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Basin evolution during Cretaceous-Oligocene changes in sediment routing in the Eastern Precordillera, Argentina

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The response of sedimentary basins to earliest onset of Andean contraction and lithospheric flexure in the southern Central Andes is debated and not well-resolved. The Upper Cretaceous to Oligocene strata of the Cuesta de Huaco anticline in the Argentine Precordillera record sedimentation, regional deformation, and climate patterns prior to the highly studied Oligocene-Miocene foreland basin phase. These deposits have recently been recognized as Cretaceous and Paleogene in age, prompting a re-evaluation of this depocenter as part of the early Andean system, prior to deposition of the aeolian foredeep sediments of the Oligocene Vallecito Formation. This work presents new data from the Argentine Precordillera fold-and-thrust belt at 30°S that sheds light on new reinterpretations of the timing of sedimentation for an important interval in Andean retroarc foreland basin history. We report the first Paleocene detrital radiometric ages from the Cuesta de Huaco 'red strata' of the pre-Oligocene Bermejo Basin. Detailed sedimentology and provenance data from the Cenomanian-Turonian Ciénaga del Río Huaco and Danian-Priabonian Puesto La Flecha formations reveal a Cenomanian-Turonian braided stream system that transitioned into a shallow freshwater lacustrine depocenter in Paleocene-Eocene time. During Late Cretaceous time, sediment in the braided river system was derived primarily from northeastern cratonic sources; during the Paleocene-Eocene, uplift and unroofing of the Andean arc and Frontal Cordillera resulted in an influx of western-derived sediment. We therefore suggest a revised timing of sedimentation for the transition to Andean retroarc foreland basin deposition.

1. Introduction

The Andes orogenic system represents an archetype of oceanic-continental subduction zone processes and deformation of the overriding continental lithosphere (DeCelles and Horton, 2003; Ramos, 2009). Much of our understanding of Cordilleran-type deformation is derived from studies of the Andes, however, fundamental questions regarding the onset of crustal thickening and topographic growth, and their impact on retroarc basin evolution remain unanswered. Although the middle to late Cenozoic deformation and lithospheric shortening are well-documented and linked to surface uplift in the Central Andes (e.g., Oncken et al., 2006; Gonzalez-Bonorino et al., 2001), more recent work elucidates along-strike heterogeneity in the nature of Late Cretaceous and Paleogene deformation (Balgord and Carrapa, 2016; Giambiagi et al., 2011; Horton, 1998, 2005; Horton and Fuentes, 2016; McQuarrie et al., 2005). While retroarc foreland basin sedimentation was underway by Late Cretaceous time along some sectors of the Andean orogen, e.g., the Neuquén and Magallanes basins to the south (Balgord and Carrapa, 2016; Fildani et al., 2003; Strecker et al., 2007), and by Paleogene time in the north (Carrapa et al., 2011; Carrapa and DeCelles, 2008; DeCelles, 2012; DeCelles et al., 2011; DeCelles and DeCelles, 2001; Horton, 1998; Horton and DeCelles, 1997, 2001; Quade et al., 2015; Welsink et al., 1995), other workers have documented a period of relative tectonic quiescence in the retroarc region of the central Andes and propose fluctuations between contractional, extensional, and neutral tectonic regimes since Cretaceous time (Horton and Fuentes, 2016).

In the Andes retroarc foreland basin, flexural modeling studies

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suggest variations in the flexural behavior and resulting foreland basin stratigraphic succession, allowing for better spatiotemporal resolution on when and how foreland deposition has evolved (Dávila et al., 2007; DeCelles et al., 2011; Horton, 1998). Along-strike variability in upper plate shortening, sedimentation, environmental conditions, and basin connectivity are all critical factors for understanding large scale fold-and-thrust belt geologic processes as well as basin and petroleum system evolution. Key components to depocenter paleogeographic reconstructions of foreland basin evolution constitute a better view of the paleoenvironmental conditions, sediment routing system, and geographic distribution of paleotopography, all of which can be interpreted from the sedimentary basin record. Much emphasis has been placed on the coarse-grained deposits in foreland basins, as these strata represent high rates of sediment supply and are commonly interested to herald the earliest phases of sedimentation (e.g., (Fildani et al., 2003; Heller and Paola, 1992).

In contrast, lacustrine deposits in these tectonic basins can contain some of the most complete sedimentary records of Earth history, including extensive records of tectonic activity and paleoenvironmental conditions (Carroll and Bohacs, 1999) during continuous sedimentation. Within the proximal foredeep depozone, the depositional system is typically overloaded by large volumes of sediment shed from the uplifting mountains, so lakes are rare records of major foredeep subsidence and sedimentation (Cohen et al., 2015). In this regard, the stratigraphy of foreland basins, particularly those preserving the evolution of lacustrine depocenters, is an invaluable archive for investigating early basin development proximal to the nascent Andes Mountains.

The Upper Cretaceous to Oligocene Bermejo Basin, northwest Argentina, records Upper Cretaceous through Quaternary sedimentation, regional deformation, and climate patterns in the southern Central Andes that reflect both the onset and evolution of Andean retroarc deformation and changing paleoenvironmental conditions. Early work on the Bermejo foreland basin developed a detailed understanding of the Miocene-Pliocene foreland basin phase developed atop Paleozoic strata (Johnson et al., 1986; Jordan et al., 1993a, 2001) and synchronous with progressive structural growth of the Argentine Precordillera (Jordan et al., 2001; Allmendinger and Judge, 2014; Levina et al., 2014). A few single crystal $^{40}Ar/^{39}Ar$ radiometric dates collected on volcanic grains in the basal eolian Vallecito Formation indicated a potential Oligocene (rather than Miocene) age (Jordan et al., 1993b), but most workers promoted the Miocene age of major foredeep deposition and initiation of the retro-arc thrust belt at this latitude. More recently, studies have confirmed an Oligocene age for the oldest parts of the Vallecito Formation (Levina et al., 2014; Fosdick et al., 2017) and recognized the 'Paleozoic pre-foreland strata' to be Cretaceous - Eocene in age (Limarino et al., 2001; Tedesco et al., 2007; Fosdick et al., 2017), leading to a new model for an earlier history of retroarc foreland sedimentation than previously accepted (Fosdick et al., 2017). In light of this new understanding of basin history and potential link to upper plate deformation in the southern Central Andes, additional information on depositional environment, basin setting, and controls from tectonic and climatic processes is needed for a complete geologic context.

We focus on the detailed sedimentology, provenance, timing, and paleoenvironmental setting of the Ciénaga del Río Huaco and Puesto La Flecha formations, which record the transition from Upper Cretaceous to Eocene sedimentation in the Bermejo Basin (Fig. 1). Fosdick et al. (2017) reported new age constraints on the timing of sedimentation and changes in detrital provenance character, and suggested that the Puesto la Flecha Fm. is genetically linked to the foreland basin stage. This companion work provides new and more detailed sedimentology and detrital geochronology data, with focus on the Ciénaga del Río Huaco Fm. paleo-river system, to better characterize and constrain the depositional setting and basin drainage routing prior to the main phase of foreland basin sedimentation.

Our findings show that a large-scale braided river system in the incipient Bermejo foreland basin initially received sediment from the uplifting fold-thrust belt during the Late Cretaceous and, by the early Paleocene, became a hydrologically isolated lacustrine system dominated by western-derived detritus shed from the uplifting Andes. This transition in depositional environment from a Cretaceous fluvial system with northeastern-derived sediment to a Paleocene-Eocene lacustrine depocenter fed by western-derived sediment is consistent with Frontal Cordillera uplift within a Cordilleran-type retroarc basin configuration, suggesting a more extensive realm of active retroarc deformation along the Andean orogen than previously proposed.

2. Geologic background

2.1. Geologic setting

The Bermejo Basin, located in the southern Central Andes between ~30 and 33°S (Fig. 1), is today a retroarc foreland basin located on the eastern edge of the Argentine Precordillera and west of the Sierra de Valle Fértil and Sierra de Pie de Palo uplifts of the Sierras Pampeanas. It is presently located in a region of flat slab subduction, where the Nazca Plate is subducting beneath the South American Plate (Anderson et al., 2007; Cahill and Isacks, 1992; Gans et al., 2011). The Argentine Precordillera at ~30°S is a retroarc fold-and-thrust belt comprised of multiple structural domains (Allmendinger et al., 1990). In the western and central domains, stacked, thin-skinned, east-verging thrust faults and associated folding deform Paleozoic, Mesozoic, and Cenozoic strata (Allmendinger et al., 1990; Alonso et al., 2014; Alonso, 2011; Jordan et al., 1993a), whereas the eastern domain primarily consists of west-verging basement-cored fault blocks (Zapata and Allmendinger, 1996; Siame et al., 2005; Allmendinger and Judge, 2014). The eastern domain reflects the structural transition from thin-skinned deformation into the Sierras Pampeanas province, where Neogene basement uplifts have resulted in a broken foreland region and reactivation of older structures (Jordan and Allmendinger, 1986; Ramos et al., 2002). Taken together, ~98 ± 21 km of shortening has accrued across the Precordillera since 13 Ma (Fig. 1) (Allmendinger and Judge, 2014). Thin-skinned deformation within the Precordillera and deep-seated deformation have, together, cannibalized the once continuous foredeep and forebulge depozones of the Cenozoic Bermejo foreland basin system (Jordan et al., 2001; Levina et al., 2014; Dávila et al., 2007; Suriano et al., 2017).

2.2. Tectonic history of the study area

The Argentine Precordillera has an extensive geologic history that includes multiple episodes of contraction, extension, and strike-slip deformation, beginning with the construction of the Cuyania terrane, which is widely interpreted as an allochthonous terrane that rifted away from the Ouachita embayment of Laurentia during the Early Cambrian and traveled across the Iapetus Ocean (Thomas et al., 2004, 2015). In this reconstruction, the microplate was amalgamated onto the proto-Andean margin of Gondwana, resulting in the progradation of a synorogenic clastic wedge during the Middle-Upper Ordovician Ocloyic orogeny (Finney et al., 2005). Subsequent orogenesis during the Devonian Chanic orogeny is thought to have led to accretion of the Chilenia terrane to Cuyania and Gondwana. This orogeny was followed by Lower Carboniferous