PSRecord and Constraints of the Eastward Advance of the Caribbean Plate in Northern South America*

J. F. Flinch[1] and V. Castillo[2]

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Abstract

A great variety of complex structures found in northern Colombia, northern Venezuela, the Lesser Antilles, Barbados, Trinidad, and Tobago record the eastward movement of the Caribbean plate relative to the South American plate through time. The development of these structures includes transtensional and foredeep basins as well as fold-and-thrust belts that become younger eastward since the Cretaceous. In northern Colombia, terrane accretion began in the Triassic and ended in the late Cretaceous, along the Gulf of Urabá, and the Sinu–San Jacinto Belt. Further east, the structure offshore Guajira, east from the Bucaramanga fault, is characterized by accretion involving the South American metamorphic basement. Well and seismic data in the Maracaibo Basin record the Paleogene flexure related to terrane collision and accretion. In the Gulf of Venezuela, offshore eastern Falcon, and La Vela, transtensional basins record the eastward movement of the Caribbean plate. Onshore northern Venezuela, the Villa de Cura subduction mélange in the Cordillera de la Costa nappes represents the accretionary wedges involving ophiolites of Eocene age. The Guarico flysch records the flexure of the accretionary wedge during Oligocene time and fills the foredeep of the same age. The Cariaco, Carupano, and La Blanquilla are pull-apart basins related to a younger Oligocene–Miocene-stage strike-slip as the Caribbean plate advances toward the east. Ophiolitic obduction of the Caribbean oceanic domain onto the accreted terranes is represented by the thrusted ophiolites of Isla Margarita. The Monagas area or Serrania del Interior Folded Belt is a characterized Oligocene to Miocene thin-skinned thrusting involving the passive margin units of the South American plate and is overlain by the Carapita accretionary wedge. The Maturin Basin is the flexural basin associated with the loading of the Serrania del Interior thrust stack and extends to the east toward the Delta Centro and Punta Pescador areas, in the Orinoco Delta and south of Trinidad. The Gulf of Paria pull-apart basin in eastern Venezuela and Trinidad developed since the late Miocene and is the easternmost strike-slip basin related to the eastward advance of the Caribbean plate, and terminates against the frontal accretionary wedge of the Caribbean plate of Barbados and Trinidad that is a Miocene to present-day shale-dominated accretionary wedge.

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ABSTRACT

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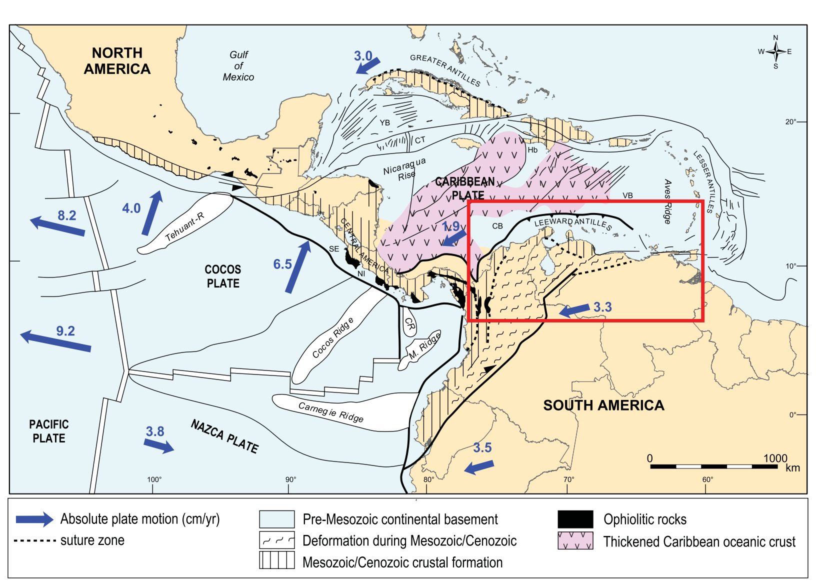
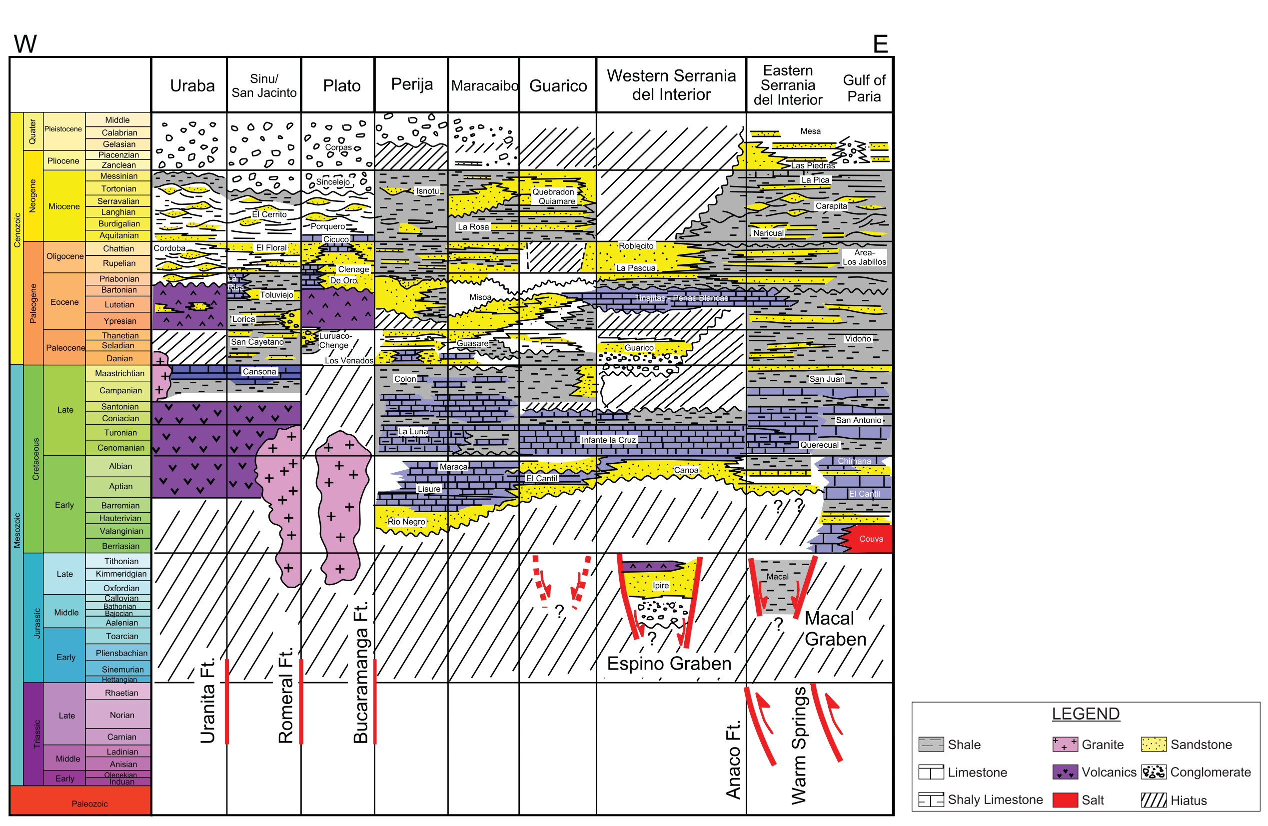


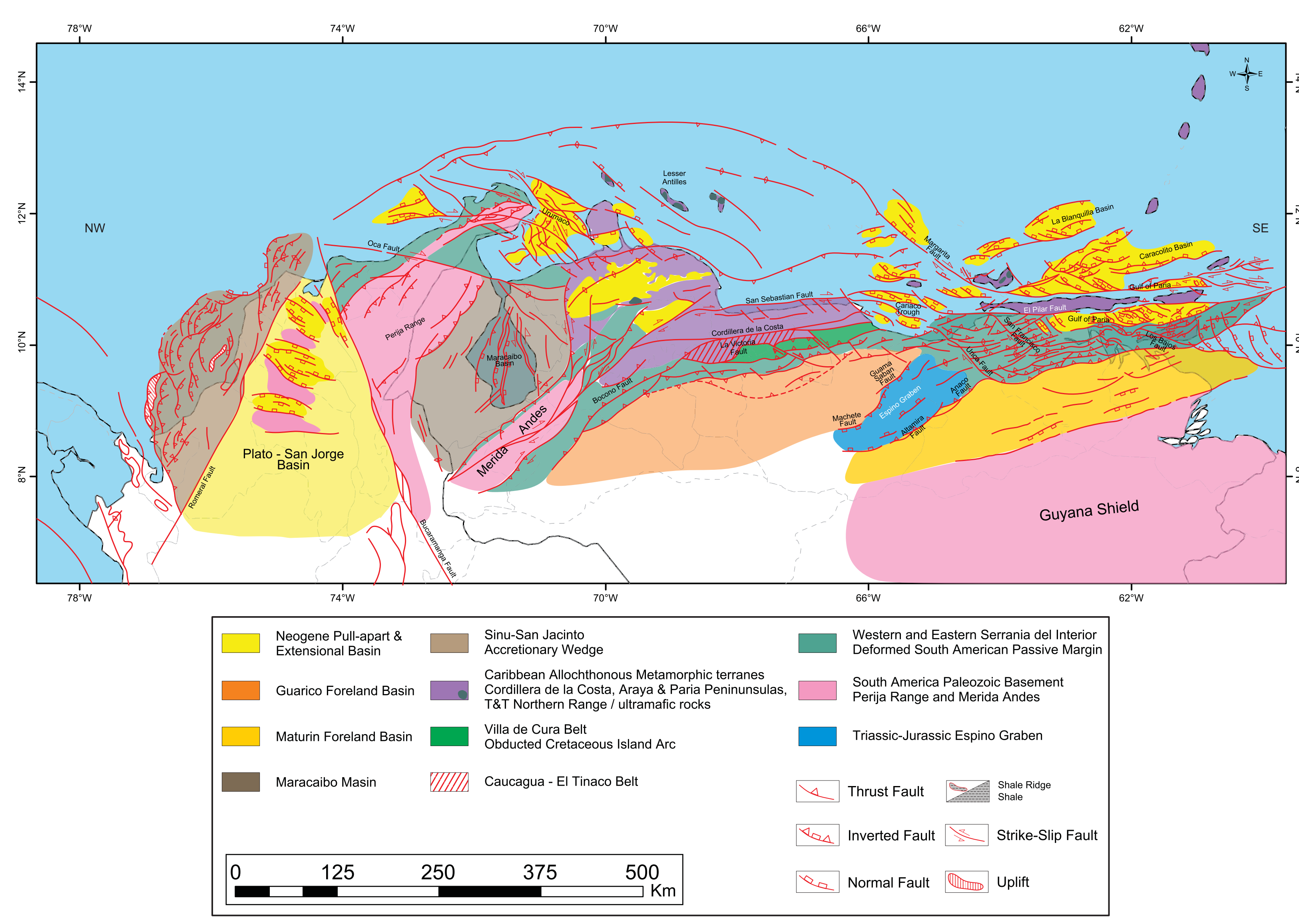
Plate tectonic map of the Caribbean and neigboring areas

(modified from Pindell and Barret, 1990; Muehlberger, 1992, and Flinch, 2003)



West to east litho-stratigraphic sketch through northern South America

(modified from Audemard, 1996; Audemard and Audemard, 2002; Barrios et al., 2011; Castillo, 2001; Castillo and Mann, 2006; Di Croce, 1995; Di Croce et al., 1999; Flinch et al., 1997, 1999, 2003, 2004; Flinch, 2003; Hung, 1997, 2005; Mann et al., 2006; Martinez et al., 2015; Montes et al., 2010; Ostos, 1990; Ostos et al., 2005b; Perez de Armas, 2005a,b; Yscaccis, 1997)



Structural map of northern South America from Panama to Trinidad and Tobago

(modified from Audemard, 1996; Audemard and Audemard, 2002; Barrios et al., 2011; Castillo, 2001; Castillo and Mann, 2006; Di Croce, 1995; Di Croce et al., 1999; Flinch et al., 1997, 1999, 2003, 2004; Flinch, 2003; Hung, 1997, 2005; Mann et al., 2006; Martinez et al., 2015; Montes et al., 2010; Ostos, 1990; Ostos et al., 2005b; Perez de Armas, 2005a,b; Yscaccis, 1997).

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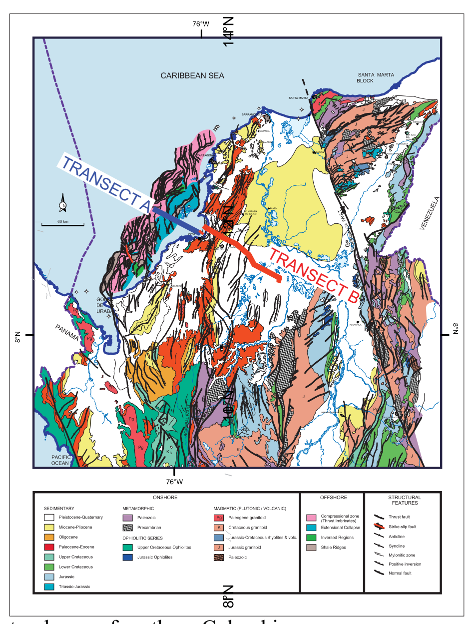
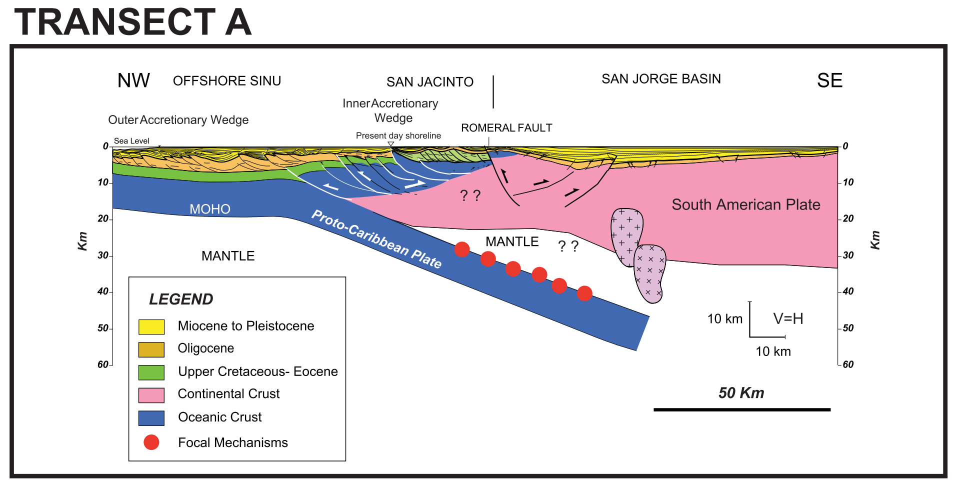
REPSOL



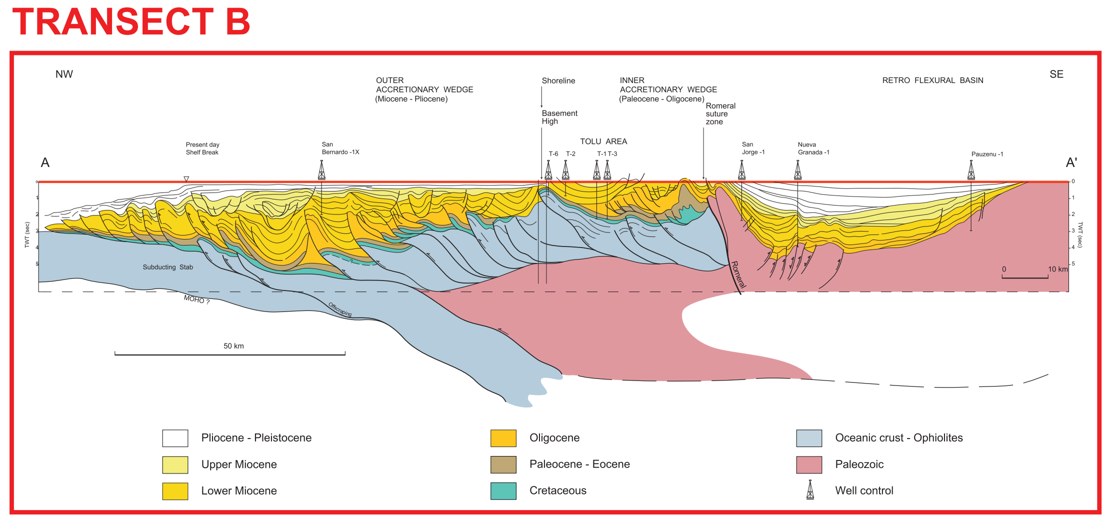
Structural map of northern Colombia (modified from Flinch et al., 2003)

TRANSECT A



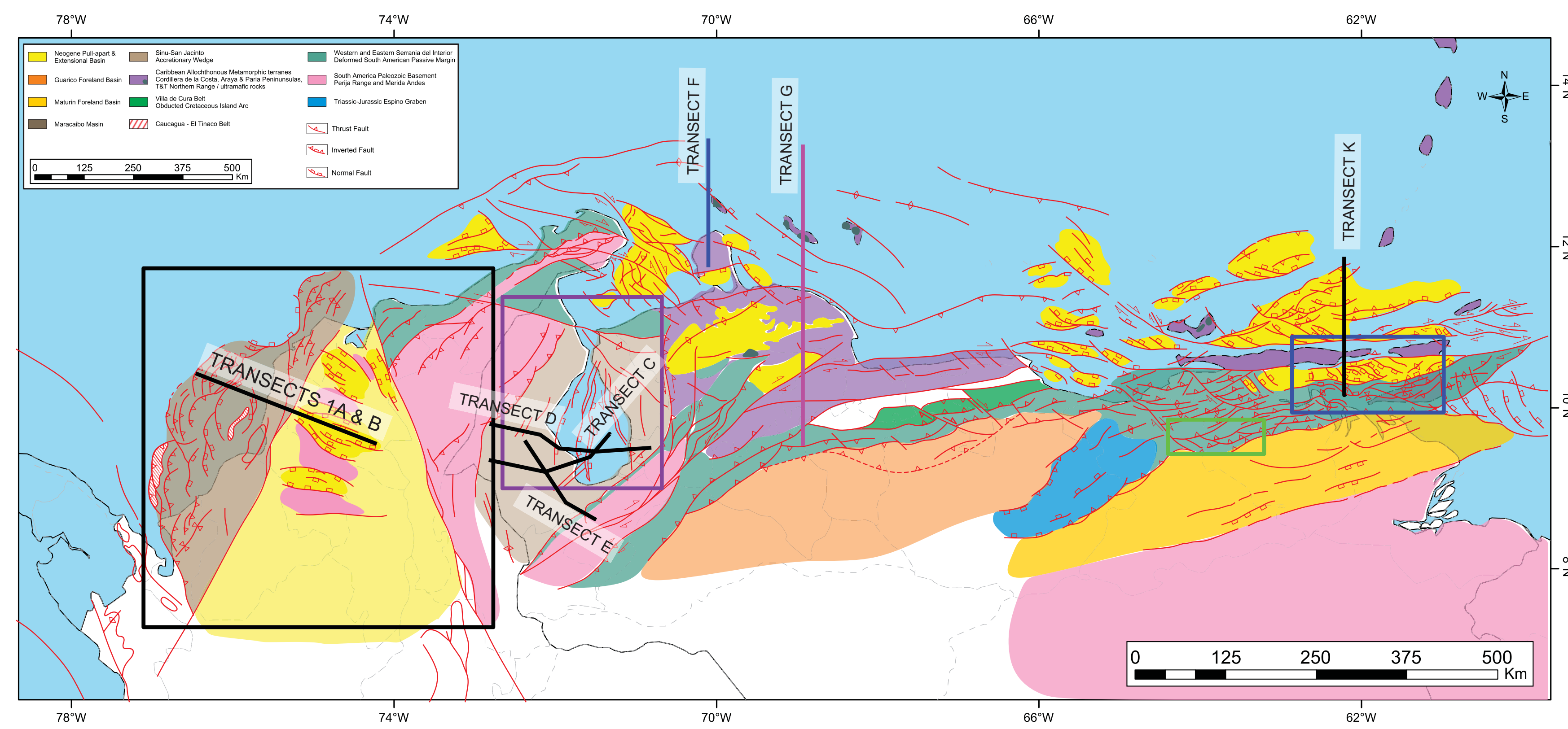
Regional depth section from the Plato–San Jorge to the offshore Sinu accretionary prism (modified from Flinch et al., 2010)

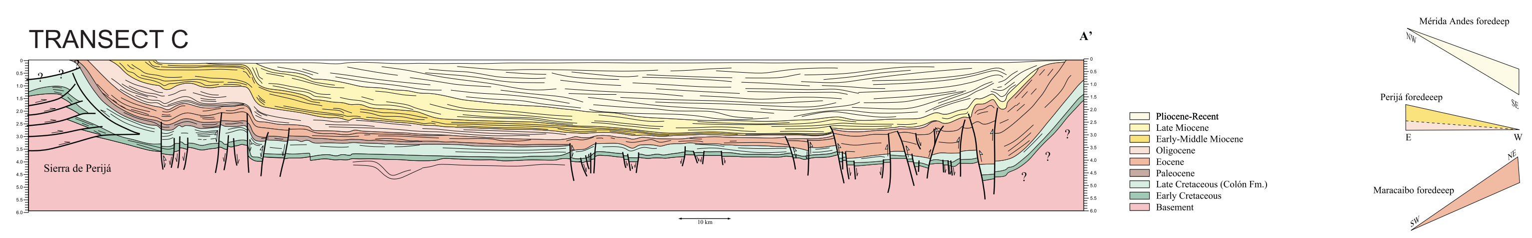
TRANSECT B

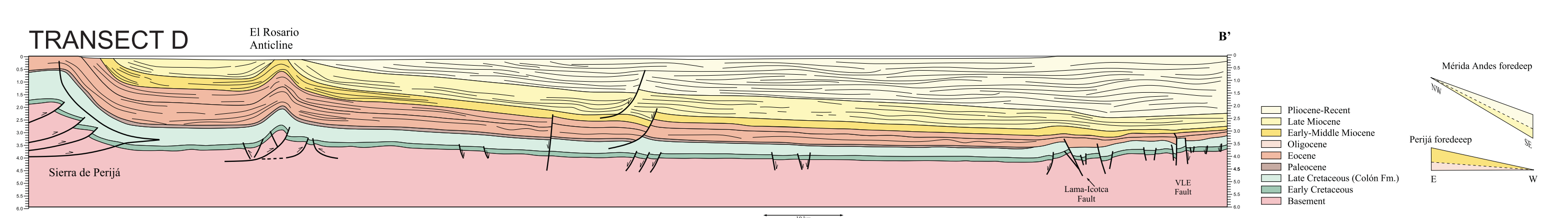


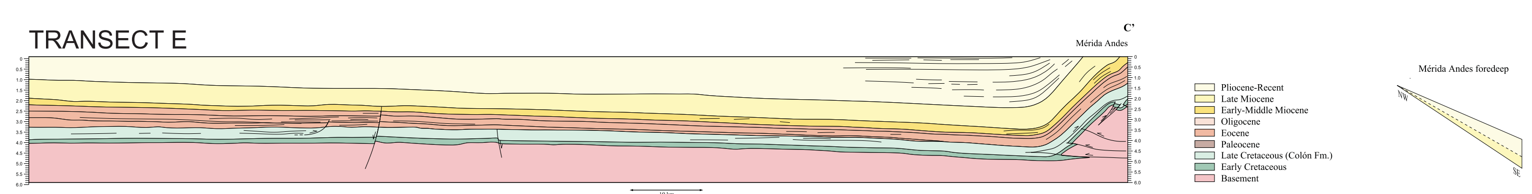
Onshore–offshore seismic line drawing through the offshore Sinu–San Jacinto accretionary wedge

(modified from Flinch et al., 2010). B) (modified from Flinch et al., 2003). Focal mechanisms are from Malave and Suarez (1995)







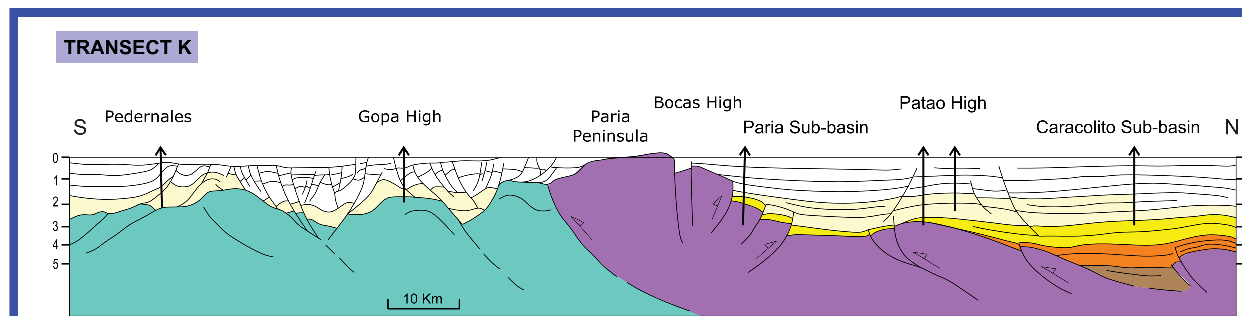


Regional seismic transects across Maracaibo Basin

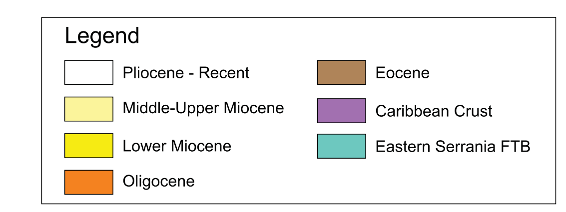
TRANSECT C Regional seismic transect extending from the eastern flank of the Sierra de Perija through the southern Lake Maracaibo. In general, the structures correspond with high-angle Paleogene normal faults that were later inverted during the Late Miocene or younger age, related to the north Andean orogeny. To the west, deformation accommodates in a triangle zone. Foredeep rotation around the Maracaibo Basin is interpreted by the superimposition of opposite sedimentary wedges. The Maracaibo foredeep is indicated by the increase in thickness of the Eocene sedimentary wedge to the east, and the Sierra the Perija foredeep is represented by the Oligocene and early Miocene sediments that thicken to the west. In the same way, late Miocene–Recent sediments thicken toward the east, being related to the Merida Andes foredeep development. (Modified from Castillo, 2001)

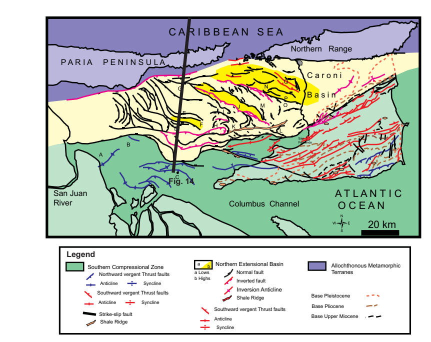
TRANSECT D Regional seismic transect that extends from the eastern flank of the Sierra de Perijá through the southern Lake Maracaibo. The most conspicuous structures correspond to the El Rosario anticline and the triangular zone that accommodates deformation in the frontal part of the Sierra de Perija. The el Rosario structure is an east-vergent basement involved thrust, and the triangular zone is interpreted as a "passive roof duplex" (Banks and Warburton, 1986) also defined as a type II triangle zone (Couzens and Wiltschko, 1996). A back thrust is interpreted along the roof thrust of the basement-involved faults within the Colón Fm. shale. These structures developed during Late Miocene or younger age because Middle and Late Miocene rocks are deformed and exposed at the surface. The Lama-Icotea fault and the VLE fault zone are displayed in the eastern part of this transect. Superimposition of opposite sedimentary wedges is related to the foredeep rotation around the Maracaibo Basin through time. The Sierra the Perija foredeep is represented by the Oligocene and Early Miocene sediments that thicken to the west. In the same way, Late Miocene-Recent sediments thicken toward the east, being related to the Mérida Andes foredeep development. (Modified from Castillo, 2001)

TRANSECT E Regional seismic transect that extends from the northern flank of the Merida Andes in the south to the west-central part of the Maracaibo Basin. This transect shows the less-deformed part of the basin. The northern flank of the Merida Andes is interpreted as a triangle zone similar to the one interpreted in transects A and B; however, the age of this deformation is Pliocene or younger, because the late Miocene sediments are deformed and exposed. This transect shows the late Miocene–Recent

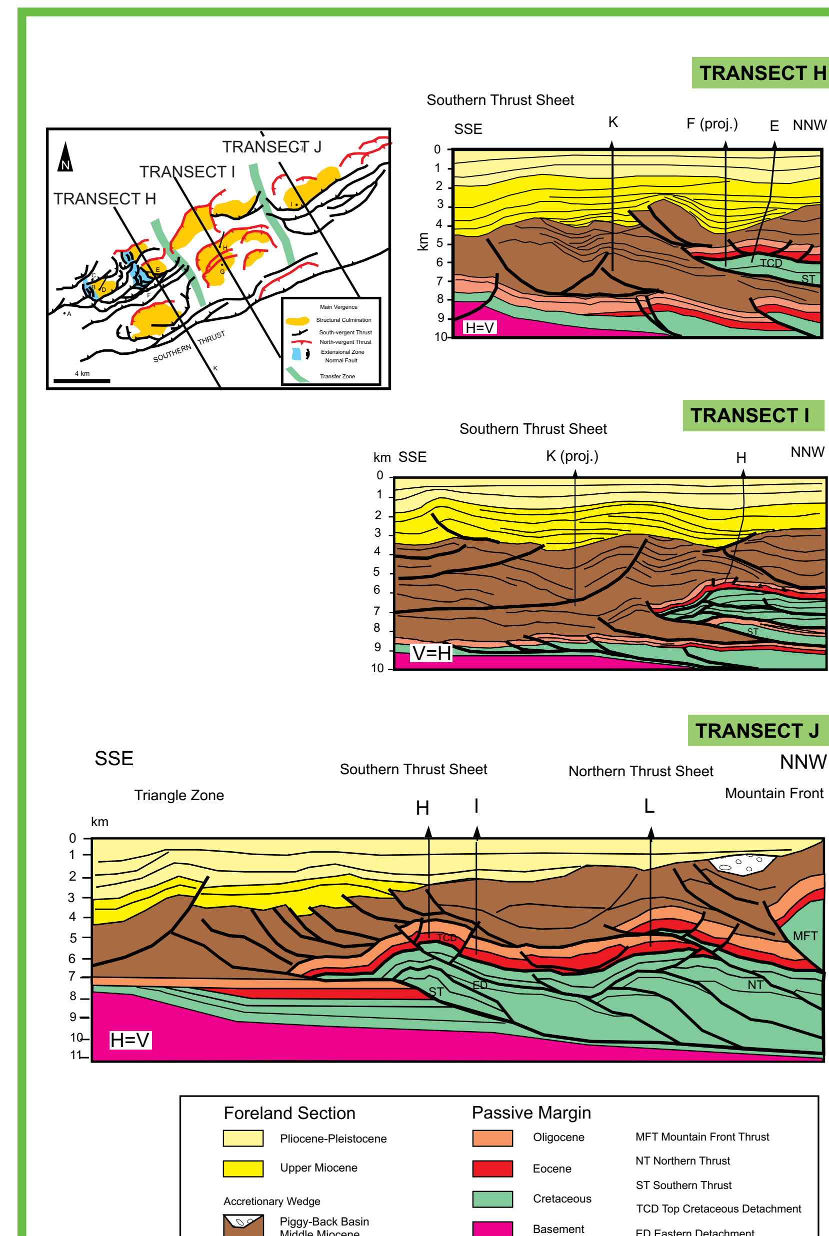


Cross section from the Cariaco trough to the Gulf of Paria (modified from Flinch et al., 1999; Yscaccis, 1997)

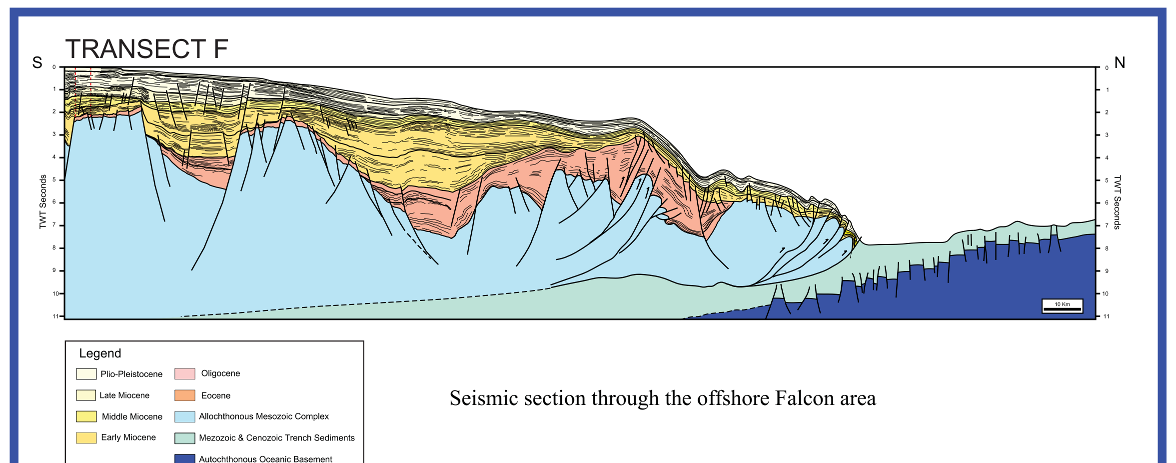




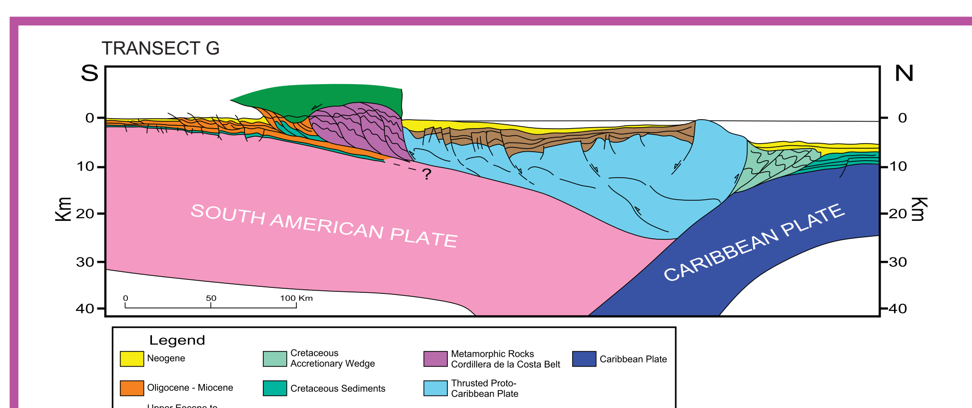
Structural map of the Gulf of Paria Pull-Apart Basin (modified from Flinch et al., 1999)



Northern Monagas Fold-and-Thrust Belt (modified from Flinch et al., 1997)



Seismic section through the offshore Falcon area



Onshore–offshore crustal cross section from the western Serrania del Interior to the Bonaire Basin

(modified from Perez de Armas, 2005, crustal thicknesses are from Case et al. (1990)

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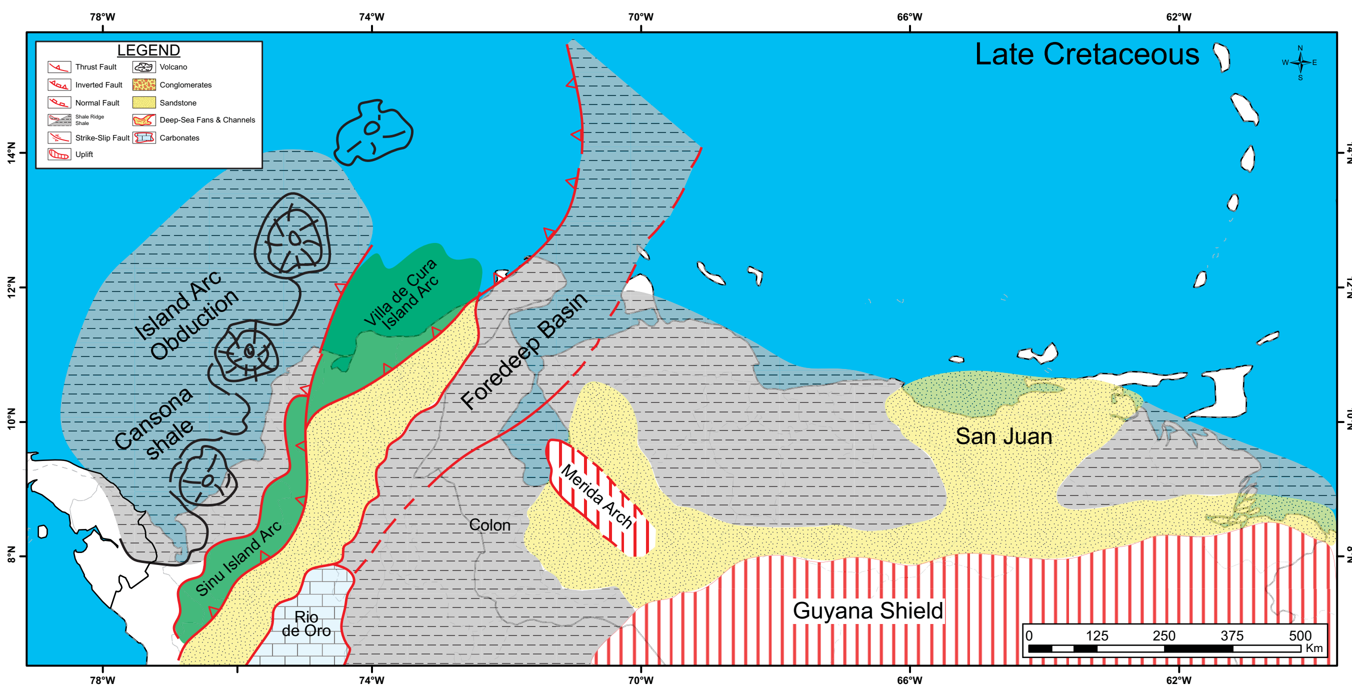
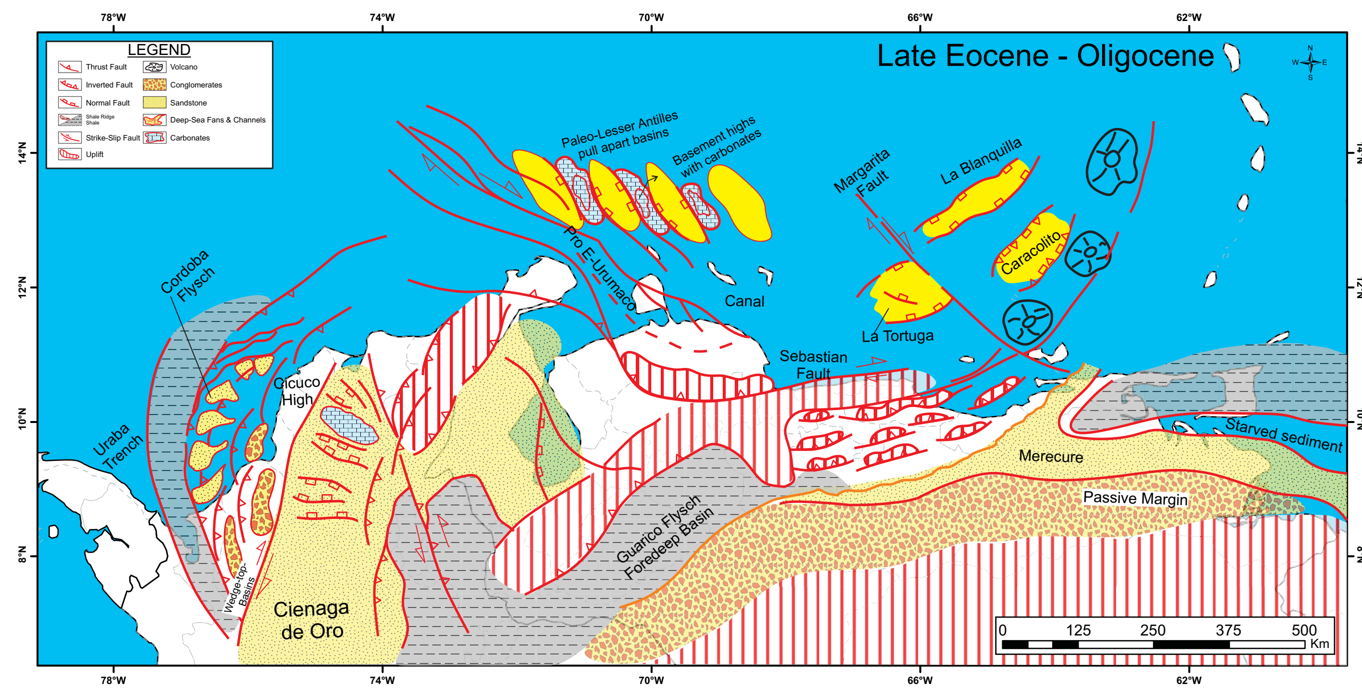
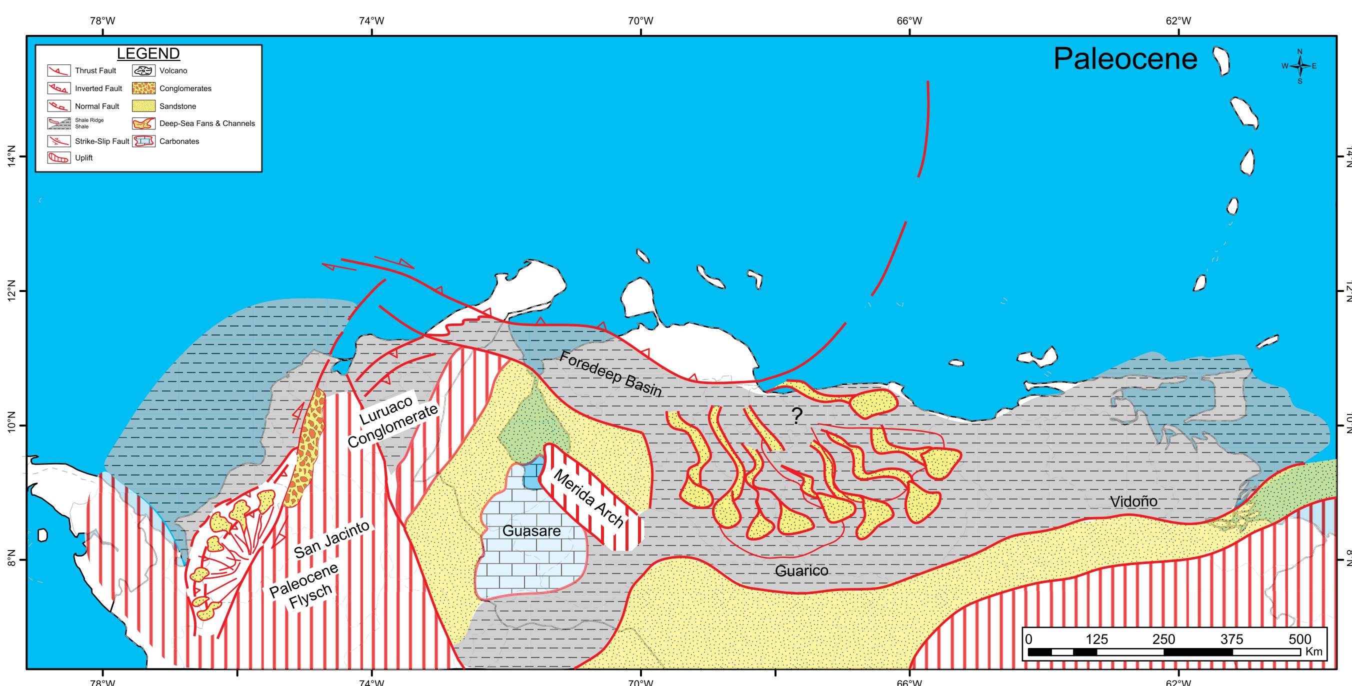
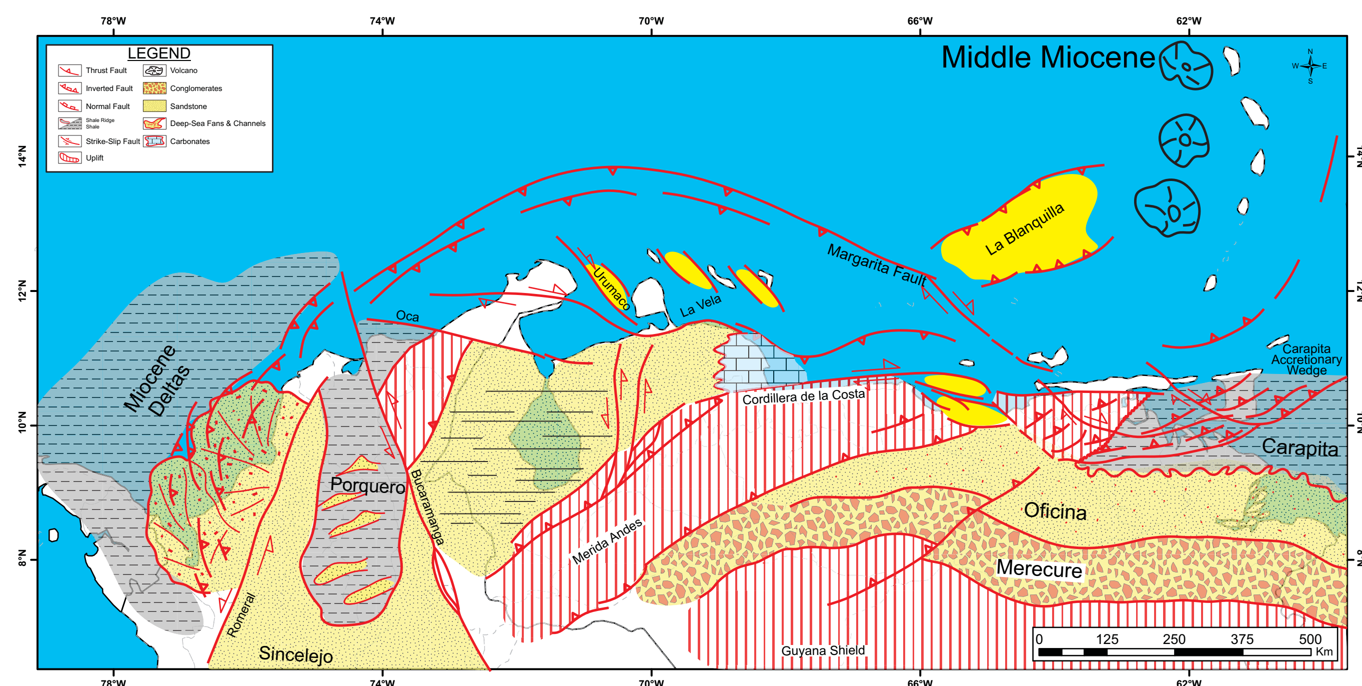
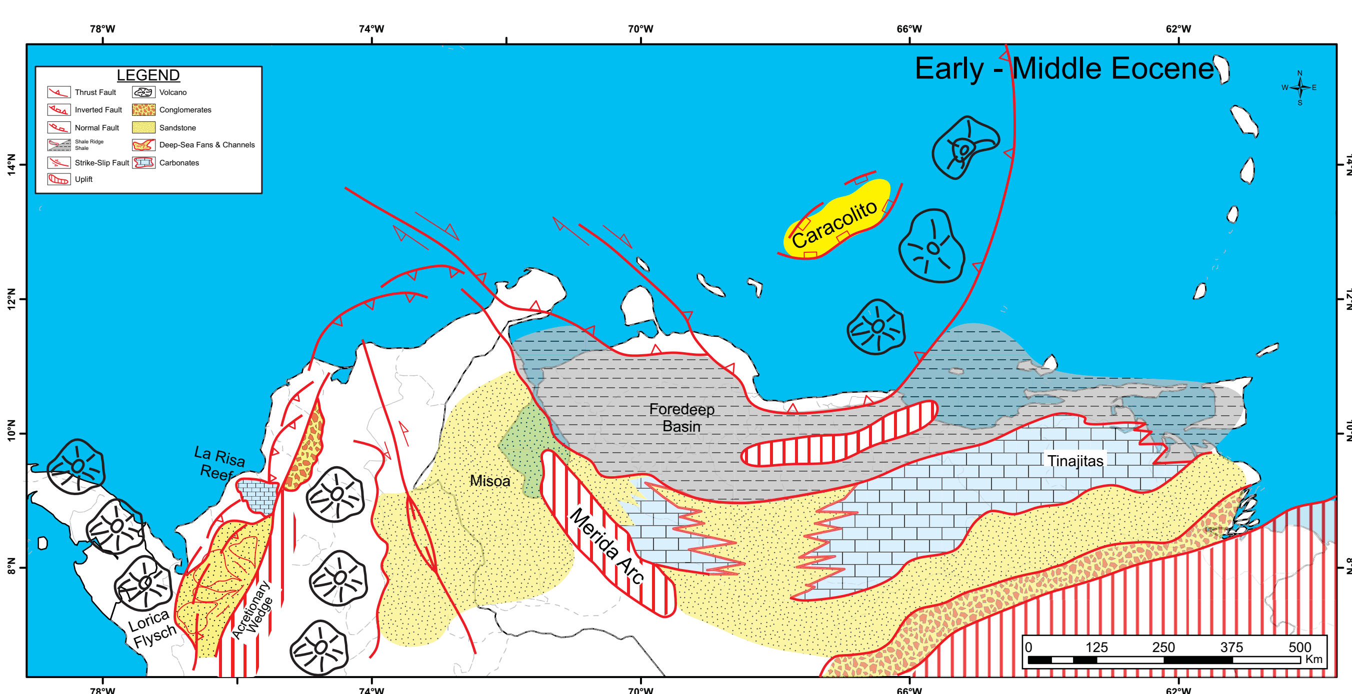
SUMMARY

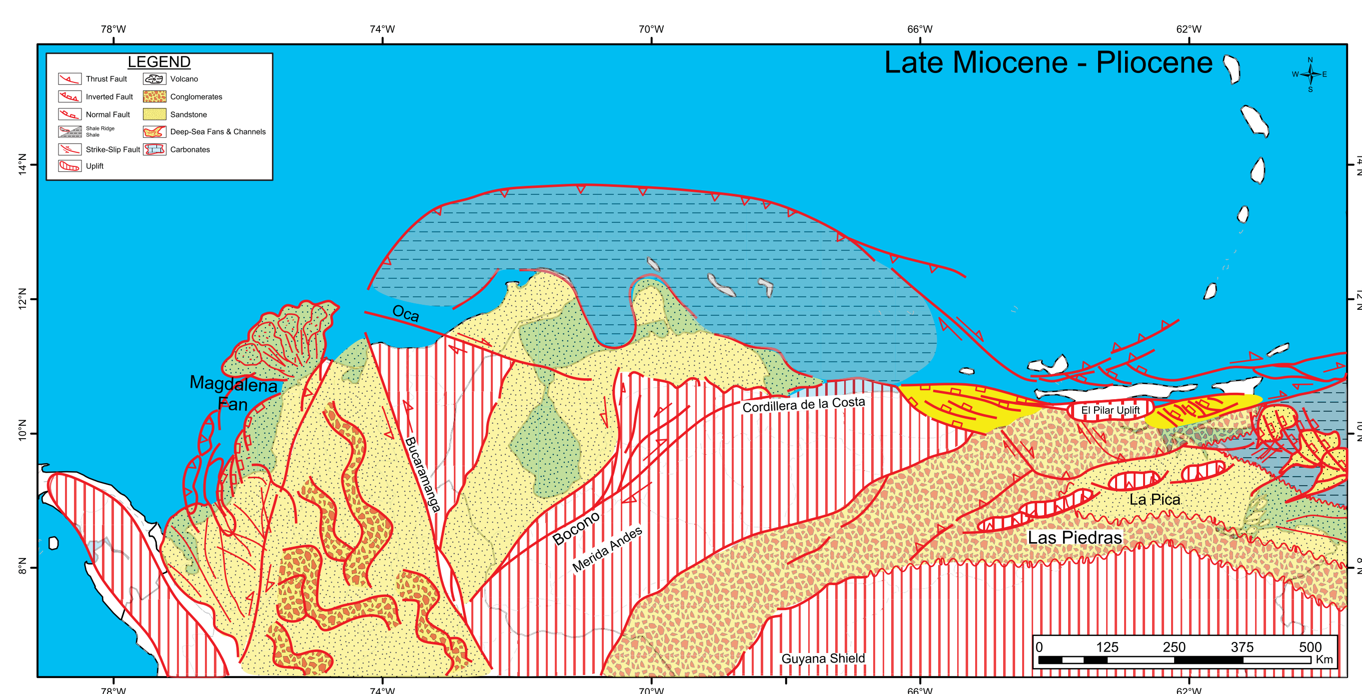












CONCLUSIONS

There are time differences from the initial subduction of the Caribbean island arc to the deformation and ulterior uplift of frontal fold-and-thrust belts and finally to the age of the flexure that was generated by tectonic loading. Back-arc extensional basins overriding the allochthonous Caribbean plate migrated eastward like the underlying accretionary complexes and island arc sections. Comparison of the timing between the geochronology of metamorphic events and AFTA cooling ages suggests that subducted and obducted island arc segments have been dismembered because of oroclinal bending and strike-slip; therefore, units that were initially close together were separated later on by hundreds of kilometers during tectonic evolution. Migration of the Caribbean plate was mostly accounted by compressional overthrusting and dextral strike-slip faulting. Within the allochthonous Caribbean plate, the structural style is characterized E-W (in the west) to NE-SW (in the east) trending extensional basins bounded by NW–SE-trending strike-slip systems and NW–SE-trending pull-apart basins. West of Maracaibo Basin, along the deformed passive margin units of northern South America, strain partitioning resulted in thrust sheets with NE–SW-trending foreland thrust axis bounded by NW–SE-trending tear faults that represent major dextral strike-slip systems. The leading edge of the Caribbean plate was somewhere near the Sinu area in late Cretaceous time. In Paleogene time, the Maracaibo–Urumaco–Falcon fault system was the frontal pull-apart of the moving plate, and during the early Miocene, the Caribbean island arc was probably located at the edge of the Paleo–Cariaco trough. Later, during middle Miocene time, widespread thrusting and folding migrated to the eastern Venezuelan Folded Belt. Finally from late Miocene to Pliocene, strike-slip was active along the Gulf of Paria and the basins located north of Trinidad and Tobago, indicating that the deformation migrated toward the Barbados accretionary complex. The age of the successively younger foredeep sections is the best indicator to track and constrain the timing of the eastward advance of the Caribbean domain. The age of the sediments that fill pull-apart basins related to step-overs between major dextral E–W strike-slip systems is another indicator of the migration of the deformation through time from west to east. GPS satellite data and neotectonic and seismological studies suggest that the Caribbean plate is still advancing toward the east against the subducting North Atlantic plate.

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