MEMOIRS OF THE COLLEGE OF SCIENCE, UNIVERSITY OF KYOTO, SERIES B,
Vol. XXX, No. 2 Geology and Mineralogy, Article 4, 1963

Stratigraphy of the Paleo-Biwa Group and the Paleogeography of Lake Biwa with Special Reference to the Origin of the Endemic Species in Lake Biwa

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(Received April 15, 1963)

Abstract

Post-Pliocene sediments around Lake Biwa are divided into Paleo-Biwa group, terrace deposits and Alluvial deposits, and Paleo-Biwa group is subdivided into 11 beds by characteristic 10 tuffs. On the other hand, many kinds of fossils obtained from these deposits have important bearing on the origin of endemic species of this lake when checking their stratigraphical occurrences. Based on these facts, the writer has established the following 3 paleolimnological stages of Paleo-Biwa Lake; "Old Closed Lake", "Open Lake" and "Young Closed Lake".

The first stage of later Pliocene age has provided the chance for the immigration of the fauna and flora of continental element to the lake and the second stage of earliest Pleistocene has prepared a quite different condition for the marine dwellers. The third stage is considered to be the age of land-locking of the aforementioned biota, which has continued until this day.

Introduction

Recently, a vast amount of information about the ancient Lake Biwa was obtained by the writer through the investigation of the Paleo-Biwa group and the terrace deposists in the Oomi-Iga basin, Central Japan. As a result, the geohistory of Lake Biwa has become almost evident, and several interesting facts obtained seem to have important bearing on the relation between the basin development of Lake Biwa and the origin of endemic species. In this paper, the writer will describe the geological data of the post-Pliocene sediments in this district and then discuss the paleogeographical problems concerning this lake, with special reference to the origin of the endemic species, by summarizing the knowledge hitherto obtained.

Among many previous works, the investigation of plant-remains by S. MIKI and the topographical survey by A. KOTANI have been most useful for the writer's work.

The writer wishes to express his thanks to Dr. M. ITIHARA for many

valuable suggestions and encouragement given throughout the present study. The writer is also indebted to Prof. S. MATSUSHITA, Prof. K. NAKAZAWA and Dr. S. ISHIDA for their kind information and discussion about the present work.

Part 1. General description

I. Geological outline of the Biwa basin

The Oomi-Iga basin is classified geologically into the follwing 4 groups:

Alluvial deposits
Terrace deposits
Paleo-Biwa group
Basement complex

The basement complex contains all kinds of pre-Pliocene rocks such as Paleozoic rocks, granitic rocks, quartz porphyry and Miocene rocks, constituting the foundation of the basin and the surrounding mountains. The Paleo-Biwa group comprises loose sediments made of clays, silts, sands and gravels, which are all lacustrine in origin. These sediments now develop forming mainly hilly lands, 200–300 m in height. The terrace deposits, consisting predominantly of gravels and sands, can be seen as a blanket on the margin of the hills. The Alluvial deposits consist of clays, sands, and gravels having plant remains, all of which have been deposited in the present lake and on flood plains.

II. Paleo-Biwa group

1. Stratigraphy

The Paleo-Biwa group of about 500 m in thickness shows a cycle of sedimentation of non-marine strata. The cycle begins with the sands of the Iga formation which intercalates many lignite seams. The Iga formation is succeeded by the clayey strata of the Kôka formation and the latter passes transitionally upward to the sand and gravel rich formation of the Katata again. The relation of these three formations is stratigraphically conformable. There are many tuff beds in the Paleo-Biwa group. Some of them are so characteristic and so continuous in the area that they are useful as key bed in subdividing the group. In this paper, 10 conspicuous tuffs are selected and the sediments are divided into 11 beds from B_1 to B_{11} in ascending order. (In the geological map of 1/200,000 they are abbreviated into 6 parts owing to the small map scale.) The boundaries between the

Table 1 Stratigraphy of the Paleo-Biwa group

Group	Formation	West of the Lake	Key bed (tuff)	East of the Lake	Facies
Paleo-Biwa Group	Katata Formation	B 11 50 m		?	sand & gravel dominant
			Kamiôgi tuff		
		B 10 30 m		B 10 40 m ?	
			Oono tuff		
		B 9 20 m		B 9 40 m	
			Ikenowaki tuff		
		B 8 ?		B 8 40 m	
			Hara tuff		
		?		B 7 20 m+	
			Kono tuff		
				B 6 10–15 m	
			Mushono tuff		
	Koka Formation			B 5 40 m	clay dominant
			Kosaji tuff		
				B 4 30 m	
			Hozoin tuff		
				B 3 30 m	
			Ichiuno tuff		
				B 2 20 m	
			Yubune tuff		
	Iga For.			B 1 180 m	sand dominant

formations are also drawn by tuff, even if the tuff beds cut the lithofacies diagonally.

All the sediments which are found overlying the Paleo-Biwa group are the terrace and the Alluvial deposits. This may indicate the fact that the younger deposits which can be correlated to the Manchidani formation in the Osaka area do not exist in the basin.

2. Key beds

10 sheets of tuff are picked out as key bed. Almost all of them are vitric and finely grained. However, they have their own features distinguishable from each other and can be used sufficiently as key bed. The microscopic and megascopic characteristics and the physical appearance of each tuff are as follows.

Yubune tuff (B_1–B_2)

This is so characteristic that it has the popular local name of "Nuka". It is widely continuous, and the lateral change is slight owing to its intercalation in thick clay; 50–70 cm in thickness and always consists of two parts; upper coarse-grained part and lower fine-grained part. The lower fine-grained part is yellowish gray in color and has a peculiar appearance on the weathered outcrops. That is, many cracks develop crosswise on the weathered surface, and along the cracks a lot of small (about 1 cm^3) cubic fragments are splintered off and piled up around the foot of the outcrops. The local name "Nuka" has derived from these phenomena.

The upper coarse-grained part is gray in color and homogeneous in lithofacies. This part shows the following composition under the microscope; clayey matrix is quite dominant, glass and quartz, 0.2–0.3 mm in diameters are scarce and little hypersthene is found. Type locality of this tuff is Higashiyubune (Loc. 85).

Ichiuno tuff (B_2–B_3)

This is the only crystalline dacite tuff found in the Paleo-Biwa group, and one of the most useful key beds. It is greenish gray to dark green in color, and yellowish dark gray when weathered; usually 15 cm thick and 20 cm in maximum; widely continuous, and the lateral change is slight. The full succession is 3 cm greenish gray fine-grained part, 7 cm greenish gray medium-grained part containing dominant color minerals and 3 cm greenish fine-grained part in descending order. Under the microscope, the following materials are found in the middle coarse-grained part: Abundant quartz, rare glass, feldspar and hornblende. Type locality is the pass (1 kmW of Loc. 48) between Kamimasugi and Higashiyubune.

Hozoin tuff (B_3–B_4)

This grayish white, medium- to fine-grained tuff is not so remarkable in character. But it is used as a key bed for its good continuity in the thick clay. The average thickness is 10 cm. Occasionally, this is divided into two seams by the intercalation of a clay lens, a few meters thick. Abundant glass, rare quartz and very scarce hornblende are found under the microscope. Type locality is Jimpo (Loc. 74).

Kosaji tuff (B_4–B_5)

40 cm in average thickness. Well continuous, consisting of three layers; 10 cm yellowish gray, fine-grained top layer, 5 cm purplish gray, fine-grained middle part and 25 cm purplish gray, coarse-grained basal part. In particular the thick basal layer is marked with dark brown spots, which are very useful as a key. In the coarse-grained basal part, abundant glass and rare quartz, feldspar and hornblende are found. Type locality is Nishide (1 km NE of Loc. 74).

Mushono tuff (B_5–B_6)

Not well continuous, but has a characteristic physical appearance and is one of the most useful key beds. Consists of two parts; the upper coarse-grained, homogeneous part and the lower fine-grained, peculiarly stratified part. Though a tuff of 80–120 cm in average thickness occasionally goes laterally over into a thick drift lens (7 m in thickness) or a thinned down seam, this quite characteristic stratification can always be recognized. Under the microscope, glass is dominant and quartz, feldspar and color mineral are rarely found. Type locality is Hara (Loc. 68) and the drift is seen at Mushono (near Loc. 71).

Kono tuff (B_6–B_7)

Not so continuous but has a rather distinct physical appearance as follows; 15 cm brown clayey top part, 10 cm brownish gray, finely stratified middle part and 10 cm reddish brown, coarse-grained basal part. The ratio of the parts is variable but the brownish color is always useful as a common mark. The thickness which is on an average 40 cm at Hino hill decreases rapidly towards the west. It is therefore rather difficult to pursue this key bed in other areas. Under the microscope, the following composition is recognized at the basal part. Fresh or half devitrified glass is common, quartz and hornblende are also found in some degree. Pyroxene is scarcely found. Type locality is Kono (Loc. 53).

Hara tuff (B_7–B_8)

This homogeneous white tuff is not continuous and has no peculiar physical appearance. But the weathered parts occasionally show pinkish color, which is the only mark. Average thickness at Hino hill and the east half of the Minakuchi hill is 30–50 cm, but decreases towards the west. At Kusatsu hill, the thin layer is found only in a limited area. Abundant glass, common quartz, rare feldspar and hypersthene are found. Type locality is Hara (2 km SE of Loc. 25).

Ikenowaki tuff (B_8–B_9)

This might be one of the two tuffs which are found on both sides of Lake Biwa; western Katata hill and eastern Kusatsu, Hino and other hills. But some doubts still remain as to its identification, especially at Katata.

In spite of this, this tuff is regarded as a useful key bed, having a somewhat remarkable physical appearance and wide distribution. It consists of the pinkish brown, clayey upper part and the pale brown, pumiceous, coarse-grained lower part with remarkable dark brown spots. The thickness varies from 20 cm to 80 cm. Under the microscope, very abundant glass fragments, rare quartz, feldspar and hornblende are found. Type locality is Ikenowaki (Loc. 25).

Oono tuff (B_9–B_{10})

This is the only distinct key bed which is found on both sides of the Lake. The tuff is not so well continuous but has a very remarkable appearance quite similar to that of the so-called "Pink tuff" in the Osaka group. The "Pink tuff" is always distinguished from the rest very easily by its typical appearance, though its thickness varies from 0 to 100 cm. And the writer considers this tuff to be the "Pink tuff" itself. Under the microscope, glass is dominant, quartz and feldspar are rare, and color minerals represented by hypersthene are very scarce. Type localities are Kitawaki (Loc. 22) on the east and Oono (Loc. 14) on the west of the Lake.

Sakawa tuff (intercalated in B_{10})

This has been recognized only at Kataka hill, and is not treated as key bed dividing the formation in the map but useful as a supplementary key bed owing to its distinct characters as follows; pure white, fine-grained tuff with a thin basal seam containing much biotite crystal. Average thickness is 2–4 cm and the biotite bearing basal seam is 0.5 cm. The continuity is comparatively good in spite of its small thickness.

Kamiôgi tuff (B_{10}–B_{11})

This is found only at Katata hill. Not well continuous, and lateral change is surprisingly great. For instance, the tuff found at Kisengawa (near Loc. 17) is 4 m thick and represented by an alternation of the brownish gray, medium-grained part and the subordinate purplish brown, fine-grained part. On the other hand, a similar tuff found at the western margin of the hill near the Hiei range is 3–7 cm thick and brownish gray, medium-grained, and homogeneous. The lateral change is therefore so great that these tuffs seem to belong to different horizons. But they are considered to be the same tuff, for the reason that there are many intermediate types such as the 30 cm thick stratified tuff at Kamiogi (center of Loc. 12 & Loc. 13) and 50 cm coarse tuff at Kurihara (2 kw W of Loc. 17). Under the microscope, glass is abundant, and quartz, feldspar, augite and hypersthene are scarce.

In any way, this tuff looks somewhat like the so-called "Azuki tuff", in its microscopic character and stratigraphical horizon.

3. Lithofacies

Iga formation

B_1 bed

The sediments which fill up the uneven basement at the beginning of the series consist of various components; predominant sands and silts, with subordinate gravels, "Kibushi" clay (coaly clay), "Gairome" clay (clay with granitic granules), ordinary clay, lignites and tuffs. Till now, some efforts have been made to classify this thick bed, but the subdivision has been quite meaningless stratigraphically, because the sediments have no regularity both horizontally and vertically, and moreover the tuffs and other components have no remarkable characteristics. Consequently, the former subdivisions have never had any meaning except showing the distribution of the sediments on the present earth surface. In fact, the bed is made up of many lenses accumulated irregularly. After all, the only fact which has been hitherto made clear is as following; all over the area, the under clay consisting mainly of "Gairome" and "Kibushi" clay with worse sorted sands are most prominant, and the so-called basal and marginal conglomerates are not common except at the southern foot of the Shigaraki plateau. The B_1 bed can be seen only in the Iga basin and its vicinity, but judging from the boring data obtained near Hino, it is supposed to stretch to a farther north area. Also another boring datum shows the thickness of the B_1 bed to be 180 m at Ueno City. This may be the maximum thickness of this bed.

Koka formation

B_2 bed

20–30 m in thickness. Consists of widely continuous clay with a few sand lenses. The clay abuts directly upon the granite in some places.

B_3 bed

25–35 m in thickness. There is no characteristic difference from B_2 in lithofacies. Consists of clay with a few sand lenses. Lateral change is generally slight with the exception of the local thickening of sand lens at Ômitobashi (Loc. 73). In the west, the clay abuts upon the Shigaraki granite mass, but in the east the clay goes laterally over into the sands and comes into contact with the basement by faults.

B_4 bed

18–30 m in thickness. Quite similar to the B_3 in lithofacies.

B_5 bed

Clay with sand lenses, which are similar to those of the B_4. But the intercalated sands become more pronounced toward the top and are marked by the plant-bearing sandy silt at its uppermost horizon. This plant-bearing horizon goes laterally over into the Kamikomazuki coal mine (2 km ENE of Loc. 60), where a few sheets of approximately 60 cm thick lignite beds are found.

Katata formation

B_6 bed

10–25 m in thickness. Upper half of the B_5 gradually transforms upward into an alternation of sands and silts, which is named the B_6. Sands and silts of lenticular shape are rather well sorted and contain no coarse materials in the central part of the basin, but change laterally into gravel rich facies near the margin. For instance, at Sasao Toge pass (directly east of the Kamikomazuki coal mine, or 2 km NE of Loc. 60), cobbles and pebbles cemented tightly with clayey matrix abut upon the Paleozoic basement.

B_7 bed

20 m+ in thickness. Lithofacies is similar to that of the B_6, but sands are larger in quantity and the lateral change is great. Marginal part where gravels are dominant is also found near the Suzuka range. Coaly silts are occasionally intercalated, where remarkable plant remains have been obtained.

B_8 bed

The distribution extends on both sides of the Lake.

(East of the Lake)

Sands and silts are main components but coarse material is more noticeable than in the B_7 and the lateral change is also more pronounced. Alternations go over laterally into gravel-rich strata towards the eastern border, where boulders over 40 cm in diameter are found in silt and sand lenses. Thickness increases also towards the east from less than 20 m at Shimoda (near Loc. 61) to 40 m at Hino Hill.

(West of the Lake)

The identification of the Ikenowaki tuff (B_8-B_9) at Katata hill is inaccurate, so there are some doubts as to the existence of the B_8 bed at this area. But the possibility of existence is very large, judging from the thickness of the sediments and the physical appearance of the tuff as mentioned in the previous chapter.

If the lowest tuff at Katata is to be regarded as the Ikenowaki, the lowest portion referable to the B_8 can be said to be silt- and clay-rich alternation with subordinate sands. This lithofacies looks like that of Taga hill.

B_9 bed

Distributed on both sides of the Lake with quite different appearance.

(East) 40 m±. Consists of gravels intercalating sands and silts. The transition from the alternation of the B_8 to the gravels of the B_9 is rapid, but no sign of disconformity is found, and the relation between the two beds is quite conformable. Gravels of 3-10 cm in diameter are common in the middle and lower part, but finer materials are found to be more pronounced toward the upper part. Rather fresh and round gravels are composed mainly of Paleozoic rocks with subordinate granite and porphyritic materials.

(West) If the above-mentioned supposition as to the Ikenowaki tuff is to be admitted, the B_9 at Katata may be as follows: 5-20 m in thickness, which is comparatively smaller than that of the east, cosisits of alternation of silts and sands without any coarse materials. Gravels and pebbles are rarely found even in the outcrops nearest the basement.

B_{10} bed

Distributed at Yokaichi hill in the east and at Kataka hill in the west.

(East) Consists of many lenses of silt, sand and gravel. The facies is similar to that of the upper part of the B_9. Thickness is unknown owing to the undiscovery of the Kamiôgi tuff (upper boundary of the B_{10}). However, if all the sediments lying on the B_9 are regarded as the B_{10}, they amount to 40 m in thickness.

(West) 30 m±. Lithofacies changes laterally greatly, for instance, dominant silts at Kitahama (Near Loc. 17), pebbles and gravels at Mukaizaiji (Loc. 15) and the fossil forest at Shimoryuge (center of Loc. 15 & 17). The fossil forest is represented by carbonized wood 50 cm thick which have taken root in the clayey matrix intercalated between the ill sorted sand and silt strata with pebbles. The horizon of the fossil forest is in the middle of upper part of the bed. Distinct indicators of disconformity are found neither above nor beneath the fossil bed, in spite of the frequent lateral change.

B_{11} bed

Distributed only at Kataka hill. Lateral change is extreme and the sediments have their own features according to the place of deposition.

(Near the backland) 40 m+. Consists of exclusively dominant gravels with few sands and silts. Gravels are fresh, round and 3–10 cm in diameter.

(Along the lake-side) 20 m+. Sands and silts with pebbles occasionally show a distinct cross bedding exactly like the delta front as shown in Fig. 1. Erosional phenomena of small scale are frequently found and many wedge-shaped sands and silts with their tips turning landwards develop directly above these erosion surfaces. A typical cross-bedding is seen at Ono (2 km SE of Loc. 16) and at Takashiro (1.5 km NE of Loc. 16).

(Intermediate part) Well-stratified and rather well-sorted sands and silts develop dominantly.

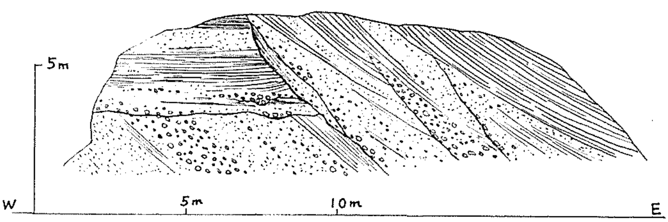


Fig. 1. B_{11} bed showing the scour and fill structure.

4. Fossils

Many kinds of fossil have hitherto been known in this area. Especially the plant remains which S. Miki has reported are excellent. These fossils and their related strata are very important in discussing the development of the basin. The writer has therefore criticized the stratigraphical horizons of these fossil-bearing beds, checking their geological occurrences. The results are tabulated below.

5. Geological structure

The Oomi basin is a land cauldron geostructurally. It is bounded by a large number of thrusts which are divided into three characteristic groups; the group having the trend of the Hira range (H_{1-3}), the group having the Suzuka trend (Su_{1-6}) and that related to the Shigaraki granite mass (Sh_{1-10}),

Table 2 Stratigraphical occurrence of plant remains

Remains	Stratigraphical horizon																				
	B_1				B_2	B_4	B_5	B_6		B_7			B_8			B_9	B_{10}	B_{11}	B		
	i	ii	iii	iv				i	ii	i	ii	iii	i	ii	iii				i	ii	iii
Cephalotaxus drupacea																○					
Abies hirsuta										○											
homolepis										○											
sp.						○										○					
Picea bicolar										○											
koribai												○									
koyamai										○											
sp.						○															
Pinus fujiii			○																	○	
koraiensis										○											
thunbergii																○			○		
parviflora										○											
Pseudolarix kaempferi												○	○							○	
Pseudotsuga subrotunda													○								
japonica													○								
sp.												○									
Tsuga rotundata						○							○								
sieboldii										○						○					
diversifolia										○											
Cunninghamia sp.											○										○
Cryptomeria japonica																○					
Glyptostrobus pensilis	○	○	○	○			○	○			○	○	○	○						○	
Metasequoia disticha	○		○		○		○	○	○		○	○	○	○	○				○	○	○
Sequoia sempervirens	○	○	○	○			○	○				○		○						○	○
Chamaecyparis obtusa						○				○											
pisifera												○				○					○
Thuja standishii						○				○						○					
Juglans cinerea											○		○		○						
Pterocarya multistriata													○	○							
Alnus japonica			○		○		○					○				○		○			
Fagus crenata																	○				
hayatae			○	○												○					
microcarpa																	○				
Quercus gilva																○					
crispula										○											
Zelkova ungeri																○					
Brasenia purpurea			○																		
Hamamelis parrotioides			○																		
Liquidambar formosana									○												
Sapium sebiferum									○							○	○	○			
Berchemia racemosa			○													○					
Paliurus nipponicus			○													○		○	○		
Nyssa pachycarpa	○	○																			
sylvatica	○		○					○													
rugosa	○																				
Styrax japonica					○		○		○			○									

Table 3 Stratigraphical occurrence of molluscs

Remains	Stratigraphical horizon										
	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8	B_9	B_{10}	B_{11}
Lanceolaria oxyrhyncha				○					○		
Unio biwae	○								○		
Unio sp.				○	○				○		
Cristaria plicata spatiosa			○						○		
Cristaria sp.		○						○	○		
Anodonta sp.	○	○	○	○	○			○	○		
Corbicula sp.				○	○				○		
Viviparus longispira	○	○							○		
Viviparus sp.				○					○		

Table 4 Stratigraphical occurrence of elephants

Remains	Stratigraphical horizon										
	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8	B_9	B_{10}	B_{11}
Stegodon orientalis										?	
Stegodon ? sp.	○										
Elephas (*Archidiskodon*) *paramammonteus*									○		
Elephas (*Archidiskodon*) *paramammonteus* ?										?	

Plants

Bed	Locality	Geological occurrence	Reporter
B_1-i	Tawara, Nabari City (3 Km NW of Loc. 99)		S. Miki 1956
B_1-ii	Tsukigase, (5 Km W of Loc. 98)	Lignite seam	" 1948
B_1-iii	Shidatani, Shimagahara Vill. (3 Km N of Loc. 97)	Coaly clay	" 1948
B_1-iv	Kamitomoo, Ayama Vill. (1 Km NE of Loc. 87)	Lignite seam	" 1948, 1957
B_2	Kamiiso, Konan Town (Loc. 82)	Coaly part in the silty sands	*
B_4	Iwamuro, Koka (2 Km NE of Loc. 76)		S. Miki 1957
B_5	Stream bed of the Somakawa (2 Km NW of Loc. 71)	Lignite seam in silt	" 1948
B_6-i	East of Kaikake, Hino (2 Km SE of Loc. 54)	Lignite bed	" 1956
B_6-ii	Bessho, Hino (2 Km N of Loc. 68)	Coaly seam in the sands and silts	*

Bed	Locality	Geological occurrence	Reporter
B_7-i	Kozuhata, Egenji (2 Km E of Loc. 25)	Coaly seam in the pebbles bearing silts	S. MIKI 1956
B_7-ii	"	Clayey part just beneath the B_7-3	" 1956
B_7-iii	Mikumo, Kosei (3 Km S of Loc. 63)	Lignite bed	" 1948, 1957
B_8-i	Nishidera, Ishibe (1 Km SE of Loc. 45)	Lignite bed	" 1948, 1957
B_8-ii	Shide, Taga (SE of Loc. 31)	Lignite bed	" 1948, 1952, 1957
B_8-iii	Hara, Hino (2 Km S of Loc. 25)		" 1955
B_9	Kitamuki, Katata		" 1938, 1948, 1957
B_{10}	Sagawa, Katata (1 Km NW of Loc. 14)	Coaly seam in the sands with pebbles	*
B_{11}	Mukaizaiji, Katata (Loc. 15)	"	*
B-i	Kamibeppu, Zeze, Otsu (4 Km NW of Loc. 42)	Coaly seam	S. MIKI 1957
B-ii	Nishi, Shigaraki (2 Km N of Loc. 102)	Coaly bed	" 1956, 1957
B-iii	Hosohara, Shigaraki (Just W of B-2)		" 1957

Molluscs

Bed	Locality	Geological occurrence	Reporter
B_1	Southeastern hill of Ueno City	Silt	Y. IKEBE, C. NAKAGAWA
B_2	Shindo, Ayama Vill. (Near Loc. 88)	Clay	*
B_3	Koji, Konan (2 Km E of Loc. 83)	Clay	*
B_4	Jimpo, Konan (Near Loc. 74)	Clay	*
B_5	Kamikomazuki, Hino (3 Km NW of Loc. 60)	Silt	*
B_8	Kitawaki, Hino (0.5 Km E of Loc. 22)	Silt	*
B_{9-10}	Katata		N. IKEBE 1933

Elephants

Bed	Locality	Geological occurrence	Reporter
B_1	Kosugi, Ayama		SUMIDA 1958
B_9	Sakawa, Katata (1 Km SE of Loc. 14)	Silts and Sands	MAKIYAMA 1924
B_{10}-Steg.	Minamisho, Katata (1.5 Km S of Loc. 14)	Sands and silts	MATSUMOTO 1924, MAKIYAMA 1938
B_{10}-Elep.	Ogi, Katata		IKEBE 1959

* Data obtained by the writer

as shown in Fig. 2. The faults belonging to the Hira trend run parallel to the Hira range indicating the distinct compression zone. Along the Suzuka range, several thrusts run side by side making échelon structure, having a NW-SE strike and NE dip, and cut the range diagonally. The faults related to the Shigaraki granite mass develop also as thrusts with NE-SW strike.

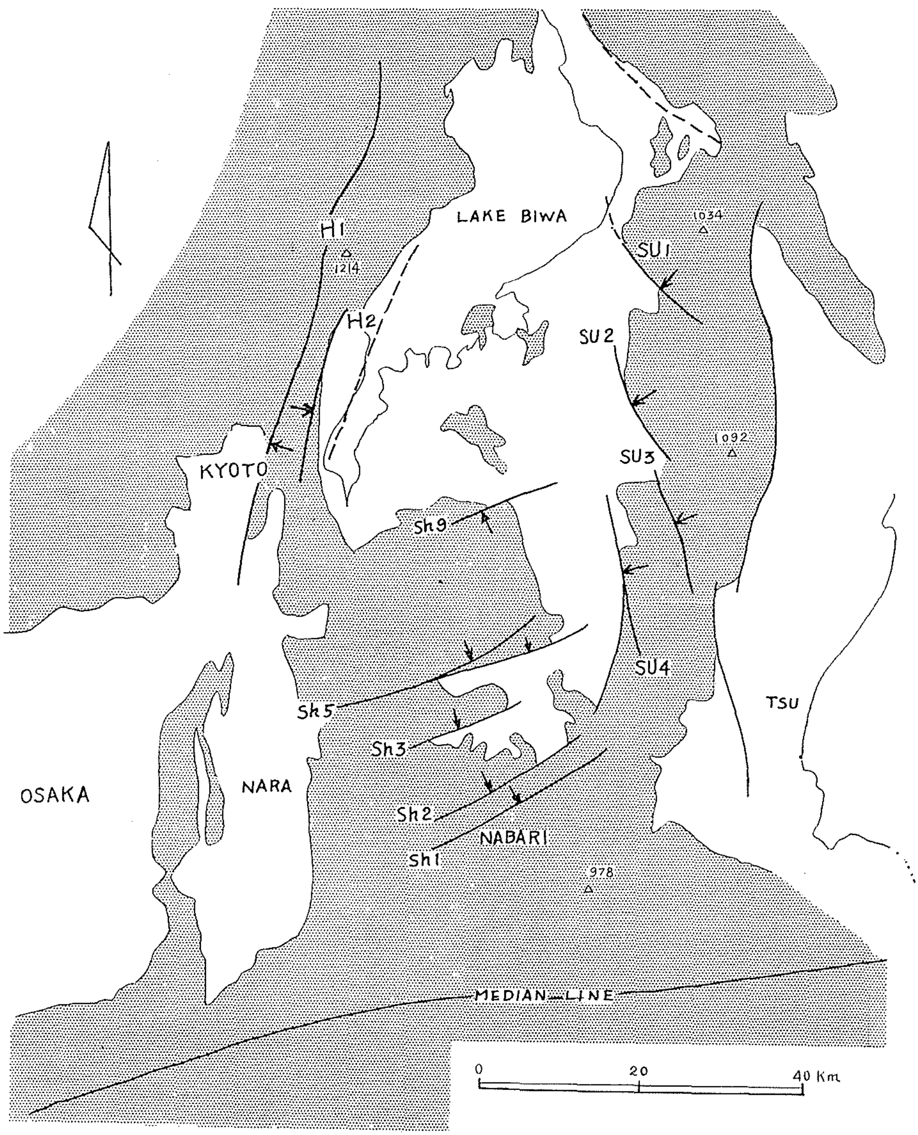


Fig. 2. Structural map of the Oomi-Iga basin and its surroundings.

These three fault groups are undoubtedly simultaneous with the uplift of the ranges and the wedge-shaped projection of the Shigaraki granite body. Each fault has the following characteristics.

Hanaore fault (H_1)

The thrust plane dipping 60°–70° E crops out at Ichijoji and Keage, the west side of Hiei-Hira range (both in Kyoto City). This strike is almost parallel to the range.

Katata region (H_2)

In this region, two faults are existing; one is the Hiei fault which runs along the eastern foot of the Hiei-Hira range and the other is the Katata fault which is assumed to have been buried below the alluvial deposits along the lake side. A sheared zone is hemmed in by these two faults. The Hiei fault is composed of two or three parallel faults. Along the fault planes, sands and silts with pebbles dip almost vertically and the high-angled reverse fault plane can be seen at Namazu (1 km S of Loc. 15). On the southern extension of these faults, two dykes of the same elongation intrude into the granite. The faults might occur along the frail zone suggested by these dykes. Along the eastern margin of the hill, an unsymmetrical anticline runs with a very steep eastern wing. The assumed fault line is drawn bordering on this almost vertical wing. A quartz porphyry shoots out along the axis of this anticline.

The compression zone sandwiched between two faults has a peculiar appearance geostructurally. That is, judging from the general distribution of the sands and silts, the strata are inclined gently towards the lake, but the bedding planes which are seen at many outcrops dip almost always toward the Hira range. These phenomena may suggest the existence of many minor faults of thrust type. In fact, minor thrusts with a shift of a few meters can be found at several places. But the details are unknown.

Two faults crossing Otsu City (H_3)

Sands and silts dip almost vertically along the assumed fault line, but the type of the fault is not known.

Taga fault (Su_1)

At Shide (Loc. 31), sands and silts dip steeply along the boundary of the basement. A narrow anticline is also adjacent to this disturbed zone. This may suggest a fault of compression type. The trend of the fault coincides perfectly with that of the quartz prophyry dyke which has intruded into the Paleozoic rocks.

Kozuhata fault (Su_2)

At Kozuhata, Paleozoic rocks are considered to thrust upon the sands and silts with pebbles, though the fault plane could not be observed. At Iwakura, on the northern extension on this fault, the strata dip at an angle of 70° to NE.

Kurotaki fault (Su_3)

A high-angled thrust plane is seen at Kurotaki and Ayugawa, where the Miocene strata generally inclined eastwards suddenly change their dip steeply eastward near the fault line and the Paleozoic rocks thrust over these steeply inclined sediments. The thrust extends southwards as well as northwards to the granite.

Tongu fault (Su_4)

At Kaminokumi (1 km E of Loc. 77), granite thrusts over silts and sands at a high angle. At Oono (near Loc. 60), Miocene sandstone also thrusts over silts and sands at an angle of 80°. But on the farther northern extension, it seems to change into a normal fault.

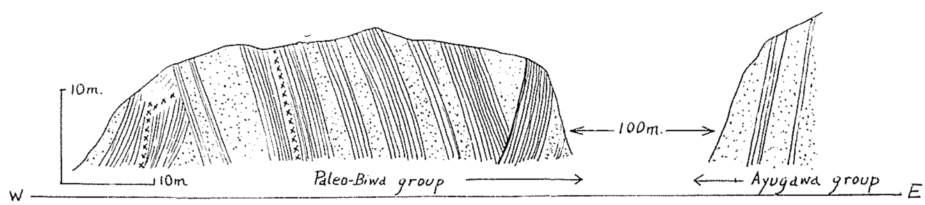


Fig. 3. Sketch of fault at Ono (Su_4).

Tsuge fault (Su_5)

Sediments dip almost vertically along the boundary between the granite and Paleo-Biwa group. But the fault plane is not known.

Yabata fault (Su_6)

Although the exact point of the fault is not known, the strata incline steeply near the boundary towards the basement rocks. Moreover, in the silt beds at Kamimura (Loc. 91) and Yabata (Loc. 92), the characteristic joints of N 55°W in strike and 50°NE in dip develop regularly at intervals of some 5 cm. This may be an indicator of the existence of the compressional force.

Osada fault (Sh_1)

A typical fault cliff is seen along the stream Osada and its SW extension. The figure of the cliff is quite similar to that of the Hananoki fault and Nishitawara fault mentioned below. But the fault plane is unknown.

Nishitawara fault (Sh_2)

At Nishitawara (4 km N of Loc. 99), granite thrusts upon the younger

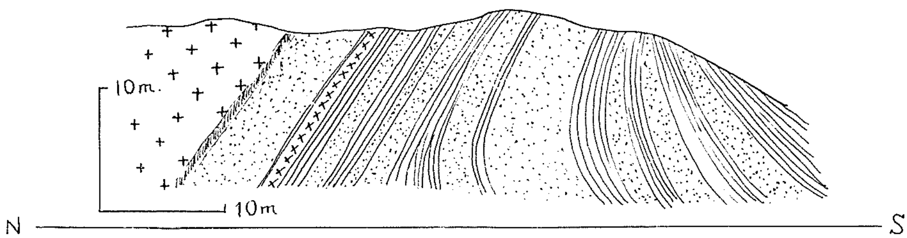


Fig. 4. Sketch of fault at Noda (Sh_2).

sediments by a fault plane dipping 55°N. The young strata also turn over along the basement rock. (See Fig. 4)

Hananoki fault (Sh_3)

A reverse fault is seen at Shiragashi (Loc. 97) and Hokke (3 km ENE of Loc. 97). At Shiragashi, granite thrusts upon the younger sediments with a thrust plane of 60°N in dip. Sands and silts within 10 m from the fault also dip northwards at an angle of 60°–90°.

Kawai fault (Sh_4)

This fault runs in the basement granite of Shigaraki plateau, but it stretches eastwards into the young sediments at Ayama hill. At Umada (1 km W of Loc. 87), a reverse type fault is found, where granite basement protrudes in the area of sands and silts along the fault line and the strata incline steeply.

Shimagahara fault (Sh_5)

At Okude (3 km W of Loc. 96), granite thrusts upon the younger deposits at a high angle, and gravel-rich strata along the fault dip almost vertically. This fault is traceable also at Suwa (6 km NE of Loc. 96), where coaly clay inclines steeply.

Koyama fault (Sh_6)

This fault runs in granite basement. The younger sediments do not incline steeply. Fault type is unknown.

Nagano fault (Sh_7)

At Nishi (2 km N of Loc. 102), the young sediments dip vertically along the boundary to the granite. This may indicate the existence of fault, but the type is unknown.

Ofuku fault (Sh_8)

Gravels dip steeply along the fault line, but the fault plane is unknown.

Mikumo fault (Sh_9)

At Mikumo (on the left bank of Yasu River), the granite mass thrusts over the younger deposits at a high angle (almost vertically), but this thrust

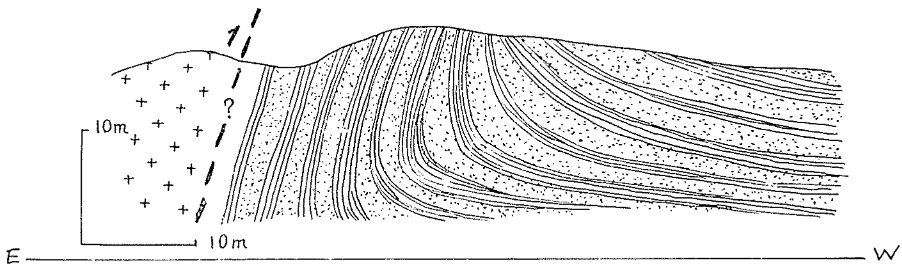


Fig. 5. Sketch of fault at Mikumo (Sh_9).

transforms into a normal fault on its east extension. General dip of the strata near Yama (4 km NEE of Mikumo) is 40°N. (See Fig. 5)

Konan shear zone (Sh_{10})

This shear zone is represented by three fault lines in the geological map.

(A zone sandwiched in between two western fault lines)

In this region, a lot of minor thrust runs parallel to the basement range, having a shift of approximately 5 m. But the strata suffer from little disturbance, or the ruptures occur almost always in the flat strata without any strong inclination. Only along the two lines drawn in the geological map, the steeply dipping strata are recognized to be accompanied by a thrust type fault.

(A zone along the eastern fault)

Strata dip vertically along the assumed fault line, but the type and the fault plane cannot be ascertained. This fault transforms into an anticline on its northern extension, and near Minakuchi (1 km E of Loc. 71) granite basement juts out into the younger deposits along the axis of the anticline.

Shiomoda anticline (S_1)

The anticline has a steep south wing and a gentle north wing. Some attendant minor faults run along the north wing, where strata dip vertically occasionally.

Kaikake fault (S_2)

Along the boundary between the Paleo-Biwa group and the basement, the sands and silts incline at a dip of 60°–80°N, which suggests the existence of a fault. But this fault transforms into a fold on its western extension. At Minakuchi hill, the strata form a step-like shape, having a rather steep north wing (10–30°) and a gently tilted (1–5°) south wing.

III. Terrace and Alluvial deposits

1. Terrace deposits

The terrace deposits in the Ômi basin can be classified into the Old

Terrace (Nunobikiyama formation) and the Young Terrace (Yokaichi formation). The Old Terrace is divided further into the Upper Old Terrace and the Lower Old Terrace.

The Upper Old Terrace develops on the top of hills along the lake or streams, having an altitude of 125 m near the lake to 340 m in the inland. This means that the blanket of the Upper Od Terrace overlies the hills locally but its depositional surface does not rise above the summit plane composed of the Paleo-Biwa group. The sediments consisting of predominant gravels are strongly affected by the red-soil-formation and dissection of the depositional surface is fairly advanced.

The Lower Old Terrace is situated lower than the Upper Terrace topographically. Along the lake side it lies over the gently sloped hills, and along the stream it develops stepwise on the circumference of the hills as a small scale river terrace. The shift from the Upper Old Terrace is gradual without any terrace-cliff, and the red-soil-formation is considerably advanced. As a whole, the Lower Old Terrace is very similar to the Upper Terraces and it seems natural to consider that both are of the same series. The Lower Old Terrace is bounded frequently by the Young Terrace or the Alluvial plane with a tiny terrace-cliff. But whether it extends beneath the Alluvial deposits or not is unknown through field observation.

The typical Young Terrace can be seen only along the upper course of the large rivers. The highest depositional surface comes up to over 15 m higher than the present stream bed, but it lowers downstream and disappears below the Alluvial plane around the mid-stream. The deposits consisting predominantly of gravels are quite fresh and the dissection can hardly be recognized. The relation of these three terraces are shown in Figs. 7, 8, 9 & 14.

Seta-Otsu region

On the hilly land between Seta and Kusatsu, typical Old Terraces develop facing the Lake, as shown in Fig. 6. The Upper Old Terrace overlies the hills having a depositional surface 125–155 m high, which is about 25 m lower than that of the summit plane of this hilly land. The Lower Old Terrace has a wide depositional surface from 95 m to 125 m in contour. It develops on the top of the gently sloping hills or as inclined small-scale patches on the circumference of the hills, of which the tops are covered with the Upper Old Terrace. Between the Upper and the Lower Terraces, a narrow area having a little steeper slope is seen at the hight of 120 to 130 m, but no terrace-cliffs can be found. Both terraces are quite similar to each other in their lithofacies. They consist predominantly of gravels of 2–6 cm in diameter and clayey matrices become more pronounced toward the top. The average thickness is 5 m and strong red-soil-formation is recognized.

In general the Lower Old Terrace is bounded by the Alluvial plane with a slight terrace cliff, 1–2 m in height. However, the strongly weathered Old

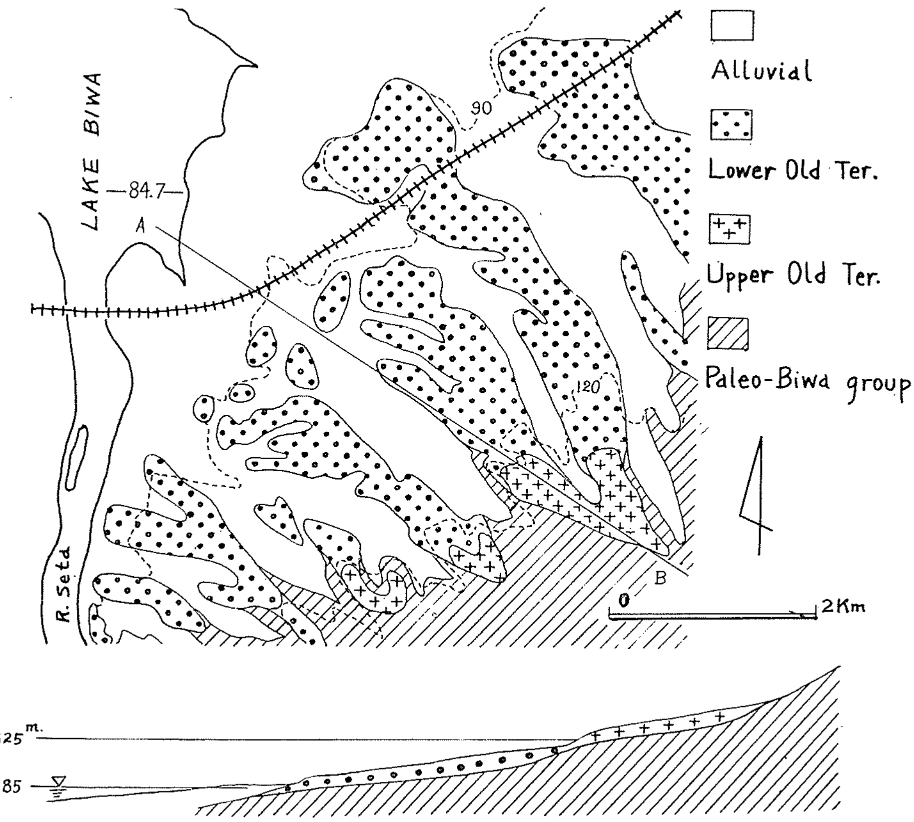


Fig. 6. Terrace near Seta : Its distribution and schematic profile.

Terrace along the Seta street is situated at 87 m in contour exceptionally, which is at least 3 m below the present Alluvial plane. This indicates the fact that the Lower Old Terrace exists beneath the Alluvial deposits at least in this locality. As mentioned above, the broad existence of this formation below the Alluvial plane is still in question, but the existence in special places is certain. At Otsu, the Old Upper Terrace attains a height of 170 m or more. But this is not the real terrace but the fan or talus. The Young Terrace cannot be found in this region.

Katata region

On Katata hill, the deposits correlative to the Old Terrace develop mainly as a fan along the foot of the Hiei and Hira ranges. The distribution is from 340 m to 220 m in height at Kurihara (west of Loc. 17), 280 to 180 m at Namazu (west of Loc. 15), and 240 to 190 m at Kamiogi (west of Loc. 12), and their inclination attains an angle of 5° to 15°. The average thickness is 2–5 m, but is locally over 10 m. Their components are predominantly granite boulders and gravels, strongly affected by the red-soil-formation. Subdivision into the upper and the lower is difficult, except the distinct Lower Old Terrace at Kamiryuge (2 km west of Loc. 16) along the river Wani.

The Young Terraces are also of fan type. One is at the foot of Mt. Ryozen, which is composed of cobbles and boulders. The other is at the foot of Mt. Hiei, where fresh arkose sands containing granitic gravels develop to less than 120 m in height. The deposits are quite similar to those of the Kitashirakawa fan which develops on the directly opposite side of Mt. Hiei. These deposits seem to disappear below the Alluvial plain.

Along the river Echi

On the left side of the river Echi, the Upper Old Terrace consists of gravels and sands with silts which are strongly affected by the red-soil-formation. Their depositional surface is distributed on the top of the hills, inclining slightly toward the river. Its height varies from 260 m in the eastern highest part to 170 m in the western transitional part to the Lower Old Terrace. This means that the surface is situated 100 m and 30 m higher than the present stream-bed of the Echi and is a little lower than that of the summit plane composed of the Paleo-Biwa group. The thickness is less than 10 m and dissection is well advanced.

The Lower Old Terrace consisting of gravels, sands and silts which also suffered strong red-soil-formation covers the hills continuously from the above-stated Upper Terrace in the eastern part, but lowers gradually westward and finally disappears below the Young Terrace deposits. On the other hand, the overlying gravels on the right side which are correlated to the Old Terrace deposits have a considerably fan-like appearance in the part adjacent to the steep Suzuka range. These gravels are distributed from the height of 28 m to 160 m and seem to belong to the Old Lower Terrace.

The Young Terrace consisting of fresh gravels and sands develops on both sides of the river Echi, with a fan-like distribution. The depositional surface of this sediment decreases westwards. Consequently, the scarps facing the the river also decrease in height westwards, for example, 13 m at Ogura, 6 m at Sone (2 km below Ogura), and disappears at Kishimoto (5 km below Ogura). The boring data also show that the basal erosion surface of the young terrace exists 15 m below the Alluvial plane at Gokanosho (Loc. 2, 11 km below Ogura). This may well suggest the fact that the depositional surface of the Young Terrace exists some 10 m below the Alluvial plane and may be lower on the far western extent. The thickness of these deposits is 2–6 m. These relations are shown in Fig. 7.

Along the river Hino

The Upper Old Terrace can not be found in this area. The Lower Old Terrace consisting of gravels, sands and silts develops around the Hino hill

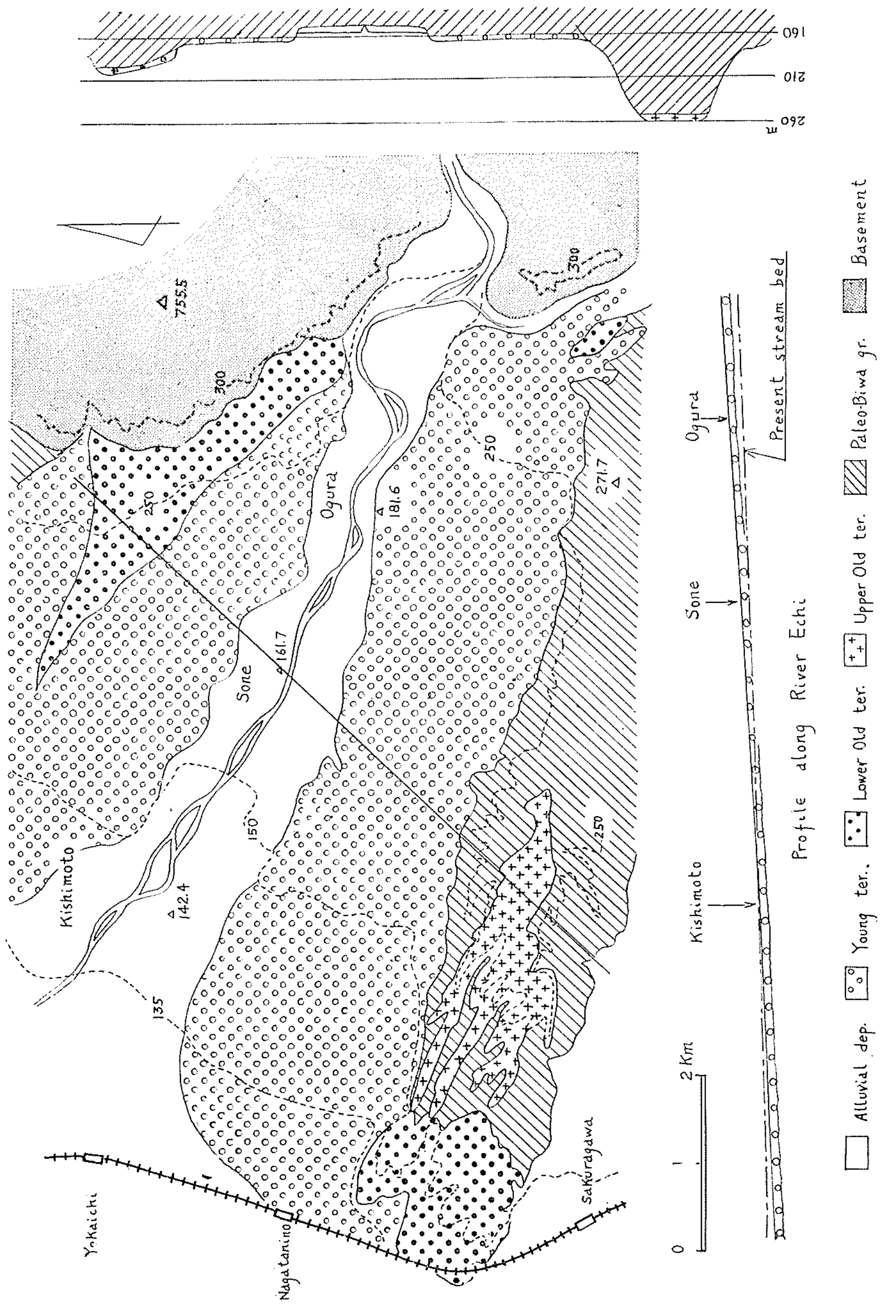


Fig. 7. Terrace near Echi: Its distribution and schematic profile.

with the maximum height of 200 m which is about 55 m above the present Hino stream. The degree of the red-soil-formation is exactly like that of the Lower Old Terrace of the Echi. The average thickness is 5 m.

The Young Terrace is also quite similar to that of the Echi in its physical appearance. The depositional surface is 12 m above the present stream at Nihongi (1 km N. of Loc. 54), and disappears below the Alluvial plane at Uchinoike (3 km S of Loc. 51 and 5 km below Nihongi). The fan-like appearance is pronounced at the upper part of the stream.

The Young Terrace transforms into a typical fan at Zao (2 km above Nihongi). The thickness at the terrace part is 2-4 m.

Along the river Yasu

The Upper Old Terrace develops on the tops of the two small hills which run parallel with the river Yasu on both sides. The depositional surface varies from 300 m in height (80 m above the present river-bed) at Oono (1 km E of Loc. 60) to 235 m (50 m above the present river-bed) at Shinjo (1 km S of Loc. 69). The deposits consist of predominant gravels witn clayey topset and strongly suffered red-soil-formation. The thickness is 4–10 m.

The Old Lower Terrace can be found only on the right side of the river near Oono. It develops as step-like patches of small scale on the mid-slope of the hills from directly beneath the Upper Old Terrace to directly above the Young Terrace. The red-soil-formation is considerably strong. The Young Terrace, 2-5 m thick, is distributed along the river Yasu and its tributary Soma. Along the main stream, the depositional surface attains to 8 m above the present stream bed at Ichiba (1.5 km S of Loc. 60) and 4 m above at Shinjo (5 km below Ichiba). On the other hand, along tributaries, it is located 8 m above the stream-bed at Hirata (1 km N of Loç. 83) and 4 m above at Ichihara (2 km W of Loc. 72, and 6 km below Hirata). The Young Terrace is not visible along the down-stream from the confluence of these two rivers.

Iga basin

The post Paleo-Biwa sediments may not be exactly correlated to those of the Oomi basin, but have similar characters in appearance and distribution.

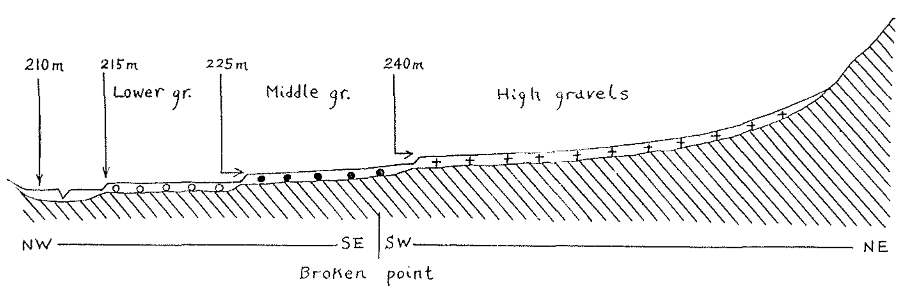


Fig. 8. Generalized Profile of Post-Paleo-Biwa Gravels across Yabata (Broken Point).

Fig. 8 shows the NE–SW cross section at Yabata (Loc. 92) which can be regarded as the standard profile of the overlying blankets in the Iga basin.

The typical high gravel bed can be found on the southern hills of Tsuge, where the gravels distributed flatly on the top of the hills increase in height eastwards and transform into a fan at the foot of the Suzuka range. The components are granite boulders and cobbles with clayey matrix and strongly affected by the red-soil-formation. The thickness is 4–8 m, and the surface is strongly dissected.

The widest and the most typical middle gravels are found at Ueno City, where considerably weathered gravels attain a thickness of 3-6 m and have a well-preserved depositional plane. At the hilly region, south of Tsuge, the coordinate gravels develop on the hill sides or fill the small valleys between the hills. These gravels are affected by red-soil-formation and dissected by the streams which have younger gravels along them. The depositional surface of the lower gravels is situated at a few meters above the Alluvial plane.

For instance, at Nishinosawa (2 km E of Loc. 93) it is 6 m above the present stream bed and also 6 m above at Tomioka (4 km SSW of Loc. 92). The sediments, 3–4 m thickn, are always fresh. Along the southern foot of the Shigaraki plateau, the above-mentioned three gravels are recongnized, but the exact classification is difficult owing to their steep inclination and small distribution.

2. Alluvial deposits

Fig. 9 is drawn from 100 boring

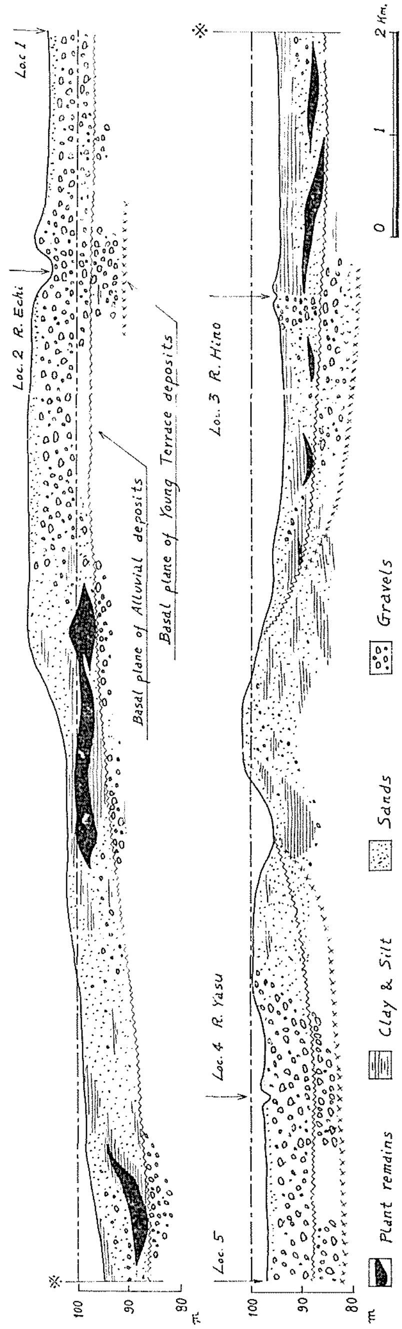


Fig. 9. Soil Profile along New Tokaido Trunk Line.

columns along the New Tokaido trunk line. This is the typical part of which the Alluvial deposits have hitherto been made clear. In this profile, only one point is to be noticed. That is, the boundary between the cobbles and sands may not mean the unconformity plane of the Alluvial deposits, but coincides with that of the young terrace. This interpretation seems to be natural, judging from the status of the terrace on the ground. However, the data of the Alluvial deposits are not enough for considering the great lateral change of the lithofacies. The writer can say very little about the youngest deposits.

Part 2. Consideration on the development of the Lake and the origin of the endemic species

Introductory Note

Essential point

Lake Biwa has a great number of endemic species in its fauna and flora which differ remarkably from those of the other parts of Japan. KURODA (1948) reported many characteristic molluscs such as *Heterogen longispira, Semisulcospira decipiens, S. niponica, Radix onychia, Gyraulus biwaensis, G. amplificatus, Lanceolaria oxyrhyncha, L. biwae, Inversidens reiniana, I. hirasei* var. *brandti, Hyriopsis shelgeli, Anodonta lauta tumens, A. calipyros, Corbicula sandai, Pisidium kawamurai, Sphaerium japonicum biwaense*. He pointed out that they are similar to those of the continent. KITAMURA stated that characteristic plants such as *Vitex rotundifolia, Cabystegia soldanella, Lathyrus maritimus, Arabis lyrata kawasakiana*, and *Pinus thunbergii* may have originated in a seaside area. On the other hand, UÉNO (1937) who studied the fishes of Lake Biwa insisted that the fauna of Lake Biwa is conspicuous in that both northern and southern species are mixed. However, the analyses on these endemic species are not formulated at present. Limnologists and biologists have said that some of them may have resulted from immigration and others may be of autochthonous intra-lacustrine evolution. The writer agree with this interpretation in principle. Probably, such phenomena may have resulted from the long history of this lake as well as from the large lake space and considerable depth.

In the writer's opinion, the existence of such miscellaneous species may be the result of immigration in the numerous times when the topographical barrier permitted their migration. In other words, he thinks that the paleogeography may at least be a key hint to the solution of the problem of these endemic species. The outline of his interpretation is compiled in Table 5 and Fig. 10. Namely, Lake Biwa has three characteristic stages, which provide quite different conditions for the invasion of the biota to Lake Biwa.

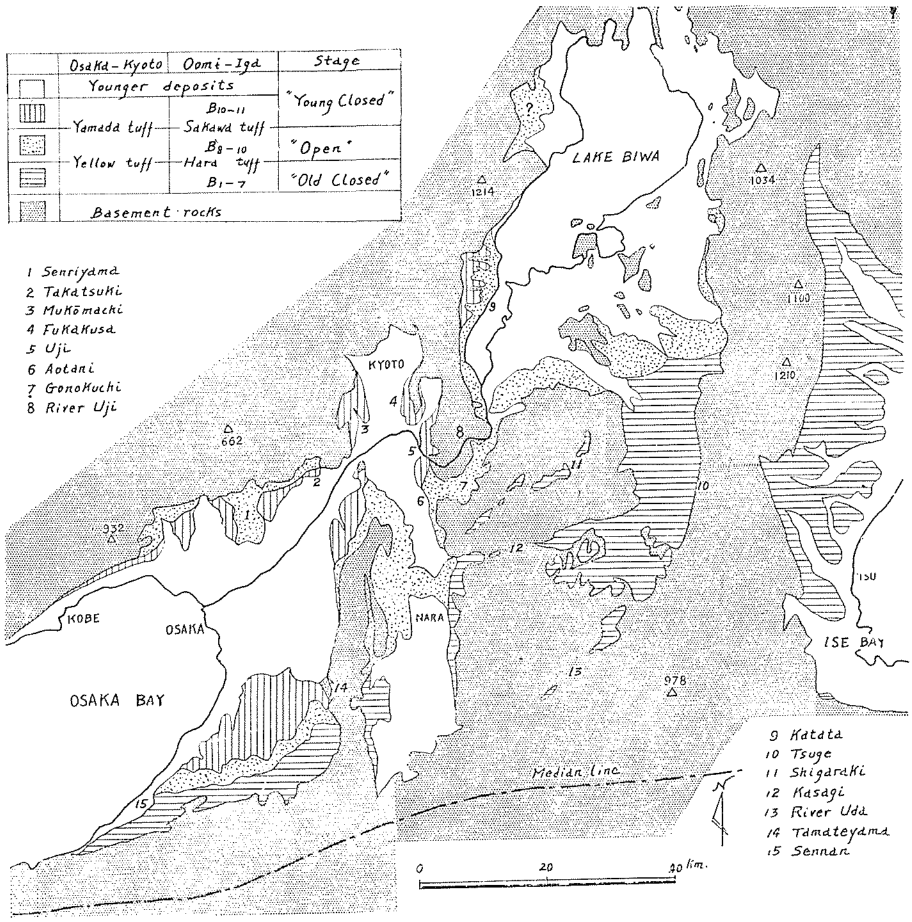


Fig. 10. Map showing the relation among three basins.

(1) "Old Closed Lake" stage: The age of invasion of the continental elements, Late Pliocene.

(2) "Open Lake" stage: The age of invasion of the marine elements, Earliest Pleistocene.

(3) "Young Closed Lake" stage: The age of land-locking, Early Pleistocene → present.

Premise

Prior to discussions, the writer must settle some fundamental supposition on which basis he will discuss in detail.

1) Indicator of the environment

(Continental element): The word "continental" is not used in the strict sense, but used in the sense of "non-marine" with dominant Chinese characters. It is said that *Hyriopsis schlegeli* and *Semisulcospira libertina* resemble very much the present continental molluscs in the coast region. *Lanceolaria*, *Anodonta*, *Viviparus* and other molluscs found in Lake Biwa are also considered as a mark of the fresh-water. The writer has therefore picked up these fresh water molluscs as the indicator of the so-called "continental" element.

(Marine element) : The writer has no adequate data about fossil diatoms, and fossil fishes could not be found. The only species which indicates the marine environment in this case is a plant remain, *Pinus thunbergii*. Prof. KITAMURA says that the present distribution of *Pinus thunbergii* is limited to the coastal region, excepting a cliff of Mt. Myogi (near Tokyo). Judging from such a standpoint, it is natural to think that *Pinus thunbergii* is a relic of "marine" origin, or may have invaded this basin when the Lake had a close connection with the sea. Thus, though the marine elements are existent, they are practically very meagre as evidence. The writer's so-called "marine" element is only a slight evidence.

2) Indicator of the age

ITIHARA (1961) discussed "The problem of stratigraphical horizon of extinction of *Metasequoia* flora", and established the Quaternary chronology in central Japan as follows: Pliocene is represented by the *Metasequoia* flora with dominant Tertiary type flora such as *Pseudolarix*, *Liquidambar*, *Ginkgo*, *Pinus fujiii* and *Keteleeria*. Earliest Pleistocene is marked by the *Metasequoia* flora without the Tertiary type flora, and the non-*Metasequoia* flora period succeeded during the whole Pleistocene. The writer has therefore adopted this chronology established by ITIHARA and has arranged plant-remains as indicators of the age.

I. "Old Closed Lake" stage

"Closed" is not used in a strictly limnological sense. It means that the Lake maintains its isolated environment from the sea, and topographically prevents marine dwellers to invade the Lake, whether there are any waterways reaching the sea or not.

1. Relation with the Miocene Ayugawa group

The Miocene Ayugawa group did not suffer strong crustal movement during the pre-Paleo-Biwa age. The sediments of the Paleo-Biwa group which overlie these Miocene sediments run almost parallel with them geostructurally. But the faunal assemblages are quite different from each other; the former has 66 species of marine molluscs (IKEBE 1934), and on the contrary, the latter has no marine species. All the marine molluscs may be completely extinct between the Ayugawa and the Paleo-Biwa.

2. Indicator of continental element

Unio biwae, *Anodonta* sp. and *Viviparus longispira* are found at the lowest part of the sediments (the B_1) belonging to this formation. Other species such as *Lanceolaria oxyrhyncha*, *Cristaria plicata spatiosa* and *Corbicula* sp. are also seen at this stage.

3. Paleogeographical environment

Chain-like distribution of lakes

FUJITA (1962) showed a paleogeographical map of the late Pliocene age, as quoted in Fig. 11, when he reported his historical review of Japan Sea. In this map, Japan islands are shown as a part of the continent with a few fresh water lakes distributed parallel to the coast.

Fig. 11. Paleogeography of Late Pliocene Age. (After Y. FUJITA, 1962).

Water-ways between the lakes

Emeritus Professor MAKIYAMA imformed the writer of the small distribution of gravels and silts along the stream Uda. This fact may well suggest the existence of a water-way along this route in the B_1 time. At the same time another water-way is supposed to have existed along the present stream Kasagi from a few patches of gravels. On the other hand, the dacite tuff found at Tamateyama hill, southeast of Osaka, may be correlated to the Ichiuno tuff (B_2-B_3) of Paleo-Biwa basin. Judging from these facts and the stratigraphical condition in the Osaka and Nara basins, the writer thinks that a few water-ways may have stretched to the Awaji island across the

Kitan straits, at the beginning of the Paleo-Biwa series.

Simultaneously or directly after the birth of these opening water-ways, a third drainage is supposed to have passed also from the Iga-Oomi basin to the Awaji island via Shigaraki and Nara. As to the relation with the Age basin, there is found a zonal area that appears to have allowed the presence of an old channel, intersecting the Suzuka range, but the writer can not find any deposits along this zone. Consequently, the existence of a water-way between these two basin is doubtful.

Even topography

The sediments of this stage are composed of predominant fine materials such as sand, silt and clay excepting the northeastern marginal part of the Iga basin. In this basin, the B_1 bed frequently has under-clay instead of basal conglomerate. Clays belonging to the B_2-B_5 beds also often abut on the basement. This indicates the fact that the topography surrounding the lake was considerably even, so that it did not produce any dominant coarse meterials.

4. Climatic environment

From the B_1 to B_6, we can find the Tertiary type flora such as *Pinus fujii*, *Pseudolarix*, *Liquidamber* and *Nyssa*, in addition to the *Metasequoia* flora, which indicate as warm a climate like that of the Tertiary. But suddenly, a thin seam intercalated in the upper part (?) of the B_7 produced the cold indicators such as *Pinus koraiensis* and *Tsuga sieboldii*, which are the first striking informers of cold climate during the Paleo-Biwa period. The *Metasequoia* flora without the Tertiary type flora then took the place of *Pinus koraiensis*, indicating again a mild climate. Chronologically this first cold horizon represented by *Pinus koraiensis* coincides with the end of the "Old Closed Lake" stage. Consequently, the writer can say that the climate has been warm throughout the "Old Closed Lake" age.

5. Debatable point

MIKI (1948) has obtained *Paliurus nipponicus* from the coaly clay at Shimagahara, Mie Prefecture, which belongs to the B_1 bed. As to the allied present species, *Paliurus ramosissimus* is generally found in the coastal region of China, Loochoo and West Japan. *P. australis* is familiar in the arid area farm southwest Asia to the Mediterranean district throughout southern central Europe. In general, *P. nipponicus* is considered to be common in marine clays of the upper part of the Osaka group. However, it is debatable whether this *Paliurus* has had any connection with the sea. The writer wants to think that *P. nipponicus* in unrelated to the sea, but has no adequated data at present concerning this question.

II. "Open Lake" stage

"Open Lake" means that the Lake had a broad channel leading to the sea without any distinct topographical barriers, though it was thoroughly lacustrine.

1. Indicator of marine element

As mentioned above, *Pinus thunbergii* which has been found at the B_9 bed is the only indicator of the marine element.

2. Paleogeographical environment

Basin-making movement of basement

Considering their lithofacies the writer classified the Paleo-Biwa group into three formation, which are summarized as follows: the lowest Iga formation is composed of ill sorted sands and silts and generally lacks the marginal gravels, the middle Koka formation is of clayey sediments without marginal conglomerates. Contrary to this, the upper Katata formation consists of sands, silts, gravels, and generally has predominant marginal gravels. The marginal gravels appear for the first time at the B_6 bed. This phenomenon suggests the fact that the condition aroud the Lake was not the same before and after the B_6. That is, the gravels of the Katata formation may be the result of the basin-making movemen and of the consequent higher land surrounding the Lake. The evidence that the upper beds are distributed farther northwards also agrees with this movement.

Birth of the Gonokuchi channel

In accordance with the basin-making movement, the center of the depositional area may have shifted northwards. Consequently, in the B_8 time, sands, silts and gravels have come to expand their distribution farther northwards and in a broader area. The writer thinks that the seidments on the mountain region east of the river Uji also contain the B_8 bed at their basal part. Moreover, he supposes that this deposit can be traced to the gravel-rich strata at the Aotani region, which are correlated to the lower part of the Osaka group. These suppositions, as a natural consequence, lead to the idea that a new channel was born in the B_8 time, which is here named the "Gonokuchi channel".

The sediments along the channel part are composed mainly of gravels but at their basal part thick clayey layers are often found, which has always been mined for raw material of roof tiles. The distribution attains to 3–6 km in width.

Considering these appearances, the writer considers that the "Gonokuchi channel" was 3–6 km in width, and especially at the early stage was so stagnant that clay could doposit in this part.

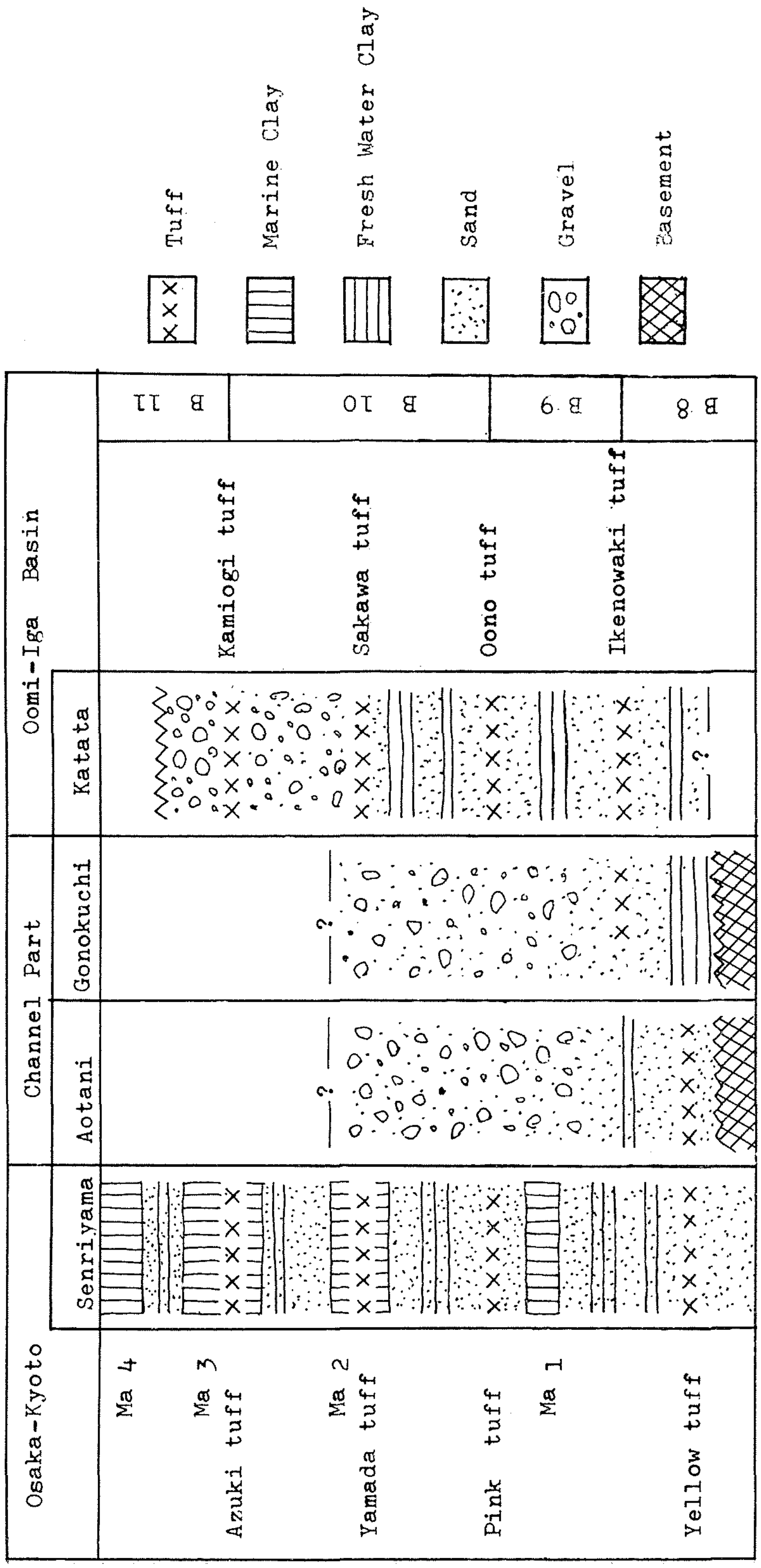


Fig. 12. Stratigraphical Relation between Osaka-Kyoto area and Oomi Basin.

Approach of the sea water

Before considering the condition of the then Osaka bay the writer wants to attempt a more exact stratigraphical correlation between the Paleo-Biwa and the Osaka group. Fig. 13 shows the stratigraphical relation of 4 places being connected by the channel. The only definite key bed common to both basins is the "Pink tuff". Though the writer has not found this tuff so far hitherto, he thinks that it must be intercalated to sands and gravels in the channel part. Moreover he supposes that the channel might exist at least near the "Yamada tuff" horizon. This judgement is based on the following affirmative evidences; first, the gravels above the "Yellow tuff" attain to more than 80 m in thickness, which indicates sufficient thickness for the appearance of the "Yamada tuff", and second, the lithofacies at Katata hill changes greatly at the "Yamada tuff" horizon ("Sakawa tuff" horizon as will be stated below in detail). With these proofs, the writer has determined the horizon of the top of the sediments in the channel part, as shown in Fig. 12. On the other hand, the "Yellow tuff" and the "Ikenowaki tuff" found at the basal part of the sediment in this region indicate the fact that the beginning of the channel coinicides with the "Yellow tuff" horizon.

The writer will next show the paleogeographical environment of the Osaka-Kyoto area during the "Open Lake" stage. The outline is shown in Fig. 13. At the early stage of the channel, (perhaps the B_8 and the early B_9) the Osaka-Kyoto area was covered by lacustrine waters. The first transgression occurred in the late B_9 time or directly before the "Pink tuff". At that time, the sea invaded Takatsuki and probably Mukomachi, though Fukakusa region was left as a lacustrine. In Nara and Aotani, marine clay (ITIHARA has called this clay Ma_1) has not hitherto been found. Probably these regions are a part of fresh water regions. This sea regressed at the end of the B_9, and then the whole Osaka-Kyoto area changed again into lacustrine till the next transgression at the middle of the B_{10}. The second invasion of the sea brought marine clays (Ma_2) to Mukomachi and Uji. The writer think that the marine elements may have invaded a part closer to the channel than at the first time, although the evidence of the transgression was not found at the Nara and Aotani regions as before. After the second marine invasion, several transgressions with marine clays (Ma_3-Ma_8) were repeated in the Osaka-Kyoto area, but the channel seems to have been already closing its route with the retreating of the second sea. After all, the marine water might have approached the entrance of the channel at least twice during the "Gonokuchi channel" stage, but it could not invade the channel.

Disappearance of the Gonokuchi channel

The channel disappeared around "Azuki tuff" horizon, partially due to the basin-making movement as well as to another origin. The writer has sufficient evidences for this phenomenon of the lowering of the water level

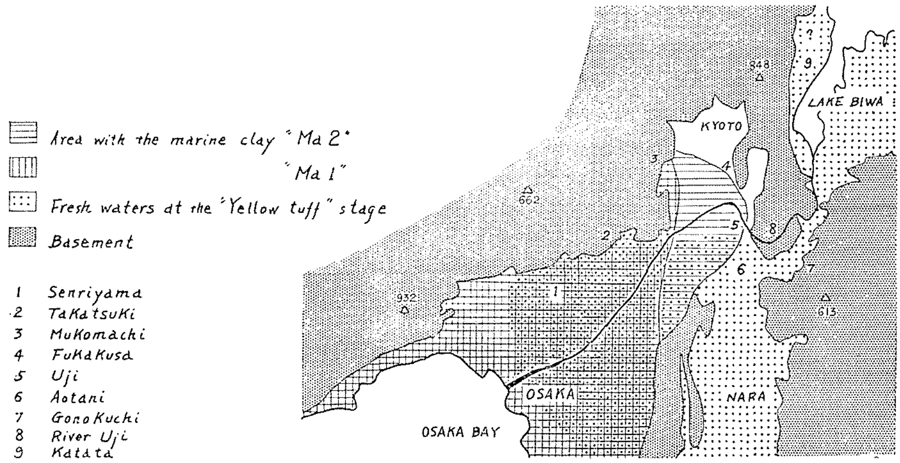


Fig. 13. Paleogeographical map of the "Open Lake" stage.

and the disappearance of the channel will be described below as follows. The most direct proof of the disappearance is the lack of the sediments along the channel of the stage. The second is a more indirect proof, that is, at Katata hill, the character of the sediments changes greatly at the boundary of the "Sakawa tuff" (correlative of "Yamada tuff"), where such a distinct cross lamination is recognized and this tendency becomes more prononced toward the upper part. The writer thinks that the scour-and-fiill structure (confer Fig. 1) is the result of the lowering of the water level. The development of the fossil forests of the B_{11} time may also be an accompanying phenomenon.

III. "Young Closed Lake" stage

The emergence of the Paleo-Biwa Lake has advanced along with the development of the basin making movement. At the climax of this movement, the Paleo-Biwa group may have been displaced or steeply inclined by the faults. After the climax, the youngest blankets of gravels overlay horizontally the folded and faulted Paleo-Biwa group. This is the most simplified history of the Lake since the end of the "Open Lake" stage.

As mentioned before, the basin has suffered a very strong crustal movement, and consequently the topography in the vicinity of the Lake may have varied greatly during this revolutional age. But in the writer's opinion, whatever may have happened, the Lake has never had again the occasion to have such a great channel as "the Gonokuchi" since its disappearence in the B_{11} time. He named this last stage without a broad channel the "Young Closed Lake" stage. Perhaps, almost all the species which had invaded before and during the "Gonokuchi channel" stage were compelled to become perfect land-locked species. In regard to the topography this new term was a preparatory stage for the construction of the present Oomi basin and Lake Biwa.

In this chapter, the writer wants mainly to discuss the history of the paleogeographical development of the basin.

Subaqueous topography

Before entering into discussion, the writer will introduce Kotani's work concerning subaquatic topography and the outline of its tentative correlation to the terestrial topography. KOTANI (1957, 1958, 1960) has stated that the present Lake Biwa has 4 distinct subaquatic terraces, the subaquatic terrace ("Kodan") III, II, I and the lake bottom plain. These 4 planes have the following depths, for example, off the River Hino: the subaquatic terrace III (3–5 m), the subaquatic terrace II (8–14 m), the subaquatic terrace I (17–23 m), and usually the bottom plain is 76–79 m below the present lake level. In addition to these 4 planes, he has reported another smaller scaled P_I plane between the subaquatic terrace I and the bottom plain, which has ordinarily a rather steep inclination. The writer considers that these 3 subaquatic planes may be correlated to the terrestrial planes respectively. Fig. 14 shows the tentative correlation between them, on which he will discuss in more detail.

i) Before the deposition of the old terrace deposits

As mentioned above, there is a long interval in time between the two sediments, the Paleo-Biwa group and the old terrace deposits. This may well suggest the fact that the Paleo-Biwa group has experienced a complicated geohistory before the latter's deposition. The most interesting point is the problem whether the Lake has once perfectly disappeared or not. But unfortunately, the writer has no adequate data at present concerning this question.

Origin of the Lake bottom plain

Instead of discussing the problem of whether the Lake has disappaered or not, the writer will consider the origin of the "bottom plain", though it is also quite uncertain.

If the subaquatic and terrestrial planes are arranged in the order of their situation, the "bottom plain" should be correlated to the "Paleo-Biwa plane" formally, as shown in Fig. 14. But this formal correlation may be meaningless, because the character of the plain is still vague, and consequently the real meaning of this plain is unknown. However, according to the writer's supposition, the following two cases seem to explain its origin; the first is that the plane was formed by the erosional action of the then lake water. If this assumption is acceptable, we must conclude that the lake has main-

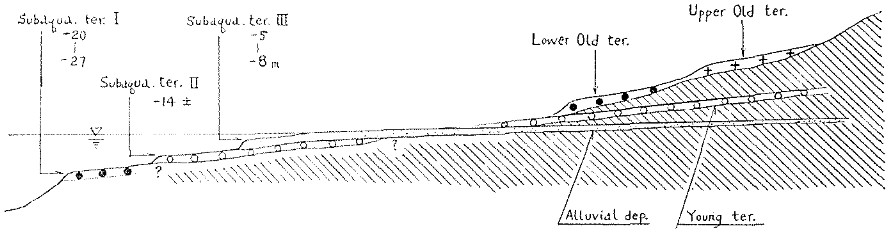


Fig. 14. Schematic Profile of terrace and Alluvial Deposits.

tained its level at as low a level as that of the present bottom plain for a considerably long time. The second is the case in which some faults play an important role. For example, along the west side of the Lake, we find a remarkable Katata fault, by which the eastern block is depressed scores of meters as against the west block which now constitutes the Katata hill. This phenomenon may suggest the origin of the Bottom plain. At present it cannot be assumed whether any faults exist along the east side of the lake or not being buried below the alluvial deposits. In other words, bottom plain may have originated by such faulting action not only along its western side but all around the Lake. Supposing that the erosional force was existent, it may be that the lake lowered its level 75 m± below the present level at its lowest time. However at present, it is debatable which one was real and whether another quite defferent factor was a prime agent. The only definite fact is that many kind of endemic species have survived throughout this period.

2. Old Terrace period

Tentative correlation between the terrestrial and subaquatic planes

The subaquatic terrace I has a broad flat plane 20–35 m below the present lake level, for example off Hino. But its physical character is unknown. Consequently, the correlation attempted by the writer at present is quite tentative and not conclusive. The only evidence in favour of this tentative correlation is the entonnire of which KOTANI (1958) has reported. He has stated that the entonnire 3.6 km off the Amanogawa delta (north of Hikone), digging into the stratified sediments which constitute the terrace I, is situated 27 m below the present water level, with a scale of 100 m in diameter and 5 m in depth. He has suggested that the entonnire was formed by the driving action of the ground water gush. The writer thinks that the main way of shallow ground water may have been limited the gravel dominant strata of the terrace, and that, accordingly, the existence of the entonnire may well suggest that the plane of which the entonnire is situated signifies the existence of gravel rich fan-like deposits. On the other hand, the fact that the subaquatic terrace II is correlated to the Young Terrace is fairly well certain. Judging from these two conditions, the writer considers that terrace I can be correlated to the Old Terrace.

Paleogeography

First of all, the general topography has become considerably similar to that of the present one, for the first time at this stage. The frame work of the present water system was achieved at this Tld Oerrace age, and no great transformation has occurred since that time. For example, a new water way, the river Uji was born instead of the Gonokuchi channel, and a few large rivers such as the Echi, the Hino, the Yasu and the Ado appeared along their pressnt route. The old shore-line at this time is also traceable. The terrace gravels on the Seta hill indicate that the Lake level was 60 m higher than the present level at its climax (confer Fig. 14). But this higher water level then lowered gradually. Supposing that the correlation shown in Fig 14 is correct, we must think that the lake level has dropped about 20 m below the present level at its lowest pitch of the depression. This phenomenon also signifies the interesting fact that the river Uji dried up perfectly and the lake had no draining water-way, during this lower level period. By the way, the drainage dries up at a gorge of Sekinotsu, Otsu City, when the lake level lowers to 3 m below the present level.

Age

The sediments found on land are affected strongly by the red-soil-formation. The degree is quite similar to that of the "Meimi gravels" (High Terrace gravels in the Osaka-Akashi area, cf. ITIHARA 1961), and the dissection also advances considerably. From these conditions, the writer thinks that the Old Terrace is almost the same as the High Terrace of Osaka-Akashi area in age.

3. "Young Terrace" period

Correlation between the Terrace and the subaquatic plane

The writer considers that the correlation between the Young Terrace and the subaquatic terrace II is of absolute certainty. He can cite the following three facts as its proof. i) The depositional surface of the Young Terrace which is more than 10 m higher than the present stream-bed at the upper-course of the rivers lowers its height downstream, and then disappears below the Alluvial plane without any terrace cliff. ii) Judging from the boring data (confer Fig. 9), the basal plane of the cobble has a depth of at least 15 m below the alluvial plane at Gokanosho (Loc. 2). This suggests the fact that the cobble base signifies the erosional basal plane of the Young Terrace deposits rather than the Alluvial plane, because the thickness of 15 m, is too large for that of the alluvial deposits at this place. iii) Among the three sediments (The Old Terrace, the Young Terrace and the Alluvial deposits), the Young Terrace gravels have a particularly large grain size.

Similarly the subaquatic terrace II is composed of large grainsized materials such as gravels with coarse sands, which are coarser than those of the I and III (KOTANI 1957). These three facts seem to justify the above-mentioned correlation.

Paleotopography

The inclination of the depositional surface of the Young Terrace is quite uniform, contrary to the step-like appearance of the Old Terrace. The deposits are almost always non-existent in the lower part of rivers or coastal region, sinking below the Alluvial plain. These two facts signify that the Lake was constatly low or gradually lowering its level during this period. The writer considers that the former case was probable, because of the complete lack of terrestrial deposits corresponding to the Young Terrace along the coastal region. Once such an interpertation is accepted, the following topography may be deduced from it. That is, the then lake level was approximately 10 m lower than the present, and consequently the river Uji dried up. And the gradient of the flow-in-rivers was 0.05° steeper than the present one.

Age

A considerable amonunt of submerged archeologic remains from early "Jomon" to later "Yayoi" in age are found on the subaquatic terrace III, and occasionally on the bettom plain. These might be useful indicators if we check their geological occurrence. Unfortunately the writer has had no chance to observe them immediately and has no adequats data concerning this problem. The only fact that he can state with confidence is the features of the terrace itself which are as follows; the gravels are fresh, not having suffered by the red-soil-formation and dissection is hardly recognized. Accordingly, he supposes that the Young Terrace is contemporary with or younger than the Itami gravels (Low Terrace in Osaka-Akashi area, ITIHARA 1961) and may be Alluvial in age.

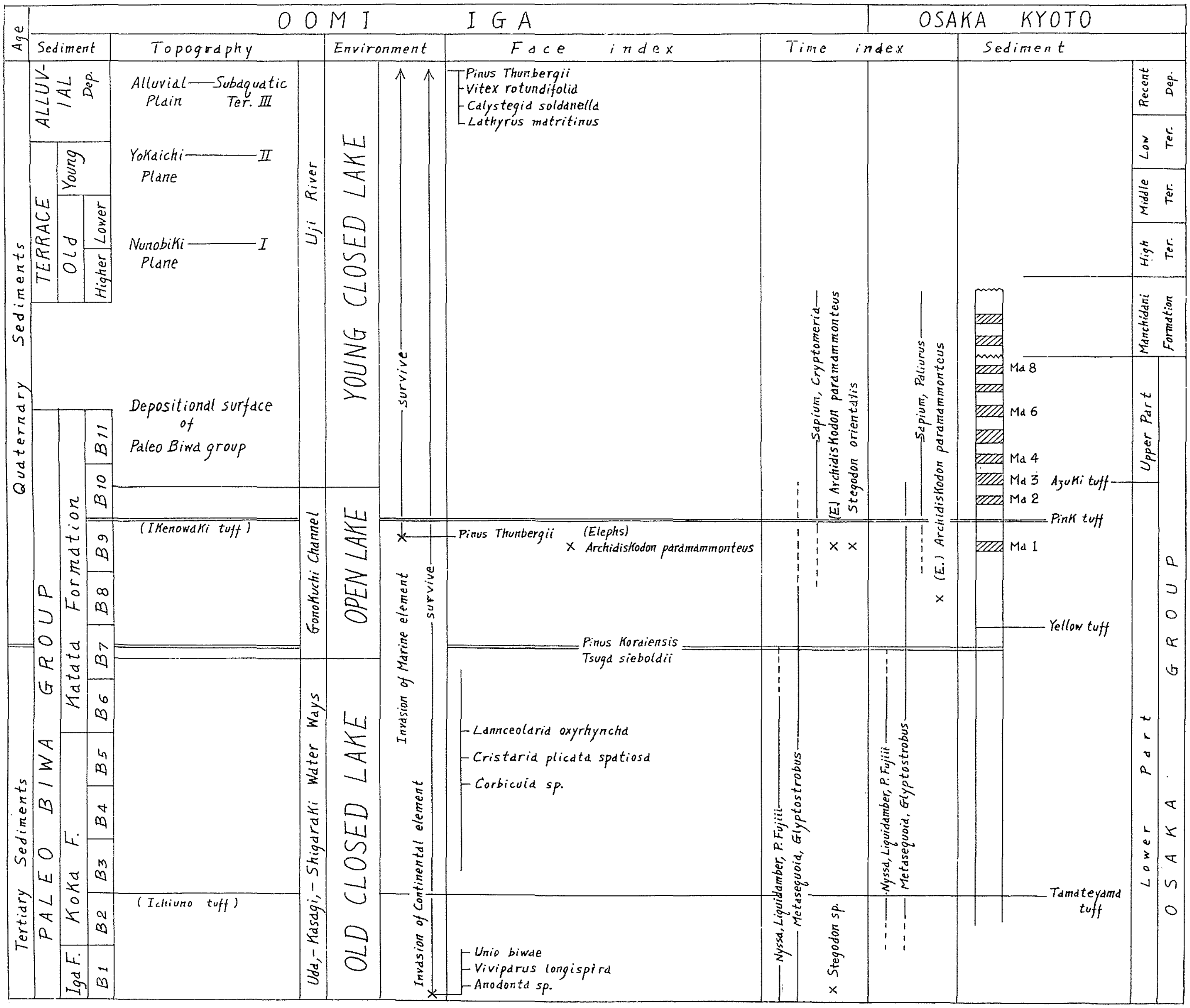
4. "Alluvial" age

The shallowest plane is called the "shelf" (Rikudana), the delta (Sankaksu) or the subaquatic terrace III (Dai III kodan) by KOTANI (1958). He has subdivided it into further details. In any way, the writer thinks that this plane can be traced to the Alluvial plain as a whole. KOTANI has also stated the recent lake reached the maximum expansion at the middle of Nara period and then the coast line retreated to the present position. This tendency has continued till the present day.

Postscript

The writer has established three stages of Paleo-Biwa Lake from the viewpoint of paleogeography, and has correlated each of them to the chara-

Table 5. Stratigraphical Table of Quaternary Sedimentaries in the Oomi-Iga Basin.



cteristic three ages preparing the chance of immigration for the biota, which are now called relics or endemic species. The writer must here make an additional remark about the accuracy of his investigation and then indicate a few future problems.

His investigation has been made far as possible from the view point of geology, but it is still incomplete in the biogeographical and limnological aspects. The reason for this is that his work has been done mainly on the basis of the geological field observation concerning the terrestrial proof. After due consideration of such a conditions, he can point out the following themes as future problems.

i) Problem of the subaquatic terraces

The writer supposes a perfectly isolated lake without any drainage, in some period of the "Young Closed Lake" stage. This might be a quite interesting problem not only for geologists but for limologists, in connection with the physico-chemical character of the then lake. The writer is expecting various criticisms on this point. Geologically and geodesically speaking, the most important work may be centred round the subaquatic terrace.

ii) More exact observation of fossils

To discuss the relation of geohistory and biogeography, a more exact observation of the fossils are required. In particular, the investigation of the diatom fossils may be most useful for this problem.

iii) Correlation with the Akashi and Age groups

The Ichiuno tuff (B_2–B_3) and the horizon of extinction of the Tertiary type flora are considered to be useful keys for correlating the Plio-Pleistocene strata in the Kinki district. The writer thinks that the latter represented by cold indicators is most important for establishing a standard chronology in this district, together with the horizon of extinction of the *Metasequoia* flora.

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Columnar Section of the Paleo-Biwa group