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Description and Morphometric Analysis of the *Mammuthus armeniacus* (FALCONER) Skull from Slavonski Brod (Croatia)

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Key words: Steppe elephant, *Mammuthus armeniacus*, Skull, Morphometric analysis, Slavonski Brod, Croatia.

Ključne riječi: stepski slon, *Mammuthus armeniacus*, lubanja, morfometrijska analiza, Slavonski Brod, Hrvatska.

Abstract

Morphometric analysis of the steppe elephant *Mammuthus armeniacus* (FALCONER) allowed confirmation of the species determination of this rare Middle Pleistocene fossil. Comparison of this data with morphometric measurements of another skull of *M. armeniacus* from Gelsenkirchen (Germany), indicate greater compression of the Croatian specimen, and highlight the morphological variability of the species. This example of the *M. armeniacus* increases the known paleogeographic distribution of the species.

Sažetak

Morfometrijska analiza stepskog slona *Mammuthus armeniacus* (FALCONER) potvrđuje specifičku determinaciju ovog rijetkog srednjopleistocenskog fosila. Usporedba ovih podataka sa morfometrijskim veličinama druge lubanje vrste *M. armeniacus* iz Gelsenkirchena (Njemačka) ukazuje na veću spljoštenost primjerka iz Hrvatske, i naglašava morfološku varijabilnost ove vrste. Ovaj primjer vrste *M. armeniacus* povećava poznatu paleogeografsku rasprostranjenost vrste.

1. INTRODUCTION

The newspaper "Brodski list" of June 21st 1957 reported that "the Brodsko Posavlje Museum has made a valuable new discovery - mammoth remains in Glogovica channel in the area of the town (Slavonski Brod, *author's note*). These remains represent the main part of the head including tusks, of which one is 1.5 m long inspite of its broken condition."

MALEZ (1978, p. 565) wrote that field-work was begun at "the place where the steppe elephant skull was discovered... Initial laboratory studies show that the steppe elephant skull was found in sediments that were deposited in a low energy environment such as a swamp or lake."

According to MALEZ (1978, p. 565, 566) "the profile is open to a height of 4.30 m. The youngest deposits are represented by yellow, rather loose soil, which is only sporadically compact. The thickness of this layer is 1.10 m. Below it lies a 90 cm thick layer of sandy blue clay. The lowest layer is represented by over 3 m of blue greasy loam, in which are, from the bottom to the top, a 10 cm intercalation of coarse-grained sand, then a 25 cm intercalation of fine-grained gravel, and finally at the contact of the greasy loam and sandy clay, there is a lens of yellow-brown sand. The steppe elephant skull was found within this clastic series."

In July 1990 the author visited the Brodsko Posavlje Museum in Slavonski Brod to measure the steppe elephant skull from Glogovica (Inv. No. - 88a) (Fig. 1). Measurements on the skull were taken by Dubrovo's method (DUBROVO, 1960; LENARDIĆ, 1991). This specimen is the only almost complete steppe elephant skull from Croatia yet known. Furthermore findings from the Middle Pleistocene are rare in this area.

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2. PALEONTOLOGICAL DESCRIPTION

Order PROBOSCIDEA ILLIGER, 1881
Family ELEPHANTIDAE GRAY, 1821
Subfamily Elephantinae GILL, 1872
Genus *Mammuthus* BURNETT, 1830
Mammuthus armeniacus (FALCONER), 1857
Plates I - III

1891. *Elephas* (*primigenius*) *trogontherii*; POHLIG, Fig. 121.
1956. *Parelephas trogontherii*; SIEGFRIED, Pl. IX, Figs. 1, 2; Pl. X, Fig. 2.
1966. *Elephas trogontherii*; AZZAROLI, Figs. 12, 12a, 13, 13a.
1977. *Mammuthus armeniacus chosaricus* (= *M. trogontherii chosaricus*); AZZAROLI, Figs. 9, 10.

Material: 1 skull (partly damaged) with tusks and M^2 and M^3 sin. and dext. in occlusion.

Locality: Glogovica channel (Slavonski Brod).

Description: The posterior part of the skull is missing. The frontal portion is damaged, particularly on the left side. The upper portion of the nasal cavity is also similarly damaged. The nasal cavity is wide with rounded edges and is slightly inclined inferiorly towards the

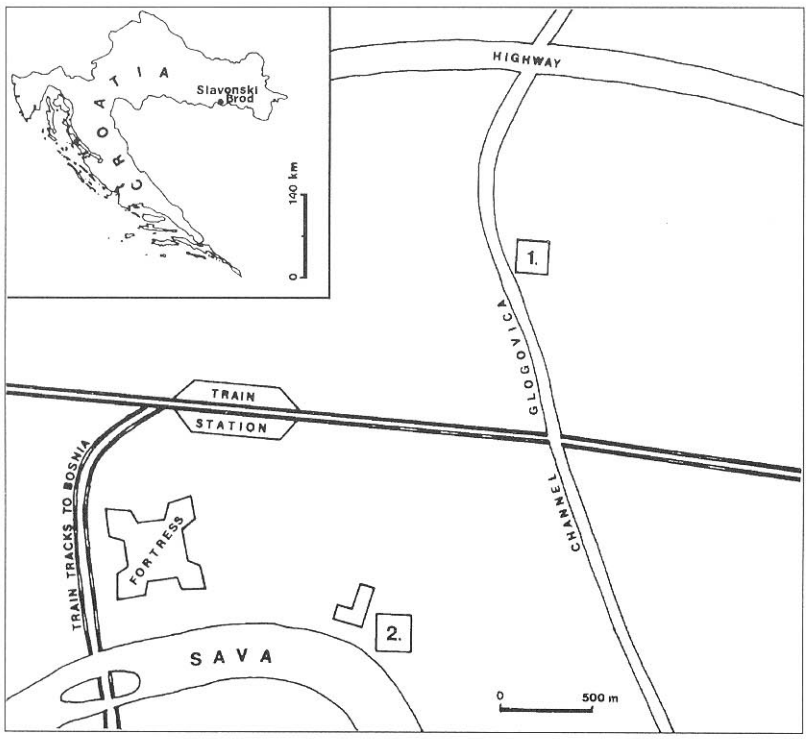

Fig. 1. Location map. Legend:1) location of the find - the Glogovica settlement II; 2) the Brodsko Posavlje Museum.

tusks. The occipital condyles are preserved. The pneumatic bone structure is visible. The right zygomatic is preserved, while the left zygomatic is missing.

From the preserved part of the skull one can conclude that the parietals were greatly elevated with a slightly concave frontal region. The skull is anterioposteriorly compressed. The praemaxillary plane is inclined downward. The tusk alveoli are slightly damaged. In the lower part they are divergent. The left tusk is well preserved, while the middle portion of the right tusk is missing. The tusks are twisted outwards and upwards. The parameters for this skull are shown in Table 1.

In the jaw M^2 and M^3 sin. and dext. are in occlusion. Such fossil findings are quite rare, thus this specimen is fairly unique. M^3 dext. has come into occlusion earlier than the left one (see Plate II, Fig. 2 and Plate III, Fig. 1). The measured parameters are within the range for the second upper permanent molars of the species *Mammuthus armeniacus* (Table 2).

The total shape of the crown, the pattern of lamellar wear on the occlusal surface, and the enamel and cement intervals confirm the specific identification based on the measured parameters.

Comparison: There is considerable variation in the measured parameters for the species *M. trogontherii* (= *armeniacus*). Teeth of this species range from short and wide to narrow and elongated crowns (Fig. 2). This is characteristic of this species, which is phylogenetically intermediate between the species *Mammuthus meridionalis* and *M. primigenius*. Earlier stages of *Mammuthus armeniacus* retain some features of the

Skull dimensions	Glogovica (Slavonski Brod)	SIEGFRIED, 1956 Gelsenkirchen
Length of the praemaxilla	54	75
Nasal cavity ratio (greatest width)	47	-
Nasal cavity ratio (greatest height)	19	-
Width of the praemaxilla (upper)	44	42
Minimal width of the forehead	38	36
Position of the occipital	49	-
Minimal height of the zygomatic bones	10	-
Length of the zygomatic arcs	33	-
Width of the palate (anterior)	7.5	-
Width of the palate (posterior)	12	-
Skull width in the area of supraorbital protuberance	68	-
Occipital condyle height	9.5	-
Skull depth	62	78
Distance from the base of nasal rostrum to the alveolar edge	55	-
Distance between outer ends of the occipital condyle	26	-
Tusk diameter at the alveola end	17	16
Outer curve of the tusk	159	140
Inner curve of the tusk	140	-

Table 1. Measuring parameters for the steppe elephant *Mammuthus armeniacus* skull (measurements are in cm).

Findings and localities / Measuring parameters	THIS PAPER		AGUIRRE (1968, 1969)	MAGLIO (1973)	GARUTT & FORONOVA (1976)	SOERGEL (1913)	HOPWOOD (1937)	HOPWOOD (1937)
	M^2 sin.	M^2 dext.	M^2	M^2	M^2	MII max.	M^2	M^2
	Glogovica Slavonski Brod	Glogovica Slavonski Brod	Different sites	Different sites	Different sites	Mosbach Süssenborn	Clacton	Cromer Forest Bed
L	178	+157	153 (140-173)	168.0-240.0	144-250	168-240	216	191
W	83	81	93.1 (88-100)	55.0-95.0	70-(82)-109	55-95	86	80
H	-	-	115 (103-126)	105.0-162.0	124-(167)-196	105-162	106	-
P	+11	+11	12-15	11-17	10-(13-14)-16	x11x-x17x	x12-13x	x≥10x
HI	-	-	1.23 (1.2-1.3)	123.2-285.5	-	-	-	-
LF	-	-	-	5.5-7.8	4.8-(7.5)-12.8	-	5.5	7
ET	1.42	1.34	-	1.3-2.8	2.65-(2.0)-1.0	1-3	2	2.5
LLQ	16.2	14.3	-	-	-	12.8-17.9	16	14.7

Table 2. Measuring parameters for the second upper permanent molars (M^2) for the species *Mammuthus armeniacus* (in mm). Legend: L = total crown length; W = total crown width; H = total crown height; P = number of plates; HI = hypsodonty index; LF = lamellar frequency; ET = enamel thickness; LLQ = length-lamellae quotient.

species *M. meridionalis*, while progressive stages are closer to the species *M. primigenius*.

Only a few *Mammuthus armeniacus (= trogontherii)* skulls have been described in the literature (POHLIG, 1891; PAVLOW, 1910; AZZAROLI, 1966, 1977; DUBROVO, 1966, etc.). The skull from the Glogovica channel has been compared with the skull from Gelsenkirchen (Westfalen, Germany; SIEGFRIED, 1956) (Fig. 3). These skulls are very similar in their overall shape, as well as in the measured parameters. Although the Glogovica skull has intermaxillary bones 21 cm shorter than the Gelsenkirchen skull, this is probably the result of a poor reconstruction of the Glogovica specimen (this part of the skull was damaged and later reconstructed with gypsum). The width of the intermaxillary bones and the minimal forehead width are 2 cm wider in the Glogovica skull; the tusks are somewhat thicker (by 1 cm) and longer (by 19 cm), while the depth of skull is smaller (by 16 cm) than the Gelsenkirchen skull. This means that the specimen from Glogovica is more compressed anterioposteriorly relative to the Gelsenkirchen specimen.

In both skulls the M^2 and M^3 sin. and dext. are in occlusion. The only difference is that in the Glogovica specimen the third molars are scarcely worn; the left M^3 is still unworn, and right M^3 has only 3 lamellae in occlusion. In the Gelsenkirchen skull the occlusal surface of the M^2 and M^3 are of similar length (on M^3

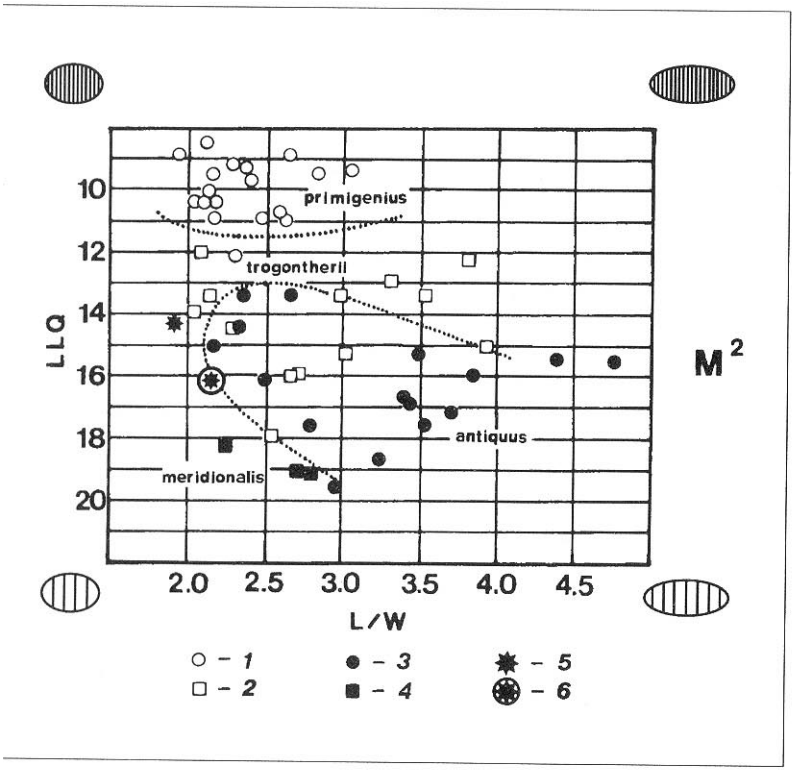

Fig. 2. Diagram with the parameter quotients for the second upper permanent molars (M^2). Legend: L/W = length-width quotient; LLQ = length-lamellae quotient; 1 = *primigenius*; 2 = *trogontherii*; 3 = *antiquus*; 4 = *meridionalis*; 5 = M^2 dext. and 6 = M^2 sin. from the steppe elephant skull from Glogovica (Slavonski Brod). Data for central European elephants (1-4) from GUENTHER (1954).

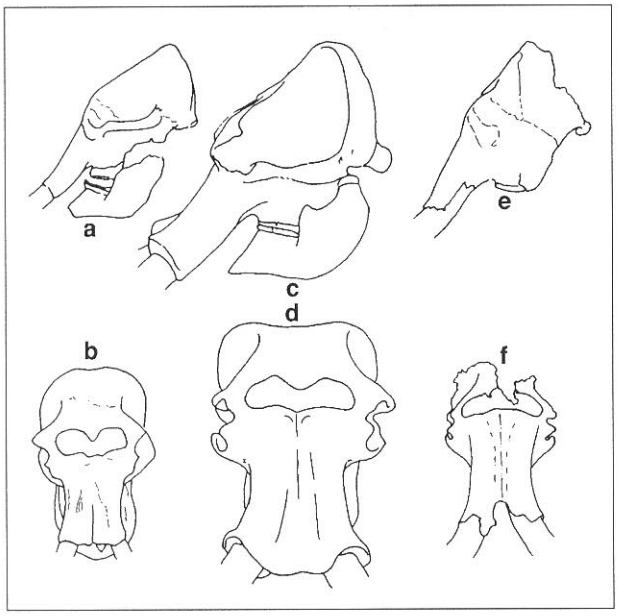

Fig. 3. The skulls of the species *Mammuthus armeniacus* (= *Elephas trogontherii*): a, b - young female, Museum in Bruxelles; c, d - Gelsenkirchen; e, f - Glogovica (Slavonski Brod). Sketches a - d approx. 1 : 13.6, from AZZAROLI, 1966; sketch e approx. 1 : 17 and f approx. 1 : 15.

dext. 11 lamellae have been worn). On the German specimen, SIEGFRIED (1956) described relatively short and strong tusks, and suggested that this skull may belong to a male animal. On the basis of the somewhat larger tusks of the Glogovica specimen, one might also infer that it is from a male animal. However, the determination of sex on the basis of these tooth and tusk measurements must remain tentative in the absence of preserved pelves. Furthermore, besides sexual dimorphism there may also be considerable individual variation in these parameters.

3. PHYLOGENY AND PALEOZOOGEOGRAPHY

Different generic and specific names are mentioned in the literature for steppe elephants. The most common are *Mammuthus* (= *Mammonteus*) *trogontherii* (in earlier papers and Russian literature) and *M. armeniacus* (in the most recent literature).

Pohlig described the species *Elephas trogontherii* on the basis of Lower Pleistocene material from Süssenborn (Germany); the lectotype is an M_3 from this locality (DUBROVO, 1977).

It is generally accepted that the species *Mammuthus armeniacus* is a descendant of *M. meridionalis*, and it is in any case intermediate, morphologically and stratigraphically, between *M. meridionalis* and *M. primigenius* (POHLIG, 1888, 1891; SOERGEL, 1913; AGUIRRE, 1968, 1969; MAGLIO, 1973; DUBROVO, 1977; HOOIJER, 1984).

AZZAROLI (1977, p. 164), on the other hand, suggested that *Mammuthus armeniacus* was not a descendant of *M. meridionalis*. He further hypothesised that the oldest species of *Mammuthus* in Europe was *M. armeniacus* (FALCONER) (= *Elephas trogontherii* POHLIG). "Perhaps the oldest known skulls of *Mammuthus* are a skull from Tarquinia, central Italy, considered to be a primitive form of *M. primigenius* by Ambrosetti, and a skull from the vicinity of Volgograd, southern Russia, chosen by Dubrovo as the type of the new subspecies *Mammuthus trogontherii chosaricus*. The two skulls seem to belong to the late Middle Pleistocene and are almost identical in shape and only slightly different in size" (AZZAROLI, 1977). Likewise, OSBORN (1942, p. 1049) removed *Elephas trogontherii* from the *meridionalis-primigenius* lineage and put it in another genus, *Parelephas*. He proposed that *Parelephas* originated in the Villafranchian of Italy, and reappeared during the first and second interglacials.

The species *Mammuthus armeniacus* was widely dispersed in Eurasia during the Lower and Middle Pleistocene (FORONOVA, 1976; MAGLIO, 1973). RAKOVEC (1954, p. 235) observed that "the majority of steppe elephant remains have been found in Germany, although they are not rare in Spain, France and England. Less material is known from Austria, Hungary and Italy. The specimens from Hungary and Romania suggest that the species *Mammonteus trogontherii* was also dispersed over the part of the Balkan peninsula." Among other remains from Croatia, this specimen from Slavonski Brod increases our knowledge of the distribution of the steppe elephant in this part of Europe.

For the steppe elephant age RAKOVEC (1954, p. 235-236) wrote that "according to German specimens, Adam has shown that *Mammonteus trogontherii* originated in Germany during the Günz. From a similar time period (Cromer Forest Bed) Hopwood identified the same species from English localities. Therefore, the separation from *Archidiskodon meridionalis* might have occured at the beginning of the first Günz interstadial or somewhat earlier in the Lowest Pleistocene. Thus this species probably first evolved in northwestern Europe. According to Adam, *Mammuthus trogontherii* shows primigenoid features by the end of the Mindel interstadial (in the lowest horizon of Steinheim and in the upper horizons from Mosbach)". DIETRICH (1965, p. 525) noted that "with the cold Mindel period began the *trogontherii*-phase, which remained until the Riss". HOOIJER (1984) gives a Middle Pleistocene age (1 - 0.2 my. BP) for this species.

The species *Mammuthus armeniacus* inhabited steppe and steppe-forest environments. The Plio-Pleistocene transition in Eurasia was marked by a cooling of the climate. With the deteriorating climate the steppe elephants developed some adaptations (e.g. changing to a rough herbal diet, as reflected in the teeth by increases in plate number, decreases in enamel thickness, greater hypsodonty etc. - FORONOVA, 1976), which according SOERGEL (1913) were most prominent during the Mindel-Riss interglacial period.

The teeth of *Mammuthus armeniacus* are highly variable in size and morphology, making specific identification difficult. However, the majority of authors agree that steppe elephants are intermediate forms between the species *M. meridionalis* and *M. primigenius*.

4. CONCLUSIONS

In this paper morphometric data of the steppe elephant skull (*Mammuthus armeniacus*) from Glogovica channel (Slavonski Brod) is presented. The skull is well preserved and was discovered within a clastic series, typical of swamp sedimentation. The parietals, parts of the posterior, and parts of the forehead are missing from this skull. Nonetheless, we can conclude from the preserved parts that the skull had an elevated vertex, a slightly concave forehead, and that it was compressed anterioposteriorly. The tusks are massive and twisted outwards and upwards. In the jaw there are M^2 and M^3 sin. and dext. in occlusion.

The skull has been compared with the steppe elephant skull from Gelsenkirchen (Germany). According to the overall shape of the skull and teeth, as well as the measured parameters, it is concluded that the Glogovica skull belonged to the steppe elephant (*Mammuthus armeniacus*).

The steppe elephants were dispersed in Eurasia during the end of the Lower to Middle Pleistocene. The majority of authors are in agreement that it is taxonomically intermediate between *Mammuthus meridionalis* and *M. primigenius*. In such transitional forms one expects great variability in the skulls, and especially in the teeth. More primitive stages of *Mammuthus armeniacus* retain some features of *M. meridionalis*, while more progressive stages are closer to the woolly mammoths (MAGLIO, 1973, p. 58, 59).

The species *Mammuthus armeniacus* lived in steppe and steppe-forest environments. In Croatia the largest steppe during the Middle Pleistocene was on the Pannonian lowlands. However, steppe elephant remains are relatively rare during this period, consisting mainly of isolated teeth. The skull from Glogovica is particularly important since it is the only steppe elephant partial skull from Croatia.

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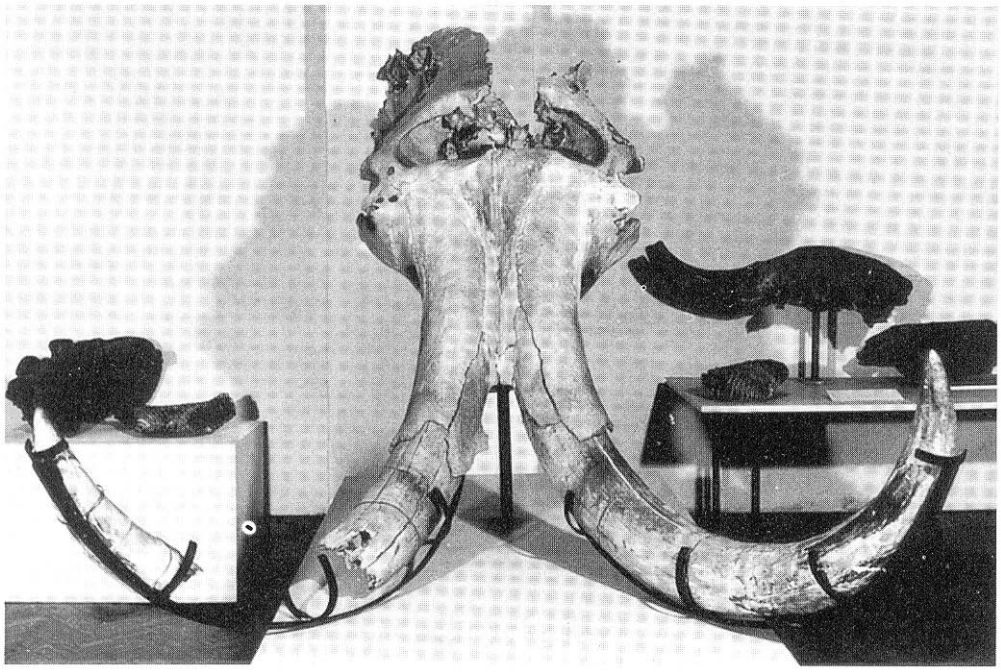
PLATE I

1 The skull of the steppe elephant (*Mammuthus armeniacus*) from the Glogovica channel, Slavonski Brod. Frontal view; approximately 1:17 of natural size.

2 Same skull from the left side; approximately 1:15 of natural size.



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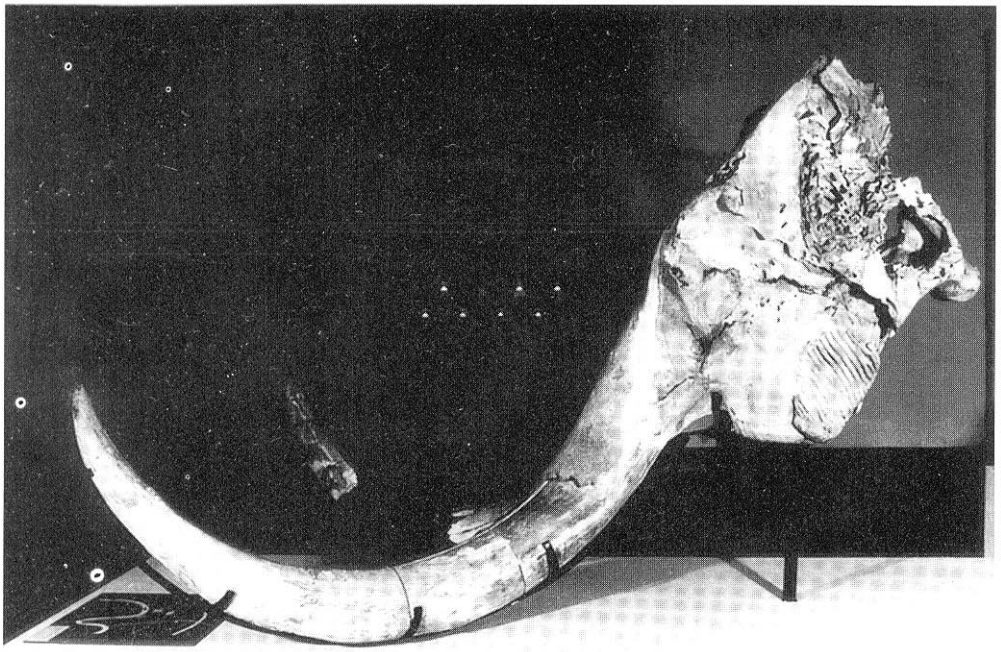

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PLATE II

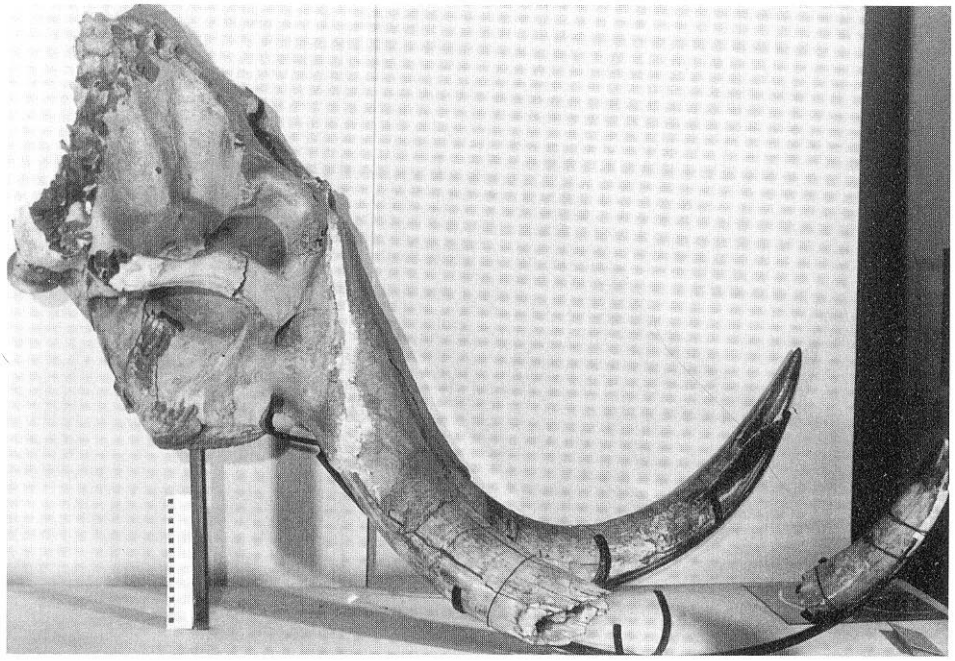
1 *Mammuthus armeniacus* skull from the right side. The scale is in centimeters.

2 Detailed view of the right side of the same skull with M^2 and M^3. Approximately 1:3 of natural size.

PLATE III

1 The occlusal surface of M^2 and M^3 dext. from the *Mammuthus armeniacus* skull. Approximately 1:1.6 of natural size.

2 The occlusal surface of M^2 sin. from the same skull. Approximately 1:1.3 of natural size.



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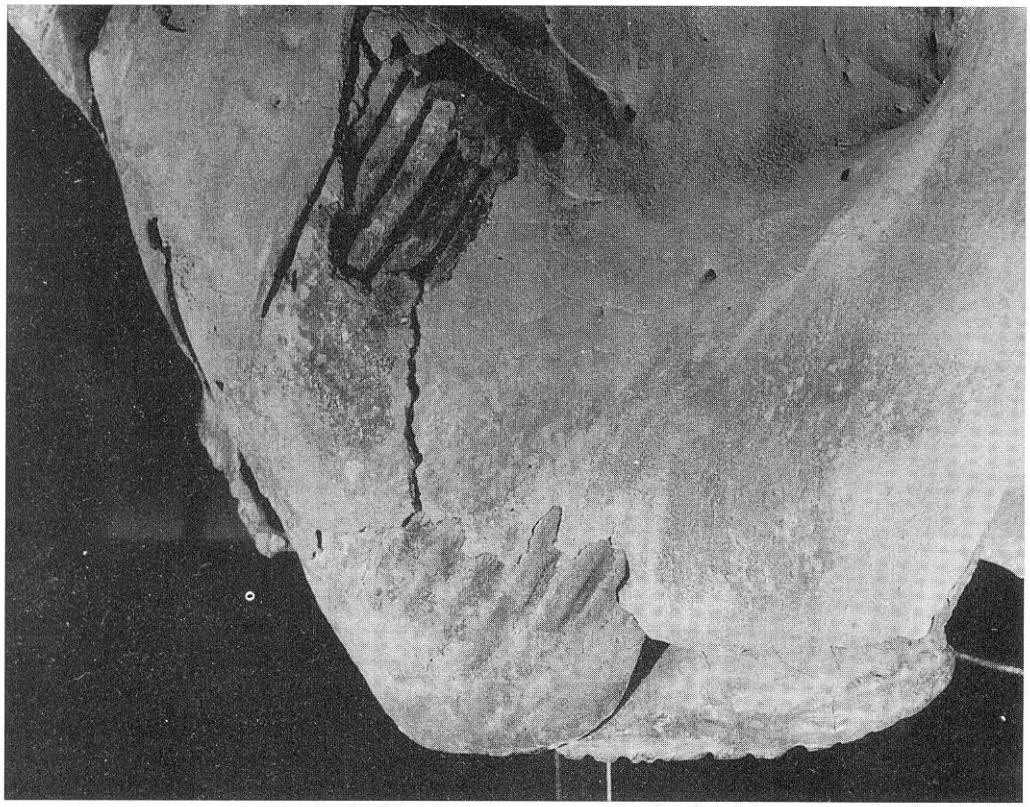

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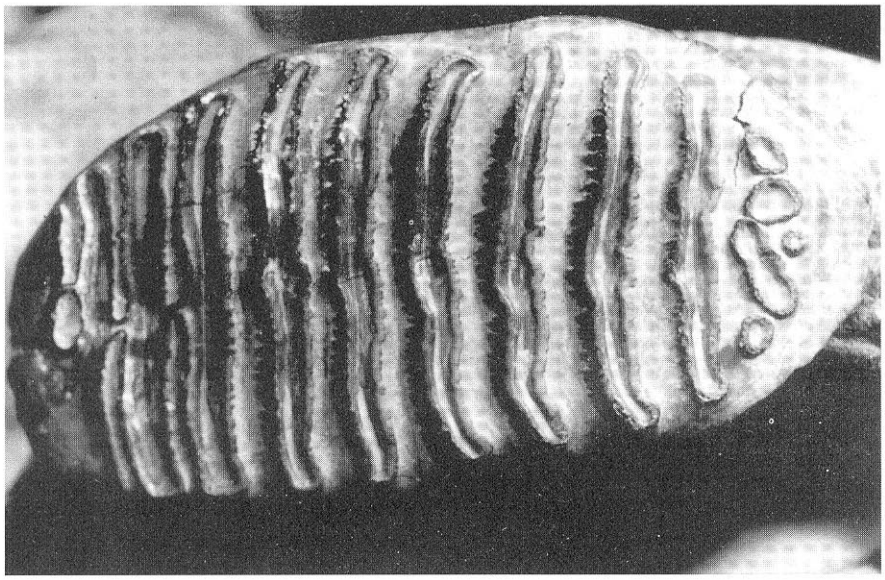

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