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SHORT NOTES

23. A NEW METHOD TO EVALUATE DISSOLUTION OF $CaCO_3$ IN THE DEEP-SEA SEDIMENTS*

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Introduction

The most part of $CaCO_3$ stored in deep-sea sediments is produced in the sea-surface by planktonic foraminifers and calcareous nannoplanktons. The $CaCO_3$ sinks down to the sea floor through water column and is deposited there. Accumulation of $CaCO_3$ is affected by its dissolution in the deep-sea as well as production in the sea-surface. While the $CaCO_3$ production reflects environment of the sea-surface, its dissolution does that of the deep-sea. Evaluation of the degree of dissolution is essentially important to analyze the change in deep-sea paleoenvironment.

Three methods have been generally employed to evaluate degree of $CaCO_3$ dissolution: (1) Solution Index (Berger, 1968); (2) the ratio of planktonic to benthic foraminifers; and (3) the ratio of fragmented to perfect tests of planktonic foraminifers. The Solution Index is based on the difference of dissolution among species of planktonic foraminifers; ratio of species more resistant to dissolution and those less resistant. However, fossil assemblage content of planktonic foraminifers is effected by the initial assemblage as well as dissolution. It is impossible to estimate accurately the degree of dissolution from the Solution Index. The other two methods are also insufficient because the initial ratio of planktonic to benthic foraminifers or the initial composition of planktonic foraminiferal assemblage is not always definite.

Oba (1969) divided a planktonic foraminifer, *Globorotalia menardii,* into three types with respect to preservation of the tests (the perfect, damaged, and fragmented) and evaluated the degree of dissolution from the ratio among the three types. This method using only *G. menardii* is better than the other methods, because it is expected to be affected by dissolution but not environmental changes. In spite of that this method was developed to estimate the amount of $CaCO_3$ dissolution (Oba and Ku, 1977; Ku and Oba, 1978), works employing the method were so far only a few (Oba, 1983).

Several papers have reported on selective dissolution of calcareous nannofossils (McIntyre and McIntyre 1971; Berger, 1973; Roth and Coulbourn, 1982), but, unlike foraminifers, calcareous nannofossils are rarely used to evaluate $CaCO_3$ dissolution in the deep-sea sediments. It was difficult to not only observe them in detail under a light microscope for their small size but also to express their degree of dissolution objectively.

The purpose of this paper is to propose a new method to evaluate the degree of $CaCO_3$ dissolution in deep-sea sediments by calcareous nannofossils and then to substantiate its usefulness by comparing with the other method by a planktonic foraminifer (*G. menardii*).

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Method and samples

A calcareous nannofossil, *Calcidiscus leptoporus* has two shields (distal and proximal) which are connected with a central column. Schneidermann (1977) investigated selective dissolution of nannoflora in core-top sediments and showed a distinctive pattern of dissolution in *C. leptoporus*. The two shields of well-preserved *C. leptoporus* are connected each other. When dissolution proceeds, however, either the proximal shield tends to dissolve along the suture line or the central column is dissolved to separate two shields. Only distal shields tend to occur in intensively dissolved samples.

In this work the manner of preservation in *C. leptoporus* dissolution is adopted to evaluate $CaCO_3$ dissolution. Fossil coccoliths of *C. leptoporus* is divided into two types, the perfect one with two shields and the broken one with only distal shield (Figure 1); a coccolith with distal shield and a part of proximal shield is included in perfect coccolith. The ratio of the two types is employed as a criterion to evaluate degree of $CaCO_3$ dissolution.

The piston core "KH84-1, St. 21" was recovered from the deep-sea floor at west-flank of the West Mariana Ridge (19°55.8′N, 142°22.3′E; water depth of 3512 m) during KH84-1 cruise of R/V Hakuho-Maru of Ocean Research Institute, University of Tokyo (Figure 2). The core is 916 cm long, essentially composed of olive calcareous ooze and intercalates thin layers of tephra and sandy silt (Kobayashi, 1985). The base of Brunhes Epoch is located at 498 cm (subbottom depth) and the top and base of the Jaramillo event at 620 cm and 670 cm, respectively from paleomagnetic measurement (Kobayashi *et al.*, personal comm.). The sedimentation rate of the core is to be about 0.7 cm/Ky. Two major biostratigraphic

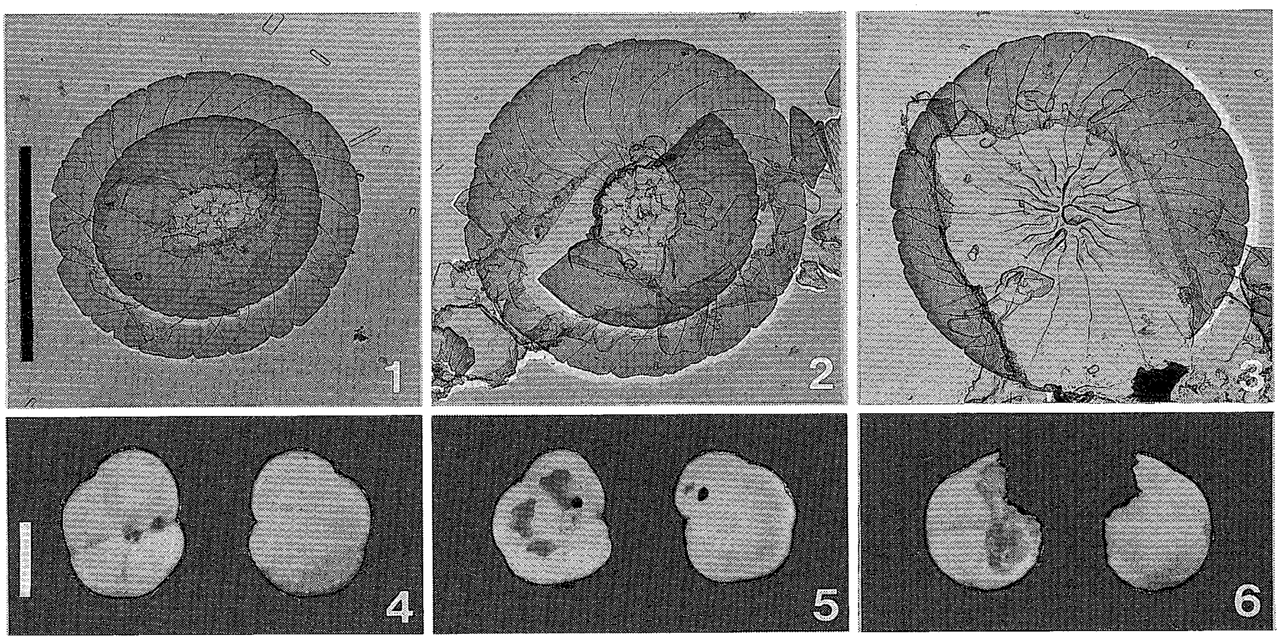

Figure 1. Photographs **1, 2** and **3** are electron micrographs and the scale bar in photograph **1** represents 5 μm. Photographs **4, 5** and **6** are optical micrographs and the scale bar in photograph **4** represents 500 μm. **1–3,** *Calcidiscus leptoporus* (Murray and Blackman), Sample at 90 cm (subbottom depth): **1**, proximal view of perfect coccolith (distal and proximal shield); **2**, proximal view of perfect coccolith (distal shield and a part of proximal shield); **3**, proximal view of broken coccolith (distal shield). **4–6,** *Globorotalia menardii* (Parker, Jones and Brady), Sample at 1 cm (subbottom depth): **4**, perfect test; **5**, damaged test; **6**, fragmented test.

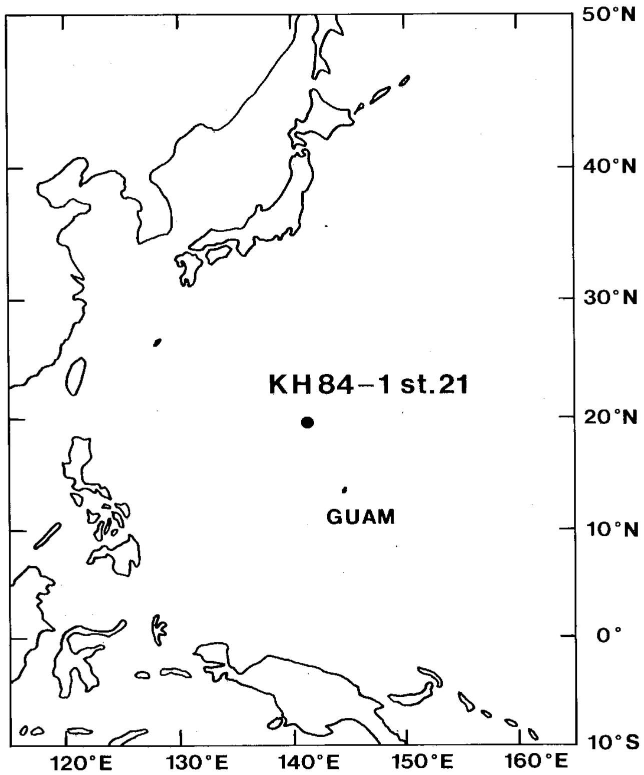

Figure 2. Locality of Core KH84-1 St. 21.

events of nannofossils are founded: the first occurrence of *Emiliania huxleyi* at 180 cm: and the last occurrence of *Pseudoemiliania lacunosa* at 310 cm in subbottom depth (Matsuoka and Okada, 1989). The proposed age of these events is 0.27 Ma and 0.46 Ma respectively (Thierstein *et al*., 1977) and is in good agreement with that determined magnetostratigraphically. Only the upper 600 cm of the core was studied in this work.

Small pieces of core samples were taken with 10 cm-interval for the *C. leptoporus* analysis. These samples were prepared to make carbon replicas to observe under a transmission electron microscope. *C. leptoporus* more than 5 μm in diameter was counted to 50 specimens to determine the ratio of the perfect to the broken coccoliths. Between 210 cm and 320 cm in the subbottom depth, however, the samples of *C. leptoporus* were counted to 100 specimens with smear slide under a light microscope because of its scarcity.

About 3 g core samples were taken with 5 cm-interval for *G. menardii* analysis. The samples were disaggregated in water and wet-sieved at 63 μm in diameter. Tests of *G. menardii* larger than 250 μm in diameter were collected to determine the ratio of perfect tests. They are divided into three groups (Figure 1) based on the criteria of Oba (1969). While 50 to 100 tests of *G. menardii* were secured from most of the examined intervals, certain intervals yielded less than 30 tests, so that the latter was excluded from the following discussion.

Result and discussion

Figure 3 shows that the curve of change in $CaCO_3$ dissolution as determined by the method with *C. leptoporus* well correlates with that by *G. menardii*. It might be doubted that destruction of coccoliths and foraminiferal tests is caused from mechanical disintegration during separation procedure but not from chemical dissolution. The specimens of *C. leptoporus* and *G. menardii* treated here are little affected by artificial destruction because experimental results with *C. leptoporus* conform to those with *G. menardii* in spite of the completely different treatments. Mechanical destruction in sedimentation process is another matter of concern. Effects of this destruction seem to be different between *G. menardii* and *C. leptoporus,* because the size of *G. menardii* test is about 100 times larger than that of *C. leptoporus* coccolith. The shape of coccoliths of *C. leptoporus* observed here is similar to the dissolution pattern described by Schneidermann (1977). The shapes of the tests of *G. menardii* treated here resemble the those artificially dissolved by Oba and Ku (1977). These findings imply that the observed destruction of coccoliths and foraminiferal tests is essentially attributable to $CaCO_3$ dissolution.

The dissolution curve of *C. leptoporus* in Figure 3 indicates that the dissolution tends to advance with increase of the subbottom

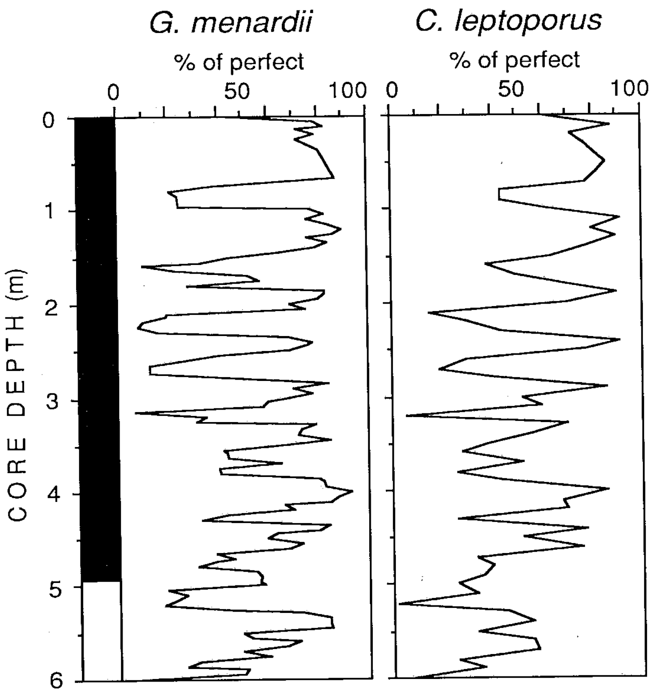

Figure 3. Correlation of percentage of the perfect test of *G. menardii* (left column) with that of *C. leptoporus* (right column).

depth, whereas that of *G. menardii* dose not indicate the same trend. Two causes may be attributed to this tendency: (1) *C. leptoporus* continues to dissolve after deposition; and (2) *C. leptoporus* tends to be damaged with compaction of sediment. Although it can not be determined which cause is responsible to the tendency, at present, it appears to be interesting with respect to diagenesis of calcareous nannofossils.

The 8 cycles are recognized in the $CaCO_3$ dissolution curve between the core top and the Brunhes-Matuyama boundary and they appear to agree chronologically with the cycles of glacial-interglacial stages. This find supports the opinion that dissolutions increased during interglacials but decreased during glacials in the Pacific Ocean. The oxygen isotope ratio of planktonic foraminifers from this core is being determined to discuss the $CaCO_3$ dissolution in more detail.

Even if the dissolution is intense, it is possible to evaluate $CaCO_3$ dissolution by the method with *C. leptoporus,* because it has intensive resistance to dissolution. *C. leptoporus* is widely and abundantly distributed and the perfect coccoliths are easily distinguished from the broken ones under a light microscope. This method with *C. leptoporus* should be convenient and time-saving tool for paleo-oceanographic studies to evaluate the degree of $CaCO_3$ dissolution.

Conclusions

Conclusions are as follow: (1) it is a useful method to measure the ratio of the perfect to the broken coccoliths of *C. leptoporus* in order to evaluate degree of $CaCO_3$ dissolution in deep-sea sediments and (2) the method based on the percentage of perfect tests of *G. menardii* (Oba, 1969) appears to be verified as a valid and reliable tool for evaluating $CaCO_3$ dissolution.

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