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# Development of the Golfo de Guayaquil (Ecuador) as an effect of the North Andean Block tectonic escape since the lower Pleistocene

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## INTRODUCTION

Based on multichannel seismic reflection profiles and well data acquired by Petroecuador (Ecuadorian Petroleum Company) during the past two decades, we document the geodynamic evolution of the Golfo de Guayaquil (GG) area. The evolution of the GG area, located at the southern tip of the North Andean Block (NAB) is related to its northward migration. During the past 1.75-2 Myr the NAB migrated to North at a rate of ~1 cm.yr-1 (Trempkamp et al., 2002) along the Dolores-Guayaquil Fault System (i.e. the eastern limit of the NAB). The evolution of the GG area (Witt et al, submitted) is controlled by six main active tectonic features, which accommodated the NAB northward drifting. It includes (**Figure 1**) major E-W trending tensional features (i.e. the Porsoja and Jambeli detachment systems the Tenguel normal fault and the Esperanza graben) and N-S trending transform features (i.e. the Domito fault system (DFS) and the Puna Santa Clara fault system (PSCFS). The precise description of these major structures and dynamics allow us constraining the tectonic reconstruction and subsidence history of the area (Figure 2).

## GOLFO DE GUAYAQUIL EVOLUTION

The older subsidence phase observed in the GG area is triggered by the normal N-S trending seaward dipping DFS during Miocene-Pliocene times (**Figure 2A**). The Esperanza and Jambelí basins exhibit also a thick sediment accumulation of Miocene to Pliocene (older than 1.75-2 Ma) age with no significant variation in thickness from one site to another. The 2 to 4.5 km of sediment, which accumulated along the Esperanza and Jambelí basins are Pleistocene-Holocene in age. The major depocenters and associated tectonic features of the Esperanza and Jambelí basins post-dated the Mio-Pliocene history.

The Lower Pleistocene is the period of major subsidence in the GG area (**Figure 2B**), and depocenter individualization. Along the Esperanza basin, the southward dipping Posorja detachment system triggered the major subsidence phase. At that time subsidence began in the Jambelí basin. A major flat detachment (i.e. the Jambelí detachment system) which dips in the opposite direction to that of the Posorja detachment system triggered the Jambelí basin subsidence. Consequently, the Puná segments of the PSCFS has to develop as a transfer fault (PS in **Figure 2B**) in order to accommodate the opposite motion between the two opposite verging Porsoja and Jambelí detachment faults. The maximum of tectonic activity to accommodate the transfer from one side to another has to be located along the segment of PSCFS, which connects the two detachments along the Puná island (**Figure 2B**). Indeed this segment of the PSCFS is the site of major deformation as evidenced by the lost of reflection over a wide corredor following the PSCFS across Puná Island (**Figure 1**). Also, it must be noted that the PSCFS shows no prolongation to the north and to the south (**Figures 1 and 2**). The PSCFS could not be interpreted as a segment of the Dolores-Guayaquil Megashear as commonly accepted. The major subsidence rates observed in the GG area, located along the Esperanza and Tenguel basins are of Lower Pleistocene age. The Tenguel fault and the major normal faults, which bound the Esperanza graben controlled the evolution of these depocenters through space and time.

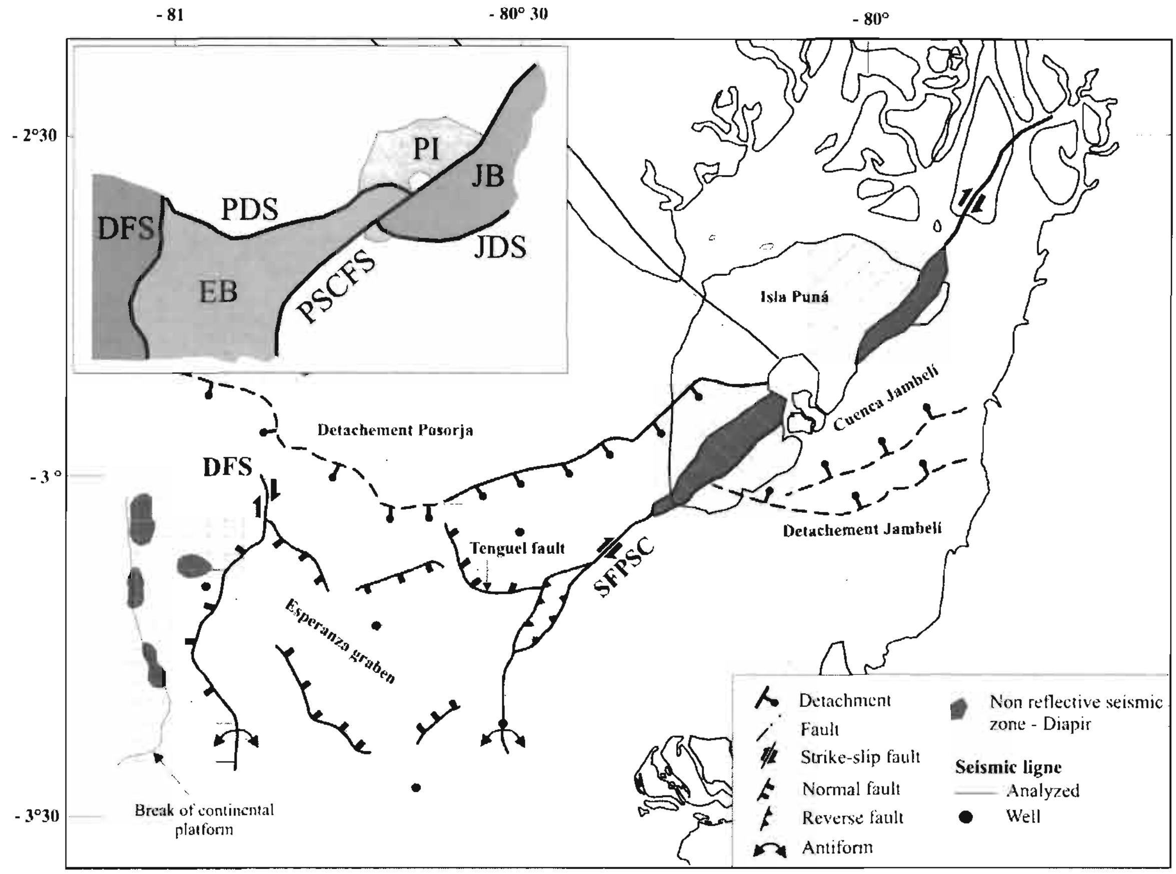


**Figure 1**. Structural map of the GG area. Solid lines show the active tectonic features while dashed lines show the inactive structures. The non reflective seismic zones and diapirs are mapped down to 2 s TWTT below sea bottom. **DFS**: Domito fault system; **EB**: Esperanza basin; **PDS**: Posorja detachment system; **PSCFS**: Puná-Santa Clara fault system; **JB**: Jambelí basin; **JDS**: Jambelí detachment system; **PI**: Puná island

Seismic profiles exhibit evidences of a pervasive unconformity associated with an emersion phase widely identified throughout the GG area. Indeed, it extends within areas located east of the Esperanza basin. Based on relations between the Present depth of the unconformity (0.4 to 0.6 s TWTT below seafloor), the regional sedimentation rate, and the age of low stands known for the past 600 kyr, we assume that the emersion occurred during the 180-140 ka glacial low stand of isotope substage 6e. This phase of emersion is roughly coeval with tectonic inversion identified along restricted segments of the PSCFS and the Tenguel fault. Instead to be related to a regional cinematic change, these confined and relatively slight compressional deformations originated from local causes (**Figure 2C**).

Since the Lower Pleistocene, the northward tectonic escape of the NAB controls the tectonic evolution and related subsidence of the GG area. We assume that the major change of extensional strain direction from E-W (DFS) to N-S (Posorja and Jambelí detachments) which occurred at ~1.75 (i.e. base of the Lower Pleistocene) is related to the initiation of the northward drifting of the NAB. Because no major cinematic change is known during the past 5 Myr, we propose that the northward tectonic escape of NAB resulted from an increase of coupling between Nazca and South America plates. This higher plate to plate coupling may be produced by the initiation of the Carnegie ridge collision with the trench axis. Indeed, previous works documented the initiation of the buoyant Carnegie ridge to enter the Ecuadorian subduction at around the Plio-Pleistocene boundary (Aalto and Miller, 1999; Cantalamessa and Di Celma, 2004; Witt et al., submitted).

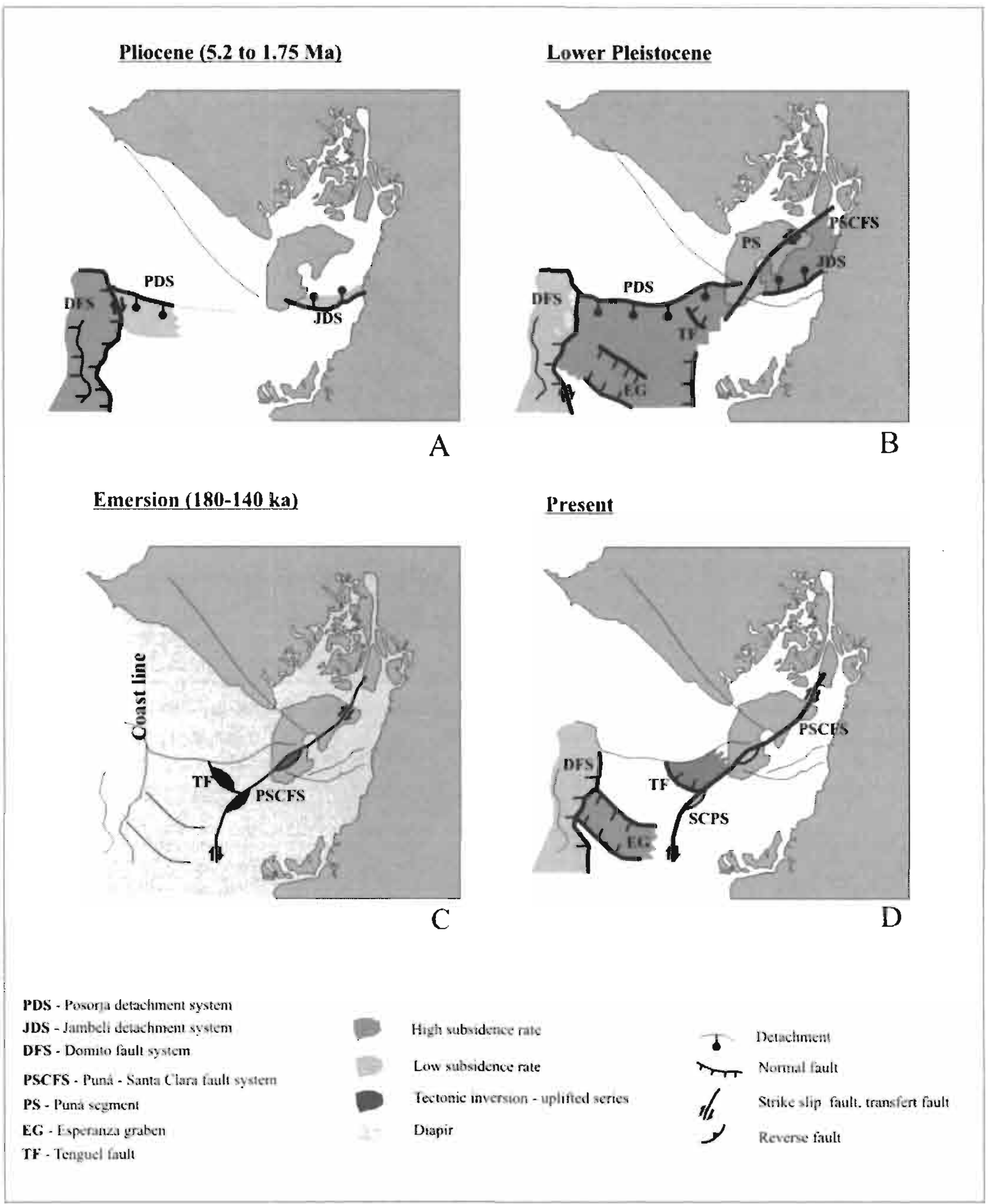


**Figure 2.** Evolution of the Golfo de Guayaquil area during the past 5 Myr. The coastline is considered only as a geographic reference. See legend table for symbol explications.

## CONCLUSIONS

The PSCFS commonly associated to the southern tip of the DGM (Dolores-Guayaquil megashear) acts as a transfer zone since the Lower Pleistocene time. It accommodated the opposite verging directions between the southward dipping Posorja and the northward dipping Jambeli detachments. The PSCFS shows no landward prolongation to the north and no seaward prolongation to the south toward the trench, it ends at sites where no transfer motion is required.

The DFS marks the limit between a zone controlled by continental margin processes and another one (Esperanza and Jambelí basins) strongly controlled by the tectonic escape of the NAB. During the Lower Pleistocene times the subsidence in the Esperanza and Jambelí basins began, it was triggered by the N-S verging detachment structures related to the tectonic northward escape of the NAB. Taking into account the strong dependence of the subsidence in the GG area with respect to NAB motion, we assume that the Pliocene–Lower Pleistocene limit is associated with a major change in the northward migration rate of the NAB. We assume that the major change of the extensional strain direction from ~E-W (recorded along the DFS) to ~N-S (Posorja and Jambelí detachment systems) is related to the initiation of NAB northward migration. Because no major cinematic reorganization exists along the Nazca-South America plates since the Pliocene (5.2 Ma) that would explain the initiation of the northward tectonic escape of the NAB, we assume that the Carnegie ridge began to collide with the trench at that time. Subsequently the ridge subduction increased plate coupling, producing the northward expulsion of the NAB.

A major emersion of the GG area occurred during glacial sea level fall of isotopic substage 6e (between 180 and 140 ka). This emersion induced the accumulation of marine sediment to stop. Also this major paleogeographic change probably caused local strain changes able to have tectonic signatures. These are the so-called Upper Pleistocene compressional deformations confined to two small segments of the PSCFS and the central segment of the Tenguel fault. We consider that these Upper Pleistocene local compressional tectonic features (inversion) have local causes. Indeed no cinematic reorganization at plate boundaries existed at that time. Therefore, we assume that no major change in the general tectonic regime existed during the Quaternary evolution of the GG area. The GG area remained under extensional strain since the Lower Pleistocene. The GG area is a zone of great sediment input since it corresponds to the end of one of the two major Ecuadorian Andean-coastal drainage basins. The emersion of the GG area allows the sediments to reach the trench axis instead of being trapped in the GG area. It has been shown elsewhere (von Huene and Scholl, 1991; Bourgois et al., 2000) that sediment supply to the trench axis is a major cause of the tectonic regime switching from subduction-erosion to subduction-accretion. This reflects the potential importance of the GG area in controlling the tectonic regime along the southern Ecuadorian margin.

At Present time, the tectonics of the studied zone is dominantly extensional (**Figure 2D**). In the GG area it is concentrated in the Esperanza graben and along the Tenguel fault. The DFS shows a reactivation as a normal fault in recent times while the Posorja and Jambelí detachments are no longer active. The extreme conditions of subsidence triggered by low angle detachment zones not directly related with strike-slip systems suggest that the GG area is not a pull-apart basin in a commonly accepted sense, as previously proposed. The GG area developed in a relation with the northward escape of the NAB, in good agreement with the extensional tectonic features bounding the main depocenters. Moreover, no eastern boundary of NAB was identified in the GG area. At the latitude of the GG area the NAB-South American plate boundary should be located landward, possibly in the Andes.

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