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Palynological analysis of extinct herbivore dung from Patagonia, Argentina

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ABSTRACT

Dung pollen studies can contribute information to the paleodiet and paleoenvironmental knowledge during the Pleistocene–Holocene transition. In this study, pollen analysis of extinct megaherbivore dung dated at 10,530 ± 620 BP was performed. Random samples from extinct herbivore dung, level 18, were collected from the archaeological excavation Cerro Casa de Piedra 7 (CCP7) (Argentine Patagonia). These samples were ascribed to ground sloths, Family Mylodontidae. Pollen extraction was carried out by acetolysis. The results were compared with microhistological analyses of feces and with sedimentary pollen analysis of the site. The diet items mainly consisted of Poaceae together with Apiaceae, Caryophyllaceae, Apiaceae *Azorella* type, Asteraceae subf. Asteroideae, *Nassauvia*, *Perezia*, *Acaena*, Ericaceae/*Empetrum* and *Ephedra*. A taxonomic coincidence between the palynological and microhistological analyses that permitted the determination of diet items was observed. The Poaceae and Apiaceae dominance allows supposing the grass steppe and the *Nothofagus* undergrowth as food areas for megaherbivores. The greater diversity of pollen grains in feces than in sediments due to the contribution of taxa with zoophilous pollination (regularly scarce or absent in sedimentary studies) demonstrates the value of dung analysis to paleoenvironmental reconstructions.

1. Introduction

The end of Pleistocene – start of Holocene extinct South American fauna consisted of great mammals including ground sloths (*Mylodon darwinii*), mastodons (*Haplomastodon*), horses (*Hippidion saldiasi*), camelids (*Paleolama*, *Lama gracilis, Macrauchenia patachonica*), felids (*Panthera onca mesembrina*, *Smilodon*) and canids (*Dusicyon avus*). They coexisted with some currently living species: *Lama guanicoe* (guanaco), *Felis concolor* (puma), foxes (*Pseudalopex culpaeus*, *P. griseus*) and *Hippocamelus bisulcus* (huemul) (Miotti and Salemme, 1999; Borrero, 2001). The causes of extinction of the Pleistocene fauna have been much discussed (Markgraf, 1985; Ferigolo, 1996–1997; Borrero, 2008). Among them are the introduction of pathogens, the aborigine hunting pressure, and post glacial climate changes, including the cold and dry climate pulse coincident with the "Antarctic Cold Reversal" (12.2–15.3 ka) (Cione et al., 2003; Sugden et al., 2005). Markgraf (1985) also mentions paleoenvironmental changes south of Patagonia at the end of Pleistocene. These changes would have affected the resource availability for animals.

Paleodiet studies can contribute information to the ecological interactions in the Pleistocene–Holocene transition. A way of knowing the food resources of past faunas is through the study of fossil traces such as feces. Feces can be found dehydrated or mineralized as coprolites, which possess remains of non-digested diet items or inclusions. Among them are pollen grains, plant remains, phytolites, hairs, parasites and fossil DNA traces. The analysis of coprolites allows for the study of paleodiets, paleoenvironment, parasitism, and site use seasonality (Reinhard and Bryant, 1992; Carrión et al., 2001, 2004, 2005; Horrocks et al.,

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2003, 2008; Chaves and Reinhard, 2006; Riley, 2012; Wood et al., 2012; among others). Studies on pollen grains and plant remains of both camelids and presumed human coprolites found in Parque Nacional Perito Moreno (Argentine Patagonia) have offered information on their main diet items during the Holocene, and also on the site use seasonality and the environmental characteristics (Velázquez et al., 2010; Martínez Tosto and Yagueddú, 2012; Martínez Tosto et al., 2012; Velázquez and Burry, 2012; Velázquez et al., 2014).

One of the problems in palynological studies of coprolites is to elucidate the source of pollen. Among the possible mechanisms of incorporation of pollen to feces are ingestion of flowers, fruits and leaves with pollen adhered to them; water-ingest; inhaling; and pollen rain after deposition of feces (D'Antoni and Togo, 1974; Carrión et al., 2004).

Coprolites from herbivores represent a sample of ancient resources and landscapes. Among extinct megaherbivores, *Mylodon* guano has been reported in layers of different sites of Patagonia (Moore, 1978; Markgraf, 1985). *Mylodon darwinii*, a strong megaherbivore, had a thick skin covered with long hairs and dermal ossicles forming a shell. It had a relatively slow walk, and had a small number of predators (Brandoni et al., 2010).

Few pollen studies have been done on feces of the Patagonian *Mylodon darwinii*. Moore (1978) studied pollen and plant macroremains from a *Mylodon* guano deposit (ca. 12,400 BP) in the cave Última Esperanza (Última Esperanza, Chile), now a steppe environment. The results reveal that the diet consisted of grasses (Poaceae) and cyperaceans (Cyperaceae). In the same site, Markgraf (1985) analyzed cuticle remains and pollen grains from several layers of *Mylodon* feces (between 13,470 ± 180 and 10,832 ± 400 BP), having found 80–95% grasses and 5–20% cyperaceans, and some herbs in the most ancient layer; on the other hand, in the most modern layer (10,832 ± 400 BP) the pollen spectrum showed dominance of Asteraceae and dicotyledonean herbaceous taxa, and low values of grasses.

As for the paleoenvironmental changes that could have affected the resource availability, Markgraf (1985) reported between 11,000 and 10,000 BP a transition from a mesic and cold environment, with a grass steppe poor in species, to a more arid and warmer environment, with a shrubby steppe rich in species, and taxa typical of more arid conditions, *Berberis*, *Empetrum* and *Perezia*. In this sense, the feeding habits of the megaherbivores seem to correspond to the vegetation type dominating the area.

Elsewhere, pollen analysis have been done from coprolites of extinct herbivores: Shasta ground sloth (*Nothrotheriops shastense*) in the USA (Thompson et al., 1980); mountain goat (*Myotragus balearicus*) in the Balearic Islands, Spain (Alcover et al., 1999; Welker et al., 2014) and camelid (*Paleolama major*) in Bahia, Brazil (Marcolino et al., 2012). Their diet items were determined and the contribution of the studies to paleoenvironmental reconstructions discussed. The aim of this study is to perform a palynological study of extinct herbivore dung dated at 10,530 ± 620 BP and to discuss its contribution to the diet and paleoenvironmental knowledge of Cerro Casa de Piedra 7 (Argentine Patagonia) during the Pleistocene–Holocene transition.

2. Regional setting

Cerro Casa de Piedra 7 (CCP7) (47°57′S 72°05′W, 900 masl) is located in a transitional strip between the Andean forest and the Patagonic steppe, in the valley of Lake Burmeister, Perito Moreno National Park (PMNP), Santa Cruz Province, Argentina. The climate in PMNP is from temperate-cold to cold in summer and glacial during the rest of the year, with predominant western winds. The mean annual temperature is lower than 4 °C, with a marked seasonality (temperatures can reach −30 °C minimum in winter and 15 °C maximum in summer). Precipitation oscillates from near 600 mm in the west to 400 mm in the east (Aschero, 1981–1982; Paruelo et al., 1998).

Nowadays on the hillsides of the Andes, between 850 and 1200 masl, a *Nothofagus pumilio* and *Nothofagus antarctica* forest grows, in addition to small woods of *N. antarctica* and *N. betuloides*, shrub and herbaceous vegetation associated with forest e.g. *Escallonia*, *Berberis*, *Fuchsia magellanica* and species belonging to the genera *Osmorhiza*, *Acaena* and *Perezia*. Toward the east, at approximately 800 masl a *Verbena tridens*, *Berberis*, *Mulinum spinosum* and *Chiliotrichium* shrub-steppe grows, and also a *Nardophyllum obtusifolium* steppe with *Festuca pallescens*, together with *Stipa ibari*, *Poa ligularis*, *Carex*, *Cerastium arvense*, *Adesmia lotoides*, *Nassauvia darwinii*, *Acaena pinnatifida* and *M. spinosum* occur. At 300 masl develops the *F. pallescens* steppe with *P. ligularis*, *Rytidosperma picta*, *Stipa*, Carex, *Colobanthus lycopodioides*, *Armeria maritima*, *A. pinnatifida*, *Polygala darwiniana*, *Nassauvia darwinii*, *Perezia recurvata*, *Mulinum microphyllum*, and *N. obtusifolium*, *Senecio filaginoides* and *Berberis heterophylla* shrubs; in addition, high altitude semi-deserts with dense patches of *E. rubrum*. Further, *Caltha sagittata*, *Plantago barbata*, *Acaena magellanica* and Cyperaceae wetland meadows grow (Movia et al., 1987; Mermoz, 1998; Ferreyra et al., 2008) (Fig. 1). The vegetation in front of Cerro Casa de Piedra is dominated by *Empetrum rubrum* that forms dense myrtle fields ("murtillar") together with *Gaultheria mucronata*, *Nardophyllum obtusifolium*, *Acaena*, *Azorella monantha*, *Senecio filaginoides*, *Mulinum spinosum* and *Adesmia boronoides*. Some sectors contain *Festuca pallescens* grass steppe and *Nothofagus pumilio* seedlings from the forest.

Geomorphological studies in the PMNP area suggest that lakes Belgrano and Burmeister could be relicts of a large paleo-basin, that could have reached 100 m above the present level of lake Belgrano (800 masl). The level would have risen several times, the oldest during the early Holocene (González, 1992). The formation of this paleo-lake together with the vegetation changes would have affected the availability of space and the access to the different resource organisms that inhabited the region (Civalero and Aschero, 2003).

2.1. Site Cerro Casa de Piedra 7

CCP7 is the only cave from Cerro Casa de Piedra hill (Fig. 2) that has yielded evidence of the Pleistocene–Holocene transition. It presents a stratigraphic sequence and a human occupation dated between ca. 10,690 ^{14}C BP (Aschero et al., 2008) and 3480 ± 70 ^{14}C BP (LP 300) (Civalero and Aschero, 2003). Palynological studies of sediments from the stratigraphic sequence have revealed a Poaceae dominance of 60–80% in a *ca.* 10,530 ± 620 BP level, thus determining a grass steppe-type physiognomy (Mancini, 2007).

Six random samples (M15-1, M15-2, M15-E, M15-F, M15-G and M15-H) from an extinct herbivorous dung level were collected from the CCP7 archaeological excavation, Area 1, microsector D11B, level 18 (2) (Table 1). The sediment is sandy-limestone, reddish, of wet appearance and carbonate (De Nigris, 2004) (Fig. 3a). A single date of 10,530 ± 620 BP (UGA 7385) with no human association is reported (Civalero and Aschero, 2003; Aschero et al., 2008). The dating was done over a dung sample from level 18(2) (Fig. 3b). Samples from extinct herbivorous dung were ascribed to ground sloths, Family Mylodontidae, Gill 1872 (Merino *pers. comm.* in Aschero et al., 2008). In this level, archaeofaunistic remains of guanaco (*Lama guanicoe*) (Civalero and De Nigris, 2005) were recovered, but no bone remains attributable to Mylodontidae have been found. Moreover, coprolites of carnivores (foxes and pumas), omnivores (presumably