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Geochronologic and stratigraphic constraints on canyon incision and Miocene uplift of the Central Andes in Peru

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Abstract

The deepest valleys of the Andes have been cut in southern Peru by the Ríos Cotahuasi Ocoña and Colca–Majes. These canyons are Late Miocene landforms based on a new ignimbrite stratigraphy supported by 42 new $^{40}Ar/^{39}Ar$ age determinations obtained on plateau-forming and valley-filling ignimbrites. Between 19 and 13 Ma, a gently sloping surface bevelling the clastic wedge southeast of the developing mountain front was mantled by widespread ignimbrites. After 13 Ma, this paleosurface was tilted up from 2.2 km a.s.l. at the mountain front to 4.3 km a.s.l. at the base of the Pliocene and Pleistocene volcanoes that crown the southwestern edge of the Altiplano. The canyons incised this topography after 9 Ma, while the dated base of younger ignimbrite valley fills suggests that these canyons had been cut down to near their present depths as early as 3.8 Ma. By 1.4 Ma, however, the canyons had been almost completely refilled by 1.3 km-thick unwelded pyroclastic deposits, which were subsequently eroded. Valley incision since 9 Ma at an average rate of 0.2 mm yr^{-1} is the response to topographic uplift after 13 Ma combined with increasing runoff due to a wetter climate recorded after 7 Ma. Although long-term aridity generated an imbalance between high long-term uplift rates and low plateau denudation rates, the combination of aridity and volcanism still promoted canyon incision because episodic volcanic fills maintained a cycle of catastrophic debris avalanches and subsequent dam breakouts.

Keywords: Andes; Peru; valley incision; tectonic uplift; ignimbrites; argon dating

1. Introduction

Tectonic uplift simultaneously generates topographic gradients that result in increased erosion (Montgomery and Brandon, 2003) and orographic barriers that collect precipitation. Removal of mass by erosion is thus focussed along narrow belts of relief and can itself induce further rock uplift, thus creating a positive feedback to evolving orogenic fronts (e.g. Willett, 1999; Thiede et al., 2004; Whipple and Meade, 2006). The western margin of the Central Andes represents an extreme case in this scenario since several kilometers of uplift has occurred in a hyperarid region, where long-term denudation rates remain particularly low but the history of valley incision documents a long record of topographic uplift and climatic changes.

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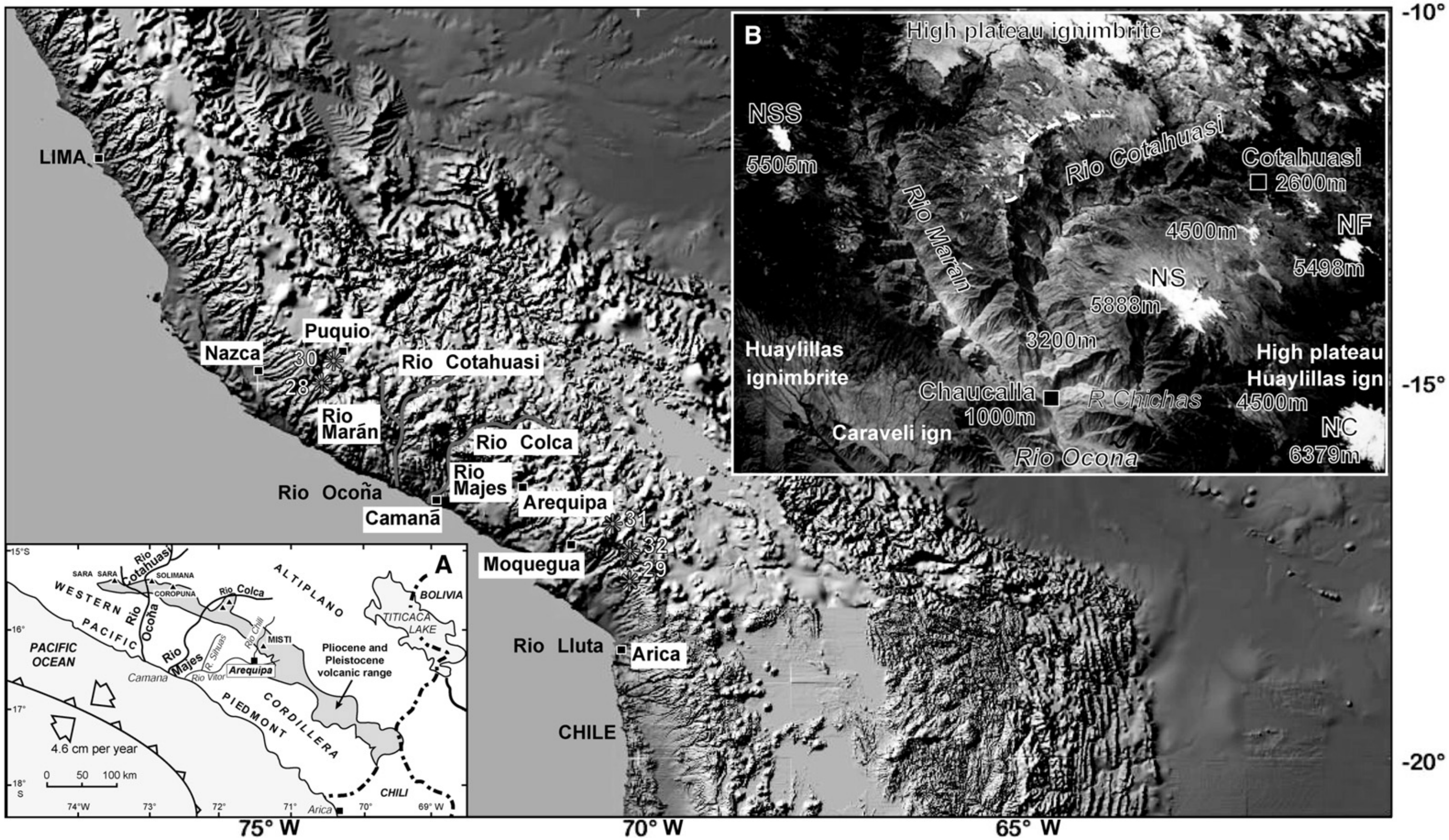

Fig. 1. Topographic Digital Elevation Model (USGS GTOPO 30 DEM) of the Central Andes (http://www.geo.cornell.edu/geology/cap/CAP_WWW.html) showing the location of the main valleys and canyons in southern Peru and northern Chile (in addition to 37 sites in Fig. 2, five sites with $^{40}Ar/^{39}Ar$ age determinations show numbers keyed to Table 1). A: map of southern Peru showing the principal structural units and the Pliocene and Pleistocene volcanic arc; B: Shuttle image of the Cotahuasi, Ocoña, and Marán confluence (www.lpi.usra.edu/publications/slidesets/geology/sgeo/slide_22html; STS-41D. August-September 1984, Picture No.14-34-005). Plateau-forming Huaylillas and Alpabamba ignimbrites at 4000–4500 m a.s.l. mantle the Miocene paleosurface and support the Pliocene and Pleistocene volcanoes (NS: Nevado Solimana 5888 m a.s.l.; NC: Nevado Coropuna 6379 m a.s.l.; SS: Nevado Sara Sara 5505 m a.s.l.; NF: Nevado Firura 5498 m a.s.l.). Note the Chaucalla–Las Lomas ridge formed by 1.6 km–thick ignimbrite cooling units; the whitish ignimbrite blanketing the high plateau 20 km north of the town of Cotahuasi; and a prominent arcuate scar above the northwest Cotahuasi canyon edge pointing to potential sources for the most recent pyroclastic valley fill found in the deepest canyon section.