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Paleoenvironmental Changes in the Izumo Area as Observed from Core-Sample Studies

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(With 7 Figures)

Abstract

Sediments from the Kando River in the Izumo Plain, up to 45m depth, consist mainly of sand, silt, clay and ash belonging to the Sakaiminato and Nakaumi Formations of mainly late Pleistocene and Holocene age.

The sediments consist of nine pollen zones and five diatom horizons. Tephra layers include AT tephra, which is dated about 22,000–25,000 YBP.

The study area, believed to be under fresh water influence about 20,000 yrs back, was subsequently submerged by rising sea level. Maximum transgression took place about 6000 YBP during the Jomon Transgression. A major event in the paleohistory of the region was the formation of present-day Lake Shinji due to entrapment of the invading sea by sediments deposited by the Hii River. Warming up of the climate during the Jomon Transgression is indicated by increase in *Cyclobalanopsis* pollen grains.

Sea level dropped slightly during the Yayoi Regression; thereafter sea level has risen and fallen at intervals due to local changes in the environment. The C/N ratio and sulphur analysis data in general support the results of other parameters.

Key Words: Izumo area, Core samples, Late pleistocene, Holocene, Pollen, Diaton, Paleoenvironmental changes

1. Introduction

1.1. Background

A major event in the recent paleohistory of the Izumo Region was the formation or the birth of present-day Lake Shinji. Studies carried out around Lake Shinji (TOKUOKA *et al.*, 1990) showed that fluvial deposits from the Hii River may have literally cut off the invading sea to form the Paleo-Shinji Lake and the Izumo Plain in the west. Fed by numerous streams from the surrounding mountains, water from Paleo-Shinji Lake began to flow eastward to Paleo-Nakaumi Bay. However, rising water level in the east due to marine transgression, reversed the direction of flow thus transforming it into a brackish-water lake. At present River O'Hashi drains the water from Lake Shinji to Lake Nakaumi.

The Izumo Plain has not only historical importance for Japan but is equally important in terms of ancient Japanese culture and religion. Lying in the central part of the San- in coast along the Japan Sea, the plain consists of two maritime coastal lakes, Lake Shinji and Lake Nakaumi, and it is drained by two rivers, River Hii and River Kando. The area has been repeatedly subjected to marine

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invasions in the past, which have had a great impact on the flora and fauna of the region. The paleoenvironment of the region has been well reported by TOKUOKA *et al.* (1990) and ONISHI *et al.* (1989, 1990). The changes in the environment are indicated by changes in pollen and diatom species in the sediments. Pollen zoning of the region has been presented in a series of reports by ONISHI (1985, 1986). KASHIMA (1990) reported on various diatom assemblages in the study area, due to differences in depositional environments. The author carried out the present investigation as a part of the Master's Course of study in Shimane University. The study was carried out on four core samples, R1, R2, R12 and R16, of lengths 26, 45, 35 and 42 m respectively, drilled on the right bank of Kando River by the Ministry of Construction for the River Conservation, Izumo Branch in 1989 (Fig. 1). The result of this study provides additional information and helps to strengthen the theory that fluvial deposits were responsible for the formation of Lake Shinji.

1.2. General geology

Recent sediments in the study area are broadly divided into the following four formations (ONISHI and MATSUDA, 1985):

Nakaumi Formation
Sakaiminato Formation
Yasugi Formation
Yumigahama Formation

Yumigahama Formation: The Yumigahama Formation (120 Ka), unconformably overlain by the Yasugi Formation, consists of two members. The lower member consists of sand and gravel and the upper member consists mainly of mud.
Yasugi Formation: The Yasugi Formation (70–100 Ka) consists of three members. The lower and upper members consist of volcanic ash layers and the middle member of silt. It is unconformably overlain by the Sakaiminato Formation.
Sakaiminato Formation: This post-glacial deposit consists mainly of silt, and the age determined was 10-20 Ka. It is conformably overlain by the Nakaumi Formation of Holocene age.
Nakaumi Formation: The Nakaumi Formation has been divided into four members, namely the lowest, middle, upper and the uppermost; all consist generally of sand, silt and mud.

2. Data and results

2.1. Analyses and results

The core samples were not continuous, hence only the second half of each meter sample could be studied. Samples of 5 cm length from both ends of 50 cm cores were treated for analysis of different parameters. The analyses carried out were:

1. Logging of the samples.

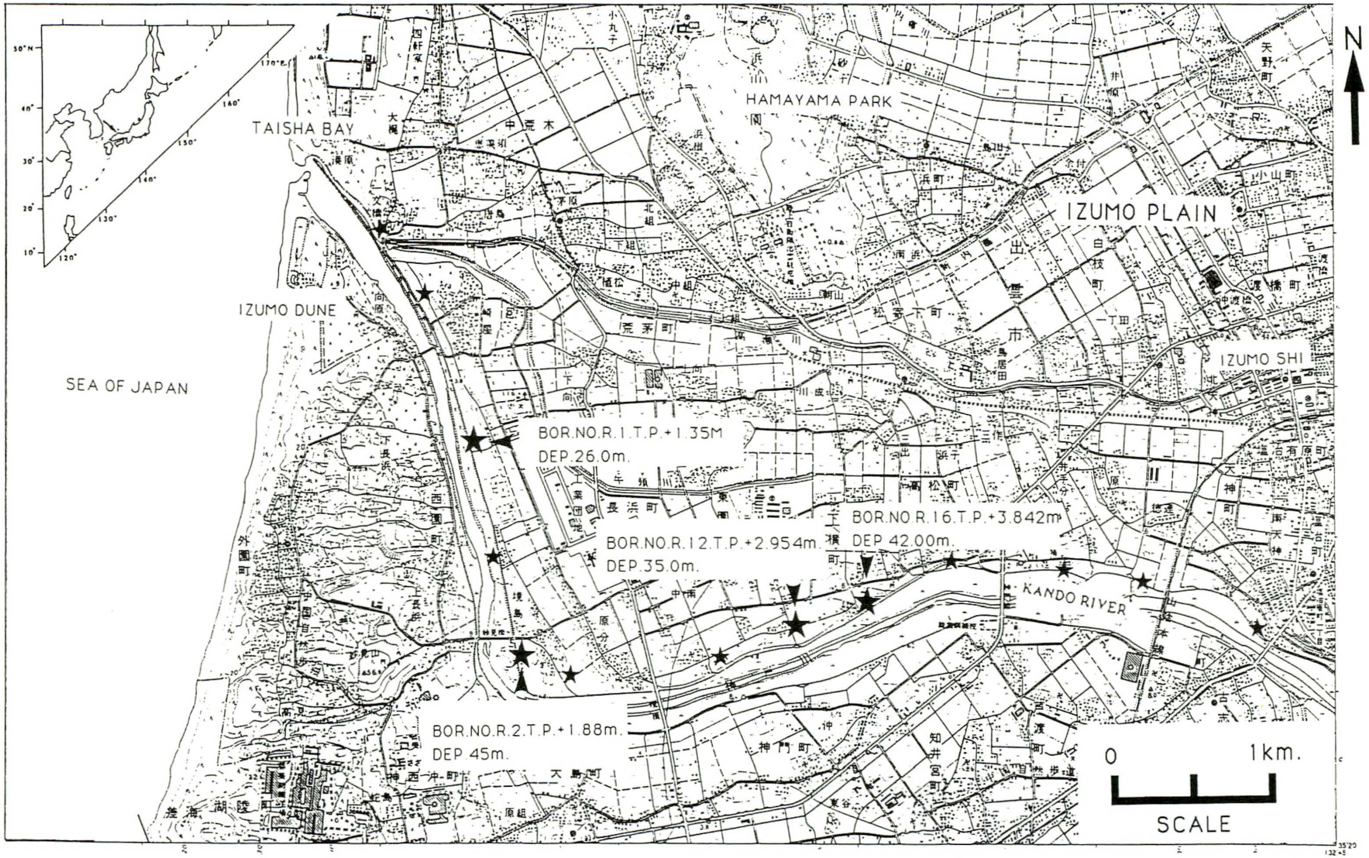


Fig. 1. Map showing location of the study area and the borehole cores. R1, R2, R12 and R16 are indicated by big stars. Small stars represent other cores in the area.

2. Diatom analysis.
3. Sulphur analysis.
4. Volcanic ash analysis.
5. CHN analysis.
6. Pollen analysis.

1. Logging of the core samples. General lithology of the four cores is shown in Fig. 2. Core samples were divided into five units. A,B,C,D and E, with reference to sediment type. Unit A consisted of sand, ranging from fine to coarse-grained; Unit B consisted of clay, often with thin sand layers; Unit C consisted of interlayered ash and clay; Unit D consisted of dark-coloured clay, often with shell fragments; Unit E consisted mainly of medium to coarse-grained sand and gravel.

2. Diatom analysis. Diatom preparats were prepared using hydrogen peroxide, with Mount Media as the embedding medium. Observations showed almost total absence of diatoms in the uppermost part (sand and ash layers) in all four cores (Fig. 2), and when present were too few in number to be significant. The main diatom-bearing horizons were the clay and mud layers. The cores were divided into the following horizons, according to abundance of diatom assemblages:

Depth	**Abundant species**
R1	
10–14 m	*Thalassiosira lineatus-Cymbella tumida*
15–22 m	*Melosira* spp.
24–26 m	*Cocconeis scutellum*, *Cocconeis placentula*, *Thalassiosira lineatus* and *Rhizosolenia* spp. *Cocconeis placentula*, *Cymbella* spp. and *Rhopalodia gibberula* present throughout.
R2	
10–16 m	*Coc. placentula*, *Cym. tumida*, *Melosira* spp.
17.50–20 m	*Thal. lineatus*, *Cyclotella caspia*
21–25 m	*Melosira* spp.
26.50–38 m	*Coc. scutellum*. *Coc. placentula*, *Thal. lineatus*, *Rhi.* spp. *Coc. placentula*. *Cym. tumida*, *Diploneis smithii* and *Rho. gibberula* present throughout.
R12	
9–20 m	Various freshwater diatoms
22–28 m	*Coc. scutellum*, *Dip. smithii*, *Thal. lineatus* and *Rhi.* spp.
28–35 m	Freshwater and marine diatoms.

R16 had very little concentration of diatoms.

25–37 m	*Coc. scutellum*, *Thal. lineatus*, *R. gibberula* and *D. smithii*.

3. Sulphur analysis. A reducing environment favours formation of sulphur compounds. The pH measurement of H_2O_2 solutions dissolved with SO_2 from the samples indicated

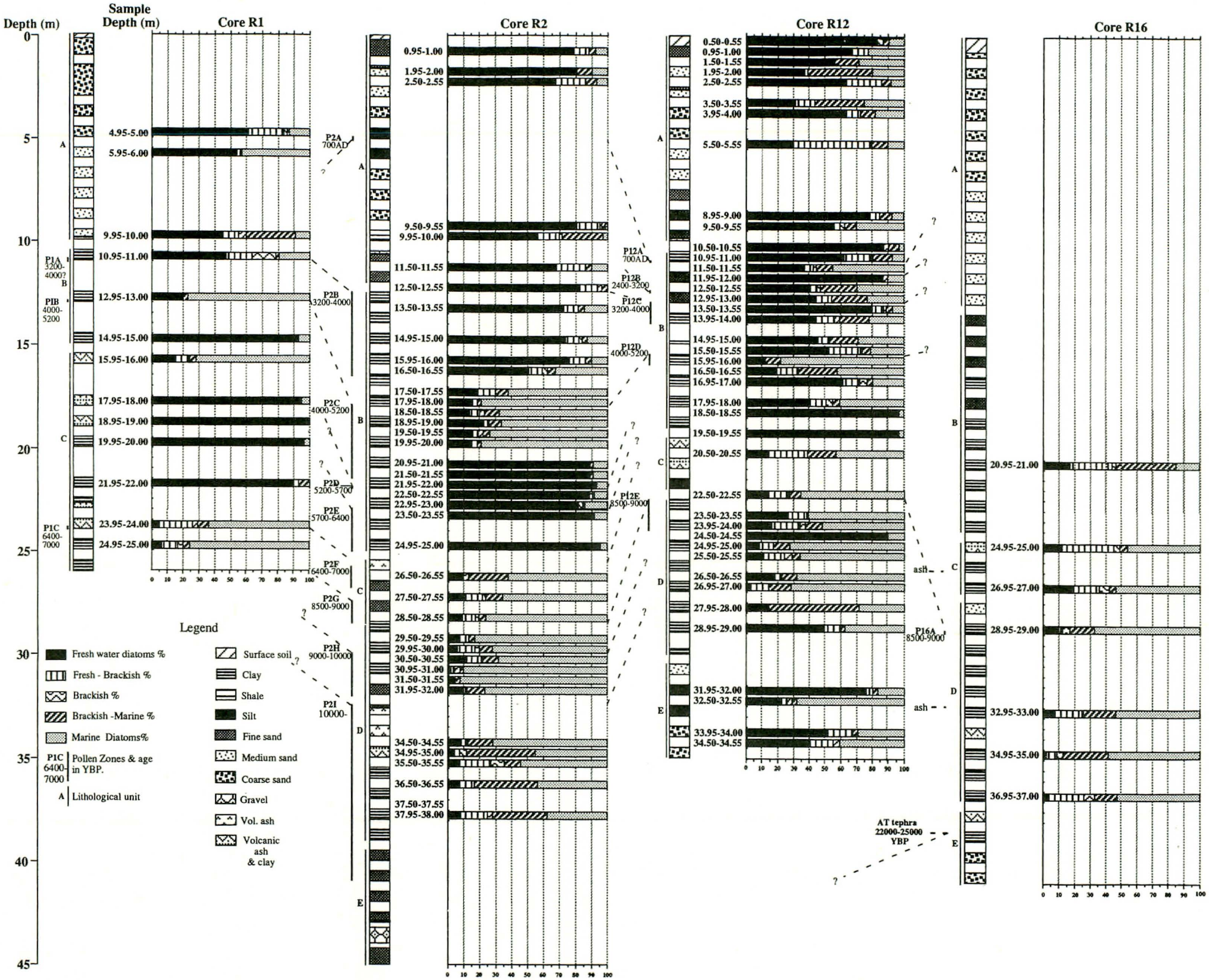


Fig. 2. Diatom distribution, lithological column and various pollen zones in the cores R1, R2, R12 and R16. Location of AT tephra present in core R16 is also shown.

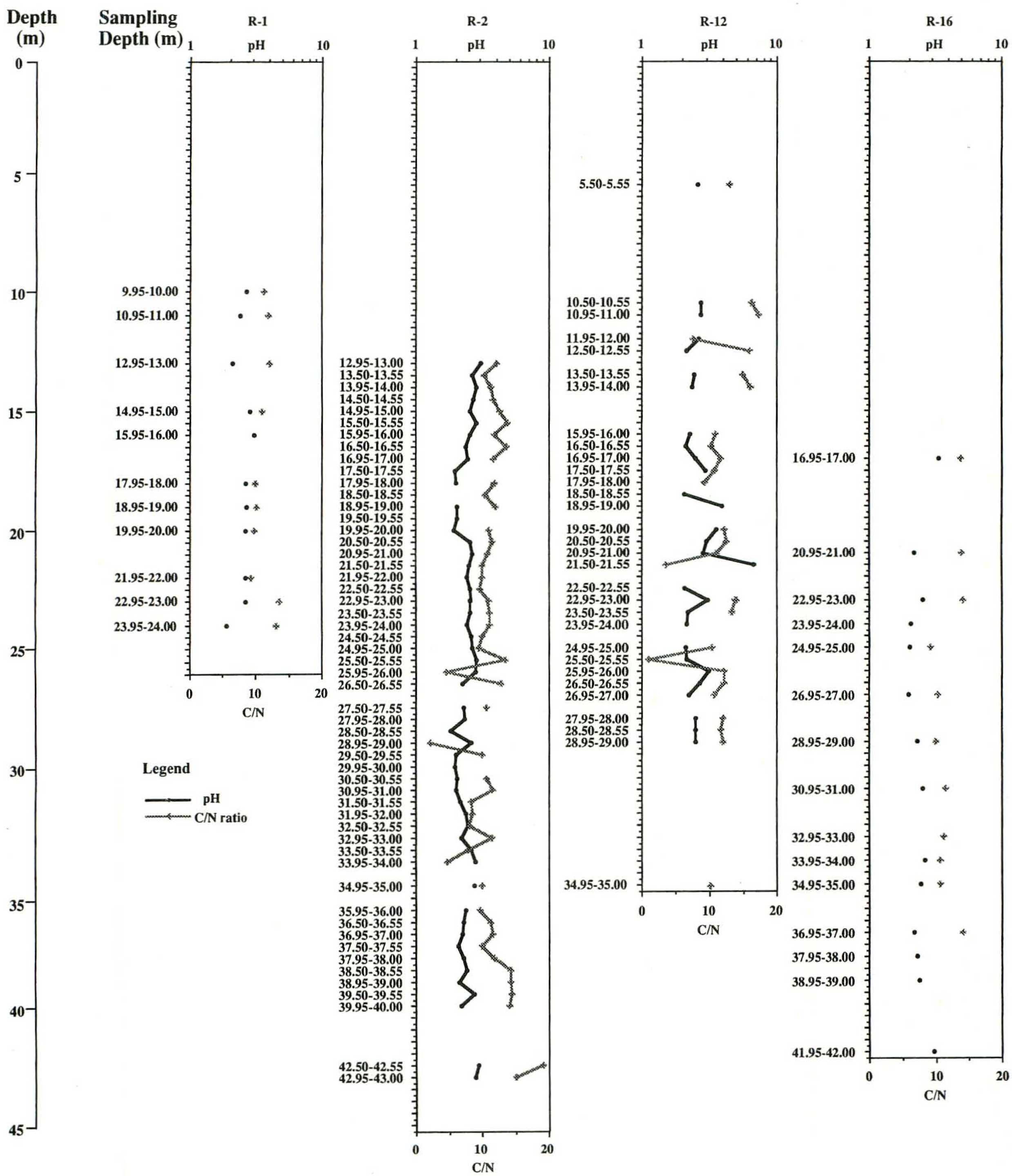


Fig. 3. Relation between C/N ratio and pH of the solution containing sulphur compound from the samples of the cores R1, R2, R12 and R16.

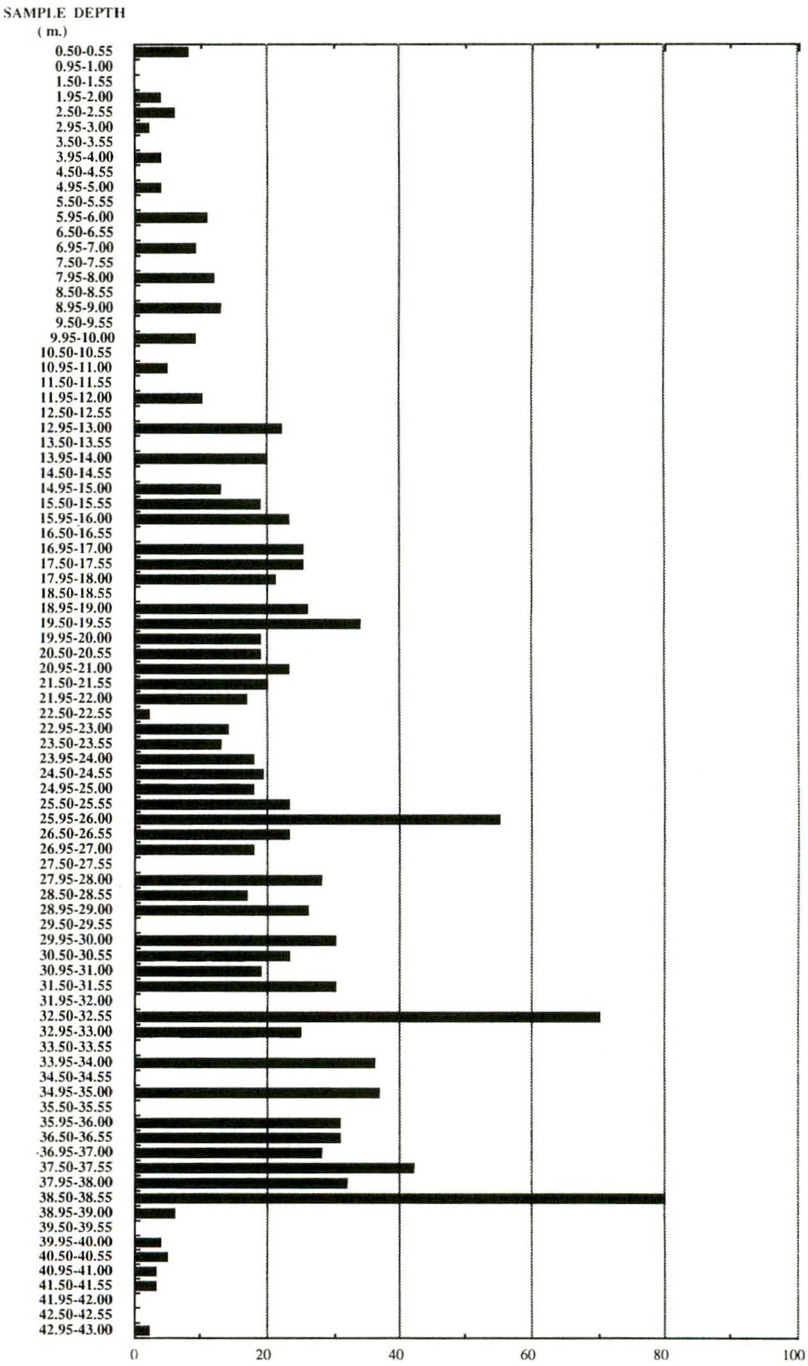


Fig. 4. Glass content, with respect to other fragments, in samples of core R16.

the relative amounts of sulphur present in the samples in the form of sulphur compounds. Thus, low pH specifies marine influence or stagnant conditions during sample deposition. The pH values in the samples ranged from 1.9 to 3.4. The plot of pH value against depth in all four figures shows a similar trend, increasing pH being observed nearer to the surface (Fig. 3).

Cores R1 and R2 had two low-pH value horizons, in R1 at 12.95–13 m and 23.95–24.00 m and in R2 at 18–20 m, and 29–30 m; R12 and R16 had one each, at 23.50--25.50 m in R12 and 24.95–25.00 m in R16. The curves in between show relatively higher pH values. But as the low-value horizons in the graphs consisted usually of single values rather than series of values, no firm conclusions were made from the analysis.

4. Volcanic ash analysis. Glass-fragment contents were studied in all the samples. The process involved wet sieving of the samples and Gliocole Futarete was used as the embedding medium to make the preparats. Only core R16 revealed ash horizons, with a substantial quantity of glass fragments.

Core R16 revealed three horizons with glass fragments exceeding 50% of the total fragments (Fig. 4). These horizons were at the depths of 25.95–26.00 m, 32.00–32.55 m and 38.50–38.55 m. Horizon 38.50–38.55 m contained 80% glass fragments, composed totally of bubble glass with Refractive Index (R.I). ranging from 1.4950 to 1.5003. This ash layer was identified as of AT tephra.

The second ash layer, at 32.50 m, revealed mixed assemblages of glass fragments with an R.I. range of 1.497–1.503; the third layer, at the depth of 25.95–26.00 m, revealed mostly pumice-type glass fragments with R.I. in the range of 1.490–1.503. Identification of the latter two ash horizons could not be carried out due to insufficient data.

5. CHN analysis. Carbon and nitrogen contents in the samples were measured by CHN corder-MT3. The main source of nitrogen in the sediment is the protein from aminoacids present in planktons. On the other hand, higher plants and herbs are composed mostly of cellulose and lingen; hence a high supply of plankton in the marine environment decreases the C/N ratio. This ratio, in fact, shows the supply of plankton to the supply of higher plants, which indirectly indicates a fresh or marine environment. The result showed the C/N ratio to be around 12–15, indicating generally a brackish environment (Fig. 3).

6. Pollen analysis. Pollen preparats were made using acetolysis and KOH solutions. Due to the presence of numerous sand layers, pollen distribution was generally poor. Nevertheless,following pollen zones were made for the four cores, based on abundance of pollen grains.

Zonation	**Depth (m)**	**Major pollen**
Core R1		
Zone P1A	10.95–11.00	*Pinus-Abies*

Zone P1B	12.95–13.00	*Corylus-Quercus*
Zone P1C	23.95-24.00	*Ulmus-Pinus*
Core R2		
Zone P2A	4.95–5.00	*Pinus*-Gramineae
Zone P2B	12.50–16.55	*Pinus-Betula-Cylobalanopsis*
Zone P2C	17.95–21.50	*Cyclobalanopsis-Betula*
Zone P2D	21.95–22.00	*Betula-Quercus-Cyclobalanopsis*
Zone P2E	22.50–25.00	*Pinus-Abies*
Zone P2F	25.50–26.55	*Cyclo.-Quercus-Betula*
Zone P2G	27.50–28.55	*Cyclo.-Quercus-Ulmus*
Zone P2H	29.95–32.00	*Carpinus-Corylus*
Zone P2I	32.55–40.55	*Alnus-Betula-Carpinus*
Core R12		
Zone P12A	10.95–11.00	*Pinus-Cyclobalanopsis*
Zone P12B	12.50–12.55	*Cyclobalanopsis*
Zone P12C	12.95–14.00	*Cyclo.-Quercus-Pinus*
Zone P12D	15.50–16.00	*Quercus-Castonopsis*
Zone P12E	22.50–24.00	*Quercus-Ulmus*
Core R16		
Zone P16A	28.95–29.00	*Ulmus-Castonopsis*

Pollen zones of the cores R2 and R12, with the respective pollen grains, are given in Fig. 5. The above pollen zonations were correlated with pollen zones SB1 and SB2 (ONISHI *et al.*, 1990; ONISHI,1993), as shown in Fig. 6.

2.2. Discussion and paleoenvironments.

The results and the data of the present study strengthen the paleoenvironmental view of the region presented by various workers in the past. Paleoenvironmental changes, as interpreted from the data obtained, are discussed below. Comparisons are also made with various stages of paleogeographic development presented in the Geohistory of Lakes Shinji and Nakaumi (TOKUOKA *et al.*, 1990).

Units E in Cores R2, R12 and R16 consisted of sand and gravel hence were correlated with each other. The ash layer identified as of AT tephra in core R16 established the age of the sediment at the depth of 38.50 m to be about 22–25 Ka. Few diatoms and no pollen grains were observed, but the nature of the sediment suggests a freshwater environment. This conforms with paleogeographic map, Fig. 1 Stage A (TOKUOKA *et al.*, 1990) at 20,000 YBP. The whole region, including the study area, was completely drained due to lowering of the sea level, to around −80 m below present level. The three rivers, Paleo-Shinji, Hii and Kando, joined together before entering the Japan Sea in the west.

At about 11,000 YBP, the study area was still above sea level, which stood at −40 m. A freshwater lake was believed to have formed at the site of present

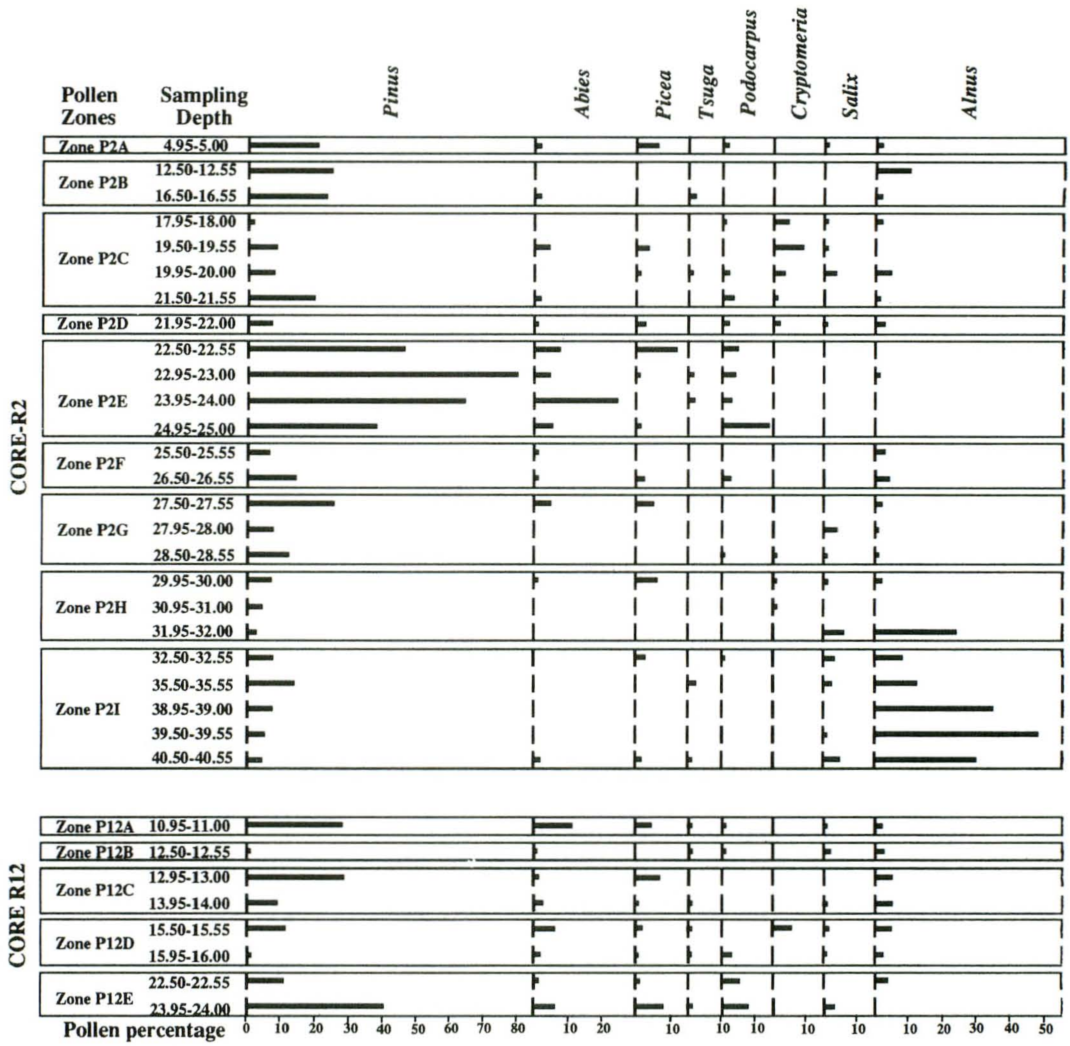
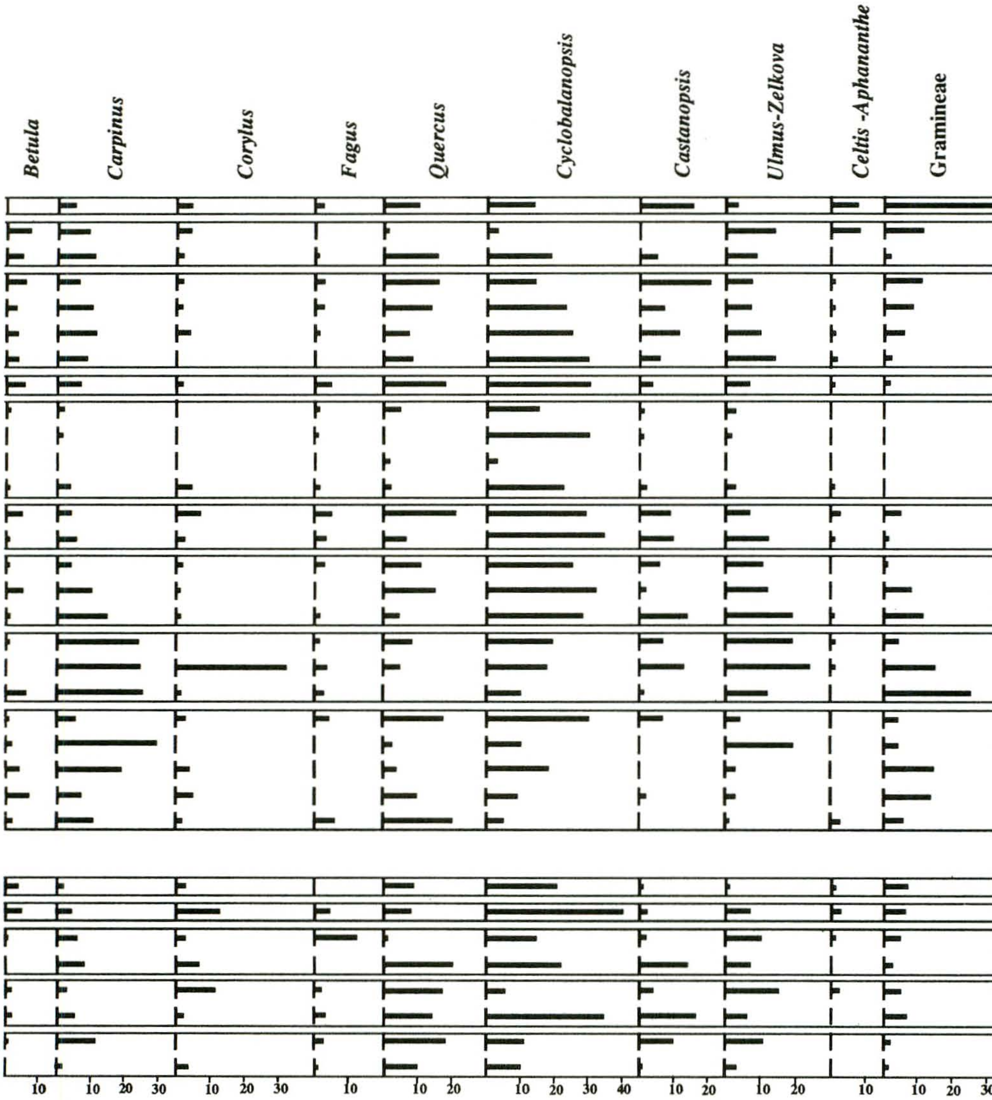


Fig. 5. Pollen distribution and pollen zonations in cores R2 and R12. Pollen percentages have been calculated against total tree pollen concentration (AP).

day Lake Shinji (Fig. 1, Stage B, TOKUOKA *et al.*, 1990). Units D in cores R2, R12 and R16 consisted predominantly of clay. Pollen zone P2I established the age as 10,000 YBP and older. Gradual dominance of brackish marine and marine diatoms can be observed from the depth of 38 m indicating marine influence. Though P2I does not have corresponding zones in other cores, a gradual increase in marine and brackish influence can be observed in cores R12 and R16 below 9, 000 YBP. Deciduous forests, dominated by *Alnus* and *Quercus*, seem to have flourished extensively. The boundary between the Lower Nakaumi Formation and



the Sakaiminato Formation divides the Holocene and Pleistocene deposits (ONISHI and MATSUDA, 1985). In core R2, this boundary lies at about 32.50 m. Thus, the Sakaiminato Formation consititutes units E and D.

Global warming, resulting in a rise of sea level, effectively brought Core R2 under marine influence by 9,000 to 10,000 YBP (P2H) with freshwater diatom concentration numbering less than 10%. *Alnus* and *Quercus* pollen were replaced by *Cyclobalanopsis* and *Ulmus-Zelkova* pollen grains, indicating warming up of the climate. By 8,500–9,000 YBP(P2G, P12E, P16A), marine diatoms overwhelmingly

Pollen Zone	Subzone	Age	Present study R1	R2	R12	R16
Gramineae	*Pinus-Cryptomeria*	1 930 A.D.				
	Pinus	1 500 A.D.				
	Cyclobalanopsis-Quercus	700 A.D.	P1A	P2A	P12A	
	Cryptomeria	2 400 BP				
Cyclobalanopsis - Castanopsis	*Podocarpus*	3 200			P12B	
	Castanopsis	4 000		P2B	P12C	
	Cyclobalanopsis	5 200	P1B	P2C	P12D	
Pinus-Abies	*Ulmus-Zelkova*	5 700		P2D		
	Abies	6 400		P2E		
Fagus-Tsuga	*Aphananthe-Celtis*	7 000	P1C	P2F		
	Tsuga	8 500				
	Carpinus	9 000		P2G	P12E	P16A
Celtis-Aphananthe	*Fagus*	9 600		P2H		
	Quercus	10 000				
Alnus-Quercus	—	10 500		P2I		
Quercus - Alnus	—	11 000				

Fig. 6. Correlation of the pollen zonations of the cores in the study area with the pollen zonations of ONISHI *et al.* (1990) and ONISHI (1993).

dominated diatom concentration, and *Cyclobalanopsis*, *Ulmus-Zelkova* dominated the pollen population.

Unit C consisted of ash, clay and some fine sand. No glass fragments were observed in the ash layers, except in Core R16, identification of which could not be carried out for the lack of sufficient data. P1C and P2F pollen zones gave the age of the sediment as 6,400-7,000 YBP. The study area was fully under marine and brackish marine influence, as also shown by the paleogeographic map, Fig. 1, Stage C. This period, termed the Jomon Transgression, experienced maximum marine transgression all over Japan. The Izumo Plain is believed to have been totally submerged by the invading sea, forming Paleo-Shinji Bay (TOKUOKA *et al.*, 1990). Dominance of *Cyclobalnopsis* and *Quercus* indicate that laurel forests had flourished along coastal areas.

Unit B consisted predominantly of clay, with fine sand towards the top. Pollen zones P2D and P2E gave the age as 5,200-6,400 YBP. Dominance of freshwater diatom was observed in this period. No corresponding zones were observed in other cores, still similar phenomena can be observed in diatom distribution in cores R1 and R12 below P1B and P12D zones, respectively.

The fact that the study area came under freshwater influence even while sea level was rising has been attributed to the terrigenous sediments deposited by the Hii River. The load was deposited on what is now the Izumo Plain dividing Paleo-Shinji Bay into western and eastern parts. The western bay has been referred to as "Kando-no-mizumi" in the book "Izumo-no-Kuni Fudoki," written around 1200 years back and the eastern part of Paleo-Shinji Bay was termed the Paleo-Shinji Lake (TOKUOKA *et al.*, 1990). This event is considered as a major event in the paleo hisotry of the Izumo Region. Deposition of terrigenous materials and division of Paleo-Shinji Bay may have influenced diatom concentration in the core samples, even though the study area is shown to be under marine influence (Fig. 1 Stage D, TOKUOKA *et al.*, 1990). *Cyclobalanopsis* still flourished, but increase in *Pinus* pollen can also be observed. Marine diatoms returned to dominate the diatom concentration at the pollen zones P1B, P2C and P12D. This is in confirmation with Fig. 1 Stage D. *Cyclobalanopsis*, *Castonopsis* and *Quercus* were the dominant pollen.

P2B and P12C show the area gradually returning to freshwater influence around 3,200–4,000 YBP. The sediment is still fine-grained in texture. Decrease in *Castonopsis* pollen is observed with increase in *Pinus*. Sea level is believed to have receded in Paleo-Shinji Bay about 2,400 YBP, during the Yayoi Regression (Fig. 1, Stage E, TOKUOKA *et al.*, 1990).

Diatom distribution in Core R12 from 1,300 YBP to the present shows frequent variations in sea level. The paleogeographic map, Fig. 1 Stage F, shows the region having undergone limited marine transgression (TOKUOKA *et al.*, 1990). Unit A in the cores consisted of medium to coarse-grained sand, with general increase in grain size towards the top. Diatom and pollen concentrations were poor. Around 300 YBP, sea-level seemed to have assumed nearly the present shoreline, and the Hii River changed its course to flow towards the east (TOKUOKA *et al.*, 1990). Wide distribution of *Cyclobalanopsis* indicates warm climatic condition over the entire period of marine transgression. High concentration of *Pinus*, Gramineae in the surface sediment, suggests intense human activity in recent years.

Sediment thickness plotted against the age shows that the sediments in core R2 had three depositional phases whereas only two were observed in core R12 (Fig. 7). Phase A in R2 represents sediment deposited before the Holocene period, when the area was drained by three rivers, thus explaining the high rate of deposition. Phase B in both the cores, R2 and R12, represent the Jomon Transgression, when the area was under total marine influence; hence the low and almost equal depositional rate. Depositional Phase C, which took place during the Yayoi Regression, has a higher depositional rate in R2 compared to R12. The cause of this is uncertain because of the complexity due to sea-level variation, coastal erosion, reworking of eroded sediments and river deposition.

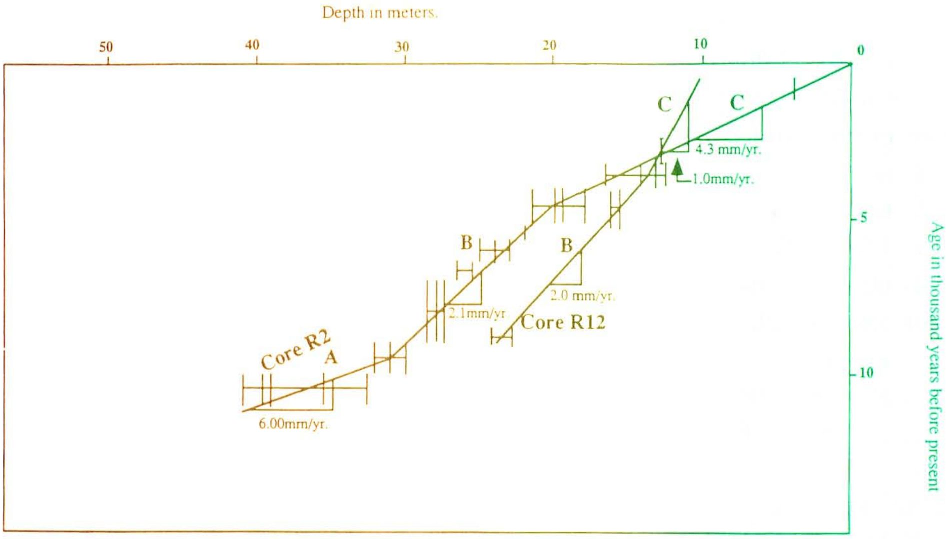


Fig. 7. Depositional rates of the sediments of cores R2 and R12. Three depositional phases (A, B and C) are observed in core R2 but only two B and C are observed in core R12.

3. Conclusions

1) Sediments in the study area consist of at least five diatom zones and ten polllen zones.

2) The paleoenvironments of the area have been reconstructed as follows:

a) About 20,000 YBP, the study area was under freshwater influence due to marine regression.

b) Since then, due to global warming, rise in sea level brought many of the presently exposed areas under its influence. Transgression reached maximum around 6,400 YBP (Jomon age). warm climate prevailed in the vicinity, as indicated by high concentration of *Cyclobalanosis* pollen grains.

c) The study area experienced a freshwater environment about 5,000 YBP, due to sediments deposited by the Hii River dividing the Paleo-Shinji Bay into "Kando-no-Mizuumi" in the west and the Paleo-Shinji Lake in the east.

d) Transgression resumed until about 4,000 YBP, with full appearance of other pollen grains.

e) Sea level began receding around 3,200 YBP,the beginning of the Yayoi Regression, as indicated by an increase in freshwater diatoms.

3) Chemical parameters, in general, confirm the above conclusions.

4) The age of sediments in the bottom part of the Core R12 was confirmed as of 22-25 Ka by the presence of AT tephra layer, which otherwise was devoid of pollen and diatoms.

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