field.

Without these kind helps given by many persons mentioned above, the author could not complete this manuscript.

References

AKAMINE, H., HOSONO, M. and KUBO, K. (1951): Coal-bearing Tertiary in the Kameyama District, Mie Prefecture (in Japanese with English abstr.). *Misc. Rept. Res. Inst. Nat. Resour.*, Nos. 19–21, pp. 149–158.

ARAKI, Y. (1953): On the Cenzoic Erathem along the Ano River, Mie Prefecture (in Japanese with English abstr.). *Bull. Liberal Arts Dept., Mie Univ.*, No. 10, pp. 63–68.

ARAKI, Y. and KITAMURA, J. (1971): On the Kentoyama Formation in the Environs of Tsu City, Mie Prefecture (in Japanese with English abstr.). *Prof.* Heiichi TAKEHARA *Mem. Vol.*, pp. 27–33.

CHUJO, J. and TAKADA, Y. (1970): Geologic Studies of Chita Bay by the Continuous Seismic Profiling (in Japanese with English abstr.). *Bull. Geol. Surv. Japan*, **21**, pp. 187–218.

CHUJO, J. and SUDA, Y. (1971): Gravitational Study of Northern Ise Bay (in Japanese with English abstr.). *ibid.*, **22**, pp. 415–435.

CHUJO, J. and SUDA, Y. (1972): Gravitational Survey of Southern Ise Bay and Mikawa Bay (in Japanese with English abstr.). *ibid.*, **23**, pp. 573–594.

HAYASHI, T. (1973): The Kobiwako Group in the Katata Hills, Shiga Prefecture, Japan (in Japanese with English abstr.). *Jour. Geol. Soc. Japan*, **80**, pp. 261–276.

HUZITA, K. (1962): Tectonic Development of the Median Zone (Setouti) of Southwest Japan, since the Miocene, With special Reference to the characteristic Structure of Central Kinki Area. *Jour. Geosci., Osaka City Univ.*, **6**, Art. 4, pp. 103–144.

HUZITA, K. (1968): Rokko Movements and its Appearance — Intersecting Structural Patterns of Southwest Japan and Quaternary Crustal Movements — (in Japanese with English abstr.). *Quat. Res.* (*Daiyonki Kenkyu*), **7**, pp. 248–260.

HUZITA, K. (1969): Tectonic Development of Southwest Japan in the Quaternary Period. *Jour. Geosci., Osaka City Univ.*, **12**, Art. 5, pp. 53–70.

HUZITA, K., KASAMA, T., HIRANO, M., SHINODA, T. and TANAKA-YAMASHITA, M. (1971): Geology and Geomorphology of the Rokko Area, Kinki District, Japan, with Special Reference to Quaternary Tectonics. *ibid.*, **14**, Art. 4, pp. 71–124.

HUZITA, K. and KISHIMOTO, Y. (1972): Neotectonics and Seismicity in the Kinki Area (in Japanese). *Kagaku* (*Science*), **42**, pp. 422–430.

HUZITA, K., KISHIMOTO, Y. and SHIONO, K. (1973): Neotectonics and Seismicity in the Kinki Area, Southwest Japan. *Jour. Geosci., Osaka City Univ.*, **16**, Art. 6, pp. 93–124.

HUZITA, K. (1976): Nippon no Sanchi Keisei Ron (Consideration on Mountain-building in Japan) (in Japanese). *Mem. Vol. Celebration* Dr. Kinji IMANISHI's *70th Birthday* (*Mountains, Forests* and *Ecology*). **1**, pp. 85–140. Chuo-Koron-Sha, Tokyo.

HYDROGRAPHIC OFFICE (1965): Bathymetric Chart of the Adjacent Seas of Nippon (1/3,000,000).

IKEBE, N. (1956): Cenozoic Geohistory of Japan. *Proc. 8th Pacific Sci. Congr.*, **2**, pp. 446–456.

IKEBE, N. (1957): Cenozoic Sedimentary Basin in Japan, with Special Reference to the Miocene Sedimentary Basin (in Japanese). *Cenozoic Research*, Nos. 24–25, pp. 1–10.

IKEBE, N. and HUZITA, K. (1966): The Rokko Movements, the Pliocene-Pleistocene Crustal Movements in Japan. *Quaternaria*, **8**, pp. 277–287.

ISHIDA, S., MAENAKA, K. and YOKOYAMA, T. (1969): Paleomagnetic Chronology of Volcanic Ash of the Plio-Pleistocene Series in Kinki District, Japan — The Research of Younger Cenozoic Strata in Kinki District, Part 12 —. *Jour. Geol. Soc. Japan*, **75**, pp. 183–197.

ISHIDA, S. and YOKOYAMA, T. (1969): Tephrostratigraphy, Paleogeography and Tectonic Development of Plio-Pleistocene in Kinki and Tokai Districts, Japan — The Research of Younger Cenozoic Strata in Kinki Province, Part 10 — (in Japanese with English abstr.). *Quat. Res. (Daiyonki Kenkyu)*, **8**, pp. 31–43.

ISHIDA, S. (1970): The Osaka Group — The Cyclic Sediments of Lacustrine and Bay in Plio-Pleistocene, Japan — (in Japanese with English abstr.). *ibid.*, **9**, pp. 101–112.

ITIHARA, M. (1960): Some Problems of the Quaternary Sedimentaries, Osaka and Akashi Areas (in Japanese with English abstr.). *Earth Science (Chikyu Kagaku)*, No. 49, pp. 15–25.

ITIHARA, M. (1966): The Osaka Group and the Rokko Movements (in Japanese with English abstr.). *ibid.*, Nos. 85–86, pp. 12–18.

ITIHARA, M. and KAMEI, T. (1970): The Osaka Group (in Japanese). *Kagaku (Science)*, **40**, pp. 282–291.

ITOIGAWA, J. (1971): Research on the Seto Group, Part 2 — The stratigraphy of the Tokoname Formation in the Environs of the Chita Peninsula, Japan — (in Japanese with English abstr.). *Prof.* Heiichi TAKEHARA *Mem. Vol.*, pp. 83–98.

ITOIGAWA, J. and MORI, S. (1971): The Tokai Supergroup (in Japanese). *Jour. Res. Group Quat. Japan "Daishiki" (The Quaternary)*, No. 16, pp. 117–120.

KAMEI, T. and SETOGUCHI, T. (1970): Some Remarks on Mammalian Faunas in the Early Pleistocene (in Japanese with English abstr.). *Quat. Res. (Daiyonki Kenkyu)*, **9**, pp. 158–163.

KATO, Y. (1957): Geologic Structure of the Area Surrounding the Southern End of the Yoro Range and the Building of the Suzuka Range (in Japanese with English abstr.). *Jour. Geol. Soc. Japan*, **63**, pp. 475–484.

KIMURA, I. and TAKEHARA, H. (1969): Stratigraphy of the "Highest Gravels" in the west-coast of Ise Bay, Japan (in Japanese with English abstr.). *Quat. Res. (Daiyonki Kenkyu)*, **8**, pp. 73–80.

KIMURA, I. (1971, 1972, and 1973): Pleistocene Sediments and Geomorphic Development in the West Coast Area of Ise Bay, Japan, Part 1, 2 and 3. *Bull. Aichi Univ. Educ.*, **20** (Nat. Sci.), pp. 165–181, **21** (Nat. Sci.), pp. 125–155, **22** (Nat. Sci.), pp. 109–131.

KUWAHARA, T. (1968): The Noobi Plain and its Fault Block Movements (in Japanese with English abstr.). *Quat. Res. (Daiyonki Kenkyu)*, **7**, pp. 235–247.

KUWAHARA, T. (1969): The Ise Bay — Sedimentary Basin in the Environs of Ise Bay and Neotectonics in Southwest Japan — (in Japanese). *Symposium Kaigan Heiya (Symposium on Coastal Plain)*, pp. 21–30, Geol. Soc. Japan.

KUWAHARA, T. (1971a): Sedimentary Facies of the Seto Group (in Japanese with English abstr.). *Prof.* Heiichi TAKEHARA *Mem. Vol.*, pp. 113–127.

KUWAHARA, T. (1971b): Note on the Neotectonics of the South-west Japan (in Japanese). *Jour. Res. Group Quat. Japan "Daishiki" (The Quaternary)*, No. 16, pp. 93–105.

KUWAHARA, T., MATSUI, K., YOSHINO, M. and TAKADA, Y. (1972): Buried Topography and Quaternary System in and around Ise-Bay, Central Japan (in Japanese with English abstr.). *Mem. Geol. Soc. Japan*, No. 7 (Coastal Plains of Japan), pp. 61–76.

KUWAHARA, T. (1973): Quaternary System in the Middle Drainage Areas of River Kiso, with special reference to developmental process of the Ena Basin, the inland basin of the Setouchi Geologic Province (in Japanese). *Jour. Res. Group Quat. Japan "Daishiki" (The Quaternary)*, No. 19, pp. 28–39.

KUWAHARA, T. (1975): Formation of the Noobi Tilting Basin and Quaternary Sediments below the Noobi Plain (in Japanese). *Rept. Land Subside. Res. Committ., Aichi Pref.*, pp. 111–182.

MAKINOUCHI, T. (1973): The Tokoname Group in the Northern Part of Tokoname City (in Japanese). *Program 80th Ann. Meeting of Geol. Soc. Japan*, p. 21.

MAKINOUCHI, T. (1975a): The Tokoname Group in the Southern Part of the Chita Peninsula, Central Japan (in Japanese with English abstr.). *Jour. Geol. Soc. Japan*, **81**, pp. 67–80.

MAKINOUCHI, T. (1975b): The Taketoyo Formation in the Southern Part of the Chita Peninsula, Central Japan (in Japanese with English abstr.). *ibid.*, **81**, pp. 185–196.

MAKINOUCHI, T. (1976): Geologic Structures of the Southern Part of the Chita Peninsula and the Tectonic Movements around the Ise Bay, Central Japan (in Japanese with English abstr.). *ibid.*, **82**, pp. 311–325.

MAKIYAMA, J. (1939): The Neogenic Stratigraphy of the Japan Islands. *Proc. 6th Pacific Congr.*, pp. 641–649.

MAKIYAMA, J. (1950): *Chubu-Chiho (Central Japan), Regional Geology of Japan* (in Japanese). 233 pages, Asakura-Shoten, Tokyo.

MATSUDA, T. (1969): Active Faults and Great Earthquakes (in Japanese). *Kagaku (Science)*, **39**, pp. 398–407.

MATSUI, H. and SHIMAZAKI, T. (1971): Stratigraphy of the Agě Group near Hokusei Town, Mie Prefecture (in Japanese with English abstr.). *Prof.* Heiichi TAKEHARA *Mem. Vol.*, pp. 39–54.

MATSUZAWA, I. and UEMURA, T. (1957): Geologic Maps of Environs of Handa City and the Northwestern Part of the Chita Peninsula (2 sheets). Aichi Prefecture.

MATSUZAWA, I., KATO, Y., KUWAHARA, T., KIMURA, T., UEMURA, T. and TSUZUKI, Y. (1960): *Geology of southwestern areas of Sanageyama* (in Japanese with geologic map). 35 pages, Aichi Prefecture.

MATSUZAWA, I. and KUWAHARA, T. (1964): Geologic Structure and Constitution below the Nohbi Plain (in Japanese). *Report of Researches on Disasters owing to the Ise Bay Typhoon*, pp. 14–39, Invest. Committ. Disaster Sci., Nagoya Univ.

MATSUZAWA, I. (1968): Anniversary Address: Tilting in Central Japan — Particularly on the Geotectonic History of the Nobi Tilting Block — (in Japanese). *Jour. Geol. Soc. Japan*, **74**, pp. 61–71.

MCELHINNY, N. W. (1973): *Paleomagnetism and Plate Tectonics*. 358 pages, Cambridge Univ. Press, Cambridge.

MORI, S. (1971a): Some Volcanic Ash Layers in the Seto and Agě Groups, Researches on the Seto Group, Part 3 (in Japanese with English abstr.). *Prof.* Heiichi TAKEHARA *Mem. Vol.*, pp. 99–111.

MORI, S. (1971b): The Yadagawa formation of the Seto group in the east of Nagoya city, Aichi Prefecture (in Japanese with English abstr.). *Jour. Geol. Soc. Japan*, **77**, pp. 635–644.

NASU, T. (1972): Floral and Faunal Changes during the Quaternary Period in Japan (in Japanese). *Biol. Sci.*, **24**, pp. 1–10, Iwanami-Shoten, Tokyo.

NISHIDA, J. and ISHIDA, S. (1975): Paleomagnetic Study of Osaka Group using Marine and Nonmarine Clays near Komyoike, Osaka Prefecture. *Rock Magnetism and Paleogeophysics*, **3**, pp. 32–35.

NISHIMURA, S. and SASAJIMA, S. (1970): Fission-Track Age of Volcanic Ash-Layers of the Plio-Pleistocene Series in Kinki District, Japan (in Japanese with English abstr.). *Chikyu Kagaku (Earth Science)*, **24**, pp. 222–224.

NISHIYAMA, K., MATSUOKA, K. and NISHIDA, S. (1975): Restudy of the Kentoyama Formation from the View Point of Plant Fossils (in Japanese with English abstr.). *ibid.*, **29**, pp. 117–129.

NOBI PLAIN QUATERNARY RESEARCH GROUP (1977): Stratigraphy and microfossil analysis of Quaternary sediments in the Nobi Plain (in Japanese with English abstr.). *Mem. Geol. Soc. Japan*, No. 14 (Quaternary Inland Basins of Japan), pp. 161–183.

OKAYAMA, T. (1969): Gipfeleflur of Japan. Quaternary Tectonic Map of Japan, Sheet No. 6.

SOHMA, K. (1958): Palynological Studies on a Peaty Lignite and a Peat from the Environs of Nagoya. *Ecol. Rev.*, **14**, pp. 289–290.

TAKEHARA, H. (1955): The Upper Part of the Agě Group and the Kentoyama Formation covering the Agě Group in the Environs of Kameyama Town, Mie Prefecture (in Japanese). *Jour. Geol. Soc. Japan*, **61**, pp. 348–349.

TAKEHARA, H. (1961): Stratigraphy of the Agĕ Group, Northern Mie Pref., Japan (in Japanese with English abstr.). *Prof.* Jiro MAKIYAMA *Mem. Vol.*, pp. 45–50.

TAKEHARA, H., MORISHITA, A. and ITOIGAWA, J. (1961, 1964): *The Foundation of Nagoya Harbour* (in Japanese with geological map), and revised edition. 45 pages. Administration Union of Nagoya Harbour.

TAKEHARA, H. (1968): On the Horizon of the so-called Kentoyama Formation in the West Coast of Ise Bay (in Japanese). *Jour. Geol. Soc. Japan*, **74**, p. 120.

TERASHIMA, H. (1965 MS): Geology of the Southern Part of the Chita Peninsula (in Japanese). Graduation thesis of Kyoto Univ.

WADA, Y. (1976): Geology of the Agĕ Group (in Japanese). *Program 83th Ann. Meeting of Geol. Soc. Japan*, p. 169.

YOKOYAMA, T. (1967): The Agĕ Group in the northern part of Mie Prefecture and the horizon of *Stegodon akashiensis* (in Japanese). *Jour. Geol. Soc. Japan*, **73**, p. 100.

YOKOYAMA, T. (1969): Tephrochronology and Paleogeography of the Plio-Pleistocene in the Eastern Setouchi Geologic Province, Southwest Japan. *Mem. Fac. Sci., Kyoto Univ.*, Ser. Geol. and Mineral., **36**, pp. 19–85.

YOKOYAMA, T. (1971): Upheaval of the Suzuka Mountain Range (1), with Special Reference to the Stratigraphy of the Plio-Pleistocene Series in Northern Mie Prefecture, Central Japan — The Research of Younger Cenozoic Strata in Kinki District, Part 19 (in Japanese with English abstr.). *Prof.* Heiichi TAKEHARA *Mem. Vol.*, pp. 55–67.

YOKOYAMA, T. (1973): Natural History of Lake Biwa — Prologue — (in Japanese). *Nature Study*, **19**, pp. 26–32.

Place Names

Agĕ 奄芸	Ageki 阿下喜	Ama 海部	Aokigawa 青木川
Atera 阿寺	Atsumi 渥美	Atsuta 熱田	Biroku 美鹿
Chikusa 千種	Chita 知多	Dohaku 道伯	Ena 恵那
Fuki 富貴	Futto 布土	Handa 半田	Hekikai 碧海
Hibara 桧原	Honjiromatsu 本城松	Ichinohara 市之原	Ichishi 一志
Idaka 猪高	Inabe 員弁	Ise 伊勢	Kagei 河芸
Kagiya 加木屋	Kameyama 亀山	Kamisue 上末	Karayama 唐山
Karegawa 嘉例川	Kentoyama 見当山	Kitashiraki 北白木	Komeno 米野
Komono 菰野	Kono 古野	Kouwa 河和	Koyama 小山
Kuragari 暮明	Kusuhara 楠原	Kuwana 桑名	Magome 馬籠
Matsusaka 松阪	Mikawa 三河	Mino 美濃	Mizunami 瑞浪
Mizuno 水野	Morozaki 師崎	Nagara 長良	Nagashima 長島
Nagoya 名古屋	Nanyo 南陽	Nawa 名和	Nohbi (Nobi) 濃尾
Noma 野間	Ohbu 大府	Oh'izumi 大泉	Ohtaka 大高
Ohtani 大谷	Ohtaniike 大谷池	Ohzone 大曽根	Okazaki 岡崎
Rengeji 蓮花寺	Saigyodani 西行谷	Sanage 猿投	Seto 瀬戸
Shinden 新田	Suzuka 鈴鹿	Tajimi 多治見	Takahari 高針
Taketoyo 武豊	Tobishima 飛島	Tokai 東海	Toki 土岐
Tokoname 常滑	Toyooka 豊丘	Tozenji 東禅寺	Tsu 津
Yadagawa 矢田川	Yagoto 八事	Yokkaichi 四日市	Yoro 養老