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The Casa del Diablo cave (Puno, Peru) and the late Pleistocene demise of megafauna in the Andean Altiplano

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ABSTRACT

During the Late Quaternary Extinction event South America lost ~83% of all its late Pleistocene megafaunal genera. As in other regions of the world, the debate about the possible drivers behind these extinctions revolves around the role of humans arriving into the continent and on the effect of the climatic changes characteristic of the Pleistocene-Holocene transition. The availability of precise chronological information, in order to estimate the timing of extinction of the different taxa affected, is critical for solving such debate. Here we present an updated study of the late Pleistocene mammalian deposits from Casa del Diablo Cave (CdD) in the Altiplano of Peru. The study includes an updated list of the mammalian faunas found in the cave and 11 taxon-specific XAD radiocarbon dates from extinct and extant megafauna bones. We compare this new chronology to the timing of major environmental changes and human arrival in the area, as well as with other megafaunal discoveries from the high Andes. The radiocarbon dates from CdD fall in the time window between 23 and 12.8 cal kyr BP. Compared to other records of extinct megafauna in the high Andes, the one from CdD presents in general younger occurrences. No temporal overlap between humans and extinct megafauna emerges from comparing first dates of appearance of humans in the Altiplano, and last appearance dates of extinct megafauna from CdD. However, the possibility of temporal overlap among the records becomes evident when we compare confidence intervals calculated to estimate true times of human arrival and megafaunal local extinctions.

1. Introduction

At the end of the Pleistocene South America was inhabited by a great diversity of endemic and North American immigrant large-sized mammals (>44 kg), many of which became extinct around the transition to the Holocene Epoch in what is known as the Late Quaternary Extinction event (LQE; Martin and Wright, 1967, Martin, 1990; Martin and Klein, 1984; Martin and Steadman, 1999; Barnosky et al., 2004; Koch and Barnosky, 2006). This worldwide event was marked by the global disappearance of 90 genera of megafauna (Koch and Barnosky, 2006). Of all major regions of the world, South America was the most affected by megafauna extinctions during the LQE, losing ~83% of all genera of megafauna known to have inhabited the continent during the late Pleistocene (Brook and Barnosky, 2012).

Globally, the debate about the causes behind these extinctions revolves around the impact of modern humans migrating out of Africa into other continents, the role of environmental changes proper to the last glacial-interglacial transition, and combinations of these (Martin and Steadman, 1999; Cione et al., 2003). The general picture at the continental level in South America suggests that the timing of megafaunal extinctions approximately coincides with the major climatic changes of the Pleistocene-Holocene transition between ~14 and 9 cal kyr BP, and also with the first evidence of human presence dated at a continental level between 18 and 11.5 cal kyr BP (Barnosky et al., 2004; Koch and Barnosky, 2006). Nevertheless, more specific analyses at regional scales suggest slightly different patterns of extinction in different eco-regions of the continent, with last appearances of megafauna occurring earlier (between 45 and 15 cal kyr BP) than human arrival (~11.5 cal kyr BP) in the northern regions of South America (Barnosky and Lindsey, 2010) and later at higher latitudes, where

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the last dates on extinct megafauan fall between 12.5 and 10 cal kyr BP, after humans had arrived there (13.3–12.9 cal kyr BP) and when climatic changes were more severe (14.5–11 cal kyr BP) (Villavicencio et al., 2016; Barnosky and Lindsey, 2010).

While the fossil record of late Pleistocene megafauna in South America is abundant, especially for the subtropics (Fariña et al., 2013), the lack of chronological information on the fossil deposits is what limits accurate analyses of the extinction process. Several studies have highlighted the usefulness of taxon-specific radiocarbon dates in documenting the last appearances of some taxa of megafauna and their relation to changes in the environment and to the timing of human arrival in the different regions of the continent (e.g., Prado et al., 2015; Villavicencio et al., 2016; Barnosky et al., 2016). These synthetic works have also emphasized how some areas of the continent are severely lacking in available chronological information when compared to the areas with the most complete records. This is the case of the South American Altiplano. Referring strictly to the area defined as Altiplano (see section 5), only a few sites containing extinct megafauna remains can be assigned to the late Pleistocene (Fig. 1); from these no publication reports taxon-specific radiocarbon dates for extinct megafauna.

The paleontological locality of Casa del Diablo (CdD) Cave, located in the southern Peruvian Altiplano (Fig. 1), was first described by the Swedish ethnographer Erland Nordenskiöld (1877–1932) who visited the area between 1904 and 1905 during one of several expeditions to South America. During his visit to the cave, Nordenskiöld collected numerous specimens of extant and extinct mammals and birds. These are currently stored at the Department of Paleobiology, Swedish Museum of Natural History (Naturhistoriska riksmuseet) in Stockholm, Sweden under specimen prefixes PAL-PZ M. One of the most remarkable features of these collections is the outstanding preservation of the bones, as documented a few years later (Nordenskiöld, 1908). This publication, together with a few revisions of particular faunal elements from the cave (Sefve, 1910; Marshall et al., 1984; Pujos et al., 2007; Pujos and Salas, 2004), represent the only scientific publications on the fossils found at this site until now.

Here we present an updated list of the mammalian fauna from Casa del Diablo, together with 12 radiocarbon dates from bones of extinct and extant mammals from this collection. All of the dates were obtained from single amino acid samples extracted from bone collagen and represent the first published geochronological information on this site and the first taxon-specific radiocarbon dates on extinct megafauna from the Altiplano. Finally, we discuss this new chronological information in the context of environmental changes that took place in the Altiplano at the Pleistocene-Holocene transition, a time when the megafauna from Casa del Diablo was disappearing from the area given the chronological information presented here.

2. Casa del Diablo

Casa del Diablo cave lies at an altitude of >3800 masl (meters above sea level) and is located north-west of Lake Titicaca, near the town of Tirapata in the Puno Department of Peru (Nordenskiöld, 1908, Fig. 1). Carved in limestone, the cave is 31 m long, 22 m wide, with a greatest height of 7–8 m, and includes two main entrances of which the largest is 8 m wide. The bulk of the bones collected were found in the left side of the cave and also among the two major fallen blocks (Nordenskiöld, 1908, Fig. 2A).

2.1. About the bone deposits in the cave

The majority of the bones excavated from the site belong to mammals, among which there is both extinct and extant megafauna, as well as medium-sized carnivores and small rodents (See section 3). The non-mammalian fauna is limited to a diversity of bird bones. The collection from Casa del Diablo in the Swedish Museum of Natural History comprises 1134 numbered specimens, but boxes with dozens of rodent postcranial elements are collected under single numbers, so that the actual number of specimens is much greater.

As it is common in cave deposits, the bone accumulations of Casa del Diablo showed signs of mixing among the different layers excavated, a situation that was originally noted by Nordenskiöld in his 1908 publication, in which he describes the occurrence of modern sheep bones mixed with *Onohippidium* (now *Hippidion cf. devillei*) in deeper layers of the excavation and also mentions the presence of an isolated *Scelidotherium* (now *Catonyx*) tail bone on the floor of the cave. The majority of the remains of this taxon were, however, located 1 m below the surface of the cave.

Nordenskiöld proposed that small mammals and bird bones were accumulated in the cave by raptors, a process that was still underway when he visited the cave. The skeletal remains of large mammals could, on the other hand, have been dragged into the cave by large predators, a hypothesis that is supported by the type of skeletal remains found (mostly limbs), the stage of development of many of the bones (young individuals are common in the collection), and the types of marks found on many of the elements, which can be attributed to the action of carnivores rather than to other sources. More recent studies identified in the cave the presence of a peculiar climbing megalonychidae sloth, *Diabolotherium nordenskioldi* (Pujos et al., 2007). Given the morphological characteristics of this taxa, is very possible it had used the cave as midden.

The preservation of the bone remains is remarkable (Fig. 2B–I). The fresh looking appearance of the elements also caught Nordesnkiöld's attention during the excavations the cave, at which time he performed a test by dissolving an element of *Onohippidium* (*Hippidion* cf. *devillei*) in hydrochloric acid to see the state of mineralization of the bone (Nordenskiöld, 1908). The good quality of the bones is also reflected in the C/N ratio obtained as part of our analyses (Table 1, section 4).

2.2. Evidence of humans in the cave?

Nordenskiöld identified a layer bearing cultural evidence represented by an obsidian arrowhead and a few potsherds. He considered this evidence insubstantial and not associated with the extinct fauna, as it lay above the layers containing *Onohippidium* (*Hippidion* cf. *devillei*) and *Catonyx*. At the same time, he mentions the absence of anthropic marks on the bones (Nordenskiöld, 1908).

3. Updated mammalian faunal list for Casa del Diablo. *Indetermined, but assignable only two one of the two taxa mentioned

- Xenarthra
  - Megatherioidea
    - *Diabolotherium nordenskioldi*
  - Megatheriidae
    - *Megatherium* sp.
  - Mylodontidae
    - *Catonyx* sp.
  - Megatheriidae
    - sp. indet.
- Artiodactyla
  - Cervidae
    - Agalmaceros wingei
  - Camelidae
    - *Lama guanicoe*