Sr-Nd isotope signatures of surficial sediments from the Portuguese continental shelf

R. Martins[1], S. Ribeiro[2], A.J.F. Silva[2], R. Freitas[1], V. Quintino[1], A.M. Rodrigues[1], M.R. Azevedo[2]

1 Departamento de Biologia & CESAM, Universidade de Aveiro, 3810-193 Aveiro, Portugal
2 Departamento de Geociências & GEOBIOTEC, Universidade de Aveiro, 3810-193 Aveiro, Portugal

Abstract: *This study focus on the Sr-Nd isotope signatures of detrital and carbonate fractions of seven samples from surficial sediments deposited in the Portuguese continental shelf. $^{87}Sr/^{86}Sr$ and $^{143}Nd/^{144}Nd$ isotope compositions of the lithic component are used to constrain potential endmember contributions and determine sediment provenance. The $^{87}Sr/^{86}Sr$ ratios measured in the acid leachates of the seven sediment samples (carbonate fraction) lie within the range 0.7088 – 0.7092, close to the value for modern seawater (0.7091 – 0.7092), suggesting a dominant biogenic origin for this component. In contrast, the Sr isotope signatures for acid-leached silicate residues (lithic fraction) from the same samples are widely variable ($^{87}Sr/^{86}Sr$ = 0.7179 to 0.7346) reflecting the input of terrigenous particles from three distinct sources (northern Iberian Variscan crust, southern Iberian Variscan crust and North African aerosols). The narrow range of εNd(0) values displayed by these samples (-8.5 to -10.6) does not allow effective discrimination between the different endmembers.*

Keywords: *Portuguese continental shelf, surficial marine sediments, Sr-Nd isotope signatures*

INTRODUCTION

The Portuguese continental shelf extends for approximately 900 km in length, from the Galicia Bank (northern border) to the Gulf of Cadiz (southern border), with an average width of about 45 km and an irregular steep slope plunging to the abyssal plain. Shelf-break slope occurs nearly at 160 m depth. The western coast of Portugal is a high energy shelf environment and receives a significant sedimentary input from several major rivers (Minho, Douro, Mondego, Tagus and Sado). In contrast, the southern sector of the Portuguese continental shelf is relatively narrow (8 km to 28 km) and has a lower energy regime. Most of its sediment supply is delivered by the Guadiana River. The majority of the Portuguese rivers drain Late Proterozoic-Paleozoic metamorphic rocks and Variscan granitoids from the highland areas of Portugal and, to a lesser extent, the Meso-Cenozoic sedimentary formations exposed along the western and southwestern margins of Iberia (Lusitanian and Algarve Basins).

Radiogenic isotopes $^{87}Sr/^{86}Sr$ and $^{143}Nd/^{144}Nd$ are widely used as tracers of chemical and physical erosion processes, like provenance studies (Tripathy et al., 2011).

MATERIALS AND METHODS

Study area

The study area comprised the entire Portuguese continental shelf, from Caminha on the Northwest (41°51.8'N, 9°15.6'W) to Vila Real Santo António on the Southeast (36°56.1'N, 7°24.7'W) (Figure 1). Nearly 500 samples of soft bottom shelf sediments were collected in the scope of several research projects and analyzed for grain-size. Grain-size analysis was performed by dry and wet sieving. Raw grain-size data were expressed as weight percentages of mud, sand and gravel contents. Classification of sediment textural type was made using a modified version of the Folk triangle classification system.

Geochemical and isotopic analyses

A subset of seven sediments samples representing different granulometric types (sands, muddy sands and sandy muds) was selected for geochemical and isotope analysis. Their locations bracket some of the most important entrances of riverine suspended matter into the Portuguese continental shelf (Table I).

Site	Latitude (°N)	Longitude (°W)	Depth (m)	Sediment type
31	41º03'	9º10'	135	Muddy sand
98	39º02'	9º37'	98	Muddy sand
119	38º36'	9º15'	17	Sand
158	37º39'	9º01'	182	Muddy sand
195	37º05'	8º31	26	Muddy sand
226	36º56'	´7º24'	148	Sand
229	37º06'	7º24'	14	Sandy mud

TABLE I. *Characterization of the selected sites for isotopic analyses.*

The < 2 mm sediment fraction of these samples was ground and homogenized with an agate mortar and analysed for major and trace elements at Actlabs (Canada). Additionally, XRD analyses were also carried in the Department of Geosciences of the University of Aveiro (Portugal), to study the main

mineralogical phases. Sample preparation for isotope analysis involved previous treatment with dilute acid to remove acid soluble phases. The strontium isotope compositions were determined on both the silicate residues left after leaching with acetic acid (lithic fraction) and leachates (carbonate fraction), whilst the neodymium ratio measurements were carried out only on the carbonate-free sediment fraction. The Sr and Nd isotope ratios were measured on a VG Sector TIMS at the Laboratory of Isotope Geology of the University of Aveiro, Portugal. Isotope ratios were normalised to $^{86}Sr/^{88}Sr$=0.1194 and $^{146}Nd/^{144}Nd$=0.7219. Analysis of NBS SRM 987 and JNdi-1 international standards gave values of $^{87}Sr/^{86}Sr$ = 0.710255 ± 4 (n=169) and $^{143}Nd/^{144}Nd$ = 0.5121007 ± 15 (n=120), respectively.

RESULTS AND DISCUSSION

Spatial distribution of the surface shelf sediments

The spatial distribution of the surface sediments of the Portuguese continental shelf shows that: (a) coarser deposits occur mainly in the inner and mid-shelf of the northwestern sector, at depths between 20 and 80 m and immediately south of the Nazaré and Setúbal canyons, (b) sand banks dominate in the near shore shelf, but can sporadically be found at greater depths, (c) muddy sands characterize the deeper shelf and (d) sandy mud and mud cover a large sector of the southern shelf and areas located off the mouths of major rivers in the western shelf. This sedimentary spatial distribution reflects the influence of different factors, mostly mainland lithology, rivers runoff, hydrodynamics, shelf geomorphology and paleoclimatic changes (related to the presence of relict coarse sediments) (Martins et al., 2012).

Chemical composition and mineralogy

All the studied samples contain terrigenous, biogenic and authigenic components in variable proportions. With the exception of CaO and MgO, the major element compositions of these samples are dominantly related to terrigenous inputs. A major input of detrital quartz for the sandy sediments located off the mouths of the Tagus and Guadiana rivers (samples 119 and 229) is suggested by their high SiO_2 contents (>78%). The Al_2O_3 (4.3 – 6.3%) and K_2O (1.2 – 2.6%) values recorded in most sediment samples point to the occurrence of moderate amounts of clay minerals (mainly illite), muscovite and feldspar. CaO and MgO are low (CaO < 10%; MgO < 0.6%) in the sand deposits, but are considerably higher in the finer sediments (CaO = 22 – 29%, MgO = 1.15 – 1.83%), reflecting the influence of carbonate minerals from skeletal debris of marine organisms. Unlike CaO, MgO is also positively correlated with Fe_2O_3(T) and may therefore have been partitioned between smectitic clay/chlorite (minor) and carbonate minerals. Some contribution of authigenic Fe-Mn oxyhydroxides particles is indicated by the relative high concentrations of Fe_2O_3(T) in the studied samples (0.92 – 9.25%), particularly in the fine sediments from the southernmost sectors (samples 158 and 226). XRD mineral data reveal that the carbonate fraction is composed of calcite and aragonite, whereas the main mineral phases present in the siliciclastic fraction are quartz, muscovite, illite, feldspar and montmorillonite.

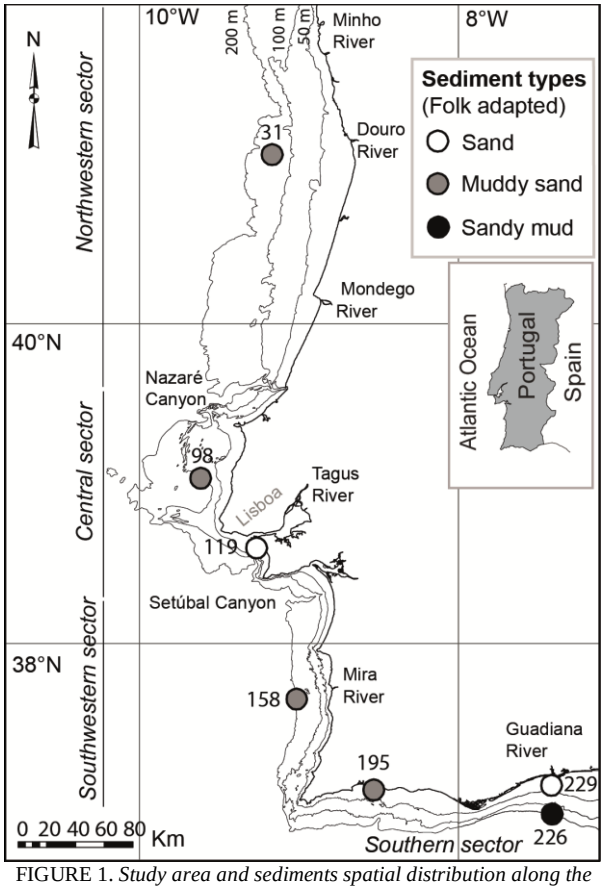

FIGURE 1. *Study area and sediments spatial distribution along the Portuguese continental shelf. Representation of the shelf sectors.*

Sr and Nd isotopes

As shown in Figure 2, the $^{87}Sr/^{86}Sr$ isotopic ratios in the leachates of all the analysed sediment samples range between 0.7088 – 0.7092. The close similarity between their isotopic compositions and present-day seawater (0.7091 – 0.7092) suggests a dominant biogenic origin for the carbonate component. In contrast, the $^{87}Sr/^{86}Sr$ isotope signature of the residual (leached) fraction is widely variable ($^{87}Sr/^{86}Sr$ = 0.7179 to 0.7346) reflecting distinct provenance areas for the lithogenic sediments entering the Portuguese continental shelf. The lower $^{87}Sr/^{86}Sr$ isotopic ratios are recorded in the sediment samples from the southern sector and tend to increase with latitude (Figure 2 – A). This may be partly due to differences in the age and lithology of the continental rocks exposed in the Iberian crust. Most of the sediment supply for the southern shelf is delivered by the Mira and Guadiana Rivers that flow through a region dominated by Carboniferous volcano-sedimentary sequences hosting some important polymetallic massive sulphide

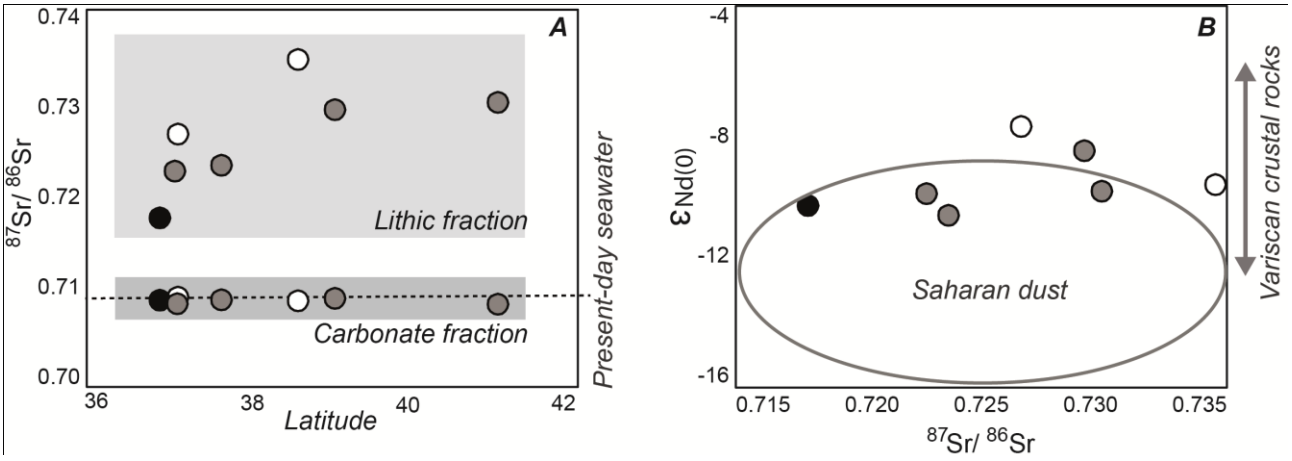

FIGURE 2. (A) *Biplot diagram of $^{87}Sr/^{86}Sr$ vs latitude in both carbonate and lithic fractions of the seven sediment samples analysed, with indication of isotopic signature of the presente-day seawater.* (B) *Biplot diagram of $^{87}Sr/^{86}Sr$ vs ℰNd(0)in the lithic fraction, showing also the literature range values of Variscan crustal rocks and Saharan dust. Dot color corresponds to its sediment type (blank – sand; grey – muddy sand; black – sandy mud).*

deposits, whilst the fluvial input for the central and northern sectors comes from rivers draining across Late-Proterozoic – Paleozoic metamorphic terrains (metapelites-metagreywackes) and Carboniferous granitoids, with more radiogenic Sr isotope compositions. Data from the literature show that metasediments and Variscan granitoids from central northern Portugal have whole-rock $^{87}Sr/^{86}Sr$ ratios ranging from 0.7049 to 0.8909, with 67% of the samples displaying values higher than 0.730 (Beetsma, 1995). A large input of radiogenic Sr from these sources can therefore be inferred for the samples with high $^{87}Sr/^{86}Sr$ ratios. On the other hand, the lower $^{87}Sr/^{86}Sr$ ratios observed in the southern shelf sediments suggest that a significant fraction of the detrital component results from slightly less radiogenic sources. Riverine suspended matter derived from weathering of the Carboniferous volcano-sedimentary sequence exposed in southwestern Iberia may constitute a suitable endmember composition. However, the contribution of airborne particles (mainly Saharan dust) with an average $^{87}Sr/^{86}Sr$ ratio = 0.72179 (Grousset et al., 1998) can also be important, particularly at lower latitudes (Stumpf et al., 2011).

Unlike the Sr isotopic compositions, the $^{143}Nd/^{144}Nd$ isotope ratios obtained in the lithic fraction lie within a very narrow range of values (ℰNd(0) = -8.5 to -10.6; Figure 2 – B), partially overlapping the intervals of ℰNd(0) reported in the literature for the different source components (northern Iberian crust, southern Iberian crust and Saharan dust) and cannot therefore be used for discrimination purposes.

This is the first study applying radiogenic isotopes to study the provenance of sediments along the Portuguese continental shelf.

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