

INFERRING THE DIET OF EXTINCT ELEPHANTS: THE CASE STUDY OF STRAIGHT-TUSKED ELEPHANTS FROM NEUMARK NORD 1 (NORTHEASTERN GERMANY)

Maria Rita Palombo¹ & Paola Iacumin²

¹Dipartimento di Scienze della Terra, Università "Sapienza", Roma

²Dipartimento di Scienze della Terra, Università degli studi di Parma.

Corresponding author: Maria Rita Palombo <mariarita.palombo@uniroma1.it>

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Inferring the diet of fossil mammals is a major approach to mammalian palaeobiology and palaeoecology. Compared to other mammals, proboscideans pose significant problems because elephants eat different kinds of food and may change it frequently. Results obtained by analysing the last molars of *Palaeoloxodon antiquus* from Neumark Nord, highlight the effectiveness of a multidisciplinary approach in inferring the dietary adaptation of elephants. The microwear pattern and stable isotope data obtained for the straight-tusked elephants from Neumark Nord 1, suggest they were mainly grazers in a wooded grassland and moderately humid environment.

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La definizione della dieta delle specie fossili è uno degli aspetti di maggiore interesse in paleobiologia e paleoecologia. Uno studio che associ l'analisi delle microtracce di usura dentale e degli isotopi stabili è particolarmente utile nel caso degli elefanti fossili, in quanto la definizione delle loro abitudini alimentari pone problemi interpretativi dovuti alla varietà di cibo assunta. Lo studio, applicato agli esemplari di *Palaeoloxodon antiquus* di Neumark Nord 1, dimostra come questi esemplari vivessero in condizioni climatiche miti e relativamente umide e si cibassero prevalentemente di erbe.

Key words: Microwears, Stable isotopes, diet, *Palaeoloxodon antiquus*, Neumark Nord 1, Pleistocene, Germany.

Parole chiave: Microtracce di usura, Isotopi stabili, dieta, *Palaeoloxodon antiquus*, Neumark Nord 1, Pleistocene, Germania.

1. INTRODUCTION

Inferring the diet of fossil mammals is a major approach to mammalian palaeobiology and palaeoecology. Therefore palaeodiet reconstruction is of increasing interest in depicting environmental changes as well as in investigating a wider range of ecological issues. Since the second half of the last century, two methodological approaches have been developed to supply this information. They are based on microwear enamel defects (produced on tooth enamel by the attrition of food particles), and on stable isotope analyses. Compared to other mammals, elephants pose significant logistical problems for dental microwear analysis (PALOMBO *et al.*, 2005, TODD *et al.*, 2007). Elephants exhibit a quite unusual manner of food comminution, depending on the extent of the masticator surface and on the high number of enamel bands of their teeth. Moreover, elephants eat different kinds of food and may change it frequently. As a result, to establish the average dietary adaptation of an elephant population, it should be convenient to combine microwear with stable isotope analyses. This study is aimed at comparing the results obtained by analysing dental microwears and stable isotopes in straight-tusked elephants from Neumark Nord 1 (Sachsen-Anhalt; Germany) (PALOMBO *et al.*, 2010), a site which provide an extraordinary

palaeontological record, counting about two hundreds of flora species, mollusks, insects, and a diversified vertebrate fauna, including fishes, amphibians, reptiles and several more or less complete skeletons of large mammals found in sediments deposited during an interglacial phase (? MIS 7, ? MIS 5e) (MELLER, 2010).

2. MICROWEARS

Analysis, performed on twenty among the best preserved ultimate e penultimate molars (M2, M3) using both stereomicroscope and scanning electron microscope, reveal a modest variability in the microwear patterns of elephants from Neumark Nord 1. Scratches, especially coarse and hypercoarse, prevail, though pits, both large and small, maybe locally abundant. Coarse scratches, large and relatively deep, with a U-shaped bottom are usually more frequent in the middle part of enamel band, while fine, sometimes, narrow, deep, and V-shaped scratches have been observed on the border of enamel band. Cross-coarse scratches are always present. Some large and deep cavities (gouges) are also observed. The presence of very small fragments of enamel prisms at the bottom of the cavities suggest the eating of hard food such as wood or bark.

The comparison of the range of variability of num-

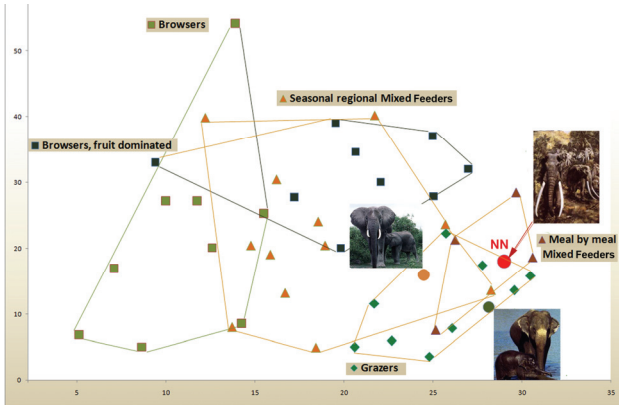


Fig. 1, Bivariate plot of the average number of pits versus average number of scratches in extant ungulates (data from SOLOUNIAS & SEMPREGON 2002), extant elephants (*Loxodonta africana* and *Elephas maximus*), and *Palaeoloxodon antiquus* from Neumark Nord 1 (NN). *Diagramma di dispersione del numero medio di cavità e strie negli ungulati viventi (dati da SOLOUNIAS & SEMPREGON 2002), negli elefanti viventi L. africana ed E. maximus, e in P. antiquus di Neumark Nord 1 (NN).*

ber of pits and scratches in extant herbivores highlights the peculiarity of microwear patterns in elephants. The morphospace boundaries were obtained by plotting the average numbers of scratches of each dietary category versus the average numbers of pits (Fig. 1). Neumark Nord 1 elephants plot within the so-called meal-by-meal mixed feeders that could change their dietary be-

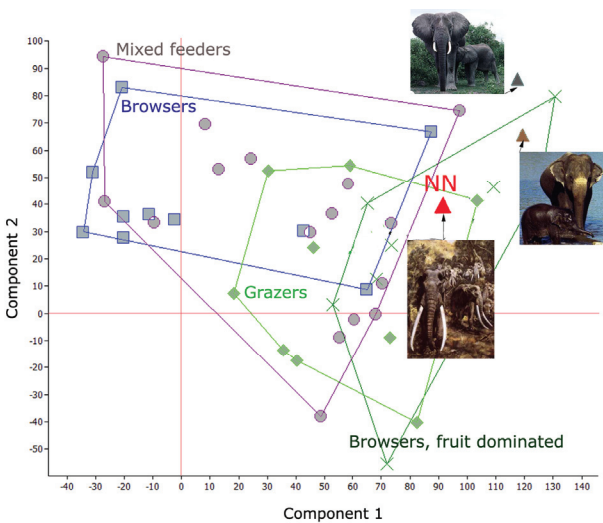


Fig. 2, Principal component analysis: scatterplot diagram of extant ungulates extant elephants (*Loxodonta africana* and *Elephas maximus*) and *Palaeoloxodon antiquus* from Neumark Nord 1 (NN). Variables are average number of pits and scratches, % of large pits, % of gouges, % of fine scratches, % of coarse/hypercoarse scratches, % of mixed scratches, % of cross scratches. *Analisi delle component principali effettuata per gli ungulati e gli elefanti (L. africana e E. maximus) attuali e P. antiquus di Neumark Nord 1. Variabili: numero medio di cavità e strie, % di cavità grandi; % di fosse; % di strie sottile; % di strie larghe; di strie "miste"; % di incroci.*

haviour depending on either the most abundant or the most pleasing food, but close to the morphospace of grazers.

In the Principal Component Analysis, extant elephants plot close to the fruit dominated browsers, while the fossil elephants from Neumark Nord 1, fall in the overlapping area of fruit-dominated browsers and grazers. This is because the variables that mostly contributed to the setting are the percentage of coarse scratches, large pits and gouges (first component) as well the percentage of cross scratches (second component), not the average number of pits and scratches that, in the bivariate analysis, permits to separate grazers from browsers.

All in all, the microwear pattern of elephants from Neumark Nord 1 suggests they were meal-by-meal mixed feeders, including a large amount of grasses in their diet..

3. STABLE ISOTOPES

Stable isotopes have proved useful in determining the dietary habits of mammals and to obtain information on past climates and environments (see e.g. DENIRO, 1987; LONGINELLI, 1994; IACUMIN *et al.*, 1996; BOCHERENS, 2003). The $\delta^{18}\text{O}$ values calculated from the Neumark Nord 1 sample, are not statistically different from those already obtained for the Italian elephants from La Polledrara di Ce-

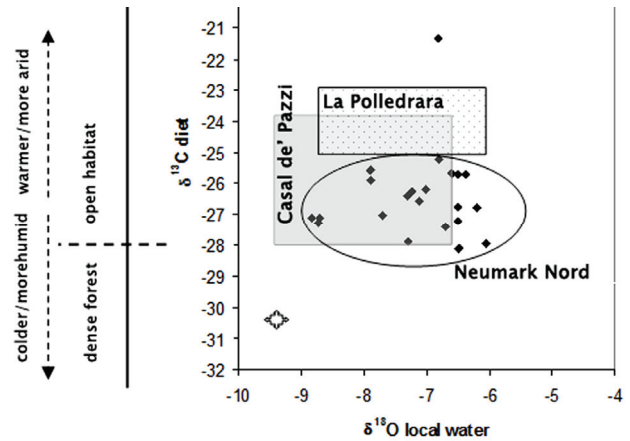


Fig. 3, Carbon and oxygen isotope values of diet and local meteoric water calculate from the measured carbon and oxygen isotope value of apatite of elephant samples preserved in Neumark Nord 1, and fields of variation of the same parameters of the Italian sites "La Polledrara" and Casal de Pazzi". The symbol represents the mean $\delta^{18}\text{O}$ value of modern precipitation in the Neumark Nord area (Halle, Leipzig).

Dieta e valori delle acque meteoriche calcolate in base ai valori degli isotopi dell'ossigeno e del carbonio ottenuti dall'analisi dell'apatite del campione di Neumark Nord 1. Sono riportati i campi di variabilità ottenuti per i siti italiani di "La Polledrara" e "casal de' Pazzi": il simbolo indica il valore del $\delta^{18}\text{O}$ delle precipitazioni moderne nell'area di Neumark Nord (Halle, Lipsia).

canibbio and Casal de' Pazzi (PALOMBO *et al.*, 2005). This may suggest that the climate were similar at the two different latitudes during the Middle Pleistocene. However, we have also to consider that, unlike the Italian elephants, the German ones are enriched in ^{18}O of about 2‰ in comparison to the modern precipitation in the Leipzig area. This probably suggests that the mean environmental condition were not far from modern ones, slightly warmer at the most.

The nitrogen isotope composition of dentine and bone collagen ($\delta^{15}\text{N}_{\text{coll}}$) are consistent with a diet based mainly on grass which has significantly higher $\delta^{15}\text{N}$ compared to woody growth forms (VIRGINIA & DELAWICHE, 1982).

Accordingly, isotope results suggest that elephants from Neumark Nord were mainly grazers in a wooded grassland and moderately humid environment.

4. REMARKS

Results obtained by analyzing the sample of molars of *Palaeoloxodon antiquus* from Neumark Nord 1, highlights the effectiveness of a multidisciplinary approach to a large data set in inferring the dietary adaptation of elephants. Elephants, indeed, are known as mega-herbivores showing the highest range of variability in feeding among the extant species. Both *Loxodonta* and *Elephas* feed on more than 80 different plant species, eating low grass as well as tree branches or fruits (the latter are eaten especially by the forest species *Loxodonta cyclotis*), as well as aquatic vegetation. As a result, the ingested food would vary meal-by-meal, and microwear patterns can change considerably, depending on geographic area, season and also during short time spans. Accordingly, isotope analysis could be a fundamental support in inferring the average dietary behaviour of fossil proboscideans as well as the physic parameters of the environment they inhabited. Among extant elephants grazing is generally related to the increase of grass availability during humid periods, whereas browsing increases when grass tend to be withered. Accordingly, the patterns in microwear shown by the elephants from Neumark Nord are

consistent with the stable isotope data obtained for the site, suggesting temperate and moderately humid environmental conditions.

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