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Invited review

Sedimentary record of Andean mountain building

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A R T I C L E I N F O

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A B S T R A C T

Integration of regional stratigraphic relationships with data on sediment accumulation, provenance, paleodrainage, and deformation timing enables a reconstruction of Mesozoic-Cenozoic subduction-related mountain building along the western margin of South America. Sedimentary basins evolved in a wide range of structural settings on both flanks of the Andean magmatic arc, with strong signatures of retroarc crustal shortening, flexure, and rapid accumulation in long-lived foreland and hinterland basins. Extensional basins also formed during pre-Andean backarc extension and locally in selected forearc, arc, and retroarc zones during Late Cretaceous-Cenozoic Andean orogenesis. Major transitions in topography and sediment routing are recovered through provenance studies, particularly detrital zircon U-Pb geochronological applications, which distinguish three principal sediment source regions—the South American craton, Andean magmatic arc, and retroarc fold-thrust belt. Following the cessation of Late Triassic–Early Cretaceous extensional and/or postextensional neutral-stress conditions, a Late Cretaceous-early Paleocene inception of Andean shortening was chronicled in retroarc regions along the western margin by rapid flexural subsidence, a wholesale reversal in drainage patterns, and provenance switch from eastern cratonic sources to Andean sources. An enigmatic Paleogene hiatus in the Andean foreland succession recorded diminished accumulation and/or regional unconformity development, contemporaneous with a phase of limited shortening or neutral to locally extensional conditions. Seemingly contradictory temporal fluctuations in tectonic regimes, defined by contrasting (possibly cyclical) phases of shortening, neutral, and extensional conditions, can be linked to the degree of mechanical coupling along the subduction plate boundary. Along-strike variations in Late Cretaceous-Cenozoic deformation and crustal thickening demonstrate contrasting high-shortening versus low-shortening modes of Andean orogenesis, in which the central Andes are distinguished by large-magnitude east-west shortening (> 150–300 km) and corresponding cratonward advance of the fold-thrust belt and foreland basin system, several times that of the northern and southern Andes. These temporal and spatial changes in shortening and overall tectonic regime can be related to variable plate coupling during first-order shifts in plate convergence, second-order cycles of slab shallowing and steepening, and second-order cycles of shortening, lithospheric removal and local partial extensional collapse in highly shortened and thickened segments of the orogen.

1. Introduction

Growth of the Andes mountains (Fig. 1) shapes erosion, sediment delivery, river courses, drainage networks, orographic barriers, climate, biodiversity, and ocean circulation patterns across South America and its periphery. Tectonic uplift of the Andes and coupled subsidence of sedimentary basins fundamentally control the distribution of topography and relief in western South America, generating not only the foremost sources of sediment but also the sinks where detrital material is accommodated over geological timescales. Mesozoic-Cenozoic patterns of sediment dispersal, sediment accumulation, river genesis, and drainage reorganization reflect processes of continental landscape evolution associated with protracted subduction and lithospheric deformation along a convergent plate boundary. In particular, the origination and advance of the Andean retroarc fold-thrust belt and foreland basin system (Fig. 1) played a pivotal role in the transition from an extensional or neutral tectonic regime with a westward (Pacific) draining pre-Andean landscape to a contractional regime with an overall eastward (Atlantic) draining landscape.

Despite the applicability of these concepts to the Andes and Andean-type ocean-continent convergent plate boundaries in general, questions persist over (1) the inception of Andean mountain building (e.g., Dalziel, 1986; Coney and Evenchick, 1994; Jordan et al., 2001a; DeCelles and Horton, 2003), (2) spatial variations and possible pulses or lulls in deformation (Rutland, 1971; Gansser, 1973; Aguirre, 1976; Mégard, 1984; Noblet et al., 1996; Horton, 2018), (3) temporal shifts in

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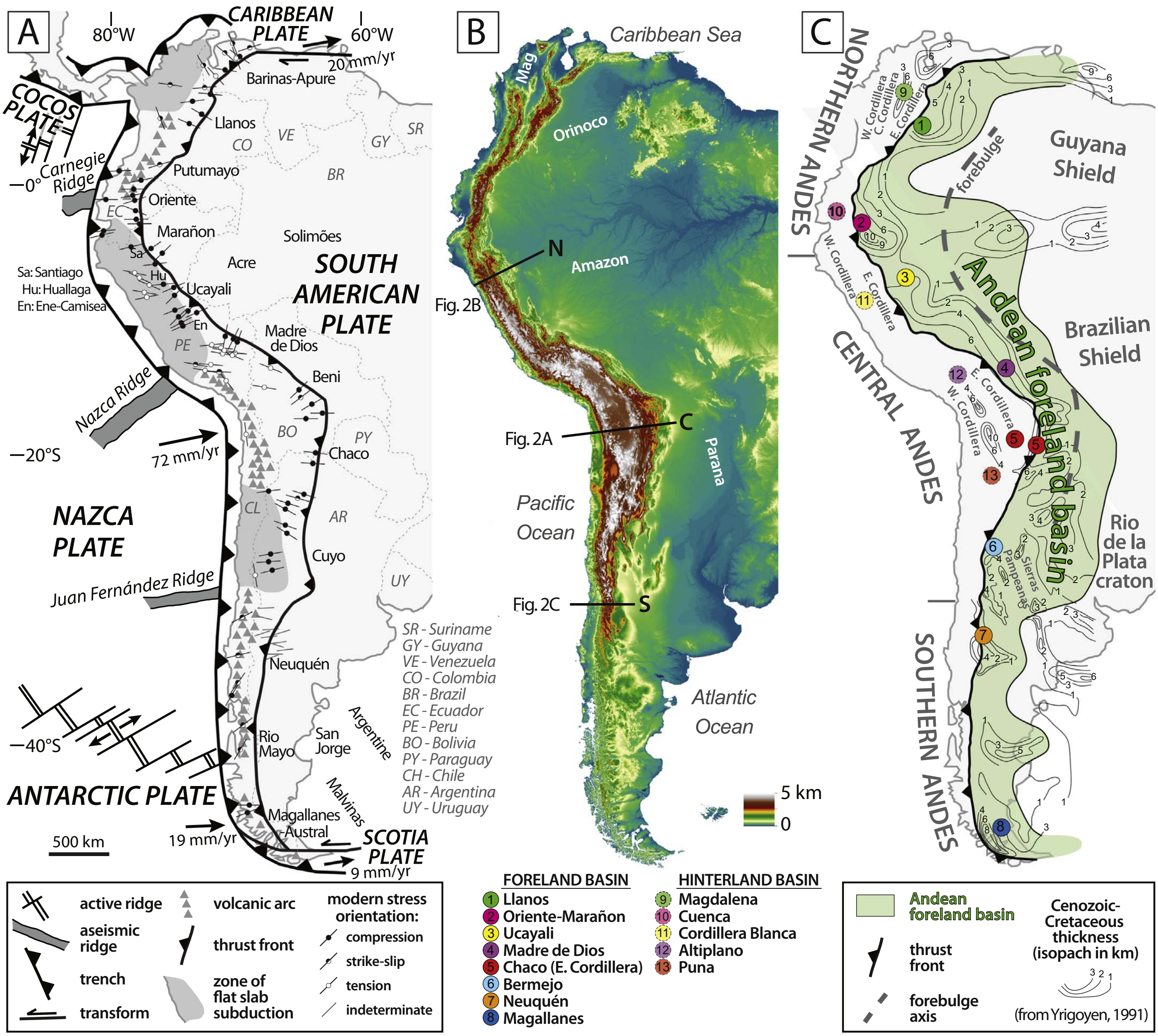

Fig. 1. Maps of (A) tectonic framework, (B) topography, and (C) sedimentary basin configuration of South America. (A) Map of plate boundaries, Andean magmatic arc (including the northern, central, and southern volcanic zones), regions of flat slab subduction, modern stress orientations from earthquake focal mechanisms, eastern front of Andean fold-thrust belt, and key segments of the retroarc foreland basin system. Plate velocities are shown relative to stable South American plate (DeMets et al., 2010). (B) DEM topographic map showing the Andes mountains and adjacent foreland region, including the Amazon, Parana, Orinoco, and Magdalena (Mag) river systems. (C) Map of Andean retroarc basins, showing isopach thicknesses (in km) of Cretaceous-Cenozoic basin fill, forebulge axis (from Chase et al., 2009), and locations of 13 sites (8 foreland basins, 5 hinterland basins) considered in this synthesis.

tectonic regime (Mpodozis and Ramos, 1990; Ramos, 2010; Mpodozis and Cornejo, 2012; Charrier et al., 2015; Horton and Fuentes, 2016), and (4) the history of paleodrainage and sediment accommodation in the basins of western South America (Potter, 1997; Lundberg et al., 1998; Hoorn et al., 2010; Roddaz et al., 2010; Horton et al., 2015a; Anderson et al., 2016). These uncertainties commonly arise from insufficient stratigraphic age control, conflicting basin structural configurations, contrasting modes of sediment accommodation, condensed stratigraphic intervals and unconformities of unclear origin, and/or limited correlation across diverse basin systems. Andean retroarc foreland and hinterland basin systems contain long-lived, chiefly nonmarine clastic successions that reflect sediment accommodation governed by a range of mechanical and thermal processes (Jordan and Alonso, 1987; Sempere et al., 1990; Jordan, 1995; Jacques, 2003; DeCelles, 2012; Horton, 2012; Carlotto, 2013). These synorogenic successions, typically 4–10 km thick, offer windows into the stages of erosional exhumation in the fold-thrust belt and magmatic arc, relative timing of Andean uplift, establishment of major sediment sources, basin subsidence and sediment accumulation patterns, key shifts in landscape development, and the establishment of topographic barriers and large river systems.

This paper integrates a range of stratigraphic, sedimentologic, and geochronological datasets in order to evaluate the Mesozoic-Cenozoic sedimentary record of mountain building in South America. A continental-scale framework spanning the northern, central, and southern Andes (Fig. 1) sets the stage for addressing several interrelated questions.

- When did Andean mountain building commence?
- How did synorogenic basins evolve, and in what structural configurations?