Diatom assemblages and Holocene sea level changes at the Tamatsu site in Kobe, western Japan

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Diatom assemblages were analysed to clarify the changes in sedimentary environments caused by the Holocene sea level changes, and the results were cross-checked with information from the field observations of sedimentary facies. Diatoms were grouped into three ecological categories; marine, brackish and freshwater. Based on the ecological spectrum of the diatoms, the sediments were divided into five diatom zones as follows: (1) Freshwater diatom zone 1 (FD-1) is dominated by freshwater diatoms. (2) Transitional zone 1 (Tr-1), where a brackish species begins to appear and freshwater diatoms are replaced by marine ones as the dominant. This zone indicates when the sea penetrated into this site at the beginning of the Holocene transgression. (3) Marine diatom zone (MD) is dominated by marine diatoms. This zone is subdivided into three subzones on the basis of the dominant species; a) Subzone MD-a is characterized by Nitzschia granulata and Diploneis pseudovalis. b) Subzone MD-b is dominated by Melosira sulcata and Cyclotella stilorum. c) Subzone MD-c is dominated by Cocconeis scutellum, Cyclotella striata, and Nitzschia lanceolata. Typical planktonic species, Thalassionema nitzschioides and Thalassioira spp., also occur with low frequencies. This subzone contains the Akahoya tephra intercalary at a horizon of -1.3 m and is considered to coincide with the culmination of the Holocene transgression. (4) Transitional zone 2 (Tr-2) is subdivided into two subzones; the subzone Tr-2a is dominated by the brackish species Terpsinoe americana, and the subzone Tr-2b is dominated by freshwater diatoms, intermixed with two marine species, Nitzschia granulata and Cyclotella stilorum. (5) Freshwater diatom zone 2 (FD-2) is characterized by the aerophilous species.

In this study, the environmental changes caused by the Holocene sea level changes were clearly reflected in diatom assemblages. The replacement of freshwater diatoms by marine ones in the zone Tr-1 was so remarkable that we could easily trace the beginning of the transgression. At this site, the horizon indicating the beginning of the transgression based on the diatom assemblages precedes that based on macrofossil records by about 2 m. The upper limit of marine deposits based on the diatom assemblages is indicated by Terpsinoe americana, the dominant species of subzone Tr-2a, and agrees with information from the field observations of sedimentary facies.

Introduction

As is well known, diatoms can offer us reliable information for salinity conditions and in the case of freshwater sediments also rather reliable statements for pH conditions of the sedimentary environment. From this point of view, diatom analysis had been previously applied to various palaeolimnological studies in Japan (Mori, 1974, 1975 etc.). It has also played an important role in the Quaternary geohistorical studies in various research areas (Ariake Bay Research Group, 1965; Niigata Quaternary Research Group, 1972; Nobi Plain Quaternary Research Group, 1977). In these studies, diatom anal-
Analysis was used to determine whether the sediment was deposited in marine, brackish or freshwater conditions. Utashiro et al. (1975) investigated the late Quaternary sediments in Kurashiki City, Okayama Prefecture, and clarified the sedimentary environments by a diatom assemblage analysis. As regards Osaka Bay, Maeda (1976, 1977, 1978) determined the sea level changes during the Holocene epoch by means of various methods including diatom analysis.

The present study intends to clarify the sedimentary environments at the Tamatsu site spanning the time from the transgression to the regression in Holocene time on the basis of diatom assemblages. The general utility and significance of diatom analysis for studying Holocene sea level changes are also discussed.

The Tamatsu site is the construction site of a sewage treatment plant and is located near the Akashi River, about 2 km away from the coast along Harima Nada, eastern part of the Inland Sea (Fig. 1). The excavation for the foundation construction in 1978 offered us good outcrops of Holocene deposits (the Tamatsu Bed), from which the sediment samples were collected. At this site, the chronologically significant Akahoya tephra was also investigated (Maeda et al. 1982).

**Materials and Method**

The sediments were collected from excavations at the Tamatsu site on October 28, 29 and December 21, 1978. Samples of approximately 5 g were used for diatom analysis. Each sample was treated with 8% hydrogen peroxide and dispersed with sodium pyrophosphate. After the removal of the clay fraction by decanting according to sedimentation velocity, the separation of diatom frustules from the sediment was accomplished by vibration and subsequent pipetting of the suspension containing the diatoms which take longer to settle than the sediment. The diatom fraction was treated with a mixture of hydrochloric acid and nitric acid to remove remnants of organic matter. A proper amount of the cleaned and washed materials...
was then mounted with Pleurax. Generally 300–500 frustules were counted in each sample along a transect chosen at random; in some instances (sample No. 14, 34, 35, 36, 37 and 38), complete diametrical transect of two slides were necessary before enough frustules were found. General reference works referred for identification of diatoms were CLEVE-EULER (1951–1955), HUSTEDT (1930a, 1930b, 1959, 1961–1966), PATRICK and REIMER (1966, 1975), and VAN DER WERFF and HULS (1957–1974). The ecological data provided by the above-mentioned authors has enabled most taxa to be grouped into three categories, marine, brackish and freshwater.

Each group of diatoms and the significant species of each group are presented as a percentage of the total count (Figs. 3, 4 and 5).

**Sedimentary facies and Radiocarbon dates**

Field observations on the sedimentary facies of the Tamatsu Bed were carried out in 1978 (MAEDA et al., 1982). The columnar sections of the outcrops observed in October and December in 1978 are shown as Sec. I and Sec. II (Fig. 2). The ages were determined by the radiocarbon method at Gakushuin University in Tokyo (GaK) and Kanazawa University in Kanazawa (KL) (Table 1).

The sedimentary facies of the two sections are sandy and very similar to each other at a horizon of about −4 m (Fig. 2). From...
the close proximity of the two sections (ca. 50 m), these sediments are judged to have been deposited at the same time under the same environmental conditions. Although this correlation was based on a physical comparison of the sedimentary facies, diatom species were also useful; the occurrence of *Auliscus* spp. was restricted to this sandy horizon. Accordingly, the two sections are thought to have stratigraphic continuity with overlap at the medium sand facies.

The stratigraphy of the Tamatsu Bed and the dated samples are described in ascending order as follows (MAEDA et al., 1982): The oldest radiocarbon date was given by a piece of wood collected from clay at a horizon of −8 m; its age was 8,680 ± 120 y.B.P. datings were also made from woody fragments forming a filamentous layer at a horizon of −5 m and a piece of wood from clay at a horizon of −3.5 m. Their ages were 8,000 ± 190 y.B.P. and 8,400 ± 180 y.B.P., respectively. The latter date does not fit with the stratigraphic sequence of other samples. The former also seems unreliable, and together they pose the problem as to when the Holocene transgression began, which will be discussed in a following section.

In the course of field observations of sedimentary facies in December, 1978, records for macrofossils were not obtained, whereas trace fossils probably formed by burrowing invertebrates were found at a horizon of −3.8 m in October, 1978 (Fig. 2). This implies the beginning of the Holocene transgression at a horizon of −3.8 m at this site. Many molluskan fossils, such as *Tegillarca granosa*, *Macoma incongrua* and *Batillaria zonalis* were obtained from the sediment of silty clay at the horizons between −3.2 m and +1.2 m. According to MATSUSHIMA (1978), they are inhabitants of the tidal zone or sandy to muddy bottoms just below the tidal zone of inner bays, belonging to his molluskan assemblages A or B. Most of them are considered to be autochthonous judging from their occurrences and species composition. The radiocarbon dating on *Tegillarca granosa* collected from the sediments at −3.0 m showed its age as 6,810 ± 150 y.B.P.. At this site, Akahoya tephra was found at a horizon of −1.3 m. Radiocarbon datings were made for two samples of *Macoma incongrua* from the sediments above and below the tephra in order to determine the ejected age from the group of radiocarbon ages, the tephra was dated at about 6,300 y.B.P. (MAEDA et al., 1982).

In the upper coarse sand and medium sand facies at about +2.0 m, trace fossils of burrowing invertebrates and roots of Gramineae were well preserved, indicating that Gramineae plants were growing on the seashore at that time. The dating was made on a piece of wood from medium sand, and the age of 3,810 ± 150 y.B.P. may be too young by the addition of young carbon. In coarse sand at a horizon of +2.0 m, there was found crystalline sulfuric matter characteristic of marine sediments (ITIHARA, 1960). Similar materials was not found in the upper coarse sand and gravel. The different appearance of the sediment indicates that some remarkable environmental changes must be taken place, and is described as a diastem at the horizon of +2.2 m shown in Fig. 2. From this point of view, the coarse sand was regarded as the uppermost marine deposit (the marine limit). In the uppermost part of Section I, three humus clay probably formed in back swamps alternated with layers of silty and fine sand, representing the sediments typically formed in the flood plain of a river. The humus clays at horizons of +2.5 m and +4.0 m were dated at 4,470 ± 160 y.B.P. and 3,390 ± 100 y.B.P., respectively.

**Diatom Zones**

On the basis of ecological spectrum grouped into three categories, marine, brackish and freshwater, the sediments can be divided into five diatom zones, named Freshwater Diatom Zone 1 (FD-1), Transitional Zone 1 (Tr-1), Marine Diatom Zone (MD), Transitional Zone 2 (Tr-2) and Freshwater Diatom Zone 2 (FD-2) in ascending order (Fig. 3). Each Freshwater Diatom Zone is dominated by freshwater diatoms, and does not include marine or brackish diatoms. The Marine Diatom Zone is dominated by over
50% marine diatoms. The Transitional Zones indicate the transitional process from zone FD to zone MD, or from zone MD to zone FD.

In zone FD-1, freshwater diatoms, which comprise more than 90% of all frustules counted, were dominated (Fig. 3). Marine and brackish diatoms were absent. *Navicula mutica*, *Hantzschia amphioxys*, *Caloneis Schroederi*, *Pinnularia borealis*, *Cymbella spp.*, *Gomphonema spp.*, *Eunotia spp.*, and *Epithemia zebra* were abundant throughout this zone (Fig. 4).
Fig. 4 Diatom diagram showing the occurrence of the significant freshwater species.
Malosira roeseana also occurred with low frequency. In the lower part of this zone, where the sediment is clay and medium sand, Frustulia vulgaris and Rhopalodia gidda occurred, although they were not abundant (Fig. 4). In the upper part of this zone, where the sediment is clay, the above-mentioned species disappeared and Cocconeis placentula and Meridion circulare var. constrictum occurred with rather low frequencies (Fig. 4). This change roughly coincides with the change in sedimentary facies from clay and medium sand to clay.

In zone Tr-1, there occurs a major change (Fig. 3). Freshwater diatoms were still dominant in the lower part of this zone, while brackish species began to appear but remained with low frequency. In the upper part of this zone, marine diatoms began to appear and increased in number rapidly. This probably reflects the change in sedimentary environments from freshwater conditions to marine conditions at the beginning of the Holocene transgression. The species of first appearing in response to the transgression was the brackish species Diploneis pseudovalis, and was accompanied by a rapid increase in Nitzschia granulata (Fig. 5).

In zone MD, freshwater diatoms declined, and marine diatoms became dominant (over 50%) (Fig. 3). This is considered proof that sedimentation took place under marine conditions. This zone can be subdivided into three subzones according to the dominant species (Fig. 5). The subzone MD-a was dominated by Nitzschia granulata, although the brackish species Diploneis pseudovalis showed its highest peak at this subzone. In subzone MD-b, N. granulata decreased and D. pseudovalis disappeared. Cyclotella striolata and Melosira sulcata became dominant and have the highest frequencies among all the zones described here. Nitzschia cocconeiformis also showed with higher frequency. Even though only very low frequencies were recorded for Auliscus spp., they were characteristic for the sediment of the upper medium sand facies and one of useful indicators for correlation between the two sections. (Fig. 2). In subzone MD-c, C. stylosum described to low level, but after the subzone transition MD-b/c it increased again and had another peak. On the other hand, M. sulcata decreased and remained low level from lower subzone MD-c upwards. Although there was a short-lived increase, N. granulata showed a tendency to decrease with much lower frequency than in MD-b. The assemblages of the subzone is dominated by Cyclotella striata, Cocconeis scutellum and Nitzschia lanceolata. Cymatotheca weissflogii, Thalassionema nitzschioides and Thalassiosira spp. characteristically occurred with low frequencies.

The zone Tr-2 was subdivided into two subzones, Tr-2a and Tr-2b. Subzone Tr-2a, the lower part of this zone, was dominated by up to 70% brackish diatoms and subzone Tr-2b, the upper part, was dominated by freshwater diatoms (Fig. 3), intermixed by two marine species, N. granulata and C. stylosum (Fig. 5). In subzone Tr-2a, the brackish species Terpsinoe americana occurred in abundance up to 60% of the sample, and N. granulata slightly increase. In addition, D. pseudovalis appeared again in subzone MD-c and showed another peak in this subzone. It seems that the subzone Tr-2a reflects the regression after the culmination of the transgression. In subzone Tr-2a, N. granulata and C. stylosum occurred together with freshwater diatoms. However, most frustules of these species were eroded, whereas in zone MD they were generally intact. T. americana, the dominant species in subzone Tr-2a, and other marine species which were frequent in subzone Tr-2a were absent in subzone Tr-2b. This fact indicates that the major environmental change had taken place at the boundary between subzone Tr-2a and Tr-2b.

In zone FD-2, Navicula mutica, Hantzschia amphioxys, Pinnularia borealis and Caloneis Schroederi were abundant (Fig. 4). This characteristics was in common with zone FD-1. Melosira spp. also occurred with rather high frequencies, but they were usually of broken frustules suggesting that they may be allochthonous. Cymbella spp. and Gomphonema spp., which were abundant in zone FD-1, occurred with rather low frequencies and Epithemia zebra was not detected (Fig. 4).
Fig. 5. Diatom diagram showing the occurrence of the significant marine and brackish species.
Discussion

1. Sedimentary environment of each diatom zone.

A deduction can be made concerning the sedimentary environment of each zone on the basis of the diatom assemblages compared with information from the field observations of sedimentary facies. In the following interpretation of sedimentary environments, special attention was given to the ecological forms of the dominant species from which most conclusions were drawn, although indicative significance was also given to some rarer but ecologically well known species.

FD-1 Zone:

On the basis of diatom assemblages, it is assumed that sedimentation took place under freshwater conditions, and there was a slight environmental change between the lower part characterized by Frustulia vulgaris and Rhopalodia gibba and the upper part by Cocconeis placentula and Meridion circulare var. constrictum (Fig. 4). This change was also reflected in a change in sedimentary facies, but could not be established sufficiently. Navicula mutica, Hantzschia amphioxys, Pinnularia borealis, Caloneis Schroederi, Cymbella spp., Gomphonema spp., Eunotia spp., and Epithemia zebra were abundant throughout this zone (Fig. 4). Many authors (Florin, 1970; Haworth, 1976; Grasse, 1978, etc.) cited recent diatoms, N. mutica, H. amphioxys and P. borealis as typical aerophilous species found in dry habitats. Round (1973) considered the above-mentioned species as aerial epiphytic algae on Bryophytes in dry situations. Melosira roeseana is one of moss diatom species in Japan (Ando, 1977). Haworth (1976) included Caloneis Schroederi in the aerophilous forms. These aerophilous species were also abundant in zone FD-2. Zone FD-1 can be characterized in comparison with zone FD-2 as follows: zone FD-1 contains haptobenthic aquatic forms such as Cymbella spp., Gomphonema spp., Eunotia spp., mainly E. sudetica, and Epithemia zebra in abundance together with aerophilous forms, whereas zone FD-2 contains them with low frequencies (Fig. 4). Especially, Epithemia zebra was absent in zone FD-2. The species of Epithemia that are encountered typically as the epiphytic forms associated with submerged plants, and species of Eunotia are commonly found in association with mosses, e.g. Fontinalis spp. (Camburn et al., 1979). Most species of Cymbella and Gomphonema are usually found in rivers and lakes as epilithic and epiphytic forms. The appearance of these haptobenthic species in zone FD-1 suggests that the sedimentary environment of zone FD-1 was more aquatic than that of zone FD-2 even though aerophilous species exist. Terrestrial diatoms were probably brought into this site by run-off of the surrounding land surface. Because of the complex feature of the zone, it is difficult to make more detailed reconstruction of the environment.

Tr-1 Zone:

In zone Tr-1, there was a remarkable replacement of freshwater diatoms by marine ones (Fig. 3); in the lower part of the zone, being dominated by freshwater diatoms, the brackish species Diploneis pseudovalis began to occur (Fig. 5), and marine diatoms increased rapidly upwards. These facts indicate the change in sedimentary environment from freshwater to marine at the beginning of the Holocene transgression. The abrupt change of the dominant species from freshwater diatoms to marine ones was so conspicuous that it seems unlikely that the sedimentation took place in a river mouth at the time of Holocene transgression. If the sediments of the zone were deposited in the mouth of river, one would expect freshwater diatoms to occur for a longer period with higher frequencies as they are carried out by freshwater distributaries. In fact, the appearance of aerophilous forms in FD-1 is considered to be a supporting evidence for the above-mentioned deduction. The conspicuous replacement in diatom assemblages permits a fairly reliable estimate for the beginning of the transgression to be made, and may indicate the rapid rise of sea level from 8,000 to 6,000 y.B.P. as reported by Maeda (1976, 1977, 1978, 1980).

MD Zone:

Marine diatoms were dominant, but fresh-
water diatoms were present throughout this zone (Fig. 3). It is considered that the sedimentation took place under marine conditions. This zone was subdivided into three subzones on the basis of the dominant species, and each subzone can be considered to reflect the changes in sedimentary environment during the course of the transgression.

The subzone MD-a is characterized by *Nitzschia granulata* and *Diploneis pseudovalis* (Fig. 5). *D. pseudovalis* is reported on shore and mud in Lake Kahoku-gata, a brackish lake (KAMIJO and WATANABE, 1973). *N. granulata* is found commonly in all intertidal levels on tidal flat in Yaquina Estuary, Oregon, north America (RIZNYK, 1973), and is found frequently on sandy shores in England (HENDEY, 1964). *N. granulata*, the occurrence of which determined the pattern of marine diatoms in the subzone (Fig. 3), indicates that the sea was shallow at this site.

KUMANO and MIYAHARA (1981) showed that *N. granulata* is an important element of the intertidal assemblage indicating the early stage of the Holocene transgression. In the present study, *N. granulata* is again indicative of the deposits in the early stage of the transgression. Since this species is easy to identify, it may become a significant indicator of the transgression. It is important, however, to note that *N. granulata* is characteristic of an organically rich substratum (RIZNYK, 1973).

The subzone MD-b is characterized by *Cyclotella styloorum* as the littoral plankton, and *Melosira sulcata* as the bottom form (Fig. 5). There is a short-lived increase in freshwater diatoms with eroded frustules in the lower part of the subzone MD-b (Fig. 3). This may indicate input of river-derived diatoms caused by the stagnation after the sea rose rapidly from 8,000 to 6,000 y.B.P. It may be assumed that the sea was still shallow, with bottom and shoreline conditions unstable.

The subzone MD-c is characterized by *Cocconeis scutellum*, *Nitzschia lanceolata*, and *Cyclotella striata* (Fig. 5). *Thalassionema nitzschioides*, *Thalassiosira* spp., *as* neritic planktons, and *Cymatotheca weissflogii* were also typical for the subzone MD-c (Fig. 5). *Cocconeis scutellum* is one of the major species of a sub-littoral diatom assemblage epiphytic on *Enteromorpha* (LEE et al., 1975), and is also a primary colonizer on a submerged marine plant, *Zostera marina* (SIEBURTH and THOMAS, 1973). According to UTASHIRO et al. (1975), *C. weissflogii* is usually found as benthic forms in the inner bay. The subzone MD-c is considered to coincide with the culmination of the Holocene transgression judging from the intercalation of Akahoya tephra (6,300 y.B.P.), and diatoms found in the subzone MD-c also show that sea was then deepest at this site. The more uniform sediment of silty clay and the occurrence of many molluskan shells suggest the most stable marine conditions at this time. From this point of view, it can be concluded that the results of diatom analysis correspond roughly to those of field observations of sedimentary facies. The sediment of subzone MD-c was deposited in deepest and most stable marine conditions at the culmination of the Holocene transgression.

**Tr-2 Zone:**

The subzone Tr-2a is characterized by a brackish species *Terpsinoe americana* (Fig. 5). Radiocarbon dating show that the subzone Tr-2a coincides approximately with a period of 5,000–4,000 y.B.P., although a piece of wood from the sediment at a horizon of +1.8 m showed a younger age. Brackish species occurring in great abundance are considered to reflect the regression after the culmination of the transgression. According to field observations of the sedimentary facies, the medium sand in the lower part of the subzone Tr-2a contains roots of Gramineae plants indicating that they were growing on a seashore at the time of the regression. *T. americana*, the dominant species in Tr-2a, is commonly found in the mid and upper intertidal levels on tidal flat in Yaquina Estuary (RIZNYK, 1973). This site might have been in the nature of a littoral lagoon at that time.

In subzone Tr-2b, the assemblages are composed mainly of freshwater species (Figs. 3, 4), intermixed by two marine species, *Nitzschia granulata* and *Cyclotella styloorum* (Fig. 5). The appearance of these marine species can be interpreted two ways; 1) a small rise of sea level during the course of the regression, or
2) only re-deposition; frustules of marine species might have been washed out from the sediments already lay bare and deposited together with freshwater species. The latter seems more reliable because most frustules of these marine species were eroded. Field observation of the sedimentary facies show that the major environmental changes took place at the horizon of +2.2 m and this horizon is regarded as the marine limit (MAEDA et al., 1982) (Fig. 2). The diatom analysis also show a change in succession at a horizon of +2.2 m, the boundary between subzone Tr-2a and subzone Tr-2b; Terpsinoe americana, the dominant species in subzone Tr-2a and many other marine species were absent in subzone Tr-2b. In the present study, T. americana indicates the marine limit at the boundary between subzone Tr-2a and Tr-2b, which is clearly observed on the sedimentary facies in the field. 

FD-2 Zone: 
Species of Melosira as planktonic forms, such as M. granulata and M. italica, occur in abundance, especially in the humus clay (Fig. 4), and seem to suggest that water was retained long enough for planktonic populations to grow at this site. Apart from the aeroophilous species, most frustules of diatoms obtained, however, were broken and probably transported from other site. On the other hand, unbroken frustules of Navicula mutica, Hantzschia amphioxys and Pinnularia borealis are considered to be autochthonous.

In zone Tr-2, there was also a rapid replacement in diatom assemblages (Fig. 3), similar to what was found in zone Tr-1. This may indicate that this site was immediately cut off from direct connection with the sea by the action of a river during the course of regression.

In comparison with zone FD-1, most diatoms were broken and haptobenthic species characteristic of zone FD-1 were scarce or absent from this zone, while entire frustules of aeroophilous species were abundant. These facts might indicate that there were rather terrestrial conditions like the flood plain of river at this site.

2. Holocene sea level changes and diatom assemblages.

In Japan, Holocene sea level changes have been reported (FUJI and FUJI, 1967; MAEDA, 1977; KAIZUKA et al., 1977, etc.). The lowest sea level has been interpreted to have occurred at about 18,000 y.B.P.. Then the sea rose and reached its present sea level. Subsequently there was a stage of transgression (2—3 m higher than present) and regression (2 m lower) during the last 6,000 years.

Both the observations of sedimentary facies and the diatom analysis show that the marine limit can be regarded to be +2.2 m above the present sea level. If this site has been stable in the tectonic sense, this is indicative of the highest eustatic sea level of Holocene.

The beginning of the Holocene transgression based on the diatom assemblages is recognizable in zone Tr-1, whereas that based on macrofossil records is recognized in the sediment of silty fine sand at a horizon of −3.8 m (Fig. 2). KUMANO and MIYAHARA (1981) pointed out the intertidal assemblages of diatoms appeared prior to those of mollusks in the progress of the Holocene transgression. Since mollusks, especially, on benthic forms, may depend largely on the structure of the bottom to live in and require more stable conditions to settle, it can be assumed that the environmental changes in response to the transgression are reflected in diatom assemblages more rapidly than in molluskan assemblages. In fact, the occurrence of the intertidal molluskan assemblages at this site corresponds to the diatom zone MD-c, where the sedimentary environment is thought to be most stable.

Diatom should yield continuous information for environmental changes. Therefore, it should be emphasized that diatom analysis is useful in an elucidation of sedimentary environments, especially in the case where no macrofossil records were available as shown in Sec. II of Fig. 2. At this site, moreover, the beginning of the Holocene transgression based on the diatom assembles is observed about 2 m deeper than that determined by field observations of the sedimentary facies. As a result, the sample of woody fragments
possessing the radiocarbon age of 8,000±190 y.B.P. poses a problem in the interpretation of the dating (Fig. 2, Table 1), because the diatom analysis reveals that the sea had already penetrated into this site at that time (Fig. 3). MAEDA (1977) estimated, from his studies concerning the Holocene transgression in the Osaka Bay, that at 8,000 y.B.P. the sea was about 20 m below present sea level. Although his work was mainly based on the occurrence of intertidal molluskan assemblages, this difference (15 m) is too great. The sample of woody fragments may show an unexpectedly old age on an account of re-deposition. As a matter of fact, Nitzschia granulata characteristic of subzone MD-a decreased at the filamentous layer of woody fragments, while freshwater species increased (Figs. 3, 5). This fact may be interpreted to indicate woody fragments were allochthonous, in other words, rebedded materials, and the old age of the sample may be attributed to re-deposition. The great difference of the sea level at 8,000 y.B.P. between the Tamatsu site and the Osaka Bay would be a problem that should be examined more fully in future.

It is important, however, to note that the environmental changes in response to the transgression based on the diatom assemblages appears prior to that based on the intertidal molluskan shells, because the tidal range in the eustatic sea level changes must be considered; diatom assemblages may reflect the high tide level in the eustatic sea level changes, whereas intertidal molluskan assemblages may reflect the low tide level. It is worthwhile to mention in this connection that we can trace the eustatic high tide level changes on the basis of diatom assemblages.

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References


神戸市玉津における珪藻遺骸群集と完新世海面変動

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（要旨）
完新世海面変動に伴う堆積環境の変化を明らかにするために珪藻遺骸群集の分析を行い，その結果と地層の野外調査から得られた情報とを比較検討した。珪藻は海産，汽水産，淡水産の3つのカテゴリに類別した。その珪藻の生態区分に基づいて，堆積物は以下に示す5つの珪藻帯に分けられた。1）淡水珪藻帯1（FD1）は淡水産種によって占められる。2）遷移帯（Tr1），ここでは汽水産種が出現し始め，優占種が淡水産珪藻から海産珪藻に交代する。この珪藻帯は完新世海進の開始期に海が本調査地に進入した時期を示している。3）海産珪藻帯（MD）は海産珪藻が優占する。この珪藻帯は優占種に基づいて3つの亜帯に区分できた。MDa亜帯はNitzschia granulataとDiploneis pseudovalisによって特徴づけられる。MDB亜帯はMelosira sulcataとCyclotella stylonumが優占する。そしてMDC亜帯ではCocconeis scutellum，Cyclotella striata，Nitzschia lanceolataが優占し，Thalassionema nitzschioides，Thalassiosira spp.などの典型的なプランクトン性種も低率であるが特徴的に出現する。この亜帯は標高を1.3mにアカホヤ火山灰を挟み，完新世海進の頂期に相当するものと考えられる。4）遷移帯2（Tr2）は2つの亜帯に細分される。Tr2a亜帯は汽水産のTerpsinoe americanaが優占し，Tr2b亜帯は淡水産種が優占するがNitzschia granulataとCyclotella stylonumの海産2種が混在する。5）淡水珪藻帯2（FD2）は好気性種によって特徴づけられる。

本研究においては，完新世海面変動に伴う環境変化が珪藻遺骸群集に明らかに反映された。Tr1帯での淡水珪藻から海産珪藻への交代は非常に顕著で海進の開始を把握することが容易にできた。本調査地では，珪藻遺骸群集に基づく海進の始まりは大型化石に基づくそれに約2m先行する。また，珪藻遺骸群集に基づく海成層の上限はTr2a亜帯の優占種Terpsinoe americanaによって指示され，それは地層の野外調査から得られた情報に一致する。