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New stratigraphic data on the initiation of mountain building at the eastern front of the Colombian Eastern Cordillera

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Introduction

The Upper Cretaceous to Cenozoic evolution of the central and eastern Colombian Andes is linked to the development and migration of a foreland basin system (Magdalena Valley Basin) coupled to the Central Cordillera (CC) that became isolated from the present Llanos Foreland Basin after the uplift of the Eastern Cordillera (EC) (Figure 1A).

Numerous works (Schamel, 1991; Cooper et al 1995; Villamil, 1999, Gómez et al, 2003; Montes, 2005) place the onset of deformation of the CC, and the concomitant development of a foreland basin system to the west, during the Upper Cretaceous. Eastward migration until early Eocene followed by westward retreat of the CC mountain front is also well documented (Villamil, 1999; Gómez et al, 2003). However, the time of initiation of mountain building at the EC remains controversial. Early workers (i.e. Van der Hammen, 1961; Dengo and Covey, 1993; Cooper et al, 1995) linked the appereance of late Miocene to Pliocene fluvial facies in the Llanos Foreland Basin to the onset of uplift in the EC. More recently, an episode of Late Eocene to Oligocene deformation at the western margin of the EC has been documented (Laumonier, 1996; Gómez et al, 2003).

Geologic evidence of an Oligocene deformation is also registered in the eastern flank of the EC (Sarmiento, 2001 and references therein). Subsurface data (Casero et al, 1997) shows thickening of the Oligocene Carbonera Formation in the Medina and Cusiana areas that could reflect crustal flexure triggered by an early uplift. Corredor (2003) also documented pre-Late Oligocene faulting and folding in the northern part of the EC. However, whether this deformation implies a tectonic load and thus the onset of mountain building in this northern portion remains an open question. Although new appatite fission track data suggest rapid Plio-Pleistocene uplift in the Quetame Massif area (Mora et al, this volume), the initial age of the EC uplift remain unclear.

The Medina-Guavio area, located in the eastern flank of the EC and adjacent to a deeply exhumed basement high (The Quetame Massif), is an ideal place to address the problem. The nearly 4-km-thick Oligocene-to-Recent sedimentary sequence provides useful constraints on the deformation and denudation of the EC. In this study, detailed geologic mapping and new biostratigraphic data demonstrate thinning to the east and drastic facies changes within the Upper Eocene to Upper Oligocene sedimentary strata, which are explained by flexural subsidence triggered by an initial uplift directly to the west, in the Quetame Massif.

Geological Background

The EC occupies the most cratonward position of the three mountain ranges – Western, Central and Eastern Cordilleras - that form the Northern Andes north of 1°N (Figure 1A). The EC is a bivergent inversion orogen which overthrusts the Magdalena Valley Basin to the west and the Llanos Basin to the east. Cretaceous depocenters, containing ca. 5-km. of marine sediments and overlying either Upper Paleozoic sedimentary rocks or Pre-Devonian continental crystalline basement, are today exposed in the inner part of the chain. Maastrichtian to Recent syntectonic sediments were deposited and are now preserved mainly within fold-and-thrust belts located along both margins of the range.

The Medina-Guavio area is located at the eastern fold-and-thrust belt of the EC, between 4.5 and 5°N. It separates the northern termination of the Quetame Massif, west of the Tesalia-Servitá Fault, from the nearly undeformed foreland east of the Guaicaramo Thrust (Figure 1B). The Paleogene to Recent sedimentary succesion of the Medina-Guavio area consists of about 4 km of shallow marine to proximal conglomeratic alluvial facies. The lower to upper Eocene Mirador Formation is made up of 240 m of sandstone and pebble conglomerate deposited in a braided alluvial system toward the base and bayhead deposits toward the top (Cooper et al, 1995). The Mirador sandstone is superseded by a interlayered succesion of Upper Eocene to Middle Miocene shallow marine and delatic sandy and muddy intervals, informally named as segments C1 to C8 of the Carbonera Formation. The dark-grey to black, ca. 400 m thick mudstone of the León Formation overlies the C1. A ca. 1600 m thick coarsening-upward alluvial succession, the Caja Formation, outcrops mainly in the cores of the Nazareth and Río Amarillo synclines, to the west and east respectively, and underlies the ca. 120 m of pebble and cobble conglomerate and subordinated sandstone of the Corneta Formation. Age constraints within the Caja and Corneta Formations are poor. On the basis of the age of the uppermost Carbonera Formation, a post-early Miocene age has been assigned (Ulloa & Rodríguez, 1976).

Methods and Results

Detailed geological mapping was carried out to document the lateral extent of facies and thicknesses of the Carbonera Formation across the Medina–Guavio area. Due to its conspicuous morphology and lateral continuity, the top of the Lower Mirador Formation was used a marker horizon and the oldest level of our observations. Above this horizon, emphasis was placed on (1) tracking the first appearance of continental facies across the area and (2) following a bioclastic guide horizon found at the top of the C6 interval. Two detailed stratigraphic sections were then measured where drastic changes in facies and thickness were evident from the mapping. One composite section was measured to the west, along the Guadualera and Gacenera creeks, within the overturned western flank of the Nazareth Syncline (Figure 1B) and a second section along the Caracol Creek, at the eastern flank of the Rio Amarillo Syncline. These sections were also carefully sampled for palynology in order to constrain depositional ages and environments

Relative continuity in facies and thickness between the top of the Lower Mirador Formation and the base of the C7 Unit was observed across the entire area. The uppermost, thick to very-thick lenticular strata of coarse and pebbly sandstone, and interbedded reddish sandy mudstone of the Lower Mirador Formation are superseded by ca. 70 of interlayered subtabular, medium to very-thick bedded, medium sandstone and strongly bioturbated, dark-grey mudstone of the Upper Mirador Formation. Flaser and lenticular bedding and oscilation waves within sandstone beds of the Upper Mirador are common, interpreted as an upper to lower shoreface depositional environment. Comformably overlying the Mirador Formation, the C8 Unit is represented by a ca. 250 m-thick interval of lower shoreface dark-grey and dark-green mudstone.

A fossiliferous (mollusk) horizon located ca. 15 m below the C6-C5 limit was found in the northern part (Point 1, Figure 1B) and carefully tracked across the entire area. It has been informally named the Gacenera Horizon. Below this horizon and above the muddy C8 Unit, the mapping shows a varying stratigraphy between the western and eastern parts of the area (Figure 2). To the east, described along the Caracol Creek, was found a 455 m interval that can divided into two units The C7 Unit is represented by a 351 m-thick succesion of medium to thick bedded, fine to medium sandstones, often forming coarsening upward intervals 1 to 2 m thick, interlayered with few-meters thick levels of dark-grey mudstone and subordinate medium coal beds. Facies analysis suggests a deltaic depositional environment. Overlying the C7, a ca. 104 m-thick unit made up almost exclusively of dark grey mudstones – the C6 Unit – underlies the Gacenera Horizon. The top of this muddy unit does not outcrop along the Caracol Creek. However, the projection of the base of the sandy C5 Unit is located ca. 75 m above the Gacenera Horizon.

Conversely, to the west of the area along the composite Guadualera-Gacenera section, an 1150 m-thick interval constitutes the lateral equivalent to the interval between the top of C8 and the Gacenera Horizon. Rather than distinguishing two units (C7 and C6), three informal members (G1, G2, G3 and G4) are recognised based on colour and lithology. They are from bottom to top: (1) G1, basal, yellow, medium to thick bedded, fine to medium sandstones and interlayered grey mudstones and subordinated thin to medium coal beds (178m), (2) G2, dark-grey and dark-green mudstones with minor subtabular, thin to medium beds of fine to medium sandstones (204m), (3) G3, interlayered lenticular and channel-form, fining upwards, medium-grained to pebbly sandstones, reddish sandy mudstones and siltstones, subtabular, medium to thick bedded, yellowish sandstones and dark-grey mudstones (266m) and (4) G4, reddish mudstones and sandy mudstones with subordinated channel-form, medium to very thick fining upwards beds of medium grained to pebbly sandstones (502m). Facies analyses suggest that the depositional environment evolved from a deltaic-complex (G1 to G3) to a meandering fluvial system (G4). Both the east and west intervals were deposited during the palynological zones Ca2 to Ca6, upper Eocene to upper Oligocene (Zones after Jaramillo and Rueda, 2004).

Rapid facies changes to the west, from deltaic to meandering fluvial sediments, show the presence of a more elevated area in the direction of the present EC. Furthermore, thickness variation from ca. 450m in the east, to ca. 1150m 20 km to the west (without restoring the folding) clearly shows enhanced subsidence in the western part of the basin. This evidence suggests an episode of tectonic loading at the present location of the EC during the Late Eocene-Upper Oligocene. Subsidence modelling is required to constrain the location of tectonic loading. However, the rapid facies change and drastically increase in stratigraphic thickness suggest an early uplift of the eastern front of the EC.

Conclusions

New detailed mapping and stratigraphic data from the Medina-Guavio area constrain the onset of mountain building in the eastern front of the Colombian Eastern Cordillera. Westward shifting facies changes within the Upper Eocene to Lower Oligocene succesion from deltaic to meandering fluvial facies are accompanied by westward thickening from ca. 450m to ca. 1150m over a distance of ca. 20 km. The basin evolution reflects higher topography in the range and enhanced subsidence activated by tectonic loading at the present position of the eastern front of the Colombian Eastern Cordillera. The stratigraphic data constrains the initial age of mountain building in this area as late Eocene to lower Oligocene.

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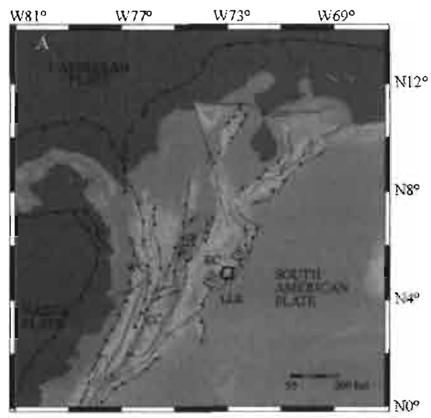

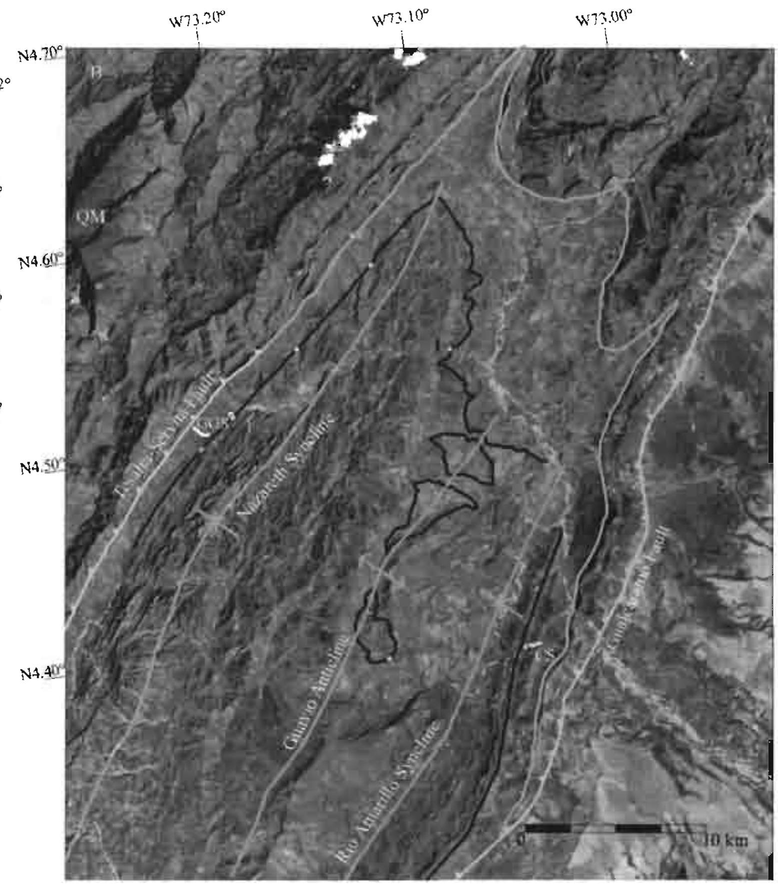

Figure 1.

A. Main structural features of the Colombian Andes and location of the Medina-Guavio Area (square) in the eastern front of the Eastern Cordillera. Abbreviations are as follows: WC, Western Cordillera; CC, Central Cordillera; EC, Eastern Cordillera; MVB, Magdalena Valley Basin; LLB, Llanos Basin; TSF, Tesalia-Servitá Fault; GF, Guaicaramo Fault.

B. Landsat image of the Medina-Guavio Area showing the top of the Lower Mirador Formation (grey line) and the Gacenera Horizon (black line). Outcrops of the Gacenera Horizon (yellow circles) and the measured stratigraphic sections (white lines) are also shown. Abbreviations are as follows: GGS, Guadualera-Gacenera Section; CS, Caracol Section, QM (Quetame Massif).

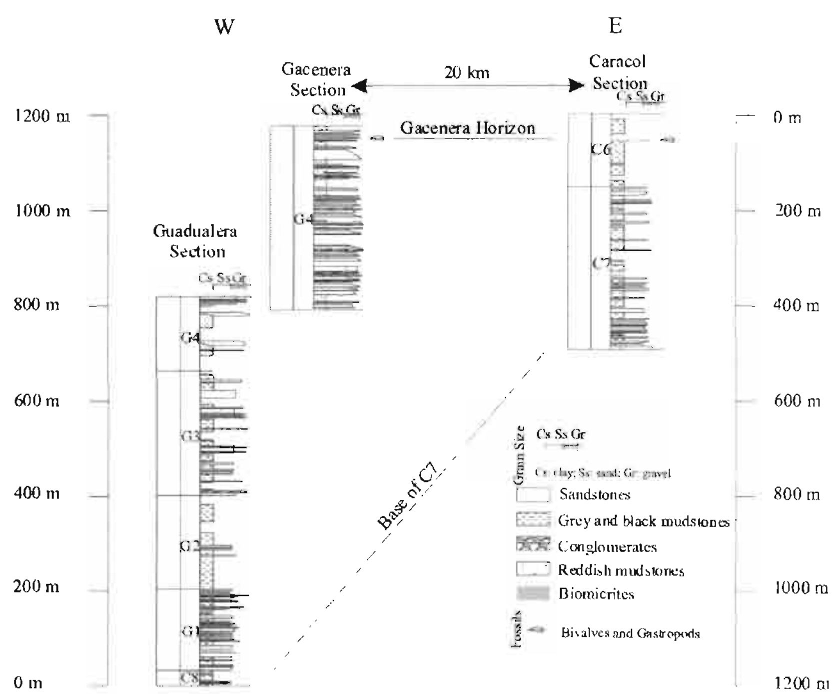

Figure 2. W-E stratigraphic correlation of the Upper Eocene to Upper Oligocene sedimentary succession of the Medina-Guavio Area. Facies and thickness variations suggest higher topography and enhanced subsidence to the west. Note vertical exaggeration. See Figure 1B for location of sections.