



High-altitude adaptation and late Pleistocene foraging in the Bolivian Andes



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ABSTRACT

The high Andes of South America were among the last environments that *Homo sapiens* colonized during its Pleistocene dispersion out of Africa. The peopling of this high-elevation environment was constrained by atmospheric hypoxia, cold stress, and resource availability. Here we report archaeological and geoarchaeological analyses from Cueva Bautista, a dry rock shelter, located at 3933 m above sea level in southwestern Bolivia. We focus on a well-preserved occupation surface containing hearths and high-quality stone tools AMS dated to 12,700–12,100 cal BP. Geoarchaeological resolution of the site supports its stratigraphic integrity and archaeological analyses indicate that the early human occupation was formed as a temporary camp by mobile foragers relying on a curated technological strategy. Regional paleoenvironmental reconstructions suggest that Cueva Bautista's occupation was synchronous with humid conditions and its abandonment with increased aridity. Our findings suggest that mobile hunter-gatherers explored – albeit not colonized – the high Andes during the late Pleistocene and provides further support that a combination of biological, behavioral, and environmental constraints affected human adaptation to this extreme environment.

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1. Introduction

South America was the last continent that *Homo sapiens* peopled during its dispersion out of Africa (Borrero, 2015; Dillehay, 2009; Goebel et al., 2008; Meltzer, 2009). Late Pleistocene archaeological sites across the continent show that people exploiting a broad range of resources, and using a wide variety of subsistence technologies, colonized disparate environments simultaneously (Barberena, 2015; Borrero and Franco, 1997; Dillehay, 1999; Jackson et al., 2007; Sandweiss et al., 1998; Steele and Politis, 2009; Suárez, 2015). Yet the high Andes, situated >2500 m above sea level (asl), likely constituted

a migration barrier as human populations had to contend with physiological and ecological challenges such as high-altitude hypoxia, cold stress, and potentially low resource availability (Aldenderfer, 2003, 2008; Beall, 2007). In fact, the oldest archaeological sites in the high Andes are few and rarely date beyond 11,000 cal. BP, which is considerably later than the earliest occupations documented in the Pacific Coast (Gayo et al., 2015; Jolie et al., 2011; Méndez, 2013; Núñez et al., 2002; Osorio et al., 2011; Rademaker et al., 2013; Yacobaccio and Morales, 2011).

Understanding when and how the Andes were peopled bears important anthropological issues, such as the domestication of economically significant cultigens and animals, including potatoes, quinoa, llamas, and alpacas (Piperno, 2011; Stahl, 2008), as well as primary state formation (Stanish, 2001). In this sense, relevant questions for explaining the evolution of these later trajectories of cultural change include how significant and effective was the initial exploration and colonization of

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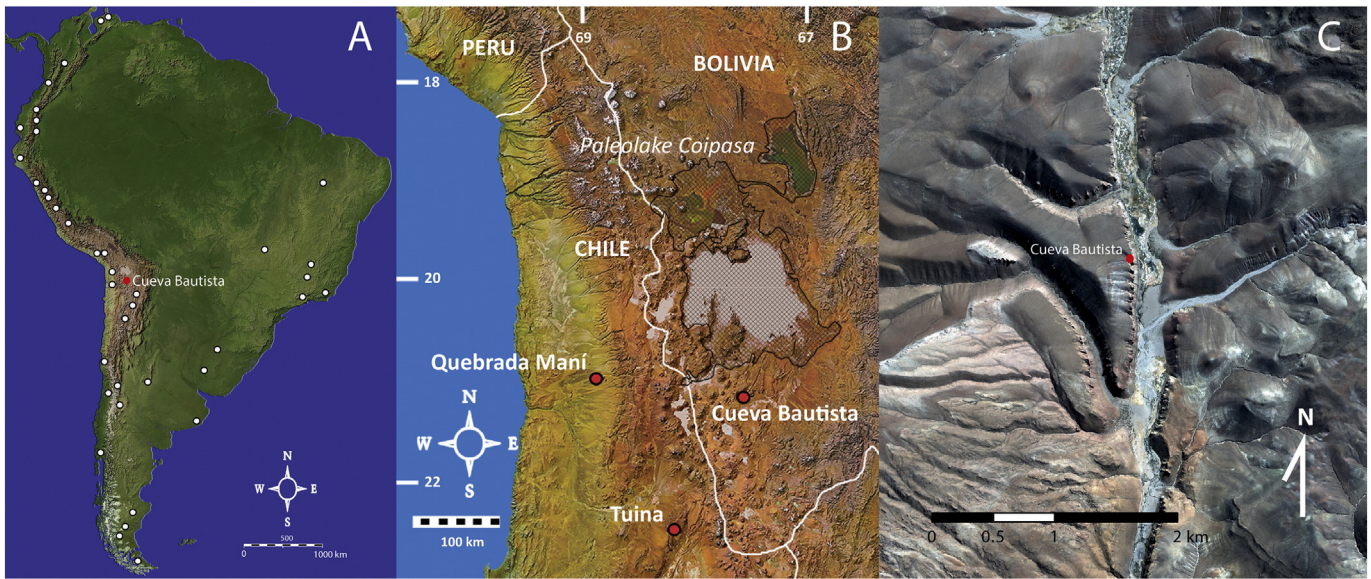


Fig. 1. A. Location of Cueva Bautista in relation to other late Pleistocene archaeological sites (Dillehay, 1999). B. The highlands of south western Bolivia and their vicinity including the location of Cueva Bautista, other contemporary sites, and Paleolake Coipasa (*sensu* Placzek et al., 2013). C. Aerial image of the Sora River valley (image courtesy of the DigitalGlobe Foundation).

the highlands, and how intrinsic (e.g., foraging strategies, technological organization, and population pressure) and extrinsic (e.g., climate, altitude, predation) factors constrained the strength and speed of these processes? (Anderson and Gillam, 2000; Barberena, 2015; Dillehay, 2000; Prates et al., 2013).

Based on evolutionary ecology principles, Aldenderfer (1998, 1999, 2006) has argued that human colonization of the Andean highlands required specific behavioral, technological, and biological adaptations to cope with high-altitude hypoxia. This model advanced the idea that a delayed colonization of the high Andes was a consequence of both biological and behavioral constraints. Support for

this contention came from archaeological sites in the Peruvian coast, such as Ring Site, Quebrada Jaguay, and Quebrada Tacahuay, which provided evidence of initial human occupation at least a thousand years before any of the earliest highland sites. Similar models have been applied to explain human colonization of the Tibetan Plateau (Aldenderfer, 2011; Brantingham et al., 2007, 2013; Madsen et al., 2006). Thus, movements into the highlands would have been progressive (as suitable lowland settings became saturated), logistical (as highland resource availability is generally seasonally constrained), and temporary (as human populations needed to cope with high-altitude physiological constraints). Nevertheless,



Fig. 2. View of Cueva Bautista from the east.

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