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Proximal–distal ichnofabric changes in a siliciclastic shelf, Early Pliocene, Guadalquivir Basin, southwest Spain

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ABSTRACT

The lower Pliocene deposits, cropping out along the Atlantic coast of Cadiz, in the Conil–Cabo Roche area, formed on a shelf gently deepening towards the W–NW. Up to five types of facies can be recognized, distributed in belts from proximal to distal parts of the shelf: 1) Coarse-grained sandstone with trough cross-stratification facies on the most proximal parts of the shelf (inner-shelf deposits). 2) Medium-grained sandstone with low-angle planar cross-stratification facies deposited in a more distal position due to storm currents transporting sediment offshore. This facies intercalates with the previous trough cross-bedded sandstone. 3) Massive fine-grained sandstone and siltstone facies laterally and vertically related with the previous facies type and representing sediments formed in the middle shelf close to the storm wave-base. 4) Tabular sandstone bed facies corresponding to storm-bed deposits intercalated within the two previous facies. 5) Greenish–bluish shale facies accumulated on the outer shelf below storm wave-base.

Three ichnofabrics associated with these facies are recognized: 1) The two cross-bedded facies are dominated by a *Macaronichnus* ichnofabric, characterized by *Macaronichnus* and *Bichordites* traces that represent colonization of a shifting sandy substrate by polychaetes (*Macaronichnus* tracemakers) and by sea urchins (*Bichordites* producers). 2) A *Rosselia* ichnofabric, consisting of vertical traces of *Rosselia* cross-cutting *Macaronichnus*, characterizes the interval of massive fine-grained sandstone and silt facies and interbedded tabular sandstones. This ichnofabric formed under high sedimentation rates with *Rosselia* traces exhibiting stacked patterns that indicate vertical readjustment following deposition. 3) Massive fine-grained sandstone and silt facies are distinguished by a *Cylindrichnus* ichnofabric. This fabric was produced by the activity of a moderately diverse community dominated by sessile, burrow-dwelling, probably superficial-detritus-feeding polychaetes (*Rosselia* and *Cylindrichnus* tracemakers) and vagile, deposit-feeding polychaetes (*Planolites* producers). In addition, infaunal deposit/detritus-feeders producing spreiten structures (*Teichichnus*) are found in distal areas. Pervasive indistinct mottling of the sediment of this facies was probably due to the activity of very shallow burrowers in the uppermost sediment tiers.

This proximal–distal replacement of ichnofabrics reflects the change of benthic communities across the shelf. This distribution does not fit the traditional Seilacherian ichnofacies model for soft-ground shallow-marine settings, in which proximal, vertical-dwelling burrows of the *Skolithos* ichnofacies dominate high-energy environments. In the Pliocene of Cadiz, shallow-tier burrows of deposit/detritus-feeders characterize the high-energy facies instead, which fit better with the *Cruziana* ichnofacies. This deviation can be related with the particular palaeoenvironmental conditions. Thus, vagile, opportunistic deposit-feeders colonized the dune foreset when the dunes were stable, and the progradation of the structure favored the preservation of the traces.

1. Introduction

Trace fossil studies, in particular ichnofacies/ichnofabric analyses, are an excellent tool for understanding the depositional setting and the ecology of palaeocommunities in shallow-marine settings (e.g., Pollard et al., 1993; Pemberton et al., 2001). Here, we present the results of an ichnological study of Pliocene deposits in the south-western margin of the Gualdalquivir Basin near Cadiz (south Spain). Previous ichnological studies in the basin have focused mostly on Miocene and Pliocene units deposited in bay and estuarine settings on the northwestern edge of the Guadalquivir Basin (Muñiz, 1998; Muñiz et al., 1998). The outcrops in the Cabo Roche–Conil de la Frontera area studied herein record lower Pliocene deposits in a different setting and allow for a detailed analysis of a proximal–distal transect of an

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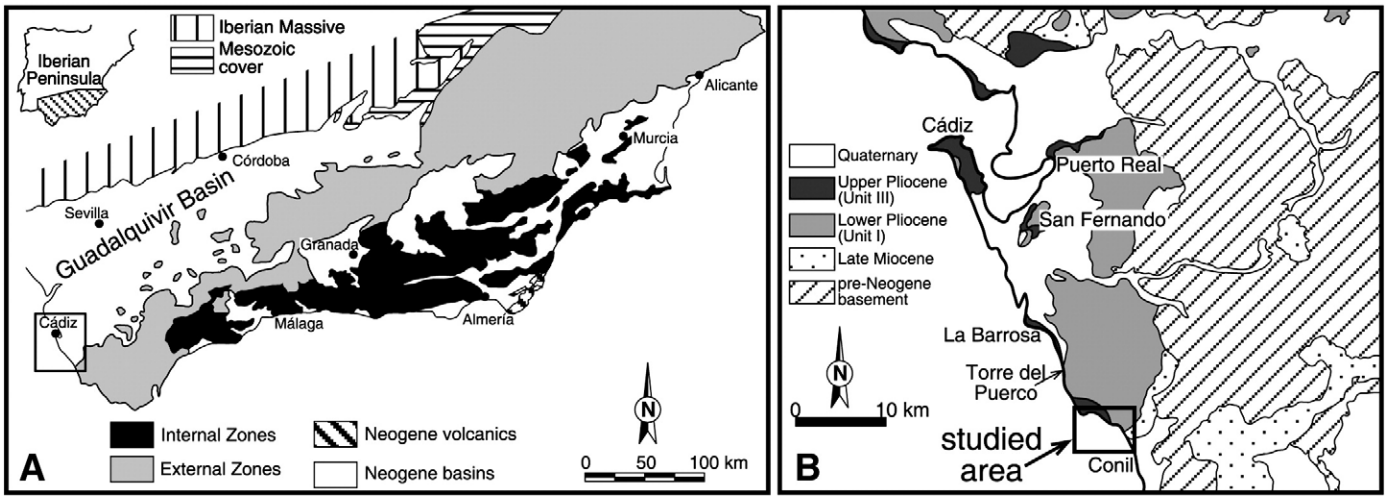

Fig. 1. Geological setting. A. Simplified geological map of the Guadalquivir Basin and the Betic Cordillera, B. Enlarged area of the inset in A. Geological map of the Cadiz sector indicating the study area. Modified from Aguirre (1995).

open-marine siliciclastic shelf. Our objectives are: 1) to first report the trace fossils present in this lower Pliocene unit; 2) to characterize the ichnofabrics and analyze their correlation with lithofacies; 3) to interpret those ichnofabrics from a depositional and palaeoecological perspective; and 4) to compare the results with the traditional shallow-marine ichnofacies model.

2. Geological and stratigraphic setting

The study area is located along the Atlantic coast of the province of Cadiz, in the Cabo Roche area northwest of Conil de la Frontera (Fig. 1). This area belongs to the southwestern edge of the Guadalquivir Basin (Fig. 1A), a foreland basin formed between the passive Iberian Massif to the north and the Betic Cordillera thrust front to the south (Sanz de Galdeano and Vera, 1992; Vera, 2000). The upper Neogene sedimentary infill of the Guadalquivir Basin consists of several sequences ranging from early Tortonian to late Pliocene in age (Sierro et al., 1996; Aguirre, 1995; Martín et al., 2009). In the southern sector of the basin, upper Tortonian(?)–Messinian to Pliocene deposits overlie olistostrome units derived from the front of the Subbetic External Zones (Riaza and Martínez del Olmo, 1996; Braga et al., 2002).

In the study area, Pliocene deposits can be divided into three unconformable units (Fig. 2) (Aguirre, 1991, 1995; Aguirre et al., 1995). The lower one (Unit I) ranges from the lowermost early Pliocene to the early–middle Pliocene transition. In the Conil–Cabo Roche area, it unconformably overlies upper Miocene (Messinian) horizontally laminated marls. This unit, which is the focus of this paper, consists of shale, silt, and fine- to coarse-grained sandstone, which crop out extensively in vertical sections along the coastal cliffs between Conil and Torre del Puerco (Fig. 1B). Farther north, at La Barrosa (Fig. 1B), this unit is locally represented by bioclastic temperate carbonates, mostly made up of bivalve rudstones (Aguirre, 1995). The top of Unit I is marked by an omission surface characterized by an intensively bioturbated surface with *Thalassinoides* (Aguirre, 1995).

The middle unit (Unit II), attributed to the middle Pliocene, unconformably overlies Unit I and is made up of bioclastic limestones (rudstone–floatstone) (Aguirre, 1991, 1995) (Fig. 2). The upper unit (Unit III) is late Pliocene in age and consists of bioclastic limestones (rudstone–floatstone) in the study area (Aguirre, 1992, 1995; Aguirre et al., 1993) (Fig. 2) and terrigenous delta deposits in the Bahía de Cadiz, farther north (Férriz and Aguirre, 1993; Aguirre, 1995) (Fig. 1B). Lake deposits formed coevally in small inland basins (Gavala, 1959; Aguirre, 1995; Aguirre et al., 1995). The top of the Pliocene deposits is heavily karstified and covered by continental (fluvial–alluvial) red sands and conglomerates attributed to the Pleistocene (Zazo et al., 1977) (Fig. 2).

3. Facies characterization of the lower Pliocene deposits of Unit I

The lower Pliocene deposits of Unit I, up to 25–30 m in thickness, are exposed in lateral continuity several kilometers along the Cabo Roche sea cliffs, between Conil and Torre del Puerco (Fig. 1B). The southeastern limit of the study area is a fault that brings into contact Pliocene and upper Miocene sediments, the latter cropping out extensively to the southeast, at El Roqueo–La Fontanilla beaches (Civis et al., 2003) (Fig. 3).

This study has concentrated on the Conil–Cabo Roche area (between Conil and the Cabo Roche lighthouse, Figs. 1B and 3). The coastal cliff exposures in this sector reveal a continuous proximal to distal transect, from ESE to WNW, across a siliciclastic shelf. Locally, at

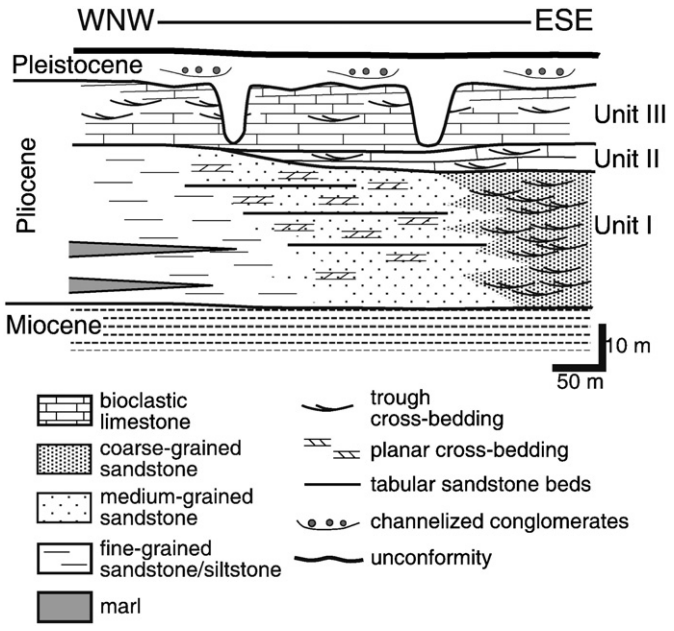

Fig. 2. Synthetic stratigraphic framework of the Pliocene and Pleistocene units between Cabo Roche and Conil de la Frontera.