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# STATISTICAL ANALYSIS OF PLEISTOCENE CALCAREOUS MICROPLANKTONIC ASSEMBLAGES: AN ATTEMPT FOR UNDERSTANDING THE VARIATIONS OF ENVIRONMENTAL PARAMETERS

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ABSTRACT: Lupi C. *et al*., *Statistical analysis of Pleistocene calcareous microplanktonic assemblages: an attempt for understanding the variations of environmental parameters* (IT ISSN 0394-3356, 2011)
The application of a multivariate statistical approach to a database concerning the occurrence of the two major calcareous planktonic groups (calcareous nannofossils and foraminifera) provides a potential additional instrument to identify the variation over time of the sea surface water parameters

*RIASSUNTO:* Lupi C. *et al*., Analisi statistica di associazioni microplanctoniche del Pleistocene: un tentativo per la comprensione delle variazioni dei parametri ambientali (IT ISSN 0394-3356, 2011)
*L'applicazione di metodi statistici quali l'analisi multivariata su di un database concernente la distribuzione dei due principali gruppi di microplancton calcareo (nannofossili calcarei e foraminiferi) fornisce un ulteriore strumento per identificare le variazioni nel tempo dei principali parametri delle acque superficiali.*

Key words: calcareous nannofossils, planktonic foraminifera, Principal Component Analysis

*Parole chiave: nannofossili calcarei, foraminiferi planctonici, Principal Component Analysis*

## 1. INTRODUCTION

In the view of the paleoenvironmental reconstructions based on the ecological meaning of fossil species, statistical methods are here used to investigate the ecological preferences of Pleistocene calcareous micro-planktonic species and assemblages (nannofossils and foraminifera) of the core MD 97-2114 (SW Pacific Ocean) in order to highlight the variability through time of the main sea surface water parameters. Several recent studies, in fact, have demonstrated the effectiveness of multivariate statistical approaches to the Pleistocene fossil record in detecting paleoenvironmental changes or paleoecology preferences of extinct species (e.g., MALMGREN & KENNETT, 1976; BOECKEL & BAUMANN, 2004; MAIORANO *et al.*, 2009). This approach highlights characteristic assemblages in order to determine, from a numerical point of view, the relations among the species involved in the assemblages. However, the knowledge of the ecology for some species presents certain ambiguities, making at times still problematical the interpretation of the past environments.
Starting from our micropaleontological database we provide statistical and graphical treatments from coccolithophorids and planktonic foraminifera firstly processing the data separately secondly making a composite database. We process together the nannofossils and the planktonic foraminifera because these groups characterize the surface water ecosystem. The application of the statistical methods simultaneously to the two major calcareous plankton groups is an innovative step for obtaining combined and crossed information.
This approach may represent a potential additional instrument for identifying the puzzling sea surface water parameters whose variations have, over time, limited the planktonic foraminiferal and coccolithophorid distribution and abundance fluctuations.

## 2. MATERIAL AND METHODS

Our case history is the core MD 97-2114 (42° 22.32'S; 171°20.42'W) which was recovered from an IMAGES cruise (*International Marine Past Global Change Study*) at a water depth of 1,935 m on the north-eastern slope of the Chatham Rise (Southwestern Pacific Ocean). The succession is 28 m thick and exhibits pelagic and hemipelagic sediments. The bio-magnetostratigraphic calibration of the core is accurately constrained (LUPI *et al.*, 2008; VENUTI *et al.,* 2007). A detailed benthic oxygen isotope stratigraphy was recently performed by COBIANCHI *et al.* (in prep.). The age model indicates that the studied succession shows a continuous sedimentary record for the past 1.07 Ma and spans from the Marine Isotope Stage (MIS) 1 to the MIS 29 with an average sediment accumulation rate of ca 2.6 cm/kyr.
The micropaleontological content was analysed in 113 samples and the data have been collected using standard methodologies (LUPI *et al.*, 2008) and then processed utilizing the basic and useful statistical methods of mono and multivariate analysis of the PAST software (PAleontology STatistic, HAMMER *et al.*, 2001) to perform a Principal Com-

ponent Analysis (PCA).
The PCA is a procedure for finding hypothetical components which account for as much of the variance in a multidimensional database (DAVIS, 1986; HARPER, 1999). These new variables are liear combinations of the original variables, in our case the nannofossils and planktonic foraminifera genera and species. The PCA may be used for simple reduction of the data set to only two/three variables (the two/three most important components), that are correlated with some other underlying variables. For ecological data, the components might be physical parameters (for example water temperature or nutrient availability). Moreover, it is possible to verify what degree (loading) the different original variables (in our case, the taxa) enter into the new variable (the components). These loadings are important when we interpret the meaning of the components. In fact, the loading diagrams reveal the affinities of the taxa with respect to the unknown components that influence the planktonic foraminiferal and nannofossil distribution in the core. Potentially, using the taxa with known ecology, we can interpret the components as environmental parameters.

## 3. RESULTS

The good to excellent microfossil preservation throughout the core allowed us to identify 48 species among the nannofossils and 30 species among the planktonic foraminifera. The nannofossil assemblages are dominated by the small *Gephyrocapsa* KAMPTNER, and subordinately by *Calcidiscus leptoporus* (MURRAY & BLACKMAN) (abundance up to 25% of assemblages), *Coccolithus pelagicus* (WALLICH) (up to 40%), *Pseudoemiliania lacunosa* (KAMPTNER), (up to 40%), medium *Gephyrocapsa* KAMPTNER (up to 40%), *Reticulofenestra minuta* ROTH (up to 30%), *Emiliania huxleyi* (LOHMANN) (up to 20%), *Helicosphaera carteri* (WALLICH) (up to 20%). Since small *Gephyrocapsa* represents on average almost the 50% of the nannofossil assemblage, this morphogroup tends to obscure the fluctuations within the less common species. Hence, for ecological interpretation and multivariate analysis, the small *Gephyrocapsa* was removed from the quantitative analysis.
The PCA highlights the two major components driving the composition of assemblages: the first one explains the 51% and the second the 23% of variance. Component 1 is positively loaded by *C. pelagicus* (0.85), and negatively by *P. lacunosa* (-0.44). Component 2 is positively loaded by *P. lacunosa* (0.69), *C. pelagicus* (0.44) and by *R. minuta* (0.45).
The most common planktonic foraminiferal species is *Globoconella inflata* D'ORBIGNY (34%) followed in abundance by *Globigerina bulloides* D'ORBIGNY, (19%), *Neogloboquadrina incompta* (CIFELLI) (11%) and *Neogloboquadrina dutertrei* D'ORBIGNY (8%). The PCA highlights that the two major components explain, respectively, the 32% and the 27% of variance. Component 1 is positively loaded by *G. inflata* (0.45) and negatively loaded by *G. bulloides* (-0.40). Component 2 is positively loaded by *Truncorotalia truncatulinoides* (D'ORBIGNY) (0.50) and *G. inflata* (0.45), and negatively by *Truncorotalia crassaformis* (GALLOWAY & WISSLER) (-0.55)
For the composite database, through the PCA we identify three major components. They account for the 33.5%, 17% and 12% of the variance, respectively. Component 1 is positively loaded by *Pseudoemiliana lacunosa* (0.49) and negatively loaded by *Coccolithus pelagicus* (-0.66). Component 2 is positively loaded by *C. pelagicus* (0.47), and *P. lacunosa* (0.41) and negatively by *Globoconella inflata* (-0.55), Finally, none species loads positively component 3, whereas it is negatively loaded by *C. pelagicus* (-0.46) and *G. inflata* (-0,69).

## 4. DISCUSSION AND CONCLUSIONS

Using the ecological meaning of the taxa, their affinities and relations with the unknown principal components (PCs), we can interpret these latter as environmental parameters. However, the ecological meaning of the some species is still matter of debate (for example *Pseudoemiliania lacunosa*) due to scarce data available or because they are extinct.
Checking the effectiveness of the statistical approach, we observe that the processing of each microfossil group separately reveals two major PCs driving the associations. The PCs found for nannofossils and planktonic foraminifera can be different but they have to be consistent because reflecting the same surface water characters. For each processing we identify a great number of species that makes the discussion very complex and full of ambiguities. Through the use of a composite database we reduce the PCs from four to three and the number of species involved decreases as well. However, these species were already present in the first elaboration confirming that the composite approach could be valid. Among the three parameters, one (PC1) mainly influences only the nannofossils. In the interpretations of the data we have to take in account this constrain searching for a parameter that could influence primarily the nannofossils (phytoplankton) with respect to the foraminifera (zooplankton), as can be for example the light. The final interpretation will be based on the ecological meaning of species with well-known preferences thus helping to clarify the environmental behavior of different

fossil groups.

As an example, in our case history the oligotrophic foraminiferal species *G. inflata,* negatively loaded with respect to PC2, appears to validate the hypothesis about the meaning of a supposed eutrophic nannofossil species (*C. pelagicus*), positively loaded with respect to the same component.

In conclusion, we proposed here, for the first time, the application of statistical methods simultaneously to two microfossil groups. The data have to come from the same samples and to be measured in the same units (percentage). This approach shows apparently some vantages. Since it is just an attempt, the idea will be checked in more case-histories adding at the database (matrix) more independent data from isotopic or sedimentologic analyses to verify and corroborate the final interpretations.

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