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The Early Pleistocene Ohkubo Formation near Ohkubo, Johen Town, Southwestern End of Ehime Prefecture –Environmental Geology of West Shikoku, part 10–

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Abstract

The Quaternary System near the Ohkuboyama dam, Johen Town, southwestern end of Ehime Prefecture along the Ohkubo river of the Sohzu river system, is newly described, as the Environmental Geology of West Shikoku. This is the Ohkubo Formation of the Early Pleistocene, once studied palynologically by Takahashi(1978), and is correlated with those in Ehime Prefecture and in Shikoku Island.

Then it also became clear that the Early Pleistocene Ohkubo Formation now exists in a small separated area, and that it was in the rather wide "Paleo-Misho lake" defined by Mitusio and Kashima(1994), however there did not occur river piracy, i.e, river route changes, that are generally found in Shikoku.

Introduction

West Shikoku including Ehime and Kochi Prefectures is the important Quaternay Geology area, because the Quaternary strata from the Early Pleistcene to Holocene are fully distributed and they are very good fields to verify the Quaternay environmental changes.

And the writers have been studying them especially in Ehime Prefecture, and this time they report the Quaternary System near Johen area, along the Ohkubo river, one tributary of the Sohzu river, southwesternend of Ehime Prefecture. And the Sohzu river flows into Misho bay facing to the Bungo straits through the Uchiumi Sea(Fig.1).

Here in this field(Fig.2), the main river is the Sohzu river system starting from Mt.Kannondake (782.2m), which runs with about 20km route length, and the Ohkubo river flows in at the junction near Kajigo of Johen Town. Misho bay which is a subsident bay with ria coasts continuing through the Uchiumi Sea to the Bungo straits.

And as for the Matsuda river system, its main tributary is called the Sasa river in Sukumo City, Kochi Prefecture, and the upper-stream of it is the Masuda river in Ipponmatsu Town, Ehime Prefecture. And the upper-stream area of the Matsuda river is called the Motokoshi river in Tsushima Town, Ehime Prefecture. On the opposite of the Motokoshi river, the Iwamatsu river flows in Tsushima Town, while a violent river piracy was taken place at Michinokawa, Miuchi, after deposition of the Early Pleistocene Yokobuki Formation reported by Mitusio and Ohta(1992), under which the Daido Formation of varved muds exist(Takahashi,1977) that will be reported later by the writers .

As for the previous studies on the Quaternary System near this field are as follows:Mizuno(1975) first mentioned on the Ohkuboyama dam and the sediments which the writers are now describing are of several ten thousands years ago. Next, Ehime Prefecture(1976) in the Iwamatsu surface geologic map of the scale of 1:50,000, reported that these varved clays were supposed to be the Quaternary sediments and the equivalent strata of the Daido Formation existing at Daido, Tsushima Town, which was reported with palynological study by Takahashi(1977), one of the writers. And also this

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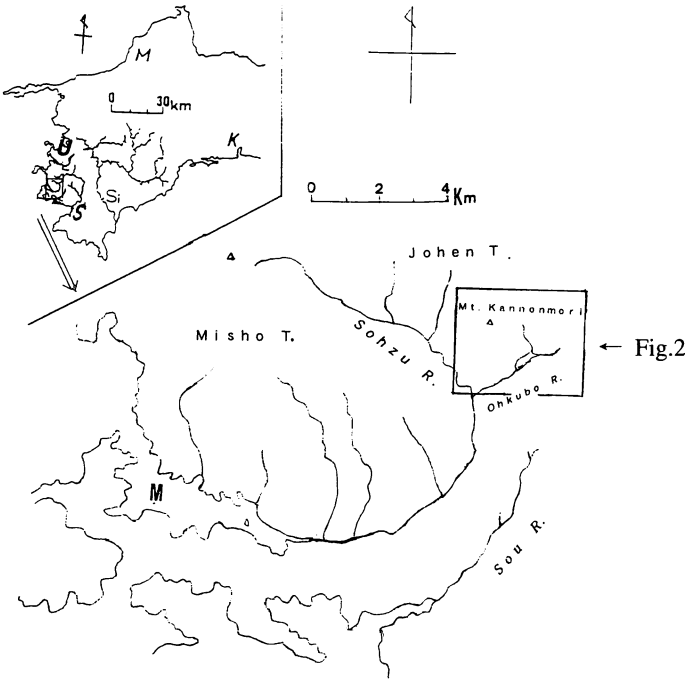

Fig.1.Index map showing the surveyed area along the Ohkubo river of the Sohzu river system in Johen Town, southwestern end of Ehime Prefecture in west Shikoku.
M, Matsuyama City *U*, Uwajima City *S*, Sukumo City, Kochi Pref. *K*,Kochi City
Si, Shimanto river system M, Misho Bay

Formation resembled closely to the Quaternary Takanoko Formation defined first by Nagai and Takahashi(1969) and redefined by Mitusio and Kashima(1994). Then Takahashi (1978) reported the palynological results and supposed as the Alluvial sediments.

After that, the writers surveyed near this area, and they dipicted this is of the Early Pleistocene and not of the Holocene age.

Here as the part 10 of their Environmental Geology of West Shokoku, the writers will describe the Quaternary sediments near the Ohkuboyama dam, Johen Town, along the Ohkubo river of the Sohzu river system. And they will describe them as the Early Pleistocene Ohkubo Formation at the lower part, on which the Ipponmatsu Formation covers unconformably(Mitusio and Kashima,1994).

And also these strata are correlated those in Ehime Prefecture and in Shikoku Island. Then it becomes clear that the Early Pleistocene strata exsist in several intramontane basins like this Ohkubo Formation, however river piracy of river route changes after deposition of the Early Pleistocene about 80ka ago, was not taken place in this field.

Outline of Topography and Geology

In order to grasp the outline of the studied area, it is needed to show the general trends of the river systems around there.

As is shown in Fig.1, the Sohzu river flows rounding clockwise with about 10km diameter, to the west of the Matsuda river system in mainly Sukumo City, Kochi Prefecture, and runs into Misho Bay, around where the ria coasts develop

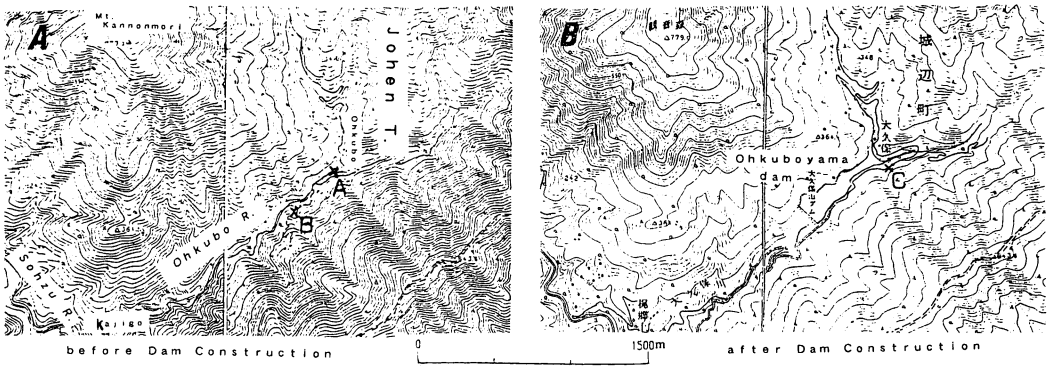

Fig.2. Topographic map comparing before and after construcion in 1979 of the Ohkuboyama dam in Johen Town, southwestern end of Ehime Prefecture.
A, before the dam construcion *B*,after the dam construcion
A, B, C; sampling localities

well. The Matsuda river starting from the northeast of Mt.Kannondake(782.2m) which exists just only 5km east of the sea coast of the Uwa Sea of Ehime Prefecture, in which the uppermost part of the river name is called Motokoshi, flows rounding clockwise with about 30km diameter, and it goes finally into Sukumo Bay, Kochi Prefecture. The Sasa river runs into the Matsuda river in Sukumo City.

The studied area is therefore along the Ohkubo river, one tributary of the Sohzu river system in Johen Town, and to sum up, the topography found in the surveyed area is mountaneous areas and very narrow Alluvial plains.

The geology forming these topography is composed by mainly the Cretaceous Simanto Super Group. And the outline of the Quaternary Geology forming the preterrace strata in this field is in ascending order as follows: The preterrace Early Pleistocene strata is the Ohkubo Fomation and the Ipponmatsu Fomation, and the Holocene strata. However,to be very sorry, the important outcrops of them, loc.A and loc.B, are sunk into the Ohkuboyama dam, that were found along the Ohkubo riverside, and only loc.C is now found after the construction of the dam in 1979. And the Alluvial plains are very narrow along the Sohzu river system and are made up of the Holocene sediments. And the Holocene sediments, however, are not defined, because there are so many strata names to avoid much confusions.

Description of the Early Pleistocene

Here the Quaternary System in ascending order is descrived in detail.

And the writers used the Mansell' soil colour chart to identify the colours of every strata, and also palynological results are re-examined to know the changes of flora and environment around this area.

The locaity maps of this area are shown in Fig.2A and Fig.2B. The former is the map before dam construction in 1979, and the latter shows that after dam construction. And their columnar sections are in Fig.3.

1) The Early Pleistocene

The Early Pleistocene Formation in this field is the Ohkubo Formation and the Ipponmatsu Formation in ascending order.

1-1) Ohkubo Formation: Early Pleistocene [pre-terrace lake sediments]

Authors:Takahashi,M., Kashima,N. and

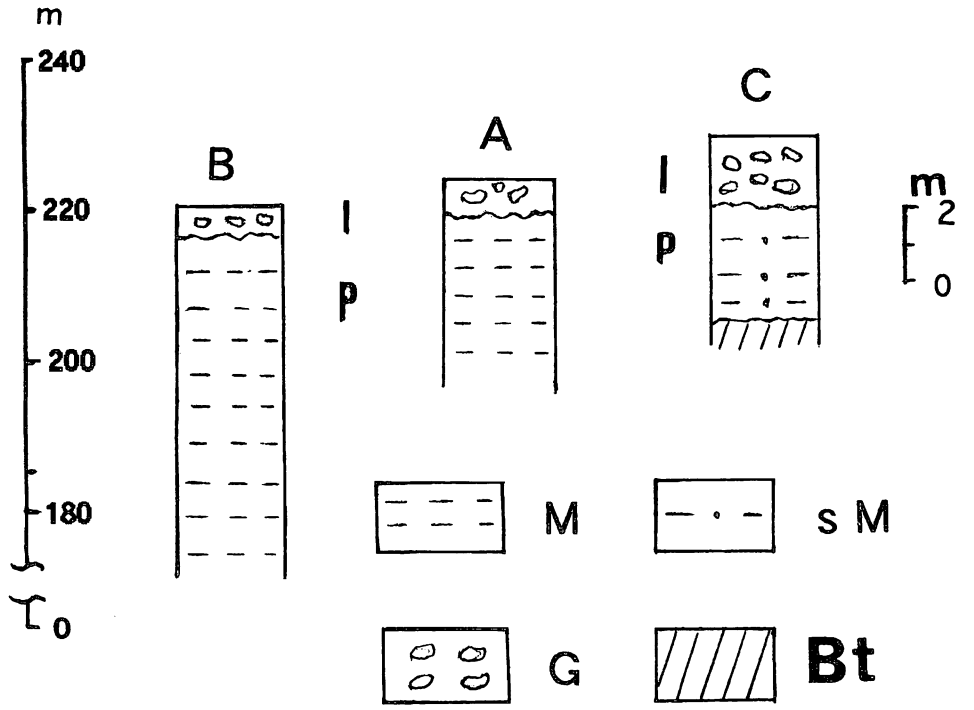

Fig.3. Columnar section of the Types of the Early Pleistocene Ohkubo Formation and Ipponmatsu Formation.
I,Ipponmatsu Formation P,Ohkubo Formation M,mud sM,sandy mud
G,gravel Bt,basements A・B・C,locality in Fig.2.

Mitusio,T.(1995)

Type locality: Near Ohkuboyama dam, Johen Town, Minamiuwa-Gun, Ehime Prefecture(loc.A and loc.B)

Distribution: type locality only

Distribution height: About 200m～220m

Thickness: About 9m+

Facies: The type locality of this Formation is defined at the Ohkuboyama dam, Johen Town, Minamiuwa-Gun, but the main outcrops are now sunk into the dam. The columnar sections in the type locality were as loc.A and loc.B of Fig.3. This Formation was chracterized by muds of varved ones. This attains about 9m+ thick. It is ill-sorted varved muds with rather compacted condition. And the colour of the mud is with bluish gray.

After the dam construction in 1979, the new locality is found as loc.C, where is by the new road side of the dam. However, this outcrop has no varve, but massive sandy mud of about 3m+ thick.

This Formation has pollen fossils to ascetain the age, and it is to be of the Early Pleistocene considering the characteristic features of the deposits as well as the pollen fossils of *Pseudotsuga* which are the extinct genus in the Middle Pleistocene by Nakamura and Yamanaka (1992), as mentioned below.

And this Formation overlays unconformably the basement rocks, and is overlain by the Ipponmatsu Formation with unconformity which can be now observed at loc.C without pollen fossils.

1-2) Ipponmatsu Formation

Ipponmatsu Formation: Early Pleistocene [pre-

terrace fanglomerates]

Authors: Mitusio,T. and Kashima,N.(1994)

Type locality: Near Nagasaki, Misho Town, Minamiuwa - Gun, Ehime Prefecture

Distribution: type locality, and its neighbouring

Distribution height: About 220m～240m

Thickness: About 10m+

Facies: The type locality of this Formation is defined near Nagasaki, Misho Town, Minamiuwa-Gun by Mitusio and Kashima(1994). The lithofacies of the type locality is chracterized by gravels, and this attains about 10m+ thick. It is ill-sorted gravels of angular ones with rather compacted condition. And the roundness and sphericity of the gravels are 0.1～0.3, and 0.5～0.7, respectively. The maximum size of the gravels is about 40cm diameter, and the predominant one is about 10～15cm diameter. The types of the gravels are occupied by predominant sandstones and a few amounts of shales. The ratio of gravel versus matrix included is 9 : 1. The colour of the gravels is mud with grayish yellow brown (10YR2/1).

The Ipponmatsu Formation in this field is the gravels which are resricted only at loc.C of the road side of the dam. They are with 20cm diameter of the maximum size, and predominant one is 3～5cm diameter with subangular to subrounded, while the Formation was once found at loc.A and loc.B, but they sunk into the Ohkuboyama dam.

This Formation has pollen fossils to ascetain the age, and it is to be of the Early Pleistocene considering the characteristic features of the lake or pond deposits. Moreover the writers recently could find out the volcanic ashes at Hana of Johen Town, then the age may be clear in future by fission track method.

And this Formation overlays unconformably the Ohkubo Formation, and is overlain by the higher terrace deposits of Kagehira Formation unconformably, which is to be descrived in the other paper.

Pollen Analysis

As for pollen analysis, many mud samples were collected in every 20cm interval to examine the flora and environmental changes. And 16 samples from loc.A and 43 from loc.B were treated by acetolysis method by Shimakura(1956). All pollen analyses were made by Takahashi(1978), and the pollen diagrams are shown in Fig.4A of loc.B and Fig.4B of loc.A.

The detailed discussion on vegetation changes should be referred to Takahashi(1978), and here the writers newly comment as follows:

The most characteristic feature of the pollen assemblages from loc.A is that *Pseudotsuga* was found. This means that this genus occured generally in the higher terrace sediments of the Middle Pleistocene, however it exists in some Alluvial plain, according as Nakamura and Yamanaka (1992) who showed the floral change in the Quaternary Period including the Pliocene age in southern Shikoku (Fig.5). Also *Pseudotsuga* was reported from the Takanoko Formation by Nagai and Takahashi (1969), and it was redifined as the Early Pleistocene by Mitusio and Kashima(1994). And *Castanopsis* or *Shiia* from Loc.A and Loc.B once at that time considered that this species only occured in the Holocene age, and therefore the Ohkubo Formation was considered as the Alluvial sediments. However, this species does not exactly exist in the Holocene age.

Then the pollen assemblage of loc.A and loc.B shows predominance of acerose or needle leaf trees such as *Abies, Tsuga* and *Picea*. And as for broad-leaf trees, *Castanopsis* or *Shiia* is abundant, and *Quecus* (*Cyclobalanopsis*) is rather abundant. However, *Fagus* is a few.

These assemblages show that the flora was coexistence of cool temperature and warm temperature. Then this flora is to be considered as the time of gradual changes from the warm temperature to the temperate climate. And the boundary of the forest at that time was lower as about 600m to 700m.

And fern spores and non-arboreal pollen are not so much, and this shows the environment aroud there was not a grassy place but a forest.

Thus, after re-examining the Ohkubo Formation the writers lead the followings: The Ohkubo Formation should be considered as the Early Pleistocene from the pollen analysis as mentioned above, as well as from the geologic features that this Formation is overlain by the Ipponmatsu

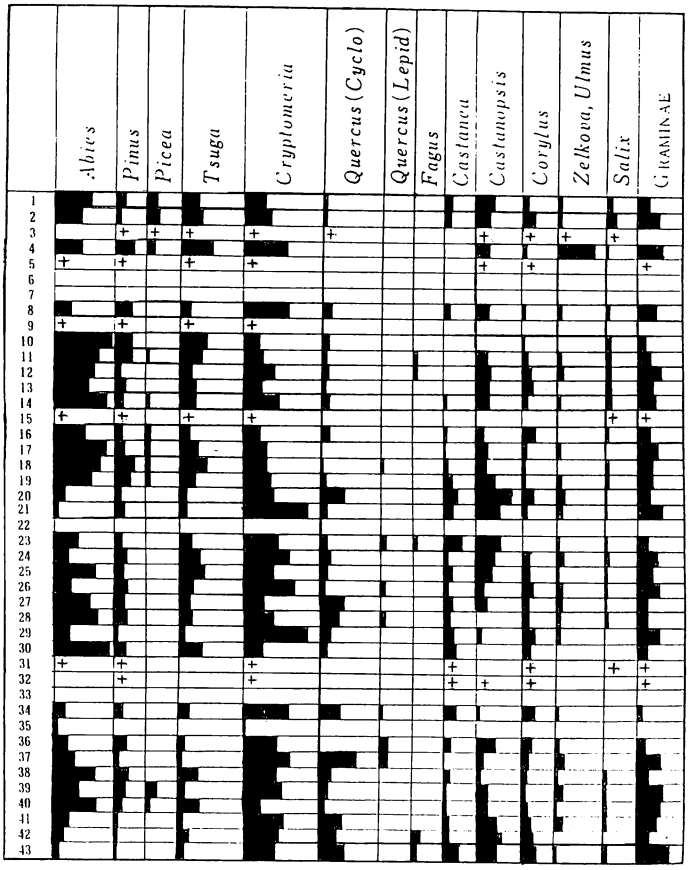

Fig.4A. Pollen diagram of the Ohkubo Formation of loc.B in Johen Town (after Takahashi ,1978).

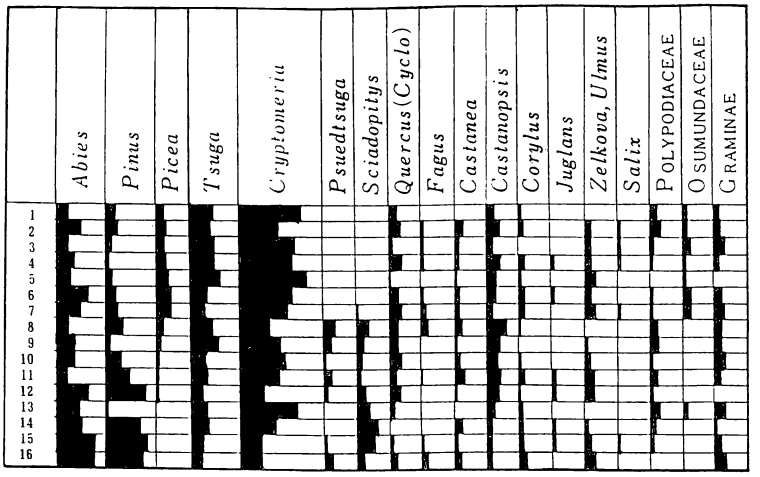

Fig.4B. Pollen diagram of the Ohkubo Formation of loc.A in Johen Town (after Takahashi ,1978).

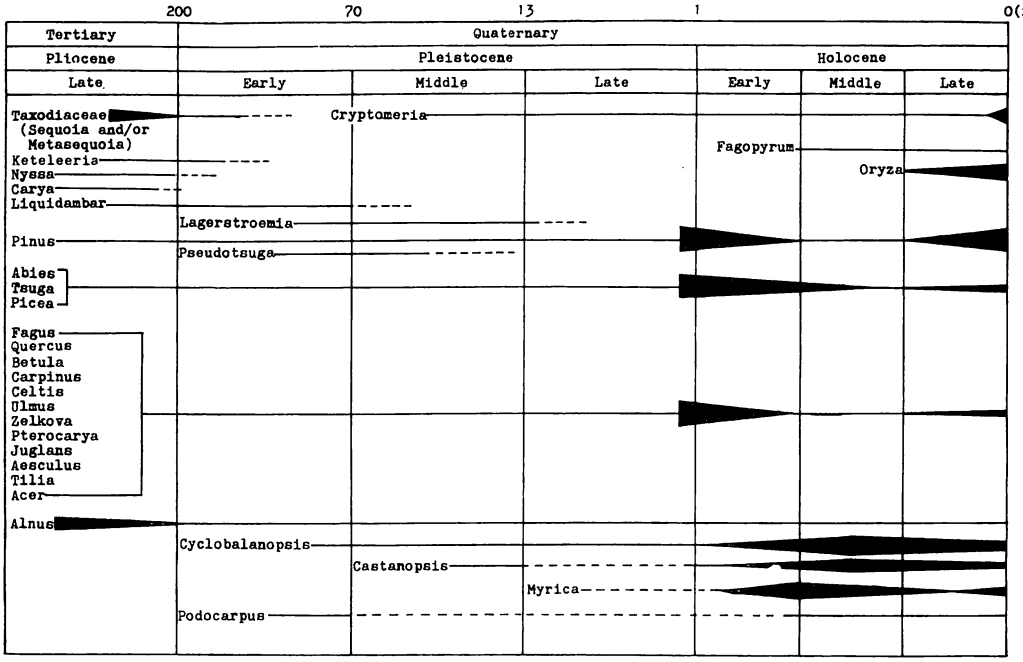

Fig.5. A schema of vegetation histry during the Quatenary Period in southern Shikoku(after Nakamura and Yamanaka,1992).

The boundary of Tertiary and Quatenary is now 170 x 10^4 ybp.

Formation of the Early Pleistocene age, and also this Ohkubo Formation has the most characteristic features of the very thin laminae of the varved muds which is not found in the Holocene sediments.

Correlation and Characteristic features of the Early Pleistocene in Shikoku

Here the writres show the correlation tables of the Quaternary strata in West Ehime Prefecture (Tab.1) and Shikoku Island(Tab.2), and they focus especially on the characteristic features of the Early Pleistocene strata.

As it is clear in Tab.1, the Early Pleistocene Ipponmatsu Formation in this field is correlated with the Yokobuki Formation along the Iwamatsu river defined by Mitusio and Ohta(1992), one part of which was once defined as Daido Formation and made pollen analysis by Takahashi(1977), as Kobayashi(1950) mentioned the fossil plants, that is existed just the opposite side over the town boundry of Tsushima and Ipponmatsu, locating at the Yokobuki valley, upper-stream area of the Iwamatsu river to the northwest of this surveyed area(see Fig.1). And this Formation is also correlatable with the Takanoko Formation(Nagai and Takahashi,1969;Mitusio and Kashima,1994) that exists along the route 197, where the river piracy was taken place. And it is also correlatable with the Mizuwakare Formation(Sangawa and Mizuno,1977;Mizuno,1980;Mitusio and Kashima, 1994) of the west of Uwajima City, where the river piracy between the rivers of Suga and Nara, a tributary of the Hiromi river system, was also taken place. And it is also correlatable with the Okinono Formation in Hiromi Town (Mitusio and Kashima, 1994).

Far north of this field, along the long and narrow

Tab.1.Correlation Table of the Quaternary System in West Ehime Prefecture.

AGE			This area	Tsushima Town Nan-yo	Hiromi r. main stream	Tributary Ohjiku r. Nara r.	Sada-Misaki Misaki T	Sada-Misaki Seto T.	Futami Town Chuyo	Matsuyama Plain
Q	HOLOCENE		Alluvial							
U		L								Lower TD I
A		A								
T	P	T	-------	Kiyoshige F	Kawakami F	Nakakumi F	------	------	-----	Lower TD II
E	L	E								
	E	M	Hiro-oka F	Iwamatsukawa F	Konishinono F	Ohata F	Uchino-*ura F	Kozaki F*	Kono-*kawa F	Middle TD
R	I	I								
	S	D								
N	T	D	Kagehira F**	Kami-imochi F**	Nobu-kawa F**	Seizui F**	Mino-koshi F**	Fusumahana F**	Futami F**	Higher TD**
	O	L								
A	C	E						Ooe F**		
	E									
R	N	E	↑	↑	↑	↑				
	E	A	Ippon-matsu F	Yokobuki F	Okinono F					
Y		R				Mizu-wakare F	------	Agekura F	------	Yakura F
		L								
		Y	Ohkubo F	Daido F	Takanoko F					Gunchu F

Symbols : *marine formation, **corroded gravel F, Formation TD, terrace deposits .

Sada peninsula, the Agekura Formation (Kashima *et al.*,1993) and also the Gunchu Formation(Takahashi *et al.*1990; Kashima *et al.*,1991a, 1991b) at the Mori coast, Iyo City (Kashima *et al.*,1980;1991a) facing to the Bungo-suidostraits are correlated with the Ipponmatsu Formation in this field. Around Matsuyama City, the Old Fan deposits such as the Yakura Formation (Takahashi and Kashima,1985) is also correlated with the Ipponmatsu Formation.

As for the correlation of the Early Pleistocene strata in Shikoku, they already mentioned before, and the addition after them is as follows: Just southeast of this field, in Sukumo City, the Mukuzu Formation(see Fig.1) is correlated with this Formation(Mitusio and Furukawa,1988;Mitusio and Kagami,1992). And along the Shimanto river system the Satokawa Formation(Mitusio and Noda,1991;Mitusio and Kagami,1992) and the newly found Oigawa Formation(Mitusio and Noda,1994) are correlatable with the Ipponmatsu Formation in this field.

Next, as for the Higher terrace strata near this field, the Kagehira Formation is correlated with the Kami-imochi Formation along the Iwamatsu river(Mitusio and Ohta,1992). And this is also correlatable with the Formations of Nobukawa and Seizui along the Hiromi river(Mitusio and Kashima,1994), the Minokoshi Formation at Misaki Town, western end of the Sada peninsula (Kashima *et al.*,1991b) and the Formations of Ooe and Fusumahana at the centeral part of the same peninsula(Kashima *et al.*,1993). And this is correlated with the Futami Formation near Futami

Tab.2.Correlation Table of the Main Quaternary System in Shikoku District.

AGE			Ehime Prefecture	Kochi Prefecture	Kagawa Prefecture	Tokushima Prefecture
Q	HOLO-CENE		Alluvial	Alluvial	Alluvial	Alluvial
U		L A T E		Furumachi F		Low TD II
A			Kawakami F	Ukibuchi F	Low TD	Hiruma F
T	P L I S T O C E N E	M I D D L E	Hiro-oka F	Ashizuri F* Hirano F*	Mid TD	Higashi-kawahara F Handa F
E			Kagehira** F	Hiromi F**	High TD**	Nakanishi F**
R		E A R L Y	Ipponmatsu F	↑	↑	↑
N				Satokawa F		D O C H U G Takaseta-nikawa F
A			Ohkubo F	Oigawa F	Highest TD	
R			↑		↑	
Y			Gunchu F		Mitoyo G	Nakaue F
T E R.	PO LC I E.					↑ Moriyama F

* marine formation ** corroded gravel F, Formation TD, terrace deposits G,Group

Town along the Bungo suido straits (Takahashi *et al.*,1990). Around Matsuyama City, the Higher terrace deposits are the equivalent of the Kagehira Formation.

Finally, the Middle terrace deposits of the Hiro-oka Formation is correlated with the Iwamatsukawa Formation along the Iwamatsu river (Mitusio and Ohta,1992), and the Formations of Konishinono and Ohata along the Hiromi river(Mitusio and Kashima,1994), as well as the Kubokawa Formation of the Shimanto river (Mitusio and Yamashita,1990;Mitusio and Noda,1991). And the Uchinoura Formation (Kashima *et al.*,1991b) and the Kozaki Formation (Kashima *et al.*,1993) of the Sada peninsula. And this is correlated with the Kohnokawa Formation near Futami Town (Takahashi *et al.*,1990). Around Matsuyama City, the Middle terrace deposits (Kashima *et al.*,1980) is correlatable with this Hiro-oka Formation.

And there are no lower teraces near this field.

Then the discussion should be done focused on the most characteristic features of the Early Pleistocene strata in west Shikoku. They are already discussed before, and it should be referred to Mitusio and Kashima(1994).

So as to say, the Early Pleistocene strata exsist in two types: that is 1) Near the sea coast in considerably large scale, and 2) In several intramontane basins in small scale.

The former is as follows: the Ipponmatsu Formation in this field, the Mukuzu Formation in Sukumo City, and such as the Iburi Formation of the Sada Group around the Ashizuri Peninsula (Mitusio and Furukawa;1977,1988;Mitusio and Nishikawa,1991) and the Aki Formation (Mitusio and Yoshikawa, 1977) and the Nahari Formation of the Geisei Group(Kagami *et al*,1992;1993) in the northeastern coastal area of Tosa Bay of Kochi Prefecture (Mitusio, 1991; Mitusio and Kagami, 1992). And in Tokushima and Kagawa Prefectures there are the Formations of the Dochu Group (Mitusio, *et al.*,1991;Mitusio and Shima, 1993;Mitusio and Hashimoto, 1994) and the Mitoyo Group (Mitusio and Furukawa,1985 ;Mitusio and Kagami,1992).

The latter is that such as the Yokobuki Formation along the Iwamatsu river, the Formations of Okinono, Takanoko and Mizuwakare along the Hiromi river, the Formations of Satokawa and Oigawa in the middle stream area of the Shimanto river (Mitusio and Kagami, 1992;Mitusio and Noda,1994), the Mama Formation (Mitusio and Yamanaka, 1985) in Kochi City, and the Kubo–Nurui Formation along the Kami Nirou river of the Monobe river (Mitusio, 1992;Mitusio and Kawaguchi,1993).

These facts mean as follows: Before the Ipponmatsu Formation deposited around here, and ancient lake/pond named the paleo-Misho lake/pond had existed in considerable large scale, and this lake/pond had been buried by debris flows circumferring there as the Ipponmatsu Formation. And after uplift movements around there, the Sohzu river and the Masuda river have been separated each other, and there were changes to make river piracy at the age between the Early and the Middle of Pleistocene, its absolute age may be considered as about 80ka ago (Kagami *et al.*,1992). And one river started to flow toward west and became the Sohzu river. The southern part became one tributary of the Masuda river. And also causing this uplift movement, the Ipponmatsu Formation in this field and the Mukuzu Formation in Sukumo City were separated, and the southern part of this area became a dividing ridge between the boundaries of the Prefectures of Ehime and Kochi, as is seen at present time(see Fig.1).

And nowadays after the piracy between the rivers of Sohzu and Masuda, these rivers have been flowing there, and deposition of the Higher and Middle terraces deposits was taken place along each river. On the other hand, those terrace deposits were thought to be sunk into Sukumo bay, and only the preterrace Mukuzu Formation can be observed around Sukumo bay.

These phenomena of river piracy also occurred near between the rivers of Hiromi and Kurose, and between those of Suga and Nara, as reported before(Mitusio and Kashima,1994). And also the Shimanto river, along which deposition of the Formations of Satokawa and Oigawa was taken place as fanglomerates filling up an ancient pond/lake in the Early Pleistocene age, changed its route toward east like today. The Niyodo river flowing eastward but changing southward at Ino town, central Kochi Prefecture, was flowing more eastward to Kochi City, and deposited the Mama Formation of the Early Pleistocene, and moreover the Joyama Formation of the Higher terrace and also the Nosayama Formation of the Middle one. On the contrary, the Monobe river has been flowing near the present river route, and this has been existed as "the Monobe River Barrier" since the Early Pleistocene age up to nowadays, as the species of *Crysanthemum* differ.

Concluding Remarks

The Quaternary Formations distributing near the Johen area is summarized as follows, and the correlation tables are made(Tab.1 · 2):

1.The newly defined sediments are the Formations of Ohkubo and Ipponmatsu of the Early Pleistocene.

2.These Formations are correlated with those of the West Shikoku and also in the whole Shikoku Island.

3.The pollen assemblages from two places of the Ohkubo Formation show the Early Pleistocene age especially from *Pseudotsuga* genus.

4.The most characteristic features in Shikoku Island are:The Early Pleistocene strata exist in two types: 1) near the sea coasts, and 2) in several intramontane basins. And after deposition of these

Formations(about 80ka ago) piracy of river route changes was taken place.

The other Quaternary System in Shikoku are to be reported on the other chance.

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*in Japanese **in Japanese with English abstract

Appendix:
Misho, 御荘　Sohzu, 僧都　Hiro-oka, 広岡
Kagehira, 影平　Ipponmatsu, 一本松