Crustal structure of the Eastern Cordillera, Colombia

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Based on surface geology, seismic, well, gravity, and aeromagnetic data, we interpret the Eastern Cordillera (EC) of Colombia as an inverted Cretaceous basin, with approximately 140 to 160 km of late Miocene to Recent shortening. Several regional retrodeformable structural cross-sections were constructed for the EC and flanking basins, Colombia (e.g., section B-B" in Fig. 1).

Cretaceous Basin Formation – Crustal Extension and Thermal Subsidence

The Cretaceous Tablazo-Caqueza (Eastern Cordillera) basin was produced by thermal subsidence following Jurassic rifting. Greater extension in the Bogota area produced a broad flat-floored basin whereas in the Tunja area and further north, lower tectonic extension generated two major grabens and a tectonic horst in the middle. Within the EC, the principal magnetic sources locate Late Jurassic-Early Cretaceous-age horsts and grabens. Particularly well defined are the western graben, the central Tunja horst, and the eastern graben. The western graben is associated with mafic rocks, high densities, and relatively high magnetic susceptibilities. The central horst has low densities and low susceptibilities. The eastern graben is associated with mafic rocks, high densities, and high susceptibilities.

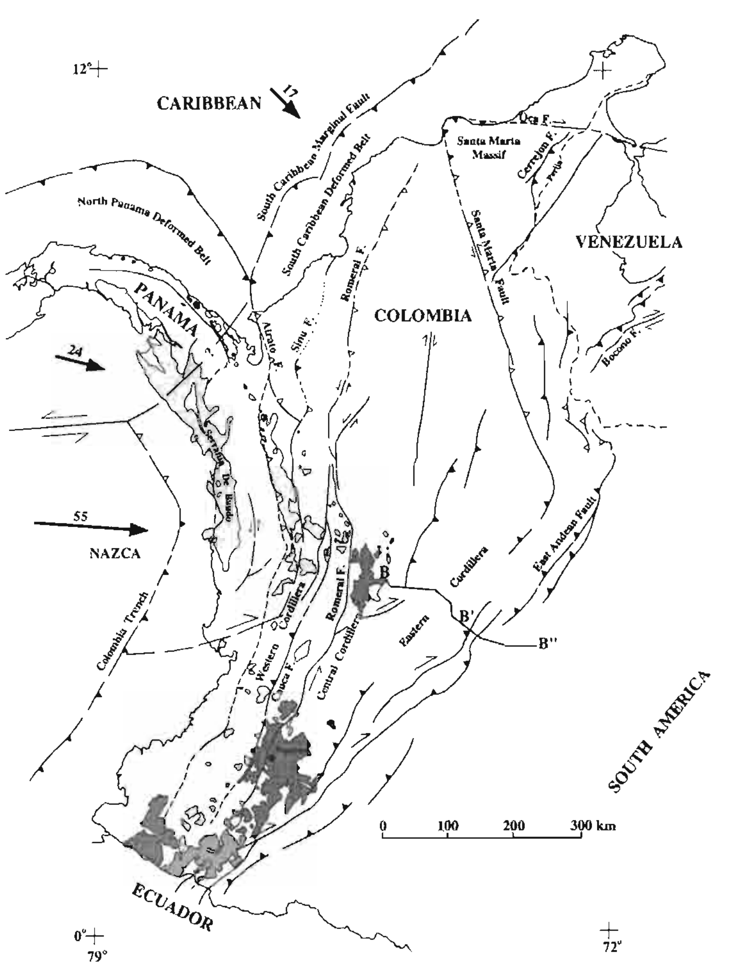

Fig. 1. Tectonic map of northwestern South America. Shaded areas are Tertiary igneous rocks. Present-day plate motions (arrows) relative to the northern Andes showing average rates (mm/yr) (Trenkamp et al., 2002).

Lower Cretaceous extension was sufficient to generate basaltic intrusions by thinning of the lithosphere and shallowing of the mantle. The southern segment of the basin was 8 km deep in the middle and about 300 km wide. To the east it continued as a very shallow basin (several hundred meters) for at least another 70 km. These results are in agreement with stratigraphic measurements on the west flank of the Cordillera as well as vitrinite reflectance measurements within the Cretaceous section. To the north the total width of the basin was about 350 km at the end of the Cretaceous. The northern part of the basin was divided into an eastern graben, a central horst, and a western graben. The eastern graben was 100 km wide and contained up to 6 km of Cretaceous sediments. The central Tunja - Soapaga - Laguna de Tota horst was 100 km wide and contained only 2 to 2.5 km of Cretaceous sediments, and the western graben was 150 km wide and contained 4.5 km of Cretaceous sediments.

Thickness of Cretaceous section

Under the center of the EC the geologic and density models indicate that the top of basement may be at a depth of 9.5 km or about 7 km below sea level (Fig. 2). The unrepeated Cretaceous section may be as thick as 8 km. The densities used for the Cretaceous units are the lowest values that are geologically reasonable: Guadalupe Fm (Kg) and Villeta Group (Kv), 2.45 g/cm^3; Hilo, Supata, and Socota (Kvs) fms, 2.50 - 2.53 g/cm^3; and Basal Cretaceous (Kb), 2.57 g/cm^3. Higher density values would require an even thicker Cretaceous section to explain the low gravity anomalies measured along this profile. These results are in agreement with stratigraphic measurements by Cardozo (1988) on the west flank of the EC as well as vitrinite reflectance measurements within the Cretaceous section. Low vitrinite reflectance values have been measured in wells penetrating the upper part of the Cretaceous section (VRE $\approx$ 0.5), while high vitrinite values (VRE > 4.0) have been measured in wells penetrating the lower part of the Cretaceous section. If the Cretaceous section were much thinner than suggested by the gravity and stratigraphic data, abnormally high horizontal geothermal gradients would be required to explain the differences in thermal maturity within the Cretaceous rocks.

Andean Shortening and Crustal Thickening

During the Tertiary, 2 to 3 km of sediments were deposited across the entire basin. In late Miocene time, the Panama island arc began to collide with the Northern Andes. The collision formed a land bridge between North and South America, changed ocean circulation patterns, and uplifted the Eastern Cordillera of Colombia with 140 to 150 km of shortening. Palynological studies indicate Pliocene to Recent uplift (van der Hammen, 1957), and apatite fission-track ages are consistent with 3.5 to 5 m.y. ages for uplift in the Eastern Cordillera (Hooghiemstra, 1984; and unpublished). Satellite geodetic measurements with the Global Positioning System show that the Panama-North Andes collision is continuing at the rate of over 2 cm/yr (Fig. 1, Trenkamp et al., 2002). Most previous estimates for Andean shortening in the EC come from northern part of the EC, and range from 68 km (Cooper et al., 1995), 90 km (Corredor, 2003), 100 km (Colletta et al., 1990), to 150 km (Dengo and Covey, 1993). The geologic model for the southern EC profile B-B" (Fig. 2) indicates 65 km of shortening on the west flank of the Cordillera (including the Cambao thrust) and 110 to 150 km of shortening on the east flank of the Cordillera. Our average estimate for total Post-Early Miocene shortening (165 km) implies that the original width of the Eastern Cordillera Cretaceous Basin along the section line was 125 + 165 km = 290 km. The minimum estimate for shortening (110 km) assumes that all the shortening on the west flank of the Cordillera and in the Caqueza-Rio Negro area is connected to shortening on the east flank of the Cordillera

(Servita and Mirador faults) by either wedge thrust geometries or by gravity gliding off the Quetame uplift. This is probably an underestimate. Most of the faults are interpreted as low angle (about 20 degrees). Most of this shortening directly involved the lower crust in the center of the range thickening the crust and forming the crustal root under the mountain.

Lower Crustal Shortening

We assume that from the end of the Jurassic Period to the end of the Oligocene epoch the crust under the EC basin was much thinner than under the present mountain range. Using the McKenzie (1978) method, subsidence curves suggest beta values of 1.5 to 2 for the basin and crustal thinning of 30 – 50%. Based on our retrodeformable cross sections, we estimate 30 to 45% post-Oligocene shortening in the EC. If the present crustal thickness is at least as great as that prior to Jurassic rifting, all of the Andean upper crustal shortening in the EC could have been accommodated in the lower crust directly under the EC. It is therefore not necessary to transfer the displacement on west-dipping faults to the base of the crust under the Central Cordillera, as suggested by Dengo and Covey (1993). Upper crustal shortening may be transferred to the lower crust beneath the EC by wedge faults, perhaps reactivating Jurassic-Lower Cretaceous age crustal-scale normal faults. Present-day deep seismicity beneath the EC suggests that shortening is continuing by brittle deformation.

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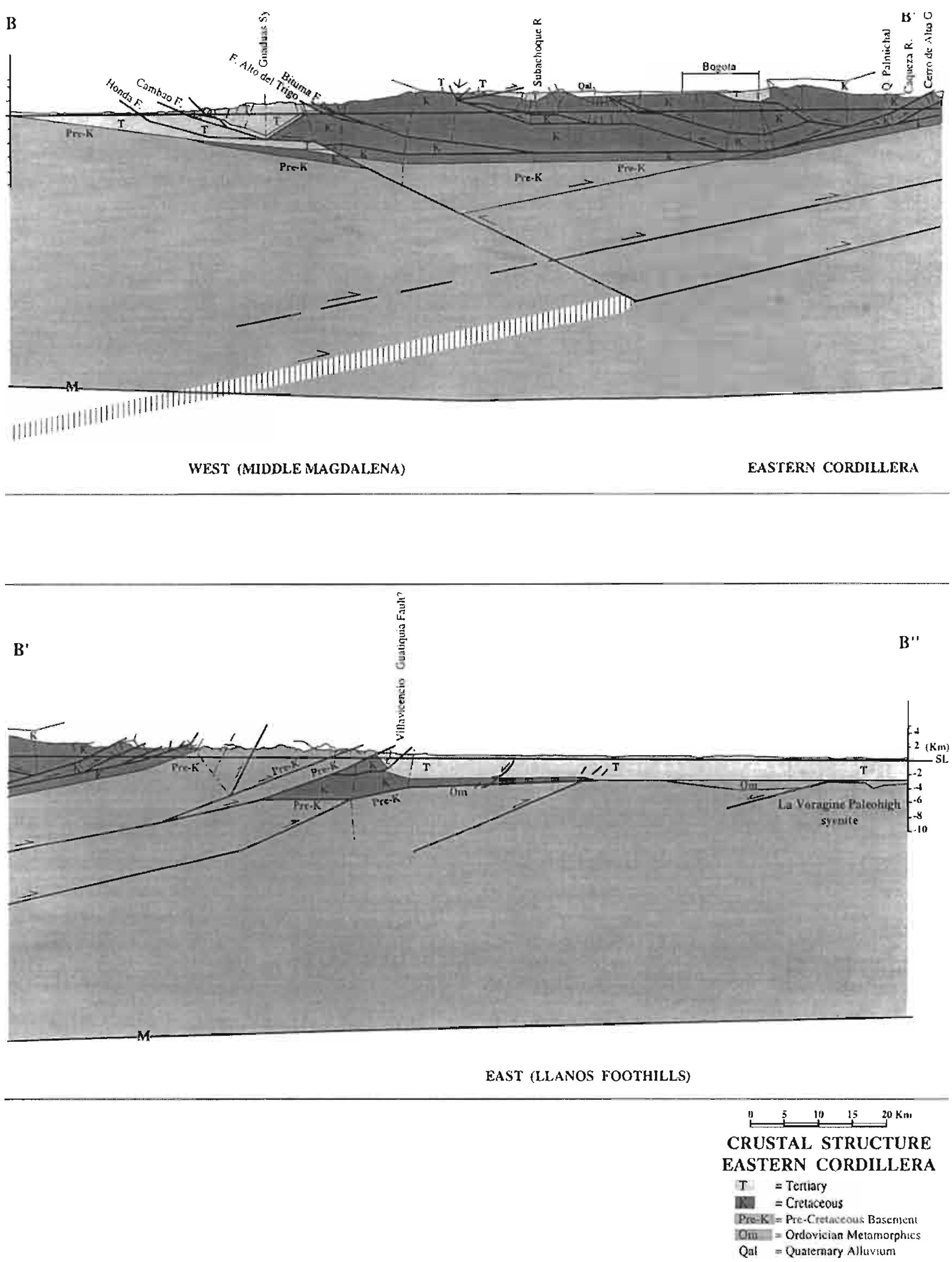

Fig. 2. Geologic cross section B-B" of the Eastern Cordillera. M: Moho boundary. No vertical exaggeration. For location see Fig. 1.