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Paleogeographic and tectonic controls on the evolution of Cenozoic basins in the Altiplano and Western Cordillera of southern Peru

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A B S T R A C T

Integrated studies of stratigraphy, sedimentology, paleogeography and tectonic controls on Cenozoic basins provide the basis for a series of time-slice reconstructions of basin evolution in the Andes of southern Peru. The Altiplano and adjacent margin of the Western Cordillera are characterized by several Paleocene–Miocene synorogenic continental basins with thicknesses locally exceeding 10 km. The evolution of these basins has been controlled by NW-trending tectonic features that mark the Altiplano–Western Cordillera and Altiplano–Eastern Cordillera boundaries and the Condoroma structural high. Sedimentary deposits of Paleocene age preserved in the Altiplano are the result of nonmarine sedimentation in a distal foreland basin. During the early Eocene, predominantly dextral strike-slip movements in the Altiplano between the Cusco–Lagunillas and Urcos–Ayaviri fault systems created the transpressional Kayra basin. The Soncco and Anta basins (middle Eocene–early Oligocene) are related to NE shortening (43–30 Ma) and represent proximal, wedge-top and foredeep basin environments preserved on the Altiplano. At ~29–28 Ma, a change to predominantly E–W shortening produced sinistral strike-slip motion along NW-striking faults, resulting in intermontane, transpressional basins. In the Altiplano, the Tinajani and Punacancha (29–5 Ma), and Paruro (12–6 Ma) basins were controlled by the Cusco–Lagunillas and the Urcos–Ayaviri fault systems. The Maure, Tincopalca–Huacochullo and Condoroma basins (22–5 Ma) of the Western Cordillera developed between the Condoroma high and the Cusco–Lagunillas fault system. Oligocene–Miocene sedimentation commonly evolved from proximal (alluvial) facies along the borders to distal (lacustrine) facies. These basins were linked to sinistral strike-slip faults that evolved into reverse-sinistral structures. Plate kinematics may play a role in Andean basin evolution, with deformation influenced by major preexisting faults that dictated paleogeographic trends, but orientations of regional compression that appear to coincide with the plate convergence direction. However, the processes of slab flattening and steepening exerted a primary control on regional crustal shortening and filling of synorogenic basins.

1. Introduction

The Central Andes define the broadest portion of the contractional mountain chain that extends along the entire western edge of South America. Associated with subduction of the Nazca oceanic plate beneath the South American continental plate, the Andean chain displays high topography and is characterized by a calc-alkaline magmatic arc recording active subduction since at least 200 Ma. In Peru, the chain is segmented by the Abancay deflection at 12–13°S (Carlotto, 1998; Marocco, 1978), located at the transition between flat subduction to the N and normal subduction to the S. The Abancay deflection contains E–W structures that connect southward with NW–SE structures of the Bolivian Orocline (Fig. 1).

In the northern Altiplano plateau between the Western and Eastern cordilleras, the most extensively exposed rocks correspond to Cenozoic synorogenic basin fill (Fig. 2; Carlotto, 1998, 2002; Carlotto et al., 2005) that overlies thin Mesozoic strata capping a Mesozoic structural high, the Cusco–Puno high. The Western Cordillera is dominated by Cenozoic volcanic rocks and intercalated basin fill that cover thick Mesozoic siliciclastic and carbonate deposits of the Western Peruvian basin (Marocco, 1978; Vicente, 1990), with important Eocene–Oligocene intrusive rocks such as the Andahuaylas–Yauri batholith (Figs. 1 and 2; Carlotto, 1998). The boundaries of the Altiplano in Peru correlate with the Cusco–Lagunillas and Urcos–Ayaviri fault systems that define the NE and SW edges of the Cusco–Puno structural high, and have been interpreted as relicts of Meso-Neoproterozoic events. Other major boundaries include the Condoroma fault system that defines another Mesozoic structural high between the volcanic arc in the W and the Sibayo–Caylloma or Toroya faults in the E (Fig. 2).

Although the boundaries of the Mesozoic structural highs apparently formed as normal faults, during the Cenozoic they acted as reverse and oblique-slip faults. The precise role of these structures in controlling the formation and evolution of sedimentary basins, the location of volcanic centers, and Andean deformation, is not well established. In addition,

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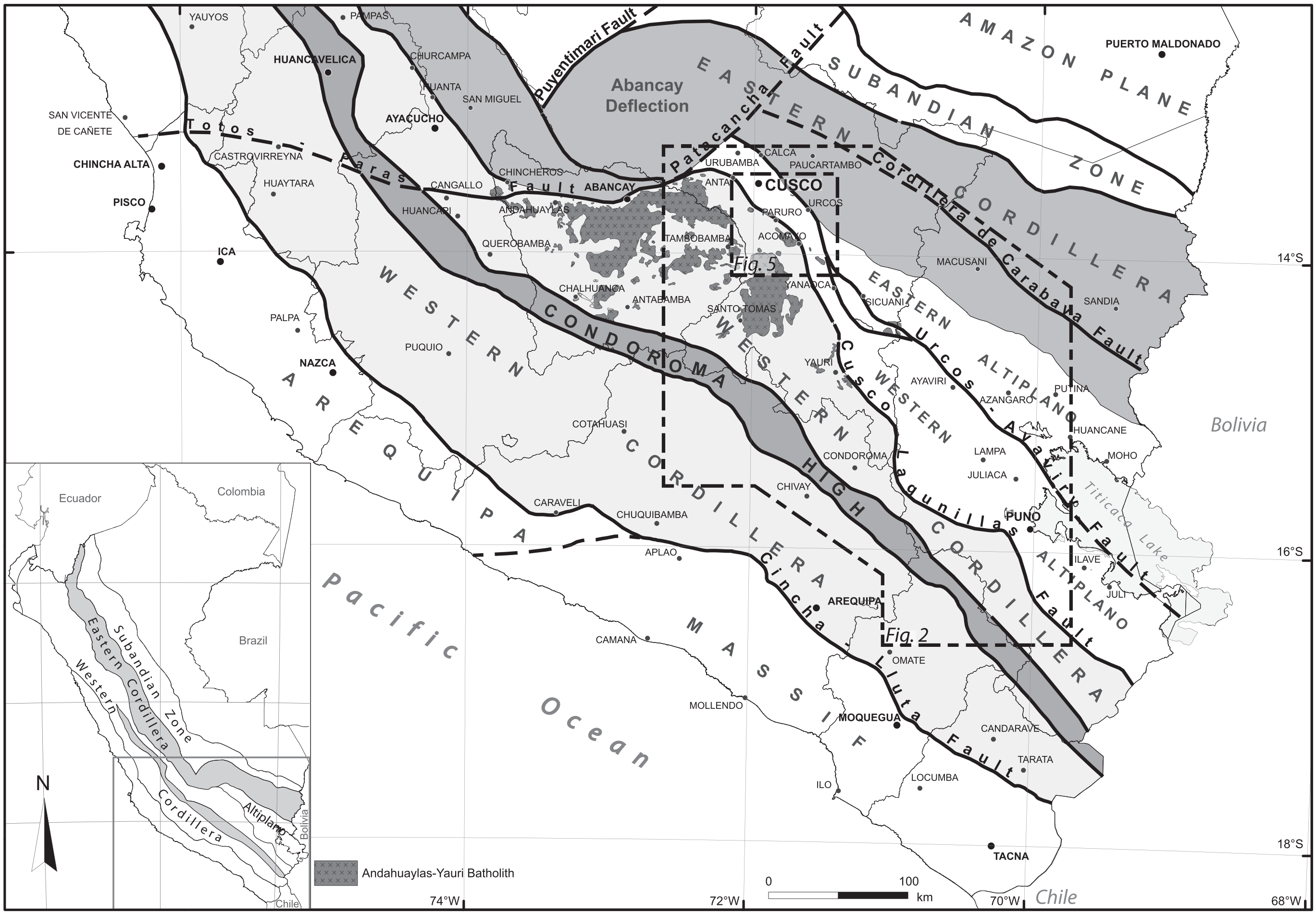

Fig. 1. Morphostructural units and location map of southern Peru. Boxed areas (dashed lines) show the broader study region (Fig. 2) and local Cusco study area (Fig. 5) of synorogenic Cenozoic basins. Outcrop locations of the Andahuaylas–Yauri Batholith are also shown (modified from Carlotto et al., 2009).

pre-existing faults of earlier tectonic stages also exert an important control on the structural style and in localizing Andean deformation (e.g., Ramos, 2010).

Also unclear is whether the segregated basin systems observed today in southern Peru formed in their present configurations or by partitioning of a more extensive precursor basin. Therefore, structural and stratigraphic analysis of these sedimentary basins is critical to understanding the evolution of the Andean mountain chain. This paper summarizes the depositional histories of Cenozoic sedimentary basins in the high Andes of Peru and their resulting tectonic evolution in an effort to explore their association with the long-term deformation history of the Andes.

2. Cenozoic Basins

Cenozoic basins in the Altiplano and Western Cordillera of southern Peru have their own characteristic size, geometry, structural controls, and sedimentary fill. The stratigraphic units and their age relationships are first described, and then the evolution of each basin in its regional tectonic context is presented.

2.1. The Paleocene

Paleocene sedimentary rocks in Peru are poorly understood, particularly in the deeply eroded Western Cordillera. These deposits are best preserved in the Altiplano and along the adjacent NE margin of the Western Cordillera. Widespread “Toquepala” volcanism between 75 and 55 Ma (Beckinsale et al., 1985; Pitcher et al., 1985) is well-documented in the Western Cordillera (Fig. 3).

2.1.1. Paleocene units in the Altiplano

The Paleocene and probably earliest Eocene epochs are represented by the Quilque and Chilca formations (Carlotto, 1998) (Fig. 3). These units overlie Upper Cretaceous rocks and are separated by erosional unconformities observed in the Cusco and Sicuani areas (Carlotto, 1992, 1998, 2002). The Quilque and Chilca formations also crop out locally along the Western Cordillera–Altiplano boundary where they unconformably overlie Albian–Turonian limestone of the Ferrobamba Formation (Carlotto et al., 2005).

Quilque Formation (>150 m) is a dark red succession of interbedded shale, sandstone, and conglomerate that coarsens upward. Sandstone and conglomerate beds are lenticular with erosional bases and trough cross-stratification. Interbedded mudstones in lower levels show intercalated charophyte fossils with abundant secondary carbonates formed in soils (pedogenic carbonate) (Fig. 4). Some mudstones show nodular carbonates with root tubules. Conglomerates include 1–10 mm limestone intraclasts and fossil vertebrate remains (Carlotto, 1992, 1998). Charophyte and nodular carbonates that represent paleosols in lower levels are representatives of lacustrine settings. The charophyte *Lamprothamnium* sp. (Carlotto, 1998, 2002) suggests a marginal marine brackish environment (Jaillard et al., 1994). Sandstones and