Subsidence Analysis of the Barinas-Apure Basin: Western Venezuela*

Maria Jácome[1] and L. Chacín[2]

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[1]Simón Bolívar University, Caracas, Venezuela (mjacome@usb.ve)
[2]Halliburton, El Rosal, Caracas, Venezuela

Abstract

A series of structural and isopach maps have been produced for the Barinas-Apure Basin, Western Venezuela, in order to determine the regional distribution of the main tectonostratigraphic units in the area, to quantify the original thickness of these units at the time of their sedimentation and to estimate the total basement-driven subsidence of the basin. The structural and isopach maps were produced using fourteen 2D seismic regional transects and well log information provided by PDVSA. Six sequences were interpreted on the seismic lines since they reproduce best the tectonostratigraphic evolution of the basin, these are: Pre-Cretaceous (S6), Lower Cretaceous Campanian (S5), Maastrichtian-Paleocene (S4), Eocene-Lower Miocene (S3), Middle-Upper Miocene (S2) and Pliocene-Pleistocene (S1).The sediment thicknesses of these units then were decompacted using a 3D flexural decompaction software. Results show that S5 was deposited in a passive margin with a maximum subsidence rate (msr) of 21.4 m/Ma, S4 marks the transition to a compressive regime associated with the collision of the Caribbean and South American plates towards the northwest of the area (msr=38.2 m/Ma), S3 was deposited in a foreland basin produced by the flexure of the western Venezuelan crust associated with the Lara Napes emplacement (msr=47.5 m/Ma) and S2 and S1 mark the formation of the Barinas-Apure foreland basin as the result of the emplacement of the Mérida Andes, in were maximum subsidence rates increased considerably to 263.5 m/Ma for S2 and 337.7 m/Ma for S1.

Introduction

The Barinas-Apure Basin (BAB) is the third oil-producing basin of Venezuela. It has an extension of about 95,000 km^2 and a maximum sediment depth of about 5,000 m. This basin is located at western Venezuela to the southeast of the Mérida Andes (MA) range (Figure 1). The NE-SW trending mountain chain constitutes a large NE oriented uplifted block of about 420 km long that reaches a maximum topography of about 5,000 m (Gonzalez de Juan, et al., 1980). The Mérida Andes uplift is responsible for the BAB subsidence (Chacín, et al., 2005). However, the subsidence history of this basin related to the tectonic evolution of the area has not been quantitatively studied. Present day stratigraphic thicknesses are the result of compaction through time, in order to quantitatively obtain the historical subsidence rates we need to decompact the units to their correct thicknesses at the time of sedimentation.

Basin Subsidence

Six tectonostratigraphic units were interpreted using 14 2D-regional seismic transects controlled with well log information, provided by PDVSA, covering the northern part of the basin (approx. 62,259 km^2, Figure 1). Two-way travel time and depth maps were then generated to the top of the interpreted units (i.e. Pre-Cretaceous (S6), Lower Cretaceous-Campanian (S5), Maastrichtian-Paleocene (S4), Eocene-Lower Miocene (S3), Middle-Upper Miocene (S2) and Pliocene-Pleistocene (S1)). These tops represent the main tectonic events that affected the basin. Subsequently, decompaction was carried out (Flexural Decompaction Software 5.3 Badley Geoscience) to understand the burial history of the BAB and to determine the original thickness of the tectonostratigraphic units. Decompacted thicknesses give information of the total subsidence associated with each stratigraphic unit, assuming that the accommodation space within the foreland basin is completely filled with sediments (i.e. palaeo-water depth estimation near sea level). The method used to decompact the sedimentary units assumes a porosity depth function (Sclater and Christie, 1980), in which porosity decays exponentially with depth. A regional 3D compilation of data covering thickness, age, porosity, lithospheric elastic thickness, density and lithology of each sedimentary unit was required to be able to apply the decompaction technique.

Results

The decompacted isopach maps show (Figure 2) that the main subsidence in the basin is concentrated in two main depocenters. One local depocenter is located towards the southwest of the basin and can be associated with a Jurassic rift structure (Lugo and Mann, 1995) another depocenter is located towards the northeast and can be related to regional tectonics. Figure 2a shows the thickness of the Lower Cretaceous to Campanian unit (S5) is greater (i.e. 1,600 m) towards the southwest and this could be associated with a Pre-Cretaceous basement structure. The northeastern part of the basin shows a maximum thickness of 1,000 m thinning towards the south, with a maximum subsidence rate (msr) of about 24.1 m/Ma (Table 1). This unit was deposited in a passive margin (Parnaud et al. 1995). Isopach map of S4 sequence (Figure 2b) shows two main depocenters one located to the southwest (1,200m) and the other one located towards the northeast (1,600 m) that could have been produced by the flexure of the South American lithosphere as the result of the emplacement of the Lara Nape (Parnaud, et al., 1995). The maximum subsidence rate (38.2 m/Ma) is almost twice of that found in S5 implying that S4 marks the transition between passive to active margin regime. The isopach map of S3 shows a change in the direction of the subsidence from NE-SW to almost E-W. During this time, the oriental cordillera of Colombia was emplaced (Parnaud, et al., 1995); this generated the accommodation space observed in this area (1,800 m) and increased the maximum subsidence rate (47.5 m/Ma). During the Lower-Middle Miocene (S2), the emplacement of the Mérida Andes is evident by the occurrence of a regional 2,200 m thick depocenter adjacent and parallel to the deformation front (Figure 2d). During this time, the subsidence rate increased considerably to 263.5 m/Ma. Plio-Pleistocene (S1, Figure 2e) represents the maximum subsidence of the basin (337.7 m/Ma) in which the tectonic load of the Mérida Andes was the greatest. The main depocenter migrated from the southwest to the northeast reaching a maximum thickness of 1,800 m.

Conclusion

A regional subsidence analysis, based on the true thickness, of the tectonostratigraphic units found in the Barinas-Apure Basin indicates that the Mérida Andes were uplifted in two mayor orogenic episodes: a first event took place towards the southwest during Middle to Upper

Miocene which flexed the lithosphere and generated the accommodation space for the first Andean foreland-type sediments; afterwards a second and more important uplift occurred towards the northeast of the basin, which generated enough subsidence to deposit 1,800 m of Plio-Pleistocene sediments. Eocene to Lower Miocene unit was deposited over a Caribbean-type foreland basin associated with the collision of the Caribbean and South American plates towards the northwest of the basin. Maastrichtian-Paleocene unit represents the transition from a passive margin regime to a Caribbean regional foreland basin subsidence. Lower Cretaceous unit was deposited over a passive margin.

Acknowledgements

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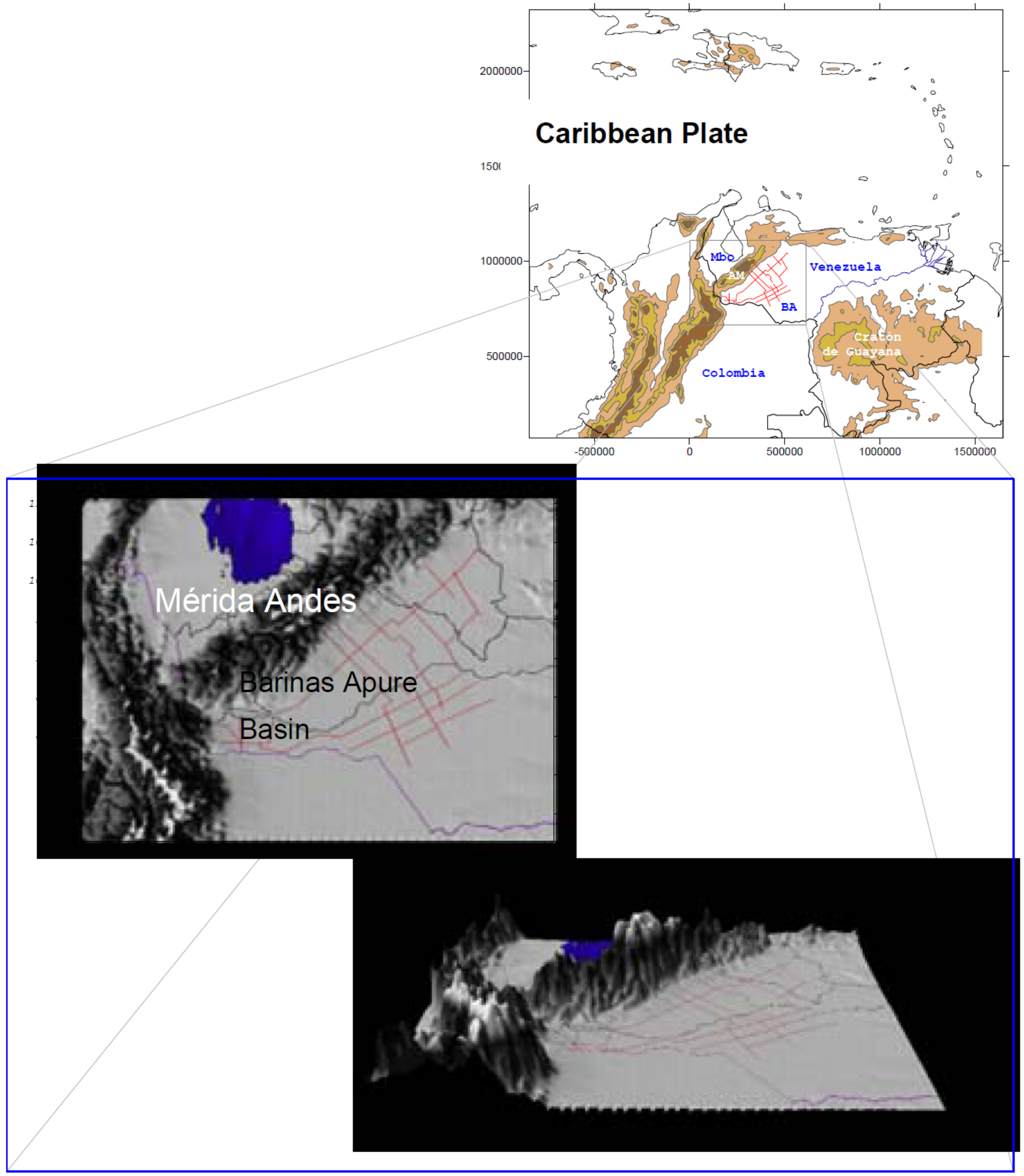

Figure 1. Location of the Barinas-Apure Basin: Western Venezuela.

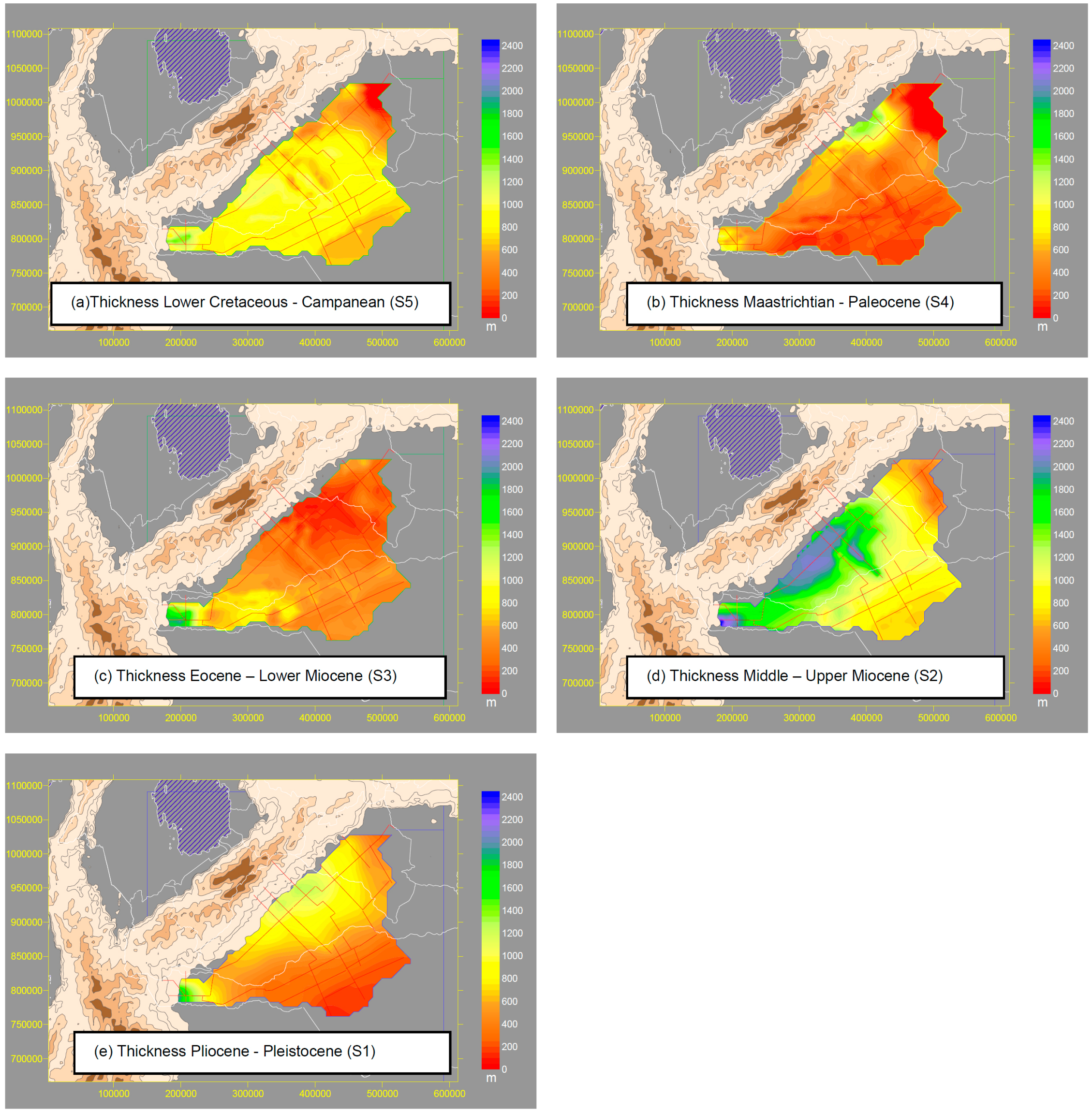

Figure 2. Decompacted Isopach maps showing the true thicknesses of the tectonostratigraphic units interpreted from the seismic lines. The units are: (a) Lower Cretaceous-Campanian (S5), Maastrichtian-Paleocene (S4), Eocene-Lower Miocene (S3), Middle-Upper Miocene (S2) and Pliocene-Pleistocene (S1). Maximum subsidence rates are greatest during Middle-Upper Miocene (S2) and Pliocene-Pleistocene (S1), which corresponds to the Mérida Andes uplift. Maximum Subsidence rates are shown in Table 1.

Unit	Maximum decompacted thickness (km)	Maximum Subsidence rate (m/Ma)	Dominant tectonic subsidence mechanism
Lower Cretaceous -Campanian (S5)	1.6	21.4	Passive margin
Maastrichtian-Paleocene (S4)	1.6	38.2	Transition to Lara Nappes thrust sheet loading
Eocene – Lower Miocene (S3)	2.0	47.5	Lara Nappes thrust sheet loading
Middle – Upper Miocene (S2)	2.2	263.5	Andean thrust sheet loading
Pliocene – Pleistocene (S1)	1.8	337.7	Andean thrust sheet loading

Table 1. Maximum subsidence rates calculated for each tectonostratigraphic unit.