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Paleoambiental reconstruction based on mineralogical data of quaternary littoral deposits occuring at Cortegaça and Maceda beaches (Ovar, Portugal)

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ABSTRACT

Key-words: Paleoambiental reconstruction; mineralogical markers; Quaternary.

The main goal of the present work is the use of mineralogical data corresponding to sediment fine fractions (silt and clay) of Quaternary littoral deposits for the definition of a more detailed vertical zonography and to discriminate the most significant morphoclimatic changes concerned with sediment source areas and sediment deposition areas. The analysis of the available mineralogical data reveals a vertical evolution of the mineral composition. The following aspects deserve particular reference: 1) fine fractions (< 38 μm) are composed of quartz and phyllosilicates associated to feldspars, prevailing over other minerals; however in certain sections iron hydroxides and evaporitic minerals occur in significant amounts; 2) clay fractions (< 2 μm) show a general prevalence of illite associated with kaolinite and oscillations, in relative terms, of kaolinite and illite contents. Qualitative and quantitative lateral and vertical variations of clay and non clay minerals allow the discrimination of sedimentary sequences and the establishment of the ritmicity and periodicity of the morphoclimatic Quaternary episodes that occurred in the Cortegaça and Maceda beaches. To each one of the sedimentary sequences corresponds, in a first stage, a littoral environment that increasingly became more continental. Climate would be mild to cold, sometimes with humidity - aridity oscillations. Warmer and moister episodes alternated with cooler and dryer ones.

RESUMO

Palavras-chave: Reconstituição paleoambiental; marcadores mineralógicos; Quaternário.

O principal objectivo do presente trabalho consiste na utilização de dados mineralógicos correspondentes às fracções siltosas e argilosas de depósitos quaternários portugueses de praia e duna para ensaiar o estabelecimento de uma zonografia vertical detalhada e de uma discriminação das modificações morfoclimáticas mais significativas ocorrentes nas áreas-fonte, e de deposição, dos sedimentos. A análise dos dados mineralógicos obtidos permite estabelecer um modelo de evolução vertical da composição mineral dos sedimentos estudados. Merecem destaque os seguintes aspectos: 1) nas fracções finas (< 38 μm), quartzo e filosilicatos, associados aos feldspatos, prevalecem relativamente aos demais minerais; contudo em algumas secções ocorrem hidróxidos de ferro e minerais evaporíticos, em quantidades significativas; 2) nas fracções argilosas (< 2 μm), regista-se predominância de ilite associada a caulinite, com oscilações, em termos relativos, dos conteúdos de caulinite e de ilite. As variações verticais e laterais qualitativas e quantitativas dos minerais argilosos e não argilosos permitiram a discriminação das sequências sedimentares e o estabelecimento da ritmicidade e periodicidade dos episódios morfoclimáticos que ocorreram durante o Quaternário na região litoral na qual se localizam as praias de Cortegaça e Maceda. A cada uma das sequências sedimentares corresponde, inicialmente, um ambiente litoral que progressivamente se tornou mais continental. As condições climáticas seriam temperadas a frias, com oscilações no que se refere à pluviosidade – aridez. Ensaiou-se a definição de episódios climáticos alternantes, ora mais quentes e pluviosos ora mais frios e secos.

INTRODUCTION

The main goal of the present work is to use mineralogical data corresponding to silt and clay fractions from sediments of Quaternary littoral deposits for the establishment of a more detailed vertical zonography and for the definition of the most significant morphoclimatic changes concerning with sediment source areas and sediment deposition areas.

The sites under study, Cortegaça and Maceda beaches, near Ovar are located in an extensive flat region (Fig. 1).

North of Aveiro, coastal erosion exposed the so-called "Praia de Cortegaça" (Granja & Carvalho, 1991, 1994) and "Praia de Maceda" Formations (Granja *et al.*, 1996) consisting of ancient beach and dune sediments.

Contributions on mineralogical data provided information about the main morphoclimatic events that did take place in the region at the time of the sediments, deposition (Machado *et al.*, 1995; Silva *et al.*,1997) .

GEOLOGICAL SETTING

The "Praia de Cortegaça" Formation (Granja & Carvalho, 1991, 1994) consists, from the base to the top, of (Fig. 2): greenish fine silty-clayey sand overlied by a sandy unit exhibiting cross-bedding. Coal fragments incorporated in the greenish fine silty-clayey sand allowed radiocarbon dates between 6850±60 and 5500±160 years BP. Overlying the sandy unit lies a podzol with bioturbated horizons. Datation on coal fragments in the podzol provided values in the range 3490±60 - 950±80 years BP. At the top of the cross-sections lie bioturbated beach and dune sands. Granja & Carvalho (1991, 1994) did present the geologic setting of the Praia de Cortegaça Formation, and did put forward stratigraphic and environmental analyses. For detailed description of the studied profiles see Machado *et al.* (1995) and Silva *et al.* (1997).

The "Praia de Maceda" Formation (Granja *et al.*, 1996) comprises from the base to the top: bioturbated,

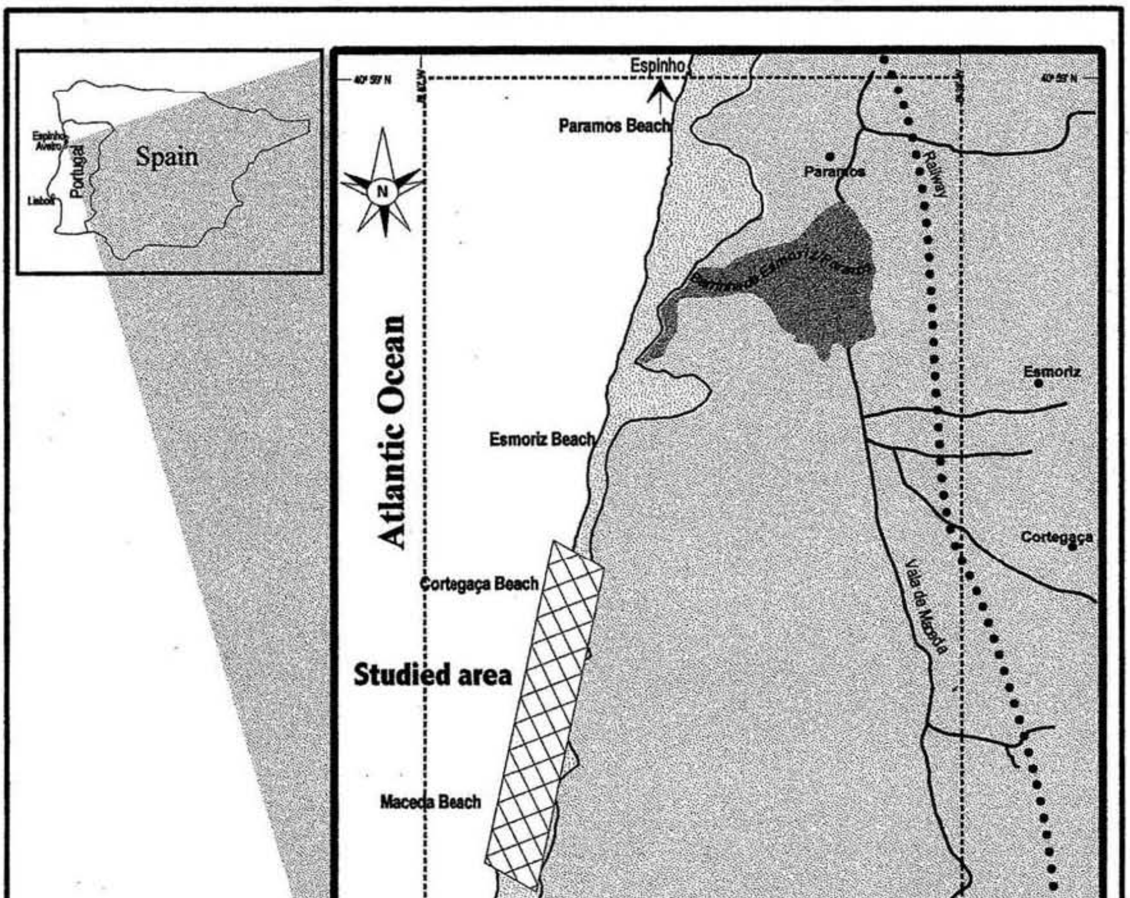

Fig. 1 – Location of the studied sites.

structureless sands; fine silty sands containing *Pinus sylvestris* dated 26700 ± 100 years BP and 27150 ± 2500 years BP; marine sands; silty sands, dated 17100 ± 200 years BP; fine silty sands, dated 13255 ± 685 years BP, as well as aeolian or fluvial sands.

MATERIALS AND METHODS

About 50 sediment samples were collected along four profiles (three at Cortegaça beach and one at Maceda beach) that have been studied afterwards.

Mineralogical composition, particularly that of fine fractions, was determined through X-ray diffraction (XRD) patterns corresponding to less than 38 μm and 2 μm fractions. Qualitative and semi-quantitative determination of clay and non-clay minerals was carried out on both size fractions.

RESULTS AND DISCUSSION

Maceda beach Formation

The first mineralogical results concerning the distinctive units of Maceda Beach Formation are presented. In general terms, the lithological units are characterized by the dominance of Illite, having source most probably on phyllitic rocks, quite widespread throughout the region. Kaolinite is abundant in some units, whereas Chlorite and irregular 10-14 Å Interstratifications are the accessory clay minerals. Iron hydroxides and evaporites are present in some units.

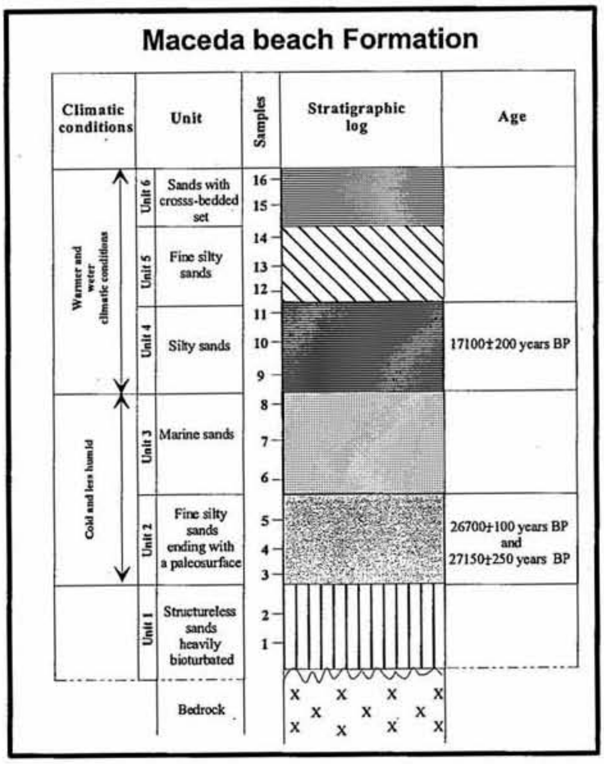

Fig. 2 – Maceda Beach formation.

In the lower part of the section, the sediments of Unit 1 (heavily bioturbated, structureless sands) present a mineralogical association consisting of Quartz, Feldspars and Mica/Illite, with a little Kaolinite and Chlorite. This association, the absence of sedimentary structures, and bioturbations, point out to aquatic littoral environments. The materials of the uppermost part of the Unit are most probably aeolian.

The mineralogical composition of Unit 2 (fine silty sands aged 26700 ± 100 years BP - 27150 ± 2500 years BP) is characterised by a strong increase in Illite contents. Both mineralogical data and textural parameters indicate that sedimentation took place in a restricted, confined, transitional environment (coastal lagoon).

Unit 3 (marine sands) show a mineralogical association quite similar to that of Unit 1, characterized by a sharp increase of coarse detrital minerals (quartz and feldspars), disclosing most probably the effects of a transgression.

The mineralogical composition of the silty sands (aged 17100 ± 200 years BP) of Unit 4 is characterized by a sharp increase of fine detrital minerals (clay minerals, in particular Illite and Kaolinite), indicating an evolution to a lagoonal environment. This evolution, and its mineralogical features, persists along Unit 5 (fine silty sands aged 13255 ± 685 years BP), that ends with a paleosurface.

Sediments of Unit 6, consisting of sands exhibiting a mega cross-bedded set (decimetric scale) at the base that passes to tabular cross-bedding (centimetric scale), present a mineralogical composition typical of aeolian deposits (represented by Quartz and Feldspars with discrete amount of clay in which Kaolinite content increases sharply in regards to the generally predominant clay mineral, Illite).

On the basis of the qualitative and quantitative mineralogy, it is possible to put forward an exercise of reconstruction of the climate conditions prevailing at the time the sedimentary processes responsible for the formation of the distinctive sedimentary units did take place.

In general terms the association of Illite and Kaolinite expresses a mild climate with slight contrasting seasons. During deposition of sediments from Units 2 and 3 the climatic conditions would be different from the general ones. In fact, the sharp increase verified on Illite contents expresses colder and less humid climatic conditions, in particular in Unit 3, whose sediments contain Illite displaying better cristallinity. The vertical evolution of the clay mineral associations point out to a gradual enrichment in Kaolinite and also to a slight degradation of Illite. This evolution allow us to consider that a progressive transition to warmer and moister climatic conditions did take place during the deposition of sediments from Units 4, 5 and 6.

To analyse the virtual climatic oscillations the following parameters: Illite/Kaolinite, Illite + Chlorite/ Kaolinite + Vermiculite and the Kubler crystallinity index for Illite, have been selected. Interpretation of these parameters allowed the discrimination of several climatic alternating episodes, either warmer and moister or cooler and dryer.

Cortegaça beach Formation

A preliminary study of the mineralogical composition, in particular of the clay fraction, from the sediments of Praia de Cortegaça formation was carried out by Machado *et al.* (1995).

Once again, and in general terms, the distinctive lithological units are characterized by the dominance of Illite, having source most probably on phyllitic rocks, which are quite widespread throughout the region. Kaolinite is abundant also in some units, whereas Smectite, Chlorite, Vermiculite and irregular 10-14 Å Interstratifications are the accessory clay minerals. Iron hydroxides and evaporitic minerals are present in some units.

These results point out to the existence of a gradual vertical evolution characterized by the following main features:

- dominance of Quartz and Phyllosilicates in the fine fraction associated to discrete amounts of Feldspar and other accessory minerals;
- occurrence of evaporite minerals and iron hydroxides in thin layers;
- general dominance of Illite over Kaolinite in the clay fraction and oscillations of Illite/Kaolinite contents ratio.

This vertical mineralogical evolution allowed the discrimination of the following three sedimentary sequences, from the basis to the top (Silva *et al.*, 1997):

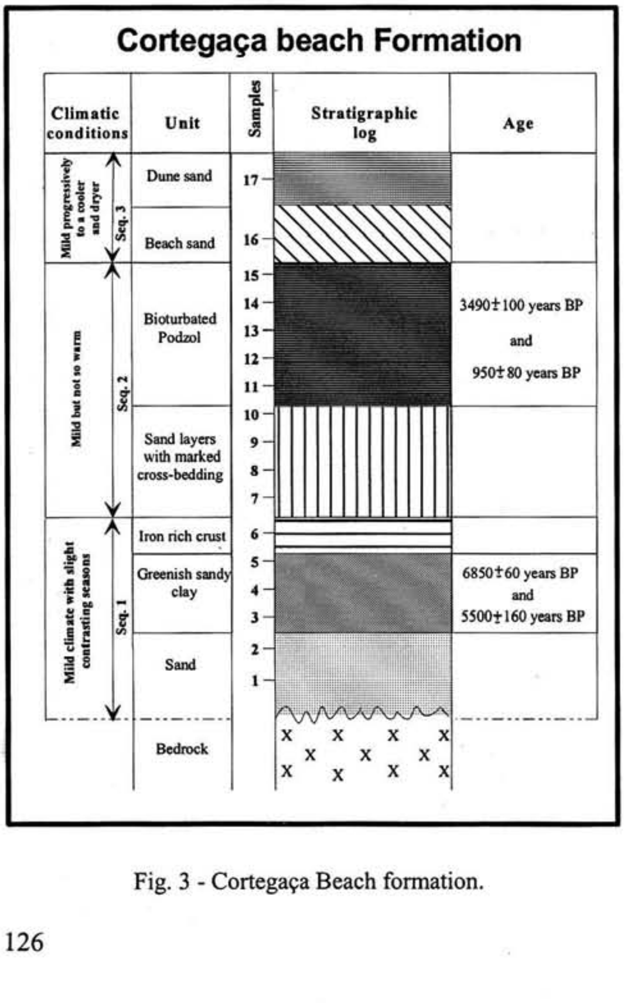

Fig. 3 - Cortegaça Beach formation.

1. greenish sandy clay;
2. sand layers characterized by marked cross-bedding having on top a bioturbated podzol;
3. bioturbated beach sand and dune sand.

Illite dominance in Sequence 1 would represent sedimentation in an environment characterized by low hydrodynamism whereas Illite gradual enrichment towards the top of the sequence would mean that the environment became progressively more confined and lagoonal. The environment changed from a littoral one, supramareal, to a lagoonal one and finally to an evaporitic one. Sequence 2 expresses at its base the effects of a transgression, followed by a new regression, since a littoral or a transition environment changed progressively to a very confined lagoonal one. Later on this type of environment changed to a continental air exposed one where a soil displaying podzol characteristics would be developed. Sequence 3 begins with beach sand and ends up with dune sand.

Based upon qualitative and quantitative mineralogical data, a model expressing the morphoclimatic conditions prevailing at the time the studied sedimentary sequences had been formed could be put forward.

In Sequence 1, the significant amounts, approximately equivalent, of Illite and Kaolinite express a mild climate with slight contrasting seasons. In Sequence 2, climate would persist mild, however not so warm as the one corresponding to Sequence 1. In Sequence 3 the prevailing mild climate changed progressively to a cooler and dryer one.

The analysis of the eventual climatic oscillations was based upon the following parameters: Illite/Kaolinite, Illite + Chlorite/Kaolinite + Vermiculite and the Kubler crystallinity index for Illite.

Interpretation of these parameters allowed us to define ten climatic alternating episodes, either warmer and moister or cooler and dryer.

CONCLUSIONS

Qualitative and quantitative lateral and vertical variations of clay and non clay minerals allowed the discrimination of sedimentary sequences and the establishment of the ritmicity and periodicity of the morphoclimatic episodes considered to have taken place during Quaternary in the littoral region where Cortegaça and Maceda beaches are located.

To each one of the sedimentary sequences corresponds, in a first stage, a littoral environment that became progressively more continental. Climatic conditions would be mild to cold, sometimes with significant oscillations in regards to humidity - aridity seasonal contrast. In fact, alternating climatic episodes could be traced, apparently expressed by warmer and moister episodes alternating with cooler and dryer episodes.

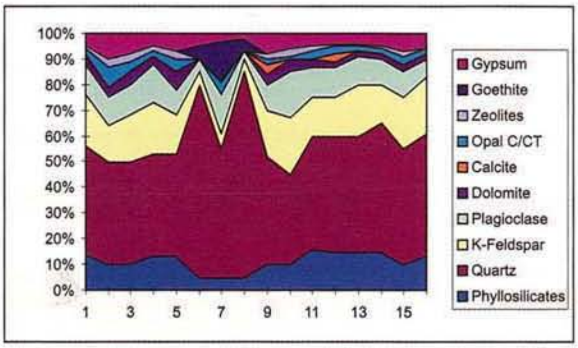

Fig. 4 - Mineralogical composition of the fine fractions (Maceda Beach Formation).

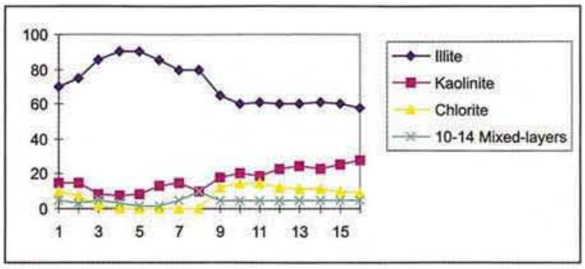

Fig. 5 - Mineralogical composition of the clay fractions (Maceda Beach Formation).

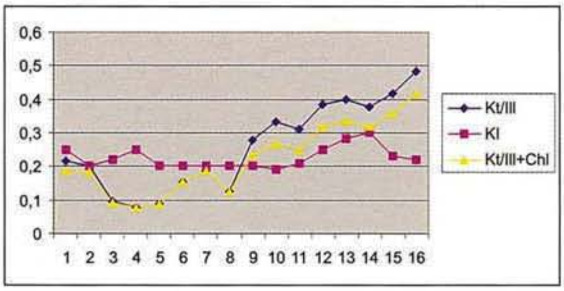

Fig. 6 - Vertical evolution of Kaolinite/Illite and Kaolinite/(Illite + Chlorite) ratios and the Kubler crystallinity index (KI) for Illite (Maceda Beach Formation).

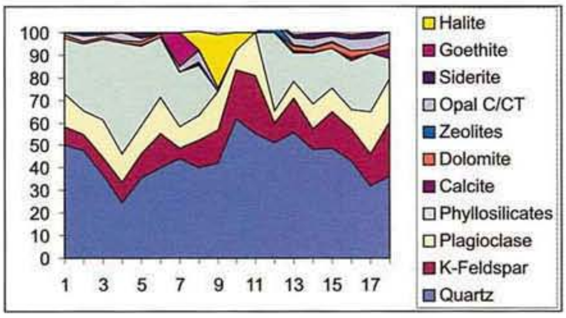

Fig. 7 - Mineralogical composition of the fine fractions (Cortegaça Beach Formation).

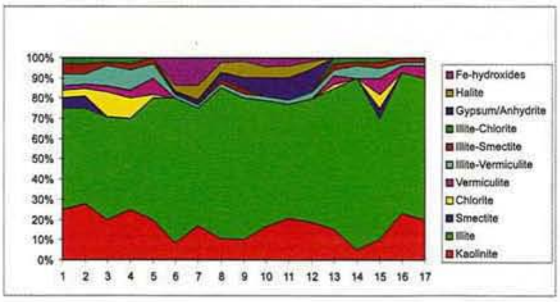

Fig. 8 - Mineralogical composition of the clay fractions (Cortegaça Beach Formation).

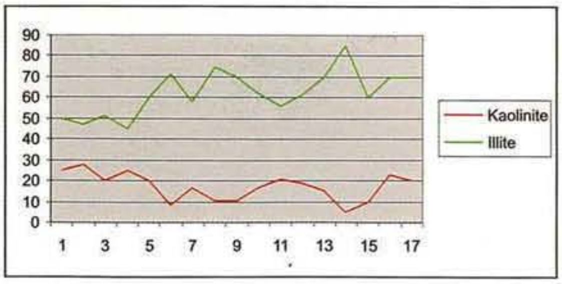

Fig. 9 – Vertical evolution of illite and kaolinite contents (Cortegaça Beach Formation).

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