Stratigraphy and sedimentology of a Lower-Middle Miocene section in the Miranda-Trebiño Basin, NE Iberia

Estratigrafía y sedimentología de una sección del Mioceno Inferior-Medio de la Cuenca de Miranda-Trebiño, NE Iberia

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ABSTRACT

This work is focused on a Lower–Middle Miocene section exposed on the northern flank of Miranda-Trebiño piggy-back basin (Cucho section). The sedimentological and stratigraphic study of the section, composed of up to 160 m of terrigenous, mixed (marls), coal and carbonate deposits, allowed characterizing three depositional environments: distal alluvial, lacustrine and palustrine. The stratigraphic arrangement of different facies reflects five 28-43 m thick sequences which are related to progradation and retrogradation of alluvial systems and consequent retraction and expansion of the lacustrine and palustrine wetlands. The alluvial deposits have been associated with the alluvial fans of the northern basin margin, which was activated by the compressive tectonics prevailing during the time of deposition.

Key-words: *Miranda-Trebiño Basin, lacustrine-palustrine facies, distal alluvial, Lower-Middle Miocene.*

RESUMEN

Este trabajo está centrado en una sección del Mioceno Inferior-Medio que aflora en el flanco norte de la Cuenca de piggy-back de Miranda-Trebiño (sección de Cucho). El estudio sedimentológico y estratigráfico abarca hasta 160 m de depósitos terrígenos, mixto (margas), carbonosos y carbonatados, y ha permitido la caracterización de tres ambientes de depósito: aluvial distal, lacustre y palustre. La secuencia vertical de facies ha permitido la diferenciación de cinco ciclos de 28-43 m de espesor relacionadas con la progradación-retrogradación de los de los sistemas aluviales y la consecuente retracción y expansión de los sistemas lacustres y palustres. Los depósitos aluviales han sido asociados a los abanicos aluviales del margen norte de la cuenca cuya reactivación estaría ligada a la tectónica compresiva del momento.

Palabras clave: *Cuenca de Miranda-Trebiño, facies lacustres-palustres, aluvial distal, Mioceno Inferior-Medio.*

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Introduction

Palustrine–lacustrine carbonate–clastic facies were common in the Iberian Peninsula during Oligocene and Miocene times, either forming extensive systems within large endorheic basins, such as the Ebro (Cabrera, 1983; Muñoz *et al*., 2002), Duero (Armenteros *et al*., 2002) and Madrid (Alonso-Zarza *et al*., 1992) basins, or discrete accumulations within smaller basins under compressional tectonic regime, associated with growing fold-thrust belts, i.e. Miranda-Trebiño (Riba, 1956, 1961) and Almazán (Huerta, 2006) basins. This work focuses on the Lower–Middle Miocene palustrine–lacustrine deposits and the related-alluvial deposits, exposed in the centre of the Miranda-Trebiño Basin (MTB; southern Basque-Cantabrian region), with the aims of identifying their constituent lithofacies and vertical arrangement, and to infer the main factors that controlled their deposition.

Geological setting

The MTB (Fig. 1A) is a 60-km long syncline depression that developed on the southern part of the Basque-Cantabrian region since the late Paleogene to the early-middle Neogene (Riba, 1956, 1961; Riba and Jurado, 1992). It is a piggy-back basin that evolved coevally to the emplacement of the Sierra de Cantabria-Montes Obarenes thrust sheet over the Ebro (Rioja sector) and Duero foreland basins. It was filled with up to 3000 m of terrigenous and carbonate deposits corresponding to different alluvial to palustrine-lacustrine systems. Based on the distribution of the main sedimentary lithofacies and systems, and the presence of stratigraphic discontinuities, Riba (1956) differentiated five unconformity-bounded coarsening-upwards megasequences within the sedimentary fill of the MTB. The thickest and best represented at surface is megasequence 3, which Martín Alafont *et al*. (1978) ascribed to the late Oligocene-Early Miocene time interval. On the eastern sector of the MTB, Riba's megasequence 3 consists of 700 m of lacustrine–palustrine carbonate deposits. The upper 160 m of this megasequence in the Cucho section, are the focus of this study. It takes its name from the main reference section located between the villages of Trebiño and Cucho (Fig. 1B). At this outcrop, up to 160 m of marls, marlstones and limestones, with interbedded sandstones, mudstones and

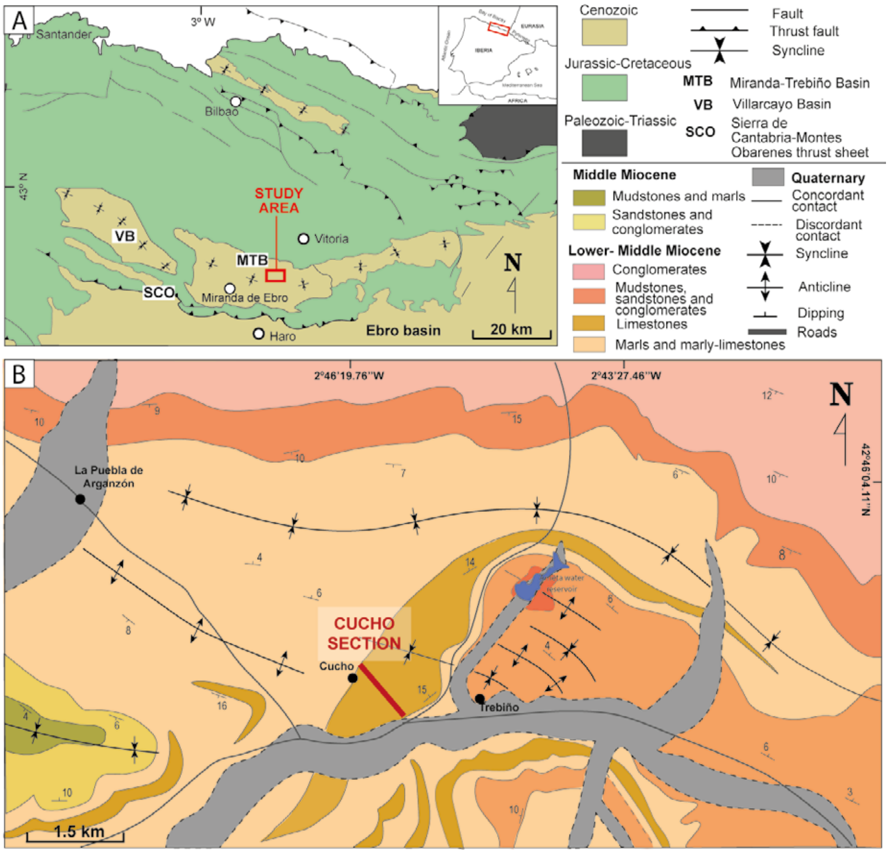

Fig. 1.- A) Location of the study area in the southern region of the Basque-Cantabrian Pyrenean Basin. B) Geological map of the study area. See color figure in the web.

Fig. 1.- A) Localización del área de estudio en la región sur de la Cuenca Vasco-Cantábrica pirenaica. B) Mapa geológico del área de estudio. Ver figura en color en la web.

thin coal seams have been logged in detail. The constituent lithofacies (hereafter "facies") and the stratigraphic arrangement of the Cucho macrosequence (Fig. 2) are described below.

Sedimentary facies

Seventeen different facies, grouped into carbonate, clastic, mixed and coal facies, can be distinguished within the Cucho macrosequence.

Carbonate facies

This group of facies is defined by well-stratified tabular limestone beds (L), 0.6 to 3 m-thick, interspersed with marls and marlstones (M) (Fig. 3A). Five main limestone types are distinguished based on their texture and structure: 1) structureless (i.e., massive) wackestones (Lwm) comprising charophyte gyrogonites and ostracods, plus minor charophyte thalli and gastropod shells. Ellipsoid and elongated chert nodules are abundant at the top of some strata (Fig. 3B). Irregular vertical root traces, desiccation cracks and incipient brecciation are frequently superposed on the above textural features, at the top of strata constituted by Lwm, producing new facies (Lwb). 2) Laminated wackestone-packstones (Lw-pl), with lamination defined by thin alternating layers formed of oriented fragments of charophytes and ostracods and micrite, at places with gradual upward transition (Fig. 3D). 3) Massive mudstones consisting of charophyte and ostracod fragments, in cm-thick beds, being the bioclasts non-oriented, and including scattered silt-sized quartz grains (Lmq) and, very locally, lenticular gypsum pseudomorphs (Lmg). 4) Laminated mudstones to wackestones (Lm-wl) with scattered silt-sized angular quartz grains and rare bioclasts. The lamination, commonly undulated, is defined by a mm-thick alternation of micrite and discontinuous spar-calcite layers formed of small bioclast fragments. 5) Nodular greyish marly limestones (Lwn) forming tabular strata, with distinct reddish mottling. Lwn are peloid and intraclast wackestones with clotted micrite matrix, abundant circumgranular and planar desiccation cracks, geopetal fills and chert nodules. (Sub) vertical root traces are common in this facies as well (Fig. 3E).

Clastic facies

These form intervals ranging 5-14 m in thickness made of two main lithologies: 1) reddish and greenish massive terrigenous mudstones (Fm) in 1.3–4.5 m thick strata. Occasionally this facies shows horizontal lamination (Fh) and bioturbation by irregular rizoliths (Fb). 2) Lenticular- and tabular-shaped sandstones beds, inters-

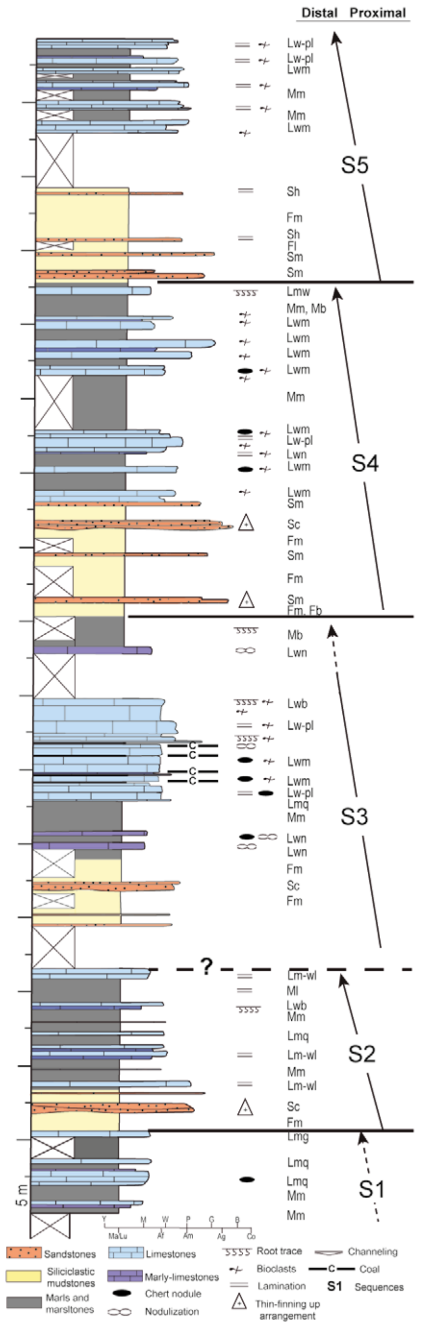

Fig. 2.- Synthetic stratigraphic log of Cucho section, with the different facies and their vertical distribution. S1 to S5 represents the differentiated sequences. See color figure in the web.

Fig. 2.- Columna sintética de la sección de Cucho con las diferentes facies y su distribución vertical. S1 a S5 indican las secuencias identificadas. Ver figura en color en la web.

persed within Fm intervals. The sandstones are fine to medium grain-sized sublitharenites made of mixtures of subangular quartz and lithic carbonate grains, including fragments of reworked large benthic Paleogene foraminifers (Nummulites, Rotalids). The sandstones mainly occur as single sharp-based beds, either structureless (Sm), or with faint horizontal (Sh) and cross lamination (Sr) (Fig. 3F), which laterally extend some tens of m. Locally, lithic sandstones also occur, forming 1–3 m-thick channel-shaped bodies made of stacked lenticular and tabular sandstone beds; the latter show fining- and thinning-upward arrangements and sparse cross bedding and lamination (Sc). Paleocurrent estimations (n=7) based on internal cross bedding and lamination and basal scour marks reveal a sediment source area located to the north and north-east, on the northern margin of the MTB.

Mixed facies

These comprise marls to marlstones of ochre to greyish colour that form cm to 7.5 m-thick packages, either showing discontinuous horizontal lamination (Ml) or structureless beds (Mm). Charophyte gyrogonites, ostracod fragments and irregular mm to cm-long root traces occur sparsely within them (Mb).

Coal facies

They occur as four intervals 8–30 cm-thick that exhibit persistent lamination largely defined by the alternation of mm-thick clay and organic- matter rich laminae (facies C; Fig. 3C). Well-preserved plant remains, sulphide and/or iron-oxide disseminations and small root-traces are common features in all coal occurrences.

Facies associations

The facies described above can be grouped vertically into three main facies associations representing different depositional environments: distal alluvial (FA1), palustrine (FA2) and lacustrine (FA3). The distal alluvial facies association comprises the terrigenous mudstone and lithic sandstone deposits. Facies Fm and Fh are interpreted as formed in muddy floodplains or mudflats with occasional colonization of plants (facies Fb), that were dissected by ephemeral shallow fluvial channels filled by m-thick sandstone packages (facies Sc) and associated sand splays (Sh, Sm).

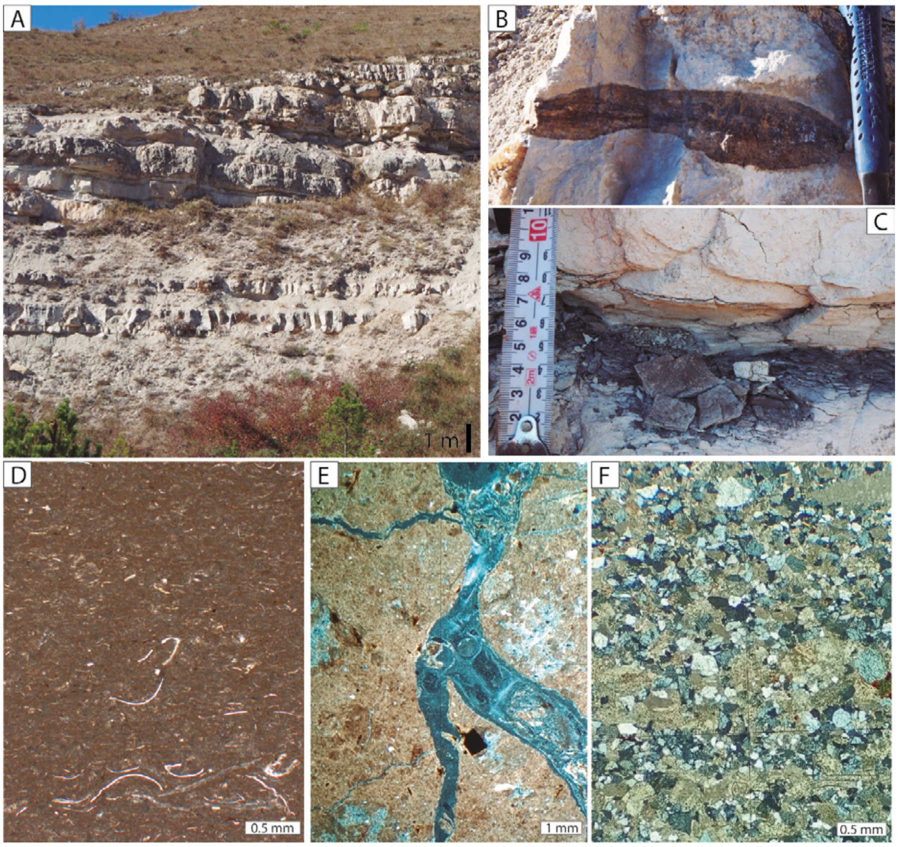

Fig. 3.- Field and thin section microphotographs of the main facies of the Cucho section. A) Outcrop photograph of the distribution of clastic, mixed and carbonate facies. B) Elongated chert nodule in massive wackestone (Lmw). C) Coal layer (C). D) Microphotograph of laminated wackestone-packstone with abundant orientated shell fragments (Lmw-pl). E) Nodular marly limestone with root traces (Lwn). F) Thin section of sublitharenite (Sh).

Fig. 3.- Fotografías de campo y láminas delgadas de las facies principales de la sección de Cucho. A) Foto de afloramiento donde se observa la distribución de las facies clásticas, mixtas y carbonáticas. B) Nódulo de chert en las facies "wackestone" masivas (Lmw). C) Nivel de carbón (C)). D) Microfotografía de la caliza "wackestone-packstone" con abundantes fragmentos de conchas orientados. E) Caliza margosa nodular con trazas de raíces verticales (Lwn). F) Lámina delgada de las areniscas (Sh).

The palustrine facies association comprises facies Lwb, Lwn and Mb. The pedogenic features of facies Lwb and Mb are characteristic of palustrine fringes recording significant variation in water level, with occasional subaerial exposure and desiccation, and plant colonization. Facies Lwn, in turn, show greater development of pedogenic features such as nodules and breccias, which point to longer periods of exposure or more intense desiccation, at times associated with an incipient development of pedogenic calcretes (Alonso-Zarza and Wright, 2010). Finally, the lacustrine facies association is mainly represented by facies Lwm and Mm, both indicative of low-energy littoral zones of shallow lakes colonized by aquatic vegetation, including calcareous algae, as well as crustaceans and molluscs. Coal facies (C) likely represent episodes in which these littoral zones recorded enhanced plant colonization and partial stagnation favourable for preservation of organic matter. In contrast, facies Lw-pl and Ml evidence deposition in more internal lake zones. The Lw-pl included sediment transported from littoral zones that were subject to episodic current activity, as revealed by the presence of numerous layers of reworked bioclasts (Alonso-Zarza and Wright, 2010). Facies Mh formed by sediment settling offshore.

Facies Lmg are indicative of shallow, low-energy lacustrine areas recording episodes of restriction and enhanced evaporation that allowed gypsum crystals to growth. Finally, facies Lmq is interpreted as formed in the relatively deeper zone of the lakes under low energy conditions, with occasional current activity and siliciclastic fine sediment supply (Larena *et al*., 2020).

The depositional model inferred for the Cucho macrosequence is like that established for the underlying deposits exposed in the Faido-Samiano area, some

10 km to the SE of the studied section (Larena *et al*., 2019).

Stratigraphic arragement

According to the vertical distribution of its constituent carbonate, clastic and mixed facies, the Cucho macrosequence can be subdivided into five stratigraphic sequences, named S1 to S5, with individual thicknesses ranging between 28 and 43 m (Fig. 2). From base to top, every unit consists of packages of distal alluvial detrital deposits that gradually evolve to mixed and carbonate facies representative of palustrine and lacustrine environments. The boundaries between the successive sequences are marked by sharp changes from palustrine and lacustrine carbonates to alluvial siliciclastic deposits. There is no evidence of enhanced erosion and/or subaerial exposure indicative of significant or prolonged stratigraphic hiatuses.

Based on the sedimentological interpretations, the five sequences represent depositional cycles that started with a sudden increase in terrigenous supply, likely due to progradation of the basin margin alluvial systems, followed by their gradual retreat and then spread out of carbonate deposition under palustrine and shallow lacustrine conditions. The allocyclic or autocyclic character of these asymmetric depositional cycles is difficult to be established based on the available information from a single section. However, previous studies in the underlying Lower Miocene palustrine–lacustrine deposits from the Faido-Samiano area located to the SE (see Larena *et al*., 2019) identified similar depositional cycles that tentatively were interpreted in terms of short-term tectonic pulses affecting the basin margins and the rates of detrital supply to the basin centre from the uplifted Cretaceous-Paleogene source areas located to the north of the MTB. As a whole, the studied section is coarsening-upward, with a relative increase of detrital content at the base of sequence S4. This evolution is consistent with increasing basin margin uplift and overall progradation of the corresponding depositional systems.

Conclusions

The study of the Lower-Middle Miocene Trebiño-Cucho section in the MTB Basin has evidenced a complex, cyclical succession of clastic, coal and carbonate sediments, with a general coarsening-upward evolution. A wide array of carbonate, coal, siliciclastic and mixed deposits have been distinguished, representative of ephemeral km-wide palustrine and lacustrine areas that expanded and retreated in close relationship to evolution of the alluvial systems that characterized the northern basin margins. Further sedimentological and geochemical studies are needed, particularly to better constraint the variations of the lake extent and its potential link to local climatic and/or tectonic controls.

Authors contribution

All the authors have participated in the field work and subsequent analysis of facies, as well as in the manuscript preparation.

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