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Preliminary analysis of dental cementum of *Lama guanicoe* for the estimation of age and season at death: Studies of modern specimens and further archaeological applications

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ABSTRACT

Cementum increment analysis has been applied with success in mammals since several decades for both current wildlife studies and studies of fauna from archaeological sites. This method provides estimations about the age and the season at death of ungulates recovered at archaeological sites and can be used to explore important issues such as hunting or herding strategies, settlement patterns and mobility.
Over the past 30 years cementum studies have expanded the range of mammalian species for which the method can be applied in archaeology. However, very few data are today available about the guanaco (*Lama guanicoe*) which was the dominant large ungulate in South America in prehistoric and historical times. The purpose of our project is to develop and improve the cementum increment analysis for this species using modern reference data sets before its application to archaeological assemblages. The present paper presents the preliminary results obtained from the study of canines and incisors of modern specimens and will discuss the potentiality and limitations of the technique.

1. Introduction

During prehistoric times and until recently, human subsistence systems and settlement patterns in Tierra del Fuego had to cope with extreme climatic conditions and were highly dependent on the seasonal availability of food and other resources. Studies of faunal assemblages from archaeological sites located in the Isla Grande, the main island of the archipelago, allow us to reconstitute the strategies of exploitation of the animal resources, both marine and terrestrial, from the acquisition to the transformation of animal products. A current research carried out by one of us (VP) focuses on the guanaco (*Lama guanicoe*) in order to address issues about its exploitation and the related practices (mobility, hunting strategies, butchering techniques, etc.). For this purpose, one of the major aims of this work is to collect data about sex, age and season at death of the hunted animals.

In zooarchaeology several methodological approaches for assessing seasonality have been developed using animal bones and teeth (Monks, 1981). For mammals, the main methods are based on the sequences of tooth eruption, replacement and wear (Wilson et al., 1982; Ruscillo, 2006), on the incremental growth structures present in hard tissues such as bones or dental cementum (Pike-Tay, 1991; Burke and Castanet, 1995), or from the analysis of the stable oxygen isotopic composition of tooth enamel (Balasse et al., 2003; Blaise and Balasse, 2011). Although not used very commonly in zooarchaeological studies, the cementum increment analysis, or cementochronology, is a reliable technique for determining the age and the season which can be easily combined with more "classical" methods (Gourichon, 2004).

So far, with the exception of some unpublished reports, cementum analysis has never been applied to archaeological teeth of South American camelids (genus *Lama*). The aim of this paper is therefore to present a preliminary research project conducting on cementochronology which was started in September 2013 at the CEPAM (CNRS, Nice, France) using modern samples of *L. guanicoe* and developed at the Centro Austral de Investigaciones Científicas (CADIC, Ushuaia, Argentina).

2. Humans and guanacos in Tierra del Fuego

Covering an area of more than 48,000 km square below the 52° parallel south, the Isla Grande of Tierra del Fuego is characterized by a great variety of environments. Separated from the American continent by the Strait of Magellan on the north and surrounded by the South Atlantic on the east and by a series of channels and fjords on the west and south, this territory is under the influence of the subpolar oceanic climate with short, dry and cool summers and long, wet and cold winters. From North to South, the Fuegian steppe, the ecotone region, the

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Andean region, the bog region and the marine coast are contrasted habitats according to the relief, the vegetation and the climatic conditions (Tuhkanen, 1992). The thermal conditions of the Isla Grande are influenced in winter (June to September) by the Pacific Ocean, showing a marked difference in the gradient between the eastern and western coasts. Minimal temperatures average −1.3 °C (Iturraspe and Urciuolo, 2007). In summer (December to March) the weather influence is more continental, with an average temperature of approximately 9 °C (Tuhkanen, 1992). In the whole area of the main island rainfall decreases from 500 mm in the south-west to 300 mm in the north-eastern part (Iturraspe and Urciuolo, 2007). Precipitation falls as rain or drizzle in summer–fall or as snow during winter–spring, although snowfalls are expected at any time of the year. Times of increased persistence of wind occur between spring and summer with an average annual rate of 3.9 m/s in Ushuaia, and about 8 m/s in the Fuegian Atlantic coast and in Rio Grande. In wintertime the average monthly wind speed is lower in the hinterland than on the coast (Tuhkanen, 1992).

The oldest traces of human occupation, dated to about ten millennia, were discovered in the northern part of the Isla Grande (Massone, 2002). The faunal assemblages found in the prehistoric sites until the historical period reflect obviously this high ecological diversity (Mansur and Piqué, 2009; Zangrando, 2009; Santiago and Vázquez, 2012; Mansur et al., 2013). Several types of animal resources have been exploited by ancient people: mainly continental resources in the steppe and forest areas, in particular the guanacos, but also marine resources along the Beagle Channel. One of the main large game species in Patagonia and Tierra del Fuego, the guanaco was used during prehistoric times for food as well as for clothing and other various craft activities (Gallardo, 1910; Gusinde, 1982; Borrero, 1985, 1990a; Alunni and Zangrando, 2012; Salemme et al., 2014; Vázquez, 2015). This ungulate played also an important role within the symbolic world of the hunter-gatherer communities that inhabited the archipelago (Gusinde, 1982; Chapman, 1986, 2008; Parmigiani et al., 2013).

The spatial distribution of guanacos respond to a seasonal-social system related to the mating behaviour and the competitions for resource access (Franklin, 1983). At least three social groups can be distinguished within the guanaco populations: the family groups which generally consist of an adult male, one or more females, the offspring of the year, with an average of 7–8 individuals; the bachelor groups which comprise exclusively young and old non-territorial males, generally between 5 and 20 individuals; and the solitary males which are physically and sexually mature, looking for territory and females to establish a family (Raedeke, 1978, 1979). In Tierra del Fuego, the animals are generally much concentrated in the steppe-forest areas (ecotone region) and the north-eastern coast during the pre-reproductive periods (summer and fall), while more groups spend the winter period in the forest area and in lowlands of the southern coast (Bonino and Fernandez, 1994; Montes et al., 2000). Indeed, recent researches conducted on the guanaco populations living in the Isla Grande have documented high correlations between elevation and distance to the coast and the seasonal cycle although there is a coexistence of sedentary and moving herds (Schiavini et al., 2009; Flores et al., 2014). According to Chapman (1986), the mobility and territoriality of the inland hunter-gatherers communities could rely on such seasonal moving patterns of guanaco herds.

Regarding the taphonomical aspects, the pH of the soil in this region has a great influence upon the preservation of the bone material (Borrero, 1990b; Frangi et al., 2004; Mansilla, 2012; Parmigiani, 2014). In the Isla Grande, the general state of preservation tends to be good in alkaline soils like shell middens and bad in acid soils like in the forests of the central area. In the northern steppe zones, up to the coast of the Strait of Magellan, soils are less acidic and in some cases slightly alkaline (Tuhkanen, 1992), which favors the conservation of faunal assemblages. In this context, due to their better survivorship, teeth of guanacos are the most useful and more informative type of faunal remains for the study of resource procurement, people's mobility and settlement patterns (Parmigiani, 2014).

Age determination of the guanacos is generally done by estimates from tooth eruption, development and wear and from epiphyseal bone fusion (Raedeke, 1978, 1979; Puig and Monge, 1983; Mengoni Goñalons, 1999; Kaufmann, 2009). For estimating the season at death, in addition to the study of tooth eruption sequences and decidual crown-height, this starting project intends to assess the applicability of the cementum increment analysis for archaeological teeth.

3. Cementum increment analysis

The cementum designed the mineralized tissues deposited continuously throughout life on the entire surface of the root of the mammal tooth (Berkovitz et al., 2009). The main function of the cementum is to anchor the teeth in the dental alveoli of the jaw by attaching to the principal collagen fibers produced by the periodontal ligament (Schmidt and Keil, 1972). Different types of cementum have been defined according to the presence or absence of cells (cementocytes) and to the nature of the organic matrix (Schroeder, 1986, 1993; Berkovitz et al., 2009). The acellular extrinsic fiber cementum (AEFC) generally covers the cervical two-thirds of the dentine root and sometimes part of the enamel crown base (especially in hypsodont teeth). The cellular intrinsic fiber cementum (CIFC) is found in the apical regions of the root and the inter-radicular areas and, contrary to the AEFC, is not directly relied to the periodontal ligament. The growth of the AEFC is slower and more regular than that of the CIFC. When both types are present alternatively, this pattern is called cellular mixed stratified cementum (CMSC; Schroeder, 1993).

The rate of the cementum deposition follows cyclic variations, producing an alternation of distinct broad and narrow layers. Several studies showed that the periodicity of the incremental growth can be correlated with a yearly cycle for many species of mammals (Klevezal' and Kleinenberg, 1969; Grue and Jensen, 1979; Klevezal', 1996; Hamlin et al., 2000). The biological origins and mechanisms of this alternation remain imperfectly explained but since it was observed in a great variety of other mineralized tissues the most probable hypothesis is that it is genetically regulated and "triggered" by environmental factors (cf. Burke and Castanet, 1995). Various terminologies have been used for describing these growth marks, depending on the optical proprieties and preparation techniques (under natural or polarized light, transmitted or reflected light, on stained or unstained sections, etc.). More conventionally, according to the nature of the growth rate, the thickest layers, more rapidly deposited, are generally called "growth zones" (GZ) while the term "annuli" (or "winter bands", "rest lines", etc.) refer to the narrowest and hypermineralized layers (Lieberman and Meadow, 1992; Stutz, 2002a). The number of increments can be used for estimating the individual age – one pair of GZ + annulus corresponding to a whole year – and the outermost layer, forming at the time of death, is expected to provide reliable estimation of the season at death (Naji et al., 2015).

The first dental cementum analysis of South American camelids was realized by Raedeke (1979: Appendix A) on modern guanacos. As far as we know, no further studies have been published regarding other *Lama* species. The population of guanacos studied by Raedeke came from the Isla Grande. It comprised a first set of 20 known-age individuals and a second one of skulls of 172 animals (more than 3.5 years old but not aged precisely) died by natural causes and collected in the field. For each individual, the selected teeth were the first incisor and/or the lower canine. The thin-sections were prepared by a commercial laboratory (current Matson's Lab, Montana, US) using a standard protocol for histological studies: decalcification of the root, microtome cuts (12 μm thick), staining of the sections in Ehrlich's haematoxylin. As expected, after taking in account the age of formation of the first cementum deposit (i.e. during the summer of the second year of life for both the first incisor and the canine), Raedeke found a high correlation between

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