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Provenance of Pliocene clay deposits from the Iberian Atlantic Margin and compositional changes during recycling

Pedro Dinis [a,b,*], Álvaro Oliveira [c]

[a] MARE – Marine and Environmental Sciences Centre, University of Coimbra, 3030-790 Coimbra, Portugal
[b] Departament of Earth Sciences, University of Coimbra, 3030-790 Coimbra, Portugal
[c] Laboratório do INETI de S. Mamede Infesta, Porto, Portugal

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ABSTRACT

The XRD mineralogy and geochemistry of recycled fine-grained deposits from the West Iberia Atlantic Margin are used to establish sediment provenance and evaluate the features that most closely reflect the nature of the source areas and the transformations during the last depositional cycle. A set of Pliocene sediment samples is organized according to grain size distribution, geochemistry, and mineralogy, and their chemical composition is compared with the composition of possible source rocks. Most deposits located to the north of the Mondego River were derived from the uplifted Precambrian metapelites of the basin edge, while to the south of the Mondego River they result mainly from recycling of Cretaceous and Cenozoic clastic units, which, in turn, were derived from Precambrian–Paleozoic granitoids and metasedimentary rocks. This differentiation is supported by several element ratios and biplots involving La, Sm, Gd, Sc, Th, U, Y, Yb, and Zr. For the specific grain size range of the deposits studied, which are mainly made up of silt and clay particles, composition is not substantially affected by the grain size distribution of the sediment. Multi-element diagrams designed to discriminate the tectonic setting and the nature of source rocks are of little use in the interpretation of provenance but help to trace geochemical and mineralogical transformations during the last depositional cycles. Despite the evidence of element leaching during the Pliocene depositional cycle, the geochemical and mineralogical indicators of weathering intensities are largely determined by the nature of the previous cycle units.

1. Introduction

The geochemical and mineralogical composition of sedimentary deposits is controlled by so many chemical and physical processes that the discrimination of their roles is sometimes difficult to perform (e.g. Johnsson, 1993; Weltje and Eynatten, 2004; Critelli et al., 2008). In theory, in laboratorial experiments, it is possible to isolate the effect of some of these processes, but a straightforward transposition of the laboratory results to natural phenomena in the field is hardly accomplished with success (e.g. White and Brantley, 2003). To approximate the roles played by each process, it is necessary a selection of independent data from sedimentary units with fairly simple and well-known geological histories and for which the lithology of possible source areas is also well constrained. Additionally, if the sedimentary units are associated with recycling of previous deposits, it can be necessary to separate the transformations that occurred during the last depositional cycle from those that may be inherited from previous geological cycles. This distinction is particularly puzzling in fine-grained deposits, for which a classical petrographic study based on the analysis of individual particles is problematic (Potter et al., 2005; Garzanti et al., 2011).

Bulk sediment geochemistry provides compositional information on a large number of variables that are differently affected by exogenous processes. Non-mobile elements during exogenous processes are frequently used to understand sediment provenance (e.g. McLennan et al., 1993; von Eynatten et al., 2003; López et al., 2005; Ohta and Arai, 2007; Pe-Piper et al., 2008; Perri, 2014; Zhang et al., 2014) whereas unstable elements are useful in estimating weathering intensity (e.g. Parker, 1970; Nesbitt and Young, 1982; Harnois, 1988; Price and Velbel, 2003; Perri and Ohta, 2014; Zhang et al., 2014). Other sedimentary processes such as those that determine selective entrainment and settling (e.g. Komar, 1987; Garzanti et al., 2009, 2011) and the physical resilience of constituent particles (e.g. Nesbitt and Young, 1996; von Eynatten et al., 2012) are able to introduce supplementary changes in sediment composition. Coupling geochemical data with sediment mineralogy and texture should allow a broad understanding of the distribution of major and minor elements in different mineral phases and size fractions, having the potential for tracing complex provenance and evaluating the roles played by other factors besides provenance on sediment composition.

The Pliocene to upper Pleistocene sedimentary succession exposed along the Atlantic margin of Iberia reveals a transgressive–regressive

* Corresponding author at: Departamento de Ciências da Terra da Universidade de Coimbra, Polo II, RuaSílvio Lima, 3030-790 Coimbra, Portugal. Tel.: +351 239 860 512; fax: +351 239 860 501.
E-mail address: pdinis@dct.uc.pt (P. Dinis).

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sequence that encompasses fine-grained palustrine and floodplain units overlying inner shelf to backshore sand-dominated formations. Although these fine-grained units record comparable depositional conditions in the West Iberia, the clay mineral assemblages for the deposits north of the Mondego River are enriched in illite (Dinis and Soares, 2007a; Dinis et al., 2011; Oliveira et al., 2013) in contrast with what is observed to the south of this river, where kaolinite is dominant (Cunha et al., 1993; Oliveira et al., 2013), indicating substantially different weathering intensity. Since the northern and southern deposits are only approximately 40 km apart and the elevations of the respective catchment areas should be broadly comparable, other factors besides climatic conditions must be responsible for the compositional differences. Assuming that the composition of the clay deposits is largely determined by the geology of the source areas, it is important to understand to what extent some features are inherited from their parent rocks and which were susceptible of significant changes during the last sedimentary cycles.

The specific aims of the present work are to (1) establish the geological aspects of the source areas that explain the largely different compositions found in the sedimentary successions north and south of the Mondego River, (2) trace the main compositional transformations during the last depositional cycle, and (3) evaluate the application

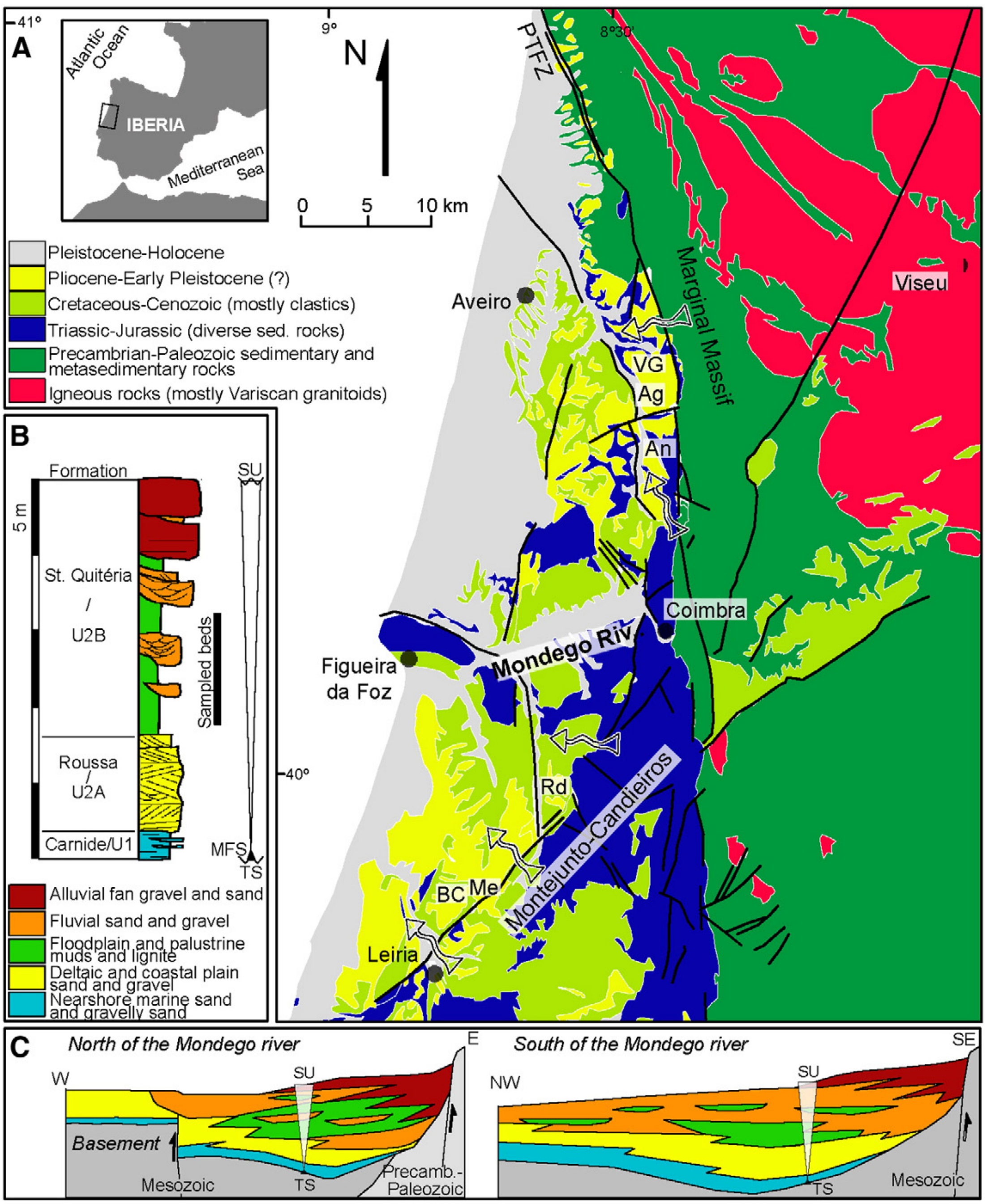

Fig. 1. Geological and stratigraphic framework. (A) Geological sketch of the West Iberia with location of the sampled areas (modified from S.G.P., 1992). PTFZ: Porto–Tomar Fault Zone. VG: Vale Grande; Ag: Aguada; An: Anadia; Rd: Redinha; Me: Meirinhas; BC: Bidoeira de Cima. Arrows indicate sediment paths inferred from facies architecture, paleocurrent data, and sediment composition (Cunha et al., 1993; Dinis, 2006; Dinis and Soares, 2007a, b; Ramos, 2009; Pais et al., 2012). (B) Idealized stratigraphic column of the Pliocene succession with the units established for the northern and southern regions. TS: transgressive ravinement surface; MFS: maximum flooding; SU: subaerial unconformity. (C) Stratigraphic scheme of the Pliocene succession in the regions north and south of the Mondego River. Not to scale; key for depositional units in the part B of this figure.