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Transition from the Farallon Plate subduction to the collision between South and Central America: Geological evolution of the Panama Isthmus

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ABSTRACT

This paper presents new geological constraints on the collision of southern Central America with South America, and the resulting deformational episodes that have affected the Panama Isthmus since the Late Cretaceous. The Panama Isthmus is located in southwestern Central America, and it represents the zone of contact between the two land masses: Central America and South America. This collision event is still active today. It has resulted in regional uplift since the Late Miocene/Pliocene and is responsible for the Great American Biotic Interchange between South and North America. Depending on the methods of investigation used, and due to the lack of data available, the time when this collision began is still widely debated and poorly constrained. To better constrain this age, we have studied the rock formations and the tectonic deformations in central and eastern Panama that have occurred since the Late Cretaceous. This study presents new rock ages, field-work documentation and analyses, and seismic-line interpretations, and it is complemented by spatial images for the eastern Panama area. During the Middle Eocene, a number of changes suddenly appeared in the geological records that were synchronous with the break-up of southern Central America into two smaller blocks: Chorotega and Chocó. Our main results identify the prevalence of an extensional tectonic regime from the Middle Eocene to the Middle Miocene that caused the formation of horst and graben structures with thick sedimentary basin fills, and a synchronous clockwise block rotation. Here, we propose that these geologic events are associated with the initiation of the oblique collision of southern Central America with South America. The first contact of the southeastern extremity of Central America occurred around 40 Ma to 38 Ma, and then propagated northwestwards. We describe here this long-term collision episode in relation to the history of the Panama Isthmus.

1. Introduction

Today, Central America forms a land bridge that connects North America and South America, and it has separated the Caribbean Sea from the Pacific Ocean ever since the Upper Miocene/Pliocene, which resulted in the Great American Biotic Interchange (Beu, 2001; Coates et al., 1992, 2004; Collins et al., 1996a, 1996b; Duque-Caro, 1990a, 1990b; Kameo et al., 2000; Keigwin, 1978, 1982; Newkirk and Martin, 2009). Southern Central America represents the onshore part of the western margin of the Caribbean Plate (Fig. 1) (Adamek et al., 1988; Cediel et al., 2003; Dengo, 1985; Pindell and Kennan, 2009). Its main feature is an active volcanic arc system that has existed since the late Campanian (Buchs et al., 2010). This was related to the ancient subduction of the Farallon Plate, and more recently of the Cocos Plate, beneath the Caribbean Plate (Wegner et al., 2011; Wörner et al., 2009). The Caribbean Plate is allochthonous with respect to the South American Plate, as it initiated in the Late Cretaceous, and later collided with the South American Plate. However, the ages and tectonic processes of this collision remain poorly constrained.

Until now, too little information has been available to satisfactorily constrain the age of the collision initiation of southern Central America against South America. The first attempt to date this collision was by Silver et al. (1990), who dated the event with a very large uncertainty range (between Middle and Late Miocene). Later, Coates et al. (2004) associated the collision event with the rapid uplift of the isthmus, which was documented by a major regional unconformity that was dated at 14.8 Ma to 12.8 Ma. However, more recently, Farris et al. (2011) and Montes et al. (2012a,b) proposed an older age range, from Late Oligocene to Early Miocene, which was based on changes in the geochemical signatures of the magmatic rocks and the paleo-rotations of several blocks.

Therefore, we focused our study on the eastern Panama Isthmus, which represents the northwestern part of the closest contact zone

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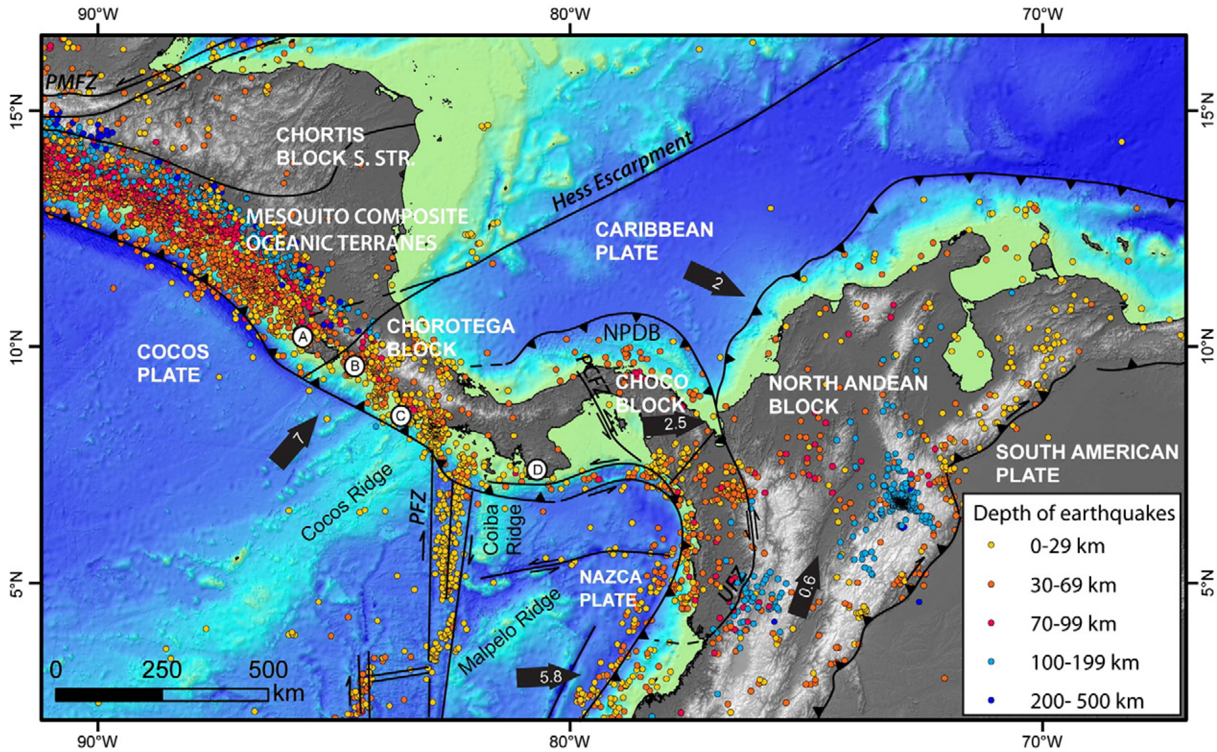

Fig. 1. Tectonic and geological context of Central America. The seismicity was taken from the USGS catalog (2002–2009) and the Engdhal catalog (1900–2002). Black arrows show present-day GPS relative velocities of major tectonic plates and blocks (white velocities in cm/yr) relative to stable South America (Trenkamp et al., 2002). Letters A to D represent accreted geological complexes: A, Nicoya; B, Herradura; C, OSA peninsula; and D, Azuero peninsula. PMFZ, Polochic–Motagua Fault Zone; CPFZ, Canal Panama Fault Zone; NPDB, North Panama Deformed Belt; UFZ, Uramita Fault Zone.

between southern Central America and South America, and which is of great significance for an understanding of this collision event. The Panama Isthmus also represents one of the least explored territories of the collision zone, as the outcrop accessibility and quality are very poor, which has resulted in poorly constrained pre-Neogene geological history.

Here, we present new data that provides a better estimation of the age and evolution of the collision in the region of eastern Panama, which include: field observations, new sedimentary rock ages, stratigraphic analysis, and thorough description of the geological structures and deformations that are complemented by seismic-line and satellite-image interpretations. This report proposes a new model of the tectonic and geological history of southern Central America prior to and during its collision with South America that is based on an integration of previous studies and our present data. We report on a number of sedimentary and tectonic events that occurred during the Farallon Plate subduction and the subsequent collision between southern Central America and South America. A change in the tectonic regime and the segmentation of the isthmus into smaller rigid blocks, and migration of the volcanic arc, mark the onset of this collision at 40 Ma to 38 Ma. We also show that the collision was not frontal, but oblique, which resulted in the first collision in the southeastern part of southern Central America (which is today the Istmina region in Colombia). This then gradually propagated northwestwards, where it is still active.

2. Tectonic and geological settings

2.1. Current plate boundaries and block composition

The Panama Isthmus is located at the southwestern edge of the Caribbean Plate, where its northwestern boundary is defined by the eastward subduction of the oceanic Cocos Plate, with its related active volcanic arc and seismicity (Fig. 1). The southwestern boundary of the Panama Isthmus is instead characterized by a major left-lateral transform fault, along which the Nazca Plate is moving eastwards and is subducting beneath Colombia. This explains the absence of an active arc volcanism and the relatively low seismic activity (Fig. 1) (Adamek et al., 1988; Kellog and Vega, 1995; Moore and Sender, 1995; Trenkamp et al., 2002; Westbrook et al., 1995). The northeastern boundary of the Panama Isthmus is weakly defined by the subduction of the offshore Caribbean Plate beneath the Panama Isthmus (Fig. 1). Despite the relatively low seismic activity of the northern margin, a Wadati–Benioff Zone provides weak evidence of the subduction of the Caribbean Plate beneath the Panama Isthmus, as was demonstrated by Camacho et al. (2010). The weak expression of the southward subduction beneath North Panama might be the result of the presence of an active accretionary wedge since the Middle Miocene, known as the North Panama Deformed Belt (Silver et al., 1990, 1995). The eastern boundary of the Panama Isthmus is defined by the Uramita Fault Zone, which represents the suture zone between the Panama Isthmus (including the North Panama Deformed Belt) and South America (more precisely, from the North Andean Block) (Fig. 1) (Duque Caro, 1990b; Mann and Corrigan, 1990; Mann and Kolarsky, 1995).

Classically, Central America has been divided into three main tectonic units (from north to south): the blocks of Chortis, Chorotega and Chocó (Dengo, 1985) (Fig. 1). More specifically, the Panama Isthmus includes two blocks: the Chorotega Block and the Chocó Block, as described here:

(1) The Chorotega Block is bound to the north by a poorly defined boundary with the Chortis Block (which is itself subdivided into a continental northern terrane and an oceanic southern terrane, the Mesquito Composite Oceanic Terranes (Baumgartner et al., 2008)), and to the south, by the hypothetical left-lateral strike-slip Panama Canal Fault Zone (PCFZ) (Case, 1974; Dengo, 1985; Duque-Caro, 1990b). This block includes the western