C. R. Palevol xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

Comptes Rendus Palevol

www.sciencedirect.com

General Palaeontology, Systematics and Evolution (Palaeopathology)

Surviving in a predator-free environment: Hints from a bone remodelling process in a dwarf Pleistocene deer from Crete

Survivre dans un environnement sans prédateurs : considérations sur un processus de remodelage osseux dans un cerf nain du Pléistocène de Crète

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ARTICLE INFO

Article history:
Received 14 December 2014
Accepted after revision 24 March 2015
Available online xxx

Handled by Michel Laurin

Keywords:
Candiacervus
Dwarf deer
Bone fracture
Crete
Pleistocene

Mots clés :
Candiacervus
Cerf nain
Fracture osseuse
Crète
Pléistocène

ABSTRACT

Islands have been regarded by scientists as a living laboratory of evolution, and a prime target for the study of forces influencing evolution. This research aims to investigate whether a dwarf deer (*Candiacervus ropalophorus*), that suffered a traumatic fracture of its metatarsal, might have survived, despite the broken limb, in the Cretan free-predator environment for a time longer than commonly expected on mainland. The metatarsal shows a healed complete and oblique fracture at level of the distal part of the diaphysis. Both macroscopic and X-ray examinations show the impressive new bone formation that occurred in the post-trauma period. The size of osseous callus, covering the fracture line and the surface next to the lesion, suggests that the deer has survived several months after the traumatic injury. In a mainland context, an injured deer would hardly have survived for such a long period, because any movement constantly irritated the fracture, dramatically reducing performance or willingness to move and the gait speed, and hampering any escape.

RÉSUMÉ

Les îles ont été considérées comme des laboratoires vivants de la biodiversité et une cible pour l'étude des forces qui influent sur l'évolution. Cette recherche vise à déterminer si un cerf nain du Pléistocène de Crète (*Candiacervus ropalophorus*) qui a subi une fracture de son métatarsien aurait pu survivre, en dépit de sa jambe cassée, dans un environnement sans prédateurs pour un temps plus long que prévu sur le continent. L'os métatarsien montre une fracture complète et oblique au niveau de la diaphyse. Les examens macroscopiques et aux rayons X montrent l'impressionnante formation d'os nouveau qui s'est produite dans la période post-traumatique. La taille de ce cal osseux, couvrant la ligne de fracture, suggère que le cerf a survécu durant plusieurs mois au traumatisme, même si tout mouvement

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http://dx.doi.org/10.1016/j.crpv.2015.03.003
1631-0683/

Please cite this article in press as: Palombo, M.R., Zedda, M., Surviving in a predator-free environment: Hints from a bone remodelling process in a dwarf Pleistocene deer from Crete. C. R. Palevol (2015), http://dx.doi.org/10.1016/j.crpv.2015.03.003

irritait constamment la fracture, réduisant considérablement les performances locomotrices, la vitesse de marche et la possibilité d'échapper aux prédateurs.

1. Introduction

Studies on palaeopathology of fossil bones, dating back to the beginning of the last century, mainly deal with investigations on human and dinosaur bones or on domestic animals from archaeological sites, while only a few concern Pleistocene mammals (see e.g. Acosta Hospitaleche et al., 2012; Aufderheide and Conrado, 1998; Bartosiewicz, 2008; Bartosiewicz and Gal, 2013; Bell and Coria, 2013; Bishop, 2011; Bricknell, 1987; Brothwell, 2008; Buffetaut et al., 2007; De Boer et al., 2013; Duckler and Van Valkenburgh, 1998; Everhart, 2008; Fisk and Macho, 1992; Franklin, 2011; Johnson and Milburn, 1982; Jordana et al., 2011; Kallal et al., 2012; Kierdorf et al., 2012; Lingham-Soliar, 2004; Martin, 2013; Martin Sander, 1992; Moodie, 1917, 1923; Ortner, 2002; Rega et al., 2012; Rothschild and Martin, 1993; Salesa et al., 2014; Tanke and Rothschild, 2010; Tasnádi-Kubacska, 1962; Telldahl, 2012a,b; Vann and Thomas, 2006; Wu and Schepartz, 2009).

During the last two decades, studies on palaeohistology and palaeopathology have been receiving increasing attention, at least partially reflecting the recent development and changing emphasis in the field of palaeoecology. Studying factors causing pathological diseases in past wild animals could, indeed, provide valuable hints for a better understanding of their life-style, behaviour and niche occupancy, in turn providing additional data to reconstruct predator-prey relationships and some aspects of population/ecosystem dynamics (see among others Gardner and Smith, 2006; Katsura, 2004; Palmqvist et al., 1999; Rothschild and Tanke, 1992; Rothschild et al., 2001; Salesa et al., 2014; Tanke and Farke, 2006). In particular, "survival of animals with injuries or diseases limiting their mobility and function suggests the possibility of "a support system" which allowed their survival" (Rothschild and Tanke, 1992, p. 73).

Therefore, studies of palaeopathology in insular endemic mammals may help determining whether resources availability, and ecological interaction and displacement or the release from predator pressure are among the major factors driving evolution and survival in isolated environments (see e.g. Lomolino et al., 2013 and references therein).

Here, we present a case study of a healed fracture of a still undescribed metatarsal of *Candiacervus ropalophorus* (the smallest among the endemic Pleistocene deer species from Crete, eastern Mediterranean), found in the latest Middle (?) — Late Pleistocene (see below) deposits of Bate cave (Rethymnon, northern Crete) (Capasso Barbato, 1990, 1992; Kotsakis, 1977; Kotsakis et al., 1976).

2. Material and methods

2.1. Bate cave and its faunal record

The metatarsal (MPUR/V coll. Bate S50) is part of a rich fossil sample collected in the seventies by a team of Sapienza University of Rome (Italy) in an unexplored cavity (named "Bate cave" by the Italian discoverers), located in the north Cretan coast, not far from the Zourida gorge, in the cliffs below the Rethymnon-Chania National Road (Fig. 1). The material is currently stored in the Museum of Palaeontology, Department of Earth Sciences of Sapienza University (Rome, Italy).

The vertebrate fauna retrieved from the chaotic fossiliferous layers filling Bate cave includes a few remains of amphibians, reptiles (*Bufo* cf. *B. viridis, Testudo marginata cretensis, Lacerta* cf. *L. erhardi, Coluber* cf. *C. gemonensis* in Kotsakis, 1977), small mammals (*Mus minotaurus)* and four deer species: *Candiacervus* ex gr. *C. ropalophorus* (*sensu* Palombo et al., 2008), the smallest and the most abundant, and three larger deer species, *Candiacervus cretensis, Candiacervus dorothensis* (= *Candiacervus* sp. V, De Vos, 1979),

Fig. 1. (Color online.) Map of the island of Crete. Localization of caves cited in the text.
Fig. 1. (Couleur en ligne.) Carte de l'île de Crète. Localisation des grottes mentionnées dans le texte.

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