Integrated geodynamic modelling of the Cordillera Central Thrust Belt and the Guárico Basin, North-Central Region, Venezuela

M. I. Jácome, K. Rondón, & A. Carballo

Universidad Simón Bolívar, Dpto. Ciencias de la Tierra, Valle de Sartenejas, Municipio Baruta, Caracas, Venezuela; e-mail: mjacome@usb.ve

Abstract

Two integrated geodynamic models of Cordillera Central Thrust Belt and the Guárico Basin have been produced, using information from depth-converted seismic cross-sections, surface geology, and Bouguer Anomaly controlled with deep seismic information. The main objectives of this modelling are: (1) to understand the geodynamic processes responsible for the formation of the Guárico Basin; (2) to quantitatively determine the contribution of the Cordillera Central thrust sheet loading in the generation of the accommodation space observed in the basin, using flexural isostatic modelling, and (3) to understand the crustal structure and Moho depth in the North-Central region of Venezuela. The flexural modelling produces important quantitative information related to the total shortening of the Cordillera Central, the total subsidence observed in the Guárico Basin and the elastic thickness of the South American lithosphere in northern Venezuela. The integrated geodynamic modelling was applied to two regional geological cross-sections across the eastern and western areas of the Cordillera Central and the Guárico Basin. It is concluded that the lithospheric load of the Cordillera Central is enough to generate the subsidence observed in the Guárico Basin. The total shortening and subsidence obtained in transect (T1) is 44 km and 5 km, whereas in transect (T2) is 10 km and 7 km, respectively. The elastic lithospheric thickness of the South American obtained from the modelling is 25 km. The deep crustal structure of the North-Central region of the Venezuela indicates a maximum Moho depth of 45 km in the south of the models (i.e. under the Guyana Shield) decreasing to the north until it reaches 25 km (i.e. under transitional crust). It is observed in the gravimetric models that under the Cordillera Central Thrust Belt Moho increases to a depth of 35 km indicating the existence of a crustal root.

Introduction

The Guárico foreland basin is located in the north central region of Venezuela (Fig. 1), limited to the north by the Cordillera Central Thrust Belt , to the south by the Guayana Shield, to the east by the Anaco Thrust and to the west by the El Baúl uplift. This 800 km-long and 200 km-wide basin has an east-west orientation and shows a maximum sediment thickness of 5 km (González de Juana *et al.*, 1980). The development of the basin started as a Cretaceous passive margin deposited above an eroded Paleozoic basement (Feo-Codecido *et al.*, 1984). During the Eocene the Caribbean Plate collided with this north-central area of Venezuela developing the Cordillera Central Thrsut Belt and transforming the basin from a passive margin to a foreland basin (Gonzales de Juana, et al., 1980, Giunta, et al 2003).

Previous flexural isostatic modelling has been applied in Eastern and Western Venezuela in order to understand the geodynamic processes that generated these foreland basins, specifically in the Maturín Basin (Jácome *et al.*, 2003) and the Barinas-Apure Basin (Chacín *et al.*, 2004). However, the formation of the Guárico

Basin had not been quantitatively studied. In this work two integrated crustal models are produced in order to quantitatively explain the regional evolution of the Guárico Basin from the Eocene to the Present.

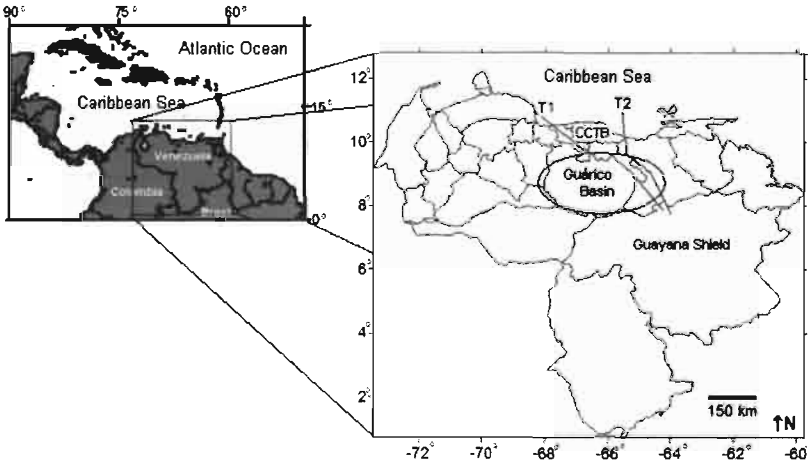

Fig. 1 Location of the Guárico Basin and the Cordillera Central Thrust Belt (CCTB). T1 and T2 are the western and eastern cross-sections modelled.

Integrated Geodynamic modelling

Two regional transects were generated (T1 and T2) crossing the eastern part of the study area (Fig. 2a). This transects were constructed using depth-converted seismic information controlled by well-logs provided by PDVSA and published surface geology information (Gonzales de Juana, et a., 1980, Feo Codecido, et al., 1984 and Bellizzia, A. 1986). The flexural model of these previously generated regional transects was produced using the software *Orogeny 5.0* (developed at the University of Liverpool, England). The flexural modelling combines flexural isostatic theory and structural balance in order to quantify the crustal shortening, the deformation sequence and detachments depths of the main thrusts in the thrust belt and the total subsidence and geometry associated with the formation of the foreland basin (Toth *et al.*, 1996). An initial condition was produced equivalent to the Eocene passive margin tectonosequence found in the Guárico Basin, then the sequence of thrust observed in the Cordillera Central Thrust Belt were reproduced until a final stage equivalent to Present (Fig. 2b). The principal physical parameters used for the modelling are summarised in Table 1 in which the highlighted values represent the best mach between observed and calculated values for the basin and the thrust belt. The results of the modelling for both transects T1 and T2 is shown in Table 2. The integrated geodynamic model (Fig. 2c) was created using gravimetric information provided by the Simón Bolívar University and published deep seismic refraction information (Schmitz, et al., 2003) in order to provide information in the regions were the flexural model lacked of control (i.e. Moho depth and crustal structure).

Transect	Te (km)	S (km)	Detachement (km)	Angle of the faults (°)
T1	5,5-**25**,25,40	40,**44**,48	25	50-60
T2	5,**25**,33,45	**10**,68,78	20,**25**	25,50

Tabla 1: Physical parameters required for the program. Te: Elastic Thickness and S: Shortening. Highlighted numbers represent the best results.

Model	Te (km)	S (km)	Decollement (km)	Angle of the faults(°)	Z (km)	Wl (km)	Comments
T1-2	25	44	25	60,60,60,60,50	5	335	Basin wavelength too narrow
T1-4	5	40	25	60,60,60,60,50	10	313	The forebulge is reproduced but the basin is too deep
T1-8	**5-25**	**44**	**25**	**60,60,60,60,50**	**5**	**325**	**The forebulge, the geometry of the basin and the thrust belt is reproduced**
T1-9	40	44	5	60,60,60,60,50	5	370	Basin wavelength is too wide
T2-2	5	10	25	60,60,60,60	9	160	Basin wavelength is insufficient and basin depth is exceeded
T2-4	**25**	**10**	**25**	**25**	7	**260**	**Preferred model. Both Basins depth and wavelength are reproduced (i.e. Guárico and Cariaco).**
T2-9	5	68	25	25,25,25,25,10	7	155	Basin wavelength is insufficient
T2-10	45	68	25	25,25,25,25,10	7	290	Basin wavelength is exceeded.

Table 2: Summary of the results of the flexural modelling for T1 and T2. Abbreviations refer to: Te= Elastic Thickness, S= Shortening, Z= Maximum basin depth and Wl= Maximum basin wavelength. Best result is highlighted.

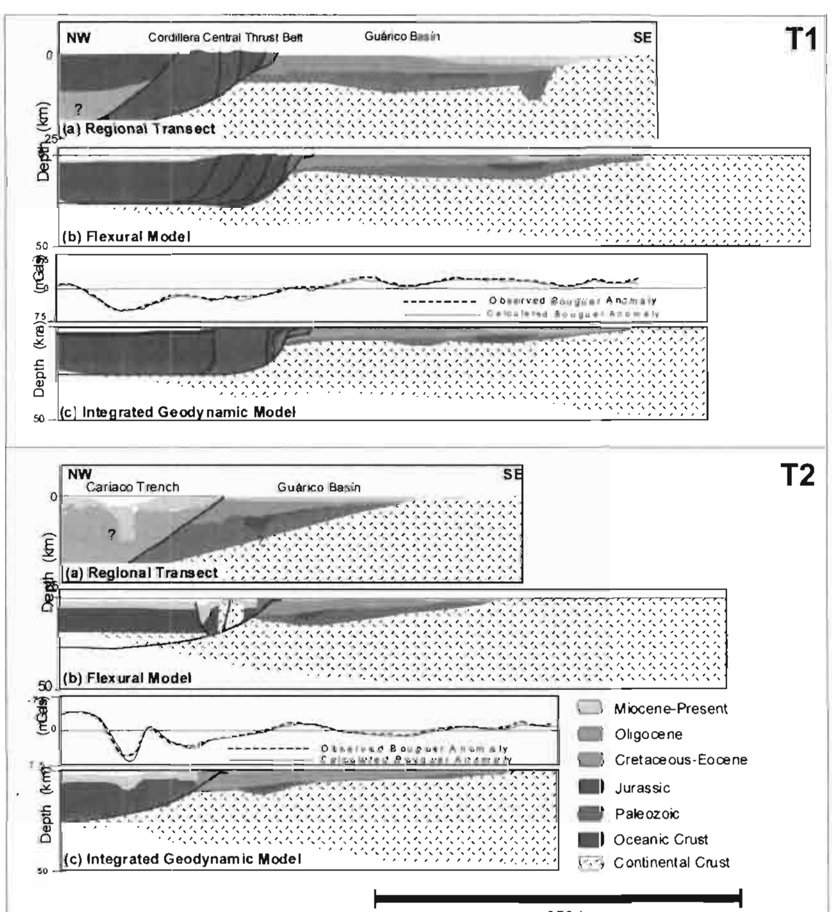

Fig. 2 (a) Regional Transects, (b) Flexural Models and (c) Integrated Geodynamic Models. Location of sections T1 and T2 in Fig.1

Summary

The flexural isostatic modelling controlled with seismic, gravimetric and geological information suggests that the load produced by the emplacement of the Cordillera Central Thrust Belt is sufficient to generate the observed subsidence in the Guárico Basin.

The modelling also suggests that the elastic thickness of the south American lithosphere is 25 km, this value is consistent with the found by Jácome, et 2003 and Chacín, et al., 2004. The modelling of T1 indicates that the total Shortening of the Thrust Belt in the west of the area is 44 km and the total subsidence is 5 km, while modelling of T2 indicates that shortening in the thrust belt decreases to the east with a total of 10 km and the subsidence in the basin increased with a total of 7 km. On the other hand, the basement fore-bulge observed in the seismic lines corresponds to a remnant basement high produced by the flexural response of the lithosphere to the load of the Lara Napa Thrust Belt emplaced to the west of the area before the uplift of the Cordillera central and formation of the Guárico Basin. The deep crustal structure of the North-Central region of the Venezuela indicates a maximum Moho depth of 45 km in the south of the models (i.e. under the Guyana Shield) decreasing to the north until it reaches 25 km (i.e. under transitional crust). It is observed in the integrated geodynamic models that under the Cordillera Central Thrust Belt the Moho depth is 35 km indicating the existence of a crustal root.

Acknowledgements

We are thankful to PDVSA, Simón Bolivar University and FUNVISIS for the information and resources provided for the development of the study. This work is part of the project GEODYNOS-FONACIT G-20020000478.

References

Bellizzia, A. 1986. Sistema Montañoso del C ootaribe, una cordillera alóctona en la parte norte de América del Sur, VI Congreso Geológico Venezolano, v. 10, p. 6657-6836.

Chacín, L., Jácome, M. I. and Izarra, C. 2005. Geodynamic modelling of the Mérida Andes and the Barinas-Apure Basin: western Venezuela, Tectonophysics, accepted for publication.

Feo-Codecido, G., Smith, F., Aboud, N. and Di Giacomo, E. 1984. Basement and Paleozoic rocks of the Venezuelan Llanos basins in Bonini, W. E., Hargraves, R. B., y Shagan, R., (eds.), The Caribbean-South American Plate Boundary and Regional Tectonics, GSA, m. 162, p.175-187.

Giunta, G., Marroni, E., Padoa, E. and Pandolfi, L. 2003. Geological Constraints for the Geodynamic Evolution of the Southern Margin of the Caribbean Plate in Bartolini, C., Buffer, R., and Blickwede,J. (eds.), the Circum-Gulf of Mexico and plate tectonics, AAPG, m. 79, p. 104-125.

González de Juana, C., Iturralde, J. and Picard, X. 1980. Geología de Venezuela y de sus cuencas petrolíferas, I y II.

Jácome, M.I., Kusznir, N., Audemard F., and Flint, S. 2003. The Formation of the Maturín Foreland Basin, Eastern Venezuela: Thrust Sheet Loading or Subduction Dynamic Topography, Tectonics, v. 22, n. 5, p. 1-17

Schmitz, M., Martins, A., Chalbaud, D., Guédez, R., and Contreras, R., 2003. Estudios recientes de sísmica de refracción profunda en Venezuela, VII Congreso Venezolano de Sismología e Ingeniería Sísmica, Barquisimeto, Venezuela.

Toth, J., Kusznir, N. and Flint, S. 1996. A flexural isostatic model of lithospheric shortening and foreland basin formation: Application to the Eastern Cordillera and Subandean belt of NW Argentina, Tectonics, v. 15, p.213-223.