CORRELATIONS BETWEEN CRUSTAL STRUCTURES OF THE NORTHERN-ECUADOR SOUTHERN COLOMBIA MARGIN FROM MCS DATA, AND RUPTURE ZONE OF 1942, 1958 AND 1979 GREAT SUBDUCTION EARTHQUAKES

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INTRODUCTION

Along the north Andean margin, the Nazca plate subducts eastwards beneath the Ecuador and Colombia at ~ 6 cm/yr. (Trenkamp et al., 2002). The margin consists of oceanic terranes accreted against the continent from Late Jurassic to Eocene (Gansser, 1973, Reynaud et al., 1999). During the XXth century, six great earthquakes have ruptured the subduction plate-interface. The largest, in 1906 (Mw 8.8), had an estimated rupture zone of ~ 500 km in length (Kelleher, 1972), which was partially reactivated by three subsequent thrust events, from Baya de Caraques to Tumaco, in 1942 (Mw=7.9), 1958 (Mw=7.8) and 1979 (Mw=8.2) (Beck and Ruff, 1984; Swenson and Beck, 1996). The cause of the segmentation between adjacent rupture zones (as defined by the aftershocks distribution), as well as the nature of seismological asperities (as defined by regions of maximum co-seismic displacement on the fault plane), have remained unclear. Deep multichannel seismic reflection (MCS) data collected across the Ecuador-Colombia margin during the SISTEUR cruise (Collot et al., 2002) in September-October 2000, together with conventional bathymetry are used to establish correlations between the margin segmentation, limits of earthquake rupture zones and seismological asperities. MCS data were recorded across the Ecuador-Colombia margin using a 45-L airgun seismic source and a 360-channel streamer. Shots were fired every 50-m, providing a 45-fold coverage. Single beam bathymetry was collected with MCS data.

CONCLUSIONS

The northern segment of the margin extends offshore Esmeraldas and Tumaco between 1°-2°30'N (Fig. 1). It is ~100-120 km wide, with a large, 800-1000 m deep reentrant containing a 3 km-thick sedimentary fore-arc basin, and a discontinuous outer ridge as shallow as 60 m below sea level. The Colombia trench that contains up to 3 km of sediment bounds the margin seaward, whereas a subsiding coast dominated by marshes and mangroves flanks the margin landward. This margin segment contrasts with the southern segment (South of 1°N) adjacent to the Carnegie Ridge, which shows a short (40-70km) trench-coast distance, thin (<100 m) trench fill, a shallow (100m) continental shelf and an uplifted coastline. The boundary between the two margin segments is sharp and outlined by the steep, NW-trending southern flank of the reentrant that is deeply incised by the active Esmeraldas canyon. This boundary coincides with the offshore extension of the major NW-trending, inherited, crustal fault ES, and matches the limit between the 1942 and 1958 rupture zones (Fig. 1).

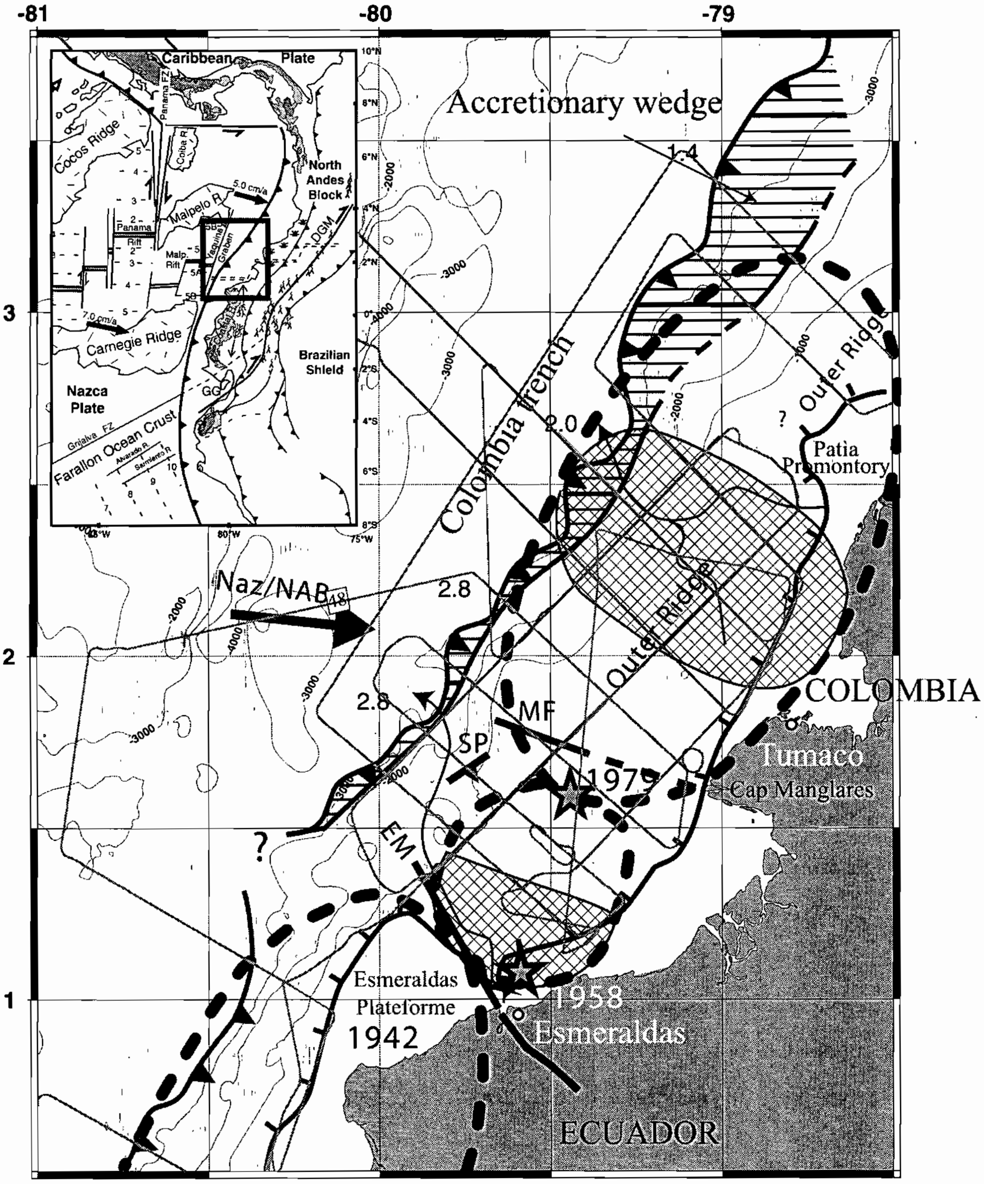

Fig. 1 Bathymetric and structural map of the northern Ecuador-southern Colombia margin with 1942, 1958 and 1979 subduction earthquake rupture zones. Bathymetric contour = 100 m

earthquake rupture zones and seismological asperity
earthquake epicenter
2.8 trench fill thickness (stwt)
thrust front
Nazca Plate-North Andean block convergence
canyons
EM = Esmeraldas Fault; **SP** = Splay Fault; **MF** = Manglares Fault
Sisteur MCS-lines

MCS data across the northern segment of the margin show evidence of a second major NW-trending crustal fault named the Manglares Fault (MF in Fig. 1). Fault MF projects seaward from Cap Manglares, a N-105°E rectilinear coast segment, and divides the margin into two areas of different deformation style. The fault coincides approximately with the limit between the rupture zones of the 1958 and 1979 earthquakes. Immediately south of fault MF, most of the active deformation occurs specifically between the margin front and a major landward-dipping crustal splay fault SP (Fig. 1), which soles out at a 12-13 km depth on the plate interface. From MCS data, the plate interface dips landward and returns strong reflections as deep as 22-24 km near the coast line. The 1979 and 1958 earthquake hypocenters project onto the seismically-imaged plate interface at depths of about 18 and 20 km respectively. Interestingly, between fault MF and Esmeraldas, the fore-arc basin is 55 km-wide and shows no evidence for recent shortening. North of fault MF, active deformation, which is dominantly compressive, is distributed over a much larger area than south of the fault. The deformation zone includes an incipient accretionary wedge, an imbricated margin front, a shallow outer basement ridge and the seaward flank of a narrow fore-arc basin. Although both faults ES and MF may no longer be active, they bound margin segments of different structural history, and seem to act as lateral barriers to the propagation of the inter-plate rupture during earthquakes of Mw 7.8 to 8.2.

The seismological asperities associated with the1958 and 1979 earthquakes correlate with drastically different seafloor and structural expressions, which may reflect different stress or friction conditions. The 1958 asperity projects onto the fore-arc basin seafloor as a smooth, long wavelength, 150-200 m-high bulge that is incised by the Esmeraldas canyon. The absence of active thrusting across the bulge together with the restriction of the 1958 earthquake rupture zone to the fore-arc basin area, suggests that the major crustal splay fault and corresponding plate interface segment accommodate most co-seismic motion and probably the long-term thrust motion. Aseismic motion may occur on secondary faults near the margin front. Sediments in the fore-arc basin appear to have recorded earthquake shaking. Continuous, sub-horizontal stratification changes locally into incoherent reflections or sequences disrupted by 100-200 m long disturbances, indicating debris flows, slumps and small-scale failures, possibly triggered by earthquakes.

The 1979 asperity is associated with part of the highly shortened margin segment, north of fault MF. The distribution of folds and active thrust faults from the deformation front to the outer basement ridge and fore-arc basin suggests a weak margin and a relatively high inter-plate friction. This wide distribution of active deformation, associated with the fact that the asperity and rupture zone areas match the margin width, indicate that the co-seismic motion and possibly the long term deformation are not accommodated by a single splay fault, but by a set of landward-dipping crustal faults in addition to the plate interface.

In the region of the 1958 and 1979 rupture zones, variations of trenchfill thickness, as well as the location of the decollement within the trenchfill, reveal along-strike changes in the accretionary process, which may reflect margin structural complexities associated with the seismological asperities. In the northernmost part of the study area, the décollement lies within the trenchfill, allowing accretion of the upper 1/2 to 2/3 trenchfill, and sediment subduction of the corresponding lower trenchfill. Further south, the décollement lies dominantly at the roof of the subducting trenchfill, thus forming a 2-3 km thick subduction channel. Consequently, despite the thick trenchfill, a narrow or no accretionary wedge has developed seaward of the 1958 and 1979 rupture zones indicating an unstable, transient-state tectonic regime (Fig. 1).

Possible explanations for these along strike variations include: 1) Rapid accumulation of trench fill may not have allowed tectonic accretion to develop fully in the south. 2) Along strike variations in physical properties within the incoming trench sediment could cause the basal friction to vary along the decollement and affect the accretionary style. 3) An underthrusting structural high beneath the margin may have locally deflected the decollement upward so that a shadow zone develops in the wake of the high, allowing the entire trench fill to be dragged into the subduction (Dominguez et al., 2000). 4) The margin may be locally exhibiting cyclical accretion, alternating between underthrusting of the entire sedimentary sequence and periods of frontal accretion with rapid local growth of an accretionary wedge. Sandbox models with a high basal friction have demonstrated this accretionary style for sedimentary input at the trench (Gutscher et al., 1998). The unusual location of the decollement at the top of the trenchfill, and the very localized deformation zone in the outer ridge supports a high-friction inter-plate surface beneath the ridge. This high friction together with the seismological asperity identified in the 1979 earthquake source function (Beck and Ruff, 1984) may correlate with an oceanic asperity buried beneath the margin.

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