Blunt, D. J., D. A. Warnke, and G. E. Pollock. 1977. Trends of amino-acid racemization in a Southern-Ocean core. In *Geological Society of America Abstracts with Programs*, 9(7): 903.

Cassidy, D. S., P. F. Ciesielski, F. A. Kaharoeddin, S. W. Wise, Jr., and I. Zemmels. 1977. ARA *Islas Orcadas* cruise 0775 sediment descriptions. In *Florida State University Sedimentology Research Laboratory. Contribution 45*, p. 76.

Dungworth, G., M. Thijssen, J. Zuurveld, W. Van Der Velder, and A. W. Schwartz. 1977. Distribution of amino acids, amino sugars, purines and pyrimidines in a Lake Ontario sediment core. *Chemical Geology*, 19: 295–308.

Lee, Cindy, and J. L. Bada. 1977. Dissolved amino acids in the equatorial Pacific, the Sargasso Sea, and Biscayne Bay. *Limnology and Oceanography*, 22: 502–10.

Olson, R. J., B. M. Tebo, E. Moussalli, A. F. Carlucci, F. Azam, and O. Holm-Hansen. 1978. Microbial investigations in the Ross Sea. *Antarctic Journal of the United States*, 13(4): 130–31.

Pollock, G. E., C.-N. Cheng, and S. E. Cronin. 1977. Determination of the D and L isomers of some protein amino acids present in soils. *Analytical Chemistry*, 49: 2–7.

Pollock, G. E., and K. A. Kvenvolden. 1978. Stereochemistry of amino acids in surface samples of a marine sediment. *Geochimica et Cosmochimica Acta*, 42: 1903–05.

Schroeder, R. A., and J. L. Bada. 1978. Aspartic acid racemization in Late Wisconsin Lake Ontario sediments. *Quaternary Research*, 9: 193–204.

Warnke, D. A., D. J. Blunt, and G. E. Pollock. In press. Enantiomeric ratios of amino acids in Southern-Ocean siliceous oozes. In *Carnegie Institute Symposium, The Biogeochemistry of Amino Acids*, ed. P. E. Hare et al. New York: John Wiley and Sons.

Warnke, D. A., J. Richter, and C. H. Oppenheimer. 1973. Characteristics of the nearshore environment off the south coast of Anvers Island, Antarctic Peninsula. *Limnology and Oceanography*, 18(1): 131–42.

Carbonate dissolution indices based on foraminifera from southern ocean sediments

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The southern ocean presents special problems in determining the record of Pleistocene dissolution cycles and the relationship of these cycles to climatic change and dissolution cycles in the Atlantic and Pacific oceans. In an attempt to develop a parameter sensitive to dissolution and immune to surface water productivity, we examined over 100 *Eltanin* trigger core-top samples from the southeast Indian Ocean (USNS *Eltanin* cruises 39, 44, 45, 47, 48, 49, 50, and 54).

Considerable effort has already been directed toward understanding the Pleistocene dissolution cycles recorded in Pacific and Atlantic sediments. Intensified carbonate dissolution in Pacific sediments is an interglacial phenomenon (e.g., Arrhenius, 1952; Hays et al., 1969; Berger, 1973). In sediments of the Atlantic Ocean and the Gulf of Mexico, carbonate dissolution is most intense during glacial episodes (Gardner, 1975; Damuth, 1975; Thunell, 1976). However, important questions concerning the relationships between productivity, dissolution, dilution, and climatic cycles remain to be answered (Berger, 1976), and little is yet known about dissolution cycles in the subantarctic and antarctic regions of the Southern Ocean.

In the subantarctic region of the southeast Indian Ocean, Williams and Keany (1977) found at least 10 intense carbonate dissolution periods during the last 1 million years in *Eltanin* core E–45-74 (47°33′S/114°26′E at 3,744 meters). They used seven parameters—foraminiferal test fragmentation; benthic to planktonic ratio; percentage of radiolaria; percentage of carbonate; coarse fraction weight percentage greater than 62 microns; percentage of *Globorotalia inflata*, a dissolution resistant species; and manganese micronodule accumulation. They used these parameters in an attempt to quantify dissolution in E–45-74, which is significantly above the present level of the carbonate compensation depth (CCD) at 4,500 meters.

Although the dissolution periods were associated primarily with glacial episodes, it was extremely difficult to differentiate carbonate changes induced by surface water productivity and by bottom water dissolution (Williams and Keany, 1978). Miyajima (1976) also found that dissolution effects override the productivity considerations in this region of the Subantarctic.

Our samples covered the southern subtropical to northern antarctic water masses and ranged in depth from 800 to 4,800 meters. From this sample set, 75 samples contained sufficient planktonic foraminifera for us to perform a total faunal analysis. A number of other parameters also were determined; namely, foraminiferal fragmentation, coarse fraction weight percentage, benthic and planktonic foraminiferal numbers, and the ratio of foraminifera to radiolaria.

Using Berger's (1968) solution susceptibility ranking, we calculated a solution index from the total faunal counts of the 75 *Eltanin* trigger core tops distributed between latitude 30°S and 54°S. Values of the solution index should increase with increasing dissolution and selective fractionation removal of foraminiferal assemblages. A plot of the solution index (S) versus water depth in figure 1 shows very little systematic increase in S over the depth range of 2,500 to 4,500 meters. Although dissolution selectively removes susceptible species, several species resistant to solution are also indigenous to subantarctic waters. In particular, *N. pachyderma*, which ranks very high in solution resistance, systematically increases in abundance with latitude and thereby overrides any change in S attributable to dissolution.

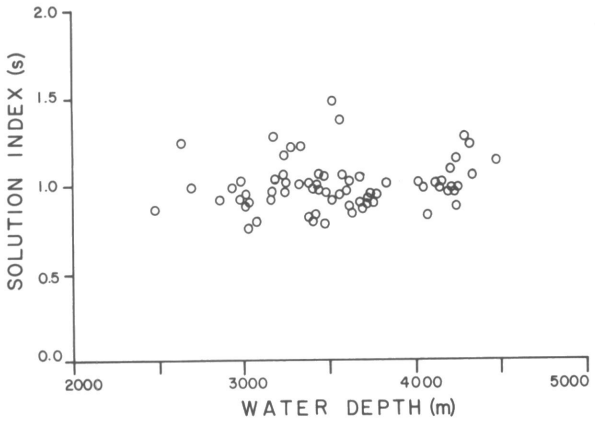

Figure 1. Plot of Berger's solution index (Berger, 1968; 1976) for foraminiferal faunas of the southeast Indian Ocean between latitude 30°S and 54°S. Notice no systematic increase in values of S with increasing water depth in this region.

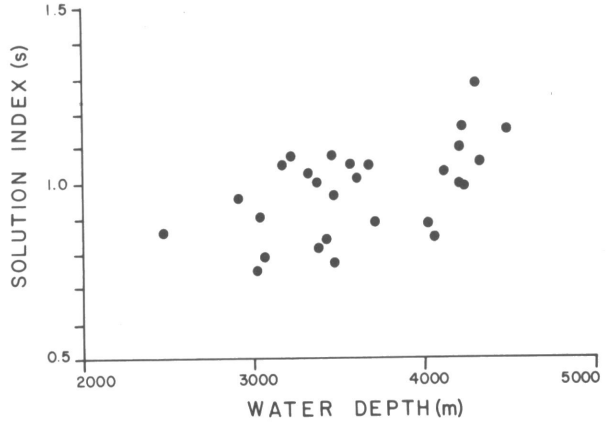

Figure 2. Plot of Berger's solution index for foraminiferal faunas of the southeast Indian Ocean between latitude 30°S and 40°S. Relatively good correlation exists between increasing water depth and increasing values of S in this region (Williams, Corliss, and Healy-Williams, in prep.).

Figure 2 shows that a fairly good correlation exists between S and water depth for samples between latitude 30°S and 40°S, where the foraminiferal fauna are more comparable to the data base of Berger (1968). Natural changes in the subantarctic fauna prevent the straightforward use of the solution index, S, to determine the effects of dissolution intensity.

Regional contour maps of other dissolution parameters reveal a relationship with water depth in the southeast Indian Ridge and South Australian Basin. The highest percentages of foraminiferal test fragmentation are distributed below the 4,000-meter bathymetric contour in a pattern similar to the flow path of antarctic bottom water in this region (Kennett and Watkins, 1976; Corliss, 1979). The same general relationship can be seen in plots of the coarse fraction (weight percentage greater than 62 microns), the log benthic foraminiferal number, and the foraminiferal number. As dissolution increases, the coarse fraction decreases, the number of benthic foraminifera increases, and the number of planktonic foraminifera decreases. Again the 4,000-meter bathymetric contour marks the boundary of significant increase in carbonate dissolution.

From these preliminary data, a multivariate approach appears to offer the best possibility of determining an acceptable dissolution index for subantarctic sediments. Once a modern index is defined, it may be possible to differentiate between productivity-induced carbonate changes and the carbonate dissolution cycles in high-latitude southern ocean sediments.

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References

Arrhenius, G. 1952. Sediment cores from the East Pacific. In *Reports of Swedish Deep-Sea Expedition*, 5: 1–227.

Berger, W. 1968. Planktonic foraminifera: selective solution and paleoclimatic interpretation. *Deep-Sea Research*, 15: 31–43.

Berger, W. 1973. Deep-sea carbonates: Pleistocene dissolution cycles. *J. Foram. Res.*, 3: 187–195.

Berger, W. 1976. Biogenous deep-sea sediments: Production, preservation and interpretation. In *Chemical Oceanography*, vol. 5, ed. J. P. Riley and R. Chester, pp. 265–388. London: Academic Press.

Corliss, B. H. In press. Late Quaternary antarctic bottom water history: Deep-sea benthonic foraminiferal evidence from the southeast Indian Ocean. *Quaternary Research*.

Damuth, J. E. 1975. Quaternary climate change as revealed by calcium carbonate fluctuations in western equatorial Atlantic sediments. *Deep-Sea Research*, 22: 725–43.

Gardner, R. V. 1975. Late Pleistocene carbonate dissolution cycles in the eastern equatorial Atlantic. In *Dissolution of Deep-sea Carbonates*, ed. W. V. Sliter, A. W. H. Bé, and W. H. Berger, pp. 129–41. Cushman Foundation of Foram. Res., special publication, no. 13.

Hayes, J. D., T. Saito, N. D. Opdyke, and L. Burckle. 1969. Pliocene-Pleistocene sediments of the equatorial Pacific: Their paleomagnetic, biostratigraphic and climatic record. *Geol. Soc. Am. Bull.*, 80: 1481–1514.

Kennett, J. P., and N. D. Watkins. 1976. Regional deep-sea dynamic processes recorded by late Cenozoic sediments of the southeastern Indian Ocean. *Geol. Soc. Amer. Bull.* 87: 321–39.

Miyajima, M. H. 1976. Subantarctic region, southeast Indian Ocean: Absolute chronology of upper Pleistocene calcareous nannofossil zones and paleoclimatic history determined from silicoflagellate, coccolith and carbonate analyses. In *Florida State University Sedimentology Research Laboratory. Contribution 42.*

Thunell, R. C. 1976. Calcium carbonate dissolution history in late quaternary deep-sea sediments, western Gulf of Mexico. *Quaternary Research*, 6: 281–97.

Williams, D. F., and J. Keany. 1977. Comparison of radiolarian/planktonic foraminiferal paleoceanography of the subantarctic Indian Ocean. *Quaternary Research*, 9: 71–86.