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CLIMATIC STAGES CONTROL ON GRAIN-SIZE CLUSTERS IN CORE ANTA91-8 (ROSS SEA)

ABSTRACT: QUAIA T. & BRAMBATI A., *Climatic stages control on grain-size clusters in core ANTA91-8 (Ross Sea).* (IT ISSN 0391-9838, 1997).

Glacial/interglacial climatic cycles, recorded in Late Quaternary glaciomarine sediments from the Western part of the Ross Sea continental slope, are inferred by means of techniques of multivariate statistical analysis, on the basis of the relationship between the vertical variations of grain-size parameters and the Western Antarctic Ice Sheet fluctuations.

KEY WORDS: Climatic cycles, Glacio-marine sediments, Grain-size, Cluster analysis, Ross Sea.

RIASSUNTO: QUAIA T. & BRAMBATI A., *Influenza del fattore climatico sulle fluttuazioni granulometriche nella carota ANTA91-8 (Mare di Ross, Antartide).* (IT ISSN 0391-9838, 1997).

Le modificazioni tessiturali, correlate alle fasi di avanzata e ritiro della calotta antartica occidentale, che intervengono nei record sedimentari glaciomarini tardo-quaternari della scarpata continentale del Mare di Ross occidentale, vengono qui analizzate mediante l'utilizzo di tecniche di analisi statistica multivariata, al fine di consentire, su basi esclusivamente granulometriche, una precisa identificazione dei livelli sedimentari appartenenti ai differenti cicli glaciale/interglaciale.

TERMINI CHIAVE: Cicli climatici, Sedimenti glaciomarini, Granulometria, Analisi dei cluster, Mare di Ross.

INTRODUCTION

Several authors (i.e. Diester-Haass & *alii*, 1993; Pudsey, 1992; Anderson & *alii*, 1984; Ledbetter, 1984, 1979; Singer & Anderson, 1984; Blaeser & Ledbetter, 1982) have pointed out the relationship between the variations in grain-size parameters in the Antarctic sediments and the paleovelocity fluctuations of the bottom currents, which can be related to the ice-sheet progradation and retreat phases, and to the different extensions of ice-shelves on the Antarctic continental shelf.

According to the Late Quaternary glacio-marine sedimentation models recently developed for the Weddell Sea by Grobe and colleagues (Grobe & *alii*, 1993, 1990; Grobe & Mackensen, 1992), and by Pudsey (1992), warmer periods (interglacials) are characterised by high biological productivity and bottom current intensification, due to sea-ice retreat, which lead to an increased transport capacity and a consequent accumulation of better-sorted sediment, with more abundant silt and sand fractions. During glacial periods the ice-sheet expansion markedly reduces the biological productivity and the bottom current strength, giving rise to the accumulation of more clayey and less sorted sediment. Moreover, the abundance of organic matter produced during interglacials causes a strong CO_2 production (Grobe & Mackensen, 1992), which acidifies the descending cold water fluxes along the continental slope, with a consequent rise of the Ccd. Conversely, during glacial phases, Ccd deepens (from 2000 to 4000 m), thus enabling the accumulation of carbonatic fractions in relatively deep environments.

The use of the most common descriptive grain-size parameters such as mean size and skewness, calculated on the only non-carbonatic silt fraction (Pudsey, 1992; Ellwood & *alii*, 1979; Mc Cave & *alii*, 1995), can provide useful indications about the bottom current paleovelocity fluctuations. In a better way, the use of multivariate statistical tools applied to the fine fraction (<50 μm) of the sediment, which is the most representative of bottom current regime, instead of simple descriptive statistical parameters, allows a more precise discrimination of the sediment textural modifications during the climatic fluctuations. This can be obtained with a cluster analysis, by means of the definition of

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the «similarity degree» between the different glacial/interglacials depositional levels.

MATERIAL AND METHODS

This study was carried out on Core Anta91-8, 511 cm-long, collected by gravity corer from the western part of the Ross Sea continental slope, NE of Cape Adare (70°46.99' S, 172° 50.39' E), at a water depth of 2383 m (fig. 1), during the 1990-91 austral summer oceanographic expedition of the R/V Cariboo (Pnra, National Program Research in Antarctica).

The core was X-rayed to allow identification of sedimentary structures, and then subsampled with a mean sampling interval of ~10 cm for $^{230}Th_{ex}$ and geochemical analysis (Ceccaroni & *alii*, 1995) and with a mean sampling interval of ~5 cm for grain-size analysis. A total of 100 bulk samples were treated with 10% H_2O_2 for 48 *h*, disaggregated using an ultrasonic bath, and wet-sieved to separate the gravel (>2 mm), sand (2000-50 μm) and pelite (<50 μm) fractions (Nota, 1959). The composition of the sand fraction was investigated by binocular microscope and the grain-size analysed on a Macrogranometer settling tube. The pelitic fraction was dispersed in a 0.05% Calgon solution and then analysed on a Micromeritics Sedigraph 5000ET particle size analyser. This instrument measures equivalent settling diameter (ϕ unit) and its output is a cumulative frequency curve. Repeat analyses of samples agree to within 3% of the percentage finer than 4 ϕ. Biogenic silica was not removed from the samples, because biogenic particles settling are subject to the same current reworking processes as are terrigenous particles, and grain-size is measured as equivalent settling diameter (Pudsey, 1992).

Grain-size statistical parameters (Folk & Ward, 1958) were calculated on the <50 μm fraction. A cluster analysis was then performed on the frequency percentages ($^1/_2$ ϕ intervals) of the <50 μm fraction (*linkage*: Ward minimum variance; *distance*: 1 – Pearson correlation coefficient).

RESULTS AND DISCUSSION

The textural composition (sand, silt and clay content) of core Anta91-8 is shown in fig. 2, together with the grain-size statistical parameters after Folk & Ward (1957). The core consists of fine-grained muddy sediment, with sand and gravel content lower than 10% on average; silt, which is the most abundant component, forms 28.9% to 71.3% of the <2 mm fraction (average: 51.41 ± 7.11%), whereas clay represents 17.2% to 69.4% (avg.: 40.14 ± 9.85%). The sediment is mainly terrigenous, composed of

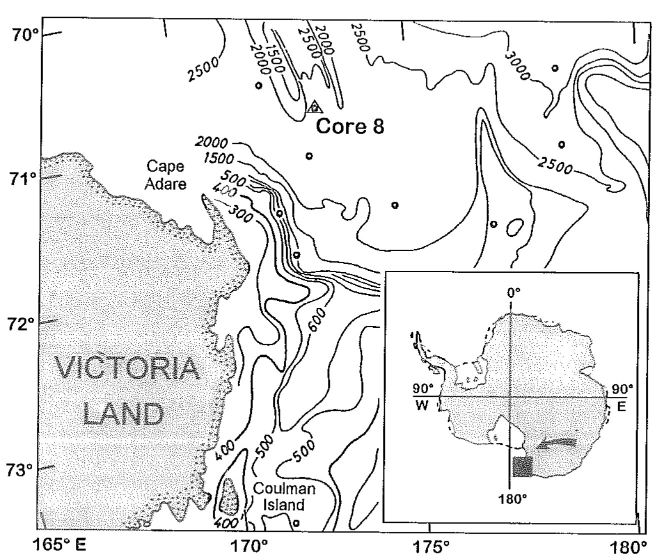

FIG. 1 - Location of core Anta91-8. Open circles indicate other Pnra coring sites.

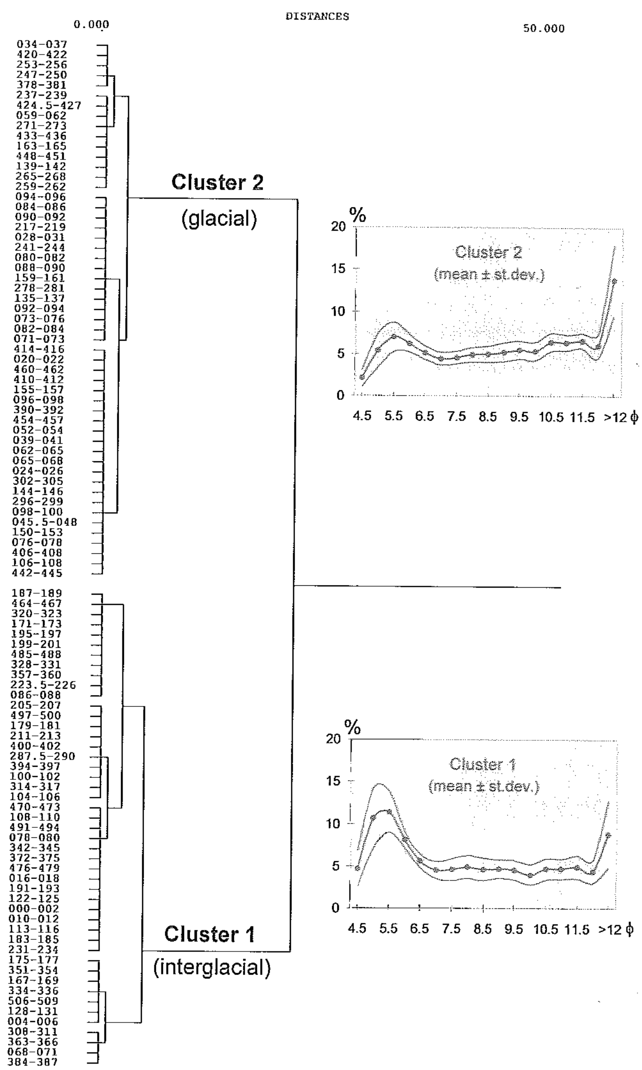

FIG. 2 - Textural composition and grain size parameters (after Folk & Ward, 1957) of Core Anta91-8. Stage boundary have been defined by correlation of grain-size clusters with the compiled chronostratigraphy of Martinson & *alii* (1987).

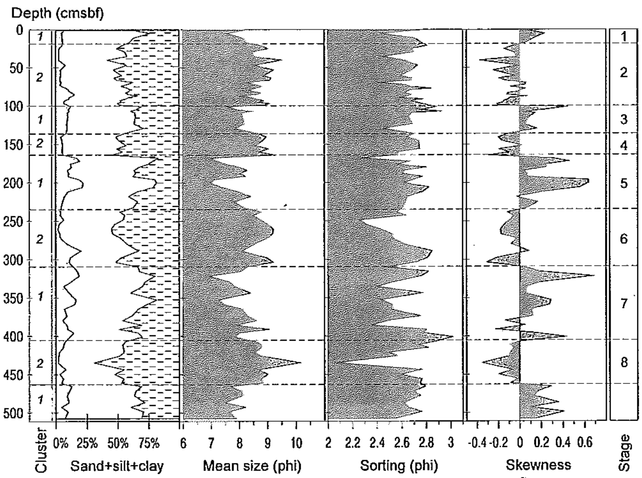

FIG. 3 - Cluster analysis: tree diagram and grain-size mean frequency distributions of the two main clusters.

quartz grains, lithic fragments and volcanic glass, with abundant bioclasts, almost exclusively composed of biogenic silica (diatoms, radiolarians, and sponge spiculae). Only a continuous thick level containing both planktonic and benthic calcareous Foraminifera, with abundant sinistrally-coiled *Neogloboquadrina pachyderma* (Ehrenberg, 1861), is located between 65 and 100 cm from the top of the core.

The cluster analysis (fig. 3) shows a clear subdivision into two main clusters with the following features:

Cluster 1

- *climatic stage*: interglacial;
- *levels* (cm): 0-20, 100-133, 166-235, 313-406, 463-511;
- *textural features*: low clay and high silt contents, better sorting, positive skewness;
- *bottom energetic level*: high.

Cluster 2

- *climatic stage*: glacial;
- *levels* (cm): 20-100, 133-166, 235-313, 406-463;
- *textural features*: high clay and low silt contents, worse sorting, negative skewness;
- *bottom energetic level*: low.

The grain-size parameters (fig. 2) show a cyclic pattern, indicative of glacial/interglacial cycles, which can be correlated with the oxygen isotope record of Martinson & *alii* (1987). Since the sediment accumulation rate for core Anta91-8, which was extrapolated from the ^{230}Th excess normalised profile, is 1.7 ± 0.4 cm /kyr (Ceccaroni & *alii*, 1995), the bottom of the core is supposed to be approximately 300 kyr old, thus comprising the last two main climatic cycles (isotopic stages 1-8).

A scheme of the cooler/warmer period subdivision, determined by means of the grain-size cluster analysis, is also given in fig. 2, together with the glacial/interglacial pattern on the basis of the stacking of the δ^{18}O curve of Martinson & *alii* (1987). The «warm» levels (cluster 1) were hypothesised to correspond to interglacial stages, whereas the «cool» levels (cluster 2) to glacial stages. The «warm» level 463-511 cm could belong to the substage 8*e* (warm event 8.5, 288 kyr), or to the early phase of stage 9 (over 339 kyr), also if in this way the age of the bottom should be shifted in respect to the $^{230}Th_{ex}$ dating (Ceccaroni & *alii*, 1995), which is, however, unreliable over 300 kyr. The glacial/interglacial scheme can then be subdivided as indicated in tab. 1.

TABLE 1 - Glacial/interglacial subdivision of sedimentary levels in core ANTA91-8

Core level (cm)	Grain-size cluster	Age (kyr)	Climatic stage	Sedimentation rate (cm/kyr)
0-20	1	0-12	1	1.7
20-100	2	12-24	2	6.7
100-133	1	24-59	3	0.9
133-166	2	59-74	4	2.2
166-235	1	74-130	5	1.2
235-313	2	130-190	6	1.3
313-406	1	190-245	7	1.7
406-463	2	245-288?	8*a-d*?	1.3
463-511	1	288?-339?	8*e* (or 9)?	—

Mean sedimentation rates (tab. 1), which were calculated assuming a constant rate for every climatic stage, were found to be particularly high during deglacial periods. During glacial stage 2 the sedimentation rate is 6.7 cm/kyr, which is 3-5 times higher than the other glacials. This latter result seems to be in good agreement with the rates found by Grobe & Mackensen (1992) for the Weddell Sea continental slope. Stage 8 shows a mean sedimentation rate of 1.3 cm/kyr if calculated from event 8.5 to glacial termination III, or <0.6 cm/kyr if boundary 9/8 was located at a depth of 463 cm. The very low accumulation rate value obtained in the latter hypothesis, if compared with glacials 2-4 and 6, could support the attribution of the lower part of the core (level 463-511 cm) to substage 8*e*.

Furthermore, the abundance of calcareous fauna in the core section between 65 and 100 cm could be interpreted as a strong deepening of Ccd due to a climatic cooling, and thus support the attribution of that level to the early glacial stage 2.

CONCLUSIONS

The sedimentological study of core Anta91-8, collected from the Western part of the Ross Sea continental slope, indicates that it is possible, on the basis of grain-size statistics, to detect the boundaries of glacial/interglacial climatic stages. However, this new method needs to be adjusted and tested on other cores. Further evidence will be inferred from the final results of ^{230}Th analyses, Ams-^{14}C dating and from the clay mineral analyses, still in progress at the present time.

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