Facies changes in the distal floodplain deposits of the Guadix Basin (Betic Cordillera, Spain): New sedimentologic data

Cambios de facies en los depósitos de llanura de inundación distal de la Cuenca de Guadix (Cordillera Bética, España): Nuevos datos sedimentológicos

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ABSTRACT

El relleno continental de la Cuenca de Guadix alberga un conjunto de interesantes yacimientos de macrovertebrados del Plioceno y el Pleistoceno. Como resultado de la excavación sistemática del yacimiento Mencal-9 (NO de la Cuenca de Guadix), han quedado expuestas una serie de secciones verticales. En ellas pueden observarse las transiciones laterales y verticales entre facies palustres (siliciclásticas y carbonatadas), de carbón y sedimentos de llanura de inundación, algunos afectados por procesos edáficos. Un detallado análisis sedimentológico ha llevado a la reinterpretación de algunas de las litofacies ya descritas en trabajos previos (Fo, Fb) y a la descripción de una nueva litofacies (Fe), así como a la propuesta de un nuevo elemento arquitectónico (FPb) formado por sedimentos siliciclásticos palustres.

Key words: *Continental sedimentation, Guadix Basin, paleosol, palustrine, Pleistocene.*

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Introduction

Distal floodplains of fluvial systems can contain palustrine and/or lacustrine deposits that exhibit edaphic features due to paleosol development (Alonso-Zarza, 2003). The literature about continental carbonates in these settings is extensive, as is literature regarding paleosols developed in overbank fluvial facies. However, palustrine siliciclastic environments have received little attention.

In the Guadix Basin (Fig. 1A), there is a unique example where palustrine siliciclastic facies have been identified in association with palustrine carbonates, coal seams and floodplain sediments, some of them showing incipient paleosol development. The excavations carried out in the Mencal-9 Pleistocene site (NW of the Guadix Basin) led to the exposure of several trenches where the transition between the above-mentioned facies could be observed (Fig. 1B). The present paper focuses on the description of the lithofacies identified at this paleontologic site and their association in architectural elements.

The sedimentologic interpretation was carried out using the following procedures: measurement of detailed 1:10 scale stratigraphic logs, establishment of correlations between them and identification of simple lithofacies and their associations in 3-D architectural elements in the sense of Miall (1985, 1996). Sedimentary surfaces defining hiatuses or erosion were also identified.

Despite the fact that there is already a description of the lithofacies and the architectural elements of the central sector of the Guadix Basin (Pla-Pueyo, 2009; Pla-Pueyo *et al.*, 2009), some of the previously identified facies are re-described taking into account the new data obtained from the logs. As a result, a new lithofacies (Fe) is described here, and a new palustrine architectural element (FPb) is proposed.

Geologic context and stratigraphic location of the paleontologic site

The Guadix Basin, located in the central sector of the Betic Cordillera (Fig. 1A), seals the ancient contact between the Internal and External Zones of this mountain range. The sedimentary infilling of the basin is divided into six genetic units. Units I to III correspond to the marine stage of the basin and were deposited during the Upper Tortonian, while the three youngest units (from IV to VI) were continental in origin and their deposition took place from Upper Tortonian to Late Pleistocene (Fernández *et al.*, 1996a, 1996b; Viseras *et al.*, 2005).

Most of the large-mammal paleontologic sites found in the central sector of the Guadix Basin are within units V and VI (Pliocene-Pleistocene) (Fernández *et al.*, 1996a; Viseras *et al.*, 2005). In these two last units, three main drainage systems could be identified (Viseras, 1991; Fernández *et al.*, 1996b).

The longitudinal system (so-called Axial System), parallel to the basin axis, consisted of a fluvial system, with high sinuosity in the study area, that drained towards a shallow lake located to the northeast in the neighboring Baza Basin. The other two drainage systems of the study area (External and Internal Transverse Systems) were formed by alluvial fans connecting transversally with the axial valley. M-9 site (Fig. 1B) is in Unit VI, associated with the distal floodplain and palustrine facies of the Axial System. Due to its proximity to the basin margin, the outcrop is affected by small-scale tectonic movements.

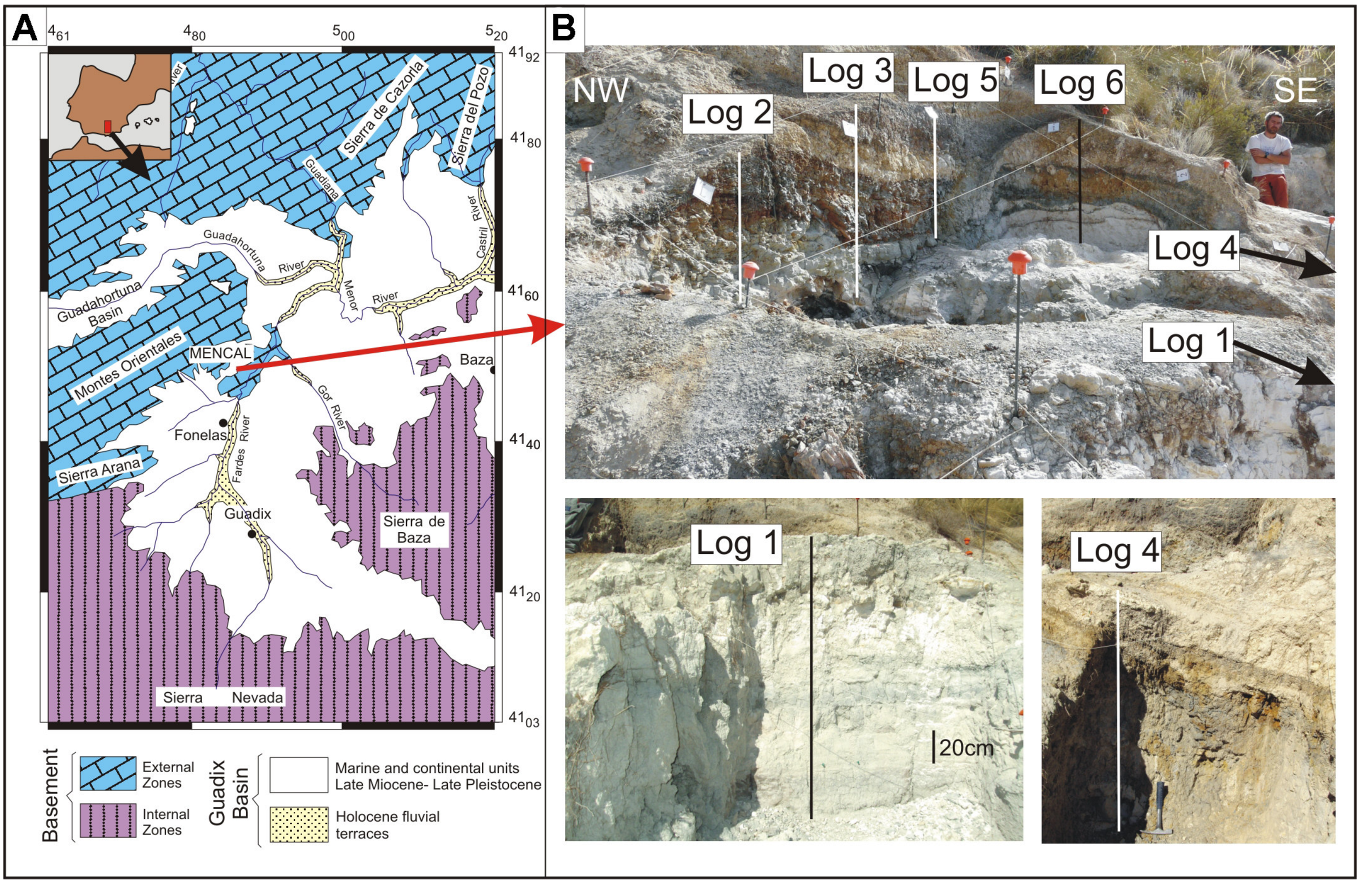

Fig. 1. - Geologic setting. A) Guadix Basin; B) Mencal-9 paleontologic site sections, showing the position of the six stratigraphic logs.

Fig. 1.- Contexto geológico. A) Cuenca de Guadix; B) Secciones en el yacimiento paleontológico Mencal-9 y posición de los seis perfiles estratigráficos.

Local sedimentary context and facies associations related to the site

Paleontologic excavation of the M-9 site has exposed several sections with different orientations. This made it possible to draw up six detailed stratigraphic logs (Fig. 1B) lying very close together and to establish a direct correlation between them. From the logs, the simple lithofacies and 3-D geometry of the sedimentary bodies cropping out at the site could be identified.

Simple lithofacies

Only fine-grained siliciclastic sediments and carbonates (see Table I) have been identified in the logs by their macroscopic features.

Lithofacies Fl (laminated fine sediments interpreted as unaltered floodplain deposits close to a fluvial channel) and Fo (oxidated and root-bioturbated sediments interpreted as distal floodplain sediments) were described in the Guadix Basin by Viseras (1991) after Miall's (1978) classification. Recent works (Pla-Pueyo, 2009; Pla-Pueyo *et al.*, 2009a) have modified the description of Fo lithofacies and its interpretation. Currently, the Fo lithofacies is described as in table I and interpreted as the result of a poorly drained paleosol development (after Kraus and Hasiotis, 2006) on overbank fine sediments. Lithofacies Fb, characterized by high organic matter content, was described for the first time by Pla-Pueyo *et al.* (2009). This facies corresponds to palustrine siliciclastic deposits, settling in shallow waters with low oxygen conditions, corresponding to the presence of marshes on the distal floodplain (Table I).

A new lithofacies, named Fe, is proposed for the palustrine siliciclastic facies that was affected by pedogenesis. It shows not only the original features of the Fb facies, but also rhizoliths, mottling, and carbonate nodules. The Fe lithofacies are interpreted as poorly drained paleosols developed on a desiccated marsh (Table I).

Coal seams (lithofacies C) may be considered soil horizons (histosols after Retallack, 2001), because autochthonous coal is formed in stagnant ponded waters with stable high groundwater levels and contains a large amount of plant remains. Calcilutite lithofacies identified at the site (Table I) were described by Pla-Pueyo *et al.* (2009) in detail.

They include relatively homogeneous micritic calcilutites (Cm), pedogenically altered calcilutites with mottling (oxides) and rhizoliths (Co) and carbonate encrusted roots forming rhizocretions (Cr). Lithofacies M, including marls and marlstones, are divided in this paper into two different types, depending on their degree of pedogenic alteration. If the marls and marlstones are unaltered, they are interpreted as a shallow lacustrine facies (Ml). The edaphization of marls and marlstones indicates palustrine conditions with a fluctuating water table and frequent subaerial exposure, which leads to the establishment of a separate lithofacies Mo (Table I). Finally, two limestone lithofacies were identified. Lo fine-grained lithofacies are quite similar to Co lithofacies, but with a higher carbonate content. Lg facies show angu-

Archit. Elem.	FTg (Grey sand-silt beds)		FPb (Palustrine-lacustrine siliciclastic beds)			CPm (Palustrine carbonate beds)						
Lith.	**Fl**	**Fo**	**Fb**	**Fe**	**C**	**Cm**	**Co**	**Cr**	**Ml**	**Mo**	**Lo**	**Lg**
Sed. Struct.	Horizontal to wavy lamination	Massive	Massive to laminated	Massive	Massive to laminated	Massive	Massive	Massive	Massive to laminated	Massive	Massive (Micrite)	Grainification
Color	Grey	Grey-brown	Bluish	Bluish + yellow-red	Dark brown-black	Grey-white	Grey-white + yellow-red	Grey-white	Cream-white	Cream-white color + yellow-red	Cream-white color + yellow-red	Cream-white color + yellow-red
O.M. content	Not significant	Not significant	Medium	Medium	High to very high	Not significant	Not significant	Not significant	Not significant	Not significant	Not significant	Not significant
Carbonate content	Not significant	Variable but low	Variable	Variable	Not significant to low	Low to medium	Low to medium	Medium	Medium	Medium	High to very high	High to very high
Malacofauna	Very scarce	Scarce	Relatively abundant to very abundant	Relatively abundant to very abundant	Relatively abundant to very abundant	Scarce to relatively abundant	Scarce to relatively abundant	Very scarce	Relatively abundant to very abundant	Relatively abundant to very abundant	Very scarce	Very scarce
Rhizoliths	Not identified	Mainly root molds filled by Fe oxides	Not identified	Mainly root molds filled by Fe oxides	Mainly root molds filled by Fe oxides or carbonate	Not identified	Mainly root molds filled by Fe oxides	Rhizocretions (carbonate concretions around roots)	Not identified	Mainly root molds filled by Fe oxides and rhizohalos	Mainly root molds filled by Fe oxides	Mainly root molds filled by Fe oxides or by peloids/ intraclasts
Mottling	Not identified	Sparse to intense	Not identified	Sparse to very intense	Sparse to very intense	Not identified	Sparse to very intense	Not present to intense	Not identified	Sparse to very intense	Sparse to intense	Very intense
Other pedogenic features	Not identified	Carbonate nodules Slickensides	Not identified	Carbonate nodules	Carbonate nodules	Not identified	Nodulization Vadose silt Alveolar and fenestral structures Mudcracks	Not identified	Not identified	Carbonate nodules Peloids	Vadose silt Alveolar and fenestral structures Mudcracks	Intraclasts Peloids Pseudo-microkarst
Bed Thick.	30cm-2.5m	30cm-8m	5cm-2m	5cm-2m	1-20cm	10-50cm	10-50cm	10-50cm	5cm-2m	5cm-2m	10cm-2m	10cm-2m
Interpretation	Floodplain	Floodplain deposits with vegetation and flooding	Marsh on the floodplain	Palustrine siliciclastic deposits with variable degree of pedogenic alteration	Swamp/Peat bog deposits in stagnant waters ponded in the floodplain	Palustrine deposits with low degree of pedogenic alteration	Palustrine deposits with medium-high degree of subaerial exposure	Calcified roots in wet sediments of the floodplain	Lacustrine shallow deposits	Palustrine deposits in distal floodplain with a variable degree of pedogenic alteration	Palustrine deposits in distal floodplain with a medium degree of pedogenic alteration	Palustrine deposits in distal floodplain with a high degree of pedogenic alteration

Table I.- 3-D architectural elements identified at the site. The most common simple lithofacies within each element are described in detail. The estimated contents in organic matter (O.M.) and carbonate content are qualitative, based in field observations.

Tabla I.- Elementos arquitectónicos 3-D identificados en el yacimiento M-9. Las litofacies simples más comunes en dichos elementos se describen en detalle. Los contenidos estimados de materia orgánica (O.M.) y carbonato son cualitativos, basados en observaciones de campo.

lar to rounded micritic intraclasts (grainification) lacking coatings in the outcrop. Both correspond to palustrine carbonates showing a variable degree of pedogenic features, with lithofacies Lg being the most altered.

Architectural elements

A previous classification of architectural elements (Pla-Pueyo *et al.*, 2009) has been applied in this research. In this classification, a capital letter is used to describe the grain size (S=sand, F=lutite) or the composition (C=carbonate), followed by another capital letter referred to the morphology of the bed (T=Tabular, P= pond shape, lenticular) and by a third letter pointing to a characteristic feature of the element (e.g. g=grey, b=bluish). After this classification, two types of laterally-associated 3-D architectural elements may be identified in the outcrop: grey sand-clay beds (FTg) and palustrine carbonates (CPm) (Table I). A third type, the so-called «palustrine-lacustrine siliciclastic beds» (FPb), named after the criteria of Pla-Pueyo (2009), is here described for the first time in the Guadix Basin.

The FTg element in the studied sections exhibits associations of lutiticmudstone lithofacies (Fl and Fo, see Table I) characterizing the fine sediments of the distal floodplain. They are interpreted to be deposited where the phreatic fringe is high and subaerial exposure is less frequent (Pla-Pueyo *et al.*, 2009). This leads to the development of poorly drained paleosols (in the sense of Kraus and Hasiotis, 2006).

Meanwhile, the CPm element (Table I) is formed mainly by marls, marlstones, and some limestones. The marls show different degrees of pedogenic exposure, from almost none at the base of some sequences (Ml) to a very high degree close to the erosional surfaces (Mo). This element represents shallow ponded zones developed in protected areas of the floodplain (Pla-Pueyo *et al.*, 2009). It is noticiable that CPm elements are displaced eastwards in the outcrop through time.

The palustrine-lacustrine silici-clastic architectural element (FPb), shows a characteristic association of lithofacies Fb, Fe, and C (see Table I). The reduced thickness of the deposits of lithofacies Fb and the absence of pedogenic features led us to interpret them as shallow lacustrine siliciclastic deposits. When these deposits were colonized by plants and exposed to subaerial conditions, they became palustrine. Therefore, the facies association of Fb-C-Fe would be interpreted as a shallow ponded area, with a relatively perennial water level (Fb) and relatively high organic matter content (bluish to dark color). The poor drainage of the clays and the abundant organic matter in the shallow ponded areas would cause the formation of coal facies (C). Both of these deposits would be rarely affected by emersion and edaphization (Fe).

After the architectural element analysis, five sedimentary local hiatuses were identified at the outcrop, corresponding to no sedimentation/ erosional surfaces.

Conclusions

Three different types of architectural elements have been identified, one of which is described for the first time in the Guadix Basin (palustrine-lacustrine siliciclastic beds, FPb). Moreover, of the twelve basic lithofacies forming these architectural elements, one is also defined for the first time in the basin (Fe), and two have been re-described (Ml and Mo). The new lithofacies (Fe) is proposed for sediments that originated from the emersion and subaerial exposure of shallow lacustrine siliciclastic sediments.

During the formation of the paleontologic site, the sedimentary environments were palustrine-lacustrine siliciclastic and carbonate settings co-existing as distal floodplain sediments with incipient paleosol development and local unconformities delimiting subaerial exposure, no sedimentation and/or erosion. Ponded areas were displaced eastwards through time. The general climatic conditions deduced from the sedimentologic features (e.g. mottled paleosols and coals) would involve wet hydrologic conditions in general with a fluctuating water level, leading to occasional subaerial exposure.

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