Sea Level Changes during the Brunhes Epoch in the Hokuriku District, Central Japan

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Abstract

The Pleistocene and Holocene sediments on sea level changes for the Brunhes Chron in the Hokuriku district are distributed localy in Noto Peninsula and in the lowland areas along the coastal areas of Japan Sea. Namely, in the Nanao area of the southern Noto Peninsula, the Quaternary sediments are divided into four units such as the middle Pleistocene Takashina, the late Pleistocene Okuhara, the latiest Pleistocene Tokuda gravel members and the Postglacial deposits. The Quaternary sediments of the Himi area in the southern Noto Peninsula are divided into six units as the Plio-Pleistocene Himi Formation, the early Pleistoce Saida, the middle Pleistocene Kamitako, the earliest late Pleistocene Kokubu, the late Pleistocene Kubo members and the Postglacial deposits. And, in the Okunoto area in the northern area of Noto Peninsula, typical terraces are divided into seven plains such as Terraces I, II,----and VII; especially, the marine terraces seem to be recorded very well for the late Pleistocene.

For sea level changes during the middle Pleistocene, the Takashina and Nango members show a small transgression correlated with the Mindel——Riss Interglacial and Yarmouth Interglacial as a schematic model illustrated in Fig. 4. During the late Pleistocene, marine sediments distributed widely, especially the Okunoto, Nanao, Himi and the southern Kaga areas show a remarkable and typical transgression named "the Hiradoko Transgression" in the Hokuriku district (Fig. 3). And also, sea level changes in the Postglacial stage are represented by the transgression correlated exactly with the Flandrian Trantgression and by the small regression named as "the Yayoian Regression" corresponded to the stage between about 3000 and 1500 years ago chronologically. The changes during the Holocene are shown Tab. 3, and Figures 3 and 4.

Introduction

In the Hokuriku district of Central Japan, marine terraces which are estimated to be dated chronologically in the Brunhes Chron are distributed, especially, widely in the northeastern part and the southern part of Noto Peninsula.

Since about 1950 year A. D., many geologists and palaeontologists of the Hokuriku district have studied on the Pleistocene marrine terraces, especially, distribution, sedimentary

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mechanics, chronology and palaeontological researches including mollusks and pollen grains of the late Pleistocene marine terraces distributed in the Hokuriku district, Central Japan.

In this paper, the present writer states chronologically a formation of marine terraces in the district from the viewpoint of sea level change.

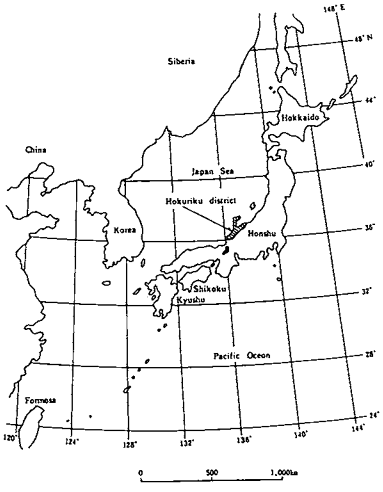


Fig. 1. Index map showing the studied district, Central Japan

1. Outline of the Quaternary Deposits

In the Hokuriku district, there are various sediments ranged from the early to late Quaternary period now exposed on the hilly lands or forming the river and coastal terraces (Hokuriku Quaternary Research Group, 1969). These Quaternary deposits can be divided into the lower Pleistocene, middle Pleistocene, upper Pleistocene and Holocene deposits; the lower Pleistocene deposits exposed on the hilly land less than 200 meters above the present sea level in the Hokuriku district have no district flat surfaces indicating the sedimentation plane, and have been suffered from intense tectonic deformations immediately after their deposition, whereas the others except for the Holocene deposits distributed on the coastal and river terraces of various altitude have been subjected to the tilting or upheaval movements after their sedimentation (Hokuriku Quaternary Research Group, 1969).

On the other hand, the Holocene deposits or the Portglacial ones are subdivided into the three major types: the coastal sand dune deposits, valley-filling deposits and alluvial fan and lagoonal deposits forming the coastal lowland areas (Fuji, 1982b, 1983, 1987).

Tentative chronostratigraphy of the Quaternary deposits of variour ages in several areas within the Hokuriku district is tabulated schematically as Tab. 1.

2. Sea Level Changes in the Several Areas

A. Sea Level Changes during the Pleistocene

The Quaternaly deposits concerning sea level changes for the Brunhes Chron in the Hokuriku district are distributed mainly in Noto Peninsula and coastal lowland areas as Nanao area of the central Noto Peninsula, Himi area of the southern Noto Peninsula, Okunoto area of the northeastern Noto Peninsula and the coastal lowland areas described in the following sections.

(a) Nanao Area

The Quaternary deposits of the Nanao area, central Noto Peninsula are divided into four units; namely, the middle Pleistocene Takashina, late Pleistocene Okuhara, the latest Pleistocene Tokuda gravel members and Postglacial deposits in ascending order (Hokuriku

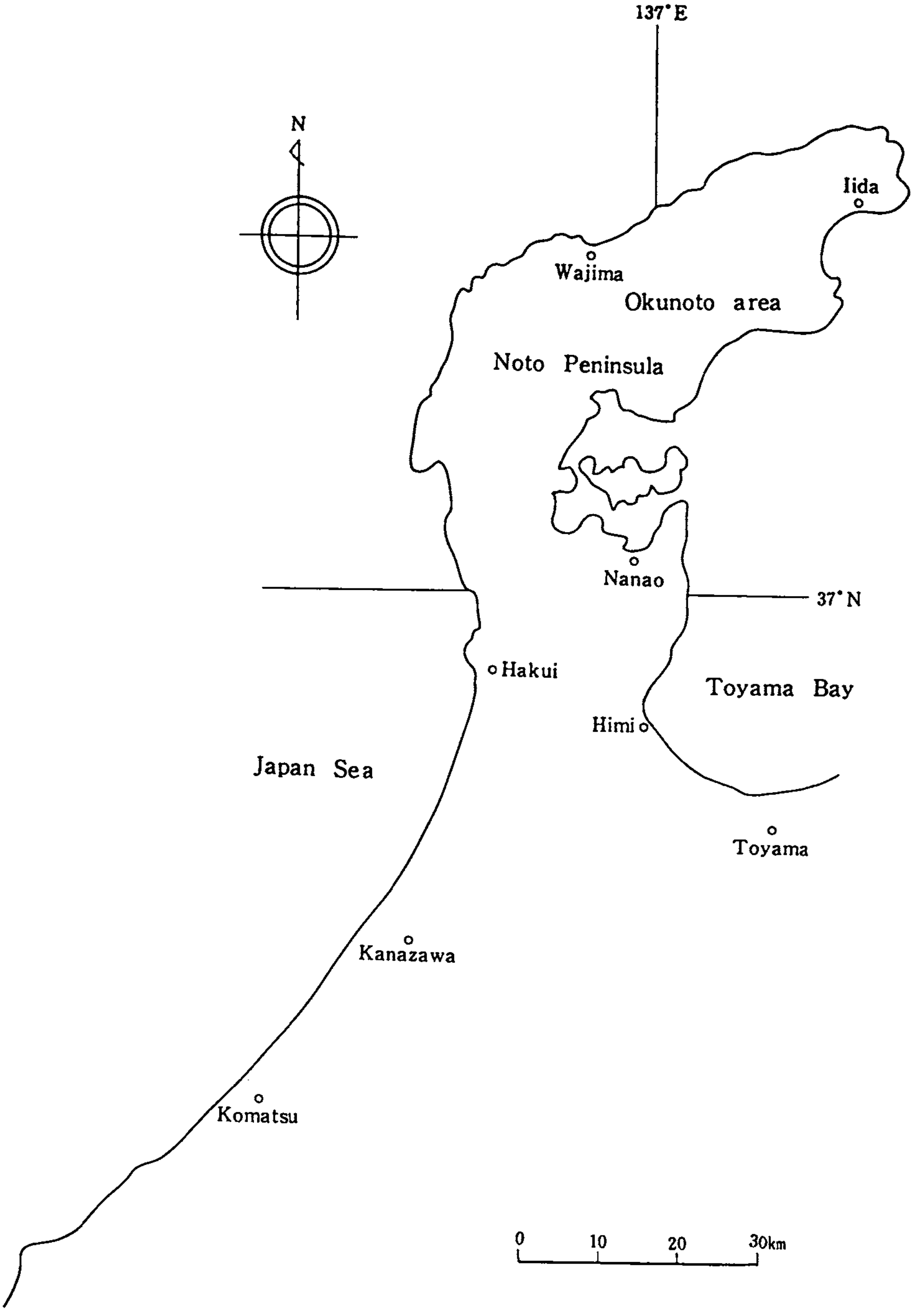


Fig. 2. Location map showing detailed areas described in the present paper.

Quaternary Research Group, 1967).

[1] the Middle Pleistocene Takashina Member

The Takashina member is distributed partially about 20 meter high above the present sea level. The member containing such marine mollusks as *Cerithideopsilla djadjariensis, C. cingulata* and *Tegillarca granosa* var. in the middle horizon of the member ranged to be the middle Pleistocene may be chronologically correlated with the Mindel-Riss Interglacial stage. It is concluded that marine marine muddy deposits with fossil mollusks might have deposited during an age of transgression probably due to glacio-eustatic movement.

[2] the Late Pleistocene Okuhara Member

The Okuhara member, which is distributed about 20-60 meter high above the present sea level, forming three sedimentary planes on 50-60 meter, 30-40 meter and 20-30 meter, includes the Wakura-eki shell bed, and is divided into two members, that is, the lower mud layer and the upper sand layer. Marine mollusks such as *Scapharca satowi, Dosinella penicillate* and *Paphia undulate,* and marine diatoms such as *Coscinodiscus* etc. are contained in the lower mud layer. A study of the deposits reveals that there occurred one transgression which attained its maximum rise up to about 50 meter in the present altitude during the late Pleistocene, probably due to a glacio-eustatic movement called as the *Hiradoko phase* in the Hokuriku district. It may be correlated with the *Shimosueyoshi phase* of the Kanto district. According to investigations on such fossils as macroplants, pollen grains, spores, diatoms, mollusks and foraminifers, the changes of the sedimentary environment, climate and sea level during the deposition of the Okuhara member are summarized as Tab. 4 and Fig. 3.

Tab. 1. Stratigraphy of the Quaternary deposits in the Hokuriku district, Central Japan.

Age		Sediment	Palaeoclimate	yrs. B. P.
				the present
Holocene		coastal sand dune & alluvial sediments	mild～warm	
		marine & lagoonal sediments	warm	
		lake & bog sediments	cool～mild	
				10000
Pleistocene	Late	Old fan & Low river terrace sediments	cold～cool	40×K
		Middle river terrce sediments	warm～mild	
		Hiradoko, Okuhara & Kubo members	warm～warmer	120×K
	Mid.	Kamitako member	cool～mild	
		Takashina member	warm～mild	
		High river terracc sediments	cool～mild	ca. 600×K
	Early.	Tomuro volcanics		
		Utatsuyama formation	cool～mild～warm	
		Himi formation	cold～mild～warm	1800×K

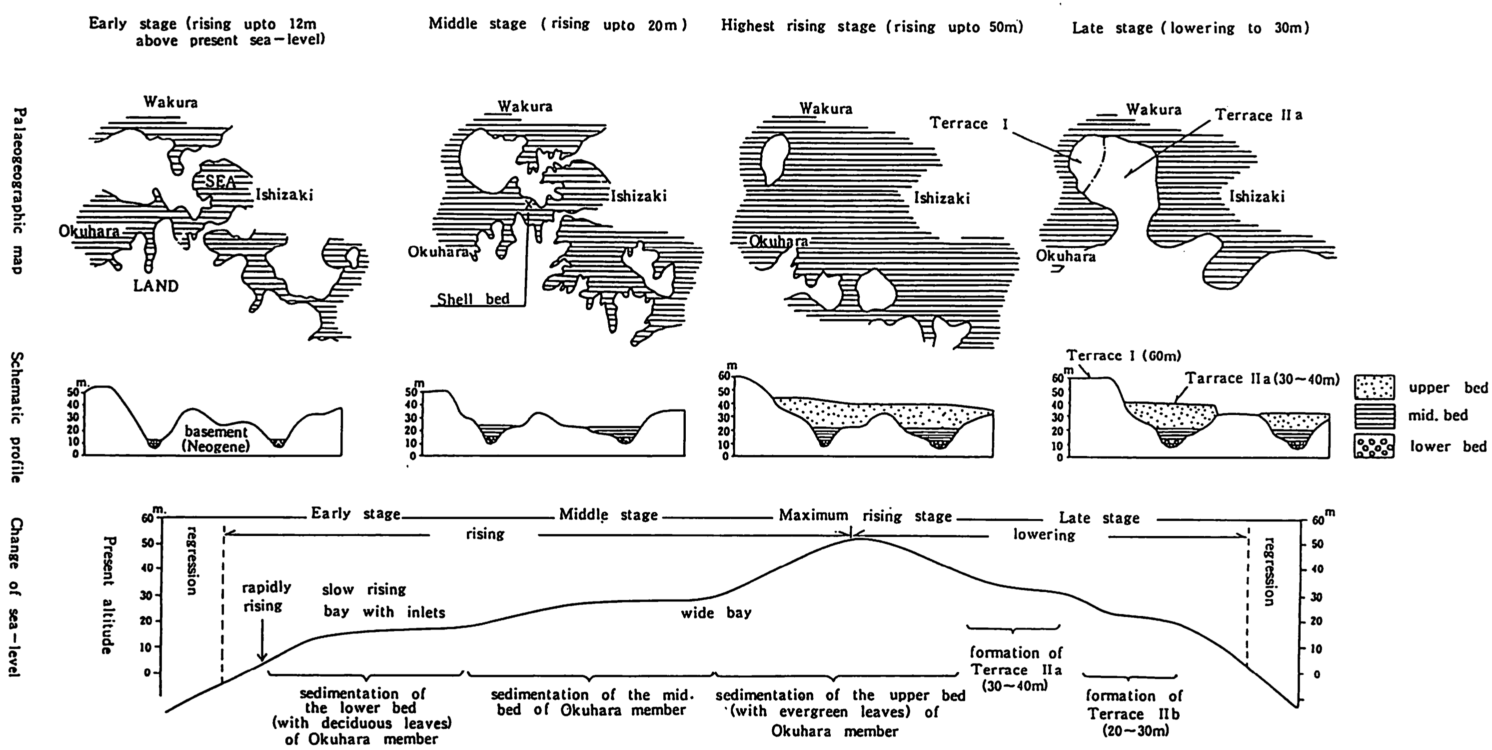


Fig. 3. Palaeoenvironmenttal changes for the sedimentation of the late Pleistocene Okuhara member in the Nanao area, Central Japan.

(b) **Himi Area**

The Quaternary sediments of the Himi area in the southern Noto Peninsula are divided into six units in ascending order as follows : the latiest Pliocene-early Pleistocene Himi formation, the early Pleistocene Saida, middle Pleistocene Kamitako, earliest late Pleistocene Kokubu, late Pleistocene Kubo members and the Postglacial sediments (Hokuriku Quaternary Research Group, 1963). Among them, the sediments concerning a relationship between sea level and palaeoclimatic changes are the Kokubu and Kubo members, and also the Postglacial sediments.

The Saida member presumably belonging to the early Pleistocene differs in both of sedimentary facies and geologic structure from those of the Himi formation ranged to the latiest Pliocene-early Pleistocene. These differences indicate a considerable upheaval of the land at this stage, meaning the retrogressive phase of the Neogene basin in the Hokuriku district.

The Kamitaku member is the non-marine sediments of valley-filling type, the age of which seems to be the middle Pleistocene. It appears that main distribution of the Kamitaku member is mostly controlled by the Ebihara fault activated after the Saida stage estimated to be the early Pleistocene.

[1] the Earliest Middle Pleistocene Kokubu Member

Marine terrace named as the Kokubu Terrace IIa is distributed 20-70 meter high above the present sea level, and its sediment is composed of a yellowish brown medium to coarse grained sand. Trace fossils of boring shells are yielded on the unconformity-plane between this deposit and basement. The deposit seems to be a significant evidence of transgression correlated presumably with the Mindel-Riss Interglacial due to glacio-eustatic movement

[2] the Middle Pleistocene Kubo Member

The Kubo member containing the Asahiyama shell bed is distributed widely in the Himi area, with such terrace plains as Terrace IIb and Terrace IIc, may be deposited during the Hiradoko phase which is recognized schematically in the Okunoto area of the northeastern Noto Peninsula and in the Okuhara member in the central Noto Peninsula, corresponded to the Shimosueyoshi phase of the Kanto district. These deposits and phases may be correlated chronologically with the Riss-Würm (in Europe) and Sangamon (in North America) Interglacial.

(c) **Okunoto Area**

Typical terraces formed by the late Pleistocene Hiradoko member are distributed widely at the northeastern area of Noto Peninsula, and divided into seven plains as follows : Terrace I (higher than 80 meter above the present sea level, erosional plain),Terrace II (60-70 meter high, depositional plain). Terrace III (35-55 meter high, sedimentary plain), Terrace IV (named as Hiradoko Plain, erosional plain), Terrace V (about 20 meter high, named as Uji Plain, sedimentary plain), Terrace VI (10-15 meter high, wave cut terrace partially) and Terrace VII (lower than 5 meter high, Holocene plain). The marine terraces (Terraces III, IV and V), 20-55 meter high above the present sea level, seem to be a well record of history during the late

Pleistocene in Japan Sea side of Japanese Islands (Hokuriku Quaternary Research Group, 1961).

The Hiradoko member is composed of the lower mud layer which yields many mollusks belonged to warm current as the Black Current (Kuroshio), and the upper sand layer with small gravel. A study of terrace sediments including several shell beds reveals that these deposits and terraces had been formed during the late Pleistocene transgression, probably due to glacio-eustatic movement. This transgression is called the Hiradoko Transgression which is perhaps corresponded to the Shimosueyoshi Transgression in the Kanto district, Central Japan. The Hiradoko phase, in when the Hiradoko Transgression had occurred, may be correlated with the Riss-Würm Interglacial, and attained its highest rise up to about 60 meter above the present sea level.

B. Sea Level Changes during the Postglacial

The sea level changes for the Postglacial age in the Hokuriku district have been investigated by means of studying emerged topography, shell beds, submerbed forests distributed on the present sea bottoms and coastal sand dunes etc (Fuji, 1982c).

Radiometric datings of various horizons of the Postglacial deposits have been obtained from humus, erect stumps, and shells of these deposits through C^{14} datings. Based on these dates, geologic and geomorphologic descriptions, the base of the Postglacial deposits is dated as old as 15,000 years ago or older. Of course, all depth of samples used do not only indicate the ancient shoreline or sea level, but the general tendency in which the sea level rose rapidly through the period from about 15,000 years ago to a few thousands years ago is recognized. From the facts stated above, the regression which took place before the sedimentation of the Postglacial deposits is interpreted as ascribable to the eustatic drop of sea level. The transgression after about 15,000 yefrs ago is corresponded to the Flandrian Transgression, and placed

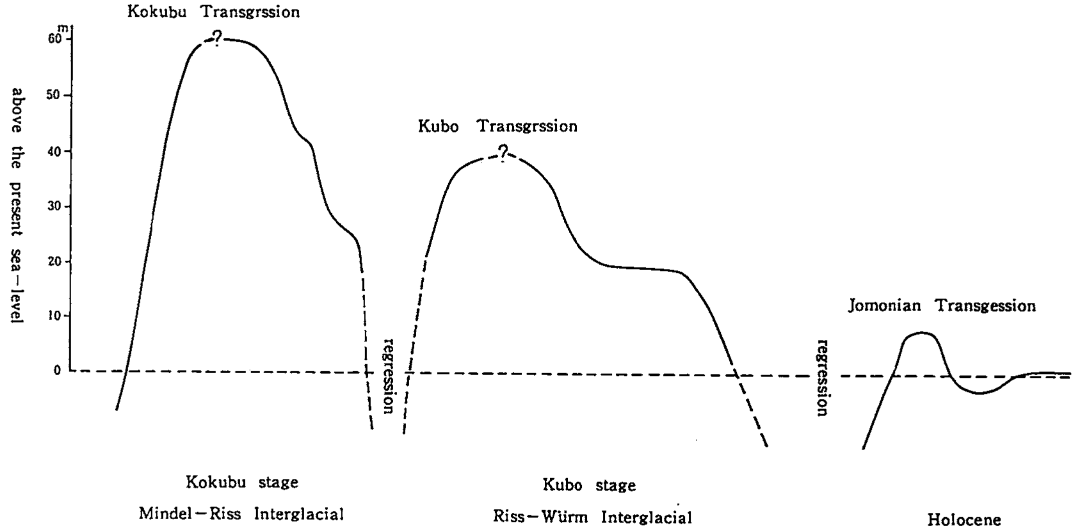


Fig. 4. Relative changes of sea level during the Brunhes Chron in the Himi area, Central Japan.

roughly at the time of the early Jomonian cultural age, 10,000 to 7,000 years ago. According to the distribution and ages of remains such as shell mounds and of the coastal sand dunes of the Jomonian cultural age, about 7,000 to about 4,000 years ago, the rise of sea level during the early to middle Jomonian ages might have reached to the present sea level or to a slightly higher, perhaps about 5 meter high, and may be correlated with the Atlantic age. On the other hand, the lowering of sea level during the period from the end of the middle Jomonian age to the Yayoian age, about 4,000 or less to about 1,500 years ago, might have been about 2 meter to 0 meter below the present sea level, and may be correlated with the Subboreal age. Of course, the Japaneses Islands have been affected by the earth movements. The levels estimated by many evidences, therefore, mean a relative sea level during the Postglacial.

The writer can summarize the relative changes of the sea level during the Postglacial as follows:

① the regression during the late Würmian stage, ca. 30,000-20,000 years ago; estimated about 40-50 meter below the present sea level;

② the lower stand of sea level is the latest Würmian stage, ca. 20,000-18,000 years ago; about 80-100 meter below the present sea level;

③ the early Flandrian Transgression, ca. 18,000-11,000 years ago; about 50-40 meter below the present sea level;

④ the slight regression, ca. 11,000-10,000 years ago; about 40 meter below the present sea level;

⑤ the late Flandrian Transgression, ca. 10,000-7,000 years ago; about 20 meter below the present sea level to the presen sea level;

⑥ the high sea level stage, ca. 7,000-4,000 years ago; about 5 meter above the present sea level;

⑦ the lower sea level stage, ca. 4,000-1,500 years ago; about 2 meter (at the lowest level) below the present sea level;

⑧ the relatively stable sea level stage with a slight fluctuation, the last 1,500 years; perhaps the present sea level.

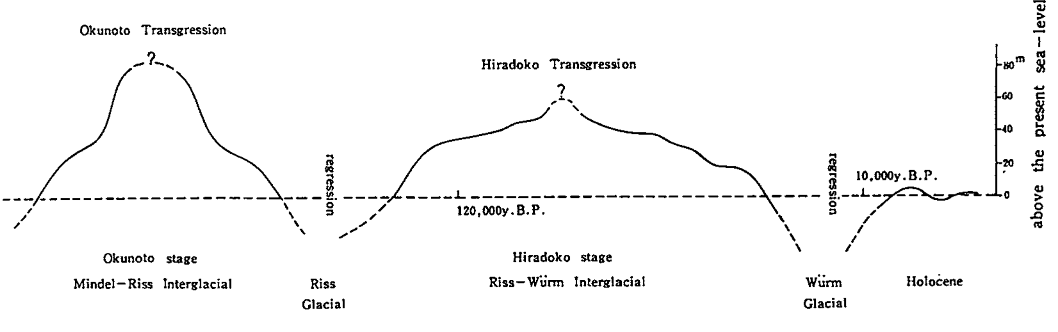


Fig. 5. Relative changes of sea level during the Brunhes Chron in the Okunoto area, Noto Peninsula, Central Japan.

In additionaly, evidence of the Holocene sea level higher than that of the present-day has been reported from the Japanese Islands by several scientists. Eustatic interpretations have been propounded. However, age and the maximum sea level of a transgression which has been named the Jomonian Transgression in Japan, vary at each locality. Judging from the presnt new data, the highest level has been reported from the coast of the Ryukyu Island and in the main island of the Japanese Islands and some peninsulas of the main island Honshu. Elevation increases towards the oceanic trenches as near Izu Peninsula etc., and the higher sea level as about 6 meter and more has been recognized is the Noto Peninsula. And, in districts concerning subsidence such as the Nobi, Kanto, Kanazawa and Toyama plains, evidence of emergence at the present-day is quite frequent. Records of several sea levels indicate that a step-by-step uplift has occurred. The Japanese Islands since the Pliocene have been subdivided geotectonically into several large blocks which have been affected by movements such as uplift, subsidence, faults and earthquakes etc. The interpretation can be explained the cause of the variely of ages and elevations of the past sea level. This inference that the sea level during the Holocene has been situated higher than that of the present sea level, is reasonable on the basis of evidence from various localities throughout the Japanese Islands. However, the writer cannot define the change of absolute eustatic sea level during the Holocene under a circumstance at the present-day.

3. Summary of Sea Level Changes in the Hokuriku District during the Brunhes Chron

(1) Evidence concerning sea level changes during the middle Pleistocene is generally poor in the Hokuriku district, except for the central part of the district. Among them, the Takashina member at the Nanao area and Nango member at the soutnern Kaga area yield marine and brackish molluskan and diatom fossils, indicating bay or brackish environment during the middle Pleistocene. The deposits as above-mentioned indicate perhaps a small transgression during the middle Pleistocene, and may be correlated chronologically with the Mindel-Riss Interglacial and Yarmouth Interglacial. It is concluded that sea level at that phase had attained to about 30 meter above the present sea level. A schematic model of eustatic change is shown as an example of Fig. 5 illustrated on basis of investigation in the Okunoto area.

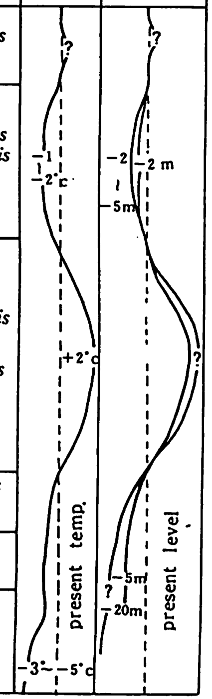
(2) Many informations on sea level changes during the late Pleistocene have been provided by the detailed studies in the Okunoto, Nanao and Himi areas. These marine terrace deposits are generally composed of the lower muddy layer and the upper sandy layer ; the former which filled up the pre-existed drowned valleys may correspond to the products of an early stage of transgression, and the latter represents the widest marine invasion phase associated with the maximum rising, about 50 meter above the present sea level. Through those studies the marine deposits and terrace may probably be refered to the Riss-Würm Interglacial. A schematic model of eustatic change has been established for instance as the Okuhara member shown in Fig. 3.

(3) Eustatic and palaeoclimatic changes for the Postglacial have been summarized gener-

Tab. 2. Schematic table showing the palaeoenvironmetal changes for the late Pleistocene in the Nanao area, Central Japan.

sedimentation & formation of terrace	Age	Sedimentational palaeoenvironment	Palaeoclimate	Sea level changes
Lower layer (mud～silt) Upper layer (sand with gravel)	early middle late	inlet-like bay narrow bay wider bay	cooler mild～warm warmer	RISING SEA LEVEL
the highest rising up to 50 meter in the present altitude				
formation of terraces	latest	narrow bay	cooler	LOWERING SEA LEVEL

Tab. 3. Chronostratigraphy, climate and relative sea level changes during the Holocene in the Japanese Islands (Fuji, 1987).

Geologic Age	Culture		years B.P.	C-14 dating (years)	climatic subdivision in NW Europe	stratigraphy: sea coast	stratigraphy: bay·lagoon	pollen zoning: Hokkaido	pollen zoning: Hokuriku	climate	sea-level
Holocene	Historical		1.000		Subatlantic	coarse sand	fine sand with silt and mud	*Pinus* *Abies*	*Pinus* *Lepidobalanus* *Cryptomeria* *Machilus*		
	Yayoi		2.000	A.D.200±90 (Uozu) B.C.31±130 (Araumi) B.C.820±120 (Oishi) B.C.870±130 (Yahatazaki) B.C.1.125±130 (Kemigawa) B.C.1.800±85 (Kiya) B.C.1.830±150 (Ilorinouchi)					*Lepidobalanus* *Cyclobalanopsis* *Fagus*		
	Jomonian Period: Latest	Araumi									
		Ubayama	3.000								
	Late	Kasori B									
		Kasori E	4.000	B.C.2.115±135 (Todoroki) B.C.2.500±145 (Obata) B.C.2.700±90 (Kobu II) B.C.2.780±165 (Orimoto)	Subboreal						
	Middle	Katsusaka									
		Goryogadai	5.000								
	Early	Kurohama		B.C.3.150±400 (Kamoyama)	Atlantic	fine sand with marine shells	silt with marine shells	*Quercus* *Ulmus* *Fagus*	*Cyclobalanopsis* *Alnus* *Lepidobalanus*		
		Futatsugi	6.000	B.C.3.240±130 (Sobata) B.C.3.820±100 (Mawaki)							
	Earliest	Kikuna II	7.000	B.C.5.010±110 (Shijimigamori) B.C.5.160±120 (Akamido) B.C.5.600±325 (Funayama)							
		Tado-kaso									
		Hanawadai	8.000	B.C.6.450±500 (Kishima)	Boreal	coarse sand with marine shells	fine sand	*Betula* *Abies* *Picea*	*Lepidobalanus* *Pinus* *Fagus*		
		Natsushima	9.000								
		Igusa Hashidate		B.C.7.290±500 (Natsushima) B.C.8.135±320 (Kamikuroiwa) II)	Preboreal		silty sand		*Fagus* *Ulmus*		
Late Pleisto.	Pre-Jomonian										

Tab. 4. Relationship among the stratigraphy, pollen zoning, cilmate and sedimentary environmental condition in the Lagoon Kahoku-gata, Kanazawa area, Central Japan.

B.P.yrs.	depth in m
0	0
2,630	10
5,260	20
7,890	30
10,520	40
13,150	50
15,780	60
18,410	70
21,040	80
23,670	90

stratigraphy			
US	Upper fine sand	Postglacial deposits	Holocene
UC	Upper clay	Postglacial deposits	Holocene
MS	Middle sand	Postglacial deposits	Holocene
L	Lower alternction	Postglacial deposits	Pleistocene
BG	Basal gravel	Postglacial deposits	Pleistocene
	Uppermost Pleistocene deposits		Pleistocene

pollen zoning		cilmate
A	d	mild
A	c	cooler
A	b	warm
A	a	more or less cold ~ cool
B	d	cool
B	c	more or less cold
B	b	cold
B	a	more or less cold

diatom zoning		sedimentory environment
Z	α	marine ~ brackish
Z	β	fresh water
Y		marine
X		fresh
W		marine
V		fresh
U	α	brackish
U	β	marine
U	γ	marine ~ brackish

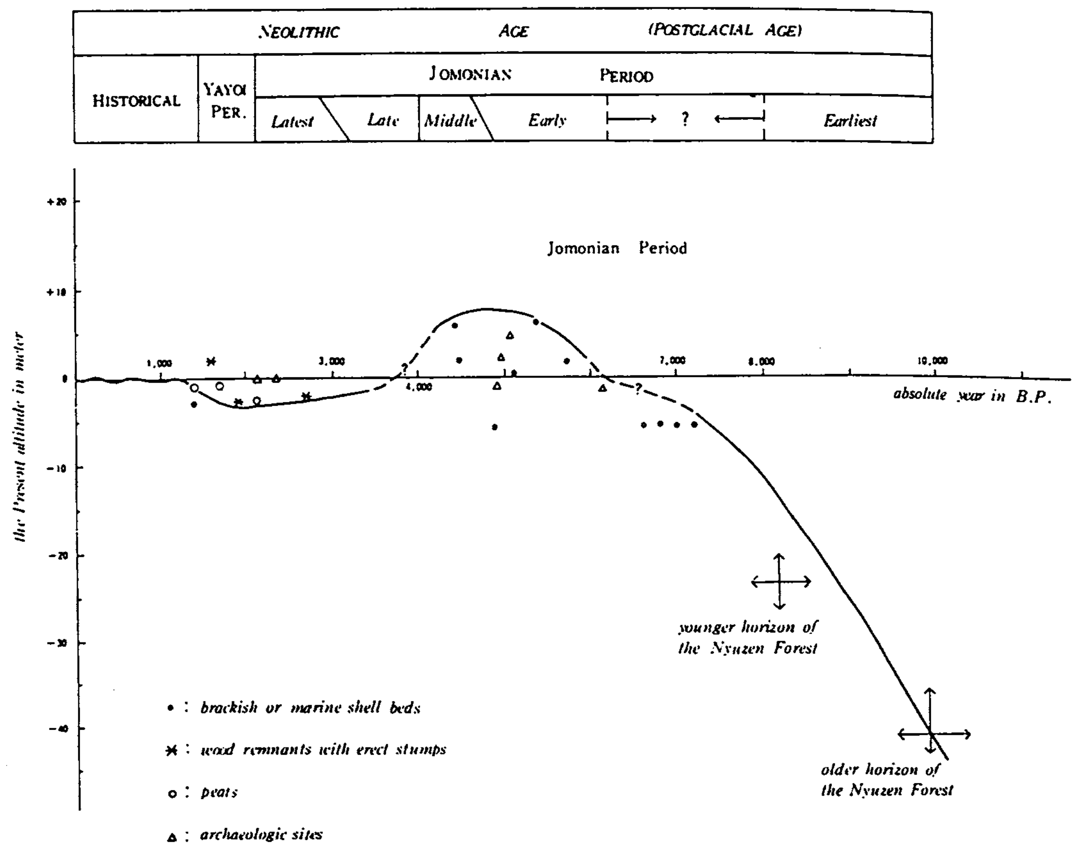


Fig. 6. Sea level changes during the Holocene in the Hokuriku district, Central Japan.

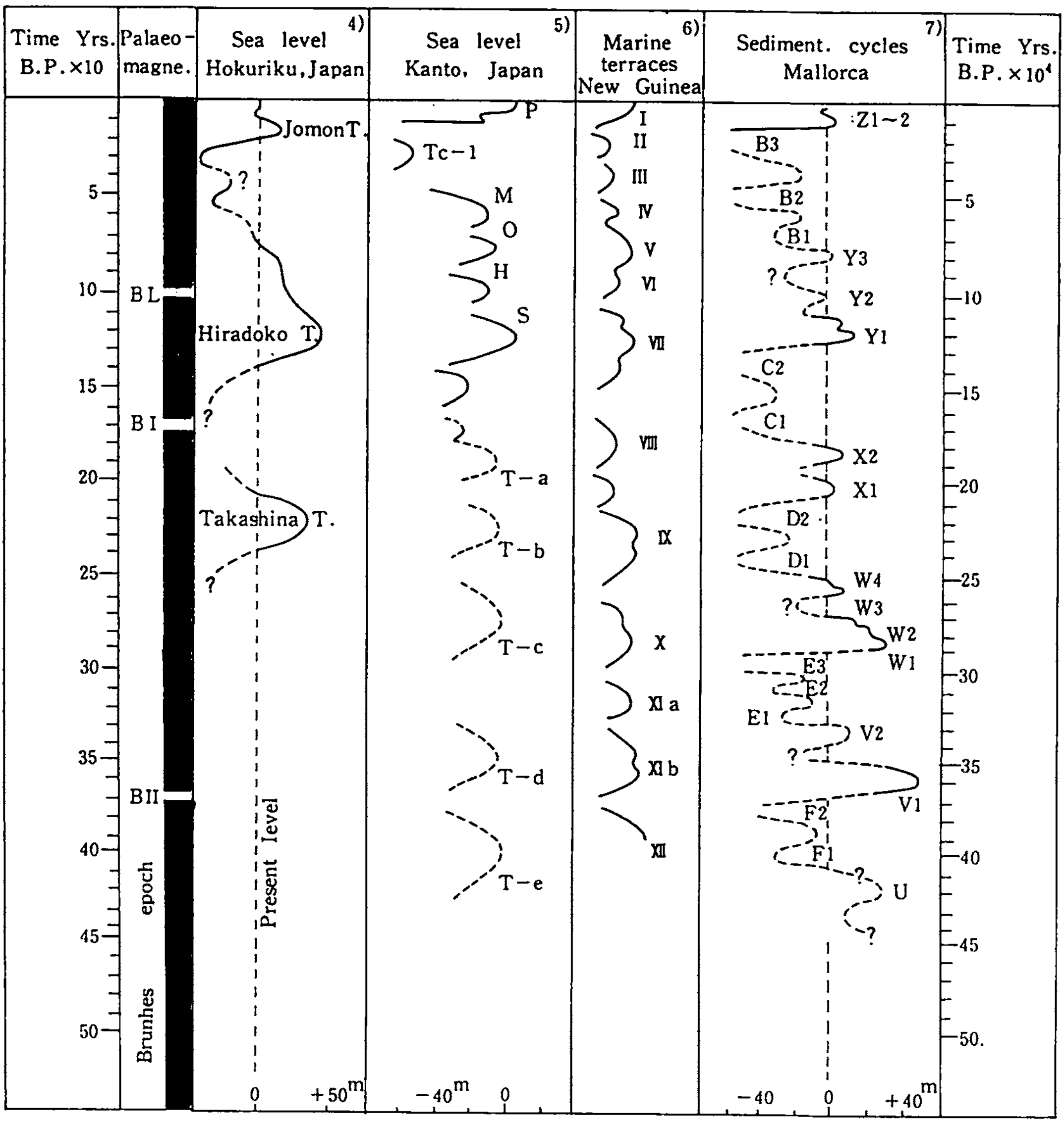


Fig. 7. Global correlation of sea level change curves from various districts. 4 : Fuji ; 5 : Machida, 1975 ; 6 ; Chappell. 1974 ; 7 ; Butzer, 1975. Palaeomagnetic data are based on Fuji (1986 a).

ally as Tab. 2. The highest sea level of the transgression for the Postglacial had rised up to about 5 meter above the present sea level. The transgression named as Jomonian Transgression is correlated exactly with the Flandrian Transgression, and the age of the highest sea level of the transgression is corresponded to the Atlantic age in the northeastern Europe.

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