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The Fluvial Analogue Escanilla Formation, Ainsa Basin, Spanish Pyrenees: Revisited

Introduction

No outcrop analogue can match a reservoir perfectly, still analogue studies are an important tool to enhance the understanding of subsurface deposits. The Escanilla Formation in the Ainsa Basin is a much applied analogue for fluvial reservoir studies. In the present study vertical and lateral facies variations are recorded through the fluvial part of the formation (~800 meters), complemented with photo mosaics. The aim has been to improve the understanding of the lateral and vertical architectural trends through the Escanilla Formation and to use this to resolve changes in the depositional environment, and discuss the factors controlling deposition. This information has been used to put the Escanilla Formation into a sequence stratigraphic framework.

Structural development

The Ainsa Basin is located at the western oblique margin of the South-Central Unit (SCU) (Muñoz, 1992) on the Gavarine thrust sheet (Seguret, 1970) (Figure 1). The central and western part of the south Pyrenean foreland basin is represented by several N-S trending folds observed both in the Ainsa Basin and westward along the Sierra Exteriores (Figure 2). The internal folds in the Ainsa Basin (Figure 3) are interpreted to represent growth folds (Dreyer et al., 1999). The Ainsa Basin is bounded to the east by the Mediano Anticline and to the west by the Boltaña Anticline.

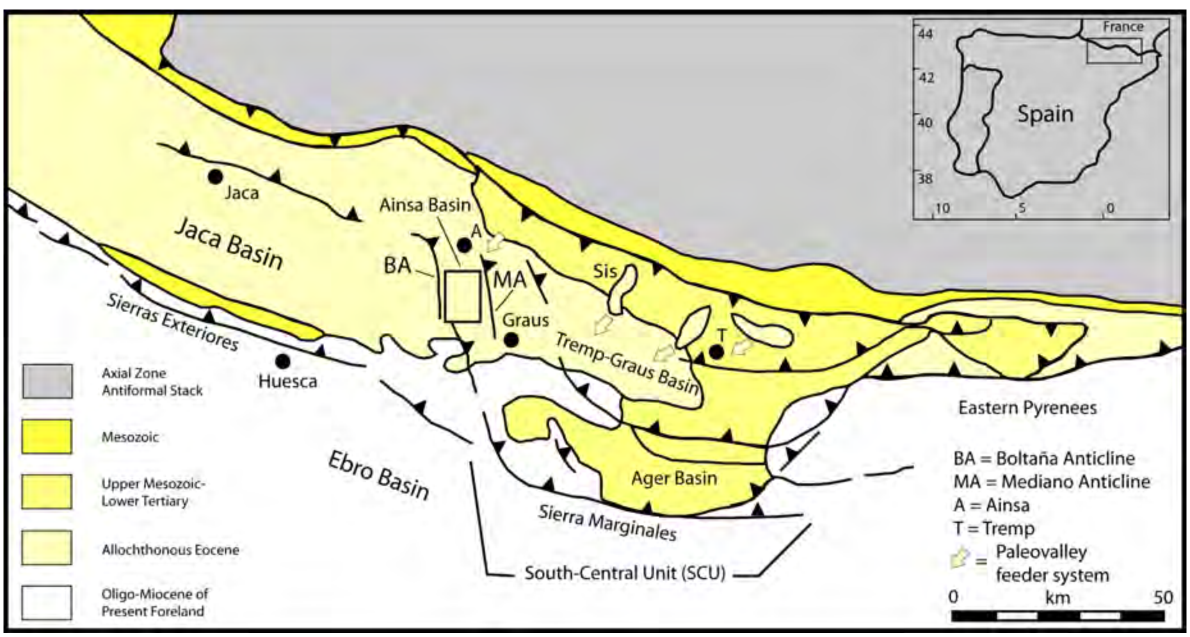

Figure 1 Main structural elements in the southern Pyrenean foreland basin. The study area is indicated by the square (Figure 2) (modified from Bentham et al., 1992)

The Mediano Anticline is suggested to be an asymmetrical detachment fold (Poblet et al., 1998) developed at a thrust termination as the displacement is transferred into folding of the leading edge of the thrust sheet (Jamison, 1987). Poblet et al. (1998) suggested that the Mediano Anticline was still active during the deposition of the Escanilla Formation (latest Eocene). On the western side the Ainsa Basin is bounded by the Boltaña Anticline. This anticline is a regional scale asymmetric anticline located above the western oblique ramp of the Gavarine thrust sheet (Holl & Anastasio, 1995). The anticline is suggested to be a fault-propagation fold above a blind thrust (Muñoz et al., 1998). The Boltaña Anticline was active between 50 - 36 Ma (Anastasio & Holl, 2001), which means that it was active during the deposition of the Escanilla Formation.

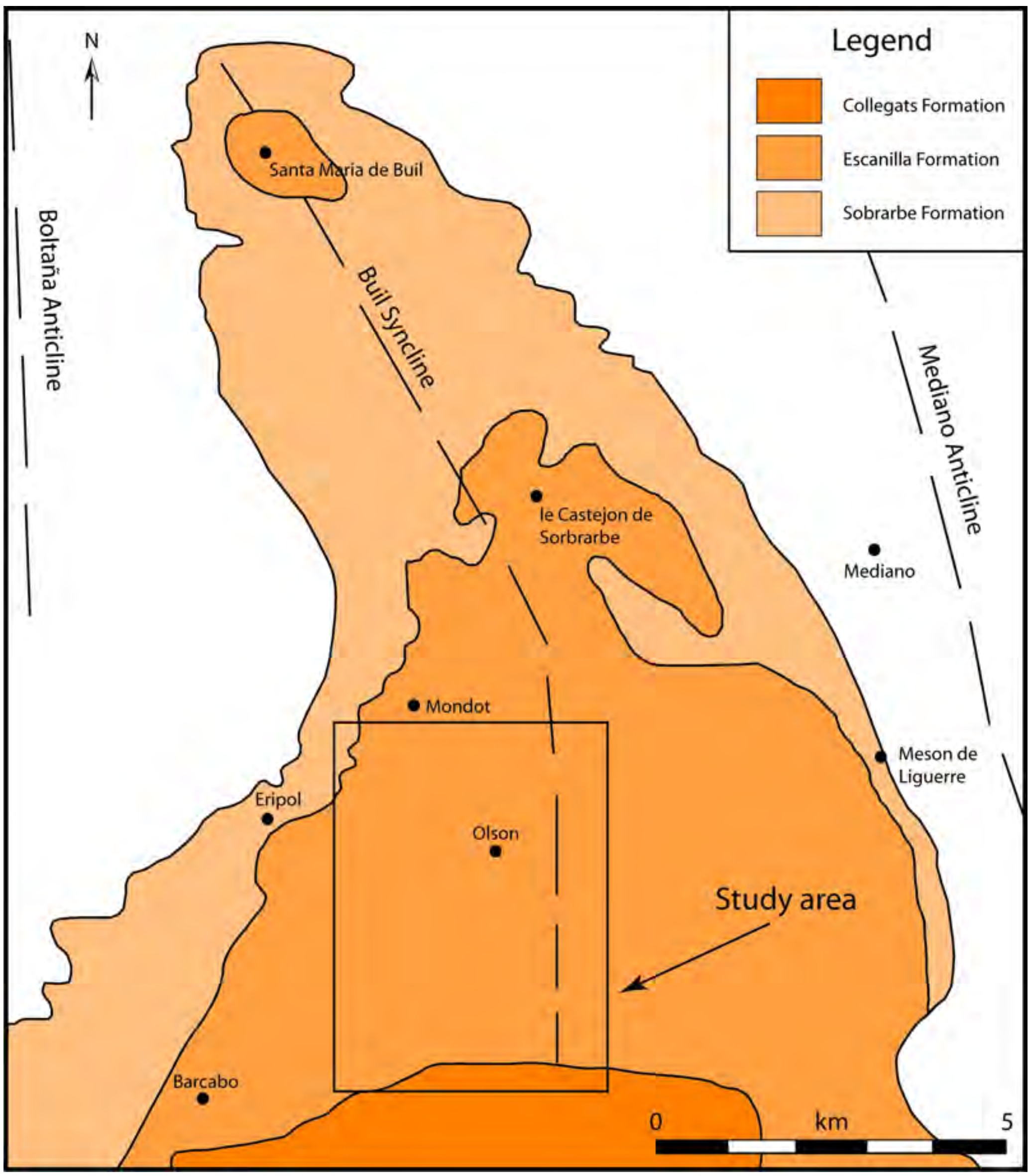

Figure 2 Sedimentological map over the southern part of the Ainsa Basin. The square is indicating the study area. The Boltaña Anticline is slightly projected from the west (modified from Bentham et al., 1992 & Dreyer et al., 1999)

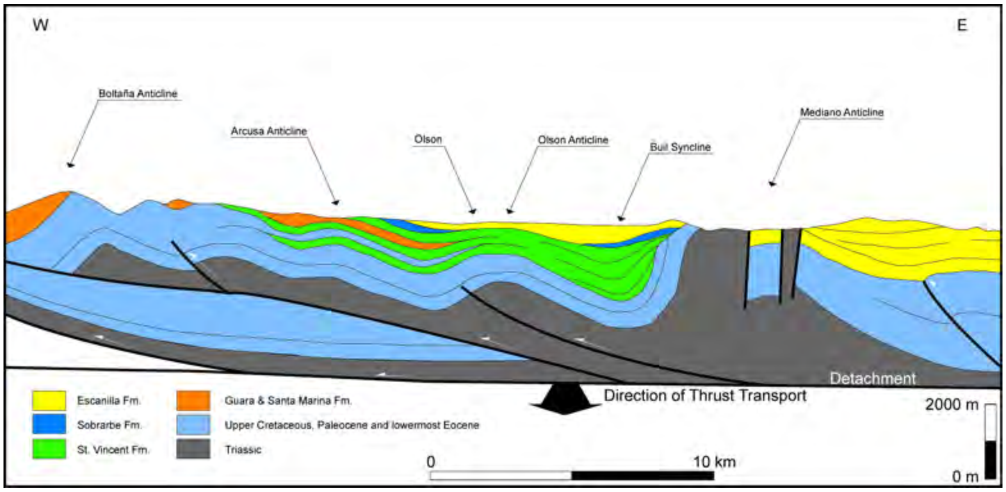

Figure 3 Cross section through the southern part of the Ainsa Basin. Notice the internal folds in the basin (modified from Millan, 1994 in Dreyer et al., 1999).

Depositional history

The Escanilla Formation was deposited between the late Lutetian and the late Priabonian time (approximately 43 - 36 Ma (Bentham & Burbank, 1996)). The Escanilla Formation is mainly sourced from the Pyrenean massif through large valleys, like the Sis palaeovalley (Vincent, 2001) (Figure 1). The Formation is divided into two members, the Mondot- and Olson members. The Mondot member is a transitional unit between the underlying deltaic Sobrarbe Formation and the alluvial Olson member. The Olson member consists only of alluvial deposits, and is unconformably overlain by alluvial fan deposits of the Collegats Formation. During the deposition of the Escanilla Formation the transport direction changed from north to west and in the final infill stage towards the south. The Collegats Formation consists of large alluvial fan deposits covering most of the south Pyrenean foreland basin. Maximum preserved thickness of the Escanilla Formation is approximately 1000 meters within the Ainsa Basin. The Formation thins towards the flanks of the Buil Syncline (Bentham et. al., 1992). It is probable that the Escanilla Formation originally was deposited on top of the Mediano and Boltaña anticlines (Bentham & Burbank, 1996), but has later been eroded.

Results & Discussion

Table 1. The Escanilla Formation is divided into 11 facies associations (FA-1 to FA-11).

Environment	FA	Lithofacies	Lateral extent	Code	Interpretation of depositional setting
Marginal marine deposits	Delta top deposits	Sandy deposits Muddy deposits		FA-1	Delta top (Sobrarbe Fm.)
Alluvial deposits	Debris flow deposits	Conglomeratic deposits		FA-2	Debris flow
	Channel deposits	Conglomeratic deposits	Study area	FA-3	Braid plain
			Moderate	FA-4	Braid plain Braided channel belt
			Narrow	FA-5	Confined braided channel
		Sand dominated deposits	Wide	FA-6	Sinuous channel
			Narrow	FA-7	Confined straight to sinuous channel
	Overbank deposits	Conglomeratic deposits		FA-8	Sheet flood
		Sandy deposits	Wide	FA-9	Crevasse, crevasse channel
		Muddy deposits	Regional	FA-10	Vertical accretion on floodplain, abandoned channel
		Calcrete deposits	Regional	FA-11	Paleosol

Environment & Controlling factors

The Escanilla Formation is in the study area subdivided into three main units based on changes in the alluvial geometry and architecture. These three units are further subdivided into 7 unconformity bounded sequences (Figure 4).

Sequence 1 (Figure 4) consists mainly of narrow, sand-dominated channel deposits (FA-7) (Table 1) interbedded with overbank deposits (FA-9 & FA-10) (Table 1), and is thought to represent an aggrading to slightly prograding coastal plain environment. The lower boundary is transitional from the deltaic Sobrarbe Formation. The architecture and geometry are thought to be controlled by a high accommodation space and high sediment supply. During deposition the shoreline position was controlled by the rate of rise of the Boltaña Anticline, and the interplay between sediment supply and the rate of rise of the Boltaña Anticline controlled the deposition in the system.

The base of **sequence 2** (Figure 4) is highly erosive, overlain by low sinuous channel deposits (FA-3) (Table 1) grading into high sinuous channel deposits (Ss-2.1) (Figure 4). The remaining part of sequence 2 is dominated by FA-6 and FA-7 (Table 1) interbedded with overbank deposits. The system was situated close to the shoreline, and this sequence represents a transition between coastal plain and alluvial plain setting. Sandstone body Ss-2.1 is thought to represent a period of low, but fluctuating A/S-ratio, resulting in a highly amalgamated sandbody with several internal erosional surfaces. The rest of the sequence is deposited during a period of first rise and then fall of accommodation space, with a high and stable sediment supply.

The base of **sequence 3** (Figure 4) marks a large basinward shift in facies, overlain by braid plain deposits (FA-3) (Table 1). Sandstone unit Ss-3.1 (Figure 4) can be traced through the entire study area. The sequence boundary is thought to represent a bypass surface caused by a prolonged low accommodation space and an increased sediment supply. The upper part of sequence 3 is highly dominated by overbank sediments, and is thought to be deposited during a period of first rising and then falling accommodation space. Sequence 3 marks a change towards a period of decreasing A/S-ratio up to Ss-6.1, and also a gradual change from temperate towards arid climate.

Sequence 4 (Figure 4) is represented by large lateral and vertical variations in the study area. The lower boundary is put at the base of an interpreted basin wide conglomeratic body (Ss-4.1). The sequence is deposited in an alluvial plain setting, mainly covered by overbank deposits, and a few aggrading fluvial channel deposits. The amalgamated conglomeratic channel deposits are thought to be formed by stabilizing of the main distributaries by differential movements of the intra-basinal folding. In this setting, intra-basinal areas with low accommodation space became barriers for lateral movement of the river systems. The high mud content also stabilized the river systems. There is a clear eastward shift of the system at the level of sandstone unit Ss-4.2 (Figure 4). This shift is thought to represent a gradual rotation of the system brought about by change in direction of the controlling folding. All the coarse-grained material in the system was either deposited in the main aggrading channels, or it was bypassing the system. The accommodation space is thought to be quite high during deposition, with a gradual decrease upwards. The amalgamated sandstone bodies of the Ss-4.1 level are interpreted to have formed as interplay between increased sediment supply and a low accommodation space. In the upper part of sequence 4, a marked increase in frequency of calcrete horizons may indicate a reduction in the A/S-ratio and a change towards a more arid climate.

Sequence 5 (Figure 4) starts with a thick lateral extensive conglomeratic deposit covering most of the study area (Ss-5.1). The remaining of the sequence is dominated by FA-6 (Table 1) grading into FA-4 (Table 1), interbedded with overbank deposits abundant in extensive calcrete horizons. Sequence 5 is thought to represent a period with low accommodation space and low sediment supply. The main distributary system is interpreted to be shifted out of the study area during deposition of Ss-5.1 (Figure 4), resulting in a high content of fine-grained material.

Sequence 6 (Figure 4) represents a shift to a hinterland stepping alluvial plain setting, and is introduced by a laterally extensive conglomeratic body. Calcrete horizons are frequently observed. The coarse grained material is interpreted to have been deposited during large flooding episodes, interbedded with overbank deposits during periods of low drainage, which implies short-lived river systems. Climate is a major factor controlling deposition in sequence 6. The decrease in coarse-grained material in the zone Z-6.3 (Figure 4), is influenced by increasing accommodation space, suggested by the lack of calcrete deposits, and an increased sand and mud content.

Sequence 7 (Figure 4) starts with a thick conglomeratic deposit interpreted to have a basin wide extent. In this sequence the first debris flow deposits are observed (FA-2) (Table 1). Such deposits suggest an alluvial fan setting. No calcrete horizons are observed in this sequence. The accommodation space is suggested to be low and the rate of sediment supply on average moderate, but strongly fluctuating. Fluctuating capacity of the river system is interpreted to have controlled the abrupt changes between mud and conglomeratic deposits. The available source material may be an important factor explaining the low percentage of sand in this sequence. Creation of accommodation space was faster than rate of sediment supply. The lack of coarse sediments to fill in the accommodation space resulted in only background sedimentation preservation (muddy intervals). The lack of lacustrine deposits are thought to be caused by the dry climate, and the low potential for lakes. Some of the deposits in the upper unit may have been deposited in short-lived lakes, but no firm evidences are found. Sequence 7 is unconformably overlain by the alluvial fan deposits of the Collegats Formation (Figure 4). Sequence 7 may be interpreted as the lowermost part of the Collegats Formation, and thus the hiatus on Figure 4 would be situated at the base of this sequence.

Conclusion

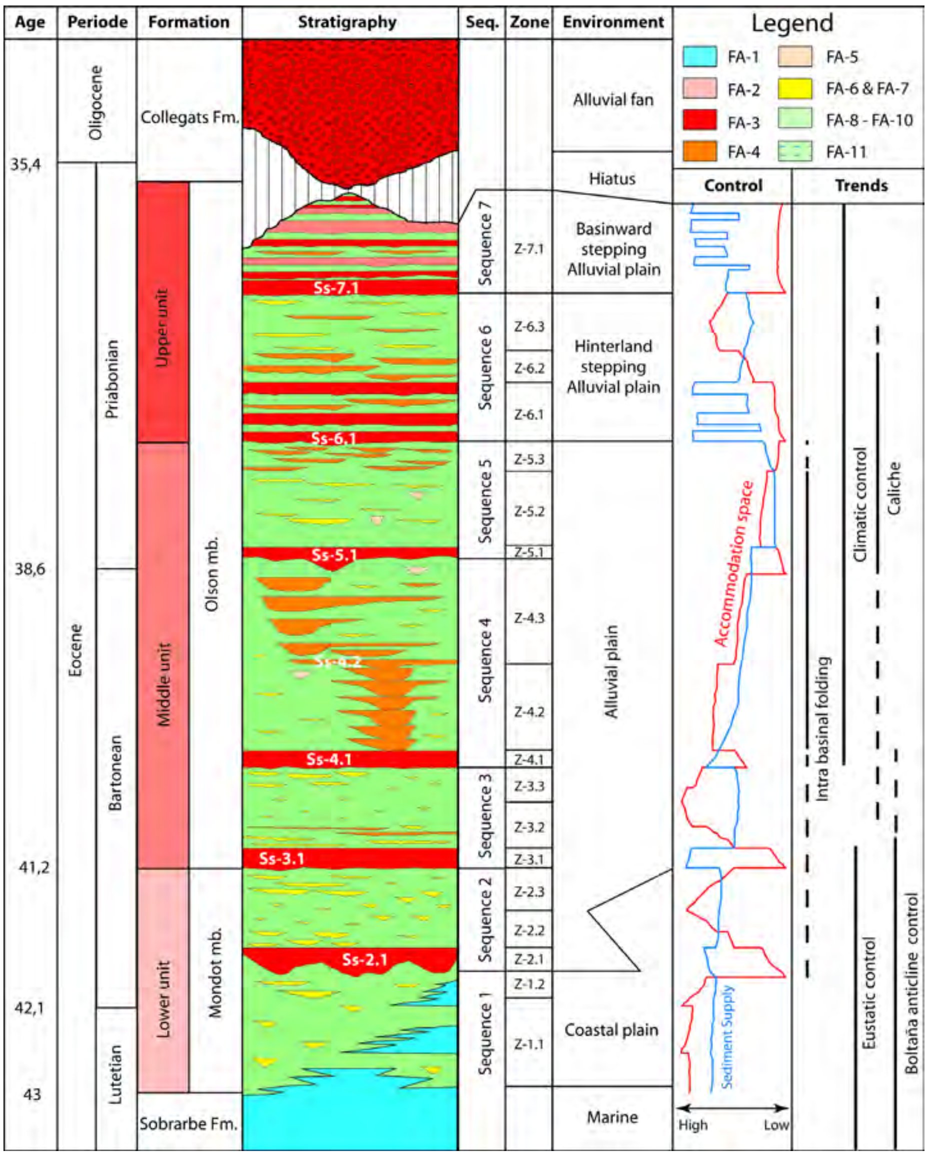

Figure 4 Summary of the sequence stratigraphic interpretation of the Escanilla Formation. The Formation is divided into seven sequences. The main controls are intra basinal folding in interplay with climatic changes. The climate is controlling the drainage, and thus the sediment input (Ages form Bentham et al., 1992).

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