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Coupling far and near tectonic signals in syn-orogenic sediments: the Olvena growth strata (Sierras Marginales, southern Pyrenees)

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ABSTRACT

The Olvena area (Sierras Marginales, southern Pyrenees) provides an outstanding example for studying the relationships between tectonics and sedimentation related to fold-and-thrust systems having shallow *décollements*. Stratigraphic and sedimentological features allow infer i) the relationship between Oligocene-Miocene locally-sourced alluvial fans and a far-sourced wider fluvial system, and ii) the control exerted by tectonics on the stratigraphic architecture. Initially, uplift resulting from folding and thrusting in the Sierras Marginales precluded the entrance through this area into the Ebro basin of a wide fluvial system sourced in internal zones of the Pyrenean chain (including the Axial Zone). A subsiding area was created in the southern front of the Sierras where west-flowing alluvial fans generated, having their source areas in the rejuvenated reliefs. The subsequent cessation of movement of the tectonic structures permitted these reliefs to be subdued and the overpassing of the north-coming fluvial system that progressively covered a wider area. Sequential evolution and stratigraphic architecture evidence thrust emplacement geometry and chronology, including out-of-sequence reactivation of structures and the influence of evaporite flow along the *décollement*. Although these syn-tectonic deposits belong to the Ebro basin succession, its megasequential evolution differs from the general sequence established for the basin fill, highlighting the importance of differentiating the influence of near-coming sedimentary systems when interpreting basin-scale sequence stratigraphy.

KEYWORDS **Continental sedimentation. Growth strata. Sequence stratigraphy. Décollement. Southern Pyrenees.**

INTRODUCTION

The most external areas of fold-and-thrust foreland belts are especially sensitive to tectonic processes since they usually record continental sedimentation synchronous to the latest tectonic pulses of the orogen. Despite climate can control the sedimentary facies distribution, the stratigraphic architecture and the timing of individual sedimentation episodes in continental range-front sediments, tectonic activity governs long-term sedimentation rates and geometrical relationships between stratigraphic units (*e.g.* Pardo *et al.*, 1989; Quigley *et al.*, 2007; Riquelme *et al.*, 2007; Bridge and Demico, 2008; Catuneanu *et al.*, 2010). In these scenarios and without important climatic changes masking the tectonic signal, distinguishing between far and near tectonism is crucial to understand the geodynamic coupling between active fold-and-thrust belts and adjacent foreland basins (Galloway, 1989a,b) and to characterize the local tectonic activity of the most external part of fold-and-thrust belts, respectively.

The rate of sediment influx to a basin also exerts a first-order control on stratal architecture (Paola *et al.*, 1992). Sediment flux can vary as a function of morphotectonic processes in the source terrain, such as fold and thrust growth, variations in bedrock lithology, drainage pattern changes and temporary sediment storage in intermontane basins. Drainage diversion in response to folding or thrusting is not normally taking into account in the interpretation of foreland stratigraphic sequences although it can produce major shifts in the location and magnitude of sediment source points (Burbank *et al.*, 1996; Tucker and Slingerland, 1996; Luzón and González, 2000).

The excellent preservation of the syn-orogenic Oligocene-Miocene rocks in the southern Pyrenees (Fig. 1A), related to the external thrust sheets, makes this area an excellent natural laboratory to analyse the relationship between tectonics and sedimentation. Within the southern Pyrenees, we have selected the western end of the Sierras Marginales Unit (Fig. 1B), one of its southernmost external thrust sheets, due to the occurrence of magnificent continental range-front growth strata and interfering sedimentary systems characterized by different sizes and source areas. A good knowledge of the structure in-depth together with the characterization of the sedimentary architecture of the syn-tectonic deposits have allowed to infer far and near tectonic activity and to highlight the influence of locally-derived sedimentary systems in the general trend of the basin-scale stratigraphic sequences.

GEOLOGICAL SETTING AND STRUCTURE OF THE STUDY AREA

The Pyrenean orogen resulted from the convergence between the Eurasian and Iberian plates from Late Cretaceous to Oligocene-Miocene times (*e.g.* Roest and Srivastava, 1991; Rosenbaum *et al.*, 2002). Its overall structure shows a largely exhumed and denuded Axial Zone at the core of the orogen, bounded by Mesozoic syn-rift and Cenozoic syn-compressional rocks, the North and South Pyrenean Zones. The latter underwent a development of foreland and then detached piggyback basins during the Pyrenean orogeny (*e.g.* Muñoz, 1992). South- and northwards, the Ebro and Aquitanian basins are the autochthonous foreland basins.

Within the South Pyrenean Zone, the Sierras Marginales is one of its outermost thrust sheets, emplaced during Late Eocene-Oligocene (Garrido-Megías, 1973; Vergés and Muñoz, 1990; Teixell and Muñoz, 2000) at the tip of the South Pyrenean Central Unit (Séguret, 1972). During Late

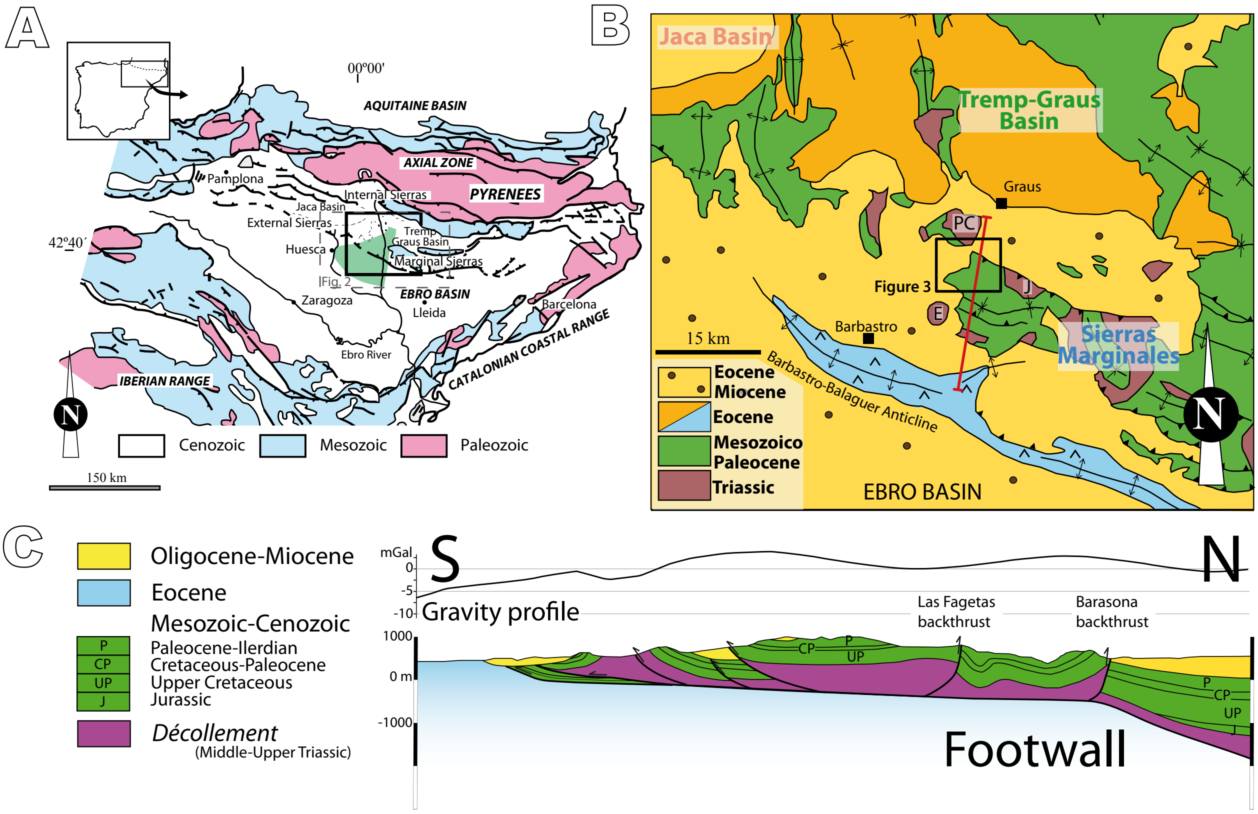

FIGURE 1. A) Synthetized geological map of the northeastern Iberian Peninsula. B) Geological map of the western end of the South Pyrenean Central Unit (black frame on A). PC: La Puebla de Castro diapir; J: Juseu diapir; E: Estada diapir. C) Representative cross-section of the Sierras Marginales thrust sheet near the studied area and Bouguer anomaly gravity profile.

Oligocene-Miocene times this thrust sheet was internally deformed by folding and fracturing (Pocoví, 1978; Teixell and Muñoz, 2000). The Sierras Marginales sheet thrusts over 4000m of syn-tectonic, continental deposits of the Ebro foreland basin along a low angle foot-wall ramp (Martínez-Peña, 1991; Senz and Zamorano, 1992; Gil and Jurado, 1998). It is structured as a doubly-verging, thin-skinned fold-and-thrust system (Fig. 1C) whose geometry is controlled by an extremely thinned Mesozoic-Cenozoic cover detached above a thickened Triassic *décollement* and by thickness variations in syn-tectonic deposits (Millán *et al.*, 2000). Consequently, thrusts, backthrusts, out-of-sequence thrusts, strike-slip faults and diapiric structures are common features (Pocoví, 1978; Martínez-Peña, 1991; Millán *et al.*, 2000; Teixell and Muñoz, 2000). The studied area lies on the western sector of this thrust sheet, in the transition zone between N-S and WNW-ESE, Pyrenean trending structures (Fig. 1B).

The regional *décollement* is represented by Middle-Upper Triassic evaporites and mudstones with interbedded limestones, dolostones (Salvany and Bastida, 2004) and doleritic sills (Lago *et al.*, 1987, 2000). Overlying them, sparse Jurassic limestones, dolostones and marls crop out (Aurell and Meléndez, 2002), but its most representative succession is characterized by Upper Cretaceous limestones and marine sandy limestones that grade onto Cretaceous-Paleocene lacustrine limestones and mudstones (Garumn facies) and Paleocene-Ilerdian shallow marine limestones (Pocoví, 1978). These rocks are unconformably overlain by a thick continental succession (Fig. 1B). To the north, it comprises the Oligocene Graus conglomerates (Reynolds, 1987) whereas to the west and south, it corresponds to the upper part of the Sariñena Formation (Fm.), as indicated by the stratigraphic correlation with close outcrops of this formation (Luzón, 2005). This correlation was established using photogeological levels, lithological features and geological mapping by Navas (2011). The Sariñena Fm. consists mainly of sediments belonging to the Huesca fluvial fan (Fig. 2), sourced in the Axial Zone and neighbouring areas, which crossed the frontal Pyrenean thrusts and spread into the Ebro foreland basin (Hirst, 1983; Hirst and Nichols, 1986). However, close to the frontal thrusts, the Sariñena Fm. also includes sedimentary systems generated in locally sourced, small alluvial fans (Senz and Zamorano, 1992; Luzón, 2001, 2005) as it occurs within its western equivalent, the Uncastillo Fm. (Arenas *et al.*, 2001). Older conglomerates, previously deformed that can be synchronous to the Graus conglomerates are locally observed in the northern part of the studied zone.

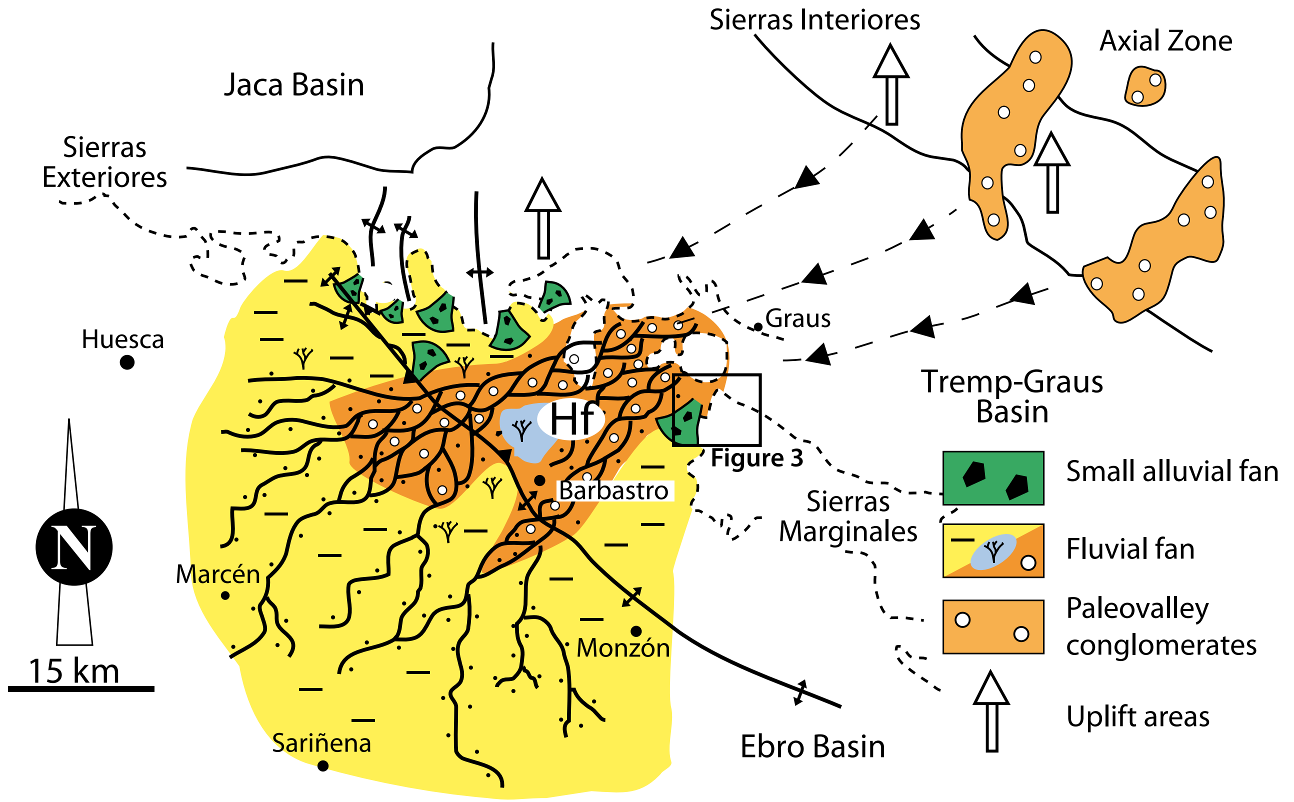

FIGURE 2. Main fluvial and alluvial sedimentary systems draining towards the Ebro Basin during Oligocene-Miocene times (modified from Luzón, 2005). Black frame indicates studied area. The Huesca fluvial fan is marked with (Hf). (Greenshaded fan in Figure 1A).

The characterization of the structure of the studied area was done by means of a detailed geological map (based on Navas, 2011) and field data (Fig. 3). It consists of a fold-and-thrust system that affects a pre-tectonic Mesozoic-Ilerdian sequence and syn-tectonic Oligocene-Miocene alluvial and fluvial deposits (Fig. 3). Two steep backthrusts (Barasona and Las Fagetas) bound a gently folded area where the Middle-Upper Triassic *décollement* thickens towards the anticline cores (Fig. 3). The overall structure shows a WNW plunge (Santolaria and Casas-Sainz, 2013), allowing the preservation of syn-tectonic deposits in its western part, that are finally covered by Quaternary fluvial deposits of the Cinca River. To the south, forelandward verging, shallower, smaller thrusts also root in the Middle-Upper Triassic *décollement* (Fig. 1C). In the northwestern sector of the studied area, the Barasona backtrust dies out into a diapiric structure and is partially covered by the youngest preserved unit, the Sariñena Fm. Las Fagetas backthrust is associated with an asymmetric anticline whose northern vertical limb is the southern limit for the continental syn-tectonic deposits. Las Fagetas backthrust can be followed from the Cinca River in the west (where it is covered by Quaternary terraces) to the Triassic rocks in the core of its associated anticline to the east. In the middle of its trace it is related to a set of strike-slip faults probably related to a NE-SW oblique relay ramp at the eastern limit of the outcrop of syn-tectonic deposits (central part of fig. 3), responsible from the strong plunge of the structure towards the west. In the western limit of the studied area, another NE-SW oblique structure affecting the syn-tectonic deposits is responsible for i) dip directions of the syn-tectonic sequence towards the NW and WNW, oblique to the Pyrenean trend and ii) the final burial of these deposits towards the Cinca River. Surrounding the studied area, the presence of three diapiric structures (La Puebla de Castro, Juseu and Estada diapirs; Fig. 1) represented by circular to elliptical outcrops of Middle-Upper Triassic evaporites and mudstones denotes the remarkable salt tectonic activity that took place in this sector.

THE SYN-TECTONIC SUCCESSION

In order to study the stratigraphic architecture of the involved syn-tectonic rocks, a photogeological interpretation and two stratigraphic logs were made and field data were collected in a selected area where spectacular relationships between pre- and syn-tectonic rocks are depicted. Firstly, the analysis of 1:5000 satellite images and field observation permitted to define the geometrical relationships between the pre-tectonic and the syn-tectonic deposits (Figs. 4; 5), whose older levels are characterized by a progressive unconformity (growth strata, Figs. 4; 5A, B) related to the movement of Las Fagetas backthrust. Towards the north, the upper part of the succession involved in the growth strata either laps

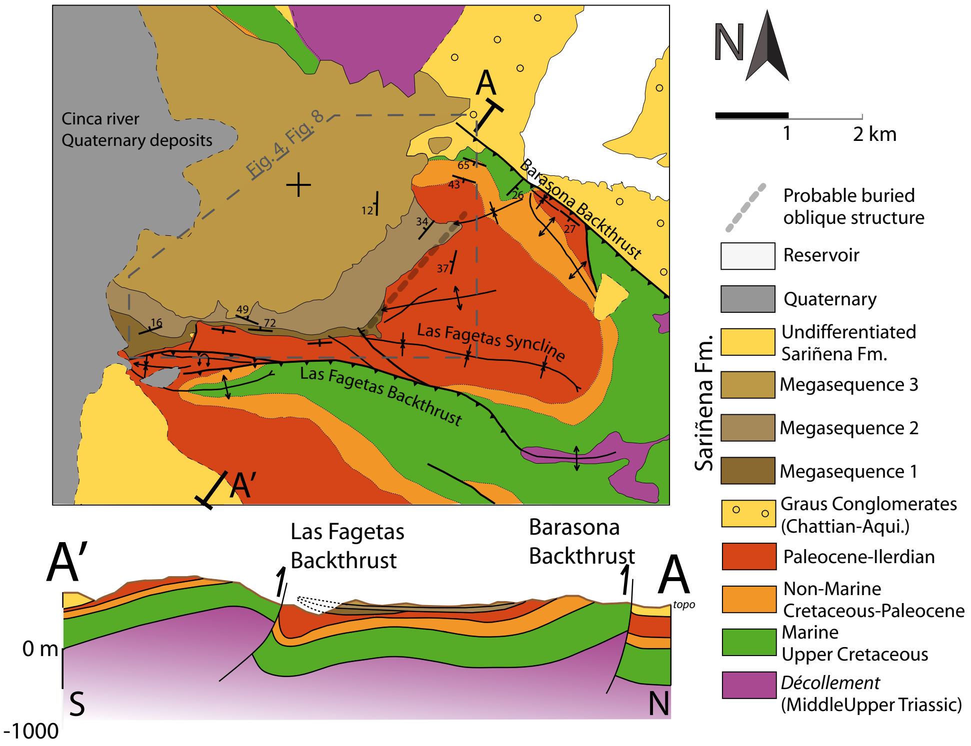

FIGURE 3. Geological map of the area and cross section where syn-tectonic megasequences differentiated in this work are included (black frame on Fig. 1B).

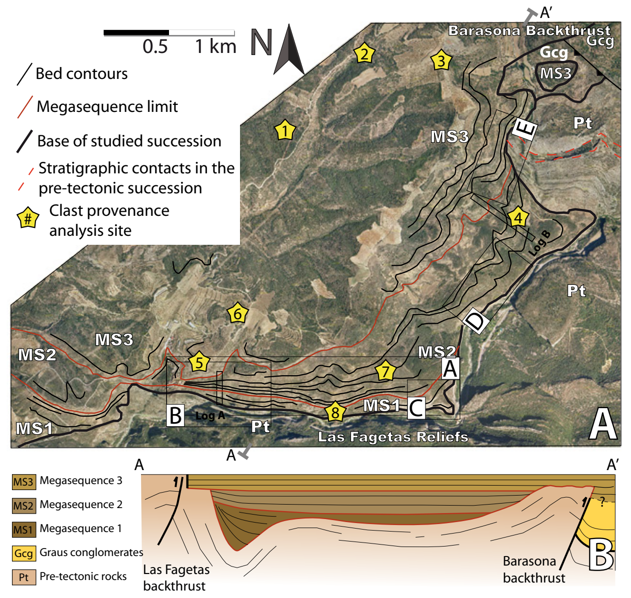

FIGURE 4. A) Interpreted satellite image where megasequence and their boundaries are depicted. B) Sketch that summarizes the geometry of the syn-tectonic succession in relation to structural features of the pre-tectonic succession (see approximate location in A).

onto gentle folds affecting the pre-tectonic series (Figs. 4; 5C), or lies paraconformably on Paleocene-Ilerdian marine limestones (Figs. 4; 5D); finally, the youngest deposits cover the Barasona backthrust and related detachment anticline (Figs. 4; 5E).

The stratigraphic logs are located i) in the southern area, along the progressive unconformity (Log A, Fig. 4) and ii) in the northern sector, where the syn-tectonic succession laps onto the eroded, pre-tectonic rocks (Log B, Fig. 4). Logs and field observations have permitted to recognize three main mappable lithofacies associations defined by lithology (including more than one lithology), bed shapes, textural features and clast provenance (Fig. 6): monogenic conglomerates (mC), polygenic conglomerates and sandstones (pCS) and mudstones and sandstones (MS).

Monogenic conglomerates (mC) are composed by clast- or matrix-supported angular to rounded, light grey limestone pebbles to boulders (Fig. 7A, B); rare well-rounded, small-sized (<5cm) siliceous clasts can be observed. They form poorly to well-sorted, up to 8m thick tabular or irregular, sometimes channeled, bodies with internal irregular erosive surfaces, fair horizontal bedding and cross bedding (Fig. 7C). Fining and coarsening upward cycles can be observed. Conglomerates intercalate rare lenticular strata of coarse to fine orange sandstone or mudstone, which include scattered carbonate clasts and show pedogenic features. Measured paleocurrents indicate W and S-SW-directed flows in the southern and northern zones of the studied area respectively. These deposits have been interpreted as generated under unconfined flows passing downstream to braided channels with low-relief longitudinal conglomerate bars. Mass flow processes were frequent. This lithofacies corresponds to the proximal sectors of near sourced small alluvial fans.

Polygenic conglomerates and sandstones (pCS) are brown in color, grain-supported and contain coarse sandy matrix. They form metric tabular bodies with channeled bases and internal surfaces (Fig. 7D). More variable clast lithology than in mC exists, with rounded to subrounded pebbles and cobbles of brown and grey sandstone, black and grey limestone, quartzitic conglomerates, quartz clasts, schists, granites and volcanic rocks (Fig. 7E). Clast percentage of each lithology changes from west to east with increasing locally derived grey limestone clasts near the tectonic structures (Figs. 6; 7F). Horizontal bedding, clast imbrication, cross bedding, and scour structures are common features. Grey to brown intercalated sandstones form tabular bodies with channeled bases and internal erosive surfaces; they show cross bedding and cross

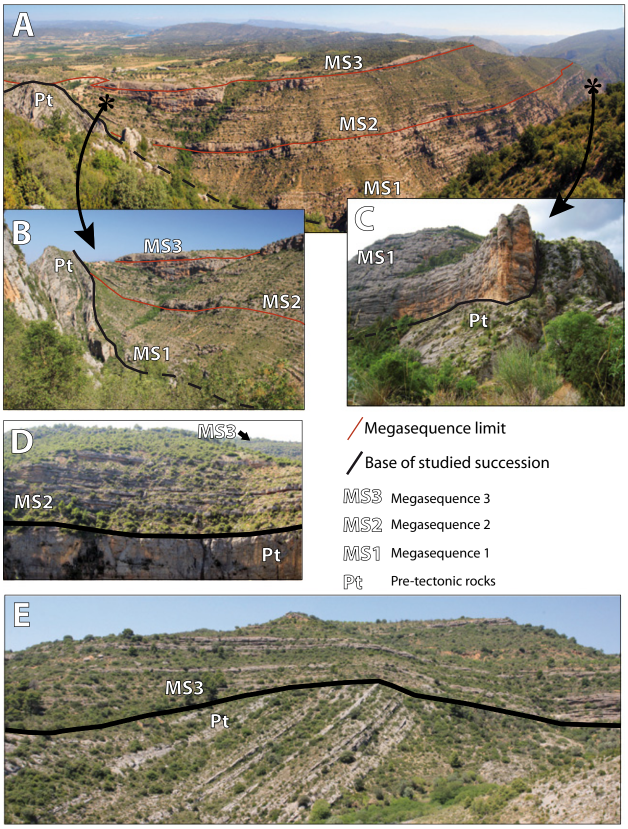

FIGURE 5. A) Studied succession at the southern margin of the area (from the Las Fagetas backthrust reliefs). B) Growth strata close to the Olvena village. C) MS1 onlapping pre-tectonic rocks. D) Paraconformity between MS2 over pre-tectonic rocks. E) Angular unconformity between pre-tectonic rocks and MS3.

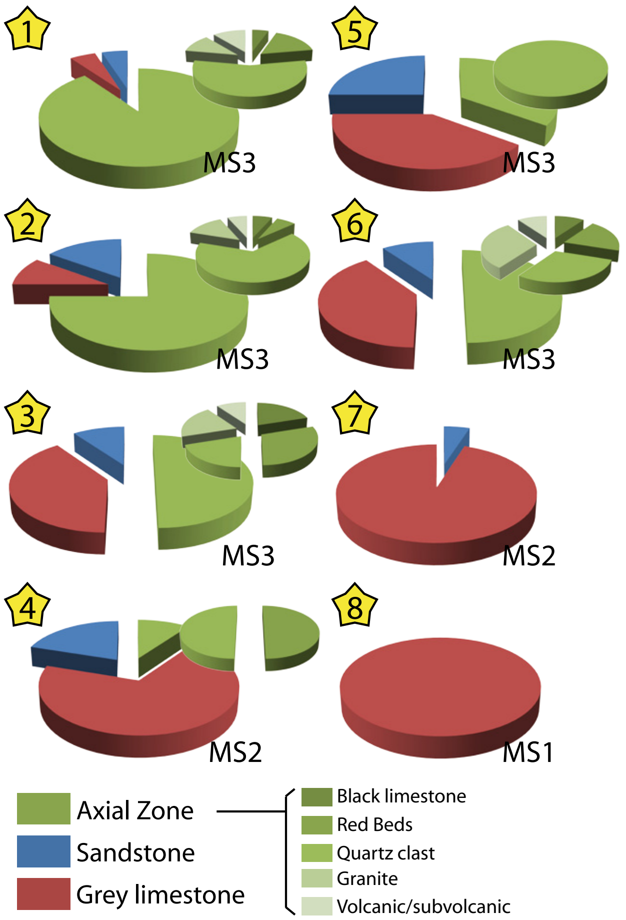

FIGURE 6. Diagrams showing percentages of each clast lithology; the provenance area and the corresponding megasequences (MS) are indicated. See Figures 4 and 8 for site location.

lamination and commonly include pebble pockets. Orange mudstones with pedogenic features are scarce. Measured paleocurrents indicate S-SW-directed flows. These deposits have been related to the development of braided shallow channels and longitudinal or transverse bars located in the middle sector of a large alluvial fan coming from northern Pyrenean areas. This corresponds with the Huesca fluvial system (Fig. 2).

Mudstones and conglomerates (MC) are integrated by orange mudstones with intercalated monogenic grey conglomerates and orange sandstones. Mudstones form metric to decametric bodies and can show pedogenic features as root traces and carbonate nodules. Conglomerates are grain-supported and integrate decimetric to metric tabular to lenticular bodies made on subangular-rounded light grey limestone pebbles to cobbles (Fig. 7G). Fine to medium sandstones form tabular decimetric strata with scattered carbonate clasts and occasional root traces. These deposits have been interpreted as generated by unconfined floods and occasional development of channels and lobes in the middle sector of locally derived small alluvial fans.

When the stratigraphic evolution is considered, three megasequences (MS1, MS2, MS3) can be identified (Fig. 8). MS1 is coarsening upwards whereas MS2 and MS3 are fining upwards. MS1 and MS2 are mainly made on mC and MC lithofacies, whereas MS3 is integrated by pCS lithofacies. In the southern area (including Log A) the 3 megasequences are present whereas towards the north (including Log B) only MS2 and MS3 crop out (Figs. 8; 9). MS1 laps onto the northern flank of Las Fagetas syncline in the southeastern basin border (Fig. 5C) and is not present northwards. In contrast, MS2 is expansive and spreads towards the north depicting, at the same time, a northwards thickening trend from the growth strata close to the southern basin border (Fig. 8). Map extension of MS3 includes most of the studied area and its vertical continuation is not considered in the stratigraphic logs. Unfortunately the preserved MS3 strata do not reach the southern and eastern basin borders. Subhorizontal disposition of MS3 close to the southern border suggests that Las Fagetas backthrust was not active during MS3 deposition. This megasequence unconformably covers the Barasona backthrust in the northern area (Figs. 3; 4; 5E; 8).

The lithofacies distribution (Fig. 9) indicates that two main alluvial fans developed (Fig. 10): a larger one spread towards the WNW and was sourced in Las Fagetas backthrust associated reliefs; a smaller one, located northwards, was sourced in the Barasona backthrust associated reliefs and spread towards the SSW. More organized, polygenic conglomerates and sandstones (pCS) represent a SW flowing fluvial system coming from Pyrenean areas closer to the Axial Zone and also shows limestone clasts derived from the near sourced alluvial fans, especially towards the easternmost part of the studied area.

MS1 coarsening-upwards trend reflects the progradation of the local alluvial fans, especially the one sourced in Las Fagetas reliefs (Figs. 5A, B; 8) whereas MS2 (fining upwards) registers the subsequent retrogradation of those fans (Figs. 5A, B; 8). Megasequence MS3 implies an abrupt sedimentological change, mainly regarding the clastic source area (Fig. 6) and a fluvial style that indicate that the north-coming fluvial system underwent a sudden expansion into the Ebro basin. Correlation, with more western zones where the megasequential evolution has been previously established (Luzón, 2005), using photogeological guide levels, allow to propose that MS1 corresponds to the upper part of UTS T3, whereas MS2 and MS3 corresponds to the lower part of the UTS T4 (Fig. 9). Transition between T3 to T4 has been demonstrated to be an episode of active tectonic activity in the Pyrenees (Muñoz *et al.*, 2002; Luzón, 2005).

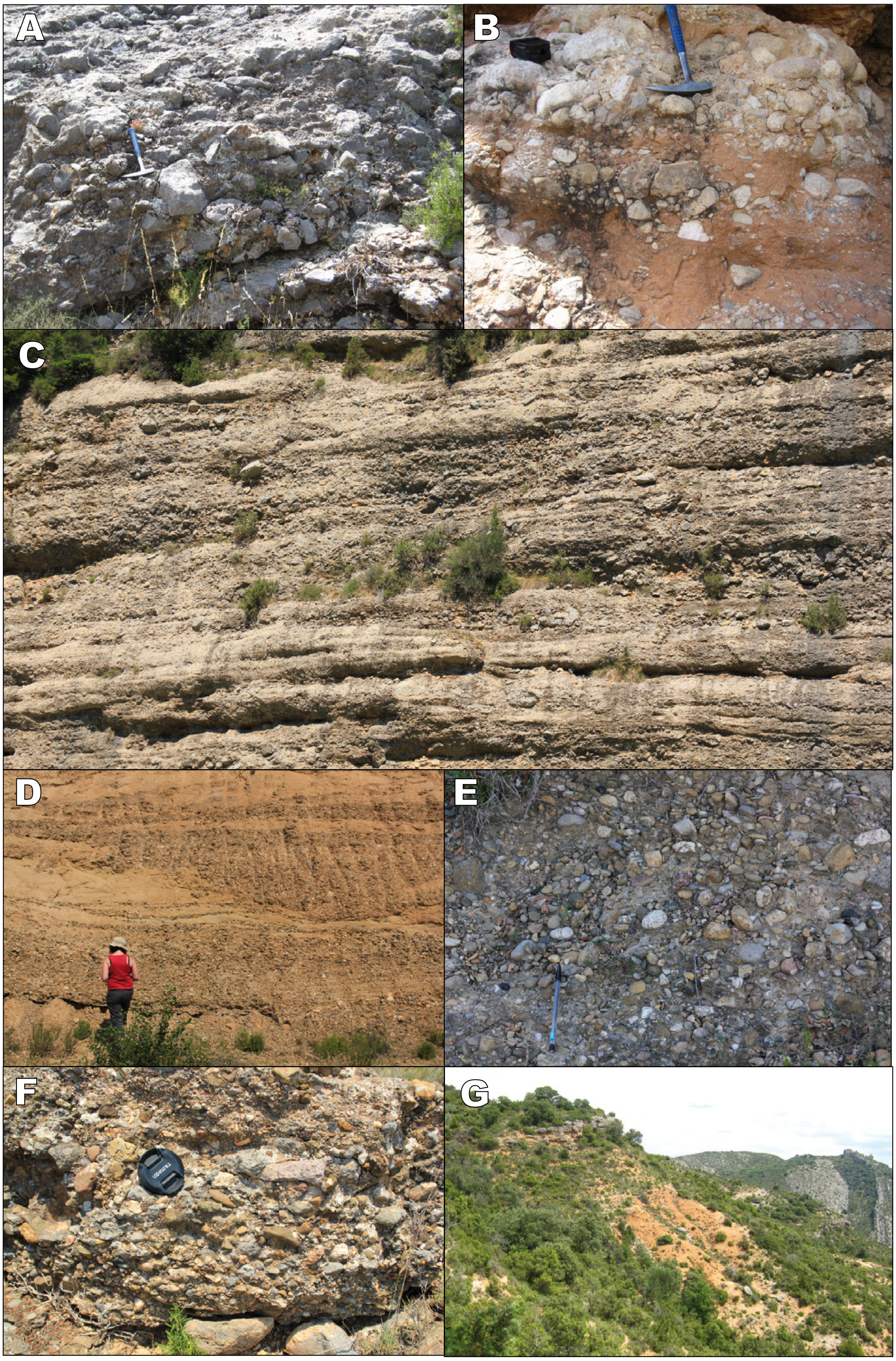

FIGURE 7. A, B, C) Monogenic conglomerates (mC) lithofacies association; D, E, F) polygenic conglomerates and sandstones (pSC) lithofacies association and G) mudstone and conglomerates (MC) lithofacies association. See text for details.

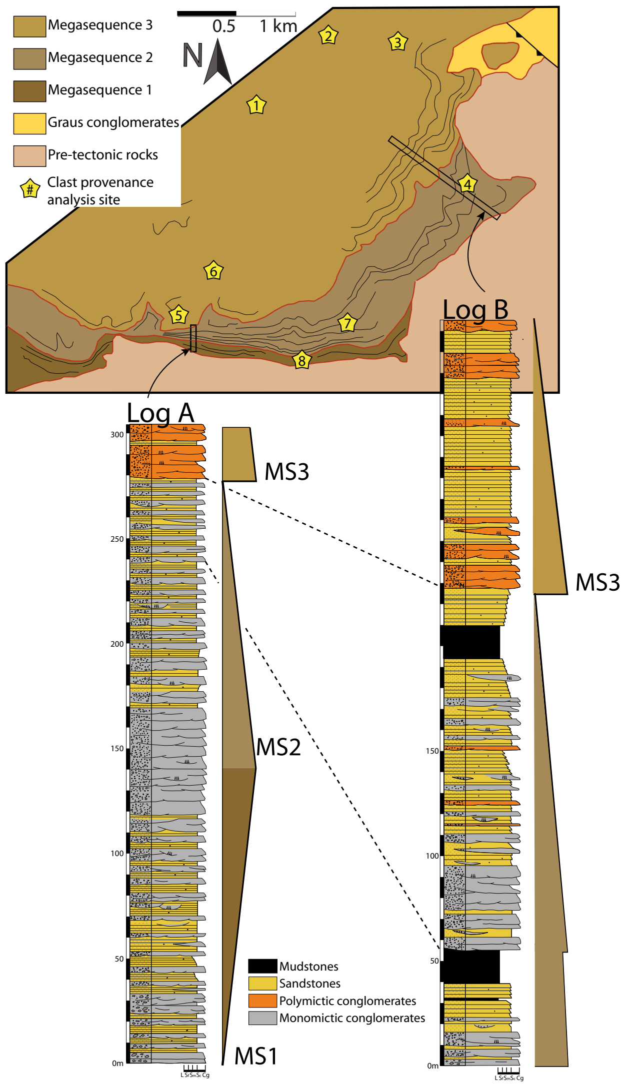

FIGURE 8. Stratigraphic logs and map showing the areal distribution of megasequences.

DISCUSSION

The syntectonic unconformity affecting MS1 and MS2 and the dominant lithofacies evidence that during their deposition, Las Fagetas backthrust grew partially together with the Barasona backthrust, and rejuvenated reliefs acted as source area for alluvial fan deposition. Uplift in more internal areas of the Pyrenees also favored progradation of the north-coming fluvial system but its expansion was locally precluded by the uplift of southern reliefs (Luzón, 2005) associated with structures forming in the sedimentary cover above the regional *décollement*, one of them was the Barasona backthrust, that forced the system entrance to be concentrated in structural lows. This is the reason for the absence of fluvial facies in the study area during MS1 and MS2 deposition, which, however, can be found towards the west. Finally, as evidenced by the lithology and evolution of MS3, the north-coming fluvial system overtopped these reliefs, at the same time that alluvial fans coming from the Barasona uplift retrograded. The combination of erosion and ceasing uplift acted as key factors for overtopping of the fluvial system during MS3 deposition since this unit lies unconformably on the Cretaceous to Ilerdian succession and includes calcareous clasts coming from these units, thus evincing that the crest of the detachment anticline related to the Barasona backthrust was eroded. Flexural subsidence recorded for the whole Ebro basin (García-Castellanos *et al.*, 2003) could also favor fluvial system entrance because of the increasing accommodation space towards the foreland as crustal deformation progressed in this sense.

Main emplacement event of the Barasona backthrust and the train of folds developed in its hanging-wall predate the deposition of the syn-tectonic sequence as can be interpreted from the onlap geometry of conglomerate beds against these structures (Figs. 4; 5). Weak reactivation stages (Fig. 10, upper part of MS2) are recorded by the southwestward dip of MS2 beds near the Barasona reliefs. Taking into account the expansive and fining-upward character of MS2, the activity of Las Fagetas backthrust reached its climax during the sedimentation of the coarsening-upward MS1 and progressively decreased during the deposition of MS2 (Fig. 8). The southern alluvial fan developed associated with the growth of this structure and, as a consequence of the structural evolution, it experienced a progradation and a subsequent retrogradation.

MS3, mainly integrated by pCS lithofacies, includes clasts from the Axial Zone, the Internal Sierras, and the Graus-Tremp and Jaca basins, as well as the South Pyrenean Sierras. Larger drainage basins guaranteed greater and more constant water discharges as interpreted from the sedimentological features of these deposits. Interestingly, monogenic conglomerates (mC) also contain, sporadically, siliceous rounded clasts from the Axial Zone (Fig. 6) that could be derived from recycling of Graus Conglomerates, that crop out in the foot-wall of the Barasona backthrust and adjacent to its associated reliefs (Fig. 3, northeastern sector).

Which is the relationship of the growth strata described in this study with the larger-scale sedimentary frame of the foreland basin? As previously indicated, the Ebro foreland basin deposits underwent a switch from a coarsening-upward to a fining-upward trend, defining the boundary between Tectosedimentary Units (or sequences in the sense of Catuneanu *et al.*, 2009) T3 and T4 (Muñoz *et al.*, 2002; Luzón, 2005) that we have correlated with the MS1 to MS2 transition (Fig. 9). This change has been interpreted as related to major tectonic pulses occurring in the Axial Zone of the Pyrenees. As it occurs in other

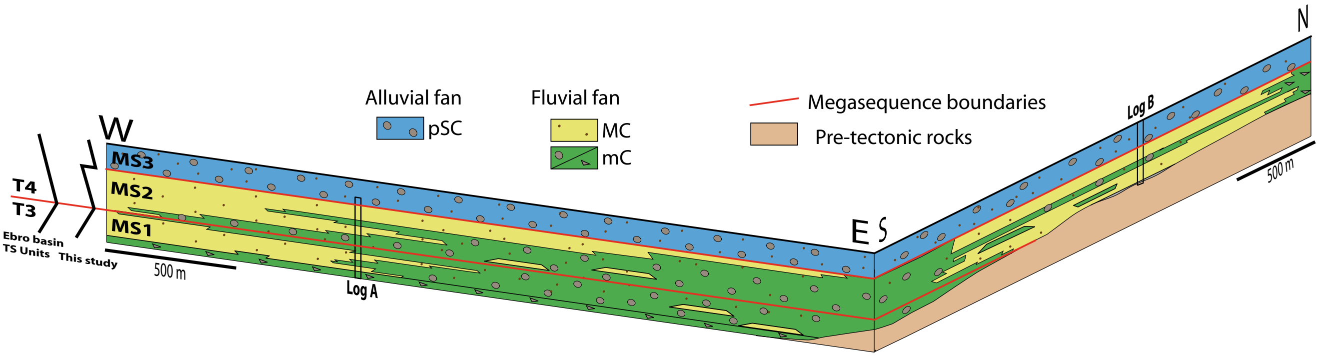

FIGURE 9. Chronostratigraphic sketch showing the lateral and vertical relationships between the main lithofacies associations.

proximal areas towards the west (Luzón, 2005) or in the southern basin margin (González, 1989, Luzón and González, 2000), megasequences defined in the studied area do not fit completely with the general megasequential trend (MS2+MS3 corresponds to the upwards-fining lower part of the T4) in the Ebro basin, a situation that should be rather explained by understanding the particular structural framework under which this series was deposited. Our results point out that local influence can mask (or completely overprint) large-scale sedimentary signal, highlighting the importance of considering local influences when interpreting basin-scale sedimentary systems. In our case, as it probably occurs in more western areas, drainage diversion in response to folding or thrusting was an additional control on sedimentation that could produce major shifts in the location and magnitude of sediment source points (Tucker and Slingerland, 1996).

A highly effective and prone-to-migrate *décollement* together with a thinned overburden are commonly found in many fold-and-thrust belts. These features usually triggered backthrusting, out-of-sequence thrusts, formation of oblique structures, reactivation and coeval growth of structures (*e.g.* Costa and Vendeville, 2002; Smit *et al.*, 2003). Such trendless evolution could be enhanced by interaction of growing structures with alluvial and fluvial deposition (Mugnier *et al.*, 1997; Duerto and McClay, 2009; McClay and Whitehouse, 2004; Fillon *et al.*, 2013) as observed southwards of the studied area (Martínez-Peña, 1991) and at the front of the Sierras Marginales thrust sheet (Senz and Zamorano, 1992). Space accommodation could generate due to the general subsidence trend occurring in the Ebro foreland basin but the western tilting of the pre-tectonic and syn-tectonic deposits and the expansion of the alluvial fans towards the west also points to the influence of another contributing factor. Surrounding the studied area, large diapiric structures crop out (Fig. 1B). Santolaria *et al.* (2012) observed a WNW increasing gravity gradient in the residual anomaly from the diapiric structure located to the east of the studied zone (Juseu diapir in Fig. 1, where the negative anomaly is located), that qualitatively indicates that Triassic evaporites progressively thin westwards from this evaporitic accumulation to finally become non-significant towards the Cinca River, out of the studied area. We suggest that eastward lateral escape of evaporites towards the core of diapiric structures could control, at least partially, subsidence on the studied area and therefore accommodation space and consequently sediment thickness. Thickness variation would trigger differential loading that would force the evaporitic horizon to scape, back-feeding *décollement* migration. Filling of the area was progressively achieved, as onlap geometry indicates, until the fluvial deposits completely overtopped the Barasona paleotopography.

CONCLUSIONS

The Oligocene conglomerates in the Olvena area are located in the western end of the N120E trending Sierras

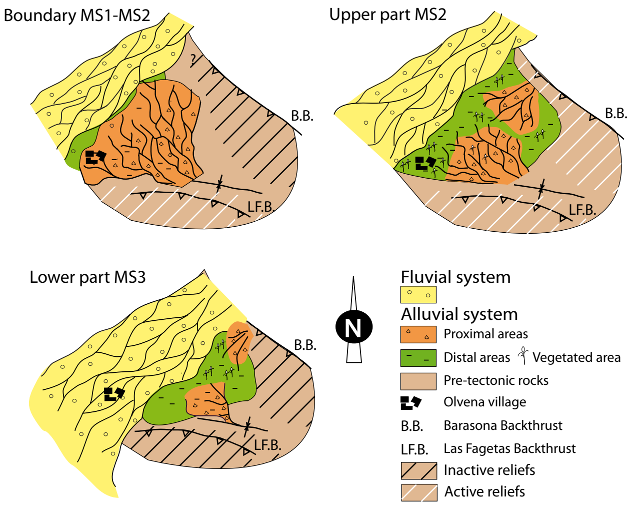

FIGURE 10. Sketches representing evolution of sedimentary systems.

Marginales thrust sheet. Alluvial deposits are limited by two steeply-dipping backthrusts rooted in the Triassic evaporitic *décollement*.

Stratigraphic and sedimentological analysis allows defining the existence of a large alluvial fan coming from Las Fagetas backthrust and a smaller one sourced in the Barasona backthrust and also north-coming deposits corresponding to the Huesca fluvial fan system.

Megasequential evolution, stratigraphic architecture, and geometrical relationship with neighboring structures permit to establish the relationship between structures and depositional systems: the Barasona backthrust predates most of the conglomerates deposition whereas Las Fagetas backthrust emplaced coevally with alluvial deposition (MS1 and MS2 megasequences).

Subsidence of this punctual trough is partially controlled by i) lateral migration of evaporites, ii) formation of oblique structures and relay ramps, associated with the westwards plunge of anticlines, and iii) progressive filling responding to the regional evolution of the Ebro basin.

Continental sequence stratigraphy has been proved to be a key tool to constrain timing of structure emplacement in a fold-and-thrust belt characterized by out-of-sequence structures and coeval sedimentation. This study also highlights the importance of considering the influence of local structures, which are prone to exert a significant control on terrain morphology and drainage net, and sedimentary systems in the general sedimentary trends.

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