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Tectono-sedimentary study on the back of the Montsec thrust sheet: the south edge of the Tremp basin (Catalogna, Spanish Pyrenees)

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This research concerns the Tremp basin. ~~It is~~ located in the Spanish Pyrenees, in the South Pyrenees Zone ~~(SPZ)~~. It's confined between the Cornelli anticline in the North and the thrust front of the sheet of Montsec. The study area is located in the ~~SW~~ edge of the basin on the back of the thrust front of the Montsec ply. The research is based on the evolution of the Tremp basin on the Montsec thrust, from Maastrichtian superior and Danian. The analysis of thin sections taken from the field could determine a depositional environment during the study period. This analysis confirms the episode of regression which took place from Maastrichtian until Ilerdian. The study of palaeocurrents helped to determine areas of subsidence at the time of discharge. This analysis is supported by the study of correlations boards, which determined the thickening of deposits from West to East. These analyzes are sustained to the analysis of the plans vulnerabilities measured in the field. This study allowed to highlights a little relation of setting up of the Tremp formation with the overlapping tectonic of the Montsec thrust.

ABSTRACT

1. Introduction

~~A study has been done to~~ analyze the evolution of sedimentary basins, as potential source of energy and hydrocarbon. The aim of this study is to identify and to determine what were sedimentary and tectonic contexts during Tremp basin formation (figure **1**), and its evolution. ~~It's located in the thrust sheet of Montsec in Spain.~~

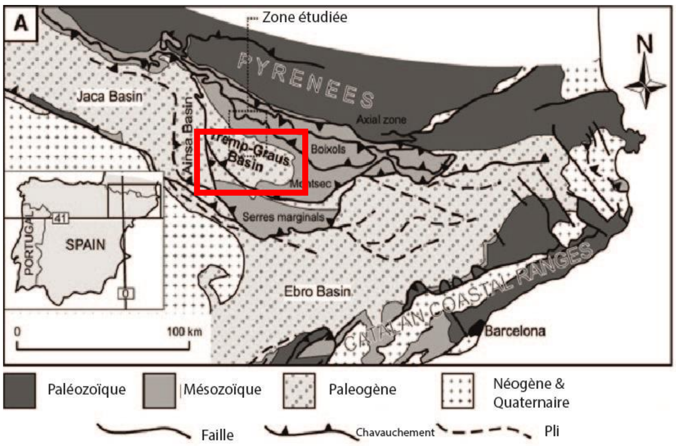

Figure 1 : Geological map of the study area in Pyreneans (Leren et al., 2010)

The collision between Iberic and European plate in Middle Cretaceous (Canerot, 2008) (figure **2**) has caused a regional compression in the Southern Pyrenean zone. Evaporite of Triassic allowed the establishment of thrust sheet in late Cretaceous. Folds and subsidence are the starting point of piggy-back basins formation like Tremp basin.

The study is located in the thrust front of the Montsec fold. The area is large of 2km and

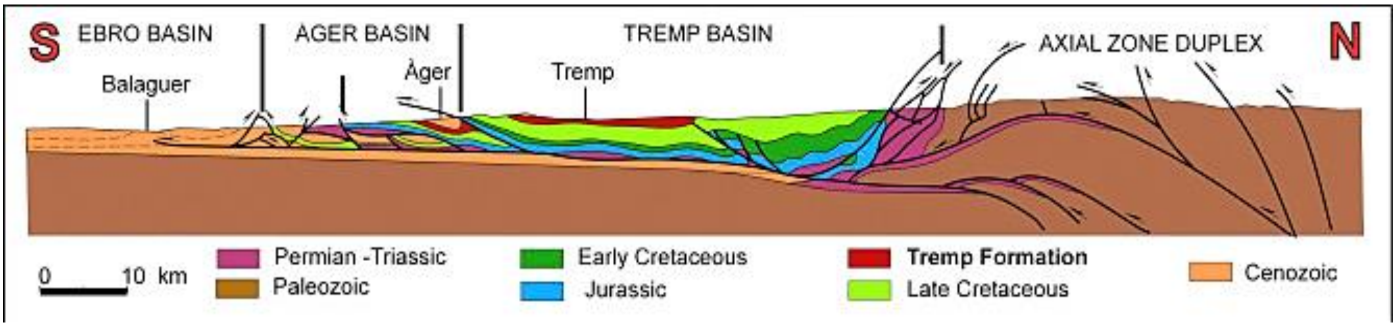

Figure 2 : Geological cross section of thrust sheets in Southern Pyrenean zone (Gomez et al, 2016)

lengths of 18km. the study is based on serial cross section executed on the ground of study. Then, several analyses of measurement of dips and paleocurrent, thin sections and serial sections had been used to understand the establishment of this area.

2. Regional setting

Pyreneans are a mountain chain based between France and Spain. This is a result of a collision which has happened 65 million years ago, at the end of Cretaceous. Indeed, the African plate moved to the North and caused the collision between Iberic and European plate (Choukroune, 1992). Pyreneans are constituted of five units (from the North to the South):

- The Northern Folded Foreland
- The Northern Pyrenean zone
- The Axial zone
- The Southern Pyrenean zone
- The Southern Folded Foreland

The study is located in the Southern Pyrenean zone (SPZ). This zone is composed by the Ebro basin in the West and by thrust sheets zone (Central Southern Pyrenean zone = CSPZ) (figure **2**). There are three thrust sheets: Boixols, Montsec and Sierras Marginales. During the compressive phase of the Pyrenean orogenic, the Axial zone moved to the South (Ori and al, 1984).

Therefore, deposits of Mesozoic stacked on top of one another, from the North to the South. Each accumulation is separated by a thrust front. Thrust sheets were created. They carry out piggy-back basins.

Tremp basin is a piggy-back basin: it is carried by the Montsec sheet. It's filled by Cretaceous and Cenozoic deposits. Montsec sheet was formed in Late Cretaceous (Maastrichtian) creating a subsidence on the thrust front. It was filled of marine and continental deposits. That is how Tremp basin was made (Fillaudeau, 2011).

2.1 Late Cretaceous

Maastrichtian was characterized by an important regression of the sea level. With erosion of the thrust front of Boixols, Tremp basin has been filled out by coarse sandstone: Aren formation. It's composed by clastics coastal deposits.

They came from subtidal zone, beach and lagoon environment. Gradually, floodplain deposits filled out Tremp basin: they constituted Tremp formation.

2.2 Tremp formation

Tremp formation was studied by several geologists (Souquet, 1967; Deramond et al., 1993; Ardévol et al., 2000). This formation was dated in Danian (Early Paleocene, 65.5-61 million years). It covers many thrust sheets: Montsec, Sierra Marginales, Boixols, Cadi (Rosell and al., 2001). Coarse sandstone (Marbore formation) are the first deposits. Finally, there is Thanetien limestone in alvéolines. Those deposits are marine deposits. Maastrichtian regression allowed to fil progressively continentals sediments.

Tremp formation is constituted by two units. Transition formation makes the transition between marine and continental deposits. It's composed first by grey clays including limestones, sandstones and organic matter. It was analyzed by coming from lagoon and estuary environment (Riera and al., 2009; Rosell and al., 2001). The second unit is called Garumnien formation. It's composed by red and multicolored clays including sand interbeds and conglomerates. It came from fluvial and floodplain environment (Cuevas, 1992; Rosell and al., 2001; Riera and al., 2009). On the top of the unit appeared lakeside limestones.

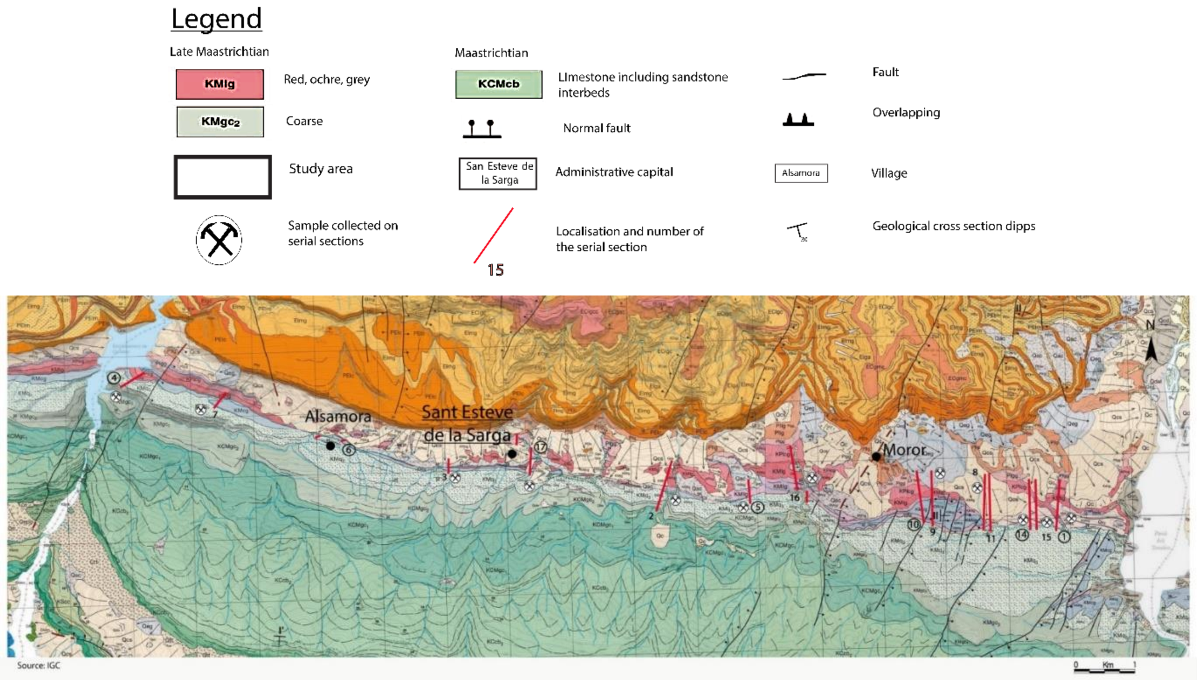

Figure 3 : Geological map of the sector (scale 1:50000)

3. Material & Methods

The present study is based on field and bibliographical analysis. The all data was acquired on the field, during one month, on the south edge of the Tremp basin, at 20 km of Tremp. Several materials and methods has been used to analyze the sedimentary ways on the back of the thrust sheet of Montsec, in relation with the tectonic of the sector.

The study zone is stretched on 70km² (figure **3**). Seventeen lithostratigraphic log has been realized to evaluate the eventual variations of facies and thickness. They has been distibute in fair way (at around equal distance from each other), depending on the quality and abundance of data. The thickness of the formations has been measured using a stick of Jacob. The identification of the facies has been done with the analyses on the LPNA microscope, using the samples sampled on the field: it is to identify deposit environment (figure **4**). Several measures of dip has been made: measures of stratification (evolution of deposit way), measures of paleocurrent (stereogram): determine the onlap or progressive deposits. Board of correlation has been realized, with different datum to evaluate the subsidence and the changes of the deposit's environments.

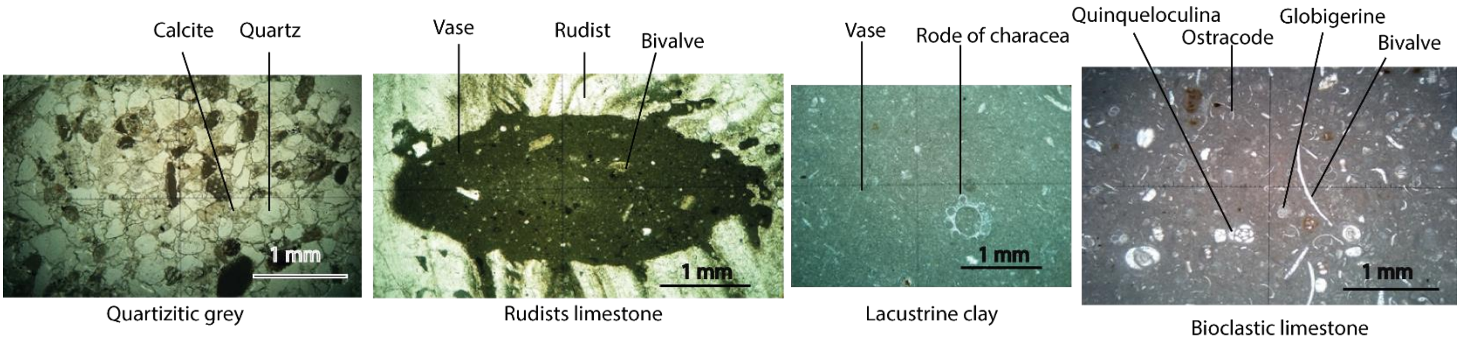

Figure 4 : Photo of the thin sections, representing the facies of the Transition formation

4. Results

4.1 Stratigraphic study

The lithostratigraphic log highlights three formations : Marbore serie, dated of Late Maastrichtian; the transition facies (Late Masstrichtian), with the alternation of clays and fine limestones ; and the Garumnien formation, with the red and pink clay, dated of Dano-Maastrichtian. The identification of the facies has been done with the samples sampled in each formation to observe the evolution of the deposit environment. The Marbore grey, (figure **4**) is composed of dominant quartz, pellets and calcite corresponds to the marine environment, with a deltaic current (with its tangential current ripples). The rudist limestone are characteristic of reef environment (figure **4**). The bioclastic limestones are originate of a continental platform (figure **4**), deducted from the presence of bivalves, globigerina, miliole, etc. The marine clay represent lagoon environment, deducted from the milioles, ostracods, pellets and peneroplis. The lacustrine clay (figure **4**) corresponds to a quiet and silted up environment: some bivalves, characea, globigerina, gastropods and bioturbations has been observed. And lacustrine limestone has been also observed with the limestone matrix and the presence of bivalves, foraminifers, etc. The paleosol come from continental environment. The red clay with gypsum are characteristic of arid and shallow environment (an area of salt water). To finish, the last deposit, the red clay, alternated with grey bench, is come from continental environment.

4.2 Tectono-sedimentary study

Analyses of dip measures allowed demonstrating the deposit way of sediment on the back of the Montsec thrust during its setting up. It could end to a syn-tectonic or post-thrust sedimentation.

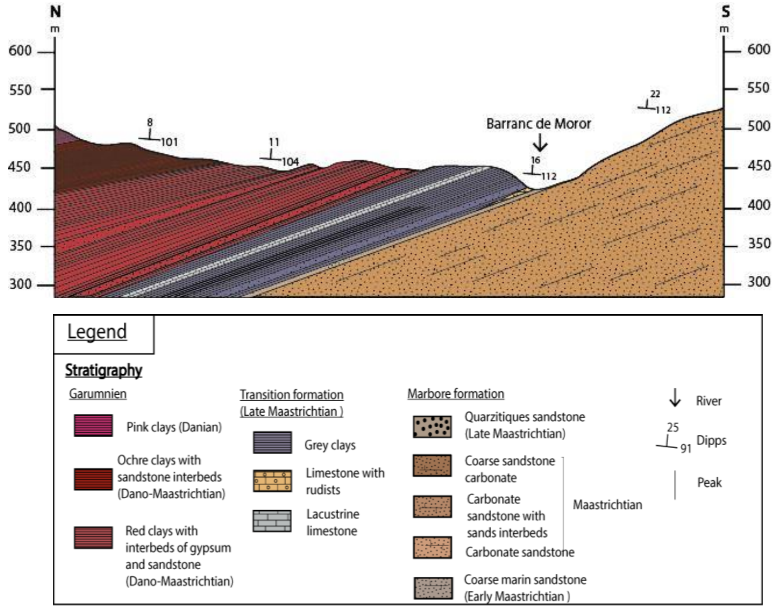

Figure 5: Section N-S n°1 representing the formations and the evolution of the dip

The realized geological section (figure **5**) shows a progressiv evolution (fan-shaped) of the dips from south to north, especially in the Garumnien formation: the dip increase from 22° in the Marbore formation (South) to around 15° in the Garumnien formation (North).

The paleocurrent measures have been done on oblique and tangential current ripples. They demonstrate a current direction to N-NE.

The fault measured are normalo strike-slip or transverse, with a principal sinistral play. These faults don’t affect the same formation : they were progressively setting up. They principally affect the Transition formation, with Lateral Facies Passage and thickness variations.

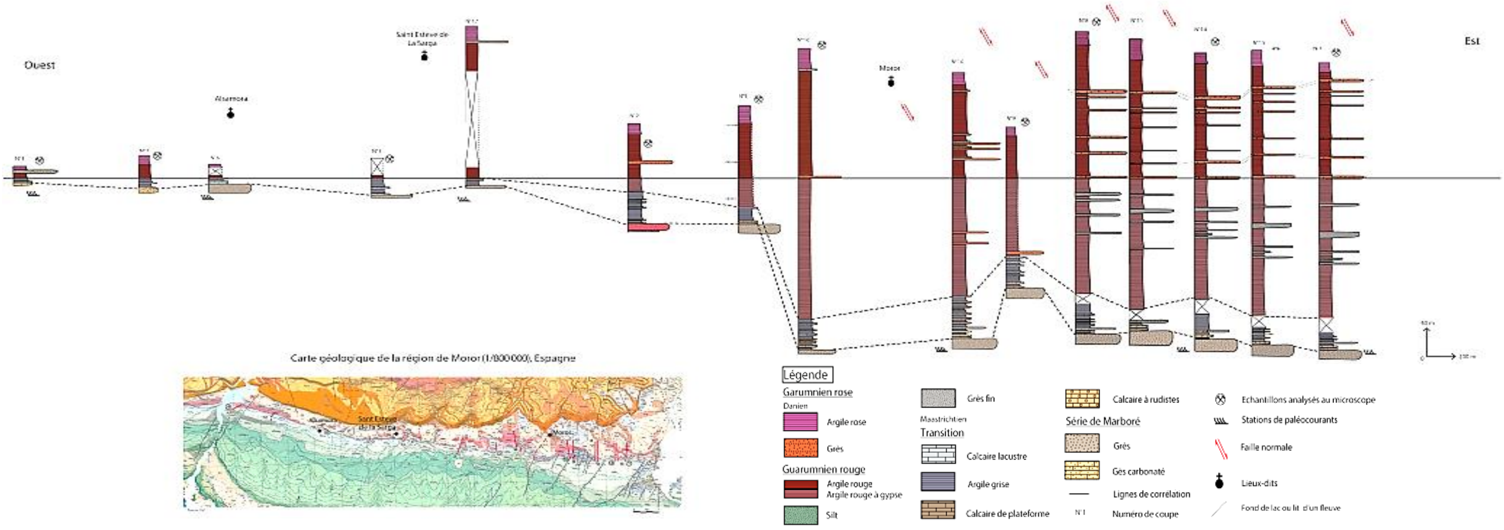

Figure 6 : Board of correlation of serial sections (lithostratigraphics logs) from West to East

5. Discussion

With the stratigraphic and tectonic-sedimentary study, it has been possible to recount the setting up of the different formations.

Measurements of dips were analyzed by serial sections from East to West. Geological cross sections highlighted a little evolution of the dip from East to West. Except for Garumnien formation, with a slight decrease to the North of dips, tectonic has any influence on deposits. The Garumnien is characteristic of syn-tectonic sedimentation. Paleocurrents had shown that Tremp basin subsidence began in the East in Late Maastrichtian with a deltaic system.

Along the lithostratigraphic log, from South to North, different deposit environments have been observed. It can be correlate with marine cycles: transgression and regression of the sea.

During the beginning of the Late Maastichtian, the sector was characterized by deltaic environment: the Marbore formation is composed by coarse sandstone overhung by quartzite sandstones. It suggests that the erosion area is close enough of sediments sites. Montsec sheet was, partially, emerged.

At the end of the Late Maastrichtian, deposits of the Transition formation came from lagoon, lacustrine and circalittoral systems.

Therefore, the regression was quite slow and intermittent including several marine phases.

In the West, marine deposits are absent: the West of the basin has only continental facies.

The Danian is characterized by the Garumnien formation which is composed of red clays with gypsum and ochre clays. First one is composed by versicolor clays including sandy limestone interbeds and gypsum. It was interpreting as coming from either a lagoon little or not connected with the sea or as a salt lake. Ochre clays are composed of ochre/brown clays including coarse sandstone with planar and oblique laminates. It's coming from a floodplain environment, alternated with fluvial phases.

Board of correlation (figure **6**) allowed analyzing deposits thickness from the East to the West. All formations thickness involve from West to East of the sector. It confirms what paleocurrents demonstrated: the subsidence is important in the East of the basin. The formation becomes progressively more and more continental from East to the West. For example, the absence of rudists limestone to the West confirms it. In the East, the Transition formation exhibited several phases of transgression and regression in Late Maastrichtian, with his alternation of marine and lacustrine deposits.

The location of the faults, where the subsidence is the most important, confirms that tectonic had influenced Garumnien deposits.

Indeed, there is an important rise of thickness deposits close to these faults (300m in the East against 10m in the West), unlike Transition deposits, which stay unaffected.
The variation of thickness deposits is very significant for Garumnien deposits. In fact, the subsidence of the basin in Late Maastrichtian-Early Danian allowed to fill out a substantial thickness of deposits in the East.
The subsidence has begun to be important during the Danian, with the Garumnien deposits. This subsidence allowed the fast regression of the sea in the East: the Garumnien formation refine rapidly starting from the log n°5.

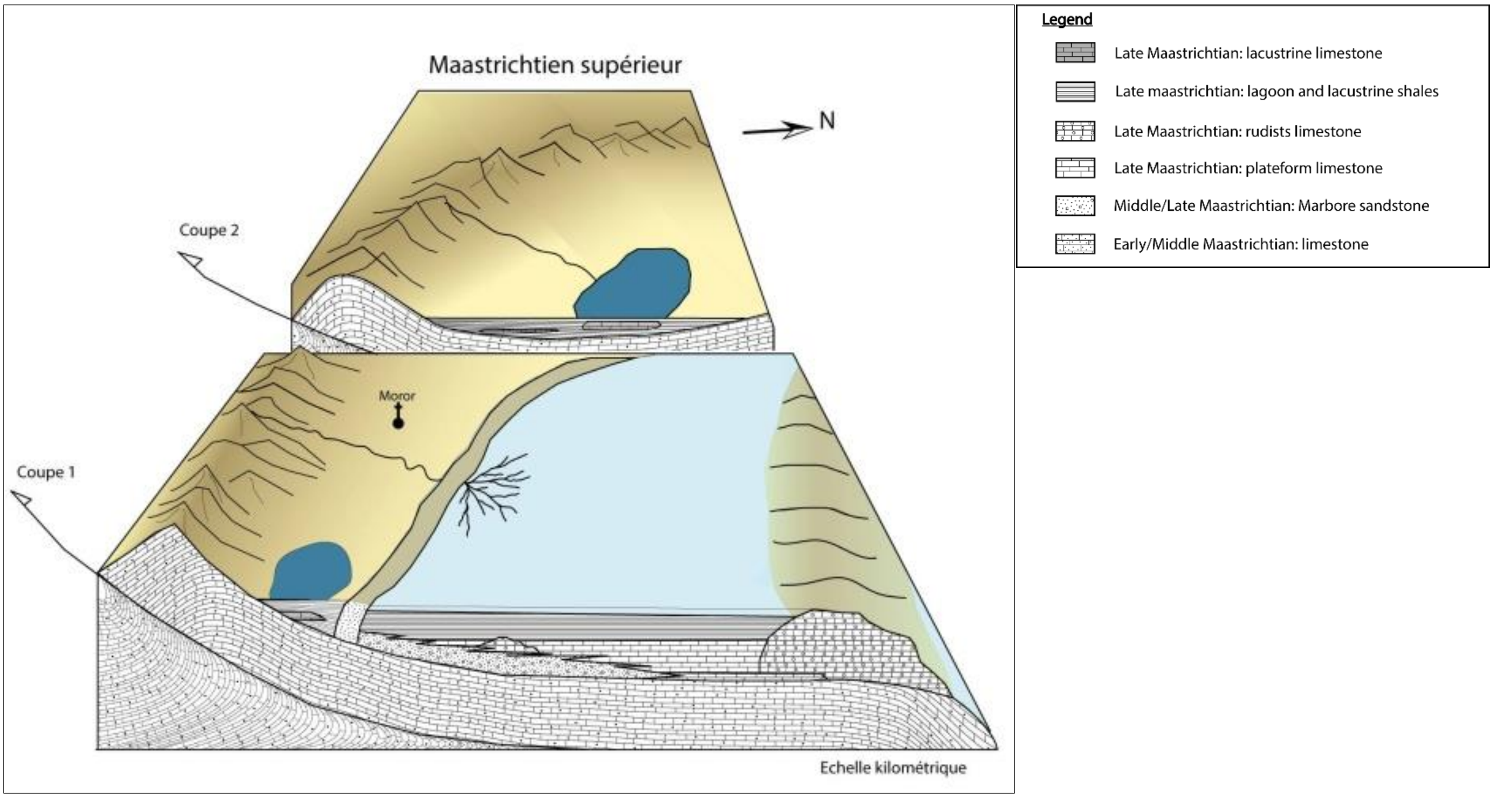

Figure 7: 3D block illustrating the different deposit environment from West to East

A 3D bloc (figure **7**) was built from interpretations of all those analyses. It represents the south border of the Tremp basin in Late Maastrichtian illustrating the difference of deposits (marine, lacustrine and deltaic) between the East and the West of the basin. The bloc is separated in two little blocs by the cross-section n°2, where rudists limestones disappeared. It is a link of the limit between see and continent. In fact, rudists come from a reef system.

Their thickness decrease gradually from the East to the West: water column became more and more insufficient to allow rudists development. Analysis allowed to show precisely several phases of the south of Tremp basin formation from Late Maastrichtian to Early Danian thanks to tectonic, serial sections et sediments analysis. This bloc illustrates particularly the deposit way, the order and the environment of deposits and what are their (interpreted) geometry.

6. Conclusion

The study of the sector allowed determining in which tectono sedimentary and stratigraphic context the deposits of the SW border of the Tremp basin were setting up. These deposits, from the grey of Marbore to the clays of Garumnien, passing by the Transition formation, had been more influenced by the subsidence of the basin than by the uplifting of the Montsec thrust. This could be correlated with the studies of Huyghe (2010) which highlight the setting up of the subsidence at the end of the Late Maastrichtian, whereas the Montsec thrust begins to undergo the compressive stresses from only the Ilerdian.

A more detailed study of the syn-sedimentary faults in the southern part of the Tremp basin would be usefull, in order to precise and determine the steps of the uplifting of the Montsec thrust. Moreover it could be explain the discontinuities of thickness variations, met in red clays.

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