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Post-sampling dissolution and the consistency of nannofossil diversity measures: A case study from freshly cored sediments of coastal Tanzania

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Abstract

This study investigates the potentially deleterious effect of prolonged sample storage on the reliability of calcareous nannofossil species abundance and community diversity measures and their subsequent interpretation as paleoceanographic proxies. Nannofossil assemblages from two freshly cored successions of hemipelagic clay were documented over a one-year period using a series of paired smear-slides, the first made from sediment samples within a day of coring and the second either 6 months or 1 year later. Diversity measured by Shannon's H is consistent between the two sets for the majority of samples, however significant changes, both positive and negative, were recorded in a number of cases and appear to be largely due to variations in smear-slide thickness and not to post-sampling dissolution. There is no significant change in nannofossil fragmentation or abundance over time, although the relative abundances of small, dissolution susceptible placoliths of *Reticulofenestra minuta* do appear to decrease with time in some samples. Counts of mineral grains show that there is a significant loss of fine, 1–2 μm, cubic pyrite within months of drilling, and this, combined with the decline in abundance of *R. minuta,* suggests that limited pyrite oxidation coupled to carbonate dissolution is occurring. Geochemical analyses confirm that these sediments contain significant concentrations of sulphate one year after sample recovery, which may be the result of gypsum formation associated with the oxidation of pyrite. Estimates of pyrite oxidation suggest that up to 3% of the original calcium carbonate has dissolved in the year after coring, which could account for the observed loss of small placoliths. Effects of this kind are almost certainly confined to hemipelagic sequences rich in organic matter and/or reduced iron but are frequently offset by the exceptional preservation of calcareous microfossils that can occur within such sediments.

Keywords: Calcareous nannofossils; Dissolution; Diversity; Tanzania; Pyrite oxidation

1. Introduction

Calcareous nannofossils, which are mostly the remains of haptophyte algae, represent the fossil record of one of the major marine primary producers. The distinctive calcified scales and other structures of a few to tens of microns in size produced by these algae have left a rich fossil record in marine sediments since they first appeared in the Late Triassic (Bown et al., 2004). Their importance in marine ecosystems and widespread occurrence in the fossil record has led to the extensive use of nannofossil species abundance and diversity data as a proxy for paleoenvironmental changes in such parameters as temperature and

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nutrient availability (e.g. Beaufort et al., 1997; Street and Bown, 2000; Herrle et al., 2003).

The use of such proxies assumes that living coccolithophore communities vary in a coherent and systematic way in response to changes in key environmental factors and that these variations are recorded in the fossil assemblages of the sedimentary record. This assumption requires that the taphonomic processes between death, burial and preservation do not attenuate the primary environmental signal to a degree where it becomes unreliable. Due to the extremely small size of calcareous nannoplankton (~1 to 10 μm) and the extent of carbonate undersaturation in the deep oceans, the principle taphonomic process of concern to nannofossil workers is carbonate dissolution within the water column, at the sediment-water interface and within sediment pore waters (Honjo, 1976; Steinmetz, 1994; Andruleit et al., 2004; Gibbs et al., 2004). Many workers have tried to quantify the extent of carbonate dissolution that has affected a given fossil assemblage of calcareous nannoplankton. Perhaps the most widely used method is a visual assessment of the preservation state of the assemblage based on the degree of etching and/or calcite overgrowth observed during light- or electron-microscopy (Roth and Thierstein, 1972; Roth, 1973; Bown and Young, 1998). Other methods include using the relative abundance of robust taxa (Roth and Krumbach, 1986) and the overall species richness and abundance of an assemblage (Williams and Bralower, 1995) to indicate the extent of dissolution.

In addition to the well-known problems of calcareous nannofossil dissolution prior to burial and during diagenesis, a recent study has highlighted a case of extensive nannofossil dissolution during the storage of sediment samples taken from two shallow on-shore boreholes in North Carolina, USA (Self-Trail and Seefelt, 2005). These authors attribute a drastic reduction in the abundance of calcareous nannofossils to acid production from the oxidation of pyrite once sediment samples were exposed to atmospheric conditions — a common phenomenon when marine clays are recovered from depth and exposed to an oxidising environment (Schnitker et al., 1980; Czerewko et al., 2003). The degree of post-sampling dissolution observed, with the complete loss of nannofossil assemblages from some samples, immediately raises concern about the reliability of nannofossil assemblage data collected from pyrite-containing sediments. However, it is our experience, and that of many other nannofossil workers, that sediment samples can still yield diverse, seemingly well-preserved nannofossil assemblages after months or even years of storage. The disparity between the severe to total post-sampling dissolution of some assemblages and the maintenance of good to excellent preservation in others is the motivation for this study, which focuses on the reliability of standard assemblage counts and diversity indices after prolonged sample storage and the role of sediment geochemistry and mineralogy in determining the extent of post-sampling dissolution.

2. Materials and methods

Two cores were examined for this study, TDP12 and TDP13 (TDP — Tanzania Drilling Project), located on the Pande Pennisular between the villages of Pande and Mkazambo, Lindi District, Tanzania (Pearson et al., 2004; Nicholas et al., 2006) (Fig. 1). The cores were recovered using local river water as the drilling fluid, without use of bentonite or other additives. TDP12 spans the Eocene–Oligocene boundary and nannofossil zones NP19–20 and 21; TDP13 is a Middle Eocene succession containing sediments in nannofossil zones NP15 and 16. Sediments from both boreholes contain diverse and abundant nannofossil assemblages, with species richness values for individual samples in the range of 60 to 100, including a range of holococcolith taxa. Sediment samples, approximately 2 cm^3 in volume were extracted from

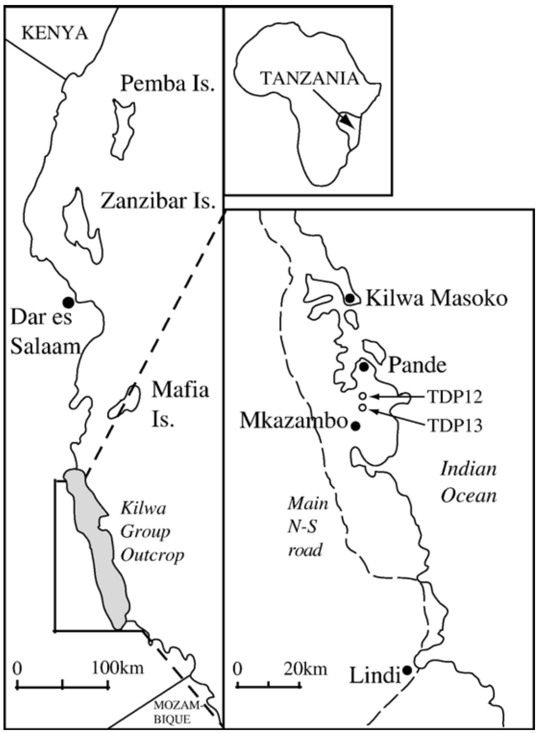

Fig. 1. Location map for TDP12 and TDP13 boreholes.