2D Seismic Data Images a Fold and Thrust Belt in Northwestern Venezuela

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Abstract

Older 2D seismic data in the Falcón basin, Zulia and Falcón states, northwestern Venezuela, indicates the probable existence of a fold and thrust belt in northwestern Venezuela. This belt is likely the result of the collision of the Caribbean Plate with the South American Plate during the Paleogene. A second pulse during the Lower Miocene is also recorded on 2D seismic profiles near the coast of Falcón. Southwest vergent thrusts are evidenced in the Cocuiza basin, on the Dabajuro high and the Coro platform. Younger south vergent thrusts with large fault propagated folds are seen within the Urumaco trough. Although some of the low-angle thrusting is due to wrench movements along the Oca fault system, much of the thrusting can be attributed to compression rather than transpression during plate collision.

INTRODUCTION

The Maracaibo-Falcón basins of northwestern Venezuela exhibit a complex and multiphase tectonic history gathered from outcrop and surface data, subsurface well data, gravity and magnetic data, and seismic profiles. In general, multiphase deformations in this intraplate foreland include, south to southwest vergent thrust belt system or systems indicating regional compression, regional dextral offset, en echelon folds, and normal faults suggesting regional transpressional systems all modified by local extension and readjustment between small-scale crustal blocks. This region is located within a triangular lithospheric wedge of the northwestern South American plate that includes the Maracaibo and Falcón basins, the Mérida Andes, the Perijá Mountains and the Santa Marta massif (Figure 1). This structural unit, referred to as the Bonaire block (Burke and others, 1984) is defined on the southeast by the northeast trending dextral Boconó fault and on the northwest by the Magdalena-Santa Marta-Bucaramanga sinistral fault (Gallagher, 1990). It is a tectonic triangular wedge that is actively escaping northward over the more dense crust of the Caribbean (Eva and others, 1989; Kellogg and Bonini, 1982; Pindell, 1991; Lugo and Mann, 1995; Stanistreet, 1993) progressively overriding the southern boundary of the Caribbean plate (Figure 2).

The Falcón basin is a small linear polygonal basin that occupies the area between the subduction zone of the Caribbean plate and the South American craton. It is essentially a rift or pull-apart zone formed by the transcurrent motions of the adjoining plates. The convergence of the Americas and the Caribbean plates brought on the initial subduction and the formation of a series of island arcs on the Caribbean plate. Oblique convergence between the plates resulted in the obduction of Caribbean terranes and the stacking of foredeep sequences onto the craton.

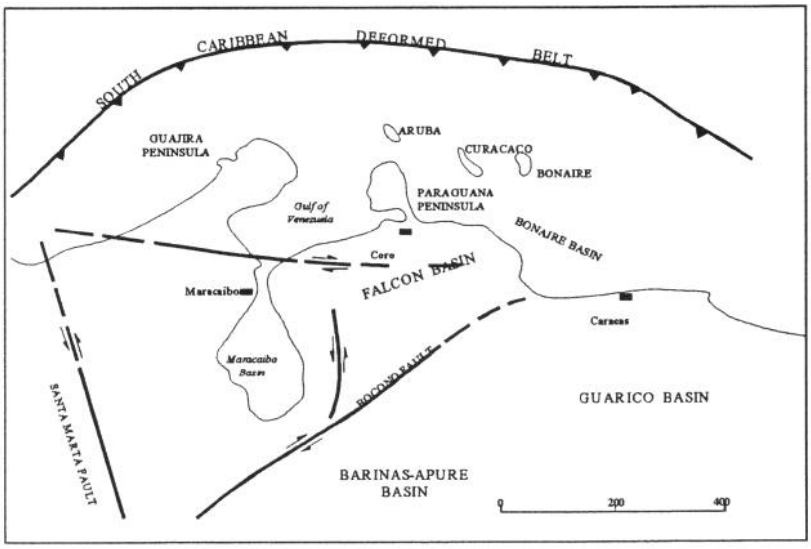

Figure 1 - Index Map of Northwestern South America

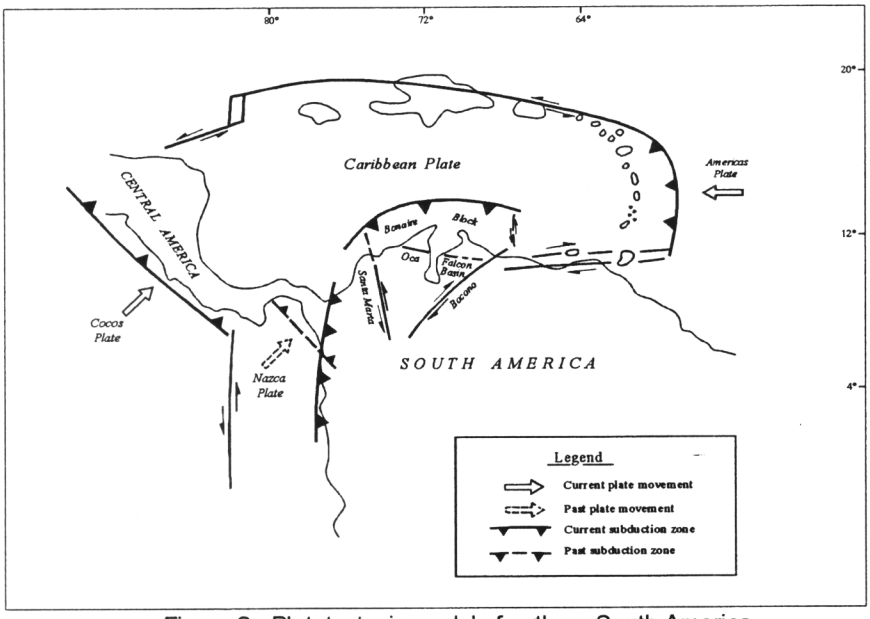

Figure 2 - Platetectonic model of nothern South America
(modified from Macellari, 1984 & James, 1990)

COMPRESSIONAL TECTONICS

Compressional tectonics appears to be a primary surface structural expression in the Falcón basin. The majority of the structures indicate regional compression from the northwest with attendant folding, faulting and differential vertical movement. Extensive northeast trending folds, some tens of kilometers in length are the dominant structural trend of the basin. These are probably the result of compressional tectonics rather than transpressional tectonics. Folds resulting from dextral movement are also northeast trending however they are smaller, easily linked to a wrench fault and more symmetrical than the numerous compressional folds. The compressional surface folds are too large for known wrench faults that display minimal lateral displacement. They are commonly asymmetric with the northern flank displaying much steeper dips than the southern flank and axial planes dipping to the southeast. They are sometimes overturned to the northwest. Although right lateral movement between the two plates has been significant, compression due to collision appears to be the dominant tectonic event in the Falcón region.

SEISMIC DATA AND THRUSTING

Very little is currently understood about the south and southwest vergent thrusts seen on seismic profiles in the southern portion of the Oca fault system and in the Cocuiza basin and the west and west-southwest vergent thrusts imaged on seismic data on the Coro platform (Figure 3). The parameters used to acquire older seismic data did not allow for the imaging of low-angle faults and accompanying sub-thrust structures. Some of the thrusts may be due to the transpressional tectonics of the Oca system rather than resulting from collision and compressional tectonics. Low-angle reverse faults that are adjacent to strike-slip faults and that appear to be rather limited in extent are thought to have generated from wrench tectonics. However, minimal horizontal displacement along the Oca strike-slip system of faults suggests that compression and thrusting were dominant over wrench tectonics. It also appears that the thrust orientations may better coincide with forces causing sinistral movement over those of dextral movement. The Oca system of faults contains at least three major faults that snake through the Falcón basin, merging with one another. However, it does not appear that these thrusts are horsetail thrusts in response to space accommodation necessary as a wrench dies out or transforms its dextral or sinistral movement at its termination. It is therefore believed that most of these thrusts are in response to a major regional compressional event prior to the regional dextral strike-slip movements. All of these thrusts mask deeper structures which are difficult to image. The general lack of data below two seconds in most of the basin is probably due to thrusting and may imply a major regional thrust belt throughout most of the Falcón basin.

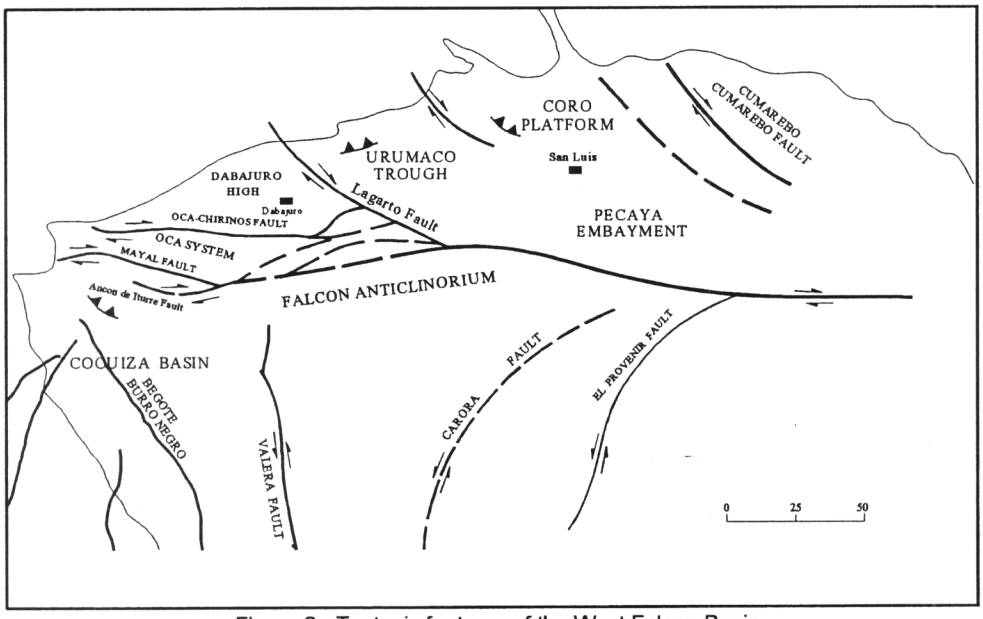

Figure 3 - Tectonic features of the West Falcon Basin

It is likely that these thrust sheets formed along and within the thick shale sections in the Cretaceous Colón Formation and the thick Eocene shale sections of the Trujillo, Misoa/Paují and Jarillal formations. It is possible that these thrusts are part of the western segment of the extensive 1500-km south-verging thrust belt and foreland basin complex along northern Venezuela (Lugo, 1991; Lugo and Mann, 1995). Jones (1995) has also hypothesized that the Eastern Cordillera, the Perijá Andes and the Mérida Andes are all part of the same multi-stage south verging thrust sheet with minor imbrications.

URUMACO TROUGH

The Urumaco tough lies in the northern portion of the Falcón basin just southwest of the Paraguaná Peninsula bordering the Gulf of Venezuela. It is thought to be one of the best regions in the western Falcón basin for the generation and preservation of hydrocarbons (Boesi and Goddard, 1991). More than 30,000 feet of Neogene sedimentation occurred in this trough area. The principal source-rock in the trough is believed to be the Miocene Agua Clara Formation. The Paleogene has not been tested in the area. In general, the area displays the geometry of inversion tectonics, which involves the reversal of extensional fault movement during compressional tectonics (Hayward and Graham, 1989). However, an older event records thrusting and the probable timing for a "second pulse" collision of the Caribbean plate with the South American plate.

FAULT PROPAGATED FOLDS AND THRUSTING

A series of dip profiles oriented north northeastward document a large fault propagated fold that trends northeast-southwest concordant with older regional structure of the Falcón basin. This feature is approximately 11 km in length and 2-2.5 km wide. It lies at about 2 to 2.5 seconds on seismic data and displays more than 300 meters of vertical closure. It is the first structure up from the current north dip in the heart of the trough and appears to have been in place since its formation. Many anticlines in northwestern Venezuela are highly complex displaying significant faulting, erosion and a complex tectonic history. This feature is not as complexly folded and faulted as most anticlines in the region. The lack of complexity is due in part to its Miocene rather than Eocene age. It appears to have been formed during late Agua Clara deposition. Cerro Pelado and younger sediments were unconformably deposited on the structure. It appears that the Santiago Member of the Agua Clara Formation is missing along the crest of the anticline.

The floor thrust detachment zone is in the 4 to 4.5 second range on the eastern half of the fold. The east half also preserves a prominent back thrust which has developed near the leading edge of the thrust and subsequent fault propagated fold. The westernmost seismic profile indicates possible duplex thrusting with multiple offset folds. In this region the basal thrust appears to detach in the 4.7 second range. There is no direct evidence of the stratigraphy in the Urumaco trough at these depths. However, it is believed that the basal thrust detachment occurs in the thick Oligocene shale sections of the Pedregoso and Pecaya formations, which outcrop, updip to the south.

CONCLUSIONS

Current 2D seismic data images possible south and southwest verging thrust faults and accompanying folds in northwestern Venezuela. Most of these thrust faults are likely the result of plate interaction during the Paleogene with a second pulse of tectonic activity during the Lower Miocene. Some of the thrusts are also due to late strike-slip movement along the Oca system of wrench faults. Large fault propagated folds where timing and stratigraphy can be adequately surmised are especially positive as potential hydrocarbon traps. Acquisition parameters for new seismic data to be acquired in northwestern Venezuela should take into account the possibility of a large fold and thrust belt.

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