The Mendiurkullu Member of the Lareo Formation: a delta-estuarine progradational system from the Etxegarate trough (Early Aptian western Aralar Mountains)

El Miembro Mendiurkullu de la Formación Lareo: un sistema progradante deltaico-estuarino en el surco de Etxegarate (Aptiense inferior del oeste de Aralar)

M. Isabel Millán, Pedro A. Fernández-Mendiola and Joaquín García-Mondéjar

Departamento de Estratigrafía y Paleontología, Facultad de Ciencia y Tecnología, Universidad del País Vasco, Apartado 644, 48080 Bilbao, Spain.
bcbmisam@ehu.es

ABSTRACT

Se describe e interpreta el miembro areniscoso y lutítico de Mendiurkullu dentro de la Formación Lareo, en el oeste del macizo montañoso Vasco-Cantábrico de Aralar (Navarra). Contiene arcillas, limolitas y areniscas finas con 13 metros de potencia total. Su edad es Aptiense inferior, parte superior. De muro a techo se reconocen: 1) arcillas con nódulos ferruginosos infrayacentes, 2) limolitas con capas de arenisca fina de base plana y ripples a techo, 3) areniscas de grano fino con estratificación horizontal y cruzada de surco, y 4) areniscas masivas de grano fino-medio rellenando canales. La secuencia vertical estrato y grano creciente se relaciona con la progradación de un sistema deltaico-estuarino, que rellenó el surco de Etxegarate con aportes terrígenos de procedencia meridional.

Key words*: delta-estuary, Early Aptian, Aralar, Spain.*

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Introduction

The Mendiurkullu Member consisting of shales, siltstones and sandstones is distinguished within the Lareo Formation of the Ataun area, western Aralar. It outcrops discontinuously along 6.5 km, approximately from the east of Ataun to Amiltzu (south of Sarastarri) (Fig. 1). Its age is Early Aptian, *Dufrenoyia furcata* ammonites Zone (García-Mondéjar *et al.*, 2008). The sedimentology and palaeogeography of the Mendiurkullu Member is here described for the first time.

Description

The outcrop of this Member forms a topographic positive relief in the middle part of a marly, lutitic and silty succession of the Ataun area, which serves as a good local correlation marker (Fig. 1). Close to Ataun, the total thickness reaches up to 13 m, and sandstones range from 1 to 13 m in different sections. Considering the whole Aralar area, the Mendiurkullu

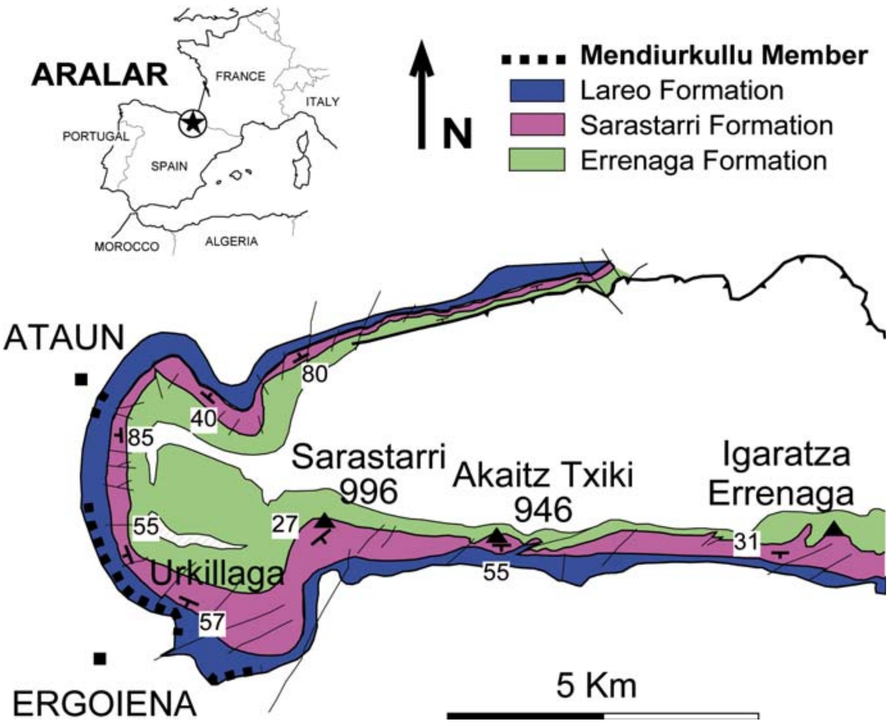

Fig. 1.- Simplified geological map of the Aralar Mountains showing the Mendiurkullu member.

Fig. 1.- Mapa geológico simplificado de la Sierra de Aralar, con la cartografía del miembro de Mendiurkullu.

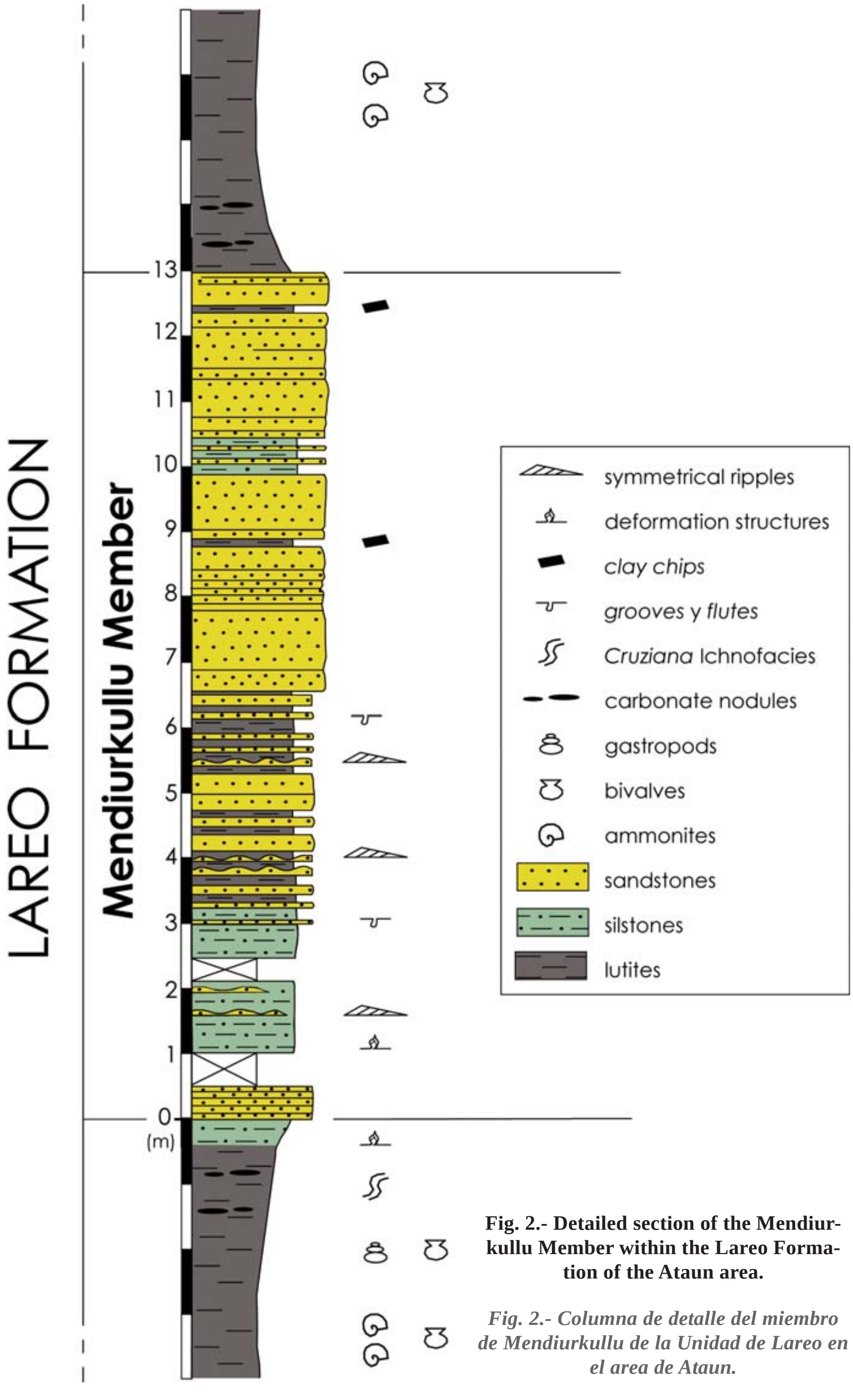

Fig. 2.- Detailed section of the Mendiurkullu Member within the Lareo Formation of the Ataun area.

Fig. 2.- Columna de detalle del miembro de Mendiurkullu de la Unidad de Lareo en el area de Ataun.

Member thins and disappears towards the eastern section of Igaratza, where it is replaced by an erosional surface at the base of the overlying Artxueta Formation. Further east, close to Iribas, a similar surface is present, but which represents a greater hiatus (García-Mondéjar *et al.*, 2008).

In the sections close to the Ataun area (Fig. 2), the Mendiurkullu Member consists of a lower heterolithic interval of fine-grained sandstones and shales. Sandstone beds are planar (< 10 cm) with symmetrical ripples at tops, or they form flaser and linsen structures with shales (Fig. 3). At least the base of one bed it displays spectacular trace fossil assemblages of the *Cruziana* Ichnofacies type (Fig. 4). The associated fine-grained facies appears as splintery shales, locally with flat carbonate nodules arranged in horizontal levels. Upward in the Member, fine-grained sandstone beds 0.2 to 0.5 m thick show slightly erosive bases, which progressively upwards become full laterally-accreted beds related to channel fill (Fig. 5). Other outcrops show only planar sandstone beds (Fig. 2). In the laterally accreted sandstones trough cross-stratification is present. Channel fill massive sandstones are of fine and lesser medium grain size, with scarcely visible deformation structures (quicksands), and rare clay chips and symmetrical ripples. They make up discontinuous lithosomes more than 100 m long and 5 to 10 m thick.

In a section without channels of the same Ataun area (Fig. 1), sandstones show horizontal stratification. They make up 0.3 to 1.5 m thick intervals alternating with dark shales. They are fine-grained with some medium-grained layers, and show flat and slightly sinusoidal parallel lamination, cross-lamination, symmetrical ripple lamination (l=23 cm, h=2 cm), interference ripples with offshoots on bed tops with small hummocks less than 5 cm apart, lutitic flasers and, in some flat-parallel laminated beds, small groove and flute casts at bottoms. The intervening dark shales contain some very thin beds (2-4 cm) of parallel-laminated sandstones.

Interpretation

The types of stratification, grain size and structures of the sandstones suggest different energy levels of transport and deposit currents. These currents were episodic and tractive (thin isolated beds), constant with low and variable energy (heterolithic sandstone-shale intervals), constant with higher and variable energy (sandstones filling channels), and oscillatory (sandstones with symmetrical wave ripples).

Features suggesting tidal influence are heterolithic wavy-bedded mudstones and rippled sandstones at the cycle base, passing upwards to thicker cross-bedded sandstones and channel fills, the latter containing mud chips (e.g. Willis *et al.*, 1999). In areas without thick channel deposits storm-wave turbulence is also invoked, as suggested by well-segregated sandstone beds within lutites, with flat bases and tops, parallel to sinusoidal lamination, groove and flute casts and small hummocky features. These are criteria for storm-wave influenced delta front successions (e.g. Battacharya and Walker, 1991).

The thickening and coarsening upwards sequence in the Mendiurkullu subunit suggests progradation of a siliciclastic submarine system on an open sea platform with ammonites fauna. Similar stratigraphic sequences with symmetrical ripples and channels at summits are associated with delta front sequences (e.g. Battacharya, 2006). Similar facies associations have also been described in recent reflux tidal deltas, but in Aralar we have no evidence of barrier island-lagoon systems. The upward coarsening and general low bioturbation are typical of deltaic progradation (e.g. Willis *et al.*, 1999). However, occasional trace fossils of the *Cruziana* Ichnofacies association (Fig. 3) permit attribution to subtidal, poorly sorted, unconsolidated substrates (e.g. Pemberton *et al.*, 2001). Deposit feeding organisms lived inhabiting these nearshore environments subjected to tidal influence; their traces tended to form horizontally in low-energy sites.

Finally, we conclude that the Mendiurkullu Member in the Ataun area represents a deltaic progradation subjected to tidal and storm influence. The Member ends with an abrupt surface separating sandstones from overlying lutites with carbonate nodules and some ammonites, restoring the open sea platform conditions again (Fig. 2). On the other hand, at this time erosional conditions were prevalent in the eastern areas (Igaratza and Iribas).

Palaeogeographic implications

The outcrop of Mendiurkullu Member in Ataun with disappearance of the sandstones to the north suggests provenance of the clastic facies from the south or southeast (Fig. 1). A slightly earlier carbonate-terrigenous mixed estuarine system within the Sarastarri limestones Formation (underlying the Lareo Formation) was described as the Aia-Zaldibia trough with bioclastic calcarenites (echinoderm packstones-grainstones) and minor sandstones fill (Lertxundi and García-Mondéjar, 1997). This system had an approximately SSE provenance of terrigenous materials, and was attributed to a probable S-N oriented active basement fault.

The Mendiurkullu system succeeded the previous Aia-Zaldibia

Fig. 3.- Detailed picture of sandstone beds with symmetrical ripples at tops.

Fig. 3.- Fotografía de detalle de estratos de arenisca con ripples simétricos.

Fig. 4.- Trace fossil assemblage of the *Cruziana* Ichnofacies type.

Fig. 4.- Traza de asociación fósil del tipo Cruziana Ichnofacies.

Fig. 5.- Laterally accreted sandstones trough cross-stratification.

Fig. 5.- Estratificación cruzada en surco de acreción lateral de canal

system in time, but it was displaced slightly to the west. It appeared as a consequence of the creation of the Etxegarate trough towards the end of the Early Aptian, following a general tilting of the whole Aralar area to the west (García-Mondéjar *et al*., 2008). This tilting had previously caused the drowning of the Sarastarri carbonate platform through two major tectonic pulses (Millán *et al*., 2007). Later on, during the Late Aptian and the Albian, the Etxegarate trough continued as a strong relative subsident area, and especially during the Albian it was the site of big limestone megabreccias and turbiditic facies emplacement with southern provenance (Fernández-Mendiola, 1987).

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