

## A PATHOLOGIC STRAIGHT-TUSKED ELEPHANT FEMALE FROM NEUMARK NORD (GERMANY)

Federica Marano<sup>1</sup> & Maria Rita Palombo<sup>1,2</sup>

<sup>1</sup>Università degli Studi di Roma Sapienza, Roma

<sup>2</sup>Università degli Studi di Roma Sapienza, IGAG - CNR, Roma

Corresponding author: F. Marano <federica.marano86@gmail.com>

**ABSTRACT:** Marano F. & Palombo M.R., *A pathologic straight-tusked elephant female from Neumark Nord.*

The elephant bones collected during more than ten years (1985-1996) in the interglacial (MIS 7 or MIS 5) lacustrine deposits exposed in the open-cast lignite mine of Neumark Nord (Germany), represent one of the most outstanding samples of straight-tusked elephants in the Pleistocene of Europe. In 1994, a skeleton of an adult female (E8 HK 2007:55) was found in nearly anatomical connection. The postcranial bones were almost all preserved, the skull was partially destroyed, and the tusks and mandible were missing. Wearing stage of molars and fusion of bones, as well as the pelvis morphology indicate a 39-40 years old female for which a height at the shoulders of about 2,9 m and a weight of about 5000 kg have been calculated. The most peculiar traits of this female are the serious scoliosis that affected its vertebral column and the invasive arthritis that deformed its femur and pelvis girdle on the right side.

**RIASSUNTO:** Marano F. & Palombo M.R., Una femmina di "elefante antico" con malformazioni ossee del giacimento di Neumark Nord (Germania).

I resti di *Palaeoloxodon* raccolti per più di dieci anni (1985-1996) nei depositi lacustri (MIS 7 o MIS 5) nella miniera di lignite di Neumark Nord (Germania), rappresentano una tra le più ricche popolazioni di "elefante antico" nel Pleistocene Europeo. Nel 1994, fu rinvenuto uno scheletro pressoché completo e in parziale connessione anatomica di una femmina adulta (E8 HK 2007:55). Il cranio è parzialmente danneggiato, mancano le difese e la mandibola, mentre le ossa dello scheletro postcraniale sono in discreto stato di conservazione. Il grado di usura dei molari superiori, lo stato di ossificazione delle ossa degli arti e la morfologia del bacino indicano che lo scheletro appartiene ad una femmina di circa 39 - 40 anni di età, alta alla spalla circa 2,9 m con una massa corporea di circa 5000 kg. Questo esemplare presenta interessanti patologie ossee, in particolare l'intera colonna vertebrale è stata affetta da scoliosi, mentre il femore destro e il bacino sono stati interessati da iperossificazione. Entrambe le patologie furono probabilmente conseguenti ad un trauma giovanile.

**Key Words:** *Palaeoloxodon*, Age, Sex, Body Mass, Pathology, Pleistocene, Germany.

**Parole-chiave:** *Palaeoloxodon*, Età, Sesso, Massa corporea, Patologie, Pleistocene, Germania.

### 1. INTRODUCTION

The site of Neumark Nord is one of the richest in remains of palaeoloxodont elephants and undoubtedly the richest in Central Europe. Since the early 80's, an extraordinary rich sample of fossil remains was retrieved from the lacustrine deposits exposed in the open-cast lignite mine of Neumark Nord 1 (Sachsen-Anhalt, Middle East Germany) (MANIA, 2010) (Fig. 1). At Neumark-Nord 1, a long stratigraphical succession documents the environmental evolution of an endorheic basin during a complete interglacial climatic cycle. The lacustrine deposits have been supposed to be late Middle Pleistocene in age (MIS 7) on the basis of vegetational data, indicating subcontinental, mild climatic conditions (GRÜBE, 2003; SEIFERT-EULEN, 2010), as well as of the presence of *Apodemus maastrichtensis*, a species present at Weimar-Ehringsdorf but not recorded from the Eemian deposits of the area (HEIRICH, 2001, 2010). This chronology has been questioned by some authors, who considered the interglacial to be the Eemian (MIS 5e) (KOLFSCHOTEN, 2000; KOENIGSWALD, 2007, BOETT-

GER *et al.*, 2009 and references in those papers). Recently ESR dating of few samples might support an Eemian age (SCHÜLER, 2010), whilst data obtained by amino-acid racemisation of the "intra-crystalline" fraction of *Bithynia tentaculata* opercula are consistent with a late Middle Pleistocene age (PENKMAN, 2010). The lacustrine sediments lie with no hiatus over a ground moraine ascribed to the "Drenthe-glaciation" by MANIA (1999), and are overlaid by thick loess layers, then the succession is closed by muddy interglacial sediments and glacial deposits, respectively, thought to be Eemian and Weichselian in age (MANIA, 1999, 2004) (Fig. 2). The rich palaeontological record comes from the first interglacial cycle, and counts about two hundreds of plant species, invertebrates, insects, and a diversified vertebrate fauna, including several, more or less complete, skeletons of large mammals (elephants, rhinoceroses, fallow deer, red deer, aurochs as well as some carnivores such as wolf, lion and spotted hyaena). Elephant remains were retrieved from 6 fossil-bearing layers within the lower, middle and upper »gyttja«, which represent successive episodes within the small lake fill-



Fig. 1 - Localization of the site.  
Localizzazione del sito.

ing (MANIA 1999, 2004) (Fig. 2). Taking into account the place the remains were collected from, their dimensions as well as the progression in tooth eruption and epiphysis fusion, the minimum number of elephant individuals found at Neumark Nord could be nearly 70, though the calculated number would be overestimated, because of the difficulty to assessing the skull fragments, and largely incomplete bones from "bone beds", which were seriously damaged by excavators (PALOMBO *et al.*, 2010). According to the research performed to date, the morphology and biometry of skulls, tusks, molars and postcranial bones indicate that the specimens fall within the variability of European straight-tusked elephants (see e.g. OSBORN, 1942; TREVISAN, 1949; MACCAGNO, 1962; AGUIRRE, 1968-1969; BEDEN, 1969; KROLL, 1991; TSOUKALA & LISTER, 1998; DAVIES, 2002; PALOMBO *et al.*, 2010).

This paper is aimed at assessing the ontogenetical age, sex and body size as well as to briefly describe the pathological bones of an almost complete skeleton found in the October 1994 in the fossiliferous level 6.1, at a distance of about 150 m from the coastline of the lake basin (Fig. 2, 3). At the time of discovery, the skull was still in articulation with the vertebrae, the pelvis was in anatomical position, while the long bones were disarticulated and partially dislocated. The exceptionally well preserved stomach contents, with the remains of its last meal, were found under the chest (GRÜBE *et al.*, 2010). The skull is partially destroyed, the maxilla is well preserved and the molariform teeth are located in the alveoli, while tusks and jaw are missing. The postcranial bones are almost all preserved except for carpal and metacarpal bones, while the tarsals are represented by calcaneus, astragalus, navicular, cuboid, right mesocuneiform and ectocuneiform bones, some sesamoids are also present (Fig.4). This specimen (E8: HK 2007: 55) is stored in the Landesmuseum für Vorgeschichte in Halle Saale (Germany).

## 2. METHODS

The completeness of the remains has made it possible to determine both age and gender, as well as body mass and shoulder height of the studied E8 individual.

The age was inferred according to the progression in tooth eruption and wear of plates of the upper molars, adapting to these teeth the method tested by LAWS (1966) on the lower molars of extant African elephants (*Loxodonta africana*) and also applied to fossil species (ROTH, 1984; HAYNES, 1991). The status of the epiphyseal-diaphyseal junction of long bones has also been taken into account (ROTH, 1984; HAYNES, 1991).

About the gender determination, several features have been regarded as of potential information about the sex of a proboscidean, e. g. body size, length and stoutness of long bones, morphology and size of skull and teeth (molars and tusks), atlas and epistropheum, pelvis and carpal bones (see PALOMBO & VILLA 2003, and references therein). The gender of E8 elephant was inferred based on the morphology and dimensions of the pelvis girdle, which have been demonstrated to be particularly appropriate and have been largely applied to determine the gender in fossil proboscideans (KROLL 1991, LISTER 1996; GÖHLICH, 2000; PALOMBO & VILLA, 2003).

Body mass was considered as the best proxy of body size, according to GINGERICH *et al.* (1982). Body mass of proboscideans has been estimated using different allometric equations (e.g. ROTH 1990, PALOMBO & GIOVINAZZO, 2005; CHRISTIANSEN, 2004). Here, we calculated the body mass of E8 by means of the regression equations proposed by CHRISTIANSEN (2004), regarded as the most appropriate when either the actual shoulder height or the inferred circumference of *manus* are not available. Measurements were taken only on the left long bones because of the pathology affecting the right hind leg of E8 elephant.

The stature was inferred combining the results of direct measurements of the forelimb (but acropodial bones) and the equation proposed by OSBORN (1942), this because of the poor preservation of the humerus, for which only the functional medial length is available.

## 3. DESCRIPTION AND RESULTS

### 3.1 Main morphological features

**Skull** - According to the preserved fragments of skull, the nuchal fossa was deep and showed rough surface (Fig. 5b), the frontal bones flat and rather developed antero-posteriorly. The fan, is moderately expanded; the tusk-sockets are rather small and gently bent towards the lateral side (Fig. 5e), the premaxillary fossa becomes rapidly shallow, broad and somewhat convex towards the distal end of the fan (Fig.5c). Maxillary bones have a thin and short pyramidal process, the last molariform teeth (see below) were not completely

erupted, and residual, small alveoli are present on both sides.

**Teeth** - The not completely erupted molariform teeth have 8 plates in use, while a not evaluable number of plates, all fused together, occupy the entire free portion of alveoli, whose posterior portion is well ossified. The lateral side of the alveoli is locally broken, enabling us to see how the roots of molars are completely formed and fused to the plates (Fig. 5d). Accordingly, the teeth have been regarded as last molars ( $M^3$ ) (MARANO, 2009), consistently with the degree of epyphyseal-dyaphyseal fusion of long bones (see below).

The morphology and dimension of the molars fall in the range of south European straight-tusked elephant populations. The molars are narrow and high crowned, the occlusal surface is ovate and slightly convex, plates are slightly bowed out on the lateral side, in the less worn plate, the enamel occlusal figures are formed by a large oval central loop and two small lateral loops. At an intermediate wear stage, the enamel figures show a moderate medial expansion. The enamel is thin, crinkled, densely and regularly folded, and the folds extend on the entire length of the enamel figure.

**Stylohyoideum** - In both right and left stylohyoideum the posterior ramus is broken, the superior ramus, the less developed, is moderately elongated, and the inferior ramus is slender, gently curved upwards and backwards, without any evident lateral deflection; in anterior view it shows a gently concave lateral outline.

**Postcranial skeleton** - The vertebral column possesses 7 cervical, 19 thoracic (including ribs as well), 4 lumbar, 5 sacral vertebrae, while the maximum number of caudal vertebrae is unknown. The morphology of the limb bones and pelvis girdle is consistent with those known for the European straight-tusked elephants (e.g. MACCAGNO 1962, TREVISAN 1949, KROLL 1991, TSOUKALA E LISTER 1998): the humerus is characterized by a large and angled deltoid tuberosity and a more or less deep deltoid fossa; the ulna is massive with a robust olecranon and wide distal articular surface; the left femur has a relatively short neck, angled on the diaphysis of about  $40^\circ$ , the diaphysis is moderately twisted as is commonly found in femora of adult individuals; the tibia possesses a weak cnemial crest, the distal epiphysis is smaller than, but nearly as massive as the proximal epiphysis. The general shape of the tarsal bones does not substantially differ from that of the actually quite variable European straight tusked elephants (TREVISAN, 1949; KROLL, 1991; FERRETTI, 2008). The pelvis shows a gently curved lateral profile of the ileum wing, less rounded than in *Elephas maximus*, but more rounded than in *Loxodonta africana africana* and *Mammuthus primigenius* (see PALOMBO & VILLA 2003 for a discussion). With the latter two species, the pelvis of E8, as well as that of straight tusked elephants, shares a ileum with a more transversally elongated wing.

### 3.2 Age, sex, body size

**Age** - The peculiar progression in displacement of the molariform teeth, characterizing elephants, provides a particularly useful means for determining their age. Accordingly, the first step in determining the age of E8 elephant was assessing the age on the basis of the eruption progress and the degree of wear of its upper

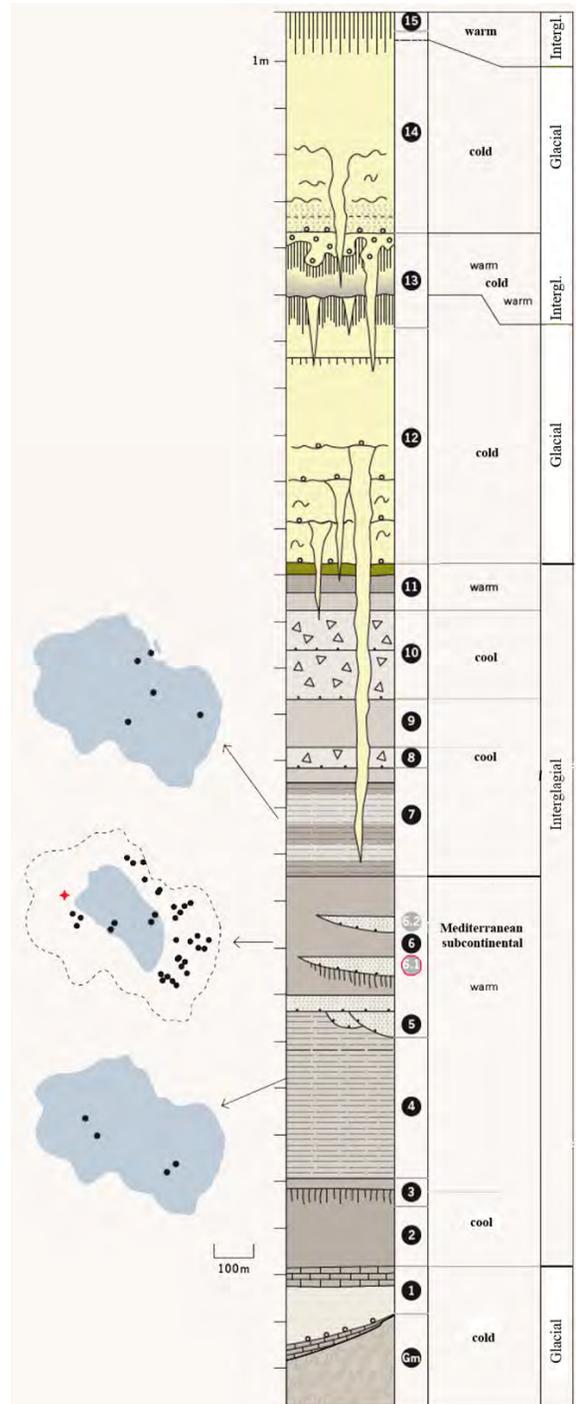


Fig. 2 - Neumark-Nord 1 basin, stratigraphical section. On the left the lake at the time of the deposition of lower (a), middle (b) and upper (c) »gyttja« (Mania, 2004); dots indicate the main findings of elephant remains, the star indicates the place where the skeleton of E8 was found (modified from PALOMBO *et al.*, 2010).

Sezione stratigrafica del bacino di Neumark-Nord. Sulla sinistra il lago al momento della deposizione del »gyttja« inferiore (a), medio (b) e superiore (c) (Mania, 2004); i punti indicano i principali ritrovamenti dei resti di elefanti; la stella indica il punto del ritrovamento di E8 (modificato da Palombo *et al.*, 2010).

molars. In E8 both molariform teeth ( $M^3$ ) are not completely erupted, furthermore, the  $M^2$  were already expelled, but residual, small alveoli of  $M^2$  are still pre-

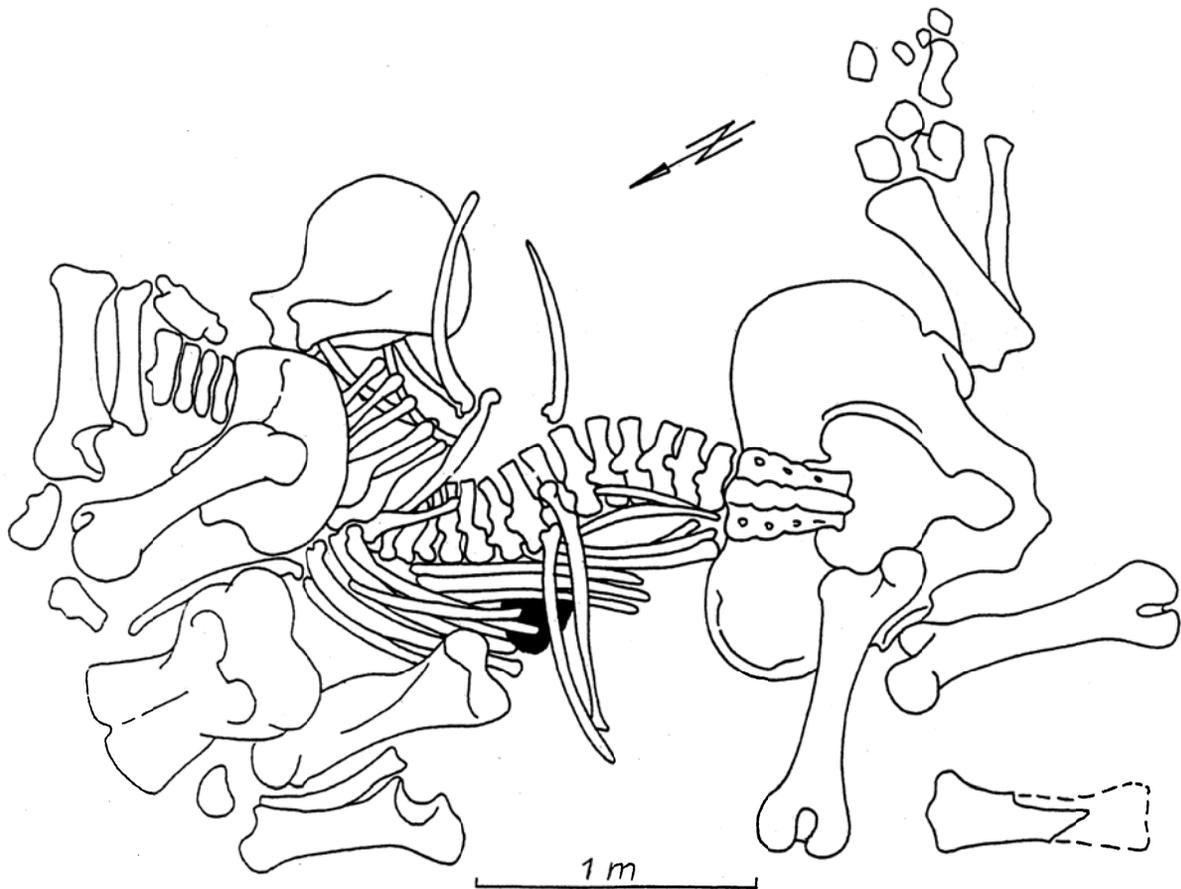


Fig. 3 - Skeleton of elephant E 8: stomach content in black (modified after Mania, 2010).

*Lo scheletro dell'esemplare E8: in nero il contenuto dello stomaco (modificato da Mania, 2010).*

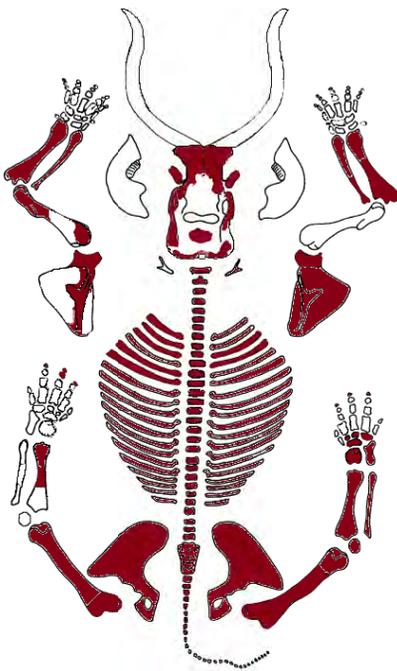


Fig. 4 - Skeletal plan of E8: in red the skeletal elements preserved and studied.

*Schema dello scheletro dell'esemplare E8: in rosso gli elementi scheletrici trovati e studiati.*

served. The stage of wear of  $M^3$  is not particularly advanced: the occlusal surface (120 mm of length) counts 8 plates, showing a complete fused enamel loops in the first five plates (Fig. 5a). According to the pattern of age proposed by LAWS (1966) for the lowers molars, but taking into account the similar progression in the both lower and upper molariform teeth often shown by straight-tusked elephants, and in particular observed in the Neumark Nord rich sample (PALOMBO *et al.*, 2010), the E8 specimen falls in the LAWS's XXII age group, which corresponds to an age ranging from 37 to 40 years.

The age inferred on the basis of the progression and wear of molars is consistent with the epiphyseal fusion of the axial and limb bones (ROTH, 1984). The vertebral border of the scapula and the *caput femuris*, indeed, are almost completely fused, showing no or faint traces of ongoing ossification (Fig. 6).

**Gender** - The morphology of the pelvis girdle is consistent with that of a female: it is characterized by a wide and rounded pelvic aperture with a transverse diameter of 540 mm, reduced thickness of the ischium and flattened ilium. The ratio of the maximum diameter of the pelvic aperture versus the minimum width of ilium is 3.1, while that of the diagonal height of the pelvic aperture versus the minimum width of ilium is 3.4. Both values fall within the variability range of females (LISTER, 1996; PALOMBO & VILLA, 2003; KROLL, 1991), the values of the same ratios being significantly lower in males.

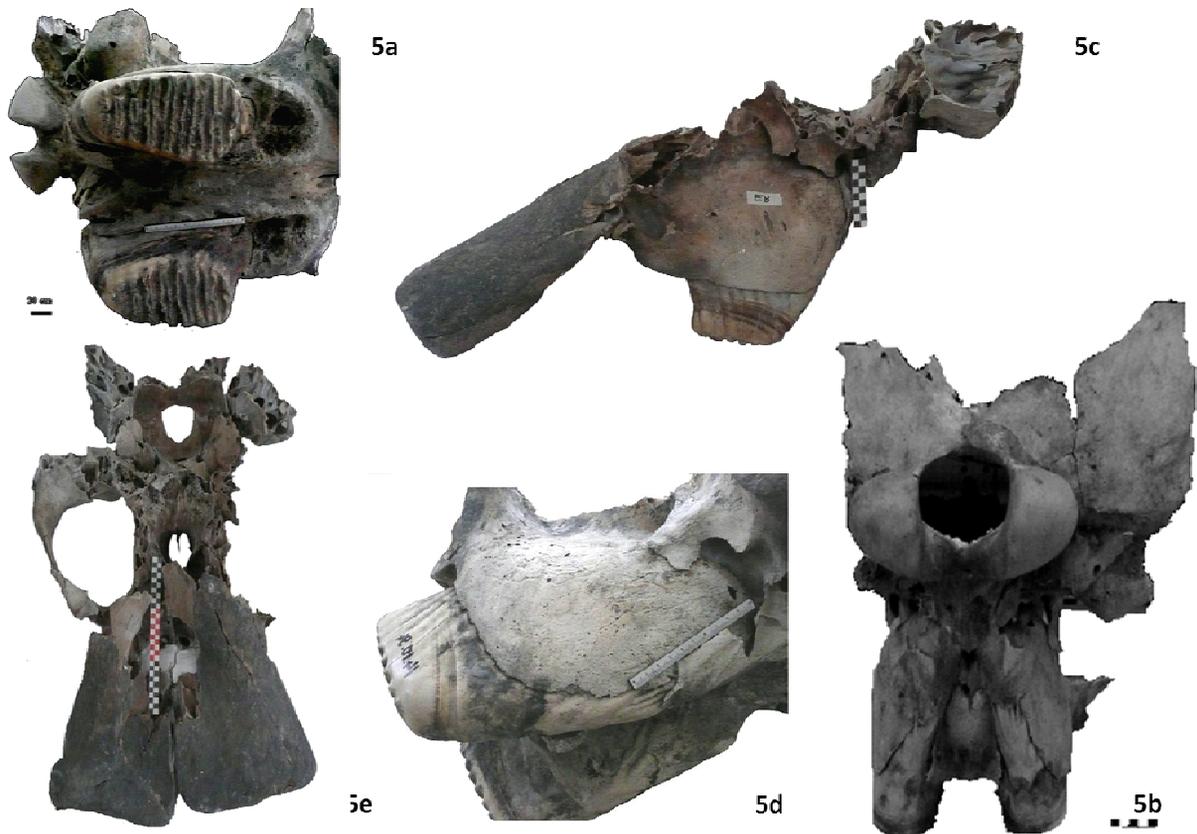


Fig. 5 - The skull of E8 elephant in ventral (a) posterior (b), lateral (c) and frontal (e) view showing the partially erupted last molars, whilst the penultimate have already been expelled from the alveoli. The postero-lateral view of the alveoli (d) shows the plates completely fused together and occupies the entire portion of the alveoli.

*Il cranio di E8 in vista ventrale (a), posteriore (b) e laterale (c). Sono visibili gli ultimi molari non del tutto fuoriusciti, mentre i penultimi molari sono già stati espulsi dagli alveoli. Il particolare degli alveoli, visti in norma postero-laterale (d) mostra come non siano presenti altre lamine in formazione.*



Fig. 6 - Scapula showing the still imperfect ossification of the distal cartilage.

*Scapola con ossificazione quasi completa dell'estremità prossimale.*

**Body size** - The estimated body mass ranges from 8511,38 kg to 3162,27 kg. The first value was calculated on the basis of the minimum circumference of the diaphysis of the humerus, the second on the basis of the maximum length of the tibia, yielding an average body length of about 5900 kg. The body mass calculated by using the minimum circumference of the ulna, which gives the best prediction thanks to the high correlation coefficient and low error rate, is approximately 4900 kg, falling close to the maximum body mass of extant African and Asian females (HAYNES, 1991).

The shoulder height, inferred by directly measuring the forelimb long bones and tacking into account the possible height of the missing more than 250 cm, while it is about 290 cm by using the equation proposed by OSBORN (1942). Accordingly, E8 should be of about 10% higher than a female of *Loxodonta africana* of about the same age (LAWS, 1996; HAYNES, 1991).

### 3.3 Pathology

Some of the elephant bones found at Neumark-Nord show anomalous ossification/growth, which is most frequent among vertebrae and teeth. In some vertebrae, such as the atlas, the ossification is incomplete and in some caudal vertebrae the neural channel is open at the top, while in others, such as the lumbar sacral vertebrae, arthritis or arthrosis had caused hyperossification

and anomalous fusion of vertebral bodies.

The skeleton of E8 shows some malformations which certainly have affected the quality of life and habits of the elephant. The most peculiar traits of this specimen are the serious scoliosis that affected its vertebral column and the invasive arthritis that deformed its femur and pelvis on the right side (Fig. 7). In the vertebral column, the last thoracic vertebrae arch toward right, while the lumbar and sacral ones arch toward left. As a result the vertebral column is markedly twisted. In the pelvic girdle, the right acetabulum is anormously large and shows a conspicuous hyperossification along its edge, while the ilium shaft is sclerous (Fig. 7, 8). The right femur, 7% shorter than the left, was deformed by



Fig. 7 - Pelvic girdle of E8 elephant showing the extensive deformation and hyper-ossification of the right acetabulum. On the left: the corresponding femur showing the caput with a strong deformation.

*Cinto pelvico dell'esemplare E8 con deformazione diffusa e iperossificazione dell'acetabolo destro. Sulla sinistra: il femore destro con il caput marcatamente deformato.*



Fig. 8 - Detail of the right acetabulum of E8.  
*Dettaglio dell'acetabolo destro dell'esemplare E8.*

arthritis (Fig. 9): the *caput femoris* is elongated and abnormally bent, the neck length strongly reduced. Conversely, no evident anomalies affected either the distal epiphysis or the zeugopodium and achropodium. Both arthritis and arthrosis are, actually, common among older, domesticated Asian elephants. In domesticated Asian elephants, most of pathological ossifications are due to goad injuries caused by keepers. Several cases have

also been reported for zoo elephants too. It seems that young animals tolerate traumatic injuries without much difficulty but, when they grow older, the problems reappear. Thus it would take a long time before arthritis effects become clear.

#### 4. DISCUSSION

Morphological features shown by E8 and results obtained by biometrical analysis, contribute to a better understanding of the morphological and dimensional variability of European straight-tusked elephants.

Although several data concur, to designating *Palaeoloxodon* as a *bona fide* elephantine genus, closely related to but separated from *Elephas* (INUZUKA & TAKAHASHI, 2004; SHOSHANI *et al.*, 2007; PALOMBO & FERRETTI, 2010), in the literature, there are different opinions about the nomenclature for Eurasian "Straight-tusked elephants". Disagreements essentially center on the taxonomic status (genus or subgenus) ascribed to "*Palaeoloxodon*", as well as on the number of species regarded as present in Eurasia. The European straight-tusked elephants have been considered as belonging either to the Asian species "*Elephas namadicus*" or, as one *bona fide* species, *Elephas antiquus*/*Palaeoloxodon antiquus*.



Fig. 9 - Femur of E8 elephant in anterior and posterior view, showing the extensive deformation and hyper-ossification, caused by the severe arthritis the female had suffered for long time.

*Femore dell'esemplare E8 in norma anteriore e posteriore con marcata deformazione e iperossificazione. A causa della forte artrite l'esemplare ha sofferto per lungo tempo.*

Alternatively, both these species have been considered present in Europe. Two morphotypes have been recently described by SAEGUSA & GILBERT (2008): the Italian “*namadicus*-like” morphotype (showing an extreme developed parieto-frontal crest, nearly reaching the external choanae), and the “German-Stuttgart” morphotype (characterized by a weak development of the parieto-frontal crest).

Although the parieto-frontal and nuchal crests of E8 skull were seriously damaged during the recovery, some preserved large fragments indicate that its forehead could have been wide and gently convex. Accordingly, the morphology of the preserved parieto-frontal part of the skull of E8 seems to confirm the peculiar development of the parieto-frontal crest, shown by some adult males from Neumark Nord (PALOMBO *et al.*, 2010), which differentiates the skulls of Central Europe (especially from Germany) from those of Southern Europe. Although the development of the parieto-frontal crest of the skulls from Neumark Nord are variable, they are mainly characterized by a moderately extended forehead and by a dorsally positioned parieto-frontal crest, as observed in skulls ascribed by SAEGUSA & GILBERT (2008) to the “Stuttgart” morphotype. Accordingly, most of the German palaeoloxodon populations do not present the morphological “*namadicus*” traits shown by the Italian continental adult elephants ascribed by SAEGUSA & GILBERT (2008) to this morphotype e.g. skulls from La Polledrara Cecanibbio, (PALOMBO *et al.*, 2003; PALOMBO & FERRETTI 2005) - as well as by the endemic Sicilian species *Palaeoloxodon mnaidriensis*, showing a parieto-frontal crest strongly advanced and folded to cover the forehead (FERRETTI, 2008; PALOMBO *et al.*, 2010). Whatever the significance of such a difference, the morphology inferred by the skull fragments of E8, seems to confirm that females possibly had a less developed crest than males.

The age of about 40 years, inferred on the basis of the degree of wear and number of plates of upper molars, is also supported by the degree of ossification of skeletal elements. This age confirms a prevalence of adults older than 45 years, in the elephant population of Neumark Nord while only the 3% of the population is younger than 6 years.

The body mass of E8, 34% lower than average body mass estimated for Neumark Nord elephants, is consistent with the small size of this individual, confirming the great morphological and dimensional variability of this species and the significant dimensional gap between male and female in fossil and extant elephant populations (PALOMBO *et al.*, 2010). Moreover the concordance among dimensional data, pelvis morphology confirms the usefulness of some pelvis features (particularly shape of pelvic aperture and proportion of the ilium shaft) as support to infer gender in proboscideans.

## 5. CONCLUSION

The specimen E8, as are all the elephants of the population of Neumark Nord, is assigned to the species *Palaeoloxodon antiquus*, pending a systematic revision on the European straight-tusked elephants (PALOMBO & FERRETTI, 2010). The analysis on the nearly com-

plete skeleton, indicates that E8 was a small female of about 40 years, weighting about 5000 kg, with a height at the shoulder about 290 cm. Accordingly, E8 has almost the same size of females, but is significantly smaller than males of the same age from the same population. Moreover, the presence of extensive bone abnormalities, indicates that the female was lame in its right leg and perhaps suffered a lot of pain during its life. The extensive sclerosis suggests that the arthritis developed over a quite long time, and probably was caused by a traumatic injury when the female was young, albeit it is difficult to ascertain what event actually caused these injuries.

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