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The deformation front in the Llanos foothills of the Eastern Cordillera of Colombia: Interaction between thick- and thin-skinned tectonics at a segmented boundary

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Introduction

The Eastern Cordillera of Colombia forms by its isolated position in the foreland of the Andean main trunk system an intracontinental mountain chain with the characteristics of a collisional belt. Its evolution mirrors two accretionary events at the Northandean margin, the first one being represented by the failed subduction and docking of a slice of oceanic crust constituting the present Western Cordillera in the Eocene, followed by the accretion and continentalization of the Sinu terrane and Panama arc in the Late Miocene to Late Pliocene. These accretionary events mark two major pulses in the exhumation in the Eastern Cordillera (Gomez et al., 2000). The second one concludes a long-lasting contractional period which manifests itself by the individualization of foreland troughs and their filling with the erosional products of an ancestral Eastern Cordillera.

Thick-skinned or thin-skinned deformation style?

In discussing the deformation of this external fold- and thrust belt, different views have been sustained with regard to the importance of the stacking of thin-skinned thrust sheets and the significance of basement-rooted faults bounding major anticlines. Evidence for basement-involved tectonics includes 1) a penetrative deformation which increases in intensity toward low structural levels and 2), the reactivation of inherited normal faults. As regards this latter point, the concept of rift inversion has been extensively applied to explain these inherited controls on the structural evolution (Branquet et al., 2002; Taboada et al., 2000). West-facing normal faults can be assigned by their basin fills to a Late Paleozoic and a Late Jurassic/Early Cretaceous rift event. They contribute by their NW-trend much to the structural grain of the Northandean chains.

Thin-skinned deformation is related to emergent faults transporting the molasse units of the foreland basins in a piggy-back manner. By their right-stepped array they attest to an obliquity between the deformation front governed by pre-existing structures and the Neogene transport direction.

Structural relays at the Llanos foothills

North of the city of Villavicencio two structural relays convey the complex interaction between inherited, basement-rooted faults and the detachment of the sedimentary cover along the Guaicaramo fault (Figure 1). In a southern segment (comprising the area of Villavicencio) the deformation front is outlined by two antiforms, an eastern one consisting of an overturned anticline (Buenavista Anticline) cored by Proterozoic (?) phyllites of the Quetame Massif, and a western one representing an upright antiform of a considerable relief and exhibiting a thick Late Paleozoic clastic sequence below the Cretaceous cover (Guayabetal Anticline; Figure 2). The overturned flank of the frontal structure (Buenavista Anticline) masks an inherited Neocomian E-facing normal fault (Mirador Fault), as may be concluded from contrasting facies associations of the Cretaceous sediments on either side of its fold hinge. The ample Guayabetal anticline at its rear ties to the Late Paleozoic Servita Fault. This fault limits a sequence of red beds, some 3000 m thick, over the whole length of the study area. In spite of this inherited throw this fault does not displace the Cretaceous unconformity. Both folds can be replicated as fault-propagation folds by the tri-shear model. By its gentle inclination the Mirador fault displaces the Servita fault and marks a post-paroxismal out-of-sequence deformation phase.

In the intermediate segment immediately north of Villavicencio the deformation front jumps to the E with the individualisation of the Guaicaramo fault (Figure 1) which soles, according to subsurface data, into Paleocene to Lower Cretaceous sediments. Its displacement increases from 4 km to 6 km, approaching the northern limit of this segment. Gravimetric modeling favors a displacement of the steeply inclined flank of the Farallones Anticline. In this segment the Guaicaramo fault designates thus an out-of–sequence thrust much in the manner of the Mirador fault of the southern segment.

In the northern segment the shortening of the thrust sheet of the Medina Syncline is taken up by a tight folding of the block west of the Guaicaramo fault, as evidenced by folds of variable plunges and a strong attenuation of Coda-waves. The Guaicaramo thrust of the intermediate segment links here to a basement-rooted fault through a continuous surface break. At this segment boundary the Yopal fault becomes individualised further east as a thrust soling in the Cretaceous cover, pointing again to a breached thrust front of the Guaicaramo fault.

Discussion

The Llanos foothills of the Eastern Cordillera record two deformation phases. A first one relates to a penetrative shortening of the Altiplano area and may account for a shortening of up to 20%. The proper deformation front of this event consisted of W-dipping monoclines with steeply inclined to overturned eastern flanks, as exemplified by the Farallones Anticline in the intermediate segment of our study area. These structures are controlled by inherited faults which lack any signs of reactivation at the present exposure level. Their importance as crustal discontinuities is, however, underscored by structural domains characterised by different fold arrays and deformation intensities that change across these inherited faults.

As deformation built up to a critical value a second deformation phase set in, forcing the deformation front to step E to its present position. This occurred by the activation of out-of-sequence faults which gave rise to strongly E-vergent basement-involved folds, where faults ceased propagating to the surface (Mirador fault), or which breached the basement-cover contact of the former deformation front and propagated from there on along incompetent units of the sedimentary cover until reaching the surface (Guaicaramo fault). By their low-angle dips these faults correlate to a ubiquitous extensional event of the Altiplano region that set in shortly after the main Andean folding and accompanied a Pliocene uplift event, as evidenced by growth faults within the Tilatá formation (Kammer, 2003). This deformation phase records thus a gravitational collapse, in which extensional faulting was limited to the upper crust and linked to late thrust faults in the foreland. The simultaneous operation of exhumation and crustal thinning during this post-paroxysmal deformation phase may have strived toward an equilibrium state.

References

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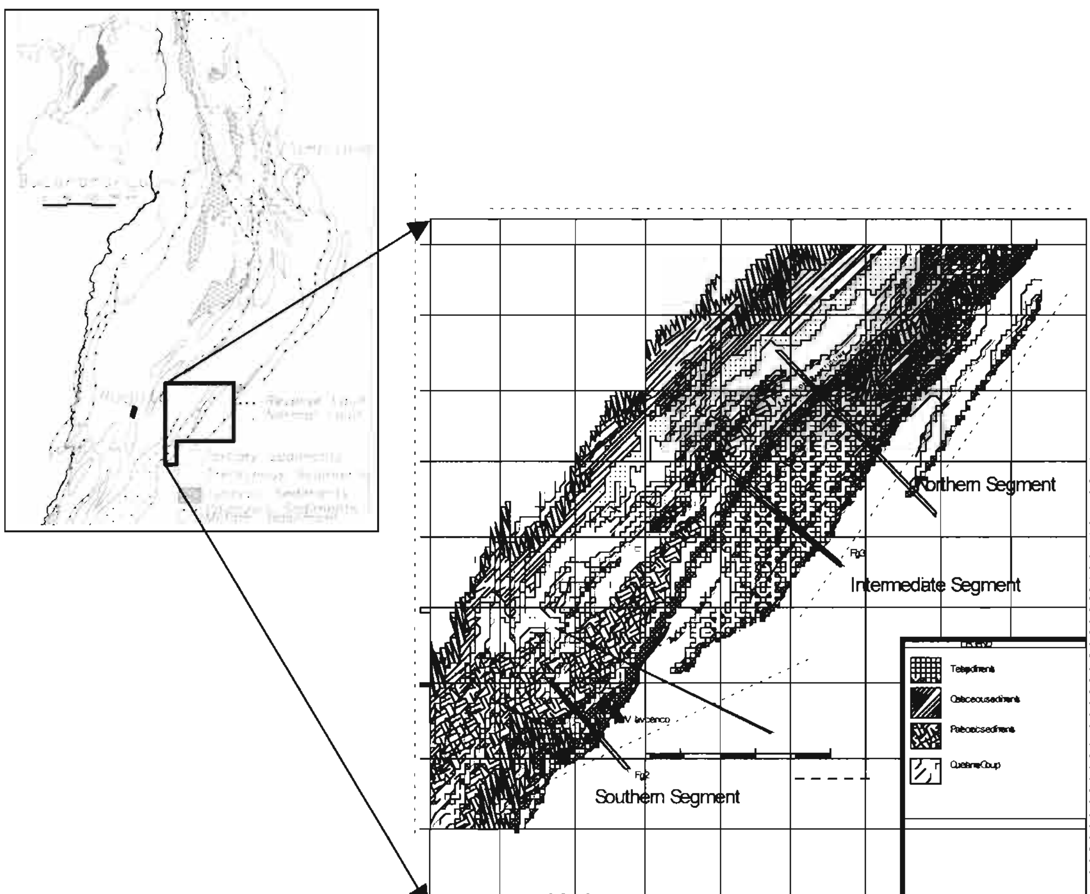

Fig. 1: Geologic map showing the three structural segments of the Llanos foothills at Villavicencio and the location of the two sections shown in Figures 2 and 3.

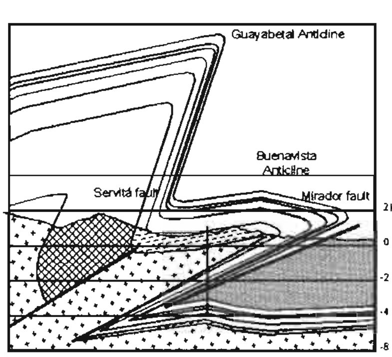

Fig. 2: Deformation front of the Eastern Cordillera at Villavicencio.

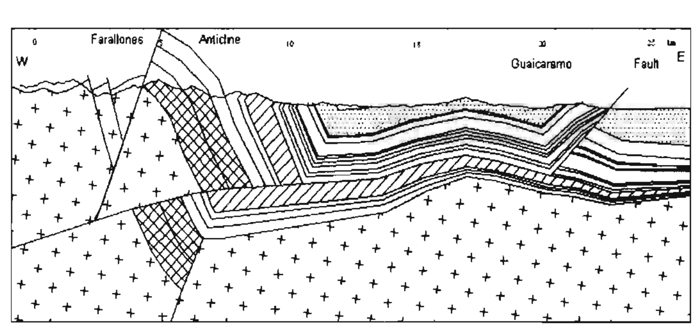

Fig. 3: Section of the Guaicaramo Fault and its associated thrust sheet.