Memoirs of Faculty of Science, Kochi University, Series E, Geology, Vol.19, p.1-13, July, 1999

Quaternary geology along the Tonda-gawa river, Wakayanma Prefecture, Kii Penisula

Taikou MITUSIO[1*] and Tomohiro KANZAKI[1*]
[1*]Department of Nartural Environmental Science, Faculty of Science,
Kochi University, Kochi, 780-8520 JAPAN

Abstract

The study on the Quaternary System in Shikoku was nearly finished, and in order to compare it, the writers surveyed along the Tonda-gawa river, Wakayama Prefecture, Kii Penisula, and the Quaternary System was made clear. The followings are concluded: The area except the Pre-Tertiary bed rocks, is mainly occupied by the Pleistocene deposits and Holocene Alluvial ones. The Pre-terrace deposits of the Early Pleistocene is the Toushima Formation (Mitusio *et al.*, 1998d), and the Middle Pleistocene of the Higher Terrace deposits, H, is the Kodougaoka Formation.The Late Pleistocene is divided into two; the Middle Terrace deposits and the Lower Terrace ones, and the former is such as the Kurisugawa Formation of the Middle Terrace deposits, MI, and the Akugawa Formation of the Middle Terrace deposits, MII. The latter is the Lower Terrace deposits of the Hokusogi Formation, L. The Holocene sediments are also divided into two of the Alluvial Terrace deposits of the Mukouda Formation, A I , and the wide Alluvial Plain, A II . These strata are correlated with those of the other areas mainly in Shikoku and partly in Kyushu and Honshu, as well as in north Taiwan.

Introduction

The writers have been surveying the Quaternary System since 1966 in Shikoku Island (Mitusio *et al.*, 1966; 1967; 1971; 1974; 1977a; 1977b; 1985a; 1985b; 1987a; 1987b; Imai *et al.*, 1968; Nakamura *et al.*, 1972; Mimoto and Mitusio, 1982). According to these results, Mitusio and Furukawa (1988b) reported the Quaternary strata in Shikoku. After that, the Quaternary strata were surveyed in various areas such as Geisei Village (Mitusio *et al.*, 1988a), central parts (Mitusio, *et al.*, 1991c), Muroto Peninsula (Mitusio, 1989a; 1990a; 1990b; 1991a; Mitusio and Yasuda, 1989b), Ashizuri Peninsula (Mitusio *et al.*, 1989b; 1989c; 1991c; 1991d; Mitusio and Nishikawa, 1991b), Shimanto river (Mitusio and Yamashita, 1990c; Mitusio *et al.*, 1995b), Kohnokawa (Takahashi *et al.*, 1989), Hijikawa (Kashima *et al.*, 1992b) and Iwamatsugawa (Mitusio *et al.*, 1992b) of Ehime Prefecture, and in the Tsushima Straits (Mitusio and Yasuda, 1990b), as well as the Holocene System in whole Shikoku (Ogura *et al.*, 1989) and in Kochi Prefecture (Mitusio, 1996c). According to these data, Mitusio and Kagami (1992a) again compiled the Quaternary System in Shikoku.

Then before and after 1992, the results of the following areas were reported: In Kagawa Prefecture (Mitusio *et al.*, 1995c; Ueki and Mitusio, 1998). In Ehime Prefecture; The Towns of Misaki and Seto of Misaki Peninsula, and along the Kurose-gawa tributary of the Hiji river, and Johen Town (Kashima *et al.*, 1991a; 1991b; 1991c; 1996) and the rivers of Sohja-gawa and Tonda-gawa (Mitusio *et al.*, 1995b; 1996), and the Hiromi river (Mitusio and Kashima, 1994b) and in Johen Town (Mitusio *et al.*, 1995a). In Tokushima Pre fecture; Along the rivers of Yoshino-gawa (Mitusio and Shima, 1993c; Mitusio and Hashimoto, 1994c), Nakagawa (Mitusio and Kuribayashi, 1997), Akuigawa (Mitusio and Ikeno, 1998) and Katsuura-

gawa (Mitusio and Sasaki MS). In Kochi Prefecture; Muroto Peninsula and in Tosa bay (Kagami *et al.*, 1992a; 1992b; 1992c; 1993), along the Monobe river (Mitusio, 1992; 1996; 1997a; Mitusio and Kawaguchi, 1993), the Hage tributary of the Niyodo river (Mitusio and Noda, 1994a) and along the Matsuda river (Mitusio and Kashima, 1996). In Kyushu (Mitusio, 1996; Mitusio and Igarashi, 1996). In the Nohbi Plain near Nagoya (Mitusio, 1973). And from the viewpoints of Archaeology related with Quaternary geology in Kochi Prefecture (Mitusio, 1985; 1986a; 1986b). And those also related with marine geology, many results were reported (for example, Mitusio and Guruge, 1994d; Mitusio, 1998a).

In addition, under the study series of "diagenesisology", that is the hydrothermal experiments of making sedimentary rocks, especially chert, limestone and dolomite, one of the writer, Mitusio *et al.* (1998) reported mainly about silica diagenesis, since 1977 (Mitusio *et al.*, 1977; Mitusio and Matsuoka, 1978) untill now (Mitusio and Watanabe, 1997b). Moreover, under the titles of "Interactions between Lithosphere and Hydrosphere", Mitusio reported some water characters of north India (Mitusio, 1996b) north and Taiwan (Mitusio,

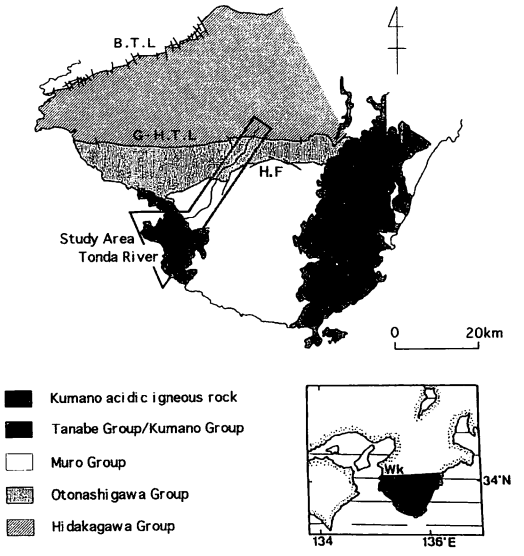

Fig. 1. Index map showing the study area along the Tonda-gawa river (revised after Co-lab. Study Group for the Tanabe Group, 1984)

1999) as the number 16 of this series since 1990. Besides above-mentioned several backgrounds, the study on the Quaternary System in the Shikoku Island was nearly finished, so that the writers began to survey the Quaternary strata of the Kii Peninsula in order to correlate them in Shikoku and Kyushu. And the ealy Pleistocene Toushima Formation near Tanabe Bay, Shirahama, Wakayama Prefecture, Kii Peninsula, is defined and reported (Mitusio, Kanzaki, and Kuribayashi, 1998).

Here, in addition to it, the writers report the results of the Quaternary geology along the Tonda-gawa river, southwestern part of Wakayama Prefecture, Kii Peninsula (Fig.1).

Outline of Topography and Geology

This area locates to the western part of Wakayama Prefecture of southwest Kii Peninsula, and this area is just facing directly to the Kii Straits. And the Tonda-gawa river system here is as follows (Fig.2): The Tonda-gawa river, starting from the high mountainous area of Mt.Kasatou (1,049 m) and Mt.Senjyou (1,026 m), those locate nearly at the central part of the Kii Mountains, flows almost linearly from the northeast to southwest direction, and it directly pours into the Kii Straits, that divides Shikoku and the Kii Peninsula, Honshu. Along this river, seven flat terrace plains are found, and the Quaternary strata forming these terrace plains are newly defined except the Pre-terrace Toushima Formation defined by Mitusio, Kanzaki and Kuribayashi (1998). The river length is about 45km, and the drainage area along this river is considerably wide, and the longitudinal profile of this river as well as the terrace plains is shown in Fig.2.

As for the background geology along the Tondagawa river, the bed rocks belong to the Cretaceous and Tertiary Shimanto Terrain, and the Middle Miocene Tanabe Group (Nakazawa *et al.*, 1988; Tanabe Group Co-lab. Group, 1984). On their basemant rocks, the Quaternary strata cover them unconformably, and Yonekura (1968) reported the marine terrace and crustal movements around here. Nakamura (1973) also reported the palynological study of the middle marine Akuga-

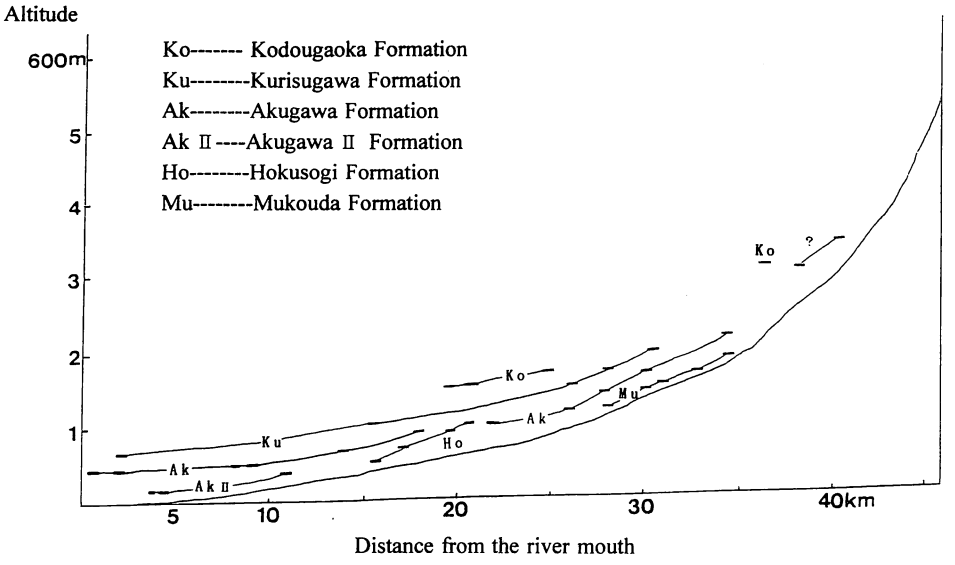

Fig. 2. Longitudial profile of each Formation and the river section along the Tondagawa river Ak II, fluvial terrace Ak, marine terrace

wa Formation from which the analyzed samples were collected by one of the writer, Mitusio.

Then the writers defined the Toushima Formation near Tanabe Bay as the Early Pleistocene (Mitusio *et al.*, 1998). Here the writers defined newly the Quaternary strata names, and they are as follows in descending order: The Early Pleistocene Pre-terrace deposits of the Toushima Formation, forming no flat plain. The Middle Pleistocene of the Kodougaoka Formation forming the Higher Terrace, H. The Late Pleistocene forms two terraces of the Middle Teraces of MI and MII, and the Lower Terrace of L. MI is the Kurisugawa Formationis while MII is the Akugawa Formation, and L is the Hokusogi Formation. And the Holocene strata are also divided into two: AI of the Holoene terrace of the MukoudaFormation, and AII forming the wide Alluvial plain but it is not defined here.

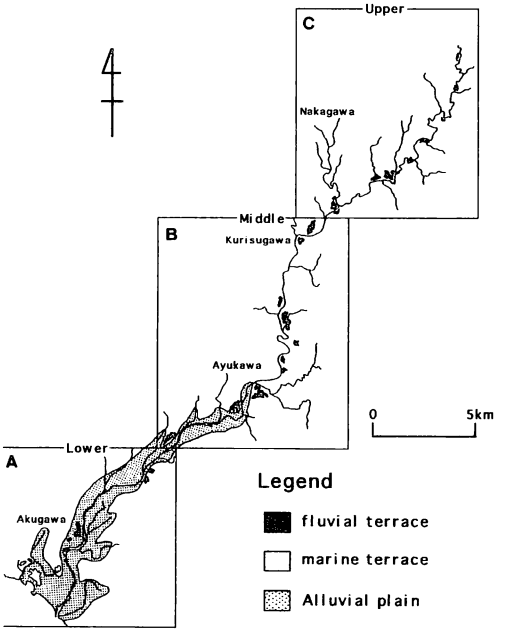

Fig. 3. Generalized distibution of the Quaternary terrace and Alluvial plain along the Tondagawa river
A, down-stream area and near sea coast area
B, middle-stream area
C, upper-stream area

Description of the Quaternary System

The Quaternary System of the Ealy to Late Pleistocene and Holocene along the Tonda-gawa river is described in descending order.

1. Early Pleistocene Toushima Formation= Pre-Terrace Deposits

The Early Pleistocene in this area is already named and reported as the Toushima Formation by the writers (Mitusio, Kanzaki and Kuribayashi, 1998), and the datails should be reffered to it.

2. Middle Pleistocene

The Middle Pleistocene in this surveyed area is newly named as the Higher Terrace Deposits of the Kodougaoka Formation (Tab. 1).

Author: Kanzaki, T. and Mitusio, T. (1998)
Name: Kodougaoka Formation
Type locality: Kodougaoka, Nakahechi Town, Wakayama Prefecture, loc.a
Thickness: 5-6m
Distribution height: 300-150m
Relative height from the river bottom: 100-90m
Topographical plain: Kodougaoka Terrace Plain = Higher Terrace, H
Distribution: This Formation distributes continuously in a narrow area along the mid-stream of the Tonda-gawa river, however it exsists only one point at the upper-stream of the same river. This is composed mainly of gravels and sands, intercalated ocasionally with silt bed. The gravels are not so much sorted, and are angular to subrounded ones. The gravels diameters are about 40cm at its maximum and one cm at the minimum one. The gravels are mainly of sandstones, mudstones and chert, with rare conglomerates and tuff. These grvels are corroded ones and the matrix is reddish brown coloured silty sand.

This Formation forms the flat terrace plain of the Kodougaoka Terrace Plain of the higher terrace plain. But this plain is very badly conserved, and every plain is separated and narrow. And this

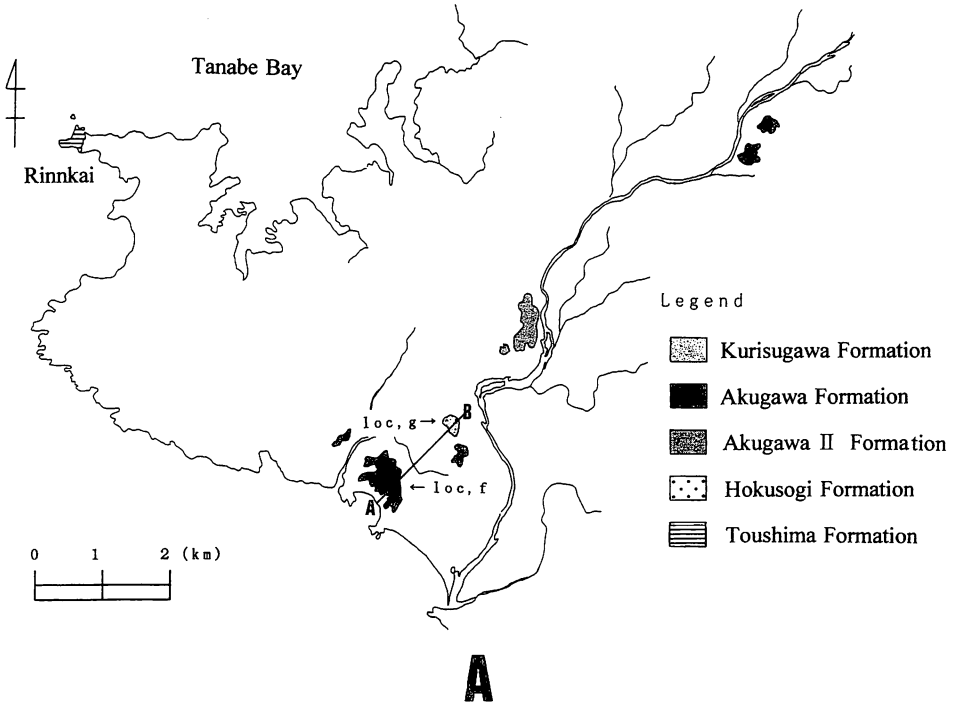

Fig. 4A. Quaternary geolgic map of the down-stream area along the Tonda-gawa river and near sea coast area
Note that the Akugawa II Formation is the fluvial terrace, and that this forms the lower plain than that of the marine Akugawa Formation, Ak.
A−B, cross section in Fig.5.

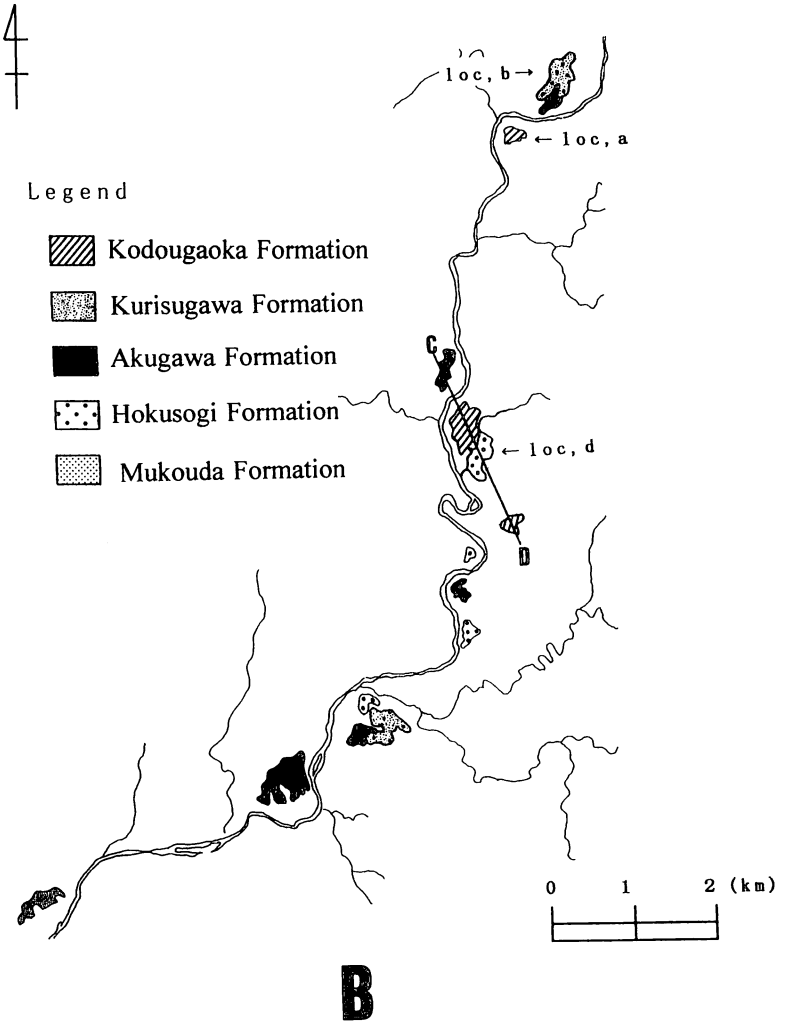

Fig. 4B. Quaternary geolgic map of the mid-stream area along the Tonda-gawa river
On this case, the Akugawa Formation is the fluvial sediments.
C−D, cross section in Fig.5.

plain declines gentlely to the valley of the Tonda-gawa river.

3 . Late Pleistocene

The Late Pleistocene in this surveyed area is mainly divided into two terraces deposits that are the Middle and Lower ones (Tab. 1).

3-1 Middle Terrace Deposits

The Middle Terrace Deposits here are composed of two: the Higher one is the Kurisugawa Formation (M I) and Lower one is the marine Akugawa Formation (M II).

3-1-A Middle Terrace Deposit, M I

The Middle Terrace Deposit of the middle one is the Kurisugawa Formation.

Author: Kanzaki, T. and Mitusio, T. (1998)
Name: Kurisugawa Formation

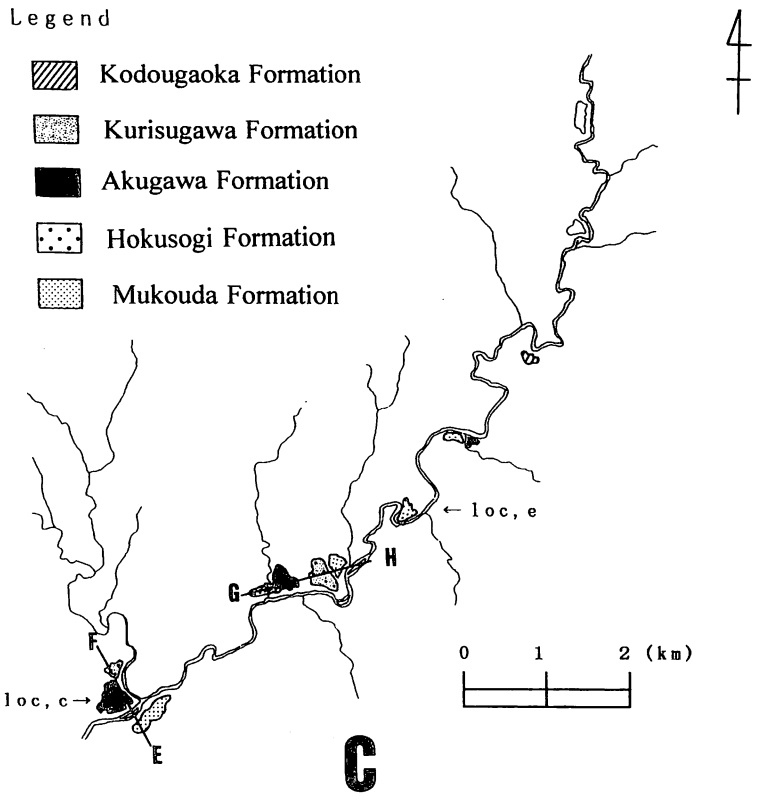

Fig. 4C. Quaternary geolgic map of the upper-stream area along the Tonda-gawa river On this case, the Akugawa Formation is also the fluvial sediments. E−F/G−H, cross sections in Fig.5.

Type locality: Kurisugawa, Nakahechi Town, Nishimuro-gun, Wakayama Prefecture, loc.b
Thickness: 5-2m
Distribution height: 190-60m
Relative height from the river bottom: 60m
Topographical plain: Kurisugawa Terrace Plain = Middle Terrace Plain, M II
Distribution: This Formation distributes widely along the mid-stream to down-stream area of the Tonda-gawa river.

This is composed mainly of gravels. The gravels are sorted, and they are pebbles, the diameters of which are about one to four cm. The roundness of the gravels increases gradually as the gravels are transported along the river from the upper-stream area to the down-stream one, where the roundness at the upper-stream area is angular, and that of the down-stream area is the subrounded gravels.

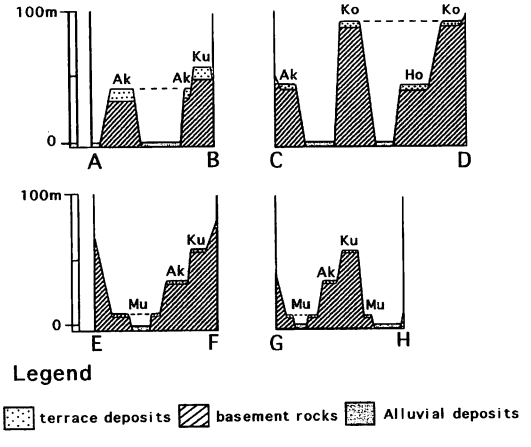

Fig. 5. Cross sections of the Quaternary System Ak, Akugawa Formation; MII Ku, Kusisugawa Formation; MI Ko, Kodougaoka Formation; H Ho, Hokusogi Formation;L Mu, Mukouda Formation; AI

The variety of the gravels is mainly of sandstones, mudstones and chert, and these are semi-corroded ones. The matrix is yellowish brown coloured silty sand.

This Formation forms the flat terrace plain of the Kurisugawa Terrace Plain of the Middle Plain MI, and this plain is well conserved. The longitudinal profile of this Formation much resembles to that of the Present Tonda river, and this plain is considerably flat and gentle.

3-1-B Middle Terrace Deposits, M II

The Middle Terrace Deposits of the lower one is the Akugawa Formation.

Author: Nakazawa *et al.* (1987); redefined by Kanzaki, T. and Mitusio, T. (1998)
Name: Akugawa Formation
Type locality: Asso-daira, Nakahechi Town, Nishimuro-gun, Wakayama Prefecture, loc.c
Thickness: 5-2m
Distribution height: 210-40m
Relative height from the river bottom: 40-20m
Topographical plain: Akugawa Plain=Mddle Terrace, M II
Distribution: This Formation exsists continuously along the mid-stream to down-stream areas of the Tonda-gawa river.

This is composed mainly of gravels with ocasinally intercalated by silt beds. The gravels are not sorted, and they are pebbles and cobbles, of which the maximum diameter is about 30cm, and the smaller one is about one cm. And the roundness of the gravels also increases gradually along from the upper-stream area to the down-stream area, alike angular to subrounded gravels. The gravels are mostly of sandstones, mudstones and chert, and these are semi-corroded ones. The matrix is also yellowish brown coloured silty sand.

This Formation has two sedimentary facies of marine and fluvial ones.

The former is found near Tanabe Bay, and it is shown as the "Akugawa Formaion" and the latter is shown as the "Akugawa II Formaion" in Fig. 4A.

This Formation forms the flat terrace plain of the Akugawa Terrace Plain of the middle plain M II, and this plain is well conserved.

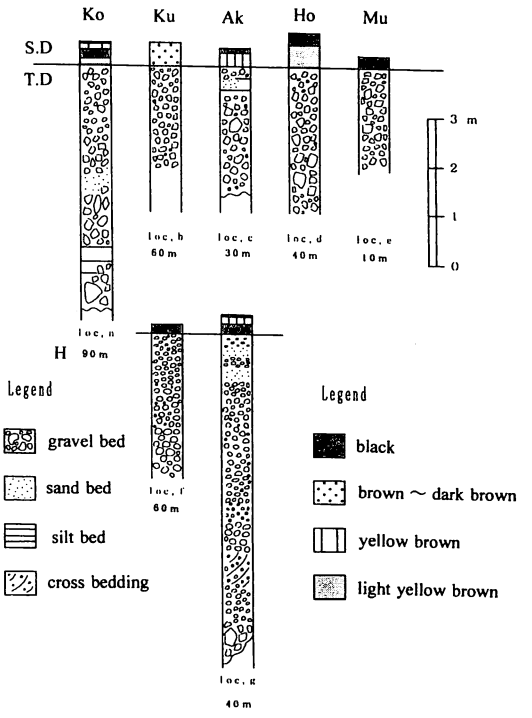

Fig. 6. Columnar sections of the Quaternary System
S. D, surface deposits T. D, terrace deposits

The longitudinal profile of this Formation also much resembles to that of the Present Tonda-gawa river, and this plain is considerably flat and gentle, alike the Kurisugawa Terrace Plain of M I.

3-2 Lower Terrace Deposits, L

The Lower Terrace Deposits in the surveyed area is the Hokusogi Formation.

Author: Kanzaki, T. and Mitusio, T. (1998)
Name: Hokusogi Formation
Type locality: Hokosogi, Nakaheti Town, Nishimuro-gun, Wakayama Prefecture, loc.d
Thickness: 3-2m
Distribution height: 100-50m
Relative height from the river bottom: 40-10m
Topographical plain: Hokosogi Terrace Plain= Lower Terrace Plain, L
Distribution: This Formation exsists narrowly but continuously along the down-stream area of the Tonda-gawa river.

This is composed mainly of gravels. The gravels are not so well sorted, and they are pebbles and cobbles, of which the maximum diameter is about 20cm, and smaller one is about one cm. The roundness of the gravels is angular to subrounded ones. The gravels are mostly of sandstones, mudstones and chert, and these are fesh and are not weathered ones. The matrix is also yellowish brown to dark brown coloured coarse sand.

This Formation forms the flat terrace plain of the Hokusogi Terrace Plain of the Lower Plain L, and this plain is very well conserved. As for the longitudinal profile of this Formation, this declines decines to the down-stream area with rather steep slope, and may be buried into the Alluvial plain. Also this plain is considerably flat and gentle.

4 Holocene Deposits

In this area, the Holocene Deposits is especially divided into two: the Mukouda Formation AI which forms the Holocene Terrace and the Alluvial Strata AII which forms the wide Alluvial Plain.

4-1 Holocene Terrace Deposits, A I

The Holocene Terrace Deposits is the the Mukouda Formation.

Author: Kanzaki, T. and Mitusio, T. (1998)
Name: Mukouda Formation
Type locality: Mukouda, Nakaheti Town, Nishimuro-gun, Wakayama Prefecture, loc.e
Thickness: 3-2m
Distribution height: 180-120m
Relative height from the river bottom: less than 10m
Topographical plain: Mukouda Terrace Plain= Holocene Terrace Plain, A I
Distribution: This Formation exsists narrowly but continuously along the upper-stream to middle-stream areas of the Tonda-gawa river.

This is also composed mainly of gravels. The gravels are not so well sorted, and they are pebbles and cobbles, of which the maximum diameter is about 20cm, and smaller one is about one cm. And the roundness of the gravels is angular to subangular one. The gravels are mostly of sandstones, mudstones and chert, and these are also fesh and are not weathered ones. The matrix is also yellowish brown to dark brown coloured coarse sand.

This Formation forms the flat terrace plain of the Mukouda Holocene Terrace Plain on the Alluvial Plain AI, and this plain is very well conserved. And the longitudinal profile of this Formation much resembles to that of the Present Tondagawa river, and this plain is also considerably flat and gentle.

4-2 Holocene Alluvial Deposits

Then this made the Alluvial plains widely along the Tonda-gawa river.

However, the writers donot define this Formation, because it cannot be observed on the surface but only beneath the underground. In addition, naming makes the complicated strata names, however one of the wrters, Mitusio *et al.* (1985; 1986) named the Holocene strata in Shikoku.

Correlation of the Quaternary System

The Above-mentioned Quaternary System is to be correlated with those where they surveyed in the other areas in the Southwest Japan and north Taiwan such as follows: The peninsula areas of Muroto and Ashizuri of Kochi Prefecture and Kagawa Prefecture both in Shikoku. Akune City of Kagoshima Prefecture in Kyushu and north Taiwan.

They are shown in the correlation table of the Quaternary System. The Toushima Formation of the Eearly Pleistocene in this area is correlatable with the Geisei Group and the Sada Group of Kochi Prefecture, and Mitoyo Group of Kagawa Prefecture both in Shikoku, and with the Akune Formation in Akune City of Kyushu. Then this Formation is also to be correlated with the Cholan Formation in north Taiwan.

The Kotogaoka Formation of the Middle Pleistocene in this area forms the Higher Terrace including corroded gravels, and is correlatable with the Formations of Kureiwa and Hiromi of both Kochi Prefecture, the Yakeotoge Formation of Kagawa Prefecture, the Higashi-Makiuchi For-

Tab. 1 Correlation table of the Quaternaruy System along the Tonda-gawa river and the other areas in the Southwest Japan and north Taiwan

Age			Tonda-gawa R. Kii Penin.	Muroto Shikoku	Ashizuri Shikoku	Kagawa Shikoku	Akune Kyushu	north Taiwan
QUATERNARY	Holoc.		Alluvium					
	PLEISTOCENE	LATE	Hokusogi F Akugawa F* Kurisu-gawa F	Murotsu F Ikumi F*	Ukibuchi F Hirano F*	Lower TD Middle TD	Hekono F Tada F*	Lower TD Middle TD
		MIDDLE	Kotougaoka F**	Kureiwa F**	Hiromi F**	Yakeotoge F**	Higashi-Makiuchi F**	Linkou F Toukoshan F
		EARLY	Toshima F	Geisei G	Sada G	Mitoyo G	Akune F	Cholan F
TER.	PLI.	LAT.						

TER, Tertiary PLI, Pleistocene LAT, Late Holoc, Holocene R, river Penin, peninsula F, Formation G, Group TD, terrace deposits D, diposits
*including marine sediments **including corroded gravels

mation of Kyushu, and with the Formations of Toukoshan and Linkou in northTaiwan.

As for the Middle Terraces of the Late Pleistocene, two Formations of the Kurisugawa MI and the Akugawa MII including marine sediments in this area form the Middle Terrace MI and MII. MI is rather scarce, and MII is correlatable with the Formations of Ikumi and Hirano of both Kochi Prefecture, the Middle Terrace Deposits of Kagawa Prefecture, the Tada Formation of Kyushu, and the Middle Terrace Deposits in Taiwan.

The Lower Terrace Deposits of the Late Pleistocene is the Hokusogi Formation, and is correlatable with the Formations of Murotsu and Ukibuchi in both Kochi Prefecture, the Lower terrace Deposits of Kagawa Prefecture, the Bekono Formation of Kyushu, and the Lower Terrace Deposits in Taiwan.

Finally, the special Holocene Terrace Deposits of the Holocene Epoch is rare, and this is the Mukouda Formation, and is rarely correlatable with those in the other Formations. Especially, this is to be correlated with the Katsuragawa area of Tokushima Prefecture and the Monobe area of Kochi Prefecture.

Concluding Remarks

The writers surveyed the Quaternary geology along the Tonda river of Wakayama Prefecture, southwestern part of the Kii Peninsula, and it is correlated with those areas where they have surveyed.

And the results of the survey are summarized as follows:

1)In this area, the Quaternary geology is divided into seven Formtions that are almost newly defined as follows: The Early Pleistocene of the Preterrace strata of the Toushima Formation (Mitusio, Kanzaki, and Kuribayashi, 1998), and the Middle Pleistocene of the Higher terrace deposits H of the Kodougaoka Formation, and as the Late Pleistocene of the Middle terrace deposits MI of the Kurisugawa Formtion and of the same deposits MII of the marine Akugawa Formation, and also the Late Pleistocene of the Lower terrace ones L of the Hokusogi Formation. The Holocene sediments are divided into two of the Alluvial terrace deposits AI of the Mukouda Formation and the wide Alluvial Plain A II.

2)These atrata are correlated with those in the other areas of maily Shikoku and partly in Kyushu.

The interaction between the Lithosphere and Hydrosphere is to be reported on the other chance, and more datailed Quatenary geology survey is needed.

Acknowledgement

The writers would like to express their sincere thanks to Messors Kuribayasi, T. and Ikeno, T. of the Department of Natural Environmental Science, Kochi University and Master Ueki, G. of the Department of Geography, Tokyo Metropollitan University, for their usuful advices.

And special thanks are also due to Sihan Nishiuchi, for reading this early draft, and they wolud appreciate the members of the Reserch Society of Human and Environmental Changes (RSHEC), for their kind helps.

Reference Cited

Imai, Y., Katto, J. and Mitusio, T. (1968): Underground water of Kochi City. *Study of Municipal Policy*, spec. vol.; 1-21.*

Kagami, H., Mitusio, T. and Nozawa, S. (1992a): Nahari Formation and Quaternary System near Nahari River in the Southwestern Part of Kochi Prefecture. *Annual Rep. Josai Univ.*, 16; 1-13.**

Kagami, H., Mitusio, T. and Yamato, Y. (1992b): Uplifting of Shikoku Mountains and Molasse Deposition of Joyama and Ryuou Formations in Nankai Fore-arc Sliver, Southwest Japan. *Quat. Res.*, 31; 271-283.**

Kagami, H. and Mitusio, T. (1992c): Supply of trench fill sediment through fore-arc basin along Nankai Trough, southwest Japan. *29th international Geological Cong.. Abst.*, 2; 322.

Kagami, H., Mitusio, T., Nozawa, S. and Kobayashi, S. (1993): Quaternary System in the Southeastern Kochi Prefecture, SW Japan. *Annual Rep. Josai Univ.*, 17, 1-15.**

Kashima, N., Hukurose, R. and Mitusio, T. (1991 a): Environment geological study of western Shikoku, part 6—Quaternary System near Misaki Town, Nanyo district, Ehime Prefecture-. *Mem. Ehime Univ.*II, 11; 55-61.**

Kashima, N., Takahashi, K. and Mitusio, T. (1991b): Environment geological study of western Shikoku, part 7—Quaternary System near Seto Town , Nanyo district, Ehime Prefecture. *Mem. Fac. Educ., Ehime Univ.*, 26; 35-46.**

Kashima, N., Okamoto, K. and Mitusio, T. (1991 c): Environment geological study of western Shikoku, part 11—Environmental change near the Kurose river, mid-stream area of the Hijikawa river of Ehime Prefecture in the Quaternary age. *Mem. Fac. Educ., Ehime Univ.*, 28; 17-29.**

Kashima, N., Mitusio, T. and Nishijima, T. (1991 d): Environmental geology of the drainage basin of the Hiji River. *Geol. Excursion Guide book, 98th Ann. Geol. Soc. Japan,* (11); 215-234.*

Kashima, N. and Mitusio, T. (1996): Discovery and its significanse of 0.82 Ma tephra in Johen Town, Ehime Prefecture. *Joint Issue Proc. Kansai and Nishinihon bran. Geol. Soc. Jp.* (122)5; (110)7.*

Mimoto, K. and Mitusio, T. 1982): Middle marine terrace deposits of Ashizuri Formation. *Quaternary*, (21); 10-18.*

Mitusio, T. and Katto, J. (1966): Quaternary System of the northwestern part of Kochi City. *Res. Rep. Kochi Univ.*, 15 (7); 53-57.**

Mitusio, T. and Katto, J. (1967): Some problems on Quaternary System in the southwestern part of Ashizuri. *Res. Rep. Kochi Univ.*, 24; 22-34.**

Mitusio, T., Kawasawa, K., Kondo, H. and Nishijima, T. (1970): Middle terrace near the northern river-mouth of the Shimanto river, southwestern part of Kochi Prefecture. *Jour. Geol. Soc. Japan.*, 76 (2); 81-82.*

Mitusio, T., Nakamura, J., Yoshikawa, O., Kuroda, T. and Amano, R. (1971): Some problems on the Quaternary System of the southeastern part of Kochi Prefecture. *Quaternary*, (17); 47-53.*

Mitusio, T. (1973): Sedimentological study of the Quaternary System ubder the Nohbi Plain--study on the Nohbi Plain, part 3--. *Res. Rep. Kochi Univ.*, 22; 7-13.**

Mitusio, T., Nakamura, J., Yuhara, I., Kawasawa, K., Kawazoe, H. and Kondo, H. (1974): Quaternary System in the Ryoseki basin. *Quaternary*, (14); 10-18.*

Mitusio, T. and Furukawa, H. (1977a): *Hydrogeological Map of Kochi* Prefecture. Ministry of Agric. Forest. and Fisheries.*

Mitusio, T. and Yoshikawa, O. (1977b): *Quaternary System from Kochi to Muroto Cape*. Geol. Guide Book, (7); 1-23.*

Mitusio, T., Yamasaki, N., Yasuda, Y., Kubota, Y. and Matsuoka, K. (1977c): Transformation of silica from various origins under hydrothermal conditions. *Res. Rep. Hydrothem. Chem. Kochi Univ.*, 2 (6); 18-21.**

Mitusio, T. and Matsuoka, K. (1978): Hydrothermal changes of silica gels, part 1. *Res. Rep. Hydrothem. Chem. Kochi Univ.*, 2 (11); 36-39.**

Mitusio, T., Shimizu, K. and Wada, M. (1985a): *Hydrogeologic map of Kochi Prefecture*, 1: 150,000.Ministry of Agri., Forest. and Fisheries.*

Mitusio, T. (1985b): Study on unused natural resources, part 4－Thermal changes of fumic volcanic ash－. *Marine & Waste Resources*, 13; 25-32.**

Mitusio, T. (1985c): Marine geology of Tosa bay, Shikoku, Japan, part 2, Marine geology of very shallow portions. *Res. Rep. Kochi Univ.*, 34; 61-72.

Mitusio, T. (1985d): Quaternary System and archaeology in Kochi Prefcture, part 1－Backgrounds of archaeology－. *Excavation, Rep. Archaeol. Soc. Kochi Univ.*, (4); 19-24.*

Mitusio, T. (1986a): Quaternary System and archaeology in Kochi Prefcture, part 2－Backgrounds of archaeology－. *Excavation, Rep. Archaeol. Soc. Kochi Univ.*, (5); 19-24.*

Mitusio, T. and Nakajima, K. (1986b): Analyses of pottery from Kochi Prefecture. *Res. Rep. Kochi Univ.*, 34 (5); 1-14.**

Mitusio, T. (1987a): Quaternary System of Muroto Peninsula. *Sci. Educ.*, (374); 96-101.**

Mitusio, T. and Yamanaka, M. (1987b): Palynological study of the Mama Formation, north Kochi City. *Rep. Usa Marine Biol.Inst.*, 12; 25-32.**

Mitusio, T., Kagami, H. and Hisatake, S. (1988a): Kanougi Formation (marine middle terrace deposits) near Geisei, west of Tosa bay. *Res. Rep. Kochi Univ.*, 37; 89-96.**

Mitusio, T. and Furukawa, H. (1988b): Quaternary strata in Shikoku District. *Mem. Geol. Soc.*, 30; 145-154.**

Mitusio, T. (1989a): The middle terrace problems in Shikoku, Japan. *Kuroshio*, spec. vol. 4; 187-202.

Mitusio, T. and Yasuda, H. (1989b): Plio-Pleistocene Geology near the Hane Cape, Muroto Peninsula. *Res. Rep. Kochi Univ.*, 38; 217-224.**

Mitusio, T., Nishikawa, T. and Mimoto, K. (1989 c): Plio-Pleistocene strata of Ashizuri Peninsula.. *Res. Rep. Kochi Univ.*, 38; 63-72.**

Mitusio, T. (1990a): Quaternary System from Kochi to Muroto Peninsula–Guide book of geology excursion for the Symposium of the Quaternary General Research Society.; 1-15*

Mitusio, T. and Yasuda, H. (1990b): Quaternary strata of Tsushima Straits–especaially on land-bridge problem–. *Quat. Res.*, 29; 63-64.*

Mitusio, T. and Yamashita, S. (1990c): Quaternary System of Shimanto river, Shikoku, especially on its formation history. *Res. Rep. Kochi Univ.*, 39; 109-126.**

Mitusio, T. (1991a): Muroto Plain (M) is not a middle terrace. *Prof. Nakagawa commemolative vol.*; 161-168.**

Mitusio, T. and Nishikawa, T. (1991b): Quaternary System of Ashizuri Region, especially on the marine middle terrace. *Quaternary*, 24; 1-17.**

Mitusio, T. and Noda, K. (1991c): Palynostratigraphical study, part 2, Quaternary strata in the

central and western part of Kochi Prefecture *Res. Rep. Kochi Univ.*, 40; 71-83.**

Mitusio, T. (1991d): Quaternary System in Ashizuri Peninsula. Guide book of Geology, Vegatation and Jomonian Relicts. Excursion, *Quat. Res.* Assoc., ; 136-148.*

Mitusio, T. and Kagami, H. (1992a): Quaternary System in Shikoku Region. *Quat. Res.*, 31 (5); 297-311.**

Mitusio, T. and Ohta, T. (1992b): Quaternary System near Tsushima Town, Nanyo District, Ehime Prefecture, Shikoku. *Mem. Fac. Sci. Kochi Univ., Ser. E, Geology*, 13; 1-10.

Mitusio, T. (1993a): Significance of the Early Pleistocene Kubo-nurui Formation along the Kami-Nirou river, upper-stream area of the Monobe River. *Mem. Fac. Sci. Kochi Univ. ser. E, Geology*, 14; 45-50.

Mitusio, T. and Kawaguchi, T. (1993b): Quaternary System along the Monobe River, Southern Shikoku. *Res. Rep. Kochi Univ.*, 41 (5); 1-22.**

Mitusio, T. and Kawaguchi, T. (1993c): Quaternary System along the Monobe River, Southern Shikoku. *Abst. Quat. Res. Soc.*, (23); 58-59.*

Mitusio, T. and Shima, S. (1993d): Quaternary System along the upper and middle stream area of the Yoshino River, Shikoku. *Res. Rep. Kochi Univ.*, 41 (6); 1-20.**

Mitusio, T. and Noda, K. (1994a): Quaternary environmental changes.–Quaternary strata along the Hage river, a tributary of the down-stream area of the Niyodo river in the Takaoka Plain of Tosa City, Kochi Prefecture–. Res. *Rep. Kochi Univ.*, 43; 101-114.**

Mitusio, T. and Kashima, N. (1994b): Quaternary System along the Hiromi river and its tributaries, southwestern part of Ehime Prefecture–Environmental geology of West Shikoku, part8–. *Mem. Fac. Sci. Kochi Univ., Ser. E, Geology*, 15; 21-39.

Mitusio, T. and Hashimoto, K. (1994c): Outline of the Quaternary System along the whole Yoshino river, Shikoku. *Res. Rep. Kochi Univ.*,43; 115-122.**

Mitusio, T. and Guruge, K. S. (1994d): Marine geology of Tosa bay, Soutwest Japan, part 4, Important sedimentological aspects –Marine geology of very shallow portions, part 16–. *Mem. Fac. Sci. Kochi Univ.ser. E, Geology*, 15; 41-48.

Mitusio, T. Takahashi, M. and Kashima, N. (1995 a): The Early Pleistocene Ohkubo Formation near Ohkubo, Johen Town, southwestern End of Ehime Prefecture–Environmental geology of West Shikoku, part 10–. *Mem. Fac. Sci. Kochi Univ., Ser. E, Geology*, 16; 33-44.

Mitusio, T., Igarashi, K. and Kashima, N. (1995 b): Environment Geological study in West Shikoku, part 8–Quaternary environmental change along the Sohja river, Imabari City, Ehime Prefecture–. *Res. Rep. Kochi Univ.*, 45; 101-123.**

Mitusio, T., Yube, M. and Ueki, T. (1995c): Interaction between Lithosphere and Hydrosphere, part 12, –Clay mineral of weathered granite from the Ryoke belt–.*Res. Rep. Kochi Univ.*, 44; 38-47.**

Mitusio, T. (1996a): Interaction between Lithosphere and Hydrosphere, part 13–Preliminary report on exploration of a new hot spring in Akune City, northwestern part of Kagoshima Prefecture–. *Mem. Fac. Sci. Kochi Univ. ser. E, Geology*, 17; 33-43.

Mitusio, T. (1996b): Interaction between Lithosphere and Hydrosphere, part 14–Some water characters of Gages river system in northern India and those of hot spring in Nepal–. *Mem. Fac. Sci. Kochi Univ. ser. E, Geology*, 17; 45-56.

Mitusio, T. (1996c): Environmental change in the Kacho Plain, Kochi Prefecture. *Study on the characters of natural diasters and preventive potentialities in Kochi Prefecture. Kochi Univ.* ; 21-39.**

Mitusio, T., Igarashi, K. and Kashima, N. (1996d): Environment Geological study in West Shikoku, part 13–Quaternary environmental change along the Tonda river, Asakura Village, Ehime Prefecture–. *Res. Rep. Kochi Univ.*, 45; 47-57.**

Mitusio, T., and Igarashi, K. (1996e): Quaternary System along the Tonda river, east Tokushima Prefecture. *Res. Rep. Kochi Univ.*, 46; 38-47.**

Mitusio, T. and Kuribayashi, T. (1996f): Quaternary System along the whole Nakagawa river, Tokushima Prefecture. *Res. Rep. Kochi Univ.*, 46; 65-78.**

Mitusio, T. (1997a): Interaction between Lithosphere and Hydrosphere, part 15–Water character in the limestone Ryuga-dou Cave of Tosa-

Yamada Town, Kochi Prefecture–. *Mem. Fac. Sci. Kochi Univ. ser. E, Geology*, 17; 1-15.

Mitusio, T. and Watanabe, N. (1997b): Hydrothermal changes of Silica gels, part 24－Effect of the double salts of Ca and Mg, part 3, with special reference to chert diagenesis–. *Mem. Fac. Sci. Kochi Unniv. ser. E, Geology*, 18; 17-33.

Mitusio, T. and Igarashi, K. (1997c): Quaternary System in the northern part of Akune City, Kagoshima Prefecture. *Res. Rep. Kochi Univ.*, 46; 79-90.**

Mitusio, T. (1998a): Environmental change near Tosa bay in Quaternary age. *1998's Open Seminer of Fac. Sci. Kochi Univ.* ; 39-58.*

Mitusio, T. (1998b): Holocene (Alluvial) System in Kochi Prefecture. *Res. Rep. Kochi Univ.*, 47; 65-78.**

Mitusio, T. and Ikeno, T. (1998c): Quaternary System along the Akui river, east Tokushima Prefecture. *Res. Rep. Kochi Univ.*, 47; 38-47.**

Mitusio, T., Kanzaki, T. and Kuribayashi, T. (1998 d): Early Pleistocene Toushima Formation of the Kii Peninsula. *Res. Rep. Kochi Univ.*, 47; 38-47.**

Mitusio, T. (1999): Interaction between Lithosphere and Hydrosphere, part 16－Some water characters and Quaternary System of north Taiwan–. *Mem. Fac. Sci. Kochi Univ. ser. E, Geology,* 19; 15-22.

Nakamura, J., Mitusio, T., Kuroda, T. and Yoshikawa, O. (1972): Palynostratigraphical study, part 1–Quaternary System in Kochi Prefecture–. *Res. Rep. Kochi Univ.*, 23; 100-108.**

Nakamura, J. (1973): Late Pleistocene of Japan by Palynology. *Quat. Res.*, 12; 29-37.**

Nakazawa, K., Ichikawa, K. and Ichihara, M. (1987): Kinki District. *Geology of Japan,*; 157-162.*

Ogura, M., Mitusio, T. and Yoshida, T. (1989): Soft bed in Shikoku District. *30th Ann. Pub. Soil Eng. Shikoku Branch*; 62-83.*

Takahashi, J., Kashima, N. and Mitusio, T. (1989): Late Quaternary System near Kohnokawa, middle Iyo, Ehime Prefecture. *Mem. Fac. Educ., Ehime, Univ.*, 9; 38 -47.**

Tanabe Group Colab. Group (1984): Stratigraphy and structure of the Tanabe Group of the Kii Peninula. *Earth Sci.*, 38 (4); 249-263.**

Ueki, T., and Mitusio, T. (1998): Uplift history of the Asan Mountains, Shikoku, southwest Japan, based on stratigraphy and lithofacies of the Plio-Pleistocene Mitoyo Group. *Jour. Geol. Soc. Japan*, 104 (4); 247-267.**

Yonekura, N. (1968): Marine terrace and crustal movement in southern part of the Kii Peninsula. *Tokyo Geogr. Jour.*, 77; 1-23.**

*in Japanese **in Japanese with English abstract

Appendix

Tondagawa, 富田川 Toushima, 塔島 Kodougaoka, 古道ケ丘 Kurisugawa, 栗栖川 Akugawa, 安久川 Hokusogi, 北端 Mukouda, 向田