XV Congreso Peruano de Geología. Resúmenes Extendidos.
Sociedad Geológica del Perú, Pub. Esp. N° 9 (2010), Cusco p. 797-800

EVIDENCE FOR A LATE MIOCENE-PLIOCENE PULSE OF EXHUMATION FROM LOW-T THERMOCHRONOLOGY IN THE NORTHERN PERUVIAN ANDES

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ABSTRACT

Quantifying exhumation rates in orogenic settings is critical in understanding the contributions of tectonic and climatic processes to orogenic evolution. We present 14 new (U-Th)/He thermochronologic ages from the northern Peruvian Andes, a region that is much less studied when compared to the Altiplano region. By using both apatite and zircon thermochronology, we are able to constrain acceleration of exhumation in the Northern Peruvian Andes in two different field sites. In the most northern field site, located on the Rio Maranon, our results indicate very slow exhumation from the Paleozoic to the Miocene, which increases to a more or less constant rate of ~0.3mm/yr since the mid-Miocene. In the southern field location, which is within the Western Cordillera, our data show an exhumation rate of ~0.05mm/yr across the Miocene and a recent, rapid increase to ~2mm/yr since the Pliocene. While this study generally supports the notion of an acceleration in exhumation from the early history of the orogen to the mid-Miocene through the present, the results from the two sites are somewhat conflicting, implying that perhaps the style and timing of orogenic growth is complex and may vary regionally.

INTRODUCTION

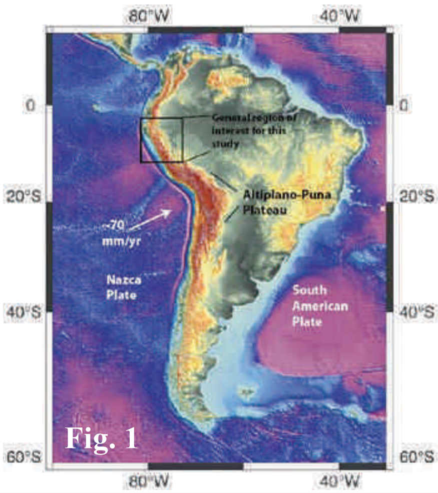


Fig. 1

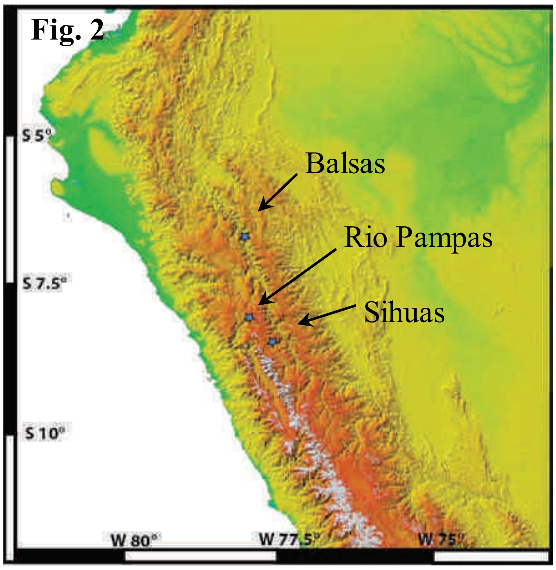
While the South American Andes represent the classic setting of oceanic-continental collision (Fig. 1), even the most fundamental controls of the generation of the high topography are still poorly understood. Tectonic elements have been recognized to differ along strike, specifically: zones of flat-slab subduction, different amounts of magmatism and different orogenic width. Isacks (1988) introduced one of the first tectonic models that accounts for these complexities by suggesting that the region of normal (30° dip) subduction in the central Andes is weakened thermally by the hot underlying asthenosphere, allowing more crustal shortening and thickening, producing the high and broad topography of the Altiplano. While the evolution of the Andes is clearly linked to long-lived (~200 Ma) subduction along the western margin of South America, recent paleoelevation studies suggest that half of the modern elevation has been generated since ~10 Ma (Gregory-Wodzicki, 2000; Garzione *et al.*, 2006; Ghosh *et al.,* 2006), requiring a significant amount (>2000 m) of surface uplift since the mid-to-late Miocene. However, subduction geometry and differential shortening alone cannot account for such recent and rapid uplift. To explain this, other models have employed additional processes, such as lithospheric delamination (Kay and Kay, 1993; Garzione *et al.*, 2006), addition of material through lower crustal ductile flow (Husson and Sempere, 2003), sedimentation (Lamb and Hoke, 1997) and/or magmatism (Zandt *et al.,* 2003). Other studies have called attention to the different climates (*i.e.* amount of precipitation) that exist across and along strike (Bookhagen and Strecker, 2008) and some studies have proposed that the efficiency of erosion on the eastern, wetter flank (Masek *et al.*, 1994; Montgomery *et al.,* 2001) may be largely responsible for the extreme range in orogenic width and in influencing the amount, style and location of deformation. Thus, understanding the relative contribution and interaction between tectonic and climatic processes on mountainous topography is critical to understanding orogenic evolution. In this study, we use bedrock cooling rates from low-temperature thermochronology to interpret the exhumational history of three field sites in the northern Peruvian Andes (Fig. 2).

METHODS

In order to investigate the exhumation signal from both the Western and Eastern Cordilleras of the northern Peruvian Andes, we collected samples of vertical bedrock transects from three sites in Peru for thermochronology analysis. We analyzed both apatite and zircon grains in most samples across two vertical transects; one is located along the Rio Maranon in the Balsas region within the Eastern Cordillera and the second, farther southwest, along the Rio Pampas on the eastern slope of the Western Cordillera (Figure 2). Exhumation in a convergent setting like the Andes is a product of both rock uplift and surface denudation, which are due largely to tectonic and climatic processes, respectively. Low-temperature thermochronometer systems, such as (U-Th)/He in apatite and zircon, are able to constrain exhumational histories of the shallow (<10 km depth) crust (*e.g.* Reiners and Brandon, 2006).

RESULTS

The Balsas transect (Figure 3a) contains five sample sites, four of which yielded both zircon and apatite grains and one yielded only zircon. Apatite (U-Th)/He ages are mid-late Miocene, while zircon (U-Th)/He ages reflect a much older, Mesozoic to Paleozoic, cooling history. The Rio Pampas transect (Figure 3b) consists of four sample sites which yielded zircon grains where only one of those also contained apatite. The zircon ages in the Rio Pampas transect range from ~20 Ma to ~2.7 Ma over an elevation difference of 600m. The 2.7Ma zircon age came from the only sample in this transect that also produced apatite, with a very young age of 2.0 Ma, the youngest cooling age in the study.



DISCUSSION

Results from studies over the past thirty years in the central and northern Peruvian Andes have supported a tectonic history consisting of five or more short, compressive pulses of activity separated by longer periods of quiescence or extensional stress (Megard *et al.*, 1984; Noble *et al.*, 1985, 1990; McKee and Noble, 1982). More recently, Wise *et al.* (2008) bounded the timing of the short-lived (<300,000 yrs), late Miocene, Quechua II phase of compression to 8.7 Ma by dating deformed and undeformed volcanic flows in the Acayucho basin. The time period ~9-10 Ma is coincident with an increase in exhumation rates from the Western Cordillera and perhaps the initiation of the rise of the Altiplano (Barke and Lamb, 2006; Garzione *et al.*, 2006; Schildgen *et al.,* 2007). However, it remains unclear if or how the tectonic "pulses" that have been identified are related to the increases in exhumation and uplift proposed by these workers in the central Andes.

In general, the data presented here support a phase of exhumation in the northern Peruvian Andes that occurred in the mid-Miocene to present. We interpret the Balsas data to indicate this region passed through the shallow apatite closure temperature during the mid-late Miocene and we estimate an exhumation rate of ~0.2-0.3 mm/yr over the past 12 Ma. The zircon grain-ages likely represent either a crystallization age or an older exhumation event and show that this section of crust has not been below 180°C isotherm (~6 km depth) since Mesozoic time. The upper three zircon ages in the Rio Pampas suite, however, are reset, reflecting a Miocene cooling history.

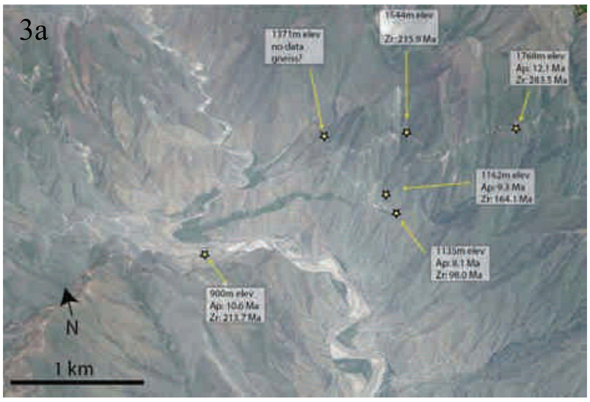


Figura 3a. Balsas section with (U-Th)/He cooling ages and elevation shown.

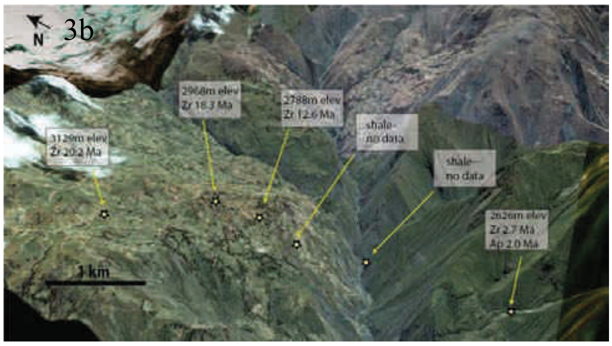


Figura 3b. Rio Pampas section with (U-Th)/He cooling ages and elevations shown.

The lowest sample produced the youngest zircon age, 2.7 Ma, and the youngest apatite age, 2.0 Ma. These ages, in conjunction with the older Miocene ages, indicate that exhumation rates increased dramatically since the late Miocene/Pliocene, from ~0.5mm/yr to ~2-3mm/yr over the past ~3 Ma.

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