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The Japanese Quaternary, its Outline and Historical Review.

By

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I. Introduction

Compositive analysis and sufficient resolving of many problems concerning the Japanese Quaternary are rather difficult though very interesting and important studies related to different kinds of scientific topics. Firstly we are oblized to deal with the trouble of chronology. As characteristics to the Quaternary in Japan, we see the following points: 1, in the temperate zone of the western border of the Pacific, marine Pleistocene formations are developed only in Japan; 2, definite chronolization is possible in relation with terrace making and marine transgression; 3, volcanism is very distinct; 4, coral reef building becomes connected with glaciation in Japan; 5, floral succession and climatic changes are determined by many data; 6, land faunal succession is closely related to migration from the Chinese continent, owing to epeirogenesis, and determines the recent zoo-geographical distribution in each of the islands of Japan. From these points of view, many authors have contributed to our knowledges of the Japanese Quaternary, among them the most eminent including M. YOKOYAMA, S. TOKUNAGA, H. YABE, J. MAKIYAMA, S. HANZAWA, S. NOMURA, Y. OTUKA, K. SUZUKI, N. IKEBE, K. HATAI, O. FUKUTA, R. TAYAMA, H. NIINO, K. KOBAYASI, M. MINATO, H. KUNO, Y. SASA, G. IMAMURA, K. TANAKA, S. ENDO, S. MIKI, H. MATSUMOTO, F. TAKAI, T. SHIKAMA, N. NAORA, M. TOKUDA, S. SUGIWARA etc.

II. How to divide the Japanese Quaternary

It is a question whether the Quaternary should be divided from the same point of view and by the same method that the Tertiary is divided. From the viewpoint of the sedimentary cycle, IKEBE is inclined to deny that the Quaternary can be established and to accept it as a part of the Tertiary, just like the Pliocene or Astian. In fact, the Quaternary is a part of the Pliocene in an abstract time range. So that it is inappropriate to divide a short time from only a biostratigrephical point of view based on megaevolution.

In a region like Japan where glaciation was not so distinct as in Europe or North America, the method of using the glacial cycle (as represented for instance, by the glacial drifts and terrace chronology) is not as useful, and as a matter of fact it is very difficult to determine where the Plio-Pleistocene- or Pleistocene-Holocene boundaries are. Even if it is to be recognized that the Pleistocene ends when the Würm glacial age is finished, the microclimatic change of the Late Glacial Age observed in Central-Western Europe is not applicable to the far distant region of Japan where the glaciation corresponding to Würm or to Wisconsin is rather ambiguous. We Japanese geologists hitherto conveniently referred the upper boundary of the so-called "Kwanto loam bed" to the end of the Pleistocene, but this opinion has recently been revised by several authors.[1]

In 1931, OTUKA proposed to divide the Japanese Quaternary by different methods standing upon marine fauna, land fauna, human culture, climatic change, physiographical data, tectonism, volcanism etc, and as a result of these considerations he used the following units in ascending order; Pd, dl_{1}, dl_{11}, du_{1}, du_{11}, a_{1} and a_{11}. OTUKA especially considered the climatic and physiographical methods as very important. His seven units seem to be mainly based upon terrace making and marine deposits developed in the Kwanto district. YABE was the first who clearly defined the basal Pleistocene and Holcene in Japan: He regarded the Naganuma shell bed (Sanukian of the writer) as the former and the Numa coral bed (Numian of the writer) as the latter.[2] It is noteworthy that he said the Holocene begins with the begining of the transgression of Tokyo Bay. Besides YABE and OTUKA, many Japanese authors since the classical studies of BRAUNS, YOKOYAMA and TOKUNAGA, have selected the Kwanto district as the type of the Japanese Quaternary. YOKOYAMA's Upper Musasino (1922) and YABE's Narita and Tokyo beds, both composing his Narita Group (1911), are generally Pleistocene in age.

In 1948, IKEBE proposed a letter denomination for the Japanese Cainozoic based upon biostratigraphy, and used the following units in ascending order for the Quaternary; I_1, I_2, J_1 (a, b, c), J_2, J_3 and K. With his words, it is evitable to use the European units as Villafranchian or Calabrian for the Japanese Quaternary deposits without clear definition. His denomination is independent from tne European standard, and each unit has its type in beds established stratigraphically and bearing significant biota. His units represent the beds themselves as time-stratigrahical units and the time in which the beds were deposited as time units (in this case the unit is represented by type beds +x). In IKEBE's designation the types of each unit are as follows: I_1 (Kanôzan bed in Bôsô peninsula), I_2 (Sanuki bed in ditto), J_1 (Jizôdô sand bed to Yabu sand bed of the Narita Group in ditto), J_2 (Manzaki and Kiorosi shell

1) YABE, 1948; FUKUTA, 1950; KOBAYASI, 1951; SHIKAMA, 1950.

2) YABE, 1924.

beds of Tiba Prefecture), J_3 (the so-called "Kwanto loam bed")* and K (raised beach deposits and alluvium). The relationship between OTUKA's and IKEBE's units is as follows:

<table>
<tr><th></th><th colspan="2">Holocene</th><th colspan="7">Pleistocene</th><th>Pliocene</th></tr>
<tr><td>OTUKA, 1931</td><td>a_{II}</td><td>a_{I}</td><td>du_{II}</td><td>du_{I}</td><td colspan="2">dl_{II}</td><td>dl_{I}</td><td colspan="3">pd</td></tr>
<tr><td rowspan="2">IKEBE, 1948</td><td colspan="2" rowspan="2">K</td><td rowspan="2">J_3</td><td rowspan="2">J_2</td><td colspan="3">J_1</td><td rowspan="2">I_2</td><td colspan="2" rowspan="2">I_1</td></tr>
<tr><td>c</td><td>b</td><td>a</td></tr>
<tr><td>YABE, 1911</td><td colspan="8">Sikisima</td><td colspan="2">Mizuho</td></tr>
<tr><td>SHIKAMA, 1950</td><td colspan="2">6</td><td>5</td><td>4</td><td colspan="3">3</td><td>2</td><td>1</td><td></td></tr>
</table>

IKEBE treated I_1 and I_2 as Plio-Pleistocene separated from Pliocene and Pleistocene. OTUKA also proposed a special age of pd (his "Soga age") as intermediate between Pliocene and Pleistocene, indicating a sedimentary cycle (Soga Group in Sizuoka Prefecture, Akimoto Group in Bôsô peninsula, Uonuma Group in Niigata Prefecture and Ryukyu limestone in Okinawa Islands).[3] But this special unit is not so valid when we examine the Plio-Pleistocene deposits in Hokkaido, and nothern and eastern Honsyu.

In 1950 the present writer divided the Japanese Quaternary in as detailed a way as possible, in ascending order as follows:

I_1		Akasian	
I_2		Sanukian	Lower Kuzuüan
J_1	a	Makutian	
	b	Sematian	Middle Kuzuüan
	c	Naritian	
J_2	a	Manzakian	Upper Kuzuüan
	b	Nisiyagian	
J_3	a		Iwazikuan
	b		Tatikawian
	c		Egotian
K_1		Numian	
K_2		Yurakutyoan	
		(Marine-lacustrine)	(Land)

The Akasian is represented by the Akasi Group in Hyogo Prefecture; the Group is mainly composed of silt, clay, sand, gravel and tuff at the type-locality west of Akasi and according to ONUKI's recent information is about 200 m. in thickness as discovered from boring cores; it contains such characteristic fauna

*) IKEBE used the name Akazuti (red earth) bed and FUKUTA used the name of Kwanto Akazuti bed.

3) OTUKA, 1931; 1948.

and flora as *Parastegodon akashiensis* TOK. & TAK., *P. aurorae* (MAT.), *P. shodoensis* (MAT.), *Elaphurus davidianus* MILNE-EDARDS, *Metaplatyceros sequoiae* SHIK., *Capreolina mayai* TOK. & TAK., *Metasequoia japonica* ENDO, *M. disticha* MIKI, *Juglans cinerea* L., *Nuphar akashiensis* MIKI, *Berberis longispinus* MIKI, *Rosa akashiensis* MIKI, *Elaeagnus akashiensis* MIKI and *Paliurus nipponicus* MIKI etc.[4] The writer regards the *Parastegodon* bearing formation in Japan as almost certainly belonging to the Akasian. TAKAI refers this to the Lower Pleistocene, while the writer formerly regarded it as Villafranchian (in 1936 synchronolized to Upper Pliocene, according to TEILHARD DE CHARDIN and others) though he now believes it to be Late Pliocene.[5]

The Sanukian is represented by the Nansyo clay bed of the Palaeo-Biwa Group in Siga Prefecture and the Sanuki bed in the Bôsô peninsula, containing *Stegodon orientalis* OWEN, *Palaeoloxodon namadicus naumanni* (MAK.), *Cervus (Depéretia) praenipponicus* SHIK., *C. (? D.) kazusensis* MAT., *C. (Sika) yesoensis* HEÚDE, *Giraffa nipponica* MAT. etc.[6] It is notable that the mammalian fossils found in the basal gravel of the Sanuki bed (Nagahama, Tiba Prefecture) are largely derived from the underlying Kanôzan bed and are distinct climatologically from the cold molluscan fauna of the gravel; hence a part of the Kanôzan bed is included in the Sanukian. The Sanukian indicates the mammalian fauna itself and the deposits including the fauna primally rather than thh matrix containing the fauna at present. Sanukian is synchronolized with the Lower Kuzuü Group (spelean deposits) carrying *Stegodon orientalis* and *Sus* cf. *lydekkeri* ZDANSKY which is correlated to the *Sinanthropus* beds of Choukuotien.[7]

The stages from Makutian to Manzakian have been designated by IKEBE, although Manzakian itself was originally proposed by YOKOYAMA[8]; they are characterized by abundance of *Pecten (Patinopecten) tokyoensis* TOK. and common occurrence of *Palaeoloxodon namadicus naumanni* MAK. established by a part of the Narita Group in Tiba Prefecture; after IKEBE, Makutian is best represented by the Zizôdô sand bed, the upper border of which lies in the Kayabasi silt bed; the Sematian is best represented by the Semata sand bed (containing Azu, Moroiti and Kamiizumi shell beds), the upper border of which lies in *Erodona* clay; and the Naritian is best represented by the Yabu sand bed (containing the Kamiiwabasi shell bed). The last mentioned bed gradually changes to the Manzakian bed and the type of Manzakian is the Manzaki shell bed in Tiba Prefecture. All the stages from Makutian to Manzakian can be distinguished only in the Narita Group, where they are not separated funda-

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4) SHIKAMA, 1936; 1941; 1943; MIKI, 1938; 1948; MAKIYAMA, 1938.
5) SHIKAMA, 1943; 1950; TAKAI, 1938.
6) MATSUMOTO, 1924; 1926; TAKAI, 1936; SHIKAMA, 1941.
7) SHIKAMA, 1943; 1949; 1950.
8) YOKOYAMA, 1922.

mentaly by each other from biota. The Middle Kuzuüan seems to be corresponding to the stages from Makutian to Naritian. The Tokyo beds composing the foundation of the Yamate terraces of Tokyo city also correspond to the stages above mentioned; as do, large parts of the Harima Group in Hyogo Prefecture, and the Siokawa and Tikuma groups in Fossa-Magna; in these beds are found *Palaeoloxodon namadicus naumanni* MAK. and "*Parelephas trogontherii* POHLIG" (a tribe of *naumanni* after MAKIYAMA).[9] The Manzakian is characterized by cold molluscan fauna.[10]

The Nisiyagian is established by the Nisiyagi bed at Akasi coast and the *Bison occidentalis* bearing bed off Syodo Island in the Seto Inland Sea, and is characterized by rich mammalian fauna as *Palaeoloxodon namadicus naumanni* (MAK.), *P. n. setoensis* (MAK.), *P. n. yabei* (MAT.), *P. aomoriensis* TOK. & TAK., *Sus nipponicus* MAT., *Cervus (Depéretia) praenipponicus* SHIK., *C. (Sinomegaceroides) yabei* SHIK., *Bison occidentalis* LUCAS.[11] The Nisiyagian is correlated with the Upper Kuzuüan, the mammalian fauna of which are near the Kushungtun beds in North Manchuria and loessic fauna in North China.[12]

The Iwazikuan is established by the Iwaziku beds near Kiriu city, occupying the lower part of the so-called "Kwanto red earth beds", and is characterized by the occurrence of the "Iwaziku culture".[13] The same horizon is also seen in the red earth beds of Tokyo city. The lower part of the red earth beds is generally shown by gravelly facies and clayey facies of lacustrine origin. In Kuzuü district Iwazikuan is indicated by the Ôkubo bed which is a boulder bed of talus origin, indicating cool climate.

The Tatikawian, originally proposnd by MAKIYAMA, is established by red earth derived from decomposed volcanic ash, which developed a coating over the Musasino terrace around Tokyo city. It is most well developed in the vicinity of Tatikawa city.[14] Tatikawian occupies the upper part of the so-called "Kwanto red earth beds". The red earth bed corresponding chronologically to this bed are widely distributed in northern, central and western Japan where volcanic activities are distinct.

The Egotian established by Egota conifer bed in Tokyo and the *Larix* bed in Sumiyosi west of Ôsaka city, and is characterized by *Larix* flora consisting mainly of *Picea jezoensis* RHD., *Larix leptolepis* MURR,, *Pinus koraiensis* S. & Z., *Picea bicol* MAYR, *Tsuga Sieboldii* CARR., *Myrica gale* L., *Oxycoccus Palstris* PERS., *Andromeda polifolia grandiflora* LID., *Potamogeton graminerus* L., *Spar-*

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9) MAKIYAMA, 1938.

10) YABE & NOMURA, 1926.

11) MATSUMOTO, 1915; 1918; 1924; 1929; MAKIYAMA, 1938; SHIKAMA, 1938; 1943; TOKUNAGA & TAKAI, 1936.

12) BLACK, TEILHARD DE CHARDIN, YOUNG, PEI, 1933.

13) SUGIWARA, 1950.

14) MAKIYAMA, 1931.

ganium cf. *minimum* FREIS., *Menianthes trifoliata* L. etc.[15] This flora represents the recent flora of 1000–2000 m. above sea level of the central high mountainland of Japan. The climatic condition of Egotian is eminently cold, 4.6°–8.7°c of annual mean temperature cooler than that in present days. The Egota conifer bed is deposited in the head or bottom of a valley made after the deposition of the Tatikawian red earth.

The Numian from the coral bed of Numa near Teteyama, Tiba Prefecture, which is classically famous since the discussion of YOKOYAMA and YABE;[16] occupies the lower part of the Yurakutyo beds; and is characterized by vigorous distribution of *Anadara granosa bisenensis* SCHENCK & REINHART. The distinct large stocks of reef building coral indicate the climatic condition was a little warmer than that of present days. According to NIINO's information, a similar coral reef is found off Noto peninsula, where the present temperature of the sea water does not permit the growth of reef building coral. The marine deposits of Numian compose the raised beach or marine terraces of abuot 15 m. above sea level. MIKI's *Sapium* bed of warm flora is also synchronolized with Numian.[17]

Yurakutyoan is represented by the upper part of the Yurakotyo beds, the climatic condition of which is not so different from that of the present. The lower border of the Yurakutyoan lies in the middle Zyomon cultural age, when the climatic condition changed from rather warm to rather cold. Numian and Yurakutyoan correspond to the Neolithic age and contain many shell mounds and cultural sites.

Of course these stages are not established by one group in a district, but the faunal succession and vertical sequence of them are clearly reduced by synchronolization of type districts.

Recently H. OZAKI, O. FUKUTA and Y. ANDO announced important observations of the northeastern part of the Yamate terraces of Tokyo city. According to FUKUTA, the order is as follows in descending order[18]:

1. Yurakutyo bed (Yurakutyo shell bed of YAMAKAWA, 1909)

This bed is composed of bluish grey silty clay with many mollusca, foraminifera and ostracoda, is 40 m. in thickness and was deposited in drowned valleys made after the deposition of the red earth bed. The upper part characterized by large shells of *Ostrea gigas* THUNBERG, and *Anadara granosa bisenensis* SCHENCK & REINHART restricted to the lowest part. Drowned valley age of FUKUTA.

2. Egota* plant bed (conifer bed of MIKI, 1938)

15) MIKI, 1938; 1941b; 1948.
16) YOKOYAMA, 1911; 1924; YABE, 1922.
17) MIKI, 1948.
18) FUKUTA, 1950.
*) FUKUTA writes as Ekoda.

Table 1. Correlation of type districts.

<table>
<tr><th></th><th>Akasi</th><th colspan="2">Ôsaka</th><th colspan="2">Bôsô peninsula</th><th>Takinogawa, Tokyo</th><th colspan="2">Kuzuü</th><th>Egota</th><th>Manzidani, Nisinomiya</th><th colspan="2">Sitamati, Tokyo</th></tr>
<tr><td>Yurakutyoan</td><td rowspan="5"></td><td rowspan="5" colspan="2"></td><td rowspan="3" colspan="2"></td><td rowspan="2">Neolithic peat</td><td rowspan="3" colspan="2"></td><td rowspan="2">Neolithic peat</td><td>Apananthe bed</td><td rowspan="2">Yurakutyo bed</td><td>Up.</td></tr>
<tr><td>Numian</td><td>Sapium bed</td><td>Low.</td></tr>
<tr><td>Egotian</td><td>Egotian peat</td><td>Egota conifer bed</td><td>Larix bed</td><td rowspan="10" colspan="2"></td></tr>
<tr><td>Tatikawian</td><td rowspan="2" colspan="2">Red earth</td><td>Red earth</td><td colspan="2">Red earth</td><td>Red earth</td><td rowspan="9"></td></tr>
<tr><td>Iwazikuan</td><td>Red earth</td><td colspan="2">Ôkubo bed</td><td>Red earth</td></tr>
<tr><td>Nisiyagian</td><td>Nisiyagi bed</td><td rowspan="2" colspan="2">Hozumi bed</td><td colspan="2"></td><td>Tokumaru shell beds</td><td rowspan="6">Kuzuü beds</td><td rowspan="2">Upper</td><td rowspan="7"></td></tr>
<tr><td>Manzakian</td><td rowspan="5">Harima Group</td><td rowspan="5">Narita Group</td><td>Manzaki shell bed</td><td>Upper Ôzi shell bed</td></tr>
<tr><td>Naritian</td><td rowspan="6">Ôsaka Group</td><td rowspan="5">Ibaraki beds</td><td>Yabu sand bed</td><td rowspan="3">Lower Ôzi shell bed</td><td rowspan="3">Middle</td></tr>
<tr><td>Sematian</td><td>Semata sand bed</td></tr>
<tr><td>Makutian</td><td>Zizôdô sand bed</td></tr>
<tr><td>Sanukian</td><td>Sasage bed</td><td rowspan="2"></td><td>Lower</td></tr>
<tr><td>Akasian</td><td>Akasi Group</td><td>Senri-yama beds</td><td colspan="2">Kanôzan bed</td><td colspan="2"></td></tr>
</table>

FUKUTA assumes that the height of Yamate terraces when this bed was deposited was 70-80 m. above sea level. Conifer forest age of FUKUTA.

3. Kwanto red earth (Akatuti) bed

This bed is about 10 m. in thickness and consists of decomposed basic volcanic ash and sand. The lower part of it intercalates one or two pumice and sand beds, indicating clear stratification and bearing plant remains. Upper is bad land age, and lower marshy land age of FUKUTA.

4. Yamate bed

Itabasi clay (=Greyish white clay of MAKIYAMA, 1930)

Yamate sand and gravel (=Yamate bed of MAKIYAMA, 1930)

This corresponds to the so-called Musasino gravel bed. Itabasi clay is composed of bentonite of 4.3 m. in maximum thickness. Yamate sand and gravel is cross-laminated, about 2 m. in thickness but attaining nearly to 8 m. at Ôzi-mati. The upper part is sandy and lower is gravelly. Upper is flood plain age, and lower river beach age of FUKUTA.

5. Tokyo beds (Tokyo bed of YABE, 1922)

The upper is alternation of sand, silt and clay and contains the upper and middle shell beds. It is lowerly cross-laminated. The lower part is alternation of sand and gravel intercalating clay and bearing the lower shell bed. The lower shell bed is the famous Ôzi shell bed exposed along the Syakujii valley near Ôzi (No. 1188, Takinogawa-mati), the lower part of the Tabata shell bed, and the *Anadara granosa bisenensis* bed at Yedogawa park.[19] The middle shell bed is represented by the shell bed at Syozu temple in Takinogawa-mati, the upper part of the Tabata shell bed and the upper shell bed at Yedogawa park.[20] The upper shell bed is represend by the TOKUMARU shell bed.[21] According to the detailed researches of ANDO, the fauna of the middle shell beds is cooler or more related to the Oyasio type than the lower and upper. ANDO made the following comparision:

	Upper (TOKUMARU)	Middle (Syozyu temple)
1. *Minolia (Conotolopia) ornata* SOWERBY		c
2. *Syrnola (Agatha) virgo* A. ADAMS		a
3. *Tectonatica janthostomoides* KURODA & HABE (qo)	c	c
4. *Pyrene (Mitrella) varians* (DUNKER)	c	c
5. *Nassarius (Tritonella) japonica* (A. ADAMS)	c	a
6. *Ringicula (Ringiculina) doliaris* GOULD	c	a
7. *Acila (Truncacila) insignis* (GOULD) (qo)		a
8. *Anadara (Saarharca) broughtonii* (SCHRENCK)	c	c
9. *Glycimeris yessoensis* (SOWERBY) (o)		a
10. *Pecten (Patinopecten) tokyoensis* TOKUNAGA	r	a
11. *P. (Notovola) albicans* SCHRÖTER	a	r
12. *Diplodonta (Felaniella) usta* (GOULD) (qo)		c
13. *Cardium (Clinocardium) californiense* DESHAYES (o)		c

19) OINOMIKADO, 1936.
20) OZAKI, FUKUTA & ANDO, 1951.
21) FUKUTA & ANDO, 1951.

14.	*C.* (*Fulvia*) *muticum* REEVE	a	a
15.	*Lucinoma annulata* (REEVE) (qo)		a
16.	*Saxidomus purpuratus* (SOWERBY)		c
17.	*Dosinia* (*Phacosoma*) *troscheri* LISCHKE	a	a
18.	*Mercenaria stimpsoni* (GOULD) (o)		c
19.	*Protothaca adamsi* (REEVE) (o)	r	a
20.	*Mactra* (*Mactra*) *sulcatalia* REEVE		a
21.	*Schizothaerus keenae* KURODA & HABE	f	c
22.	*Macoma tokyoensis* YOKOYAMA	f	a
23.	*Solen krusensterni* SCHRENCH (qo)		a
24.	*Cryptomya busoensis* YOKOYAMA	c	c
25.	*Mya* (*Arenomya*) *japonica* JAY	c	

o: Species of the Oyasio type. qo: Ditto of quasi-Oyasio type. c: Common. r: Rare. a: Abundant. f: Few.

FUKUTA is considering the middle shell bed correlated to the Manzakian.

The writer observed with H. OZAKI the cliff near Otonasigawa Hotel in Takinogawa-mati and its neighbourhood, where the lower and middle shell beds are exposed: the lower bed is composed of massive grey silt, bearing abundant shells, while the middle bed consists of fine laminated clayey silt and cross-laminated sand, bearing many casts of shells, and overlying upon the lower unconformably. Furthermore upon these beds lies unconformably a brown sandy bed with chert pebbles and some shells as *Cyclina orientalis* SOWERBY, *Anadara granosa bisenensis* SCHENCK & REINHART, and *Batillaria* sp. The Otonasigawa shell bed of the writer, can probably be correlated with the Tokumaru shell bed or a part of the Yamate bed. Upon these lie unconformably 2 beds of black loamy sand with chert pebbles, and the lower of these probably corresponds to Egotian.

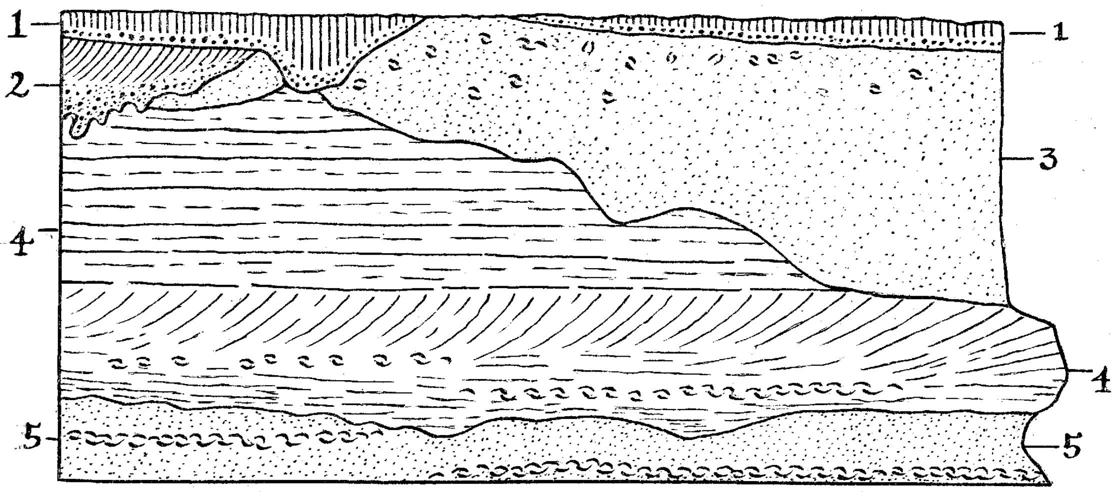

Fig. 1. A cliff at Otonasigawa Hotel, Takinogawa-mati, Tokyo.
1: Black loamy sand (Yurakutyoan-Numian). 2: Black loamy sand (Egotian). 3: Brown sand with shell (Takinogawian). 4: Laminated clayey silt with shell (Manzakian). 5: Massive silt with shell (pre-Manzakian). ⌒: Shell fossils.

Here the writer proposes Takinogawian for the Otonasigawa bed and Tokumaru shell bed. Takinogawian is synchronolized with Nisiyagian. The Yamate bed is also probably included in the Nisiyagian. Large parts of the so-called plateau gravel, terrace gravel and dissected fan deposits and some parts of the mountain gravel, widely distributed throughout Japan, are generally correlated to Nisiyagian in age.[22] Nisiyagian is the age of wide scaled terrace making (the M plane, Musasino terrace, DU_1 terrace of OTUKA) in Japan; uplifting is distinct and the Japanese Islands were connected to the Chinese continent; hence the exotic rich fauna of the Upper Kuzuüan could migrate from China or Manchuria.[23]

When revised bio-stratigraphically, the stages of the present writer above mentioned—except J_3—are characterized by distinct fauna and flora as follows:

Akasian: *Parastegodon* fauna and *Metasequoia* flora.
Sanukian and Lower Kuzuüan: *Stegodon orientalis* fauna.
Middle Kuzuüan: *Parelephas trogontherii* and *Palaeoloxodon namadicus naumanni.*
Upper Kuzuüan: *Palaeoxodon aomoriensis,* Japanese megacerid and *Bison occidentalis* fauna.
Iwazikuan: (Iwaziku culture)
Egotian: *Larix* flora.
Numian: *Sus nipponicus* fauna and *Sapium* flora.

These faunal and floral successions, of course, are due to migration, reflecting not evolution but distribution: Hence, though they are helpful in considering Japan, they are not useful for other areas; but this is inevitable in studying the Quaternary chronology. From the view point of the Eurasian mammal evolution, the Japanese Pleistocene can be divided only into Lower (*Stegodon* fauna) and Upper (*Palaeoloxodon* fauna), just as the European Pleistocene is separated into Lower (*antiquus*) and Upper (*primigenius*). But if we treat the Quaternary stratigraphy, we can't satisfy ourselves with such large-scaled chronology. If considered from the view point of abstract time interval, Akasian represents a time range of about 500,000 years, each stage from Sanukian to Nisiyagian represents about 100,000, those from Iwazikuan to Egotian about 10,000 years each, and Numian and Yurakutyoan about 7,000 and 3,000 years respectively; so that the time range of J_3+K is far less than that of Nisiyagian or Manzakian. Compared to Akasian, Yurakutyoan is almost negligible in time range, so that biostratigraphically the stages of J_3+K loss their characteristics. Hence Cainozoic stratigraphers who are familiar with Tertiary sediments, find the Quaternary chronology a somewhat narrower field of study than the Tertiary. Of course, we must also remember that the higher we ascend the chronological scale of the Quaternary, the smaller each

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22) NAKAMURA, 1933; OZAWA, 1926; OTUKA, 1931; OTUKA & YATSU, 1948; SHIKAMA, 1943; 1950.

23) YABE, 1929; SHIKAMA, 1943.

stages becomes in time range although it becomes more important in weight of episodes. The sediments of Yurakutyoan or Tatikawian represent a short time but they are exceedingly widely distributed like a kind of film coating and they are very familiar to us.

In this paper the writer intends to arrange all the stages by their order of time range as follows:

I (Series)	II (Stage)	III (Substage)	IV (Class)
−50	−10	−1	−0.7 (10 thousand years)
		Sitamatian (1)*	Yurakutyoan (0.3) =Azutian* Numian (0.7) =Sumiyosian*
	Yamatean (3)*	Egotian (1) Tatikawian (1) Iwazikuan (1)	
Musasinoan (60)*	Nisiyagian(10) =Takinogawian* Manzakian (10) Naritian (10) Sematian (10) Makutian (10) Sanukian (10)		
Kanôzanian (40)*			
Akasian (50)			

* Here newly proposed.

After IKEBE's time-stratigraphical denomination, the first order corresponds to series, second to stage, third to substage and foursh to class,[24] and bio-stratigraphically megaevolutional succession is not seen in any subdivision below the stages. In determining the succession of substage and class, we must adopt the methods compositively of climate, terraces, culture and biota. Here Akasian is excluded from Quaternary and as the basal stage of Quaternary is proposed Kanôzanian, the type of which is the Kanôzan bed in Tiba Prefecture.

In 1949 S. HANZAWA indicated the following episode succession for the Japanese Quaternary in ascending order:

Pls. Stage I. Tectonism of Plio-Pleistocene and its succeeding emergence.
„ II. Deposition of Naganuma bed. Transgression.
„ III. Deposition of Byobugaura bed. Transgression.
„ IV. Deposition of Sanuki bed. Transgression.

24) SUZUKI, 1950.

„ V. Deposition of Narita bed. Transgression.
„ VI. Post Narita Group (from Naganuma to Narita) tectonic movement. Uplift.
„ VII. Deposition of Amadan shell bed. Transgression.
„ VIII. Deposition of Aobayama gravel bed. Regression and composing several marine terraces throughout Japan. Deposition of Kwanto loam.
H. Stage IX. Transgression. Deposition of Yurakutyo shell bed. Submergnece of 15 m. depth.
„ X. Cyclic emergence and appearance of several marine terraces.

His stages are synchronolized with the writer's stages as follows:

Table 2. Quaternary sedimentation and terrace making in Japan.

	Hanzawa	Shikama				Terraces			Glacial
		Sedimentary		Spelean, Eolian		Aoki, Tayama	Otuka	Yabe	
Holocene	X	Yurakutyoan	Sitama-tian		6 (K)		A11		
	IX	Numian				PL	A1		
Pleistocene		Egotian	Yamatean		5 (J3)	B	DU11	M	W
				Tatikawian					
	VIII	Iwazikuan		Iwazikuan		↑	↑	↑	
	VII	Nisiyagian (Takinogawian)	Musasinoan	Upper Kuzuüan	4 (J2)	M	DU1	T	R
	VI	Manzakian				A	DU1a		
	V	Naritian		Middle Kuzuüan	3 (J1)				
		Sanukian							
		Makutian				T	DL		M
	IV III II	Sematian		Lower Kuzuüan	2 (I2)	PN	Pd	PN	G
	I	Kanôzanian			1 (I1)	↑	↑	↑	
Pliocene		Akasian							

III. Boundary between Holocene and Pleistocene in Japan

As stated above, it is rather difficult to establish the Holocene-Pleistocene boundary. YABE's opinion is very important in that the Egota conifer bed and the coral bed of Numa are both deposited after the Kwanto loam bed and their climatic conditions are very different, the former being very cold and the latter rather warm.[25] At least we can't accept such a cold age as indicated by the Egota conifer bed for inclusion in the Holocene. Thus Egotian is older than Numian, and probably included in the latest Pleistocene. According

25) YABE, 1948.

to FUKUTA the valley bottom when the Numian transgression was opened, now lies 35 m. below sea level: hence the height of the terrace surfaces when the valley was not drowned and an Egotian forest developed upon the surfaces comes to be 35+(35—40)=70—75 m. above sea level. (35—40 m. is the height of the terrace at present). The height of the Egotian floral acmae is 1000—2000 m. above sea level; hence the difference indicates that in the Egotian the annual mean temperature was 4.6°–9.7°c cooler than in present days. The flora is purely homogenous and not mixed with the low land flora; hence it is not transported from distant districts, but autochtonous. MIKI says that the Egotian floral remains are widely distributed from Simane to Aomori Prefectures. The peat deposits of Karakemi, Aikawa and Mihara in the northern part of Nagano Prefecture also belong to Egotian, and contain many remains of ***Brasenia purpurea*** CASP. (seed), coleopterian carapace and viviparid operculum. KOBAYASI divides the peat bed into the lower ***Menyanthes*** bed and the upper ***Brasenia*** bed.[26] ***Menyanthes*** is not rare in the lignite or peat beds in northern Honsyu; for instance, in the Noheji bed in Aomori Prefecture it is found accompanying ***Palaeoloxodon aomoriensis***.[27]

Throughout the Japanese coast, raised beach deposits are common, and eustatic submergence is recognizable. The shell beds correlated to the Yurakutyo bed or to the Numa coral bed are widely distributed in the Pacific coast area of west-central Japan.[28] In 1932 S. NOMURA reported such beds in southern Kwanto, and recently T. MAKINO has been studying the raised beach shell bed of Kami-Ooka, Ôfuna and Hayama in Kanagawa Prefecture. M. MINATO announced an interesting study of the Holocene history of Abasiri lake and its neighbourhood. According to his study, a gradual emergent changing of water level is observable and four stages (***Paphia*** sea, ***Ostrea*** sea, ***Corbicula*** lake and ***Anodonta*** lake in ascending order) are pointed out. The oldest Neolithic culture begins from the age of the ***Ostrea*** sea in the Abasiri district. Although in the Holocene the tendency of emergence or submergence does not coincide in different districts throughout Japan, generally emergent history is more well known than submergent as far as archaeological records are concerned. In the Kwanto district, it seems that the Holocene submergence reached its maximum in the middle stage of the Zyômon cultural age.[29] At any rate it is not deniable that Egotian occupies the latest part of the Japanese Pleistocene and Numian the lower part of the Japanese Holocene.

IV. Succession of Biota and Climatic Changes

From the zoogeographical point of view, Japanese land fauna is only a division of the East Asiatic fauna. In 1943, the writer discussed the relation-

26) KOBAYASI, 1951.
27) IWAI, 1951.
28) OTUKA, 1931; 1948.
29) SAKAZUME, 1948.

Table 3. Tectonism of the Harima coast west of Kôbe city.
(v): Volcanism.

Stage	Deposition	Epeirogenesis	Erosion		Fault movement
6 (K)	Later stage of submerged coast	Small uplift Submergence Uplift	Recent pluvial plane Intermediate planes (10 m. high above sea level)		
5 (J_3)	Akasi gravel Lateritization?	Tilting (?) Uplift	Low. terrace (B)	Ôkubo plane (20-30 m.) Hitomaru p. (40-50 m.)	Fault
4 (J_2)	Torrential deposits (Ôkubo gravel) (Nisiyagi bed)	Tilting Uplift	Mid. terrace (Du)	Nagata p. (60-80 m.) Tarumi p. (100-130 m.) Akasi p. (140-160 m.)	
3 (J_1) 2 (I_2)	Maiko shell bed Delta and pluvial deposits Fan	Tilting Submergence Subsidence Tilting	Up. terrace (Dl)	Husebata p. (200-220 m.) Sirakawa p. (260-270 m.) Aina p. (290-310 m.)	(v)
1 (I_1)		Tilting Uplift	Higher planes	Ôbu p. (350-370 m.) Takao p. (390-420 m.) Other higher planes	Fault and thrust Block movement Uplift of Rokko mount.
	Akasi Group				(v)

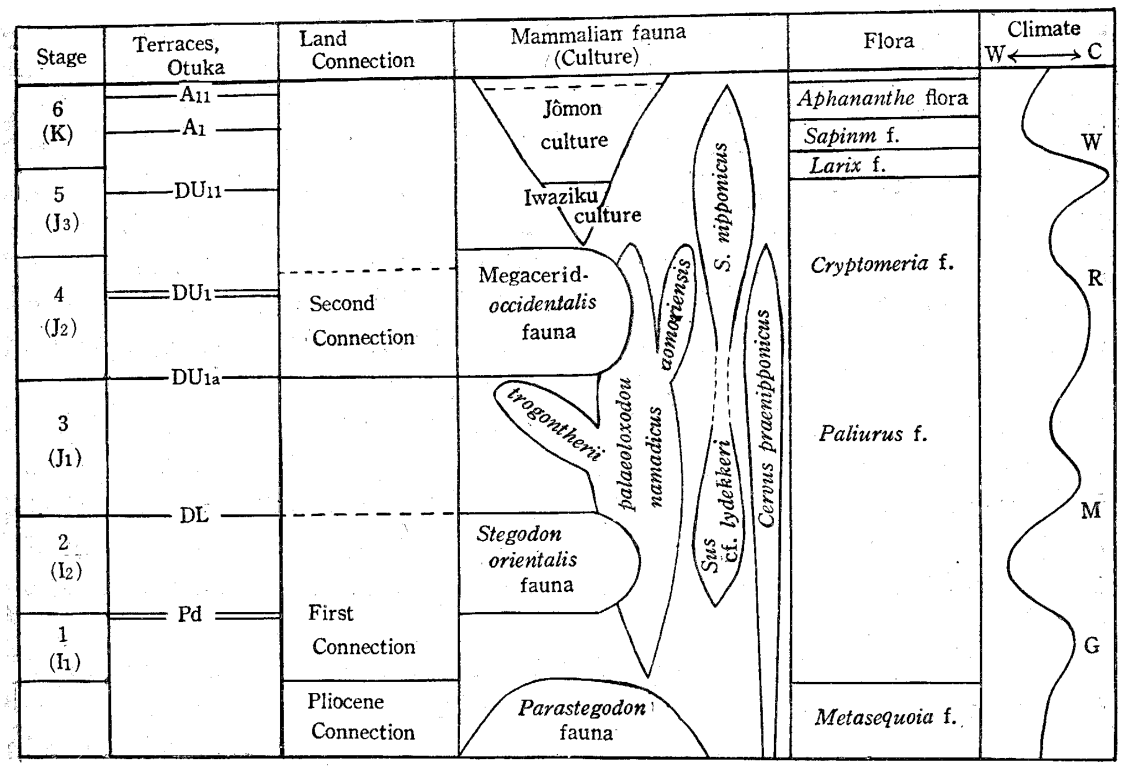
Table 4. Quaternary tectonism of Okinawa Island.

Stage	Deposition	Epeirogenesis	Erosion
6 (K)		Uplift	Raised beach plane (1-3 m.) Mabuni plane (5-6 m.)
		Submergency	
5 (J_3)	Red earth	Uplift Local submergency Uplift	I-e plane (15 m.) Naha plane (20-30 m.) Okinawa plane (50-90m.)
4 (J_2)	I-e bed (*Muntiacus* bed) Kunigami bed (sand & gravel) Marine travertine of cave		
3 (J_1) 2 (I_2)	Ryukyu limestone (reef building)	Submergency	
1 (I_1)		Uplift	Simaziri plane (100-130 m.) Kunigami plane (200m.)

ship between mammalian faunal appearance and epeirogenic movement in Japan. In Japan we see the uniform development of two distinct terraces above or below sea; that is the Pre-Narita (PN) plane and the Musasino (M) plane. In the Japanese Quaternary there were two (PN–Pd. M–Du_1) or three (N–Pd, T–Dl, M–Du_1) distinct emergent ages and this especially observable in western Japan as shown in Table 3.

The first distinct emergence is seen in stage 1 (Kanôzanian), the second one is in stage 4 (Nisiyagian) and eminent submergence is seen in stages 2 and 3. Land connection of Japan with the Asiatic continent began in the Kanôzanian (I_1) and again in the Manzakian (J_2), and by the landbridges of these connections, continental elements of fauna and flora migrated into Japan. The relationship of them is shown in the following table.

Table 5. Faunal and floral succession of Japanese Quaternary.



The archaic flora (*Metasequoia, Glyptostrobus, Liquidamber, Juglans cinerea* etc.) and fauna (*Parastegodon, Metaplatyceros, Capreolina* etc.) of the Akasian suddenly disappeared in the Kanôzanian, as far as we can tell from any valid record of characteristic mammals, and the writer regards the cause of their extinction in Japan to be climatic change. From the Akasian to the Kanôzanian, land connection was continued as indicated by PN planes, but in western Japan (northern Kyushu) the land bridge seems to have been cut by a strait, so that in the Kanôzanian we cant's see any invasion of continental elements.

In the Sanukian the *Stegodon orientalis* fauna appeared and then disappeared in the Makutian. Its appearance is perhaps the result of the land connection of the final stage of PN emergence, while its extinction may be due to climatic change. *Palaeoloxodon namadicus* or *Cervus* (*Depéretia*) *praenipponicus* continues to the end of the Upper Kuzuüan. The Malayan elements, as *Parastegodon* fauna, and the South Chinese elements as *Stegodon orientalis* fauna, were both extinguished by cold climate, but the temperate elements as *namadicus* or *praenipponicus*, could survive. In the Middle Kuzuüan the mammlian fauna is rather poor; the aberrant form of *trogontherii* elephant is found (Siokawa bed in Nagano Prefecture). In the Upper Kuzuüan we know vigorous development of continental fauna which could invade Japan by the Manzakian land connection.[30] Into the Ryukyu Islands, *Palaeoloxodon namadicus, Capreolus tokunagai, Cervus ryukyuensis, Muntiacus astylodn,* Ovid and ape could migrate from the Asiatic continent.[31] From the Upper Kuzuü bed, the Inland Sea, and the Tukinoki asphalt bed in Akita Prefecture we know rich fauna, characterized by *Palaeoloxodon aomoriensis* TOK & TAKAI, *P. namadicus yabei* MAT., *Rhinoceros shindoi* TOK., *Dicerorhinus* sp., *Sus nipponicus* MAT., *Moschus moschiferus* L., *Cervus* (*Depéretia*) *praenipponicus* SHIK., *Cervus* (*Sinomegaceroides*) *yabei* SHIK., *Nemorhaedus nikitini* SHIK., *Bison occidentalis* LUCAS, *Ursus tanakai* SHIK., *Vulpes* cf. *vulpes* L., *Meles leucurus kuzuüensis* SHIK., *Putorius kuzuüensis* SHIK., *Mustela* (*Mustela*) *erminea* L., *Felis pardus* L. etc. Nearly 60% of them are Amur-Manchurian elements. Here it is noteworthy that *Mammuth primigenius* (BLUM.) or *Parelephas armeniacus* Falc., characteristic of the Kushungtun fauna (Malan stage), occurs in the Rukutama bed in South Saghalien and is dredged from Sôya strait; it sesms to be included in the Upper Kuzuüan.[32] In the Yamatean a large part of the exotic elements were destroyed; hence in the *Larix* flora of Egotian we can't see any distinct exotic mammals; perphaps they were extinguished in the volcanic activity of the Tatikawian (falling of ash and lack of foods) and in the climatic changes which took place.

Quantitative researches concerning the appearance or disappearance of Oyasio - quasi Oyasio types of molluscan fauna of the Musasinoan should be performed, since no accurate results have been announced sine OTUKA's general view. At any rate, decisively warm climate is shown by the Sanukian-Lower Kuzuüan land fauna, Numian marine fauna and Sumiyosian flora, and clearly cold climate is indicated by Manzakian marine fauna, Upper Kuzuüan land fauna and Egotian flora.

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30) SHIKAMA, 1949.

31) MATSUMOTO, 1926; TOKUNAGA, 1936; 1940; TOKUNAGA & TAKAI, 1939; SHIKAMA, 1943; OTUKA, 1941.

32) SASA, 1937; URITA, 1937; SHIKAMA, 1943.

V. Pre-Zyomon Culture and Early Man in Japan

In 1949, S. SUGIWARA, T. SERIZAWA, T. AISAWA and others found and excavated some lithic implements from the so-called "Kwanto rėd erath beds" near Kiriu city. In 1951 the writer and SUGIWARA announced the stratigraphical position of the beds in question, for which is given the name Iwaziku beds. They occupy the lower part of the Kwanto red earth beds, coating widely the M terrace (Saba terrace land) of 120–140 m. high above sea level between Kiriu and Maebasi in Gunma Prefecture, and are divided into four beds in ascending order as follows:

Inariyama bed.
1. Inariyama grey clay bed (5 m.)

Iwaziku beds.
2. Konpirayama brecciated clay bed (1-4 m.)
3. Iwaziku dark brown clay bed (0.3-0.6 m.)

4. Azami pumiceous sand bed (0.2-1 m.)
5. Sakurazaka yellowish brown clay bed (0 4-1 m)

6. Kasakake black earth (0.45-1 m.)

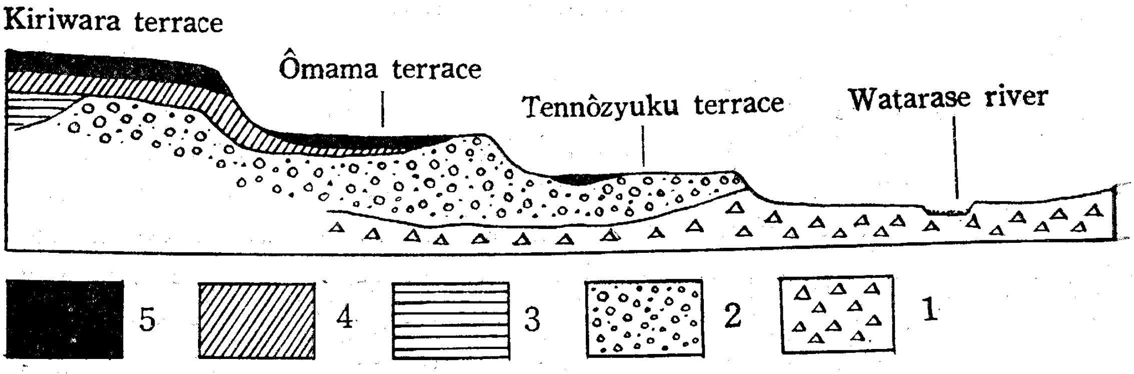
Of these, the Inariyama bed may correspond to the Itabasi clay bed or the Tokyo bed, and Kasakake black earth is a kind of surface soil. In Inariyama of Iwaziku, Sakurazaka, Daiyama of Yabutuka, Mituya of Ôgo-mati and Gongenyama in Uehasu-mura etc., from the Iwaziku beds are found lithic implements and no pottery is associated with them. Some cultural layers are known in Inariyama and Mituya as follows:

Beds.	Cultural layers			Types of culture
	Inariyama	Mituya	Daiyama	
6	Inaridai	II		Earliest stage of Zyomon culture
5	II b	barren		Pre-Zyomon culture
4	II a	I		
3	I	barren	I	
2				
1				

Some stone implements and pottery fragments are found not only from the surface soil but subsiding in the uppermost part of the 5th bed; they belong to the Inaridai cultural stage, the oldest known stage of the Zyomon culture.

The cultural layer I of Inariyama and Daiyam contains large-sized implements such as *coup-de-poing* made of gray hard shale; II a of Inariyama carries *racloir* and *grattoir* made of grey to dark grey chert; II b of Inariyama and I of Mituya contain *grattoir* of obsidian; otherwise some fine *lames* of obsidian are found from Inariyama though their stratigraphical horizon is not precisely known, SUGIWARA add SERIZAWA including them in cultural layer III, which occupies the horizon between beds 5 and 6. It is notable that the northeastern border of the Saba terrace land is retouched by a younger terrace (Tennôzyuku terrace), the surface of which lacks Iwaziku beds except for secondary deposition of loamy soil in local portions.[33]

Fig. 2. Generalized cross-section of Iwaziku and its vicinity.
1: Volcanic ejecta. 2: Watarasegawa gravel bed. 3: Inariyama bed.
4: Lower Iwaziku beds. 5: Upper Iwaziku beds.



The geological history of the neighbourhood of Iwaziku is summerized as follows;

Table 6. Geological history of Iwaziku and its vicinity.

Stage	Cultural stage	Deposition	Erosion
6 (K)	Earliest Zyomon (Inaridai)	Kasakake black earth Local secondary loam	Present river floor (A_{II}) Tennôzyuku terrace (A_I)
5 (J_3)	Pre-Zyomon	Iwaziku beds	Present plane of Ômama terrace (DU_{II})
4 (J_2)		Inariyama bed and Watarasegawa gravel bed	Original plane of Ômama terrace and Kiriwara terrace (DU_I)
?		Volcanic ejecta	Higher erosion planes (PD)

33) TADA, 1950.

Hence the deposition of Iwaziku beds, including the Iwaziku culture, comes before the composing DU_{11} plane (J_3) and is synchronolized with the deposition of the Kwato red earth bed in the Tokyo district. This stage is included in the Latest Pleistocene as described above. Recently some cultural sites of obsidian implements have been found by SUGIWARA and others from the Kwanto red earth bed of Moro (Kamiitabasi) and others in Tokyo city. At present no fossils have been found from these sites. In 1931 NAORA reported human bone (pubis and ischium) from the Nisiyagi bed on the Akasi coast. Different opinions about this remain have been discussed amoug the Japanese anthropologists; Hasebe regards them as fossil man. In 1936 TOKUNAGA reported some bone implements from the I-e bed (cave travertine) of I-e Island in Okinawa. At any rate, the possibility of the appearance of early man in Japan since J_2 can not be denied.

VI. Glaciation in Japan

Nowadays it is generally accepted that in Japan are seen, though not large-scaled, some traces of hanging-, valley head- and valley-glaciers in the high mountain ranges above 3000 m. above sea level, sueh as the Hida-, Akaisi-, Kiso- and Hidaka-ranges.[34] In 1949, the writer and K. KOBAYASI announced their opinions about the geological ages of the Hida- and Kiso- ice ages. These ice ages are synchronolized with each other, and related to the old gravels of the Fossa Magna and to the Tenryu gravel bed in the valley of Ina; these beds belong to the Upper Kuzuüan (J_2). The emergence of M–Du_1 planes in J_2, combined with the cold wave of a climatic curve in J_2, brought the high mountain ranges above the snow line, and hence they are glaciated. The cold waves of I_1 and J_1 could not bring glaciation to the high mountain ranges, owing to the low leveled emergence. Perhaps the cold wave of J_3 also brought glaciation on the glaciated portion of the high mountain ranges, but physiographically to distinguish them is almost impossible. The group of cirques of Hida range is made after the block movement and faulting of the range is finished (J_2 after KOBAYASI) and a part of the Kar Bodens is already eroded by the recent tributaries. It is noteworthy that in the upper level of Mt. Fuji, which is higher than the glaciated level of the Hida range, is not found any alpine flora although it is very common in the Hida range. The finishing of the recent physiographical outline of Mt. Fuji is in K, while a part of the Kwanto red earth bed is related to the detritus of Mt. Hakone,[35] which is more strongly dissected than Mt. Fuji. According to K. KOBAYASI, the red earth of the Fossa Magna (brown ash), belonging to J_3 and synchronolized with the Kwanto red earth bed, is related to the volcanism of Mts. Ontake, Norikura, Yakedake,

34) IMAMURA, 1937; 1940; TANAKA, 1941; SASA, 1934.
35) KUNO, 1936.

Tate-yama, Omine etc. by the existence of biotite:[36] on these volcaeoes we can see alpine flora. To conclude, the glaciation in Japan is seen in the third (J_2) and fourth (J_3) cold ages and perhaps the former is synchronolized with the Riss ice age.

VII. Synchronolization with the Chinese Quaternary

The eminent pluvial periods of the Chinese Quaternary are as follows in ascending order: Sanmenian, Choukuotienian, Malan and Black earth age. From faunal consideration, Akasian is correlated to Nihowan, Sanukian to *Sinanthropus* formation of Choukuotienian. Upper Kuzuüan to Malan and Probably Egotian-Numian to Black earth age. The physiograpnical changing between the Choukuotienian reddish clay and the Malan yellow earth (loess and its allied earth) is very eminent, and TEILHARD DE CHARDIN attributed this to gradual emergence of the continental shelf accompanied with some other factors. This eminent interval (Chingshui stage) corresponds to the erosion interval between coral reef limestone (Ryukyu limestone and Maliana limestone) and terrace deposits in the Ryukyu and Maliana islands and also to the beginning of DU_1 terrace making. Generally speaking, the Choukuotienian pluvial age corresponds to the Lower add Middle Kuzuüan or the submergence of Ryukyu limestone, and the Malan pluvial age is synchronolized with the Upper Kuzuüan. About the correlation of glacial ages of China and Europe, differences of opinion are seen, as indicated in the following table.

Table 7. Correlation of the Chinese and European glacial ages.

China	Shikama 1951		Teilhard de Chardin 1941	Movius 1951	de Terra 1941
Panchiao	6 (K)				
Black earth			W	W	
	5 (J_3)	W			
Lopa					
Malan	4 (J_2)		R		W
		R			
Chingshui					
Choukuo-tien	3 (J_1)			R	R
		M			
	2 (I_2)		M	M	M
Huangshui	1 (I_1)				
Sanmen		G		G	G
			G		

36) KOBAYASI, 1951.

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