SEDIMENTOLOGICAL PROVINCES DEFINITION
BASED ON MINERALOGICAL EVIDENCES
ESPINHO TO CAPE MONDEGO (PORTUGAL)

J. VIDINHA(1), F. ROCHA(1), C. ANDRADE(2), C. GOMES(1) & M. C. FREITAS(2)

ABSTRACT

The common sedimentological studies of littoral deposits, namely in the Atlantic coastal sector comprised between Espinho and Mondego Cape (NW Portugal), are focused on the sand fractions, which results from the fact that the main coastal environments are arenaceous, in spite of the occurrence of silt and clay sediments in the solid load. Two continental areas drain to this coastal sector. The Douro and Vouga watersheds drain to the designed as northern sector and southern sector, respectively, with the last one draining to the Atlantic Ocean through Aveiro lagoon, that is connected by an artificial outlet. The fine-grained fraction (lower than 63µm) minerals suites consist mainly in phyllosilicates (F), quartz (Qz), k-feldspars (Fk), plagioclases (P), opal c/ct (Op), zeolites (Z), calcite (C), dolomite (D), anhydrite (An), pyrite (Py) and siderite (Sy). Significant different contents it was found in some minerals between the beach and dune deposits of the coastal sectors considered above. The phyllosilicates and anhydrite show a significant higher content in the beach and dune deposits from the northern sector, while plagioclase, k-feldspar and calcite exhibit significant higher contents in the beach and dune deposits from the southern sector. The observed longshore content evolution, of the most representative minerals identified, make remarkable the nourishment of the Douro and Vouga watersheds and additionally of the coastal sandy formations by erosion. The same content evolution allows concluding that the Douro watershed extends its sedimentological influence until Aveiro lagoon inlet, while Vouga watershed imprints its sedimentary contribution in the coastal deposits away from that morphological accident and to the south direction.

INTRODUCTION

The common sedimentological studies of littoral deposits are focused on the sand fractions, which results from the fact that the main coastal environments are arenaceous. The littoral studies in Portugal don't run out of this way, namely because the largest extension of its coast (the occidental coast) is
submitted to high energy conditions. However, fifteen percent of the solid load drained to the oceans by the rivers consists in silt and clay sediments (Irion & Zöllmer, 1990), the clays representing about half of total marine sediments.

Therefore, it is important to look to the silt and clay minerals in beach and dune littoral deposits, even if they occur just as trace components (lower than 1%) of sandy sediments, such as in the present case, because they can give some information, namely from the clay minerals, about the source area lithology, depositional environments, climate and topography.

The Atlantic coastal sector comprised between Espinho and Mondego Cape (NW Portugal) - Figure 1 - it is located far west of the mesocenozoic sedimentary outcrops (Orla Ocidental Mesocenozoica), over which occur holocene and pleistocene detrital deposits, composed by alluvial, alluvial-marine, beach and dune sediments, with these later ones forming a barrier system that originate the Aveiro lagoon. This coastal sector exhibits sandy beaches and frontal dunes, the latter supplied with aeolian sediments remobilized from neighbouring beach deposits (beach face and berm) - Figure 2.

Two continental areas drain to this coastal sector: the Douro watershed, at the north area (northern sector) and Vouga watershed, which drains to a wide lagoon (Aveiro lagoon) that is connected with the Atlantic Ocean by an artificial outlet and draining to the south area (southern sector).

In the Douro watershed outcrop mainly granites, schists and greywackes, while in the Vouga watershed and in the surrounding region of the Aveiro lagoon outcrop gneisses, migmatites, granitoids, micaschists, schists, sandstones and shales.

Pursuing previous studies concerning the clay fractions (Vidinha et al., 2002), the present paper has as goal to outline sediment dispersion and unravelling the source areas of beach (beach face and berm) and dune sedimentary deposits from the Espinho-Mondego Cape coastal sector, supported on the mineralogy of the sediments lower than 63µm, namely how wide is the sedimentological influence of the Douro and Vouga watershed on this coastal sector.

METHODS AND MATERIALS

A total of 45 cross-shore profiles, spaced 2000 m apart, have been sampled along this coastal section. Three sand samples were collected in each profile, from the beach face (at mid-tide level), from the back-beach (at half width of the higher berm) and from the upwind foredune slope. Each sample was taken from the uppermost sand layer in order to preserve the textural signature of the last depositional event. The fine-grained fraction (< 63 µm) was extracted by wet sieving of the total sediment. The silt mineralogy has been determined by X-ray Diffraction, using one Phillips X’Pert PW3040/60 equipment, and the X’Pert 2.0 software.

The semiquantification of the silt mineral assemblage was undertaken measuring the peak areas and the intensities being corrected using recommended reflection powers recommended by Barahona (1974), Schultz (1964), Thorez (1976), Mellinger (1979) and Pevear and Mumpton (1989).

Two mineralogical indexes were computed (according to Vidinha et al., 1997, 1998, 2000) for each sample: fine/coarser detrital minerals ratio - phyllosilicates/(quartz+feldspars) - and carbonates / detrital minerals ratio.

The descriptive statistics from the results obtained was determined and submitted to non-parametric statistical tests (Kolmorov-Smirnov test) with the aim to evaluate the differences between the samples distribution.
RESULTS

The fine-grained fraction minerals suites consist mainly in: phyllosilicates (F), quartz (Qz), k-feldspars (Fk), plagioclases (P), opal c/ct (Op), calcite (C), dolomite (D), anhydrite (An), pyrite (Py) and siderite (Sy).

The descriptive statistics point to three mineral groups with different representation on the sampled deposits. One formed by the terrigenous minerals (the most abundant), which include phyllosilicates, quartz and feldspars, with contents between ~15% and ~20%. A second group with lower abundance (between 2% and 10%) composed by chemical minerals, i.e., anhydrite, opal, calcite and dolomite, and finally a second chemical minerals group, composed by pyrite, zeolites and siderite showing each one just trace contents (lower than 1%) - Table 1.

The northern and the southern sector show the same minerals suites. However, Kolmorov-Smirnov non-parametric statistical test points to some significant differences in several minerals contents between the beach and dune deposits of the coastal sectors considered above (Table 2). In fact phyllosilicates and anhydrite show a significant higher content in the northern beach and dune deposits, while plagioclase, k-feldspar and calcite exhibit significant higher contents in the beach and dune deposits from the southern deposits (Figure 3).

DISCUSSION

The fine fractions (<63µm) mineralogy from the beach and dune sediments is analogous to the mineralogy identified in the Douro and Vouga watershed soils (Vieira e Silva, 1983; Pereira, 1989) and in samples from Douro estuary (Drago et al., 2002), as well as in the neighbouring platform deposits (Oliveira et al., 1995; Oliveira et al., 2002; Drago, 1995). The same mineralogy was found on the sub-superficial and superficial sediments from Vouga watershed (Rocha, 1993) and Aveiro lagoon (Rocha et al., 2000), respectively, and on Paramos and Maceda sandy outcrops (Rocha et al., 1999; Machado et al., 1995; Silva et al., 1997), located on the northern sector border and presently exposed to a severe coastal erosion.

Table 1.
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<th>Minerals identified in the fine-grained fraction in the northern and southern sectors from beach deposits (left table) and dune deposits (right table) and descriptive statistics (in percentage): mean (M), median (Mdn), standard deviation (Std) and median absolute deviation (Mad).</th>
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<tr>
<td><strong>Beach Deposits</strong></td>
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<td><strong>Northern Sector</strong></td>
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However, as above related, upon comparison, based on central tendency measures (\(M\) and \(Mdn\)), of the minerals contents on beach and dune deposits from the northern sector with those from the southern sector, it was found that they exhibit distinct contents, with the Kolmorov-Smirnov test giving statistical significance to the found content differences. I.e., the content of phyllosilicates and anhydrite is significantly higher in the northern sector comparatively to the beach and dune deposits from the southern sector, while plagioclases, k-feldspars, calcite and dolomite contents show an opposite behaviour, this particular trend being recognized only on the beach deposits. That is, the later minerals have significantly higher contents in the southern sector than in the northern one.

The different contents in the northern and southern sectors can be interpreted as a signal of the lithologic types outcropping in neighbouring continental areas that drained to this coastal sector, Douro watershed (at the north) and Vouga watershed (in the south), to nourish the littoral deposits occurring between Espinho and Mondego Cape. Consequently, the longilitoral contents variation of the minerals identified on the fine fraction allow marking out watershed sedimentological influence that feeds this costal sector, i.e., allow the definition sedimentological provinces.

The higher phyllosilicates content in northern sector suggests a higher sediment input from the Douro hydrographic basin in the north and the sedimentary source proximity. In spite of the tendency of the silt and clay to be deposited on the neighbouring river mouth deep platform (Einsele, 1996), with the coarser sediments (sandy sediments) standing nearby, the relative higher phyllosilicates links the northern littoral deposits to Douro watershed.

The lower content in the southern sector is related with the different geomorphological settings. In spite of the high fine fraction contents, which in bottom samples are among 70% and 61% of illite (Oliveira et al., 2002), the Douro river discharges in an open estuary while the Vouga river mouth opens on a closed lagoon. So, in these transition environments, the selective imprisonment of these platy minerals, related with silt-clay flakes dynamic behaviour (according to Wolanski & Gibbs, 1995), is more effective in the Aveiro lagoon than in the Douro estuary. Therefore,
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the lower phyllosilicates contents in the southern sector is explained by the Aveiro lagoon filtration effectiveness, estimated by Teixeira (1994) in 60%, as it is by the increasing distance from northern source - Douro watershed.

The fine/coarser detrital minerals ratio, either in the beach or dune littoral deposits, puts into evidence the loss of phyllosilicates in the fine fraction from northern to the southern sector, whereas the coarser detrital minerals increase their importance (Figure 4). In fact the feldspars trend suggests higher contents in the southern sector, which lower mineralogical maturity is indicative of source proximity. Therefore, in spite of the low phyllosilicates content, we may conclude that some sedimentary inputs from the Vouga watershed do exist in this coastal sector, with the Aveiro lagoon behaviour as selective trapping environment to the silt and clay sediments.

The higher carbonates content (calcite and dolomite) was higher in the southern sector than in northern, setting out longilitoral enrichment trend to carbonate sediments. The relative carbonates enrichment towards the south sector is clearly displayed by the carbonates / detrital minerals ratio (Figure 4), in both sampled sedimentary environments. Oliveira (2001) identified the same calcite (0-10%) and dolomite (0-6%) in the Douro river particulate suspended matter, as well as in the platform sedimentary cover. But, the higher contents in the southern sector suggest Vouga watershed as another feeding area. Studies carried out by Rocha (1993) on the outcrops of this watershed leaded to the identification of lower carbonate contents. Gomes (1987) previous studies point to carbonates occurring in suspended particle matter from Aveiro lagoon channels. So, it's likely that the carbonate content in the beach and dune sediments from southern sector have a detrital origin. However, the observation of coccolithophores species in the beach and dune fine fraction, namely Gephyrocapsa oceanica, Syracosphera sp, Gephyrocapsa ericsoni and Emiliania huxleyi, and the biological production associated with the Aveiro lagoon, may contribute to the observed relative enrichment of the beach and dune sediments at the south of Aveiro lagoon inlet (southern sector).

The lack of anhydrite in the Douro river flow sediments (Ferreira, 2000) doesn't explain the trend to higher contents in the northern sector. The recognition (Rocha et al., 1999) of this chemical mineral in the arenaceous deposits that outcrop on the northern sector (Paramos - S. Pedro Maceda), and the recognized contribution of these deposits, by erosion, to feed the adjacent beach deposits, seems to support the observed different contents in considered sectors, with the anhydrite from Aveiro lagoon superficial sediments (Rocha et al., 2000) explaining the contents of the same mineral towards south of the inlet (southern sector).

CONCLUSIONS

The longshore content evolution of the most representative minerals identified on the fine sediments from beach and dune littoral deposits from

![Figure 4](image-url)

Tendency lines of the fine/coarser detrital minerals and carbonates/detrital minerals ratios from the northern to the southern sector.
Espinho - Mondego Cape sector, in the western portuguese coast, make noteworthy the nourishment of the Douro and Vouga watersheds and additionally of the coastal sandy formations by erosion. The same content evolution allows concluding that the Douro watershed extends its sedimentological influence until Aveiro lagoon inlet. Away from this morphological accident and to the south direction, Vouga watershed imprints its sedimentary contribution in the coastal deposits.

REFERENCES


