# Cuncaicha Rockshelter, a Key Site for Understanding Colonization of the High Andes

## Reply to Capriles et al.

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We thank Capriles, Santoro, and Dillehay (2016, in this issue) for commenting on our 2014 *Science* publication (Rademaker et al. 2014), where we presented preliminary data from linked terminal Pleistocene (TP) archaeological sites in southern highland Peru. We agree that Cuncaicha represents a key site for understanding human colonization of the Andes, the evolution of adaptations in extreme, high-elevation mountain environments, and the formation of Andean cultural patterns. In this response, we will clarify misunderstandings and discuss briefly some broader issues of method and theory.

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Capriles, Santoro, and Dillehay question whether accelerator mass spectrometry (AMS) ages from Cuncaicha rock shelter reliably register an early human presence. The Cuncaicha chronology is based on 35 AMS ages on terrestrial animal bone collagen obtained at multiple laboratories (Rademaker et al. 2014:468). Twenty-one ages constrain the TP site component (table S2 in Rademaker et al. 2014), making Cuncaicha one of the most thoroughly dated TP sites in South America (Aceituno et al. 2013; Bueno, Dias, and Steele 2013; Capriles and Albarracin-Jordan 2013; Constantine 2013; Delgado, Aceituno, and Barrientos 2015; Dickau et al. 2015; Lopez Mazz 2013; Martínez, Flensborg, and Bayala 2013; Méndez 2013; Prates, Politis, and Steele 2013; Rademaker, Bromley, and Sandweiss 2013).

We reported no hearths. Sediment micromorphology identified probable anthropogenic ashes in TP sediments. Carbonized plant remains are also present (Rademaker et al. 2014:468, Materials and Methods 4, 5, figs. S5*b*, S6). We chose not to date these fragments because of the potential for translocation via bioturbation (Rademaker et al. 2014:467, 468) and old-wood effects.[1] Our identification of parenchymous storage tissue is tentative. Additional analysis is in progress and must be completed before destructive direct dating of these small remains.

We dated faunal remains because these were abundant, well-preserved, introduced into Cuncaicha via clear human agency, and in direct association with unequivocal artifacts (Rademaker et al. 2014:467). The inherent molecular information content of bone is much higher than that of charred plant remains.[2] Modern collagen ultrapurification methods consistently lead to accurate AMS ages (Jull, Burr, and Hodgins 2012) and are especially reliable when multiple statistically consistent ages constrain events of interest. Moreover, AMS ages obtained on terrestrial animal bone are not susceptible to marine reservoir and old-wood effects and therefore are preferable to marine materials and to wood and charcoal in arid environments.[3]

1. If the spherulitic calcite particles are remnants of burned *Azorella compacta* (fig. S5), then a significant old-wood effect is possible. Modern growth rate estimates suggest mature examples of this species range in age between hundreds and thousands of years (Kleier et al. 2015; Ralph 1978).

2. The objective chemical criteria for measuring bone preservation, collagen yield, carbon yield on combustion, C/N ratio, and stable isotope values (van Klinken 1999) bore out field observations. The five oldest dated bones had collagen preservation levels of 20%, 31%, 47%, 66%, and 32% of modern bone (AA101130, AA101138, AA96307, AA94254, and AA96308, respectively). This is extraordinarily good preservation for bones of this age. Better preserved samples produce more reliable dates.

3. Unfortunately, many early South American site chronologies rest solely on radiocarbon ages obtained on marine materials or on wood or charcoal. Such ages incorporate unknown reservoir and old-wood effects and are problematic for inferring the spatial and temporal patterning of human colonization, especially in arid zones.

Tables S6 and S5 in our article reported preliminary information on faunal identifications and taphonomy. Intense fragmentation is prevalent at Cuncaicha, resulting from complete processing of animal carcasses (Rademaker et al. 2014: 468). Zooarchaeological analysis identified only three large mammal species (vicuña, guanaco, and taruka). All AMS-dated faunal specimens are nondiagnostic camelids or cervids.

There are three possibilities for the deposition of large herbivore bones: (1) three herbivore species died in the rock shelter, (2) carnivores transported herbivore carcasses, or (3) humans transported carcasses. Scenario (1) is unlikely, because no skeletal elements are articulated in anatomical position, and nearly every element has been broken. Many exhibit classic percussion scars of fresh bone fracture and clear cut marks for both disarticulation and marrow extraction. Scenario (2) is also unlikely, because no carnivore skeletons or dung have been found in the site, and no signs of carnivore damage were present on any TP faunal remains (Rademaker et al. 2014, table S5), including dated specimens. The even representation of forelimb and hindlimb elements and the high frequency of low-utility parts, such as phalanges (Rademaker et al. 2014:468), argue against carnivore transport. Finally, all faunal remains are in direct association with abundant chipped-stone artifacts (Rademaker et al. 2014, table S3).

Consistent with entire animal carcasses, a complete lithic operational chain is indeed present within the rock shelter. Alca obsidian constituted the dominant raw material for Cuncaicha's lithic industry, unsurprising given the site's location within one of South America's largest obsidian sources (Rademaker et al. 2013). Alca obsidian likely was procured from an outcrop ~40 m below the shelter, where there is a multicomponent workshop (Rademaker et al. 2014, fig. S1). The rock shelter contains abundant complete and broken bifacial tools in preform and finished stages and middle- and late-stage debitage. Cores and scrapers made from minimally retouched obsidian pebbles likewise were discarded within the shelter (Rademaker et al. 2014, table S3). All stages of obsidian procurement, reduction, and tool production took place at Cuncaicha.

Hunter-gatherers exhibit diverse mobility and settlement patterns, influenced by the resource structure of their environments (Bamforth 1986; Kelly 1995; Surovell 2000). Sites need not be interpreted as either permanent, year-round occupations or ephemeral stopovers. In the diverse Central Andes, the pattern of complementary resources in vertically stacked ecological zones may have encouraged seasonal residential mobility (Lynch 1971).

We did not claim that people permanently occupied the high-elevation Pucuncho Basin in the TP or early Holocene (EH). Although plant and animal resources are available year round, we suggested several reasons why early highland occupations may have been seasonal (Rademaker et al. 2014:468, 469). Wet-season hazards in the highlands and the need to maintain social contact with nonplateau groups might have prompted descents to lower elevations. Some lithic and paleobotanical remains at Cuncaicha have their sources in lower-elevation zones. Conversely, the presence of Alca obsidian artifacts at contemporary TP and EH coastal site Quebrada Jaguay-280 indicates either that a single group was moving between the Pacific coast and the Pucuncho Basin or that separate coast and highland groups were part of an exchange system (Sandweiss et al. 1998; Sandweiss and Rademaker 2013).

Capriles, Santoro, and Dillehay interpret Cuncaicha as resulting from "tactical foraging" or "intermittent exploration" of the plateau rather than as a residential base (Rademaker et al. 2014:468). This is an important distinction, because the interpretation of Cuncaicha's function within its settlement system bears directly on whether we understand colonization of the high Andes as a gradual process of tentative exploration from lower-elevation bases (Aldenderfer 2006, 2008)[4] or as one that occurred near synchronously with initial settlement of adjacent lowland zones (Rademaker et al. 2014: 469). Beyond highlighting that our empirical data do not correspond with Aldenderfer's model, Capriles, Santoro, and Dillehay provide no justification for their interpretation of Cuncaicha as a logistical site.

We discussed explicitly why Cuncaicha is characteristic of a residential base and why it would be an impractical logistical site (Rademaker et al. 2014:468): large quantity of materials and tools; diverse tool types; complete, intensely butchered animals; complete lithic operational chain; overwhelming reliance on local resources; and optimal location in the well-watered heart of the arid high-elevation plateau, ~40 to 50 km from elevations ≤2,500 m above sea level.

Excavation of ~2.5 $m^2$ of 40-cm-deep TP deposits provided our reported sample of TP artifacts (Rademaker et al. 2014, table S3). This single cubic meter of sediment contained >13 kg of faunal remains, 1 kg of debitage ($n = 1,570$), and 74 formal tools. Although space limits preclude comparisons here, it is clear that the density of Paleoindian faunal remains and artifacts at Cuncaicha exceeds that at most TP sites in South America. If higher material densities truly are correlated with residential bases, then either Cuncaicha was a residential base or few (if any) South American TP sites can be interpreted correctly as residential bases.

Cuncaicha merits new approaches beyond general evolutionary models that assume Andean colonization was a slow, homogeneous march toward ever-higher elevations. The most parsimonious explanation of the empirical data is that, by 12,000 years ago, hunter-gatherers had already incorporated high-elevation Andean oases, such as the Pucuncho Basin,

4. If a model of gradual exploration leading to permanent, year-round settlement of Andean lands >4,000 m elevation is correct, on the basis of current data, this process would have spanned many thousands of years. The oldest replicated ($n = 2$) AMS ages from Cuncaicha average 12.4–11.8 ka (thousands of calibrated years before present, 95% probability age range). The earliest high (>4,000 m) Andean occupation argued to have been prolonged and nonseasonal postdates ~6.0 ka at Panaulauca Cave (Moore 1998; Rick and Moore 1999).

into their settlement systems. In the absence of late-glacial environmental barriers (Bromley et al. 2009, 2011*a*, 2011*b*; Rademaker et al. 2014:469, Materials and Methods 5–7), successful and redundant (Binford 1980) use of these rich habitats would be predicated only on the acquisition of landscape knowledge needed for navigating and finding critical resources. Redundant residential use of Cuncaicha rockshelter (Rademaker et al. 2014, fig. 3) defines successful Paleoindian colonization of the high Andes. If readers remain unconvinced, we invite you to stay tuned. Our ongoing interdisciplinary research will soon bring new information on chronology, seasonality, and assemblage comparisons to shed further light on Andean colonization.

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