Crustal structure of the southwestern Colombian Caribbean area

A. Mantilla-Pimiento [1], C. A. Alfonso-Pava [2], G. Jentzsch [1], & J. Kley [1]

1 Institut für Geowissenschaften - Friedrich Schiller-Universität Jena (Germany)
2 Empresa Colombiana de Petróleos - ECOPETROL S.A (Bogotá D. C., Colombia)

INTRODUCTION

In the past, most of the research in the Colombian Caribbean Area has been restricted to conceptual models generated from the interpretation of refraction or reflection seismic information and general interpretations of magnetic or gravity anomaly maps. Since the Mesozoic northwestern South America has developed in a complex tectonic setting, related to major transpressional oblique collision between the South American and Caribbean plates. Two major tectonic events (Late Cretaceous-Eocene and Late Oligocene (?) to Recent) have been recognized. Due to the strong younger overprint the Paleogene event is difficult to recognize. Nevertheless, distinguishing the effects of these two major phases of deformation has important implications for understanding both the regional geological evolution and the hydrocarbon exploration potential of the area. In this study, we present the structural style of the onshore and offshore areas and the crustal structure of the Southwestern Colombian Caribbean (Morrosquillo Area) using a combination of 2D seismic information, surface geology, well data and a large scale 2.5D density model derived from gravity data.

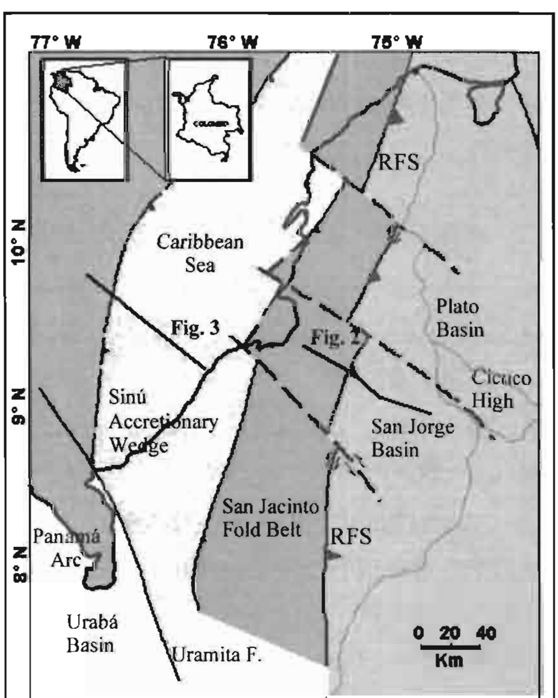

Figure 1. Tectonic Setting – Colombian Caribbean Area (modified after ESRI-ILEX Ltda., 1995).

TECTONIC SETTING

The complex tectonic interactions between the Caribbean and South American plates since Late Cretaceous time have controlled the tectonic evolution of northwest Colombia. Recent models (Pindell and Kennan, 2001) indicate a pacific origin of the Caribbean plate east of the Galapagos hotspot, which is consistent with the regional Caribbean geology. The measured GPS site velocities on the Caribbean Plate and in the north Andes suggest that the plate boundary is located in the South Caribbean Deformed Belt (Freymüller et al., 1993). The calculated rates of convergence along the northwestern Colombia are 1.7 cm/yr (Kellog and Bonini, 1982), 1 cm/yr (Freymüller et al., 1993) and 1.3 ± 0.3 cm/yr (Van der Hilst and Mann, 1994). Seismicity (Malavé and Suárez, 1995) and seismic tomography (Van der Hilst and Mann, 1994) studies indicate that the Caribbean Plate is subducted amagmatically under the South American Plate.

Five major structural provinces have been identified, which include from east to west (Figure 1): the Lower Magdalena Valley Basin (Plato and San Jorge sub-basins, separated by Cicuco or Magangué High), the San Jacinto Fold Belt, the Sinú Accretionary Wedge, the Urabá Basin and the Panamá Arc. These five structural provinces are separated by three major structures: the Romeral Fault System (RFS) considered as a major Paleo-suture between the Lower Magdalena Valley and the San Jacinto Fold Belt, the Sinú Lineament between the San Jacinto Fold Belt and the Sinú Accretionary Wedge, and the Uramita Fault , between the Sinú Accretionary Wedge and the Urabá Basin (Duque-Caro, 1979, 1984, 1990).

REGIONAL STRATIGRAPHY

The Lower Magdalena Valley is a Neogene basin underlain by metamorphic rocks of Precambrian to Paleozoic age, locally intruded by Lower Jurassic granodiorites (Ingeominas, 1997). The Tertiary sedimentary section consists of marine and continental strata (Duque-Caro, 1979). The San Jacinto Fold Belt is formed by Upper Cretaceous to Neogene strata, including marine pelagic, turbiditic, clastic, fluvial and lacustric deposits (Duque-Caro, 1984). The basement present in the Sinú Accretionary Wedge is exposed in the Urabá Basin. These rocks are of oceanic affinity according to the well data. In onshore and offshore areas, Oligocene to recent distal turbidites are present (Duque-Caro, 1984).

REGIONAL STRUCTURAL PATTERN

The interpretation of the 2D seismic information, integrating the surface geology and well data allows to define four of the major structural domains introduced above including from east to west:

1) The San Jorge basin is characterized by initial extensional structures and later by thrusting and inversion genereted by a major transpressional tectonic regime (Figure 2). During Early Oligocene and Miocene, the N-S extension and related normal faulting allows the development of the structural oriented NW – SE faulting, which characterizes the San Jorge and Plato basins, as well as the Cicuco High (ESRI – ILEX,1995). The basin is bounded to the west by the Romeral Fault System, a major dextral transcurrent fault system with a long and complex history of evolution, which forms the accretional boundary of the San Jacinto Fold Belt onto the northwestern margin of the South America Plate, during late Cretaceous to Eocene.
2) West of the Romeral Fault system a major compressional domain is developed, which includes the San Jacinto Fold-Thrust Belt and part of the Sinú Accretionary Wedge (Inner Accretionary Prism). This zone is characterized by growth folding, Eocene (?) to Oligocene mud diapirism and dominant west-verging thrust faults (Figure 3). Piggy back basins and local gravity–driven rafts of Pliocene age can be also identified in the hanging-walls of the major thrusts. Shortening is concentrated into some anticlines, where the underlying ductile mud can flow towards the anticline cores leading to the formation of compressional

diapirism. These mud diapirs do not necessarily extrude up to the surface, but can be stopped and sealed by further sedimentation. The layers of syn-tectonic strata deposited during iplift of the anticlines and diapirism display fan-like patterns with progressive onlaps onto the limbs of anticlines, leading to unconformities with overlying sediments.

3) The oceanward distal compressional domain characterizes an outer accretionary wedge adjacent to the modern Caribbean oceanic crust. This younger part of the prism consists mostly of seaward vergent thrusts involving Eocene, Oligocene and possibly Upper Cretaceous sediments, which characterize a plastic unit overlain by Miocene competent layers (Figure 3). The Pliocene sediments form a syn-tectonic unit and the Pleistocene represents fill deposits. This structural domain is a zone of strong shortening resulting in short wavelength folds and complicated patterns of syn-tectonic deformation. The main basal detachment is interpreted to lie at the top of oceanic basement. The mechanics of deformation of this imbricate system is analogue to accretionary wedges along compressive plate boundaries as described by Davis et al (1983).
4) The Abyssal Zone is characterized by an undeformed sediment succession of Neogene age. The Paleogene strata are locally affected by extensional faults (Figure 3).

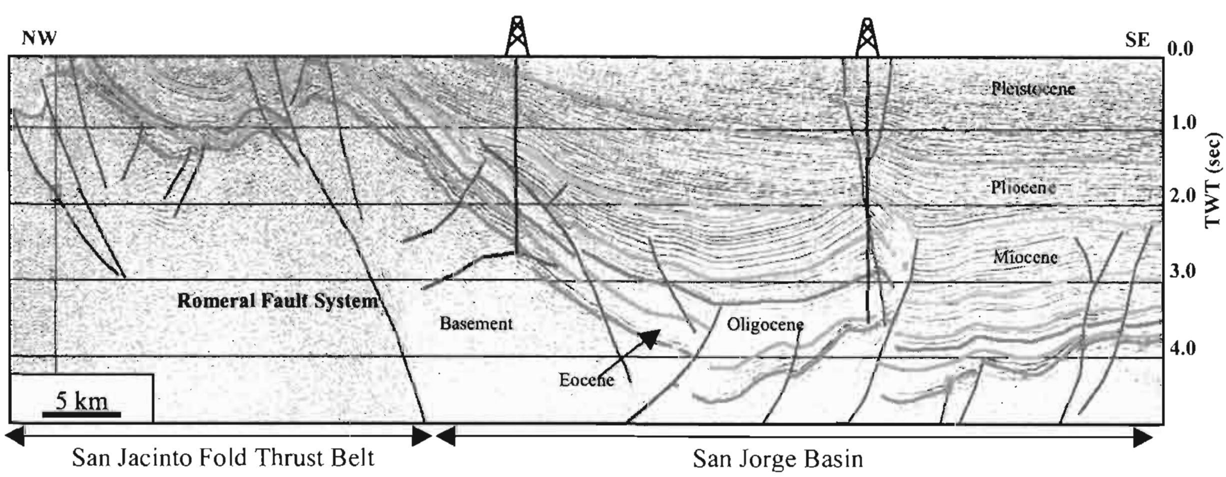

Figure 2. Seismic expression of the San Jorge Basin, the Romeral Fault System and eastern San Jacinto Fold-Thrust-Belt

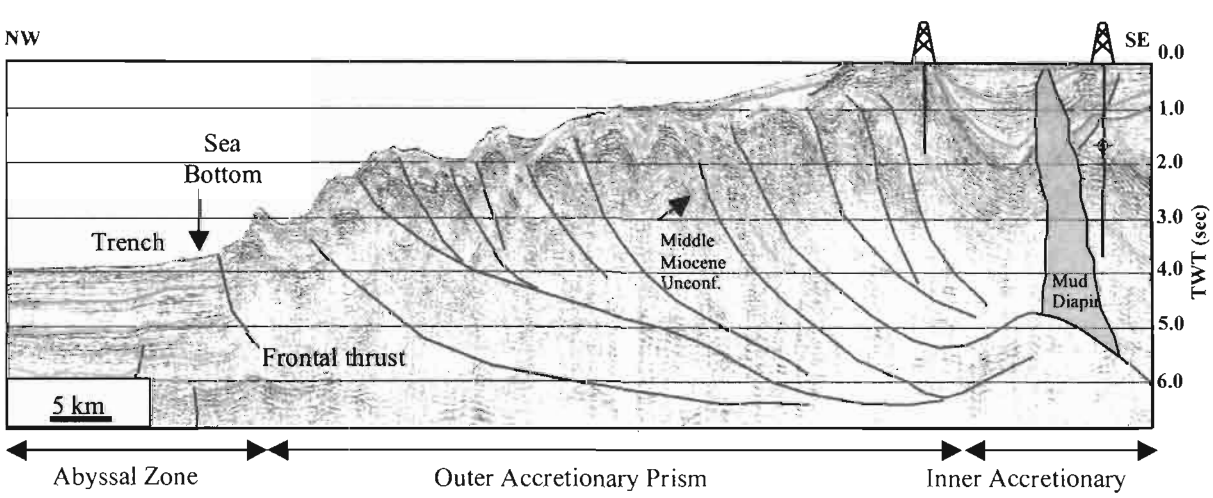

Figure 3. Seismic expression of the Abyssal Zone and the Accretionary Complex (offshore area).

CRUSTAL STRUCTURE

In addition to seismic interpretation, the gravity field (Figure 4) was used to define the boundary between the Caribbean and South American Plates and to determine the crust type present in the collision front. The main features of the large scale 2.5D density model are (Figure 5):

- The San Jorge Basin corresponds to a negative anomaly that decreases eastward from about 0 to -50 mGal. In this area the upper crust is divided in two sedimentary horizons of Tertiary age, which according to seismic interpretation and well data correlate with Paleocene – Miocene and Pliocene – Recent sequences. The gravity modeling confirms that the basement present in the San Jorge Basin is of continental origin.

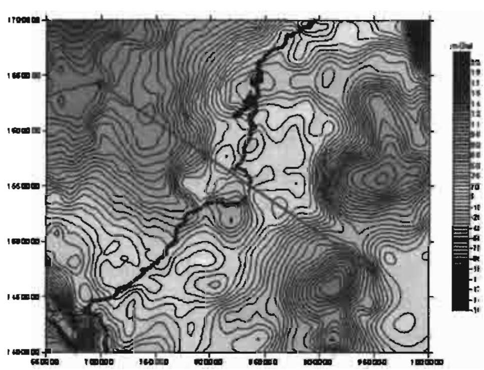

Figure 4. Complete Bouguer Anomaly Map of Northwestern Colombia and location of 2.5D Density Model

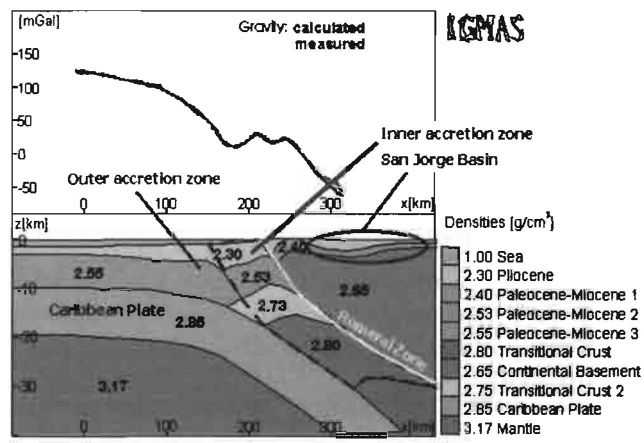

Figure 5. Large scale 2.5D Density Model along the Southwestern Colombian Caribbean. The model was developed using IGMAS software (Schmidt and Götze, 1995)

- The Paleogene accretionary wedge (Inner accretion prism) is represented by the San Jacinto and Sinú fold-thrust belts, which were emplaced to the South American Plate during Eocene to Miocene time (Laverde, 2000). This area corresponds to a local positive anomaly of 33 mGal which decreases towards the continental crust in the east to 20 mGal and towards the current subduction zone in the west to 12 mGal. Several different interpretations of the basement composition were tested for the Paleogene accretion zone (west of the Romeral Fault system). Finally two crustal bodies of different density were included. These bodies are interpreted as transitional crust including material of mainly oceanic affinity.
- The oceanic crust of the subducting Caribbean Plate is represented as one layer in the 2.5D density model. According to the gravity modeling, the Caribbean Plate dips between 6° and 7° in ESE direction.

SUMMARY AND CONCLUSIONS

The Sinú Accretionary Wedge is developed seaward of the San Jacinto Fold-Thrust-Belt, which was previously accreted to the South American margin along the Romeral Fault System in Late Cretaceous to Eocene time. Two zones with different structural style we have indentified in the Sinú Accretionary Wedge. To the west a seaward-vergent imbricate system is developed. The area east of this imbricate system is characterized by growth folding, mud diapirism, piggy back basins and local gravity–driven rafts.

The results of the 2.5D gravity modeling indicate that the zone east of the Romeral Fault system consits of continental crust, while the deep basement of Sinú-San Jacinto accretionary wedge is interpreted as transitional crust of mainly oceanic affinity. The gravity modeling suggests that the Caribbean slab subducting at a low angle of 6° to 7° in ESE direction. Possibly due to the low subduction angle of the Caribbean Plate a magmatic arc in the continental margin was not developed.

Integral evaluations involving data from several sources are fundamental to understanding both the regional geological evolution and the hydrocarbon exploration potential of the area.

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