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21. DIATOM BIOSTRATIGRAPHY: LEG 128[1]

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ABSTRACT

Diatom datum levels are defined for Leg 128 sites. In order to determine the utility of these datum levels in correlating Sea of Japan sediments to sediments of the northwest Pacific, a number of sites from this region were also included in this study. Because of dissolution and the presence of near monospecific oozes of *Coscinodiscus marginatus* it was not possible to identify datum level markers before the late Pliocene with any degree of confidence. By utilizing standard biostratigraphic methodology as well as ecological first appearances and changes in diatom abundances it may be possible to use diatoms to detail the late Quaternary paleoceanographic history of the Sea of Japan.

INTRODUCTION

Ocean Drilling Program Leg 128 occupied two primary sites (798 and 799) and reoccupied a third site (794 previously drilled by Leg 127) with the following objectives in mind: (1) to obtain a Miocene-Holocene paleoceanographic reference section; (2) to determine the depositional history of a failed back-arc rift; and (3) to analyze the structure of the deep crust and upper mantle beneath the southern region of the Sea of Japan. Three holes were occupied at Site 798 (37°38.32′N, 134°47.976′E) in ~900–903 m of water. A 517-m-thick section of early Pliocene through Quaternary diatomaceous and terrigenous clays, claystones, oozes, and volcanic ash was recovered at this site. An average sedimentation rate of 120 m/m.y. at this site suggests that the recovery of a high resolution paleoceanographic history is possible. Further, the absence, or near absence, of terrestrially derived turbidites from this site suggests that the paleoceanographic record has not been compromised by transient phenomena.

Three holes were occupied at Site 799 (39°22.046′N, 133°86.685′E) in ~2071 m of water. More than 1000 m (1084 m) of Miocene to Quaternary sediment consisting of biosiliceous and fine grained detrital sediment together with carbonate-rich intervals and ash was recovered. The opal A/opal CT boundary occurs at 457 mbsf, below which there is a pronounced change in density and lithification. Sedimentation rates range between 15 and 175 m/m.y. with an average rate near 70 m/m.y. Highest rates occur in upper Quaternary sediments and below average rates occur in the Pliocene. Reworking of older microfossils into younger beds is common at this site which appears to compromise its value for paleoceanographic studies.

The Ocean Drilling Program Leg 128 cruise was the third into the Sea of Japan while five cruises have been conducted into the adjacent northwest Pacific. These cruises, particularly those in the northwest Pacific have resulted in the establishment of a zonal scheme for the late Tertiary, a scheme which is also considered valid for the Sea of Japan. Significant contributors to diatom biostratigraphy in this region include Barron (1980), Akiba (1982), Koizumi (1975, 1978), and Koizumi and Tanimura (1985). Although it was originally devised for the northwest Pacific, in our shipboard analysis we used the stratigraphic scheme of Koizumi and Tanimura (1985) largely because it is a refinement of previous schemes and because it was set up within the context of an excellent paleomagnetic reversal record (Bleil, 1985).

This report targets the late Pliocene to Quaternary diatom stratigraphy of Leg 128. Although diatoms are more abundant below sediments of late Pliocene age, the dominance of a single species (*Coscinodiscus marginatus*) in older sediments above the opal A/opal CT boundary makes it difficult to apply the biostratigraphic method with any degree of confidence. The taxa which define zones are either dissolved or are masked by the more abundant *C. marginatus.* A focus on sediments of late Pliocene and Quaternary age also seems justified since it is within this time interval that a high resolution paleoclimatic and paleoceanographic record can be achieved; i.e., by integrating microfossil datum levels and the *N. pachyderma* coiling change curve with oxygen isotope stratigraphy, percent opal stratigraphy, and well logging (Dunbar et al., this volume; deMenocal et al., this volume; Kheradyar, this volume; Muza, this volume) it may be possible to resolve oceanographic and climatic variations within a hundred to thousand year time scale. Further, the presence of dark/light sediment rhythms (massive to finely laminated) in late Pliocene to Quaternary sediments of the Sea of Japan (Föllmi et al., this volume; Tada et al., this volume) suggests that it may be possible, at least in some parts of the section, to resolve time on decadal time scales. This approach, and some of the rational behind it, is discussed further in Föllmi et al. (this volume) and in the biostratigraphy synthesis by Burckle et al. (this volume).

SOURCE OF MATERIALS AND SAMPLE PREPARATION

All samples used in this study were collected by the author on board ship or during a subsequent trip to the College Station, TX, storage facility. In addition to ODP Leg 128 sites, two piston cores, one from the Sea of Japan (RC12-379, 36°53.5éN, 134°33éE) and one from the northwest Pacific (V32-126, 35°19.1éN, 177°55.4éE) were also examined. Samples were prepared using methods described by Schrader (1974). One of two general methods are usually employed in doing biostratigraphy; the analyst may focus on first and last appearances of a taxon and present the data adjacent to a stratigraphic column to identify relative time, or the analyst may use a sequence of first and/or last appearances to define zones (i.e., to identify intervals of relative time). Within the last 25 yr, the power of the biostratigraphic method has been considerably enhanced with the addition of the use of the paleomagnetic reversal record. Unfortunately, this has led to some abuses; i.e., the micropaleontologists may sometimes define a zone or a first or last appearance based upon an a priori interpretation of the magnetic reversal record rather than upon actual microfossil occurrences. In this paper, I have used datum levels rather than zones. Where appropriate I have also indicated where particular datum levels are to be applied with caution.

[1] Pisciotto, K. A., Ingle, J. C., Jr., von Breymann, M. T., Barron, J., et al., 1992. *Proc. ODP, Sci. Results,* 127/128, Pt. 1: College Station, TX (Ocean Drilling Program).
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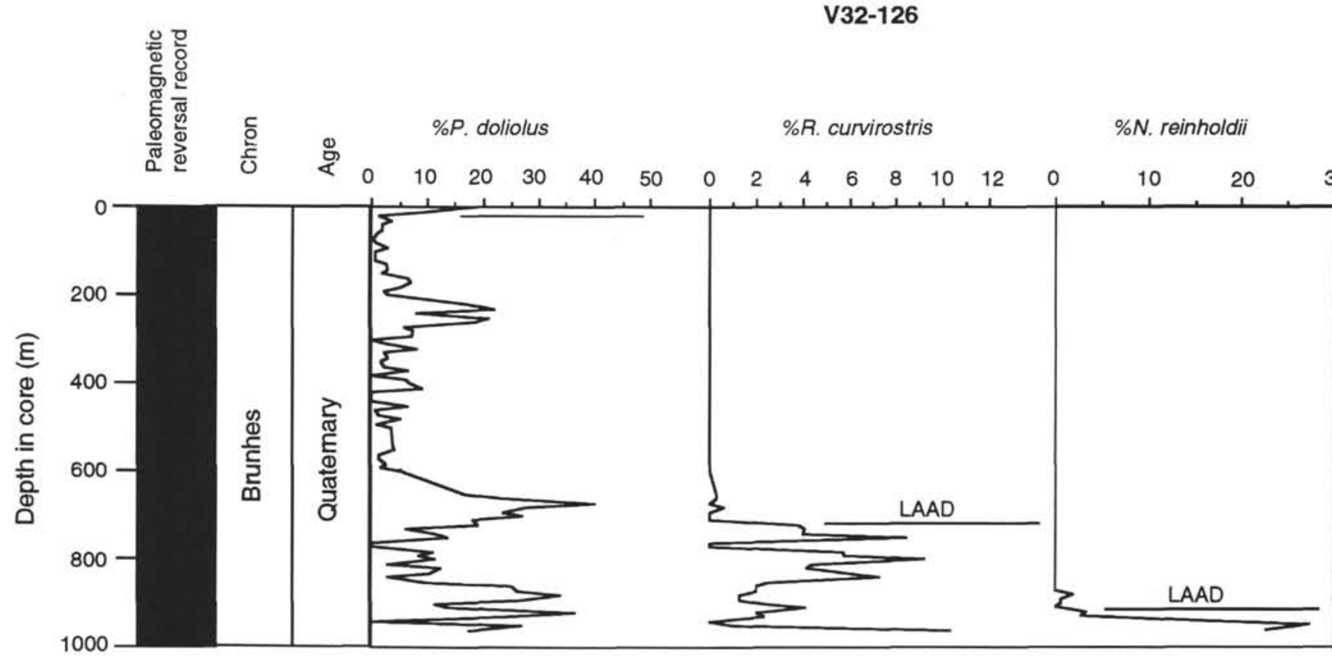

Figure 1. Quantitative biostratigraphy for piston core V32-126 from the northwest Pacific. LAAD = Last Abundant Appearance Datum.

RESULTS

V32-126

Core V32-126 was taken at 35°19.1′N, 177°55.4′E on top of the Hess Rise. It consists largely of mixed biosiliceous and biocalcareous sediment. The paleomagnetic reversal record indicates that it did not penetrate below the Brunhes magnetic reversed chron, a point which is supported by the biostratigraphy (Fig. 1). Three datum levels are recognized in this core; the youngest, based upon the youngest increase in relative abundance of *Pseudoeunotia doliolus* is included here because its abundance fluctuations appear to parallel changes in this species in the Holocene record of the Sea of Japan. The next youngest datum level, the last appearance datum of *Rhizosolenia curvirostris,* was previously tied to the oxygen isotope record in northwest Pacific sediments by Morley et al. (1982). These authors determined that this datum occurred at ~276 ka and it appears to be a consistent last appearance over the North Pacific. The last appearance of *Nitzschia reinholdii* is found near the base of this core and is evidence that the core bottomed near the Brunhes/Matuyama magnetic boundary. Burckle (1977) gives its last appearance in the equatorial Pacific at ~620 ka. There has been some suggestion in the literature that this last appearance may be slightly diachronous in the North Pacific but, in the absence of oxygen isotope evidence, this is difficult to support.

RC12-379

Piston core RC12-379 was recovered at 36°53.5′N, 134°33′E off the coast of Honshu. It consists of an olive gray clayey silt with moderate concentrations of biosiliceous and biocalcareous sediment. Distinct laminae occur in the interval dated to the Last Glacial Maximum (Maiya et al., 1976). These authors radiocarbon-dated one level at 30 k.y. and estimated ages above that level using a combination of sedimentation rates and foraminiferal biostratigraphy (i.e., the abrupt change from left to right coiling *Globigerina pachyderma*). In Figure 2, I have recalibrated this chronology using the offsets above 9 k.y. determined by Fairbanks (1989) and plotted the first appearance of *P. doliolus* as well as changes in its abundance. The first appearance of this species during the post glacial occurs between 9 and 10 k.y., apparently paralleling the increase in relative abundance of this species in the northwest Pacific (see Fig. 1). This date closely approximates the date for the first post-glacial appearance of this species in the Sea of Japan determined by Oba et al. (in press). Of interest are the further points that the Holocene entry of this species into the Sea of Japan occurs when sea level over the Tsushima Strait had risen to –30 m to –40 m below present sea level and that its appearance coincides with a Holocene increase in abundance of diatoms and radiolarians (expressed as numbers of specimens per gram of sediment; Burckle, unpubl. notes).

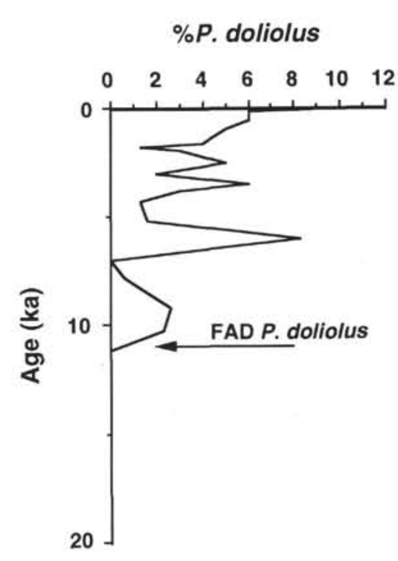

Figure 2. Age plot for piston core RC12-379 from the southeastern part of the Sea of Japan showing time of first appearance of *Pseudoeunotia doliolus* in the Sea of Japan after the Last Glacial Maximum.

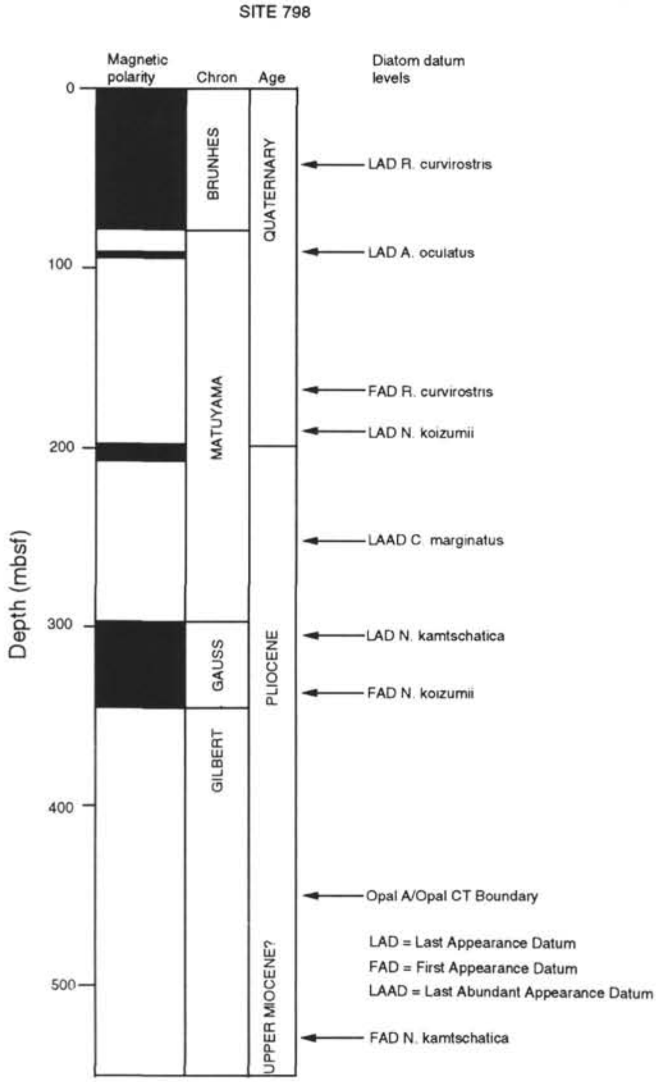

Figure 3. Diatom datum levels plotted against magnetostratigraphy for Site 798. Age of lower part is uncertain because of dissolution.

Site 798

Ocean Drilling Program Site 798 contained poor to well preserved diatoms in the Quaternary section and alternating diatomaceous oozes and moderately well preserved diatoms in the Pliocene section down to the opal A/opal CT boundary (which occurs at about 457 mbsf). Diatom datum levels (first and last appearance as well as the last abundant appearance datum level of *C. marginatus*) are shown in Figure 3. The youngest datum level, *Rhizosolenia curvirostris,* is found over much of the North Pacific (Koizumi and Burckle, 1985) and disappears from this region at ~276 ka in oxygen isotope Stage 8 (Morley et al., 1982). This is perhaps the most reliable diatom datum in the Quaternary of the North Pacific and the Sea of Japan. Another last appearance datum which occurs in the equatorial and North Pacific (last occurrence of *Nitzschia reinholdii*) was not observed in sediments of Site 798. Although this species occurred sporadically throughout the Pliocene and early Quaternary sections, its last appearance was never consistent within the lower part of the Brunhes magnetic chron (the level at which it disappears elsewhere in the North Pacific).

The *Actinocyclus oculatus* last appearance was observed in conjunction with the Jaramillo magnetic event. Unfortunately, the occurrence of this species is spotty and, without suitable paleomagnetic findings as a guide, this datum probably would have been overlooked. A similar comment may not be made for the next oldest datum level (the first appearance datum of *Rhizosolenia curvirostris*). This datum level has been widely recognized in the North Pacific and the Sea of Japan (Koizumi and Burckle, 1985; Koizumi and Tanimura, 1985) and is regarded as a reliable marker for the early Quaternary. The last appearance datum of *Neodenticula koizumii* also occurs in the early Quaternary just below the *R. curvirostris* datum level. Unlike the latter datum, this level is somewhat difficult to pick, again because of the spotty nature of its occurrence.

I include here the last abundant occurrence of *Coscinodiscus marginatus* in late Pliocene sediments. This level was also observed in Site 799 and is treated elsewhere (Burckle et al., this volume). There are some data to suggest that this last abundant occurrence is isochronous between the Sea of Japan and at least some parts of the North Pacific. The last appearance datum of *Neodenticula kamtschatica* near the top of the Gauss magnetic chron is a reliable marker that has been observed in both North Pacific and the Sea of Japan sediments (Koizumi and Burckle, 1985; Koizumi and Tanimura, 1985). The same can not be said for the next oldest datum (the first appearance datum of *Neodenticula koizumii*), at least for the Sea of Japan. This first appearance is spotty and, like some other datum levels, cannot be considered reliable without paleomagnetic control.

I chose not to make use of the paleomagnetic control below the Gauss chron in Site 798. This is because both the pattern of paleomagnetic reversals is not easily interpretable and the increase in relative abundance of *C. marginatus* and the presence of the Opal A/Opal CT boundary make it difficult to identify first and last appearance datum levels. One possible exception to this is the first appearance datum of *Neodenticula kamtschatica* below the Opal A/Opal CT boundary (Fig. 3). Burckle and Opdyke (1986) have pointed out that the first appearance of this species is diachronous over the North Pacific, making its first appearance during the late Miocene in the Gulf of Alaska but appearing later as one goes toward the middle latitudes. In middle latitude regions, its first appearance appears to be around the Miocene/Pliocene boundary. This suggests, but does not prove, that the first appearance of this species in Site 798 may approximate the Miocene/Pliocene boundary.

Site 799

Ocean Drilling Program Site 799 contained poor to well preserved diatoms in the Quaternary section and alternating diatomaceous oozes and moderately well preserved diatoms in the Pliocene section down to the opal A/opal CT boundary (which occurs at ~430 mbsf). Diatom datum levels (first and last appearance as well as the last abundant appearance datum level of *C. marginatus*) are shown in Figure 4. Although Site 799 penetrated into sediments older than Site 798, problems were still encountered with dissolution below the Opal A/Opal CT boundary. Similarly, that part of the section just below the Pliocene/Pleistocene boundary shows what is presumed to be increased dissolution marked by the increase in relative abundance of the dissolution-resistant form, *C. marginatus.* Both of these factors make accurate biostratigraphy below the level of the Pliocene/Pleistocene boundary difficult.

DISCUSSION

It seems apparent that the zonation worked out by Koizumi and Tanimura (1985) is not always applicable to the Sea of Japan. Specifically, the *A. oculatus* last appearance datum, and the *N. koizumii* first and last appearance datum levels seem to be applicable only when used within the context of the paleomagnetic stratigraphy. Similarly, the sporadic occurrences of zonal markers below the Opal A/Opal CT boundary can be used as age indicators only in a general sense because of the lack of continuous occurrences. Judging from our view of the biostratigraphy and the problems with dissolution below the Pliocene/Pleistocene boundary (Burckle et al., this volume) it appears that only the late Pliocene–Quaternary will yield a high resolution paleo-

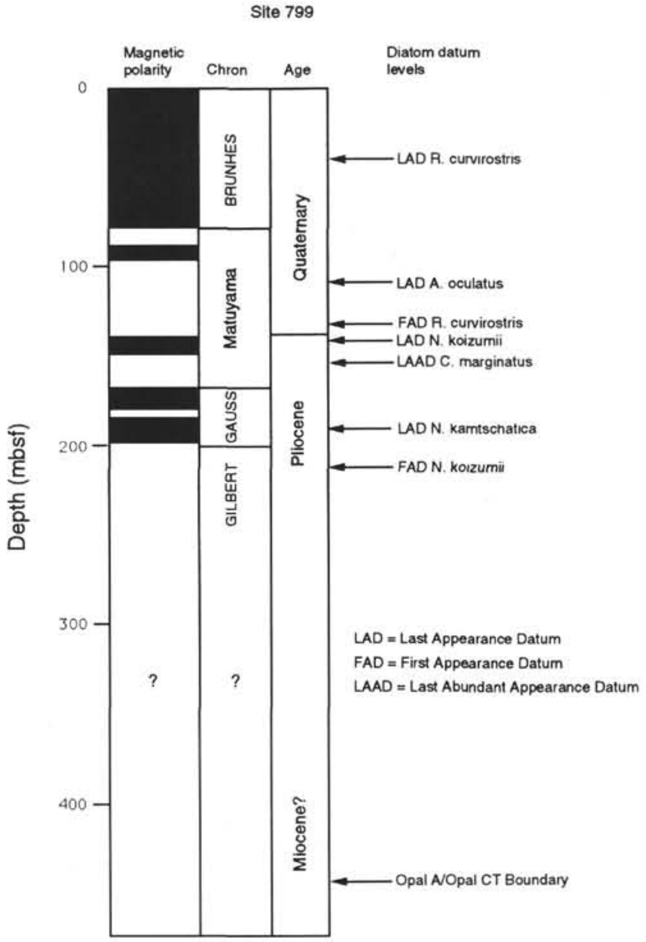

Figure 4. Diatom datum levels plotted against magnetostratigraphy for Site 799. Age of lower part is uncertain because of dissolution.

ceanographic record. This part of the record, however, promises to be superb. Some diatom datum levels which have been tied to the oxygen isotope record in northwest Pacific sediments are apparently correlative in time with the same diatom datums in the Sea of Japan. Further, changes in abundance of some diatom species (e.g., *Pseudoeunotia doliolus*) appear to be correlative between the Sea of Japan and the northwest Pacific.

The interest in using changes in abundance of individual species of diatoms (and, indeed, the value of using diatom abundance) is illustrated in Figure 5. Here, I have plotted the sea-level curve of Fairbanks (1989) against the distribution of three microfossil groups from core RC12-379 (coiling direction change of *N. pachyderma,* Maiya et al., 1976; absolute abundance of radiolarians, Morley, pers. comm., and diatoms). I have also plotted the level of first appearance of the diatom *P. doliolus*. The age model is taken from Fairbanks (1989) and the age model of Maiya et al. (1976) is modified slightly to conform to it. If one assumes that the Tsushima Strait is the major source of warm water into the Sea of Japan then *N. pachyderma* is the first to respond to deglacial warming. The mid-point in the switch from left to right coiling occurs at ~13 ka when sea level had risen to about –70 m (i.e., sea level was some 70 m below present sea level). Next to respond are the radiolarians. The midpoint in the transition from low glacial abundances occurs at ~9.5 ka when sea level had risen to about –25 m. Finally, the diatom response (from low glacial to high interglacial abundances) occurs at ~7 ka when sea level has almost risen to modern levels (–15 m).

It seems apparent that, during much of the late Pliocene and Pleistocene, stratigraphic markers will enter the Sea of Japan from the south and/or southeast (i.e., the Tsushima and Tsugaru Straits). Therefore, many of the useful stratigraphic markers should have a low or middle latitude source. Being much deeper, the more southerly gateways to the Sea of Japan should also have a marked influence on diatom abundance in sediments and on the floral composition of diatom assemblages. In Figure 6, I have plotted the maximum depths of each of the four major gateways into the Sea of Japan. The northern gateways, the Mamiya Strait and the Soya Strait, are the shallowest and are between Sakhalin and the Asian mainland and Sakhalin and Hokkaido, respectively. It's apparent from this plot that the more northerly gateways had very little influence on the physical oceanography of the Sea of Japan during much of the Quaternary. Using rough approximations drawn from $\delta^{18}O$ records I estimate that during ~85% of late Quaternary time the Mamiya and Soya Straits did not serve as gateways to the Sea of Japan. In contrast, it appears that there was some interchange between the Sea of Japan and the northwest Pacific via the Tsushima and Tsugaru Straits during most, if not all, of the late Quaternary.

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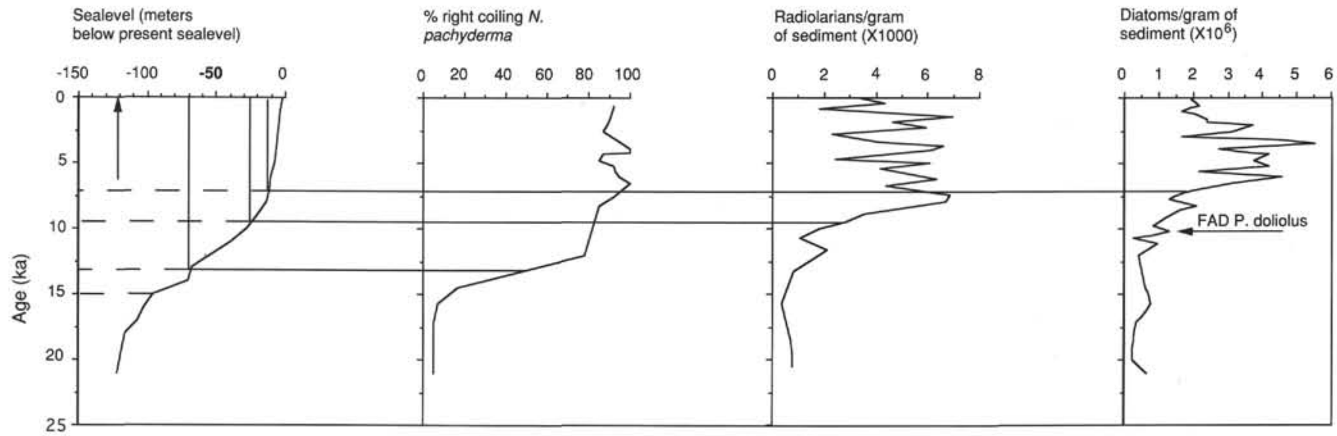

Figure 5. Sea-level curve and age model of Fairbanks (1989) covering the last 18 ka plotted against the distribution of *N. pachyderma*, radiolarians, and diatoms in piston core RC12-379 from the southeastern part of the Sea of Japan. Arrow refers to proposed maximum lowering during the Last Glacial Maximum.

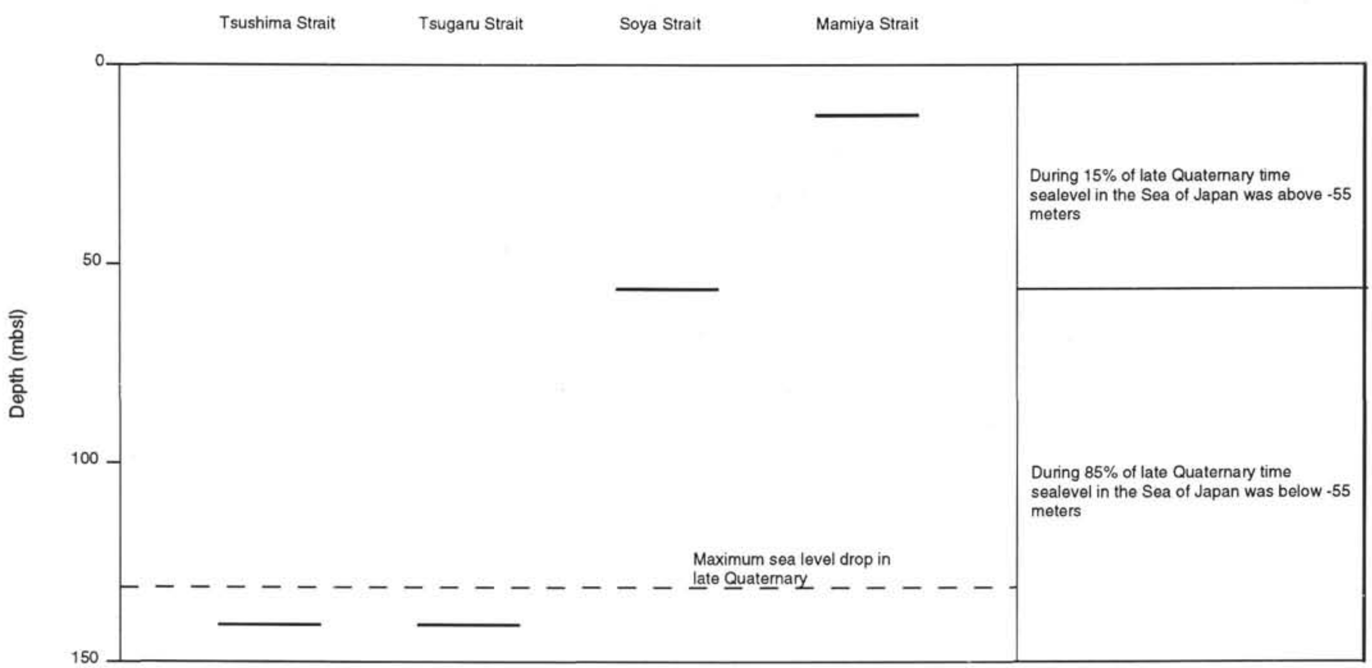

Figure 6. Maximum depths of the four major straits leading into the Sea of Japan. The Tsushima Strait is the most southern and the Mamiya Strait the most northern.