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Transverse zones controlling the structural evolution of the Zipaquira Anticline (Eastern Cordillera, Colombia): Regional implications

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A B S T R A C T

We report paleomagnetic, magnetic fabric and structural results from 21 sites collected in Cretaceous marine mudstones and Paleogene continental sandstones from the limbs, hinge and transverse zones of the Zipaquira Anticline (ZA). The ZA is an asymmetrical fold with one limb completely overturned by processes like gravity and salt tectonics, and marked by several axis curvatures. The ZA is controlled by at least two (2) transverse zones known as the Neusa and Zipaquira Transverse Zones (NTZ and ZTZ, respectively). Magnetic mineralogy methods were applied at different sites and the main carriers of the magnetic properties are paramagnetic components with some sites being controlled by hematite and magnetite. Magnetic fabric analysis shows rigid-body rotation for the back-limb in the ZA, while the forelimb is subjected to internal deformation. Structural and paleomagnetic data shows the influence of the NTZ and ZTZ in the evolution of the different structures like the ZA and the Zipaquira, Carupa, Rio Guandoque, Las Margaritas and Neusa faults, controlling several factors as vergence, extension, fold axis curvature and stratigraphic detatchment. Clockwise rotations unraveled a block segmentation following a discontinuos model caused by transverse zones and one site reported a counter clockwise rotation associated with a left-lateral strike slip component for transverse faults (e.g. the Neusa Fault). We propose that diverse transverse zones have been active since Paleogene times, playing an important role in the tectonic evolution of the Cundinamarca sub-basin and controlling the structural evolution of folds and faults with block segmentation and rotations.

1. Introduction

Curved structures in orogenic systems (e.g. faults and folds) have been widely studied around the world due to their implications in understanding of the kinematic of deformed regions at large scale (e.g. Macedo and Marshak, 1999; Weil and Yonkee, 2010) and a small scale (Rouvier et al., 2012). The Eastern Cordillera (EC) of Colombia, located in the northern Andes (Fig. 1), is considered a divergent fold and thrust belt with a complex geological evolution, formed as a Mesozoic extensional basin and inverted during the Andean Orogeny (Colletta et al., 1990; Cooper et al., 1995; Mora et al., 2006, 2009). The EC shows a regional curvature that was studied by Jiménez et al. (2014) from paleomagnetic and magnetic fabric data, who consider that its curved-shape formed as a primary arc, instead of due to vertical axis rotation (VAR). Curved belts and folds can be studied from many approaches; one of them, considering the influence of transverse zones, has been previously reported in such global cases as the Appalachians (e.g. Thomas and Bayona, 2002) or in the Colombian Andes (Jiménez et al., 2012).

Thomas (1990) describe transverse zones as lateral connectors, transverse or oblique to the tectonic transport direction, that can be expressed in plan-view by along-strike terminations of thrust faults, curves, offset in strike, direction of vergence, etc. Lateral connectors within a transverse zone show a wide range of types (e.g. lateral ramps, transverse faults or transference zones in rift systems), scales and senses of apparent offset (Thomas, 1990). The cause for location of transverse zones could be related to pre-existing anisotropy in the basement as well as stratigraphic variations like thinning, pinch-out and facies change as it has been demonstrated by analog modelling (Soto et al., 2002, 2003).

In the axial part of the EC, within the Cundinamarca sub-basin (CSB), mapped folds shows a similar curvature with the EC (Fig. 2), bounded by faults and lineaments barely studied before, all

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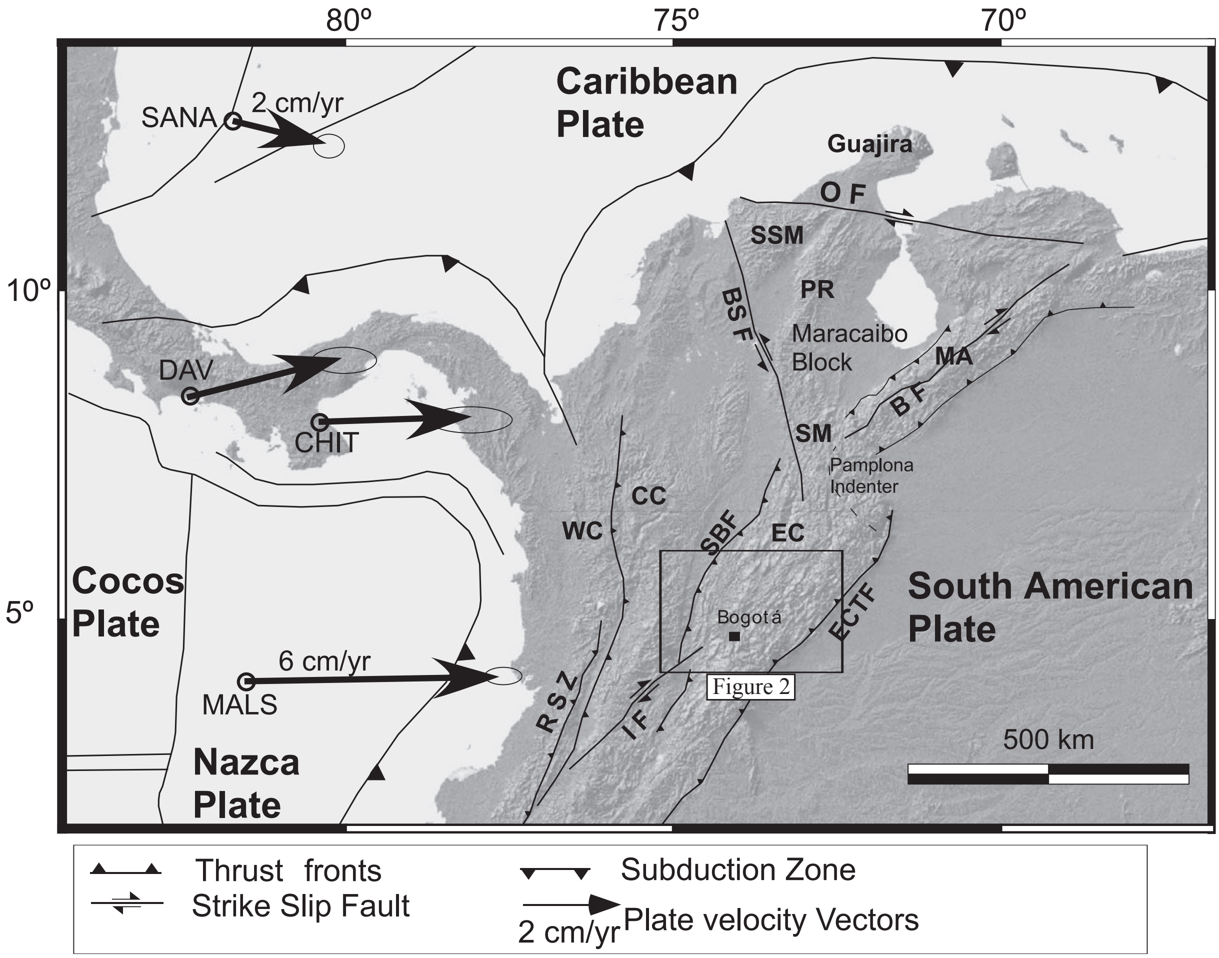

Fig. 1. Major tectonic features of the NW corner of South America with plate tectonic velocity vectors from Trenkamp et al. (2002) and other structural elements of the northern andes. EC = Eastern Cordillera, CC = Central Cordillera, WC = Western Cordillera, SBF = Salina-Bituima Fault, ECTF = Eastern Cordillera Thrust Front, MA = Mérida Andes, SM = Santander Massif, BF: Boconó Fault, SSM: Santa Marta Massif, IF: Ibagué Fault, RSZ: Romeral Suture Zone, OF: Oca Fault, PCB = Panama Choco Block. Modified from Jiménez et al. (2014).

of them transverse to the regional trend of the EC and associated with a left-lateral strike-slip system controlling the extension of faults and with important seismic activity (Velandia and De Bermoudes, 2002; Fierro-Morales and Angel-Amaya, 2008).

An example of this relationship between transverse faults (or zones) and folds is the Zipaquira Anticline (ZA), an overturned fold with multiple axis curvatures (Fig. 3). The Neusa Fault (NF) and the Zipaquira Lineament (ZL) correspond to the WNW-ESE oriented features mentioned above, separating the ZA into two (2) different domains: north (NZA) and south (SZA) (Fig. 3).

In this paper, we report regional structural analyses, anisotropy of magnetic susceptibility and paleomagnetic data from the ZA to constraint the influence of transverse zones in the structural evolution of the fold and, from this point, their importance in the tectonic evolution of the EC.

2. Geologic setting

2.1. Tectonic evolution of the Eastern Cordillera and Cundinamarca sub-basin

The Eastern Cordillera of Colombia is a Mesozoic rift inverted during the Andean Orogeny and bounded by two (2) major reverse structures: the Bituima-La Salina Fault system to the west and the Guaicaramo Fault to the east (Cooper et al., 1995; Mora et al., 2009) (Fig. 2). The mountain range is formed by a crystalline basement of Precambrian to lower Paleozoic igneous and metamorphic rocks, covered by faulted and folded sedimentary rocks including volcaniclastic, marine and continental sequences from upper Paleozoic to Neogene times (Cooper et al., 1995; Branquet et al., 2002; Bayona et al., 2008). Sarmiento-Rojas et al. (2006) studied the basin compartments and their stratigraphic and tectonic evolution, suggesting a Jurassic-Early Cretaceous back-arc extensional regime combined with a transtensional component (e.g. the Paleo-Magdalena-La Salina fault system, western boundary of the EC). Bayona et al. (2013) studied spatial and temporal variations of the sedimentary record to support the multiphase deformation evolution for the EC and a prior stage of positive inversion of normal faults associated with the convergence and subduction of the Caribbean plateau from Maastrichtian to lower Eocene times. In the eastern flank of the EC, a late Eocene event is described by Corredor (2003), where a NE imbricate fan detached from Upper Cretaceous shales, representing a major unconformity in the stratigraphic record, covered later by continental Late Oligocene deposits. The same event mentioned above is recognized in the western flank along the Nuevo Mundo Syncline, where the Mugrosa, Colorado and Real formations recorded the uplifting and erosion of Paleozoic and Mesozoic sedimentary rocks from the EC, with an initial event in Paleocene ties associated with the Lisama Anticline (Caballero et al., 2010).