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Late Quaternary stratigraphy for the equatorial Pacific based upon the diatom *Coscinodiscus nodulifer*

ABSTRACT

Stratigraphy based upon size change in the diatom *Coscinodiscus nodulifer* A. Schmidt is presented for Late Quaternary sediments of the equatorial Pacific. The size difference is expressed as a simple ratio of $<60/>60\ \mu\text{m}$. Correlation with oxygen isotope curves in the same sediment cores demonstrates that highest ratio values (maximum small forms) occur in Oxygen Isotope Stage 2 (18,000 yr B.P.), while the lowest ratio values (maximum large forms) occur in Oxygen Isotope Sub-stage 5e (125,000 yr B.P.). The use of this stratigraphy will permit us to greatly extend our data base for 18K and 125K age sediments.

INTRODUCTION

In previous studies it was shown that Late Quaternary size fluctuations of the marine diatom, *Coscinodiscus nodulifer* Schmidt, are isochronous in the equatorial Pacific, and may be used as a stratigraphic tool (Arrhenius, 1952; Burckle and McLaughlin, 1977; Maloney and Burckle, 1979). We have prepared a stratigraphy based upon size change in this species which is tied to the oxygen isotope record and calcium carbonate fluctuations and which may be useful in the Late Quaternary of this region. This stratigraphy will be of value in identifying the 18,000 yr B.P. level (Oxygen Isotope Stage 2) and in enlarging the data base for this time slice in the eastern equatorial Pacific. Further, we can demonstrate that this method can be used to identify Oxygen Isotope Sub-stage 5e.

Three cores were selected for this study (table 1) and oxygen isotope and *C. nodulifer* size change stratigraphies were determined for each core. Standard methods were used for the isotopic analyses (Shackleton and Opdyke, 1973). Sample preparation follows the method of Burckle et al. (1978), while the size change curve is based upon Burckle and McLaughlin (1977). These authors suggested that a curve could be constructed from a simple ratio of 2 separate size categories of *C. nodulifer* and that it might yield significant stratigraphic information. An eyepiece micrometer containing a circle calibrated to $60\ \mu\text{m}$ was used to separate *C. nodulifer* into 2 size categories: $<60\ \mu\text{m}$ and $>60\ \mu\text{m}$ diameter. A curve based upon the ratio $<60\ \mu\text{m}/>60\ \mu\text{m}$ from a count of 300 specimens at each sample level was then made (figs. 1, 2).

NOMENCLATURE

In this paper each significant size change interval is identified by a number (with 1 being the youngest) followed by the letters Cn (= *Coscinodiscus nodulifer*).

THE DATA

Figure 1 shows the results of this study. In each of the cores, oxygen isotope values were determined at least through the upper part of Stage 3. For Core RC10-65 the oxygen isotope curve for *Neoglobobulimina dutertrei* (d'Orbigny) was determined back through Sub-stage 5e (fig. 2). Analyses of benthic species (not shown here) confirm the presence of 5e. The maximum isotopic value of Stage 2 represents the glacial maximum at approximately 18,000 yr B.P. (CLIMAP, 1976). The Isotopic Stage 2 peak is well defined as sample spacing is on the order of 3–4 cm in cores RC11-210 and RC10-65 (10 cm in core V19-29). *Coscinodiscus nodulifer* ratio curves were drawn from data col-

TABLE 1
Core numbers, locations, and depths used in present report.

Core #	Latitude	Longitude	Water Depth (in m)
V19-29	03°35.0'S	83°56.0'W	3157
RC10-65	00°41.4'N	108°37.2'W	3588
RC11-210	01°49.0'N	140°03.0'W	4420

lected every 10 centimeters. Despite this difference in sampling interval, the *C. nodulifer* ratio curves closely approximate the isotopic curves. Lower ratios (that is, greater abundance of large forms relative to small ones) characterize the Holocene, while the Pleistocene/Holocene boundary is generally characterized by a sharp increase in ratio values (an increase in

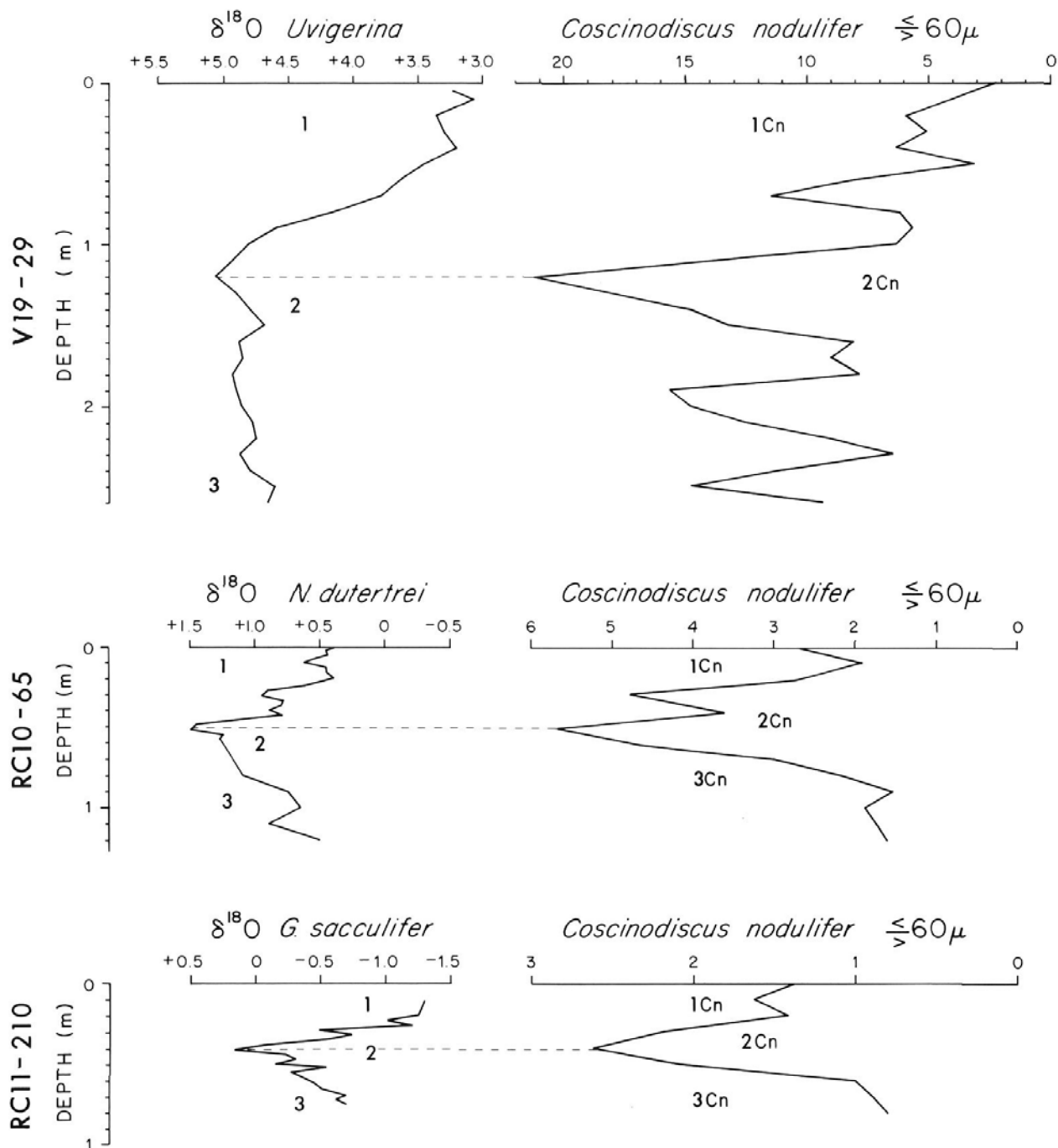


FIGURE 1
 $\delta^{18}\text{O}$ record and *Coscinodiscus nodulifer* Schmidt size change stratigraphy for 3 cores in equatorial Pacific.

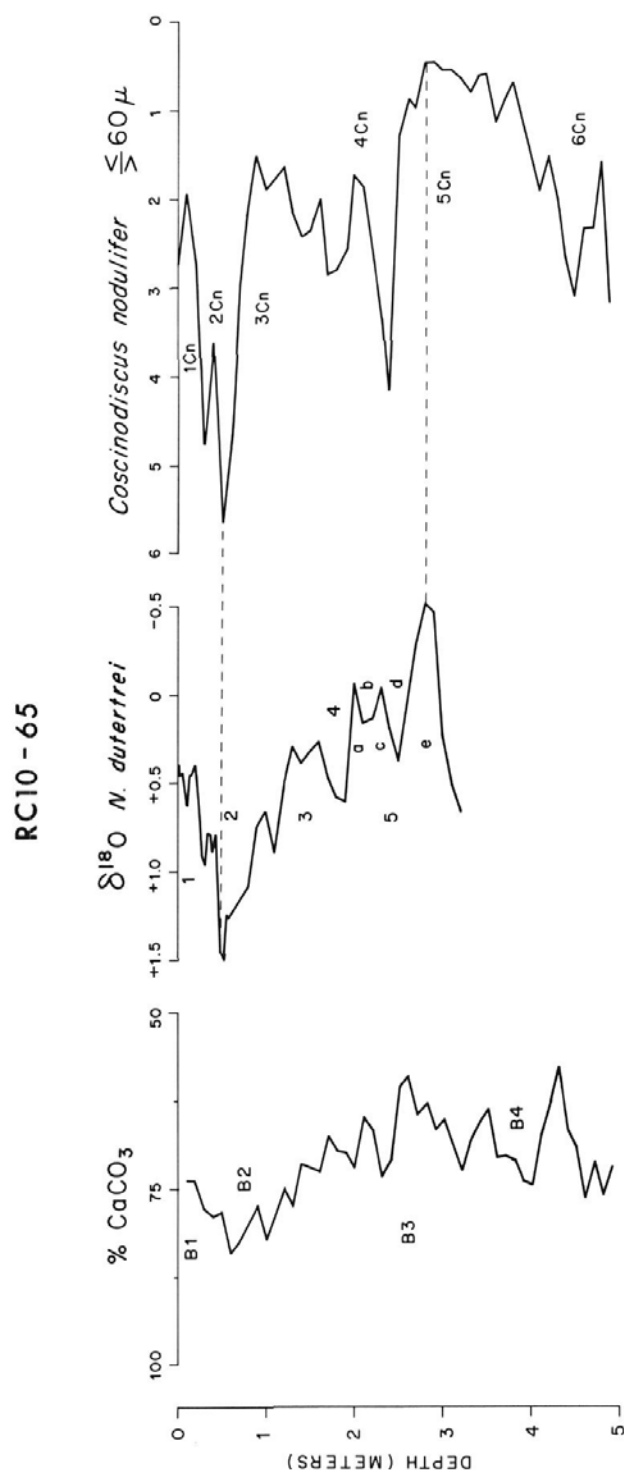


FIGURE 2
Late Quaternary record for RC10-65 of CaCO_3 percent, δO^{18} and *Coscinodiscus nodulifer* Schmidt size change.

smaller forms). Maximum isotopic values in Stage 2 (18,000 yr B.P.) are strongly correlated with maximum *C. nodulifer* ratios. In V19-29, where δO^{18} and *C. nodulifer* sample intervals are identical (10 cm), the 2

peaks occur at the same depth. In RC10-65 and RC11-210, the oxygen isotope peak occurs 1 cm below the *C. nodulifer* peak, obviously an artifact of different sample spacing.

Figure 2 shows percent CaCO_3 , size change ratio of *C. nodulifer* and δO^{18} down to Isotopic Stage 5 for RC10-65. The upper part of the curve (Isotopic Stages 1 and 2) is shown in figure 1. Figure 2, however, permits us to document our size change stratigraphy in the eastern equatorial Pacific for the entire Late Quaternary. We should also point out that the geometry of this size change stratigraphy appears to be unique, since we have duplicated it in several other cores from this region for which no oxygen isotope data are available.

Several points can be made in comparing the *C. nodulifer* and δO^{18} stratigraphy in this core. The 2Cn/3Cn boundary closely approximates the Isotopic Stages 2/3 boundary. This is also evident from figure 1. Similarly, Isotopic Stage 3 is closely correlated with lower *C. nodulifer* values in 3Cn, while Stage 4 closely parallels higher values in 4Cn at 165- to 185-cm depths. The Isotopic Stages 4/5 boundary coincides with an abrupt change in ratio at about 195-cm depth. Isotopic Sub-stages 5b, c, and d are characterized by rising or high ratio values of *C. nodulifer*.

The ratio values that we obtained in 5Cn are unique. We have identified this level in several other cores and typically these values fall below 1. In 2 long cores that we have studied, which cover most of the Quaternary, it is only in this interval that we obtain such values. Figure 2 shows that the lowest *C. nodulifer* values closely parallel the minimum isotopic values of Sub-stage 5e and that the minimum ratio values in 5Cn occur in the lower part of B3 on the calcium carbonate stratigraphy (Hays et al., 1969). This correlation was previously suggested by Burckle (1977). Similarly, Nin-kovich and Shackleton (1975) noted that Oxygen Isotope Sub-stage 5e is correlative with the lower part of B3. In other cores that we have studied from this region, the minimum *C. nodulifer* ratio values (that is, interval 5Cn) consistently occur in the lower part of the CaCO_3 stratigraphic interval B3 suggesting that interval 5Cn is correlative across the eastern equatorial Pacific (see also Arrhenius, 1952).

DISCUSSION

We have presented a stratigraphy for Late Quaternary sediments of the eastern equatorial Pacific based upon size change in the marine diatom *C. nodulifer*. The nature of the data (i.e. the abundance and size frequency distribution of *C. nodulifer*) insure that this stratigraphy can be obtained relatively rapidly. Ties to the oxygen isotope stratigraphy make it possible for

us to identify specific target dates and intervals (e.g. 18,000 yr B.P., Isotopic Stages 5/4 boundary, Isotopic Sub-stage 5e) of interest to paleo-oceanographers and to extend the data base for such dates and intervals into the carbonate-free areas of the eastern equatorial Pacific. Using this method, a more accurate comparison of the Recent and last glacial maximum (18,000 yr B.P.) can be obtained for the eastern equatorial Pacific.

In a previous paper (Burckle and McLaughlin, 1977) we speculated on the probable causes of changes in *C. nodulifer* size. At present, we are continuing a study of size change ratios in surface sediments of the eastern equatorial Pacific as well as during specific target dates (18,000 yr B.P. and 125,000 yr B.P.). These data, although incomplete, show that higher ratio values (smaller *C. nodulifer*) predominate in the easternmost equatorial Pacific in Recent sediments. At 18,000 yr B.P., high ratio values are common throughout most of the eastern equatorial Pacific. At 125,000 yr B.P. (Oxygen Isotope Sub-stage 5e), however, extremely low ratio values (large diameter *C. nodulifer*) occur across this region. The use of this unique property of *C. nodulifer* will allow for a much expanded data base of 18,000 yr B.P. and 125,000 yr B.P. sediments from this region. We have begun similar studies in the equatorial Atlantic and Indian Oceans.

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REFERENCES

- ARRHENIUS, G., 1952. Sediment cores from the east Pacific. Swedish Deep-Sea Exped. 1947-1948, Repts., 5(1):1-91.
- BURCKLE, L. H., 1977. Pliocene and Pleistocene diatom datum levels from the equatorial Pacific. *Quat. Res.*, 7:330-340.
- BURCKLE, L. H., CLARKE, D. B., and SHACKLETON, N. J., 1978. Isochronous last-abundant-appearance datum (LAAD) of the diatom *Hemidiscus karstenii* in the sub-Antarctic. *Geology*, 6:243-246.
- BURCKLE, L. H., and MCLAUGHLIN, R. B., 1977. Size changes in the marine diatom *Coscinodiscus nodulifer* A. Schmidt in the equatorial Pacific. *Micropaleontology*, 23(2):216-222.
- CLIMAP PROJECT MEMBERS, 1976. The surface of the ice-age earth. *Science*, 191:1131-1137.
- HAYS, J. D., SAITO, T., OPDYKE, N. D., and BURCKLE, L. H., 1969. Pliocene-Pleistocene sediments of the equatorial Pacific: their paleomagnetic, biostratigraphic, and climatic record. *Geol. Soc. Amer., Bull.*, 80:1481-1514.
- MALONEY, J., and BURCKLE, L. H., 1979. Size change in *C. nodulifer* in Pleistocene sediments of the equatorial Pacific—stratigraphic and paleo-oceanographic implications (Abstract). *Transactions, Amer. Geophysical Union*, 60(18):273.
- NINKOVICH, D., and SHACKLETON, N. J., 1975. Distribution, stratigraphic position and age of ash layers "L" in the Panama Basin region. *Earth Planet. Sci. Lett.*, 27:20-34.
- SHACKLETON, N. J., and OPDYKE, N. D., 1973. Oxygen isotope and paleomagnetic stratigraphy of equatorial Pacific core V28-238: oxygen isotope temperatures and ice volumes on a 10⁵ year and 10⁶ year scale. *Quat. Res.*, 3:39-55.

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