# TECTONIC INHERITANCE AND STRUCTURAL STYLES IN THE MERIDA ANDES (WESTERN VENEZUELA).

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**KEY WORDS:** Venezuela, Merida Andes, tectonic inversion, crustal scale balanced sections

## INTRODUCTION

Unlike the adjacent Caribbean and Central Andean orogens, the Merida Andes (Fig. 1) do not relate to direct interactions between the South American craton and either arc terranes or oceanic domains, but represent only minor intraplate readjustements between the Eastern Cordillera in the south and the South Caribbean transform margin in the north.Although no deep seismic profiling has yet been attempted across the Venezuelan Andes, a large set of conventional seismic reflection profiles has been recorded by the petroleum industry in the Maracaibo and Barinas-Apure basins, respectively along the North and South Andean foothills. In addition, isolated refraction and magnetotelluric data are available. However, only the gravimetric coverage is really complete, thus providing a relatively coherent image of the basement architecture.

## STRUCTURE OF THE SOUTH ANDEAN FLANK

The Barinas-Apure basin extends from the Andean foothills in the northwest to the Guyana shield in the southeast, thus encompassing most of the drainage area of the Rio Apure, a tributary of the Orinoco River. Southwards, it connects directly with the Llanos basin in Colombia. The Barinas basin hardly compares with a flexural basin. It is largely dominated by either north- or south-verging basement-involved structures. The tectonic inheritance is obvious, as Paleogene normal faults are locally inverted and early emplaced Paleogene Caribbean nappes are frequently reactivated or refolded by younger oblique Neogene Andean structures. Seismic profiles in this area also attest to the strong Neogene structural inversion of Upper Jurassic-Lower Cretaceous grabens. Seemingly, Paleozoic, Hercynian or more likely Caledonian structures were reactivated during both the Tethyan rifting and the Andean deformations, and account for local pre-existing crustal heterogeneities.

## STRUCTURE OF THE NORTH ANDEAN FLANK

Tectonic inheritance is less obvious along the North Andean flank, with most structures being exclusively derived from the Neogene Andean compressions. Although outcrop conditions are rather poor, numerous seismic lines and exploration wells also provide good control of the overall architecture of this part of the orogen. In the north, a flexural basin developed in Neogene times between the Andes and the Lake Maracaibo. North-verging thrusts are mainly detached in the pre-Cretaceous substratum and form a deeply buried antiformal stack, whereas secondary décollement levels occur either in the Upper Cretaceous or Tertiary strata, accounting for the passive roof thrust of a conventional frontal triangle zone.

## CRUSTAL ARCHITECTURE OF THE MERIDA ANDES

Although no deep seismic and only scarce refraction data are yet available, two trans-Andean regional profiles (Fig. 1 and Fig. 2) have been balanced and constrained by an inversion of the gravimetric data. Both sections fit with a progressive deepening of the northern Moho and require minimum south-dipping subduction of the infra-continental lithospheric mantle of the Maracaibo microplate. The shortening for both sections averages 60 km.

Palinspastic restorations assume a relative cylindricity for the deep crustal architecture of the Andes and minimize the possible effects of a progressive right-lateral escape of the Maracaibo microplate with respect to stable South America along the Bocono Fault. Due to strain partitioning, the Neogene oblique convergence induced surficial thrust fronts parallel to the plate boundary, strike-slip motion in the allochthon along the Bocono Fault, and an asymmetric subduction (wedging) at depth.

## CONCLUSIONS

The Venezuelan Andes constitute a Neogene transpressional feature. In detail, however, the tectonic inheritance of older structures accounts for contrasting structural styles along the strike of the North Andean flank, or between the northern, central and southern segments of the orogen:

Pre-existing Paleozoic thrusts account for the asymmetry observed during the subsequent Jurassic episode of rifting, as well as for the localization of intra-crustal southeast-verging Neogene conjugate backthrusts.

Pre-existing late Paleozoic or Jurassic extensional structures account for a pre-orogenic thinning of the Maracaibo lithosphere in the southern Andean segment, resulting in its presently moderate reliefs. In addition, the Neogene inversion of Jurassic grabens controls locally the structural culminations, especially in the southern part of the Barinas basin.

By contrast, pre-existing Paleogene normal faults and reactivated Eocene Caribbean thrusts are essentially restricted to the northern part of the North Andean foothills, in the Barinas basin.

An estimate of 60 km of Neogene shortening results from the construction of crustal-scale balanced cross sections. Constant along the strike of the Venezuelan Andes, this value precludes any major rotation of the Maracaibo microplate with respect to the stable South American craton.

The Merida Andes are a key example of an intercratonic orogenic belt, developed in response to oblique convergence between two independent continental lithospheric blocks. In this case, only the northwestern foreland develops as a conventional flexural basin. The surficial asymmetry of the orogen is effectively highly significant of what is happening at depth. Unlike the coastal Caribbean belt in eastern Venezuela and Trinidad, or farther south in the true Andean Cordillera, the South American lithosphere is not subducted beneath the Merida Andes. By contrast, it is the Maracaibo lithospheric microplate that is progressively involved in a southeast-dipping A-subduction.

The understanding of these particular and contrasted structural styles is of major importance for petroleum exploration. Numerous prospects indeed appear to postdate the major episodes of hydrocarbon generation and migration, and thus would not be of any interest unless a remigration of early entrapped hydrocarbons occurred.

Hopefully, this is frequently the case, as attested to by numerous discoveries in the Barinas basin, and the oil seeps that frequently occur along the North Andean foothills.

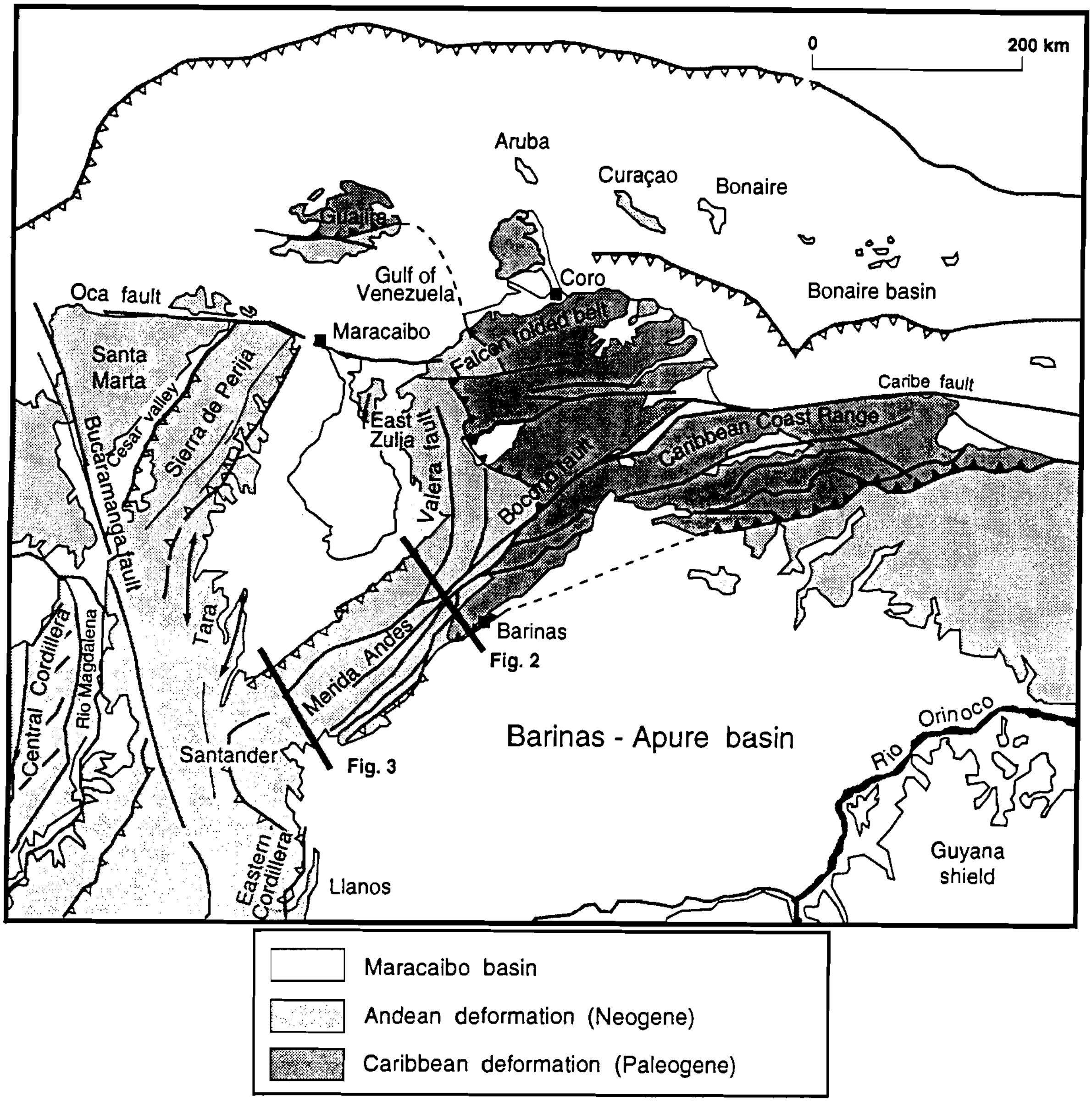


**Figure 1:** Structural map of the northwestern part of South America, imaging the Merida Andes, the Bocono Fault and their relationships with the Colombian Andes in the south, the Caribbean allochthon in the north-east.

**Figure 2:** Crustal-scale balanced section across the Central Andes. Notice the progressive underthrusting of the Maracaibo lithosphere (upper mantle) beneath the South American plate, and the progressive wedging of the upper crust. See Fig. 1 for location.

**Figure 3:** Crustal-scale balanced cross-section in the Southern Andes. Notice the relative thinning of the lithosphere in the restored section (Jurassic rifting), in place of the future Andes. For location, see Fig. 1.

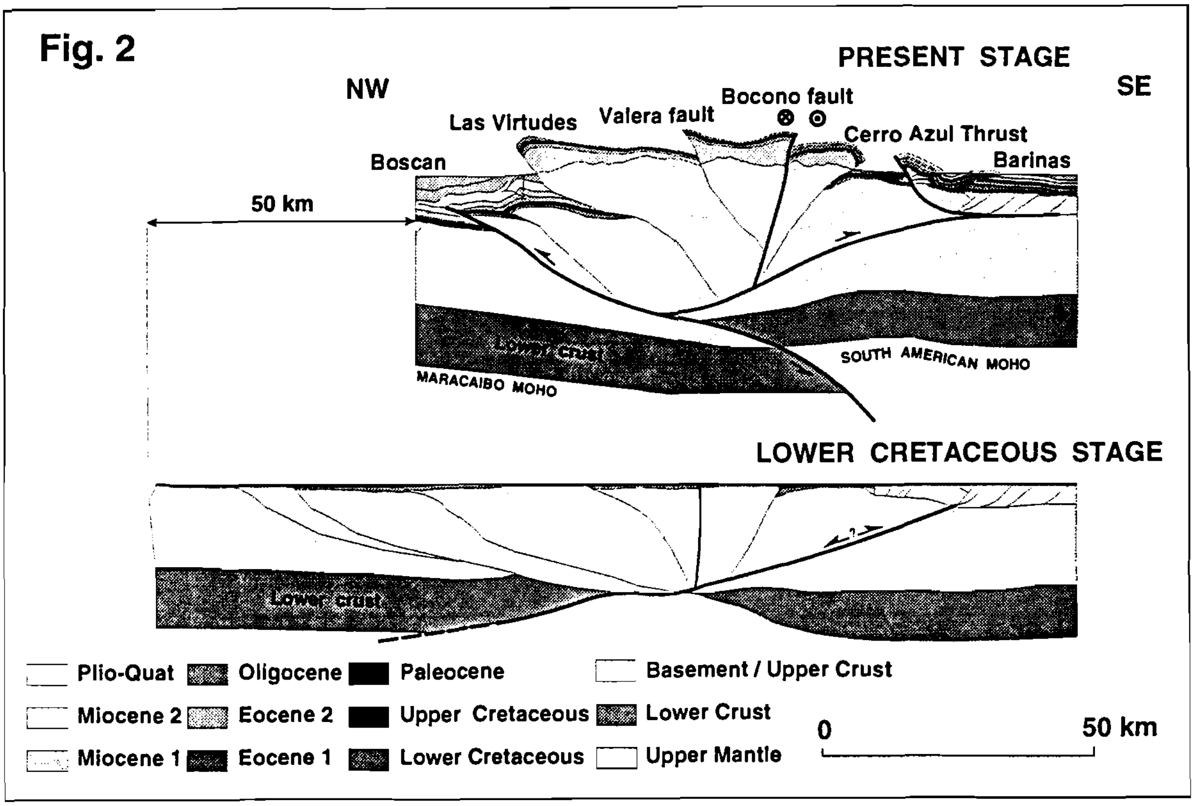
Fig. 2
PRESENT STAGE
NW
SE
Las Virtudes
Valera fault
Bocono fault
Cerro Azul Thrust
Boscan
Barinas
50 km
Lower Crust
SOUTH AMERICAN MOHO
MARACAIBO MOHO
LOWER CRETACEOUS STAGE
Lower crust
Plio-Quat
Oligocene
Paleocene
Basement / Upper Crust
Miocene 2
Eocene 2
Upper Cretaceous
Lower Crust
Miocene 1
Eocene 1
Lower Cretaceous
Upper Mantle
0
50 km

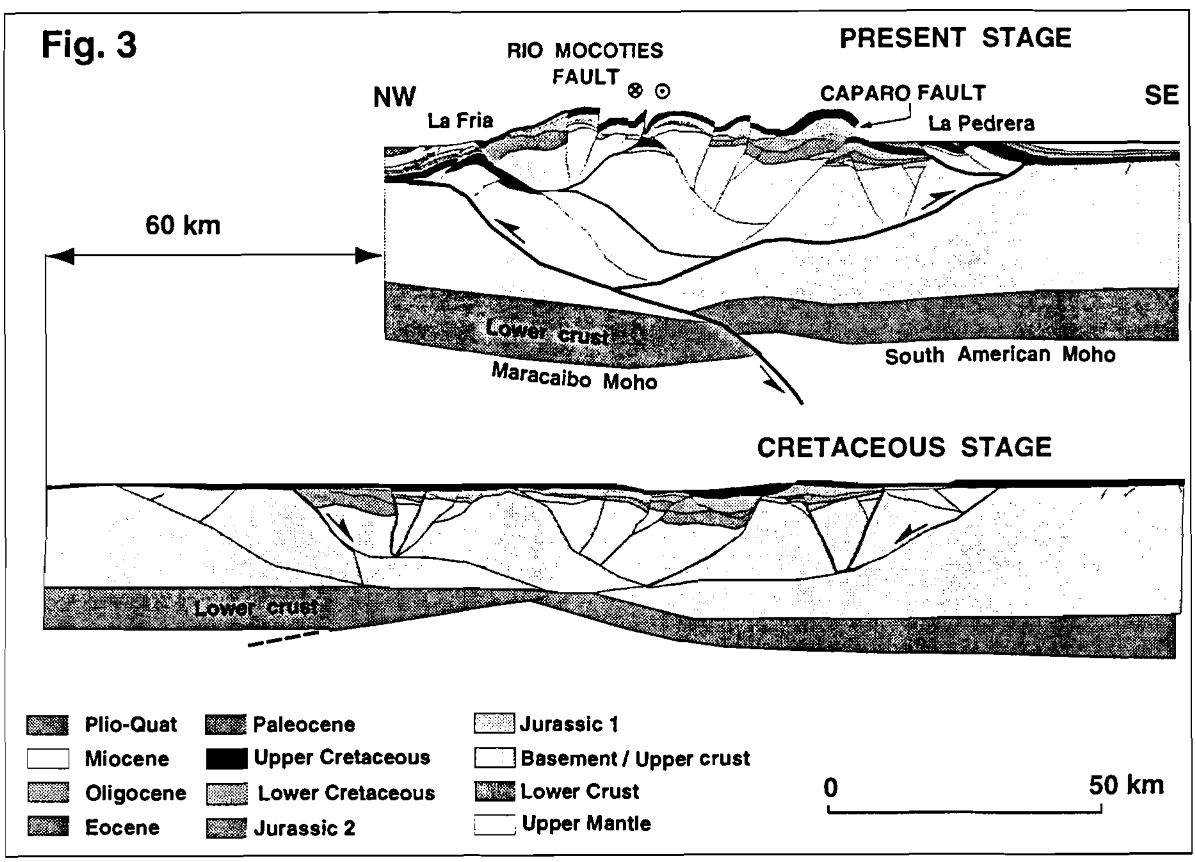
Fig. 3
PRESENT STAGE
RIO MOCOTIES
FAULT
NW
SE
La Fria
CAPARO FAULT
La Pedrera
60 km
Lower crust
South American Moho
Maracaibo Moho
CRETACEOUS STAGE
Lower crust
Plio-Quat
Paleocene
Jurassic 1
Miocene
Upper Cretaceous
Basement / Upper crust
Oligocene
Lower Cretaceous
Lower Crust
Eocene
Jurassic 2
Upper Mantle
0
50 km