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Basin development at the eastern border of the Northern Puna and its relationship with the plateau evolution

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Seismic and field-sedimentary evidence from the eastern border of the Northern Puna represent important constraints for depositional development in Andean sedimentary basin studies. The studied basin fill sequences unconformably overlay the Paleozoic Santa Victoria Group and the Cretaceous – Paleocene Salta Group. Erosive truncations, folds and faults of the Salta Group seismic sequences suggest the existence of a pre-Upper Eocene phase of deformation, which was characterized by generalized erosion and the development of a proto-depocenter. The landscape that emerged from this early stage of deformation subsequently controlled the onset of the Upper Eocene sedimentation. Cenozoic sequences are characterized by syntectonic features, such as onlapping basal geometries and growth strata. Paleoflows and sourced clasts data from the Casa Grande Formation support the pre-Upper Eocene uplift of the basin-bounding ranges. Undeformed Cenozoic sequences suggest that basin-boundary thrusts preferentially settled contractional deformation. Steeply dipping, variable verging reverse faults exhumed basement ranges and defined the depositional area. Furthermore, the eastern border of the depocenter was established along the morpho-structural boundary between the Puna and the Eastern Cordillera, which enhanced the basin isolation. Seismic, sedimentary and structural features are discussed regarding the influence of the plateau evolution on controlling the development of the isolated deposition along the eastern border of the Northern Puna.

1. Introduction

The Altiplano-Puna plateau is the most extraordinary topographic feature of the Central Andes (Fig. 1). The plateau growth is related to the geometry of the subducting plate along the western side of South America, which governed the shortening, magmatic addition and thickening of the crust (Allmendinger et al., 1983; Jordan et al., 1983; Allmendinger et al., 1997; Kay and Coira, 2009; Kennan, 2000; McQuarrie et al., 2002). The mean elevation of the plateau would have exceeded 3 km during the Plio-Pleistocene (Pardo-Casas and Molnar, 1987; Gubbels et al., 1993; Cladouhos et al., 1994; Allmendinger et al., 1997; Lamb and Hoke, 1997; Gregory Wodzicki, 2000). Currently, the base level of isolated basins located in the Argentine portion of the plateau is greater than 3000 m (Isacks, 1988; Allmendinger et al., 1997; Strecker et al., 2007).

The unequal responses of major terranes and the pre-existing structural and stratigraphic discontinuities in the basement determined the spatially and temporal disparate uplifts across the Andes (Kley et al., 1999; Strecker et al., 2012). The temporal range of the uplifts increases from west to east (Reiners et al., 2015), and regional data revealed that the uplifts were diachronic in the north-south direction. Thermochronological data from the Puna, southern Altiplano, and Eastern Cordillera suggest that the onset of the Paleogene deformation caused the exhumation of the Aguilar (78–60 Ma and 35–25 Ma, Insel et al., 2012), Cobres (66–55 Ma, Insel et al., 2012), Tanque (46–37 Ma, Letcher, 2007), and Luracatao (45–30 Ma, Deeken et al., 2006) Ranges and the uplift of the ranges bounding the Uyuni, Tupiza (40–36 Ma and 30 Ma, Ege et al., 2007; 40–36 Ma and 33–30 Ma, Scheuber et al., 2006), Arizaro and Antofalla Basins (36 Ma, Canavan et al., 2014, Fig. 2). Later deformation exhumed the Calalaste Range (29–24 Ma, Carrapa et al., 2005), while Miocene deformation and exhumation occurred in the Luracatao (22–16 Ma, Deeken et al., 2006) and Cachi Ranges (15 Ma, Deeken et al., 2006; Pearson et al., 2012, Fig. 2).

The style and history of the plateau evolution and their

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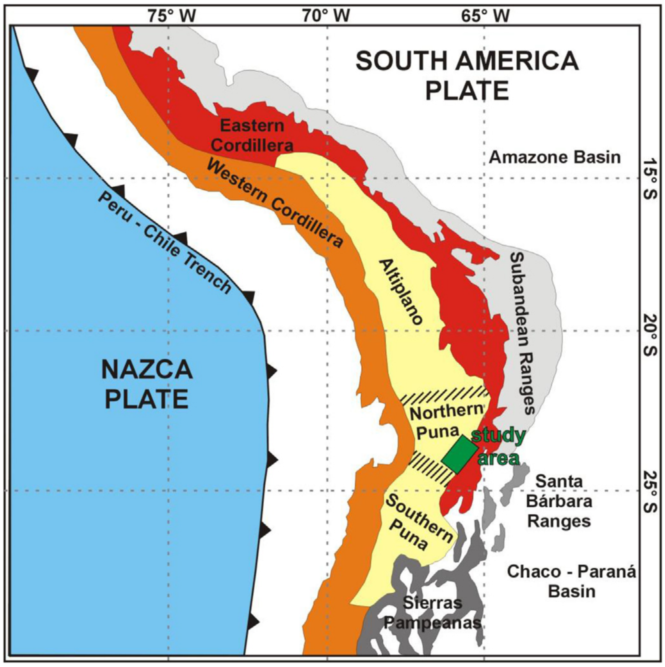

Fig. 1. The Altiplano-Puna plateau extends in the central part of the Andes. The Puna is the Argentine portion of the plateau and extends southwards latitude 22°S. The study area is located at the eastern border of the Northern Puna.

influences on depositional development remain topics of active research. According to DeCelles et al. (2011), crustal shortening controlled the formation of a foreland flexural wave, which resulted in the development of a regional basin system (Fig. 3A). Within this retroarc foreland basin, variable connected depozones are characterized by the eastward decreasing influence of the Andean deformation (DeCelles and Giles, 1996; DeCelles et al., 2011; DeCelles, 2012). By contrast, Strecker et al. (2009) proposed that the plateau growth disrupted the depositional system (Fig. 3B). This perspective considers that the isostatic compensation, which includes both crustal thickness and density contrasts, constituted major control of the higher elevations of the Altiplano-Puna relative to the modern eastward foreland (Tassara et al., 2006) and controlled the development of isolated depocenters (Kley et al., 1999).

The Paleogene continuous foreland system would involve interconnected basins that drained the incipient Andean orography (Jordan and Alonso, 1987; Vandervoort et al., 1995; Allmendinger et al., 1997; DeCelles et al., 2011). The deposits that accumulated during this continuous foreland stage have been recognized in basins in the Southern Puna, including the Pastos Grandes (Carrapa and DeCelles, 2008) and Antofalla Basins (Carrapa et al., 2014, 2005, Fig. 2). The regional foreland would extent eastward and include the depositional areas of the eastern Puna and Eastern Cordillera (Carrapa et al., 2011), such as the Angastaco (Carrapa et al., 2014), Luracatao (Deeken et al., 2006), La Viña (Hein et al., 2011), Quebrada de Humahaca (Pearson et al., 2012; Pingel et al., 2013) and Cianzo Basins (Siks and Horton, 2011, Fig. 2). Moreover, the Middle Paleocene successions in the Eastern Cordillera of southern Bolivia likely accumulated during the continuous foreland stage (DeCelles and Horton, 2003).

Carrapa and DeCelles (2008) proposed that subsequent segmentation of the continuous foreland stage occurred during the Upper Eocene in the Southern Puna based on evidences from the Pastos Grandes depozone, while the isolation of the Angastaco and the Antofalla Basins ocurred during the Middle Miocene (Carrapa et al., 2005, 2014). The eastward propagation of the deformation would reach the Eastern Cordillera (Deeken et al., 2006; Pearson et al., 2012), where the isolated sedimentary deposition within the La Viña, Quebrada de Humahaca and Cianzo Basins began during the Upper Miocene (Hein et al., 2011; Siks and Horton, 2011; Pingel et al., 2013).

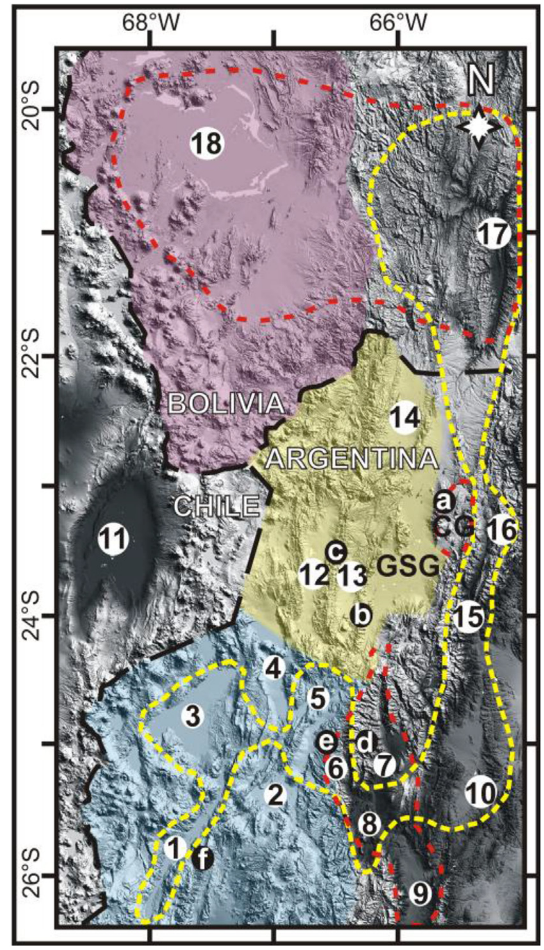

Fig. 2. Location of sedimentary basins in the Central Andes between 20° S and 26° S. The Bolivian Altiplano, Northern Puna and Southern Puna are represented by the pink, yellow and light-blue areas, respectively. The Paleocene – Eocene continuous foreland system would involve basins located within the region delimited by the yellow dashed-line (DeCelles and Horton, 2003; Carrapa et al., 2005; Carrapa and DeCelles, 2008; Hain et al., 2011; Siks and Horton, 2011; Pingel et al., 2013; Carrapa et al., 2014). A Paleocene – Eocene fragmented foreland would involve basins located within the areas that are delimited by the red dashed-lines (Scheuber et al., 2006; Alonso et al., 2006; Ege et al., 2007; Hongn et al., 2007; Payrola Bosio et al., 2009; Payrola Bosio et al., 2010; Hongn et al., 2011; del Papa et al., 2013; del Papa et al., 2014; Galli et al., 2014a,b; Montero et al., 2014). White circles indicate the sedimentary basin locations and black circles are employed for ranges. 1: Antofalla Basin, 2: Hombre Muerto Basin, 3: Arizaro Basin, 4: Pocitos Basin, 5: Pastos Grandes Basin, 6: Luracatao Basin, 7: Cachi Basin, 8: Angastaco Basin, 9: Calchaquí Basin, 10: La Viña Basin, 11: Atacama Basin, 12: Cauchari – Olaroz Basin, 13: Pastos Chicos – Coranzulí Basin, 14: Pozuelos Basin, 15: Quebrada de Humahuaca Basin, 16: Cianzo Basin, 17: Tupiza Basin, 18: Uyuni Basin, a: Aguilar Range, b: Cobres Range, c: Tanque Range, d: Cachi Range, e: Luracatao Range, f: Calalaste Range, CG: Casa Grande Basin, GSG: Guayatayoc – Salinas Grandes Basin. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

By contrast, other regional data point to the formation of Paleocene isolated depocenters. The development of these isolated basins would have been structurally controlled by pre-existing heterogeneities in the basement rocks (Kley et al., 1999; del Papa et al., 2004; Hongn et al., 2007, 2010; Monaldi et al., 2008;