Paleogene Depocenter along the Northeast Margin of the Maracaibo Basin: Structure along an Exhumed, Eocene Age Lateral Ramp Fault in the Maracaibo Basin, Western Venezuela*

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Abstract

Two different tectonic models have been proposed for the thick Eocene depocenter located along the northeastern margin of the Maracaibo basin, Venezuela. The first model proposes that the depocenter is a foreland basin controlled by southwestward-directed overthrusting during late Paleocene-middle Eocene collision between the Caribbean and South American plates. The second model proposes that the northeast sedimentary wedge was controlled by a large tear fault, or lateral ramp, separating SE-directed, but independently moving, thrust sheets. Regional seismic lines reveal the structure of the Paleogene depocenter in the northeastern area of the Maracaibo basin. The Burro Negro fault forms a line of separation between shallow to outer shelf, less deformed rocks to the SW from deep marine highly deformed rocks to the NE. Configuration of the basin and faults mapped on regional-scale 2D seismic lines tied to wells supports a tear, or lateral-ramp fault origin, which allowed SE migration of the thrust front east of the Maracaibo basin.

Introduction

In Venezuela, a west-to-eastward younging pattern of thrusts and lateral ramp faults are developed along the Caribbean - South American boundary (Fig. 1). In present-day Maracaibo basin, these lateral ramps and thrusts are largely inactive, but exposed by later inversion related to the North Andean orogeny. The main objectives are to illustrate the overall structure of the Burro Negro fault, an exhumed Eocene age lateral ramp fault exposed along the eastern edge of the Maracaibo basin, by using a compilation of outcrop and subsurface observations compiled from previous workers and regional 2D seismic data. These data show that the Burro Negro fault, is rigth-lateral strike-slip in character and separates an unthrusted, asymmetrical shallow to deep basin from a thrusted area of deepwater sedimentary rocks.

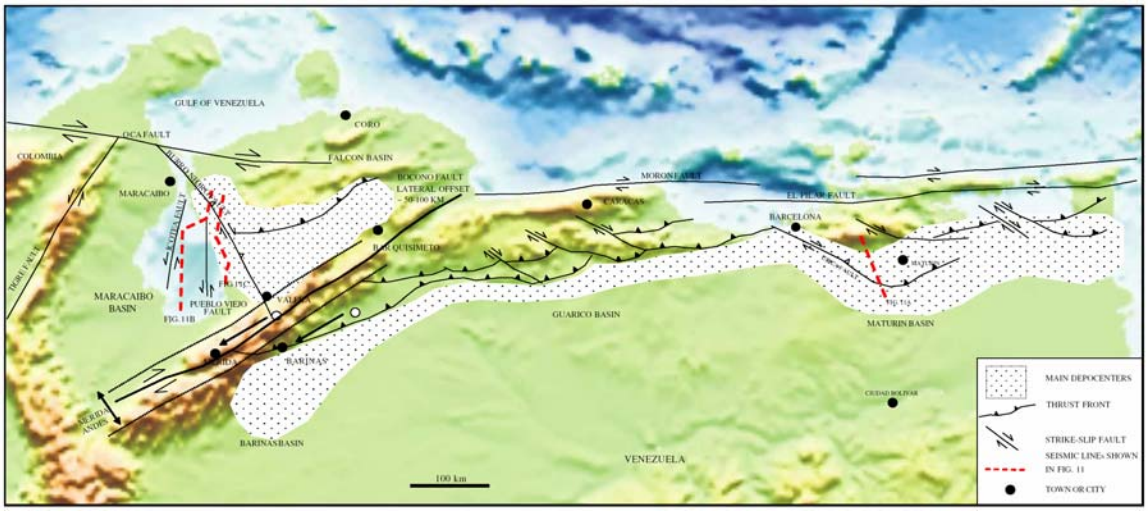

Figure 1. Major structures and foreland depocenters of Venezuela. Location of major Cenozoic sedimentary basins and major thrust, lateral ramp and strike-slip faults as product of the collision between the Caribbean plate and northern South America (modified from Stephan, 1985, and Babb and Mann, 1999)

Regional Setting

Figure 2 shows the present-day configuration of the Maracaibo basin, located in western Venezuela. The basin is a triangular depression bounded by two main mountain ranges trending NE and NNE. The Sierra de Perijá and Oca fault bound the basin to the west and north, respectively. The Mérida Andes bounds the basin to the SSE. The Boconó fault, a dextral strike-slip fault, follows the crest of the Mérida. To the east the depression is bounded by the Trujillo Mountains, trending NW-SE and ending near the Valera fault. East of the Trujillo Mountains are the Lara nappes folded into an anticlinorium trending NE-SW (Mathieu, 1989).

A regional time slice at 3400 ms, covering most of the Lake Maracaibo area and part of the eastern alluvial plains, (Figure 2), intersects Cretaceous to Miocene rocks. Prominent structural features within the 3400 ms time slice include NNE striking faults (e.g., Icotea and Pueblo Viejo faults), formed during Jurassic rifting and reactivated as Eocene strike-slip faults. Another family of east-west-striking faults is observed, mainly in the central part of the basin. These faults were previously interpreted as a flexural response to the subsidence of the South American plate due to load of the Caribbean plate during the Paleogene (Castillo, 2001). Two models for the structural evolution of the Maracaibo basin and the development of the Eocene depocenter located in the northeast-east have been proposed:

A) Foreland basin (Lugo, 1991; Audemard, 1991; Lugo and Mann, 1995): A NE-dipping thrust front, located in the northern part of the basin and Falcón area, controlled a parallel Eocene foredeep. The thrust front and foredeep migrated southeastward with the emplacement of the Lara nappes.

B) Tear fault or lateral ramp or transversal (Stephan, 1985; Mathieu, 1989): A depocenter located SE of the tear fault or lateral ramp. The tear fault allowed independent SE migration of the thrust front. Terminal collision of the Lara nappes (Caribbean arc) and South America continental crust led to emplacement of the Lara nappes, east of the Maracaibo basin.

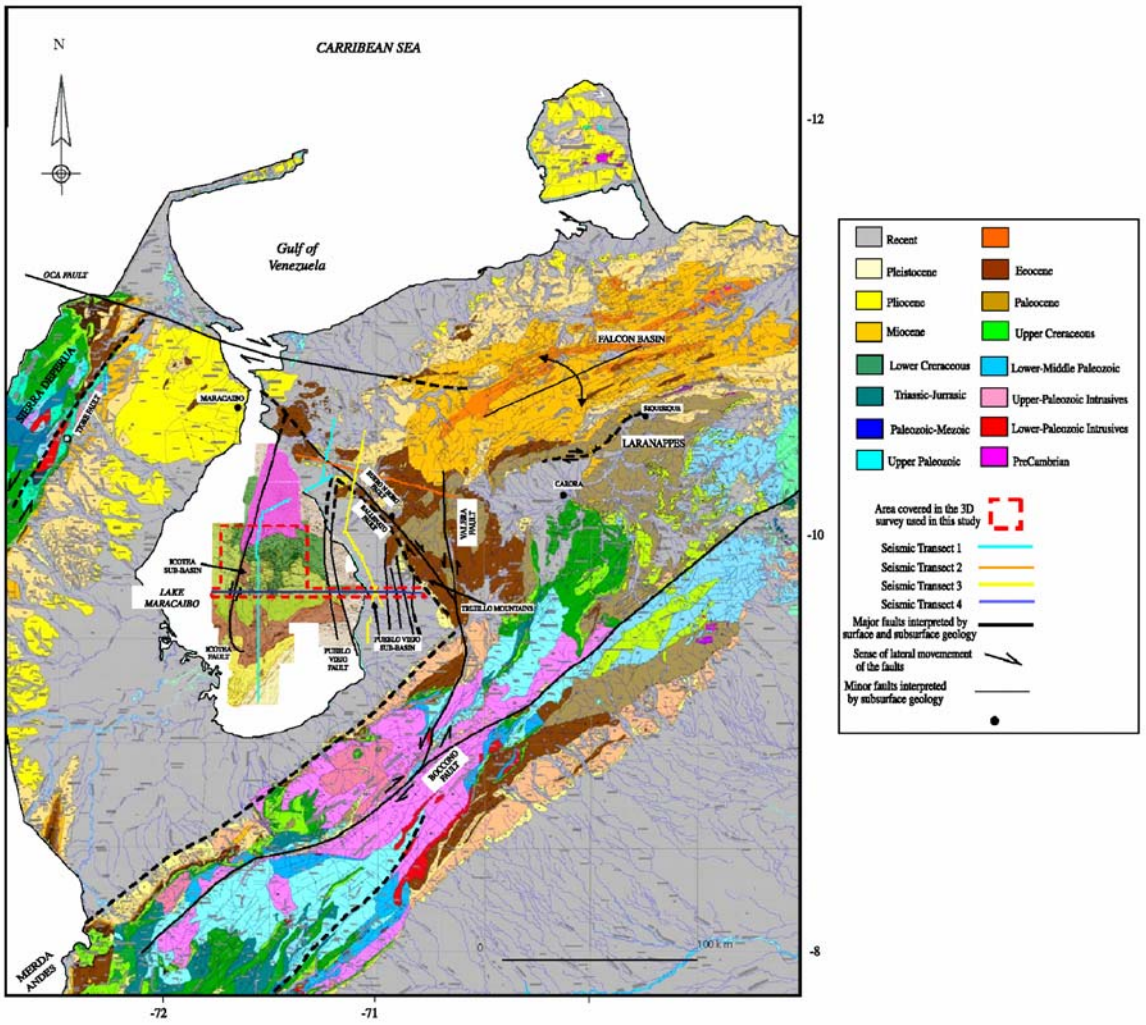

Figure 2. Surface geologic map of the Maracaibo basin region and time-slice map at depth of 3.4 seconds beneath the Lake Maracaibo area.

Database and Methodology

This study uses 2000 km^2 of 3D seismic data, located at the center of the Maracaibo basin, and approximately 500 km of 2D seismic lines. Regional time slices, produced by merging many of the 3D seismic surveys of the Lake Maracaibo area (Castillo, 2001), were also used. Five deep exploratory wells located in the central and eastern parts of the basin were tied to seismic data. A fence diagram shown in Figure 3 orients the various tectonic elements interpreted in the eastern map of the Maracaibo basin.

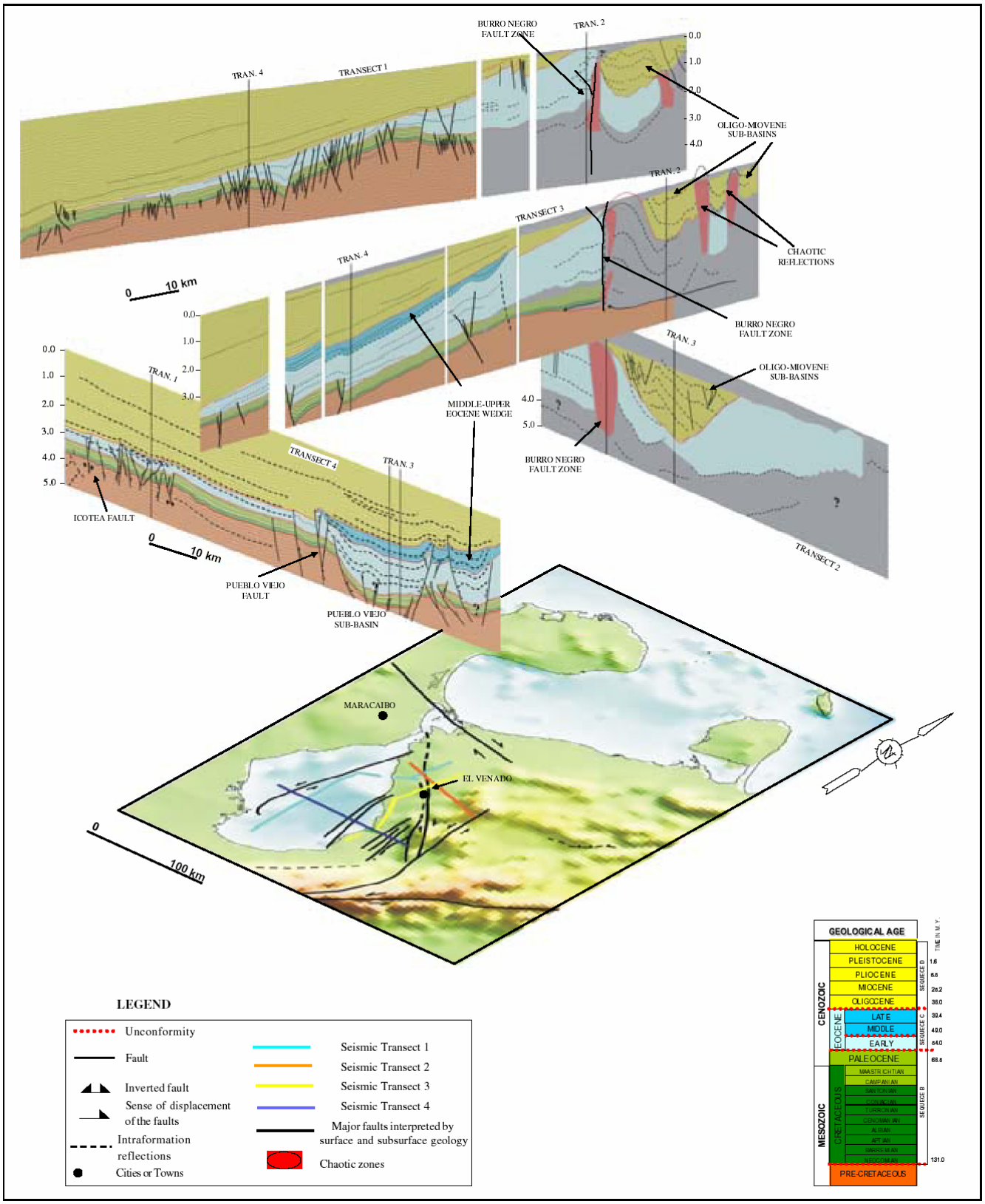

Figure 3. Fence diagram showing the main structural elements of the central and eastern part of the Maracaibo basin and location of the main faults in the map view.

Tectonic Elements

Lower Eocene Clastic Wedge: Foreland Basin, Forebulge, and Thrust Front

In the Maracaibo basin, lower Eocene rocks onlap the Paleocene unconformity and back-step from north to south (Figure 3). Southward migration of younger, onlap deposits over the Paleocene unconformity indicates southward migration of the forebulge as subsidence increases. By middle Eocene most of the Maracaibo basin was subaerially exposed. Isostatic rebound and cessation of tectonic loading over the basin suggests a termination of the Maracaibo foreland basin.

Burro Negro Fault Zone, Platform Break and Lateral Ramp

Deeper Eocene rocks are to the NE from a stable shallower platform to the SW. Gonzáles de Juana et al. (1980) defined a paleogeographic boundary between the shallow marine environments to the south (platform province) and basinal environments to the north, coinciding with the mapped surface trace of the Burro Negro fault zone. Orientation of Eocene convergence, west of the Burro Negro fault, indicates SW vergence (Mathieu, 1989). Main depocenters were located in front of the folded system during the end of the Eocene east of the Burro Negro fault (Mathieu, 1989), where Paleocene-Eocene flysch and slumps have been observed. Therefore, the Burro Negro fault area can be defined as the shelf edge between the deep basin located to the NNE and the platform to the SSW. The fault was reactivated by oblique collision of the Caribbean coming from the west using the Burro Negro fault as a continental bathymetric reentrant within the NE-trending South American plate boundary where the Caribbean plate could be translated towards the SE, acting as a lateral ramp between collided and uncollided parts of a diachronously forming fold-thrust belt.

Chaotic Zones: Fault Zone, Shale Diapirs?

Structurally chaotic zones separate the Oligocene-Neogene sub-basins, north of the Burro Negro fault. These chaotic zones exhibit characteristics similar to those observed in highly fractured fault zones or shale diapirs, where basinal shale is overpressured by the Eocene-present compression.

Eocene Barinas Basin

The Eocene Barinas basin depocenter is separated by the Mérida Andes and Boconó, and is located between 50 to 100 km southwest from the Eocene Maracaibo depocenter. Horizontal displacement along the Boconó fault is estimated to be more than 30 km and less than 100 km (Audemard et al., 1999). Removal of Late Tertiary dextral motion along the Boconó fault aligns the Barinas Eocene depocenter with the Eocene depocenter east of the Burro Negro fault, south of the Lara nappes thrust front interpreted by Stephan (1985).

Paleogene Evolution Model for the Maracaibo Basin

An integrated reconstruction of the evolution of the Maracaibo basin during the Paleogene is summarized in Figure 4. Three main stages can be described as follows:

a. Late Paleocene - early Eocene (Figure 4A): The Maracaibo basin begins to downwarp as a response of tectonic loading in the north and northeast as the Caribbean plate collides with northern South America. A flexural bulge that formed in the central part of the basin migrated southward in response to the thrust belt located in the north- northwest.
b. Middle - late Eocene (Figure 4B): Tectonic loading ends in central and south Maracaibo basin, producing a regional unconformity by tectonic rebounding. The thrust front begins to move southeastward, bounded to the west by the Burro Negro fault in the northeastern part of the basin.
c. Late Eocene - Oligocene (Figure 4C): The Caribbean plate moves ESE into the deepwater reentrant and induces strike-slip motion in the area; coeval folding continues east of the Burro Negro fault.
d. Late Tertiary (Boconó fault; Figure 4D): Uplift of the Mérida Andes during the Late Tertiary separates the Maracaibo basin from the Barinas basin. Later motion along the Boconó fault displaces the Maracaibo basin northeastward towards the Barinas Eocene depocenter.

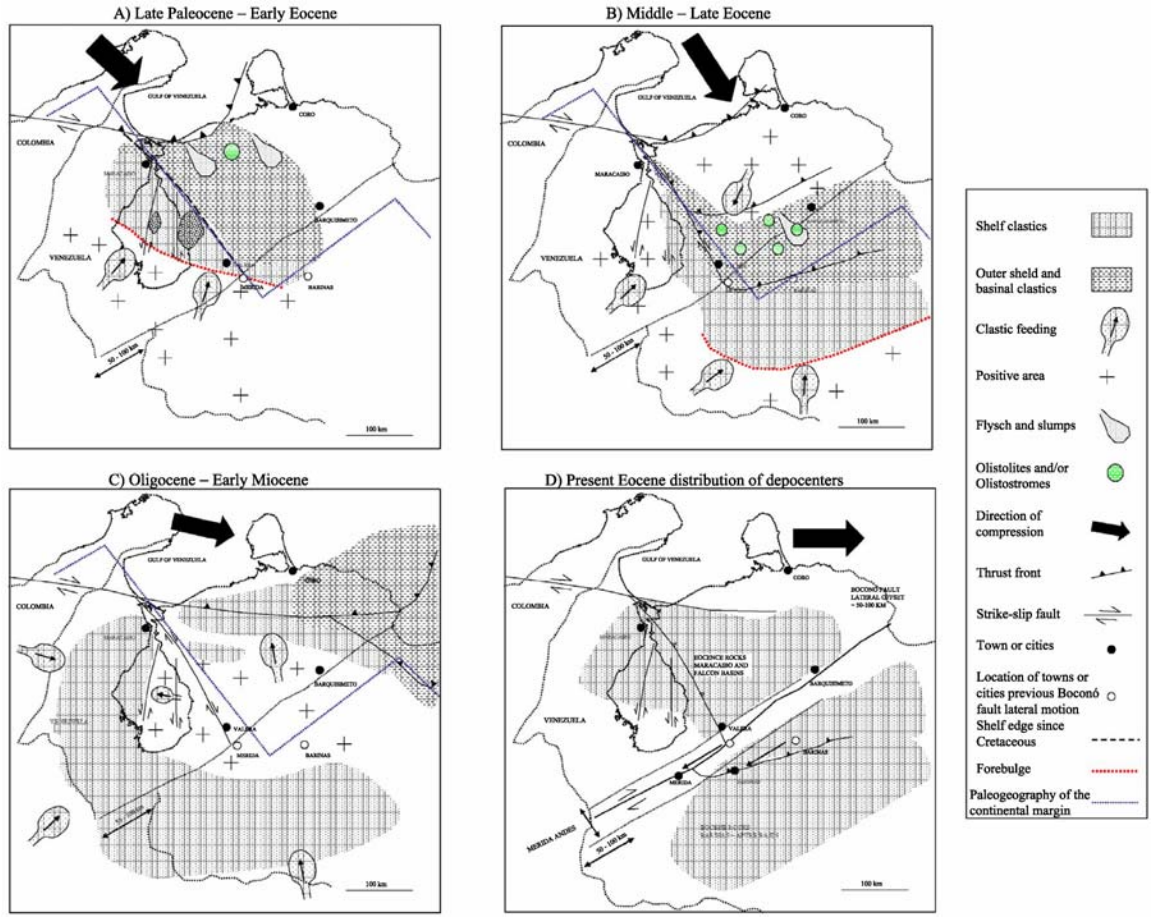

Figure 4. Schematic tectonic reconstruction of northwestern South America during the late Paleocene-Recent. A) Paleocene-early Eocene; B) Middle - late Eocene; C) Late Eocene-Oligocene-Miocene; D) Present distribution of Eocene depocenters after lateral motion along the Boconó fault.

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