Exterior of the mammoth

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Summary

For many years the mammoth's appearance and body shape have been quite superficially and often erroneously described. Aspects of skeletons assembled in museums, or tusks mounted in skulls, continue to be topics of enduring discussion.

In this work, Vereshchagin and Tikhonov have critically reviewed European and Siberian Paleolithic images of the mammoth as well as modern representations of the appearance of this animal in drawings, paintings, and sculptures. Their review is also based on renewed scientific research and new expositions of paleontological materials (for example, skeleton, soft tissue, and hair) of mammoths preserved at the Zoological Institute of the Russian Academy of Sciences as well as material studied during their field excavations. The results include a comparison of the proportions of ancient, contemporary representations with the actual measurements obtained from their own work. For example, in this study the "lowered hind quarters" of the mammoth seen in ancient representations are considered the result of an immature artistic perception of reality, although those contemporary artists and their reconstructions do possess the charm of antiquity. The study of the topography, macro- and microstructure, and coloration of the woolly covering in six old and recent finds of mammoth remains permits a reconstruction of the true-life appearance of these animals and adds to our knowledge of these extinct creatures.

Samenvatting

Jarenlang werd het uiterlijk en lichaamsvorm van de mammoet oppervlakkig en vaak fout beschreven. Er is een voortdurende discussie over de wijze waarop skeletten in musea zijn opgezet of stoottanden in schedels zijn gemonteerd. In dit artikel geven Vereshchagin en Tikhonov een kritisch overzicht van de Europese en Siberische Paleolithische afbeeldingen van de mammoet maar gaan ook in op hoe dit dier in een meer recent verleden is vormgegeven in tekeningen, schilderijen en beelden. Hun overzicht is gebaseerd op nieuw wetenschappelijk onderzoek en nieuwe exposities van paleontologisch materiaal (zoals skeletten, weke delen en haar) van mammoeten uit de collectie van het Zoölogisch Instituut van de Russische Academie der Wetenschappen in combinatie met materiaal dat tijdens veldwerk onderzocht is. Dit leidde onder meer tot een vergelijking van de lichaamsverhoudingen in oude en recente afbeeldingen met meetgegevens van hun eigen wetenschappelijke werk. Zo wordt bijvoorbeeld het verlaagde achterlichaam van mammoeten in prehistorische afbeeldingen gezien als een artistiek primitieve weergave van de werkelijkheid, alhoewel de authenticiteit van deze tekeningen door "ooggetuigen" natuurlijk zijn eigen charme heeft. Onderzoek naar de plaatsing, macro- en microstructuur en kleur van de wollige vacht in zes oude en recente vondsten van mammoetresten maakt het mogelijk om hun uiterlijk te reconstrueren en levert een belangrijke bijdrage aan onze kennis over deze uitgestorven dieren. Aan het eind van het artikel is een uitgebreide Nederlandse samenvatting, met verwijzing naar alle figuren opgenomen.

Introduction

Stone Age people were attentive to the outer appearance of the northern woolly elephants for thousands of years, because the survival of the tribe often depended on the successful hunting of these animals. Not surprisingly, the earliest know artwork includes frequently painted, sculpted or drawn representations of mammoths. Even in modern times artists enthusiastically draw and sculpt mammoths.

Today's African and Asian elephants are used as the primary models for the mammoth's appearance, but to archaeozoologists and paleozoologists, however, representations based on elephants are unsatisfactory. The appearance of the mammoth was distinctive and sharply differed in detail from that of elephants.

The characterization of the outer appearance of the mammoth in numerous scientific and popular articles and books of the twentieth century has been, as a rule, superficial and even erroneous. Beginning with the first article by Brandt (1831), the visualization of mammoths was revised by Zalenski (1909b) and Abel (1925) and was made more precise by Osborn (1942). Garutt (1946, 1960) made an attempt to compare the outer appearance of mammoths with that of African and Asian elephants. Dietrich (1912) and Garutt (1964) also discussed a museum reconstruction of mammoths.

Wrongly drawn or sculpted representations appear over and over in Russian and foreign publications. Notably, the errors do not arise in the striving for innovative and stylized images, but are simply due to the absence of real knowledge and artistic feeling for things biological.

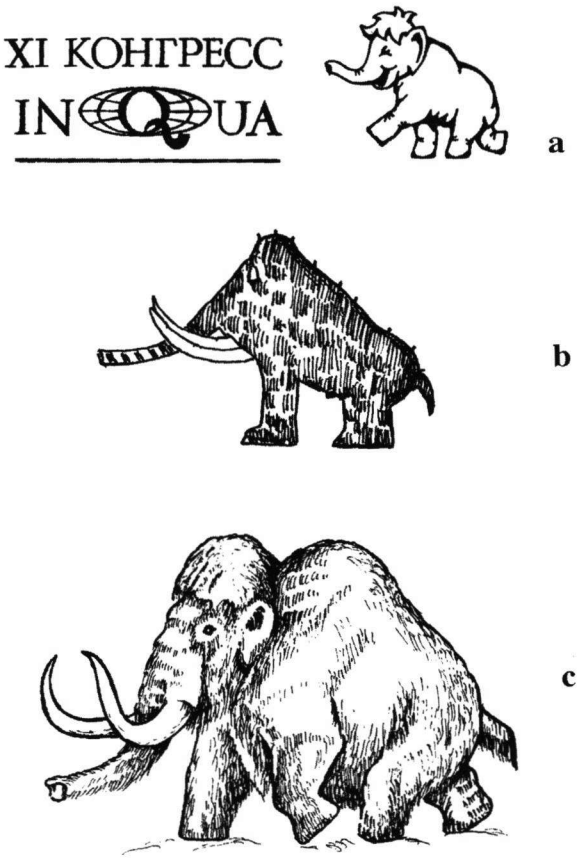

Fig. 1 Models of contemporary stylized drawings of mammoths: a) The emblem of the 11th INQUA Congress, a mammoth calf as represented by the organizing committee. b) A mammoth drawn by the Canadian schoolgirl Heidi Sharp. c) The cover of the book "The Yuribei Mammoth" (Sokolov, 1982). An unsuccessful pose from the first leaflet of the Academy of Science, where the figure of the mammoth was drawn by V.A. Vatagin.

Fig. 1 Recente impressies van mammoeten: a) het logo van het 11de INQUA Congres, een mammoet kalf zoals weergegeven door het organiserend committee. b) een tekening van een mammoet door de Canadese scholier Heide Sharp. C) de voorkant van het boek "The Yuribei Mammoth" (Sokolow, 1982). Ontleend aan de eerste folder van de Academie der Wetenschappen, waarvoor de mammoet was getekend door V.A. Vatagin.

Some recent (and amusing) examples are in Fig. 1. In these drawings the representations are not mammoths, but lop-eared, plush-toy little elephants with distorted trunks and false proportions, especially so at the lowered rump. The same may be said for some contemporary sculptures, such as at the Institute of Permafrost Studies in the city of Yakutsk where there is a figure of a mammoth with large ears and sharpened "whisker-tusks" directed sideways. The natural history museums in Cincinnati and Ottawa have "mammoth" sculptures similar in form to Asian elephants, but not like real mammoths.

Absurd arguments are constantly provoked by the tusks, their size and weight, and especially their placement in the jaw. For example, it was stated in 1903 that one individual's ". . . tusks are up to 7 m long [!–here and elsewhere, author's emphasis], [and] more than 30 cm in diameter [!]" (Nikolskii, 1903). Obermaier (1913) wrote that the weight of mammoth tusks reached 400 kg [!]. Garutt (1960) provided a smaller value, 150 kg, for a tusk measuring 265 cm in length. Actually, up to now a weight of 86 kg for a tusk 380 cm in length is the maximum accurately registered weight for a single tusk from the continental shelf beneath the Dmitriya Lapteva Strait. For nearly 50 years, at the Moscow University Museum the tusks of Trofimov's Mammoth from the Gyda Peninsula were placed in the skull in reverse order (left in the right side and right in the left, making them appear much more overwhelming in size). The same situation has been observed in other museums. The only justification for such occurrences is the poor condition of the carcasses and parts of mammoths when they came into the hands of researchers. So much the more lamentable for the reason of usual poor condition, therefore, was the loss of an entire mammoth carcass on the Gyda Peninsula in the summer of 1987.

In 1987 and 1988 we studied factual material on mammoths that had been preserved in the Museum and scientific collections of the Zoological Institute, Russian Academy of Sciences, up to 1986. This material represented items disorganized through the restructuring of exhibitions and through careless reorganization of the osteological collections.

For our reconstruction of the true life appearance of mammoths, that is, their exterior, build, and topography, as well as the macro- and microstructure of their woolly covering, we used the following materials: 1) Paleolithic drawings and sculptures; 2) representations in the works of present day artists; 3) descriptions and representations provided by the discoverers of mammoth carcasses; 4) parts of carcasses, soft tissues and skin, and mounted skeletons; and 5) samples of guard hairs (coarse hairs of considerable length) and underwool(specialized fine underhair coat) collected at the excavation sites of the carcasses and skeletons.

The image of the mammoth in art of the stone age

By now hundreds of ancient images of mammoths in caves and in open sites have been published, from sites in northern Eurasia ranging from the Pyrenees in the west to Lake Baikal in the east. These examples of ancient art have been much discussed by paleontologists and archaeologists, and even by art critics (Obermaier, 1913; Osborn, 1924, 1942; Efimenko, 1938; Bader, 1968; and others).

The skilled craftsmen of the Upper Paleolithic portrayed mammoths on stone and bone, using flint engravers and small brushes dipped in pigments of ochre, such as iron oxide (red) , or of manganese dioxide (black). The pigment apparently was ground with fat or bone marrow prior to its application. For flat drawings the artists chose the vertical limestone of cave walls, tablets of slate and graphite, and fragments

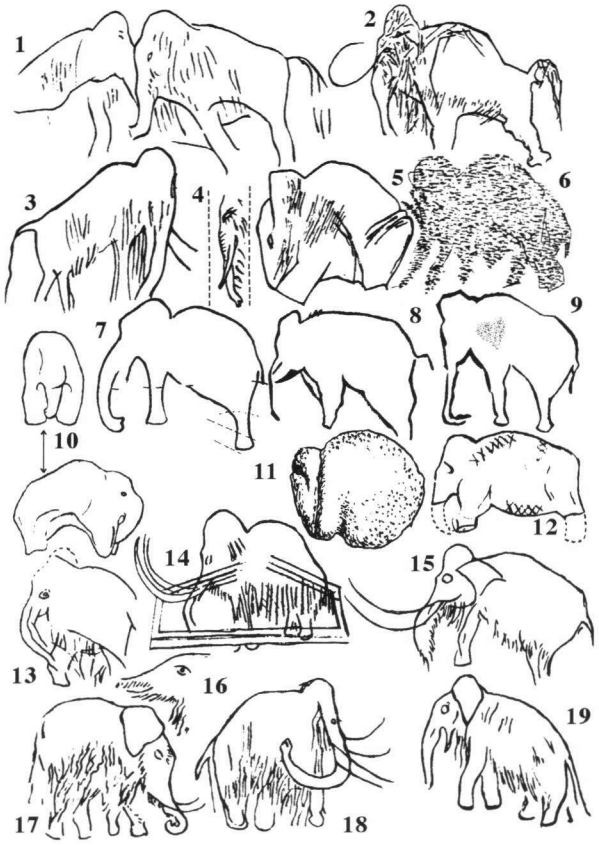

Fig. 2 A series of Paleolithic drawings of mammoths from the survey of Powers and Stringer (1975), with additions: 1) Bas relief on deer antler (Laugerie Haute, France). 2) Engraving on mammoth tusk (La Madeleine, France). 3) Black outline drawing (Pech Merle, France). 4) Engraving on a bone point (Saint-Mihiel, France). 5) Sculpture from a mammoth vertebra (Predmost , Moravia). 6) Mural painting in ochre (Sulgan-Tas, or Kapovaya, cave, South Ural Mountains, USSR). 7) Mural painting (Les Bernous, France). 8) Red outline on a wall (El Castillo, Spain). 9) Red outline mural and "heart" (El Pindal, Spain). 10) Statuette in marl (Doln -Vestonice, Czech Republic). 11) Statuette in bone (Kostenki I, Russia). 12) Statuette in mammoth ivory (Vogelherd, Germany). 13) Mural engraving (Les Combarelles, France). 14) Mural engraving (Bernifal, France). 15) Mural engraving (Les Combarelles, France). 16 & 17) Mural engraving (Arcy-sur-Cure, France). 18) Mural engraving (Les Combarelles, France). 19) Mural engraving (Arcy-sur-Cure, France).

Fig. 2 Een reeks Paleolitische tekeningen uit het overzicht van Powers en Stringer (1975) met enkele toevoegingen: 1) bas reli f op hertengewei (Laugerie Haute, Frankrijk). 2) gravure op mammoet ivoor (La Madeleine, Frankrijk). 3) schetsmatige weergave in zwart (Peche Merle, Frankrijk). 4) gravure op benen punt (Saint-Mihiel, Frankrijk). 5) Sculptuur van een mammoetwervel (Predmost , Moravi). 6) wandschildering in oker (Sulgan-Tas, of Kapovaya, grot, zuidelijke Oeral, USSR). 7) wandschildering (Les Bernous, Frankrijk). 8) schets in rood op een wand (El Castillo, Spanje). 9) rode schematische wandschildering en "hart" (El Pindal, Spanje). 10) sculptuur in mergel (Doln -Vestonice, Tsjechi). 11) sculptuur van bot (Kostenki I, Rusland). 12) sculptuur van mammoet ivoor (Vogelherd, Duitsland). 13) wandgravure (Les Combarelles, Frankrijk). 14) wandgravure (Bernifal, Frankrijk). 15) wandgravure (Les Combarelles, Frankrijk). 16 & 17) wandgravure (Arcy-sur-Cure, Frankrijk). 18) wandgravure (Les Combarelles, Frankrijk). 19) wandgravure (Arcy-sur-Cure, Frankrijk).

of tusk. Mammoth sculptures were carved by stone tools out of fragments of tusk, or from marl or slate. These completed figures may have been talismans or clan totems. Their several possible uses and meanings are not discussed here. What is more important to note here is that the ancient artists knew living mammoths well, and could represent their motions and habits in paintings and engravings.

As a rule, in discussions of representations of ancient art the difficulty with which these paleo-artists came into conflict with their primitive technological resources is not taken into consideration. Further, corresponding to our theme we refer only to the representations of mammoths that help us understand the nature and true-life image of these animals. To this end, we have re-examined the primary sources: for example the work of Breuil et al. (1910), the splendid publications of Leroi-Gourhan (1965) and Graziosi (1956), the catalogue of Müller-Karpe (1966), and the shorter article on cave drawings of Pleistocene animals by Powers and Stringer (1975) (Fig. 2).

The outline drawings in the cave at Font de Gaume (France) provide the greatest amount of information for the reconstruction of the mammoth's body (Breuil et al., 1910). In western Europe's Upper Paleolithic mammoths were drawn standing in profile. These drawings show mammoths as large-headed, humpbacked animals with a sharply pronounced neck inlet and notably lowered hindquarters. Figure 3 shows characteristic examples from Font de Gaume. This lowered hindquarters, which is unnatural, may partially be a result of perspective, i.e., the portrayal of the animals moving towards the observer from some angle. In sculptures, as a rule, the "hump" is located in the middle part of the back. The archedness and the location of the highest points of the profile of the spine at the border of the chest and waist of proboscideans has been fully justified as causing the stability of the spinal column, supporting the huge load of internal organs. This arch is particularly characteristic of the Asian elephant.

In antiquity the head was drawn or sculpted as a rounded bump in the "standard" position, that is, with the forehead and trunk line sloping slightly anteriorly or with this line oriented vertically. The dimensions of mammoth heads, judging from the drawings, were notably larger than those of present-day elephants. In representations, the highest point of the mammoth's body was located, as a rule, at the top of the head. In the neck region there is almost always drawn a sharp indentation. The trunk, tusks, tail, and legs are portrayed clearly only in drawings. In sculptures and painted representations these features are only slightly defined. As a rule, ears were not represented. Ears did not draw the attention of the artists, being half-hidden in wool. The representation of mammoths with large, leaf-like ears similar to those on Asian elephants occurs in mural engravings from the French caves Les Combarelles and Arcy-sur-Cure (Fig. 2, portraits 15, 17, 19). These representations possibly point to the attempt to denote good hearing. On the other hand, eyes were nearly always drawn as small circles and sometimes also outlined by a single line portraying the eyelid.

In a large portion of the ancient representations, the trunk was depicted with normal proportions, i.e., those characteristic of modern elephants. In engravings of males portrayed in the cave at Les Combarelles, France, however, the trunk is exceptionally massive and long, and is even shown to be dragging on the ground [Editor's note: fide Gary Haynes, pers. comm., 1998, trunk dragging is normal for African elephant bulls]. The end of the trunk is shown either as simply rounded or as split into two extensions, as for example, in representations in the caves of Grand Pierre and Les

Combarelles. The base of the trunk at eye level almost always has a characteristic bulge at the skull's nasal aperture. As is well known, a similar bulge appears on modern elephants, allowing air to pass freely through the trunk and into the skull. In addition, the bulge is the summit of the forehead-facial profile.

The tusks are represented either as gently sloping, sabre-like, and curved, or are only crudely drawn lines. The tusk's spiral twists were apparently difficult to engrave or outline well, and therefore were not attempted.

In most cases, the tail was represented as a small, hairless appendage, terminating halfway down the hip. In two cases, at Les Combarelles and La Madeleine, the tail was engraved as erect with a hanging hairy plume, which pose, in analogy with elephants, is characteristic of an infuriated, attacking animal. Either all four legs are represented, or only two are portrayed, that is from one side. In sculptures as a rule the legs are not modelled, or they are marked only as short, massive protuberances. The hoofs or toenail plates of the feet are not portrayed since this would have been very difficult to achieve with the technological means available.

The vast majority of representations of mammoths discovered in European sites was executed with an incising technique, sometimes with the addition of pigment. Lines incised with flint engravers on limestone walls were painted with powdered iron-red ferrous and manganese pigments, ground and mixed with fat. At French sites representations primarily depict adult males in static poses; representations of mammoths in dynamic poses are rare, comprising approximately 10% of known examples. The representations usually are small, measurements being on the order of 20 × 30 cm.

Fig. 4 A lying-down female mammoth, probably dead. Gönnersdorf site; Bozinsky and Fischer, 1980.

Fig. 4 Liggende mammoetkoe, waarschijnlijk dood. Gönnersdorf; Bozinsky and Fischer, 1980.

At the Gönnersdorf site in Germany, Bosinski and Fischer (1980) discovered a great number of pictures of horses and mammoths, drawn with brush strokes on slate tablets. There, the drawings are primarily of half-grown females (Fig. 4). Importantly, this series of drawings has permitted us to distinguish three growth stages of mammoths in Paleolithic drawings: mammoth babies, half-grown individuals of both sexes,

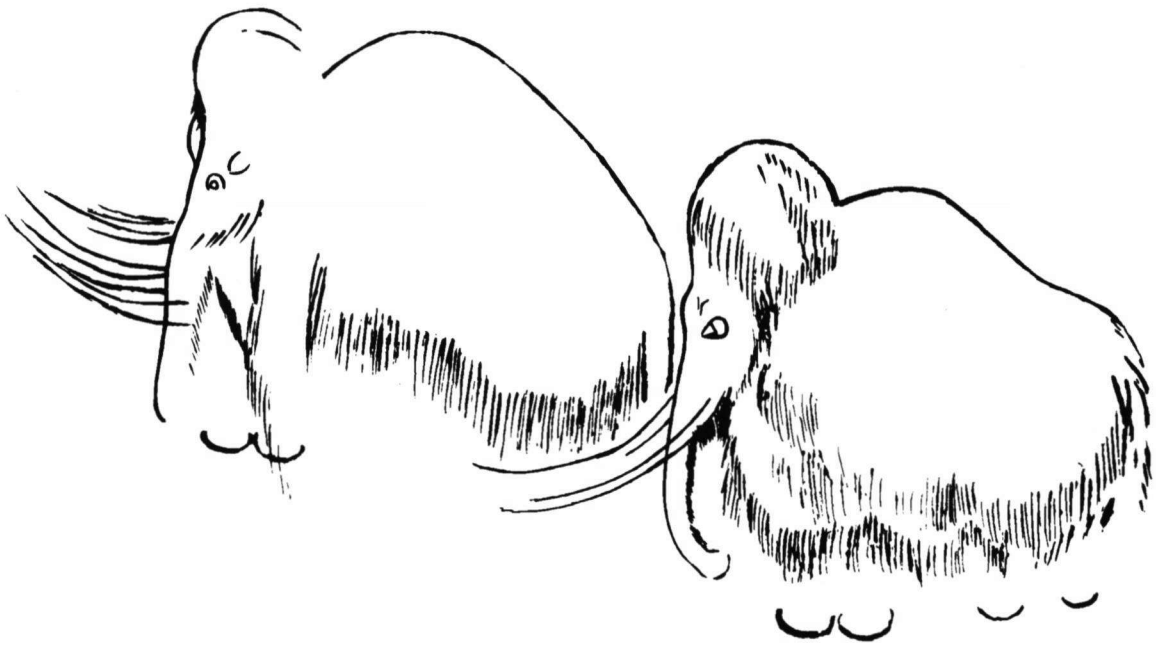

Fig. 3 Typical outline drawing of mammoths from a cave at Font-de-Gaume (France).

Fig. 3 Typische schematische weergave van mammoeten uit een grot bij Font-de-Gaume (Frankrijk).

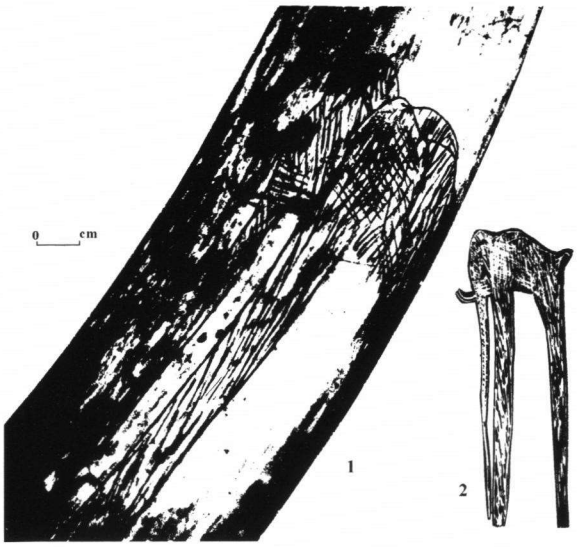

Fig. 5 1) Representation of a mammoth in mammoth ivory from the Berelekh site. 2) A tracing of the image by the artist Nakharito (Bader, 1977).

Fig. 5 1) Afbeelding van een mammoet in mammoetivoor uit Berelekh. 2) Een reconstructie van de afbeelding door de tekenaar Nakharito (Bader, 1977).

and adult males and females. Previous attempts at distinguishing the seasonal changes in pelage from Paleolithic drawings, that is, summer and winter hair length from animals represented as fully covered with hair (Osborn, 1942), had little foundation. Attempts such as those by Garutt (1960) to identify large, medium, and small forms of mammoths in ancient drawings are premature and, in our view, insupportable.

Within the boundaries of the former USSR there are outline drawings and sculpted representations of mammoths, for example sculptures from the Kostenki I, Avdeevo, and Malta sites (Abramova, 1962). Important discoveries were made in the 1960s in Sulgan-Tas, or Kapovaya, Cave in the southern Urals, and subsequently in Ipatyevskaya Cave. Painted murals in Kapovaya Cave were drawn with powdered ochre on a calcite wall of the cave's second level. The pictures were preserved for millennia under a thin coating of calcium carbonate deposits (Bader, 1968). These deposits obscured the paintings and saved them from probable destruction by subsequent cave visitors. The mammoths represented in Kapovaya Cave are adult males in basic features and proportions of their build; they are not notably different from western European examples (Fig. 2, portrait 6).

The figure from the Berelekh site in Yakutia, described by Vereshchagin (1977), is particularly unique. On the terminal fragment of a tusk having a diameter of 65 mm there was engraved the figure of a mammoth with excessively long legs and trunk, exceeding the height of the body by a factor of five (Fig. 5). Small upturned tusks were directed perpendicular to the plane of the forehead and the tail was raised in a display of aggression. The figure was viewed by archaeologists to be latest Paleolithic (Bader and Flint, 1977) [the dating of the Berelekh site is within the interval 10 - 12 thousand years ago (years BP)], although such stylization is not characteristic of that epoch. The geologist Gromov hypothesized that the ancient artist saw only the carcasses of mammoths, thawed from frozen ground, and had not observe the living animals. Therefore "for insurance" the artist lengthened the legs and the trunk of his representation. Present day artists, however, argue differently. In their view the ancient artist, in his drawing, presumably focused on the most familiar feature–the long and narrow tusks–and thus the vertically-lengthened representation of the mammoth is understood as a natural and faithful interpretation of what the ancient artist observed.

Now we examine the characteristic proportions of the mammoth body in ancient drawings. We used published measurements and made our own on selected painted outlines, engravings, and sculptures from Paleolithic sites in western and eastern Europe. (Table 1).

Although there is some variance in the figures we studied we can generalize that in the huge territory of Eurasia inhabited prehistorically, the tendency in the representation of mammoths is for a uniformity of body proportions. This must imply only one thing–the object was realistically reproduced by the paleoartists.

Usually mammoths were represented with straight legs, i.e., with minimal angles of deflection of the levers of the long bones (humerus-ulna, femur-tibia), from the straight line constituting them. The paired extremities of modern elephants (especially those in Africa) are disposed exactly in this way, both at rest and in motion. This can be easily discerned in a series of excellent photographs of African elephants by I. and O. Douglas-Hamilton (1976). Such a straightened position of the paired extremities, retained in living elephants and responsible for their surprisingly swift gait, is entirely natural when one bears in mind the elephant's colossal load of several tons of muscle and other soft tissues. Gigantic terrestrial dinosaurs had similar locations for the levers comprising the legs, and presumably also an elephant-like gait, with left and then right side pacing movements.

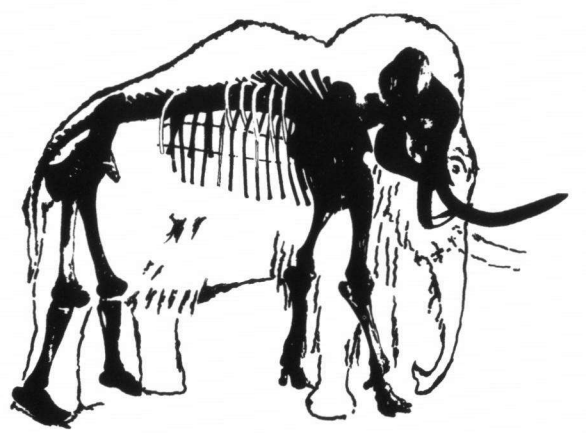

Fig. 6 The skeleton of the Berezovka mammoth roughly traced inside the outline of the animal at the cave in Les Combarelles (France).

Fig. 6 Het skelet van de Berezovka mammoet geprojecteerd in een mammoettekening van de grot bij Les Combarelles (Frankrijk).

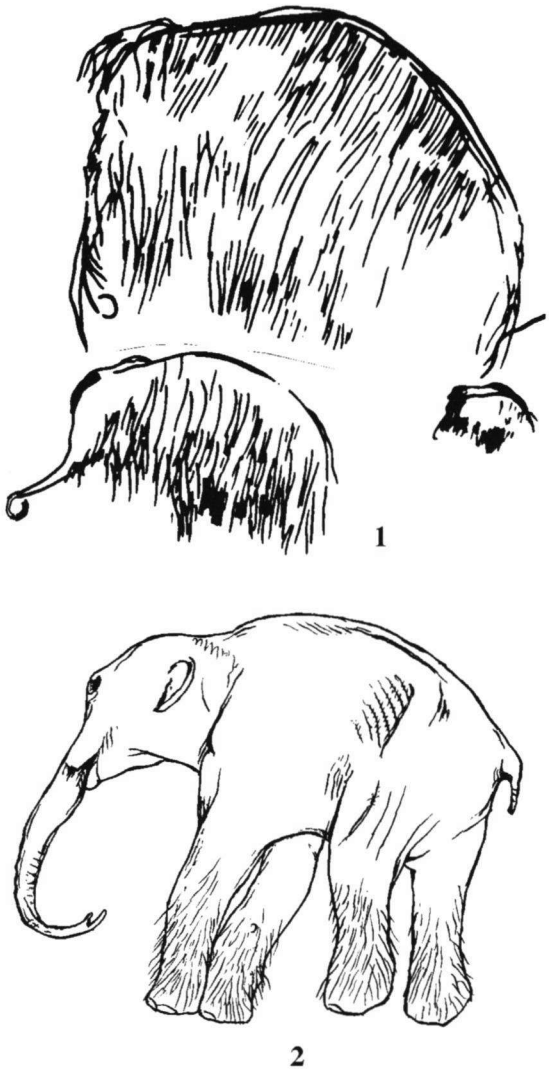

Fig. 7 Outlines of drawings: 1) Three baby mammoths from the Gönnersdorf site. 2) Magadan baby mammoth (note similarity).

Fig. 7 Vergelijking van tekeningen van drie baby-mammoeten van Gönnersdorf (1) met de Magadan baby (2).

Accurately mounted skeletons of mammoths in museums allow us to evaluate ancient representations in relation to the proportions of the framework of these animals and in this way to notice any discrepancies and deviations.

We compared ancient representations with the outlines of accurately mounted skeletons and observed clear disparities–the skeletons do not conform within the contours of the ancient representations (Fig. 6). In the representations mammoths are shown to be excessively large-headed and too extremely humped; they are also portrayed too low in the hindquarters. The inconsistencies are obvious from differences in the indexes of body frameworks calculated for the ancient drawings and engravings (Table 1) and for the skeletons from the collection of the Zoological Institute (Table 2).

The index of size calculated from the skeletons is 78% [(oblique length)/(height at withers) x 100]. This value was on average 3.3% less than the same index calculated from the ancient representations. The difference is explained, possibly, by the mentioned foreshortening in the ancient representations, by the presence of a disheveled mane, and even the fatty hump at the withers, above the spinous extensions of the thoracic vertebrae. A similar difference is seen in the index of height at the rump [(oblique length)/(height at sacrum) x 100] which equals 98.6% for the skeletons, as opposed to 103.8% when calculated from the representations.

The difference in the index of head length [(length of head)/(height at the withers) x 100] of 43% for the skeletons as opposed to 46.7% for the representations appears to confirm the presence of a fluffy parietal (sinciput, summit of the head) "coiffure" that the contemporary people depicted in their art and presumably saw in life. It is also characteristic of ancient representations from sites in western Europe and the southern Urals, that in 96% of the cases the sinciput occupies the highest point of the body. We should make a revising statement to the effect that the extreme lowness of the hindquarters, or the sloping of the hind end, of the mammoths in the creations of the paleoartists is not absolute but is only characteristic of representations of old males, when the shoulder-withers hump and the shaggy hair covering of the head is emphasized. For 25 outline drawings of mammoth males from French sites, conspicuous lowering of the hindquarters occurs in 75% of the examples. At the Gönnersdorf site, with its depictions primarily of young female mammoths, a distinct lowering of the hind end is observed in only 11% of the 27 representations. The ancient artists drew outlines of young females (from 10 to 15 years in age) with only a slightly fashioned head, a thin bare trunk, sometimes with small tusks, with no shoulder-withers hump, and with a weakly convex back. At the same site a clear representation of baby mammoths occur, of which the contour of the head and spine form a single weakly curving arch; at the front end a slightly twisted trunk is represented by a thin stroke, and there is a small protruding tail.

Fig. 8 Characteristic suspension of outer hair under the trunk and on the chest of the mammoth. Rubicon Cave, France.

Fig. 8 De typisch hangende buitenvacht onder de slurf en de borst van de mammoet. Rubicon Grot, Frankrijk.

Here it is appropriate to discuss the juvenile features of the body of the baby mammoths as represented at Gönnersdorf and to compare these features with the frozen carcass of the six-month-old Magadan baby mammoth (Dima). Bosinski and Fischer (1980:33, pl 88; table 4) illustrate the young (less than one year old) Gönnersdorf mammoths. As is known, the exterior features of adult individuals are usually subdued in young animals and thus are masked in juveniles. The index of size of the young Gönnersdorf mammoths is approximately 86-88%. For the Magadan baby mammoth this index equals 74% at the withers and 75.5% at the sacrum (author's data, presented in Vereshchagin and Mikel'son, 1981); when the lines of the head, neck, and spine are brought to one and the same scale, however, they are very similar (Fig. 7). It is characteristic that there is no "hat" of hair on the head or a neck inlet, but there is an abundant hair covering of the body.

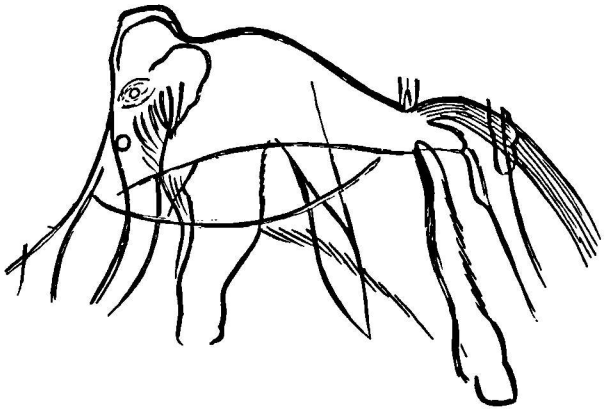

Fig. 9 The powerful trunk and uplifted tail, characteristic of aggressive animals. La Madeleine Cave, France, (Breuil, 1910).

Fig. 9 De krachtige slurf en opgeheven staart, kenmerkend voor agressieve dieren. La Madeleine Grot, Frankijk (Breuil, 1910).

Attempts by paleo-artists to represent the topography of the hairy covering and its distribution on the body give especially valuable insight into the real-life image of mammoths. Ancient representations on stone and bone, as a rule, portray mammoths with a smooth contour of the head and spine and with a large "fringe" of long (up to 1 m) straight hair, hanging down in the appearance of a "skirt." This skirt hangs from the dewlap, sides, and underbelly. The series of representations at Font de Gaume and Rubicon caves (France) (e.g., Fig. 8) provide the most information concerning hair covering. In these depictions it is clearly visible that the dense covering of the trunk was directed downwards and forward. It obviously concealed the circular skin folds of that organ. The hair trimming the under (ventral) side of the trunk was well marked; moreover the hair was longer than on the upper (dorsal) side, at least twice as long, and near the trunk tip still longer. The coarse, long hairs of the head were also directed forward. The forward-directed "fringe" of long hair, or forelock, descending from the top of the head to the forehead as well as on the sides of the head, and also the large "beard" under the jaw and on the neck, were portrayed clearly and confidently.

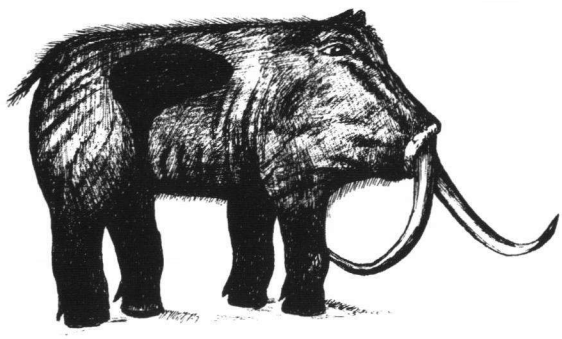

Fig. 10 The Adams mammoth, drawing by R. Boltunov.

Fig. 10 De Adams mammoet, tekening door R. Bultonov.

Especially long "fringes" of hair on the trunk, chest, sides, and belly were portrayed in outline drawings of mammoths in Pech Merle Cave (southern France) (Graziosi, 1956).

Hair was rarely drawn on the tail. An elevated hairy tail, in an attitude characteristic of aggressive animals, was portrayed on a fragment of bone from La Madeleine Cave (France) (Fig. 9). A woolly covering of the shoulders, sides, thighs, and hips was always marked by lines transversing the body. Such peculiarities of the topography of the woolly coat have been con-

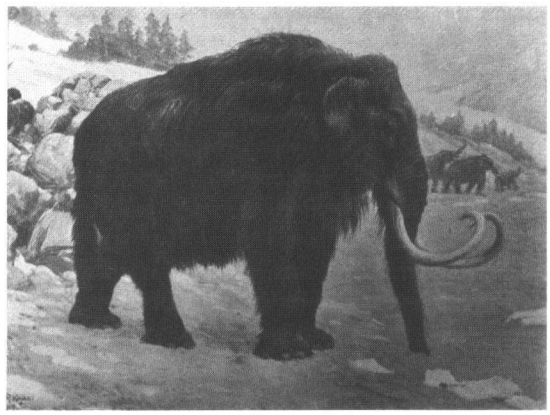

Fig. 11 1) An old mammoth in the representation by Charles Knight (Digby, 1926). 2) A herd of mammoths in the representation by Charles Knight (Osborn, 1942).

Fig. 11 1) Een impressie van een oude mammoet door Charles Knight (Digby, 1926). 2) Een impressie van een kudde mammoeten door Charles Knight (Osborn, 1942).

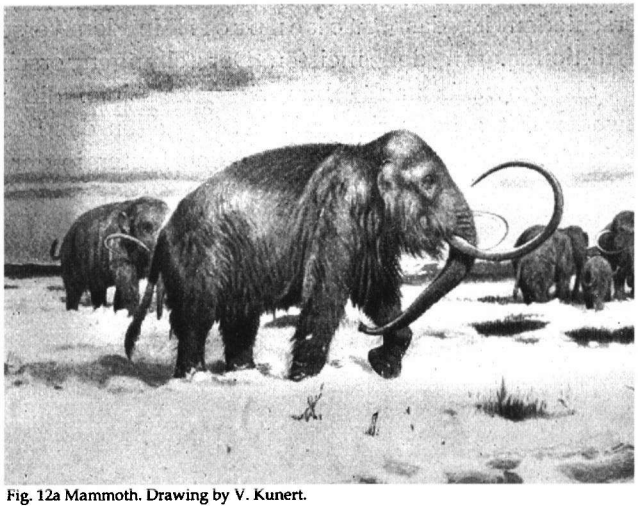

Fig. 12a Mammoth. Drawing by V. Kunert.

Fig. 12a Mammoet, tekening door V. Kunert.

firmed in the Gönnersdorf site's series of drawings of half-grown mammoths and baby mammoths.

This seems so far to exhaust the information on topography of the woolly covering of mammoths gathered on the basis of Paleolithic representations.

The mammoth in representations of modern artists

Artist-naturalists and dilettantes have in the past and continue today to expend much effort in the reconstruction of the external image of the mammoth and its "attire". The first attempt in Russia belonged, apparently, to the merchant Roman Bolsunov, one of a few people who observed the carcass of a mammoth found near the Lena River delta in 1803. His unsophisticated drawing of the four-legged animal with a straight, angular body, no trunk, and with tusks illustrated and positioned in the appearance of the dovetail of an anchor (Fig. 10), was repeatedly reproduced in print

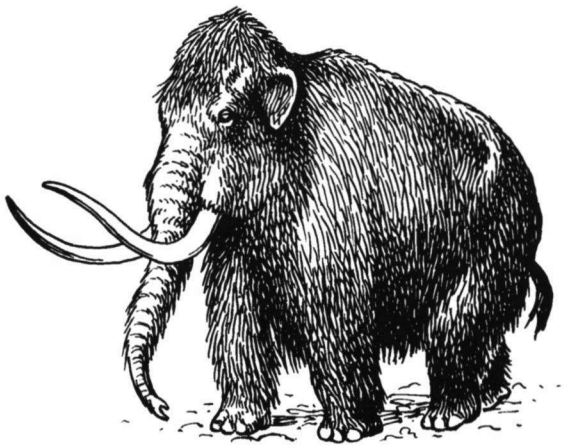

Fig. 12b Male mammoth. From Pfizenmayer (1939).

Fig. 12b Mammoet stier. Uit Pfizenmayer (1939).

(Bolsunov, 1866). This drawing provided little information representing the mammoth's figure and hairy covering. Short wool was schematically shown along the spine, on the small tail, and hanging from the neck and belly. The right shoulder was portrayed as bare; probably a result of the wool having been sloughed or damaged there. The lateral hanging hooves portrayed by Bolsunov on the legs possibly depicted the coarse hair, or "brushes," on the wrists and tarsals.

French artists whose pictures at the beginning of the century were displayed at the museums of Paris, in particular the Museum of Human Paleontology, more or less accurately represented mammoths. There is without a doubt an influence from prehistoric drawings and the guiding direction of French archaeologists in these compositions.

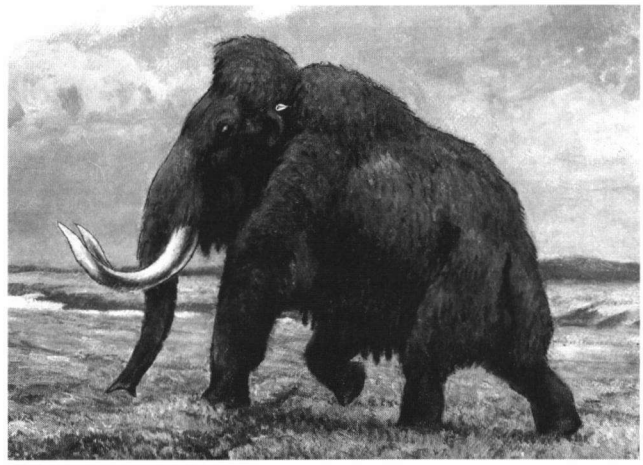

Fig. 13 An adult male mammoth, in a picture of K.K. Flerov. This is considered one of the best representations, but it has the characteristic shortcomings: a strongly lowered rump, short hind legs, a bare trunk, etc.

Fig. 13 Een volwassen mammoet stier in een afbeelding van K.K. Flerov. Deze tekening wordt gezien als een van de betere reconstructies, maar ook hier zien we de veel voorkomende fouten: een sterk verlaagde romp, korte achterpoten, een onbehaarde slurf, enz.

In natural history museums in New York, Los Angeles, and other cities in the United States, the artwork of Charles Knight is exhibited. One of his representations depicts a tranquilly standing male mammoth (Fig. 11a). The massive straight angular body with a pronounced posteriorly-sloping contour of the spine, a small head similar to that of an Asian elephant, excessively large ears, a bare tail, a trunk lowered to the level of the heels of the feet, five toenails instead of the typical three, and a coat too sparse for the winter season depicted are typical inaccuracies and errors of this representation. The photograph of this picture is from Digby (1926). More realistically rendered mammoths, in herd groups or as individuals, characterize other portrayals by Knight, as do reproductions in Carrington (1958:124) and in the monograph by Osborn (1942) (Fig. 11b). Cristmen, illustrating the earlier of Osborn (1924), depicted mammoths almost devoid of a woolly coat. The erroneous naked trunk and unusual position of the tusks can be seen on the drawing by Kunert (Fig. 12a). A more or less authentic early image of a mam-

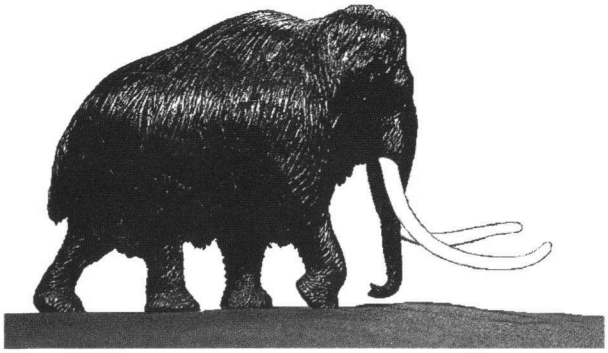

Fig. 14 Plastic statuette of an old mammoth, British Museum (Natural History).

Fig. 14 Plastic beeldje van een oude mammoet, British Museum (Natural History).

moth in our view was conveyed in a line drawing by Pfitzenmayer (1939) (Fig. 12b).

During the 1950s and 1960s the pictures of the artist-zoologist Flerov were exhibited at the Paleontological Museum of the USSR Academy of Sciences in Moscow (e.g., Fig. 13); at the Zoological Museum in Leningrad, the pictures of the artist Steinberg were exhibited. Figures of adult mammoths and of baby mammoths in static pose and in motion were borrowed by Flerov from the French artist-naturalists working at the beginning of the century. The artist Zakharov, in our opinion, satisfactorily represented mammoths. Also quite accurate is the work of the Czech artist Burian (Augusta and Burian, 1962).

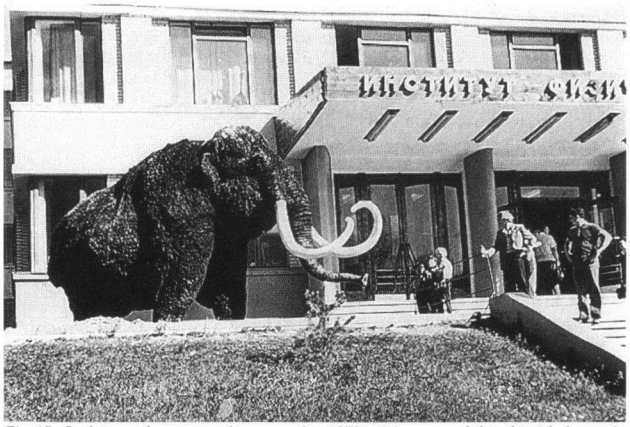

Fig. 15a Sculpture of a mammoth prepared in 1979 in Moscow, exhibited in Khabarovsk.

Fig. 15a Mammoetbeeld dat in 1979 in Moskou gemaakt is, tentoongesteld in Khabarovsk.

There have been repeated attempts at reconstructing the general appearance of mammoths, including its "attire." These attempts represent huge stuffed animals in various museums of the world, as well as statuettes in plastic and ceramics, including porcelain.

A stuffed mammoth, of near natural size, was prepared and exhibited in London at the beginning of the 20th century by the well-known museum proprietor P. T. Barnum. The massive trunk was depicted bare and with transverse wrinkles modelled in relief, tusks were placed as gigantic whiskers directed sideways, and on the feet five toenails were moulded. The photograph of this stuffed animal was also reprinted in the book by Digby (1926).

In the 1970s the British Museum (Natural History) produced a large number of copies of a sculpted plastic figure of a male mammoth measuring 8 x 12 cm. It is a handsome toy, but as a reconstruction it is faulty: the hind end is excessively lowered, its bare trunk has short terminal processes, its tusks are disproportionately thin, and it has five toenails on the uncovered feet (Fig. 14). Finally, a stuffed black mammoth of natural size, the work of Moscow designers, was displayed in Khabarovsk in 1979, at the XIVth Pacific Ocean Congress (Fig. 15a). The Khabarovsk reconstruction was angular and possessed a trunk not covered in wool. For their reconstruction of the outer appearance of the mammoth the Moscow designers and fabricators relied primarily on Paleolithic representations, having conceived their mammoth without due critical analysis or adequate study of paleontological materials.

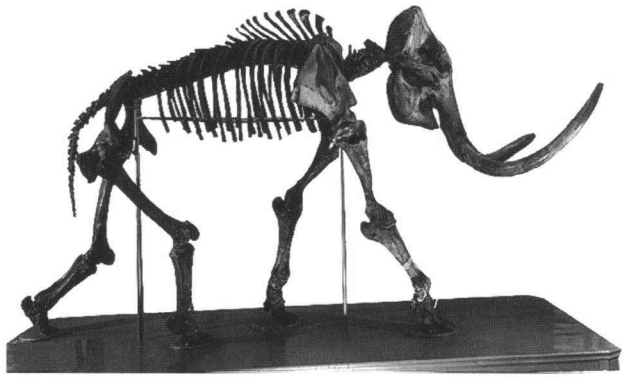

Fig. 15b Skeleton of the Taimyr mammoth.

Fig. 15b Skelet van de Taimyr mammoet.

Paleontological finds of mammoths

In our survey of paleontological discoveries we examined three mounted skeletons of adult males; a large series of long bones and girdle elements of primarily female mammoths comprising four adult groups from the Berelekh "cemetery"; the carcass of the Magadan (Kirgilyakh) baby mammoth (popularly called Dima); a series of tusks from the intertidal zone of the Laptev and East Siberian seas and from the Berelekh mammoth "cemetery"; as well as samples of soft tissues, wool, and skin from several different mammoth carcasses.

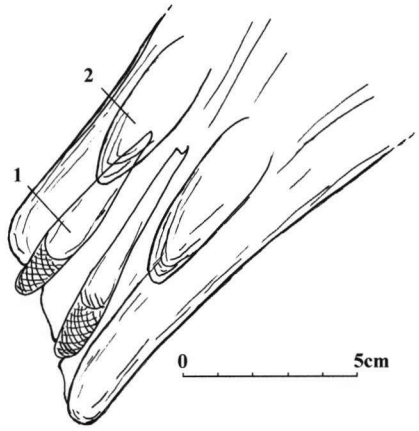

Fig. 16 The positioning of the milk tusks in the jaw - 1) milk, and 2) permanent tusk of the 6-month Magadan baby mammoth. One can see the enamel caps of the first and their remains on the second. Based on an x-ray image.

Fig. 16 De positionering van de melkstoottanden in de kaak - 1) melk, en 2) permanente stoottanden van de 6 maanden oude Magadan baby mammoet. Men kan de email-kapjes bij de melktanden zien en de aanleg daarvan bij de permanente stoottanden. Gebaseerd op een röntgenfoto.

Skeletons

In Russian and foreign museums skeletons of mammoths have been mounted more or less correctly, either in a static pose of "attention" or dynamically, as though walking slowly on extended limbs. These mounts correspond to the previously mentioned reconstructions based on the levers and mechanics of movement of modern elephants. The desire of some taxidermists to give the skeletons other dynamic poses, for example, a stalking, "catlike" posture with bent-kneed hind legs, however must be rejected (Fig. 15b.)

The scarcity of full skeletons combined with the absence of stuffed and mounted specimens/individuals of female mammoths in Russian museums prevents us from describing sex-specific differences based on the bones of the skeleton, including the skull (one partial female skeleton is displayed in the museum in Novosibirsk). Judging from the skeletal remains from Berelekh collected by us in 1970 from Yakutia, female mammoths on average were however smaller than males, with smaller and less massive long bones and girdle elements comprising the extremities (Baryshnikov et al., 1977). Females also differ on the basis of their tusks.

Tusks

Our study of 235 tusks of mammoths of different ages and sexes shows the presence of sexual differences and also reveals characteristics of the dynamics of growth. Milk tusks were cut by mammoth calves from the gingiva (rostrum) at six months and grew to 5 - 6 cm in length. An enamel cap was developed on their tips. The loss of the milk tusks and their replacement by the permanent set, lacking enamel, occurred at 12 - 18 months of age (Fig. 16). The tusks grew slowly during the first 10 - 15 years of life, but by 20 - 25 years tusks had reached a length of 100 - 120 cm with an al-

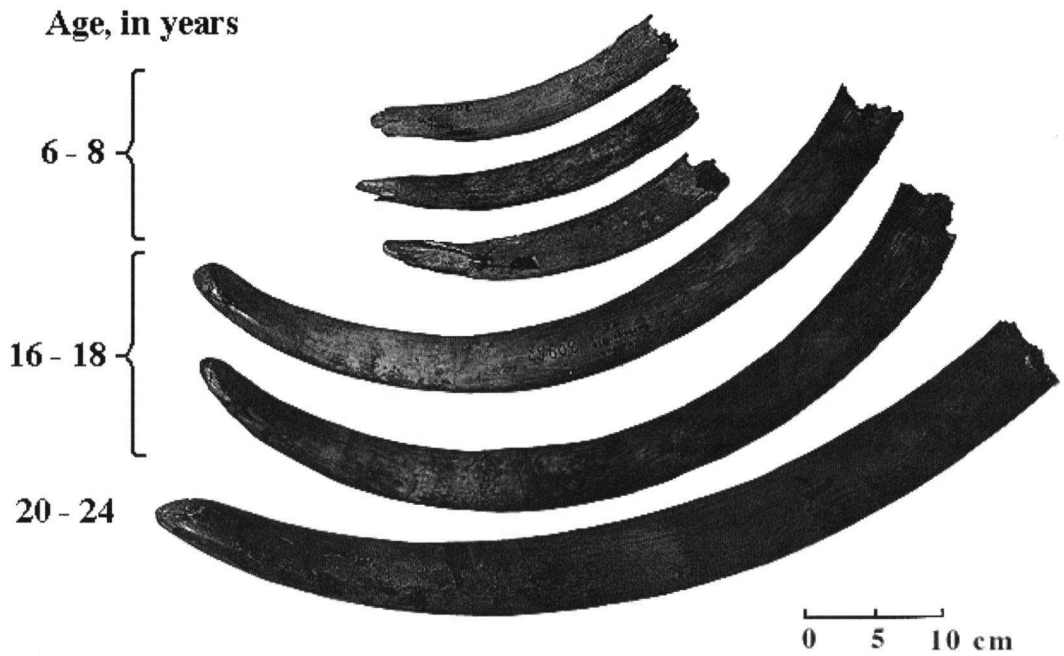

Fig. 17 A series of left tusks from young females at the Berelekh "cemetery". The initial zones of wear on the ends are visible. The approximate age in years of the groups is shown.

Fig. 17 Een serie linker stoottanden van jonge vrouwtjes van het Berelekh "kerkhof". Aan de uiteinden zijn de eerste slijtzones zichtbaar. De tanden zijn geordend naar de geschatte leeftijd.

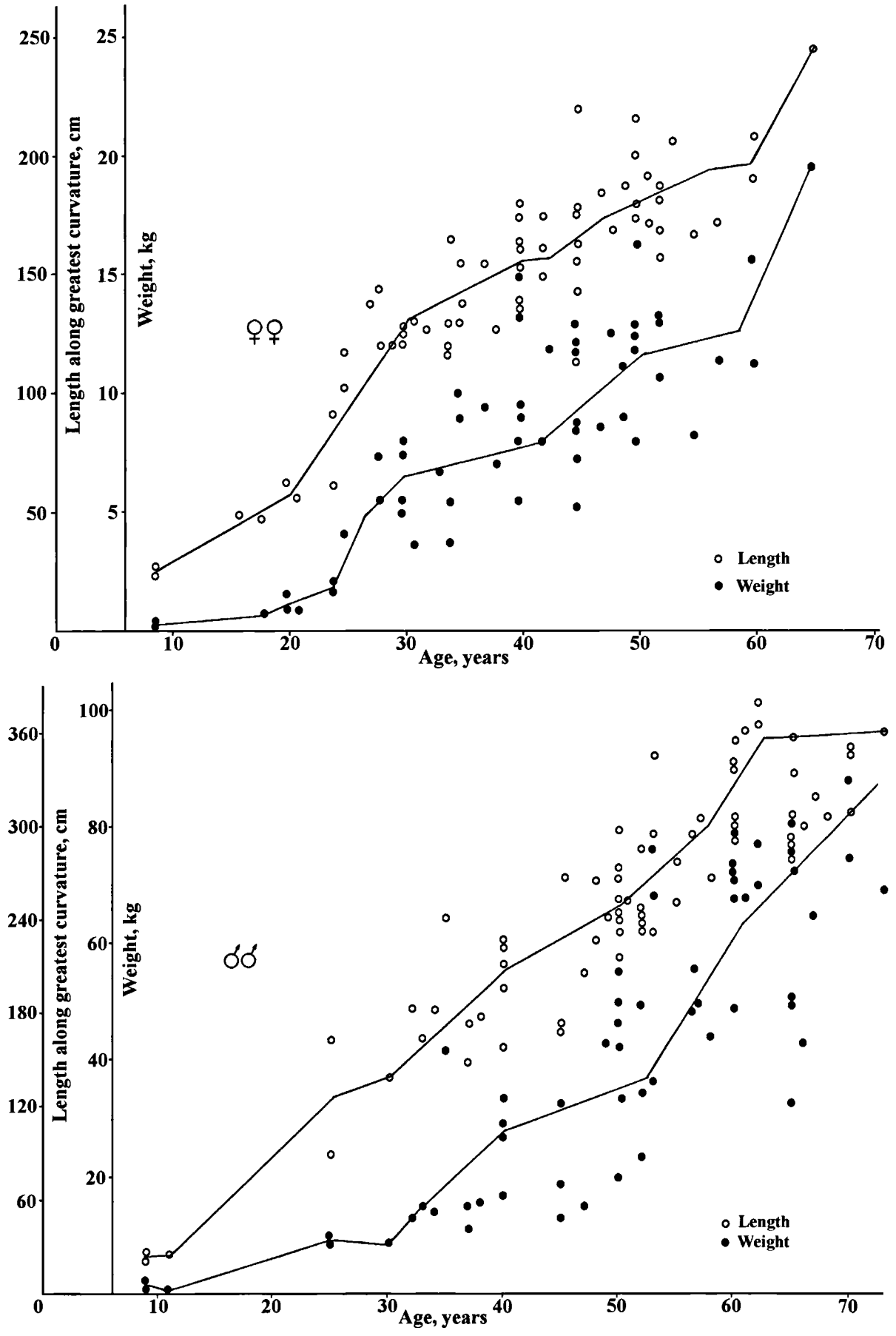

Fig. 19 Diagrams of the growth in length and mass of tusks a) in females, and b) in males. Upper curve = length in cm, lower curve = weight in kg.

Fig. 19: Diagrammen met de groei van slagtanden in afmeting en gewicht bij a) vrouwtjes, en b) mannetjes. Bovenste lijn = lengte in centimeters, onderste lijn is gewicht in kilogrammen.

veolar diameter of 50 - 60 mm. From the moment a tusk emerged, its tip was continually worn back, commencing at the outer, lateral surface (shown by the formation of a ground facet) (Fig. 17). During growth, the tusks of males, branching off to the sides and curving sabre-like in the vertical plane, began to twist inward slightly by 30 - 40 years of age, with the tips converging, i.e., the left toward the right, and the right toward the left (heteronomously), with the formation of a gently sloping spiral. This twisting spiral was weaker or entirely absent in tusks of females. With twisting of the tusks the wear facets at their ends moved in stages from the outside to the inside of the tusk. During the second half of the individual's life, three wear facet stages had developed (Fig. 18). Tusk growth for females and for males are shown in Figs. 19a, b. The maximum length of tusks of males along the greatest curvature reached 380 cm. These maximum tusks attained a weight of 86 kg and had a diameter at the alveolus of 18 cm. Corresponding measurements of the tusks of females are 247 cm, 19.7 kg, and 9.3 cm. Presumably there were larger specimens, i.e., in males up to 400 cm in length and 100 kg or more in weight. Right and left tusks are readily distinguished on the basis of curvature (Vereshchagin and Tikhonov, 1986). The base of the trunk of mammoths was situated directly on the tusks, since the tusk alveoli were situated adjacent to one another and in a strictly parallel plane. This is a characteristic distinction between mammoths and today's African elephants, the tusk alveoli of which diverge to the sides and are linked by a thin wall. Presently it is possible to find both misshapen tusks and tusks distinguished by great beauty and elegance of form on the littoral or intertidal shelf of the Laptev and East Siberian seas (Fig. 20).

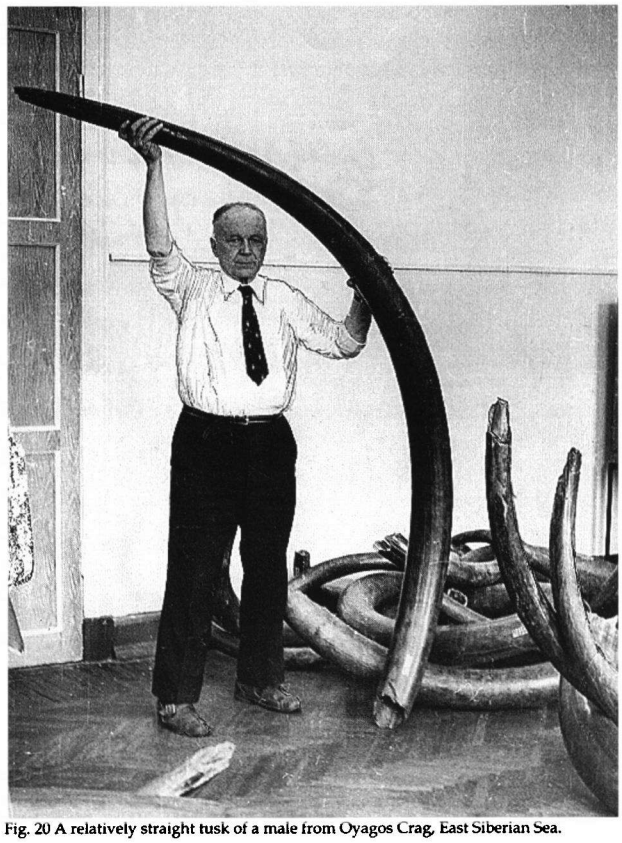

Fig. 20 A relatively straight tusk of a male from Oyagos Crag, East Siberian Sea.

Fig. 20 Een betrekkelijk rechte stoottand van een stier uit Oyagos Crag, Oost Siberische Zee.

Specific discoveries

Here we present details of the structure of the trunk, ears, legs, and woolly covering of the mammoth, on the basis of specific materials.

As is known, the outer appearance (referred to as the build and constitution) of mammals depends to a large extent upon the condition of the fur, to its "developmental stage," and at certain periods, to moulting. In the morphological characterization of the mammoth's woolly covering, basic items of information include: its topography, or distribution on the body of the animal; data from measurements of the length of hair of different varieties and from different body regions, their twisting, combinations and thicknesses, i.e., structure of the strands as well as the diameter ("fineness") of individual fibres; coloration and the distribution of pigment; and the macro- and microstructure of the hair.

Methods of study of the woolly covering of domestic animals, especially those of sheep and the fur-bearing mammals, have been developed around the world, and they have had a long tradition in Russia (Zhitkov, 1928; Sokolov, 1973).

Up to now, the woolly covering of mammoths has been only slightly studied. We discuss the topography, coloration, and macro- and microstructure of the mammoth's woolly covering and its distinct varieties of hair. We have not studied the mechanical properties of mammoth hair (e.g., the tensile strength of fibres, their resistance to wear, or their insulating properties), although the significance of these properties are not yet adequately understood (e.g., Krause, 1978).

Here we present original observations as well as details from literature sources on the woolly covering and soft tissues of the mammoth. As far as possible we have considered questions of moulting and natural coloration, as opposed to colour possibly associated with degradation of hair pigments during the course of deposition and fossilization. In our discussion of the microstructure and topography of the fur, information recorded in Paleolithic drawings, especially in the caves at Les Combarelles and Pech Merle, has been taken into account.

The Lena Mammoth of Adams

An aged male, 65-70 years old; geological age of approximately 35,800 years before the present (B.P.). Discovered in 1799 by the hunter Shumakhov on the Bykovskii Peninsula in a yedoma (a frozen precipice, often with ice wedges, exposed to the sea, a river, or lake) north of the present day Laptev seaport of Tiksi. At the time of discovery the carcass was perfectly in-

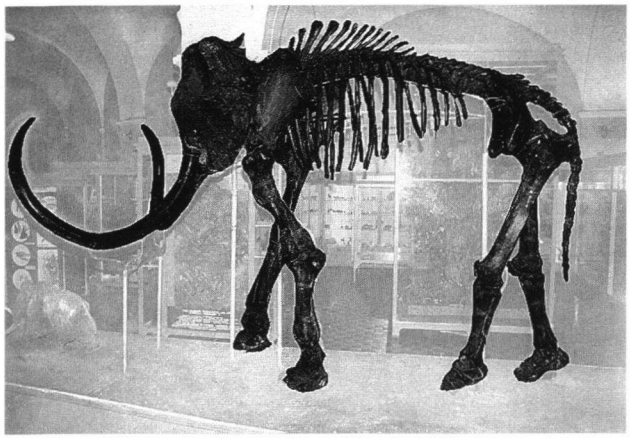

Fig. 21b The same skeleton as in figure 21a, remounted in 1960.

Fig. 21b Hetzelfde skelet als in figuur 21a, opnieuw opgezet in 1960.

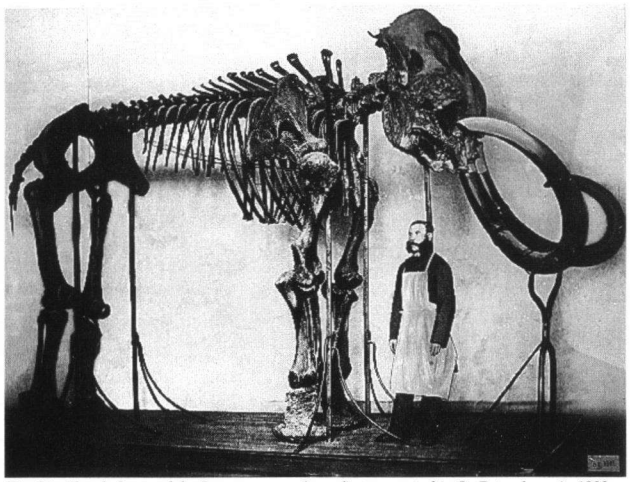

Fig. 21a The skeleton of the Lena mammoth, as first mounted in St. Petersburg in 1808.

Fig. 21a Het skelet van de Lena mammoet, zoals die oorspronkelijk in 1808 in St. Petersburg was opgezet.

tact, including the hair coat. Within six years, the carcass had completely thawed and had fallen from its precipice. The preserved portions including skeleton and scraps of skin and hair were collected and brought to St. Petersburg in 1806 - 08 by M. F. Adams, an adjunct of the Academy of Sciences, with the assistance of the merchant Roman Bolsunov. The material has been mounted (Fig. 21a, b). Dried skin was preserved only on the sides of the head, without attached hair. The right wrinkled ear remained intact. The ear was extended along the vertical axis (38 × 16 cm); the earlobe measured 8 cm in length. In form this is somewhat reminiscent of the ear of a human (Fig. 22). On the soles of the feet (approximate diameter = 46 × 50 cm) four horny toenails were preserved. According to the reports of Bolsunov and Adams, the long wool, sloughed off during the decomposition of the carcass, was of black, reddish, and red-brown colour. The tusks, with a diameter of 18 cm at the alveolus, had been chopped off and removed prior to Adams' arrival. The tusks brought to St. Petersburg with the Lena skeleton, when placed against the alveoli, have a diameter of only 14 cm. This calls into doubt whether the tusks currently associated with this skeleton really belong to it (Adams, 1807).

The Berezovka Mammoth

An adult male approximately 50 years of age. (The determination of individual ages presented here and onward was developed by us on the basis of the tusks. These ages will vary from (typically exceed) ages based on other dental criteria, e.g., tooth wear). The geological age of the mammoth is around 44,000 years B.P. as determined by R. Nydal from Trondheim (Norway) (The majority of other dates were obtained by Kh. Arslanov from St. Petersburg University (Russia).). Excavated by an expedition from the Russian Academy of Sciences, St. Petersburg, under the leadership of O. F. Herz, in 1901 - 02 on the bank of the Berezovka River, a right tributary of the Kolyma River. The trunk was not preserved. The skin of the head and the front portion of the body were also destroyed (Fig. 23).

Herz (1902:154) made the following notes during the excavation: "On the left cheek the hair is up to 23 cm in length, red-brown to black, and with a portion blonde, in colour. The underwool is less thick, than on other parts, the hair is yellowish, as on the whole body, and reaches lengths of 35 mm. Under the throat, behind the lower lip, the guard hair of the awn or beard is black, and towards the legs it becomes ashy-blond.... On the chin and upper chest large bundles of hair reached 36 cm, but bearing in mind that they had broken off, it follows to take [as] their full length 50 cm. On the left shoulder [bone] and, probably, up to the withers the wool is completely ashy or pale-blond. Here it is the longest.... From the left shoulder to the belly the hair at the roots is red-brown, in the middle reddish-blond, and at the ends yellowish. . . . .Thick wool [was preserved] on the lower side of the left front leg, especially on the metacarpal joint. In the midst of yellow-brown underwool, reminiscent of felt and similar in colour to the summer wool of the young camel, there are very many guard hairs 10 - 12 cm in length. The colour of these hairs is roan, and the hairs on the external and inner sides up to the middle of the forearm are dark brown and towards the end they become lighter. Besides this, it is possible to notice five [!] blunt toenail-like ends of the toes.... The wool of the left hind leg varies from rusty-brown to roan, less dense than on the front leg, and the underwool is yellow-brown, here a little shorter. The length of the guard hairs that are broken on the ends varies form 4 to 12 cm. . . . The guard hair and the underwool from the outer side of the right hind leg [from the thigh] is rusty-brown to black in colour.... In the fold of skin between the [penis]... and the hind leg [i.e., in the groin] the crumpled hairs of the underwool reach 30 - 35 mm, the blond guard hairs reach 32 cm.... The tip of the tail with long stiff hairs, their length 20-35 cm, is of a rusty-brown colour, more dense at the very end of the tail and along the sides. The length of the tail along the [under] . . . side is 36 cm.. The bristly hair was resilient in the fresh air, and at room temperature they instantly hardened and became brittle."

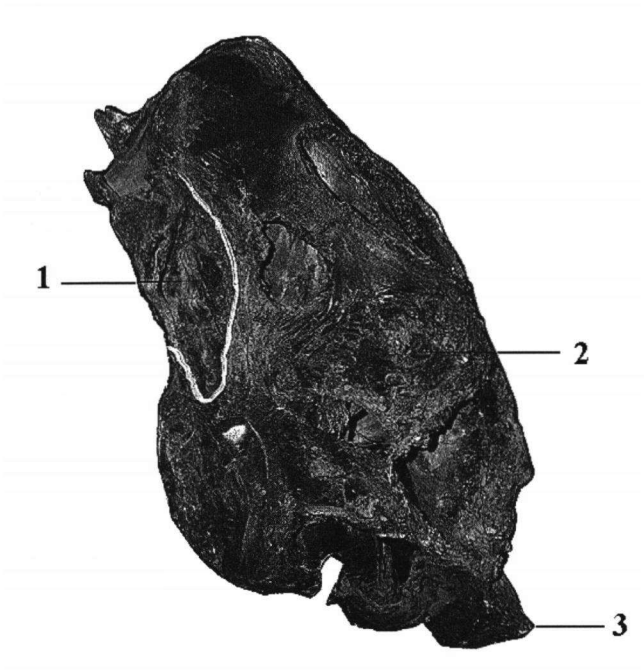

Fig. 22 The head of the Lena mammoth; 1) ear, 2) eye, 3) the base of the right tusk.

Fig. 22 De kop van de Lena mammoet; 1) oor, 2) oog, 3) de basis van de rechter stoottand.

In the reconstructed, taxidermically mounted skin of the Berezovka mammoth in the Zoological Museum of the Russian Academy of Sciences, the topography and coloration of the woolly covering, partly preserved in the skin and partly glued onto the general features, is in accordance with Herz's journal notes. Herz discovered five hooves (or toenails) on the toes of the left front leg. Similar instances of such numerous thick growths of corneous tissue on the toe-sole juncture are known elsewhere and indeed occurred from time to time.

Since its installation the mounted skin comprising the body of the Berezovka mammoth has become world famous as the distinctive emblem of the Zoological Museum. We note the following errors in the reconstruction of its body in the front (plaster-restored) portion: an excessively humped frontal-facial profile; excessively large and highly placed round rather than angular, ears; and a strongly annulated trunk. The sexual organ of the mammoth as displayed is dorsoventrally compressed, sword-like, and is in fact reminiscent of the human's in form. An unknown quantity of wool from the Berezovka specimen was apparently given to other European museums by participants of the expedition. Extensive information about the Berezovka mammoth has been reported in three volumes of scientific results of the expedition of the Imperial Academy of Sciences (1901, 1909, and 1914).

The Sanga-Yuryakh Mammoth

An adult female 50-55 years old, which was entrapped and died in silt on the bank of the Sanga-Yuryakh River in the Yano-Indigirka lowland. The geological age by some determinations is approximately 29,500 years B.P., by others, nearly 44,000 years B.P. The skull, trunk, pieces of skin, hair, and the front and hind limbs were preserved. The time of death, probably, was midwinter, e.g., December or January. Excavations of the mammoth were conducted by K. A. Vollosovich and E. V. Pfitzenmayer in 1908 (Nasonov, 1908).

The following description of the woolly covering is from Pfitzenmayer (1939):"The trunk of this specimen was similar to the trunk of a contemporary elephant, distinguished only by its hairiness along the upper side. . . . Corneous toenails of both front legs, three in number, were well developed. . . . Both of the hind legs had long dark brown bristly ("guard") hairs and short dark coloured wool, of very good preservation. This woolly covering reached the toenails. The guard hairs, covering the carpals and tarsals, were on average 15 cm in length. The guard hairs on the hide above the proximal ulnar articulation of the right leg reached 35 cm in length."

In the same publication by Pfitzenmayer (p. 168) there is a photograph of a piece of skin from the back and the right flank possessing tangled strands of guard hairs approximately 47.5 cm in length.

Much of the wool on the trunk and legs of this mammoth, preserved in the Zoological Museum since 1908, appears to have been lost. The middle portion of the trunk, mounted for exhibition in the shape of an oval arc, is for all practical purposes "naked" on the dorsal surface. The surface of the skin is smooth in those sections with preserved epidermis and rough in the shallow dimples and small wrinkles where the epidermis has been torn off. On the left side of the dorsal part of the trunk, a patch (5 × 5 cm) of brown hair of transitional type having a length of 30 - 40 mm is preserved, but for the most part the hair was broken off, directed forwards and therefore downwards. In the middle of the trunk, on the ventral or under side, sections of soft light brown underwool with fibre lengths of 30 - 50 mm is preserved, possibly bordering on the right side the hairless lower middle region or strip of the trunk. From the left side and from the bottom of the trunk individual dark brown hairs with a length of 80 - 90 mm (obviously hanging from the side) and small patches of underwool were preserved. The direction of this and other hair streams is also to the front and downwards. All of this wonderfully confirms the realism of the Paleolithic drawings of mammoths with woolly trunks in the cave at Font de Gaume (see Fig. 3).

Although once abundantly covered with wool, the right front leg as presently conserved has had preserved soft tissues removed, presumably to facilitate the study of the carpal bones. The powerful corneous sole of its foot, with a diameter of 37 - 39 cm, protrudes 35 - 40 mm from beneath the hairy edge of the toes. The corneous sole is dissected by deep fissures into 40 irregular separate regions. Traces of three sloughed toenails were noted, having lengths of 8 - 10 cm. Their heights were 35 - 40 mm. The hairy edge above the toe-

Fig. 23 The Berezovka mammoth at the site of excavation. Photograph by O.F. Herz.

Fig. 23 De Berezovka mammoet tijdens de opgraving. Foto O.F. Herz.

nails is composed of brown hair of transitional type and of underwool having a length of 30 - 35 mm.

On the hind leg, a sparse woolly covering is preserved below the knee and on the tarsals, thence down to the toenails. It is composed of fine underwool and guard hairs of light brown colour. The underwool, with length of 30 - 40 mm, is of lighter colour than the guard hairs. Below the knees the guard hairs are 12 - 13 cm in length, and on the back side of the tarsals, 16 - 17 cm in length; these long hairs are in the form typical of a brush.

A piece of dried skin from the back and the right flank shown in a photograph in Pfitzenmayer (1939:168 - 169) measures 149 cm in length × 117 cm in width. The skin has a thickness at the level of the hip of up to 11 mm, and at the level of the neck on the back of around 6 mm. Strands of shaggy wool with a length of 47.5 cm, seen in this photograph, are not now preserved on the skin. The preserved wool is extremely variable in colour and size composition.

Along the lower back (in the area of the kidneys), a section of coarse brown guard hairs was preserved, streaming posteriorly towards the tail. These lower back guard hairs reached a length of 12 - 13 cm. Under these guard hairs was hidden a very thick and dense greyish underwool having a length of 25 - 30 mm.

Scattered brown guard hairs with lengths of 5 - 6 cm were preserved on the side of the neck and over the scapula. A thick, felt-like underwool beneath these guard hairs was coloured light-chestnut and chestnut. On average, this underwool was 25 - 30 mm, and in places 35 - 40 mm, in length.

On the flank medial to the elbow, a covering hair of transitional variety attains 7 - 8 cm in length. Light-grey underwool of 25 - 30 mm length also occurred there.

In the area of the posterior thorax and in the groin, a large patch of fur consists of coarse, thick, brown hairs 14 to 15 cm in length, and thick rusty- or ochre-coloured underwool 25 to 30 mm in length. This underwool coloration is possibly brought about by iron or other oxides, which are not unusually deposited on the surfaces of the bones and tusks. In the belly part, the groin area has preserved coarse dark brown and chestnut-brown guard hairs 14 to 15 cm in length. On the surface of the knee and beneath it a bunch of springy chestnut-brown hairs occur. This hair is 0.15 - 0.20 mm in diameter and 18 to 30 cm in length. All guard hairs are streaming posteriorly and downwards.

K. A. Vollosovich considered the short underwool evidence of a spring-fall moulting cycle analogous to the moulting of the reindeer. Such a comparison is not unfounded, taking into consideration that probable winter underwool reached lengths of 100 to 150 mm.

The Lyakhovskii Mammoth

A smallish male 25 years old from Bolshoi Lyakhovskii Island; geological age unknown. It died, presumably, in middle summer, after being mired in the muddy current and sediments of Eterikanka Brook. The skeleton, with left and right tusks, was preserved with pieces of skin and soft tissue from the left side. The tusks are curved into a gently sloping spiral. The right tusk and the trunk had been cut off by the manufacturer A. Gorokhov. Preserved on the remains were the skin of the left cheek including the left ear, the skin of the back and the left flank, and the skin and tissues of the legs. These remains were excavated, salvaged, and taken by dogsled to Yakutsk in 1909 - 1910 on behalf of the geologist K. A. Vollosovich with funds provided by Count A. V. Stenbok-Fermor. Stenbok-Fermor presented this material to France. A description of the preserved woolly covering according to Vollosovich (1915) is given here. It has also been presented by Pfitzenmayer (1939).

The trunk, 2 meters in length, was covered with dark, almost black hair. This hair was longer on the bottom and the sides than on the upper portion of the trunk. Brown and dark brown wool was preserved along the border of the lips. On the facial side of the head, the thin skin was covered with thick, short, dark brown, almost black, wool. Hair on the back of the head and on the neck was longer, thicker, but nearly the same dark brown colour as on the facial side. The left ear, of triangular shape, was covered with short dark brown wool. Wool on the left cheek was appreciably longer and of reddish-brown colour. The skin of the back preserved

in places sections of short dark brown wool that in the middle part and near the tail took on a light reddish shade. Wool on a piece of skin of the left side varied in length from short to medium to long, and in colour from light grey and grey to brown and dark brown. In the opinion of Vollosovich, this variation in wool length and colour is the result of replacement of the winter wool coat by its summer condition.

The Middle Kolyma Mammoth

Famous for the fragment of trunk, found in 1924 on the bank of the Bolshaya Baranikha River; the geological age is not known. The trunk was given to the geologist K.Ya. Pyatovskii by an inhabitant of Srednekalymsk, Kondratyevaya in 1929, and from Pyatovskii it went to the Zoological Museum. In all probability the trunk came from the most completely preserved mammoth carcass known, but history does not preserve the circumstances of the discovery. It was described by Flerov (1931) under No. 71922, ZIN, AN SSSR. So far, this is the only specimen of its kind in the world. The trunk fragment is deformed and wrinkled as a result of mummification. The total length of the fragment along the anterior (or dorsal) side was reported to be 280 mm (Flerov, 1931), but after preservation with paraffin now measures 260 mm. On the anterior (dorsal) surface of the trunk, 40 mm from the end, 22 to 23 transverse annulated rounded folds having a width from 5 to 10 mm are observed. The dorsal proboscideal process or "finger" of the trunk is of a beak-like shape. This upper process has a length along its edge margin of 95 mm and width at the base of 60 mm. It is bordered with rough edges. The ventral proboscideal process or finger has a lip of spade-like shape. The ventral process has a length of 50 mm, measured along the right edge, and a width of 65 mm. The front edge of the ventral "lip" bears a small flute (Fig. 24). The surface of the wrinkled skin, with a thickness on the upper surface of 2 mm, is entirely invaginated or covered with little depressions. These invaginations, with a diameter of up to 0.1 mm, are the follicles of fallen-out hair.

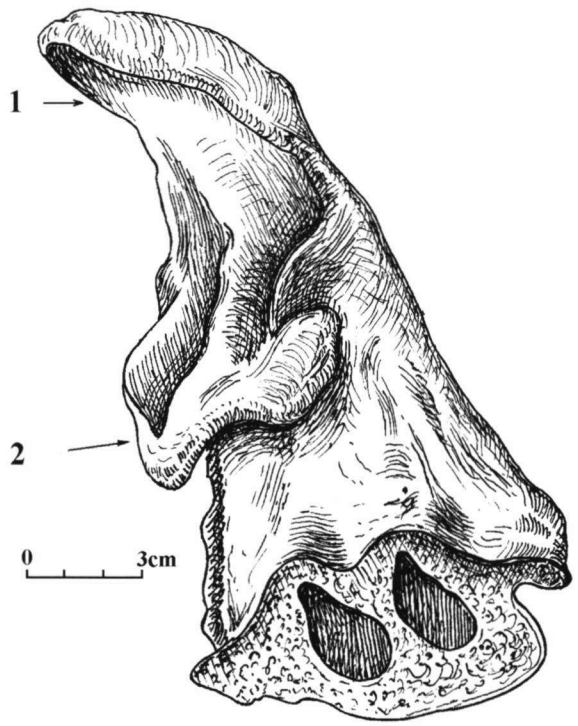

Fig. 24 Mummified terminal portion of the trunk of the Srednekolymski mammoth, collection no. 71922, Zoological Institute, Russian Academy of Sciences. 1) upper, 2) lower extension.

Fig. 24 Het gemummificeerde uiteinde van de slurf van de Srednekolymski mammoet, collectie nr. 71922, Zoölogisch Instituut Russische Academie der Wetenschappen. 1) bovenste, 2) onderste "vinger".

Here and there on the annulated skin folds are preserved very thin whitish hairs as well as little strands of underwool with a length of 3 - 5 mm. The lower (ventral) surface of the trunk and the inner funnel-shaped exterior opening to the nares were covered with similar hairs. Scattered guard hairs also are preserved. The nares opened inside the end of the trunk by means of two oval orifices having diameters now of 25 x 40 mm. These orifices of course would have been larger in life. The cartilaginous-muscular tissue of the trunk as preserved resembles slate coloured microporous rubber.

The Taimyr Mammoth

An adult male approximately 50 years of age. The geological age is 11,500 years B.P. It was discovered by geologists in 1948 in the valley of the Mamontovaya River in the northwest Taimyr Peninsula. Burial occurred in peat soil of the first terrace above the flood plain, and most probably, all things considered, in a former flood plain lake. The excavations were conducted in 1949 (Portenko et al., 1951). Nearly a complete skeleton was exposed and collected, as was "a certain quantity of guard hairs, partly coarser bristles and underwool, particularly on the right scapula and the limbs." With this quotation from Portenko et al. specific information on the pelage of this mammoth is exhausted. However, these authors also expressed the same thought as Vollosovich, that mammoths "changed their wool in the summer to shorter [lengths] and that the length of the hair which was found [the summer coat] does not correspond to the idea of a very shaggy animal," which is usually represented.

In the sample of wool from the Taimyr mammoth (around 200 g) preserved in the Zoological Institute, several varieties of hair are distinguishable (the former position of the hair on the body is not clear, however, since the authors, apparently, did not try to record the progress of the excavation nor to preserve the collected wool):

1) a tangled mass, approximately one-fifth the whole by volume, of black and dark brown hair and hair fragments with a shaft thickness of 0.2 - 0.25 mm and predominant lengths of 30 - 35 cm. Individual hairs attain a length of 50 cm. In all probability a portion of this tangled mass is from the tail, and a portion from the head, of the animal.

2) brownish-black strands of straight hair with a shaft thickness of 0.15 - 0.18 mm and up to 30 cm in length,

accompanied at the base by a reddish underwool with a length of 40 - 45 mm. These strands and underwool are, probably, from the forehead.

3) light brown strands of guard hair with lengths of 45 - 47 cm, slightly curly, with the length of the wool curl or wave being 12 - 13 cm, in part with the root bulb preserved and in part broken off at the level of the skin surface. This hair comprises up to one-fifth the sample by volume. These hairs have a weak lustre in reflected light. At the base of these guard hairs there is luxuriant soft light grey or light brown underwool with a length of strands of 20 -30 mm. The bulk of these hairs comes, most probably, from the sides and head of the animal. The ratio of fibres of guard hair to those of underwool in the strands is 36.6%, or approximately 1 to 3 in 1,070 hairs examined.

4) light brown and yellowish tufts of guard hair having lengths of 30 - 32 cm, with light yellow underwool having a length of 30-35 mm. These hairs are present in small amounts and originate probably from the sides of the neck, the crest of the dorsum, and from the hips.

5) matted hair, worn into little balls, represents locks of underwool of very light brown and yellowish colour, with the length of fibres being 20 - 30 mm. Less then one-fifth the sample by volume. The location is problematic.

6) the major mass of underwool comprises brown, thick strands having a length up to 50 mm, with lighter coloured ends extending 30 mm. More than one-fifth by volume. From different regions of the body.

7) matted balls of wool of reddish-brown or red-brown-ochre colour, less than one-fifth by volume, probably from the belly and the inguinal parts of the mammoth.

The Berelekh Mammoths

A large series of skeletal remains, numbering 8,830 bones (including at this count, four skulls, more than 180 cheek teeth and tooth fragments, and 44 tusks), from 156 individual mammoths collected at the Berelekh mammoth "cemetery," on the Berelekh River, a left tributary of the Indigirka River in Yakutia (Fig. 25). Approximately 75% of all the individuals collected and presumably representative of those preserved at this locality were females. In addition to the bones, about two kg of tangled hair (wool and guard hair) was recovered (Fig. 26), as were several small pieces of partially-rotted skin, and a well preserved hind leg with skin. The excavations and washouts [melting of permafrost by water pump] of the strata of the banks of the Berelekh were conducted by an expedition lead by N.K. Vereshchagin, B.S. Rusanov, and P.A. Lazarev in 1970, 1972, and 1980. The geological age of the Berelekh material according to radiocarbon age determination of tusk ivory is 12,240±160 years B.P., but on the basis of 14C age determination of ligament and skin the geological age of the material is 13,700±400 years B.P. The death of the individuals and the burial of their skeletons and carcasses occurred in a flood plain lake,

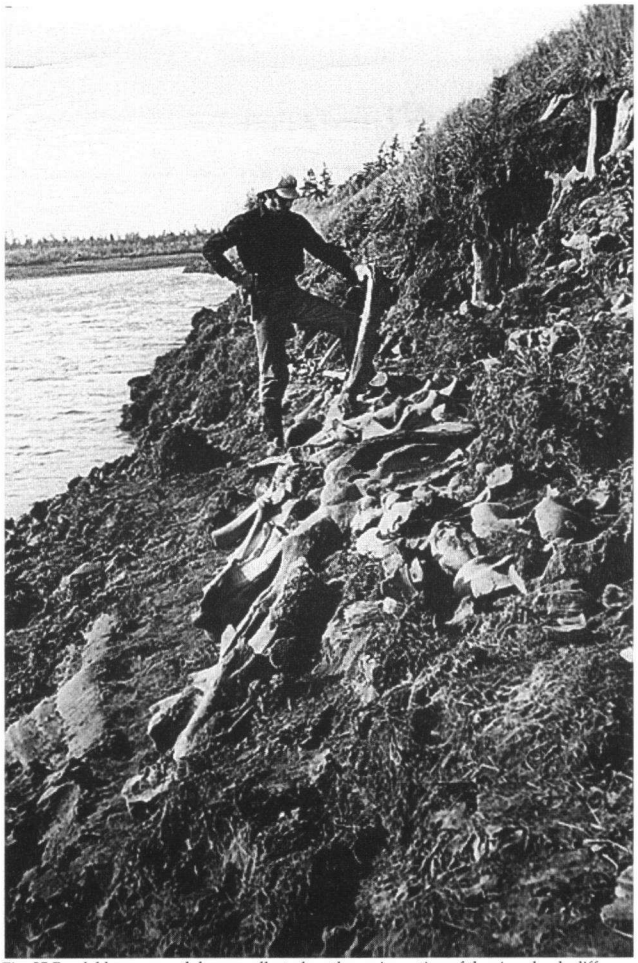

Fig. 25 Berelekh: mammoth bones collected on the main section of the river-bank cliff, 1980.

Fig 25 Berelekh: mammoetbotten verzameld in de belangrijkste sectie van de aangesneden rivieroever, 1980.

representing the late Pleistocene bed of the proto-Berelekh River.

The hind leg of the mammoth, with measurements of the sole of the foot of 24 x 25 cm, preserved four toenails. Dense wool in the area of the tarsals and on the lower shin portions, with a length of 30 - 40 mm, was of a reddish-gold colour. Over the lower part of the femur, the hair covering reached 20 - 25 cm and more in length. Its colour was gold-chestnut; under the guard hair was brownish underwool. The skin was light brown in colour. The skin of the modern African elephant is usually gray or dark brown in color (Sikes, 1971). The leg from Berelekh is exhibited in the Mammoth Museum in Yakutsk.

The major mass of guard hairs (arranged in locks or tufts, chaotically twisted around the long bones of the disarticulated skeletons) was light brown and light coffee-brown in colour and possessed a slight lustre. The dimensions and colour of the hair locks and individual hair fibres are characterized by great variety that is probably connected with collapsing banks that tore the hair from the carcasses, with their having been co-mingled, and with the varying age composition of the individuals. Especially striking, were the dense, large "manes" of resilient, wire-like hair. This hair was

brown and light coffee-brown in colour, and was shot through with gold and bronze tones. These manes attained a length of a meter and more [!]. Individual measured strands were 94, 102, and 115 cm in length and possessed shaft thicknesses of 0.2 - 0.3 mm. They probably originated from the tail [Editors note: Very long thick "mane" hairs grow on the lower third of the tail of modern African elephants; Sikes, 1970: 27], from beneath the chin, and from the neck and the shoulders (Fig. 26). Matted into balls and partially concealed in the manes composed of guard hairs, were small locks of fine yellowish and brick-brown underwool. Fibres of this underwool reached lengths of 15-20 cm (Vereshchagin, 1977). Four types of hair were subsequently distinguished on the basis of the Berelekh materials: first order cutting guard hairs, with an average length of 91.6 cm (range = 60 - 105 cm); second order guard hairs measuring on average 39.8 cm in length (range = 12 - 56 cm); transitional hairs measuring on average 18.6 cm in length (range = 14 - 23 cm); and downy hairs on average 8.6 cm long (range = 5 - 11.5 cm).

The Terektyakh Mammoth

In the summer of 1971 a party composed of B. S. Rusanov and P. A. Lazarev (Fig. 27) excavated the well-preserved skeleton, with soft tissues, skin, and hair coat, of a male mammoth on the Terektyakh River, a tributary in the middle course of the Indigirka, at the settlement of Sutorokh. The excavation descriptions and records are not detailed. The skeleton is mounted in the museum at Yakutsk.

The Shandrin Mammoth

Discovered in 1972 on the right bank of the Shandrin River, east of the mouth of the Indigirka. An old male about 60 - 65 years of age. Nearly the entire skeleton, including the entrails, was preserved (Fig. 28). The geological age is 43,000 years B.P. It was washed out with water jets operated by mechanical pumps by the team of Rusanov and Lazarev. Although initially intact over the ribs, pieces of skin were destroyed by this process, as were the organs in the thoracic cavity. A mass of hair on a half-rotted piece of skin was preserved. This skin, measuring 8 x 10 cm, was frozen to the monolith representing the mammoth's intestines. The skin piece originates from the right abdominal wall and was preserved under the protection of the knee, which was pressed against the belly. Small fragments of rotted skin epithelium contained thick strands of brown underwool up to 50 mm long as well as straight, black guard hairs having lengths of 70 - 80 mm. Like the fragment the hair samples are in large part from the inguinal portions of the mammoth's belly. The skeleton of the Shandrin mammoth has been restored in one of the museums at Novosibirsk.

The Khatanga Mammoth

The skull and other remains of a very large male, 55 - 60 years of age. Excavated by N. K. Vereshchagin in 1977 - 78 at a depth of 5 - 5.5 m in sandy loam deposits forming the left bank of the Bolshaya Rassokha River, a tributary of the Novaya River, which flows into the Khatanga River. The geological age is 53,170 years B.P. In addition to the skull, preserved portions include: the trunk, without the tip section; pieces of skin from the trunk, head (including the left ear), and neck; the left forefoot bound in skin, and the right tibia and hind foot. The trunk had a diameter of from 28 - 30 cm, measured near the middle of its length. The diameter

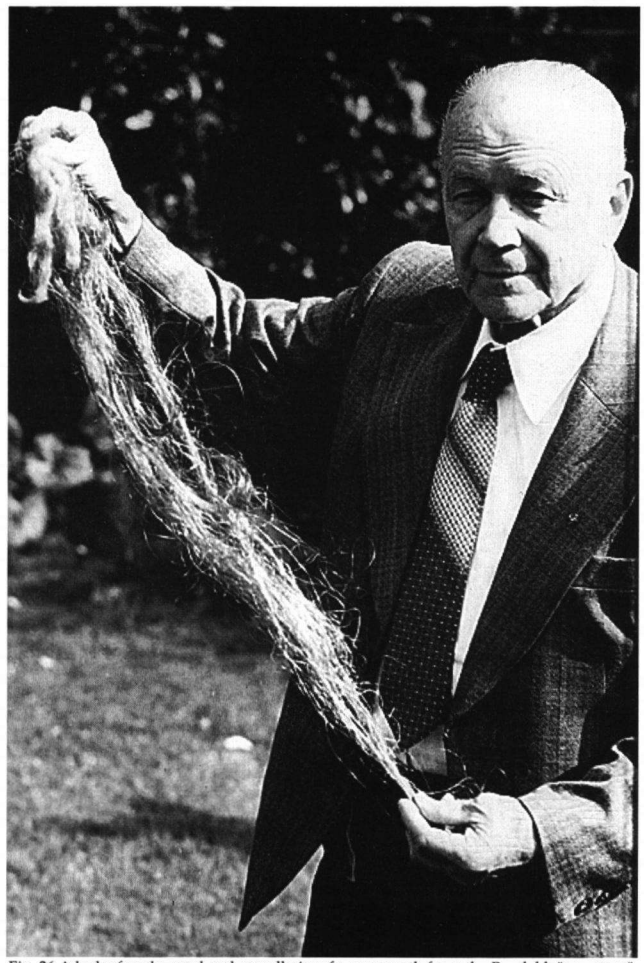

Fig. 26 A lock of underwool and guardhairs of a mammoth from the Berelekh "cemetery", displayed by N.K. Vereshchagin.

Fig 26. Wol en borstelharen van een mammoet van het Berelekh "kerkhof", getoond door N.K. Vereshchagin.

of the tusks at the alveoli is 18 - 20 cm. Hair was absent on the skin of the trunk. The trunk and its skin were mangled, scattered, and ultimately lost during the opening of the burial by the party of Dr. P. P. Gambaryan, sent from the Zoological Institute to prospect and salvage the mammoth in July of 1977 (Fig. 29).

Measurement of the sole of the right front foot is 44 × 40 cm. Remains of three corneous hooves were preserved opposite digits II, III, and IV. The sole of the right hind foot is elongate-oval in shape; its diameters measure 49 × 39 cm. Remains of two hooves were preserved opposite digits II and III (Fig. 30).

Among the preserved hair on the forehead, three varieties are discerned. Among these are short hairs measuring 3 - 6 cm in length. These are thick, coarse

(having been in part broken off) and straight, and possess black and blackish-brown coloration. The second hair type consists of long hairs measuring from 12 - 17 cm in length. These long hairs are of average thickness and of black - brown coloration. The third type of hair is short, measuring 10 - 20 mm in length. These hairs are fine, slightly curly, and brown to light brown in colour. All the hair on the parietal part of the skull and on the frontal surface was streaming forwards. Hair was not preserved on the left cheek and ear. Individual black and brown hairs of undetermined topography were found scattered in the layers of sand at the level of the skull. The left ear of this large male mammoth had dimensions of 33 × 16 cm and adjoined the neck; the ear opening, located anteriorly in the ear flap, was 8 cm in length (Fig. 31). The skin of the head and ear was brown in colour.

On the portion of the shin opposite to the back side, sparse strands of tangled hair covering were preserved. The coat in this location was primarily straw-coloured. Again a variety of hair types occurred. The strands included thick, coarse hairs 18 - 34 cm in length and coloured black and black-brown. The colour pattern was either monochromatic or consisted of alternating dark and light sections. A second type includes slightly curled, straw-coloured hairs of average thickness, with lengths of 12 - 25 cm. A third type includes fine downy hairs, of light coloration, with lengths 40 - 70 mm as well as particularly fine and light hairs having lengths of 15 - 20 mm and less. The length of the primary mass of these tangled strands of hair is 18 - 20 cm (Vereshchagin and Nikolayev, 1982).

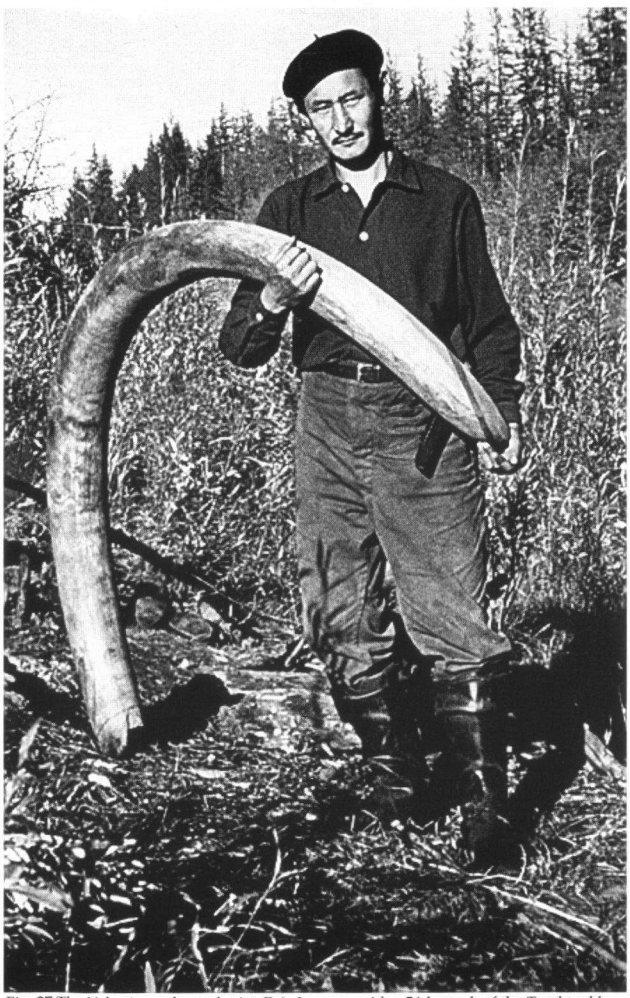

Fig. 27 The Yakutian paleontologist, P.A. Lazarev with a 54-kg tusk of the Terektyakh mammoth, 1971.

Fig 27 De paleontoloog P.A. Lazarev met een 54 kilo zware stoottand van de Terektyakh mammoet, 1971.

The realism of Paleolithic artist's representation of the wool on the mammoth's head is clearly supported by the hair pattern interpreted from the skull of the Khatanga mammoth. This realism is demonstrated in the artist's representation of the distinctive "bonnet" or "hairdo," shown to be a shock of black hair, streaming forwards. It is interesting that a similar "bonnet" on the head is characteristic of the American bison, *Bison bison*, where it is ideally suited to breasting the winter snowstorms of the prairie.

The Yuribei Mammoth

The exposed head was found by Nenet reindeer herders and destroyed. Later the remains were observed by the fishermen Khloponin and Berdov. A relatively small female of 10 - 14 years. Excavated at a depth of 8 m from the edge of a sandy loam bed on the right bank of the Yuribei River on the Gyda Peninsula. The geological age is 10,000±70 years B.P. The carcass was lying on its back (Fig. 32). At the time of our excavations in September of 1979, the hind end and the hind legs of the body remained intact (Fig. 32). The time of death (tentatively) was at the end of the warm season, perhaps September. In the stomach there was a greenish-yellow grassy mass. The excavations were conducted in September 1979 by a multidisciplinary expedition representing three institutes of the USSR Academy of Sciences (Vereshchagin, 1982; Sokolov, 1982).

The woolly hair covering was preserved on the belly, rump, tail, sides, and upper hind legs. The skin was well preserved only on the belly, from which it was removed as an intact piece, together with a mummified layer of abdominal muscle having the form of a thick, black crust with an overall thickness of up to 40 - 45 mm.

On the back, sides, and upper hind legs, the skin and underlying tissue were destroyed. During clearing, these tissues deteriorated into pale yellow fragments, and then into whitish-grey dust. Somewhat better preserved skin was present on the soles of the feet. The diameter of the slate-coloured roughened soles of the feet was equal to 32 × 28 cm. On the back, above the spine, skin and hair were poorly preserved; it appeared as though they were washed off or eroded by water flowing under the carcass. On the rump very thick and short underwool 35 - 40 mm long was covered by coarse and brittle rust-brown guard hairs having lengths of 15 - 18 cm. The thickness of the guard hair shafts was 0.25 mm. The rusty and rust-ochre hue of the ends of hairs was probably a result of their staining by iron oxide and by azovskit, a phosphatic mineral recently described from the Azov region in Russia.

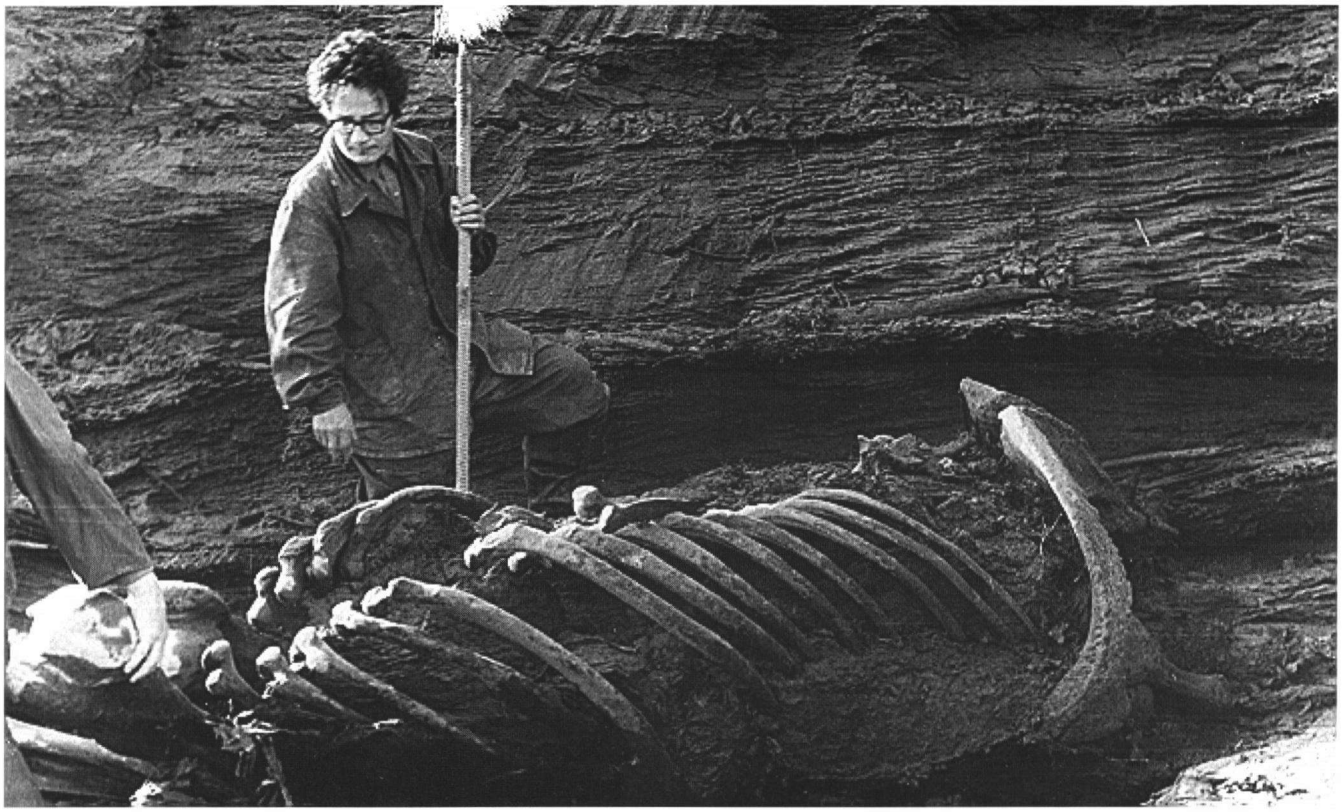

Fig. 28 Excavation (sediment removal with a motorized water pump) of the skeleton and intestines of the Shandrin mammoth. 1972. Photograph by B.S. Rusanov and P.A. Lazarev.

Fig 28 Opgraving (sediment verwijderen met behulp van een gemotoriseerde waterpomp) van het skelet en de ingewanden van de Shandrin mammoet. 1972. Foto B.S. Rusanov en P.A. Lazarev.

The body of the tail was destroyed, but a plume of coarse straight hair remained, yellowish-red and brown in colour, with a length of 60 - 65 cm. At the base of what would have been the body of the tail, these hairs were notably thicker, with a rich brownish colour in the middle part. The greatest diameter of the plume of hair in its now compressed form is 8 cm.

The sides of the mammoth were covered with thick, surficial brown fur, well divided into underwool with a length of 40 - 45 mm, and guard hair 8 - 9 cm in length with a shaft thickness of up to 0.1 mm. On the lateral surface of the thigh, greyish-ashy underwool 40 - 50 mm long was covered with dirty-yellow guard hair with a length of up to 50 cm [!] and with a shaft thickness of 0.25 mm.

On the belly (from the base of the sternum to the anus), the fur covering was completely preserved. This was comprised primarily of thick underwool 50 - 60 mm long with a small admixture of yellow guard hairs. Upon removal from the sandy loam, the underwool appeared ashy-violet. The hair of the belly was easily removed in layers with an upper layer of flat epithelium, revealing a smooth, black surface. On the groin area the underwool appeared less thick than in the area of the navel. Here there were the distinctive thin cutting hairs, the upper third possessing a reddish or rusty colour, as if slightly "burnt." The ratio of guard hairs to down hairs in locks from the lateral side of the thigh was approximately 1:4 (26.5%:73.5%) in 900 hairs examined.

During screening of the sand from the anterior portion of the carcass that had been destroyed by local reindeer herders, up to 1.5 kg of tangled strands of guard hair of brownish and greyish-yellow colour was collected. On the basis of topography this hair belongs to the head, neck, and anterior portion of the carcass.

The external and internal tissues of the Yuribei mammoth present a diverse range of preservation, from complete destruction and replacement of their form by mineral particles (the aorta, uterus, kidneys), to parchment-like tissues of the bowel, and, in natural appearance and colour, rugose skin of the sole of the foot, and most of the hair cover.

Most likely, the pelage described represents the initial growth, at the beginning of the fall, of the future winter fur coat of a young mammoth.

The Magadan Baby Mammoth

The carcass of a six-month-old male baby mammoth was discovered by the gold prospector A. Logachev in June of 1977 at the Susuman gold mine in the watershed of Kirgilyakh Brook, a tributary of the Berelekh River in the upper reaches of the Kolyma River [not the same Berelekh of the mammoth "cemetery"]. It was lying under two-meters of frozen silt and gravel on a gentle slope of the right side of the drainage (Fig. 33).

Fig. 29 The stratum containing the head and legs of the Khatanga mammoth, Eastern Taimyr, 1977.

Fig 29 Aardlaag met het hoofd en de poten van de Khatanga mammoet, oostelijk Taimyr, 1977.

The geologic age is 39,000 years B.P. The season of death was the beginning of fall. The animal was in extreme stages of emaciation (Fig. 34). The surface of the skin on the back and sides, when washed clean, was yellowish and light brown in colour.

Basic measurements (in cm) of the Magadan baby mammoth are: height at the withers = 100, at the sacrum = 98, of the body at the breast = 52, at the scapula joint = 70; oblique length of the body = 74, of the head (from the alveoli of the tusks to the back of the head) = 48, the full trunk = 80, the suspended body of the tail = 12. Indices: of size = 74%, of height at the sacrum = 75.5%, of length of the head = 48%. The distinguishing juvenile characters are: smooth line enclosing the head and body, relatively large, massive legs (for their seeming length because of the absence of wool), the soles of the front feet = 14 × 15 cm, hind feet = 13 × 15 cm. The feet possess up to three small hooves. The trunk (Fig. 35) has a length of 80 cm; from the region of the alveoli of the tusks, the trunk measures 58 cm in length and possesses 73 annulations. The length of the upper, beak-like, proboscideal process is 5 cm, of the lower, lip-like, process, 2.5 cm. The leaf-like ears are 13 × 6 cm (see Fig. 31). The bare belly of the Magadan baby mammoth clearly exhibits a short preputial pouch in the area of the perineum, and two small raised teats in the axillary region.

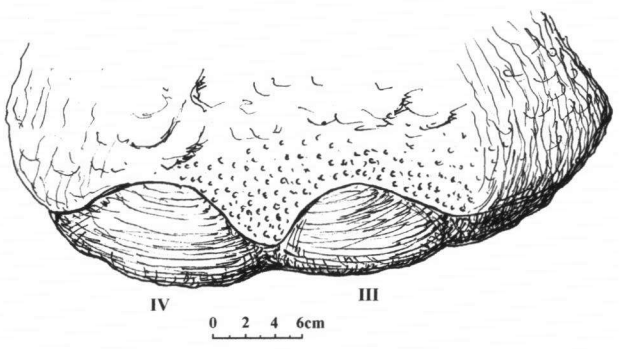

Fig. 30 Anterior region of the foot of the Khatanga mammoth, showing traces of two toe nail plates, on digits III and IV.

Fig 30 Voorste gedeelte van de voet van de Khatanga mammoet, met resten van twee teennagels aan de derde en vierde teen.

The woolly hair covering was preserved in places on the head, trunk, and other portions of the body, but as a result of the baby mammoth's removal and the embalming process, hair remains only on the wrist and ankle areas. The strands on the frontal portion of the trunk were comprised of guard hair up to 70 mm in length, and down 25 - 40 mm long, coloured dark brown. Similar strands were preserved on the right cheek. On the wrists, ankles, and feet guard hairs were of a yellowish-brown colour, or more rarely light

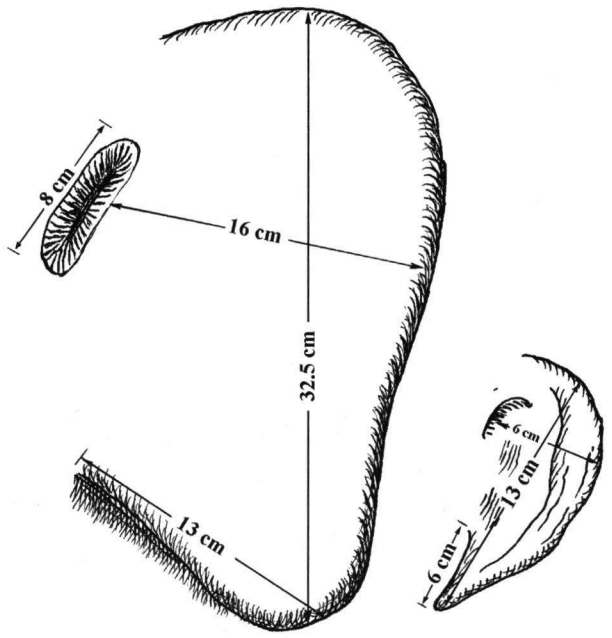

Fig. 31 Outlines and measurements of the external ears (without wool) of the old Khatanga mammoth, and the 6-month-old Magadan baby mammoth, with post mortem deformation.

Fig 31 Omtrek en maten van de oorschelpen (zonder wol) van de oude Khatanga mammoet en de 6 maanden oude Magadan baby, met post mortem vervorming.

brown or yellow. These hairs attained lengths of 12.5 - 14 cm. The primary mass of hair occurring in strands, dull yellowish and reddish in colour with a length of 20 - 22 cm, came from the breast, shoulder, sides, and belly. This hair was collected from deposits surrounding the carcass. The hair of the underwool was downy, on the whole light yellow in colour, with a height of 60 - 80 mm, and slightly curly. Strands of this downy type accounted for 40 - 45% of the hair collected. It is proposed that this juvenile fur for the fall season was gradually replaced by the winter covering; as a true moulting was not apparent (Vereschagin and Mikhel'son, 1981).

The Yamal Baby Mammoth

The carcass of a young female (Fig. 36) 3 - 4 months old. Discovered in 1988 by the commander of the vessel "Porog" lying exposed on its left side on the lower right bank of Yuribeteyakha Rivulet, 20 km from its mouth on the west shore of the Gulf of Ob. The geological age is 39,100±1,420 years B.P. (LE-2263). The carcass was brought to the Zoological Institute. In all likelihood, the baby mammoth was eroded from frozen deposits of late Quaternary age and carried away

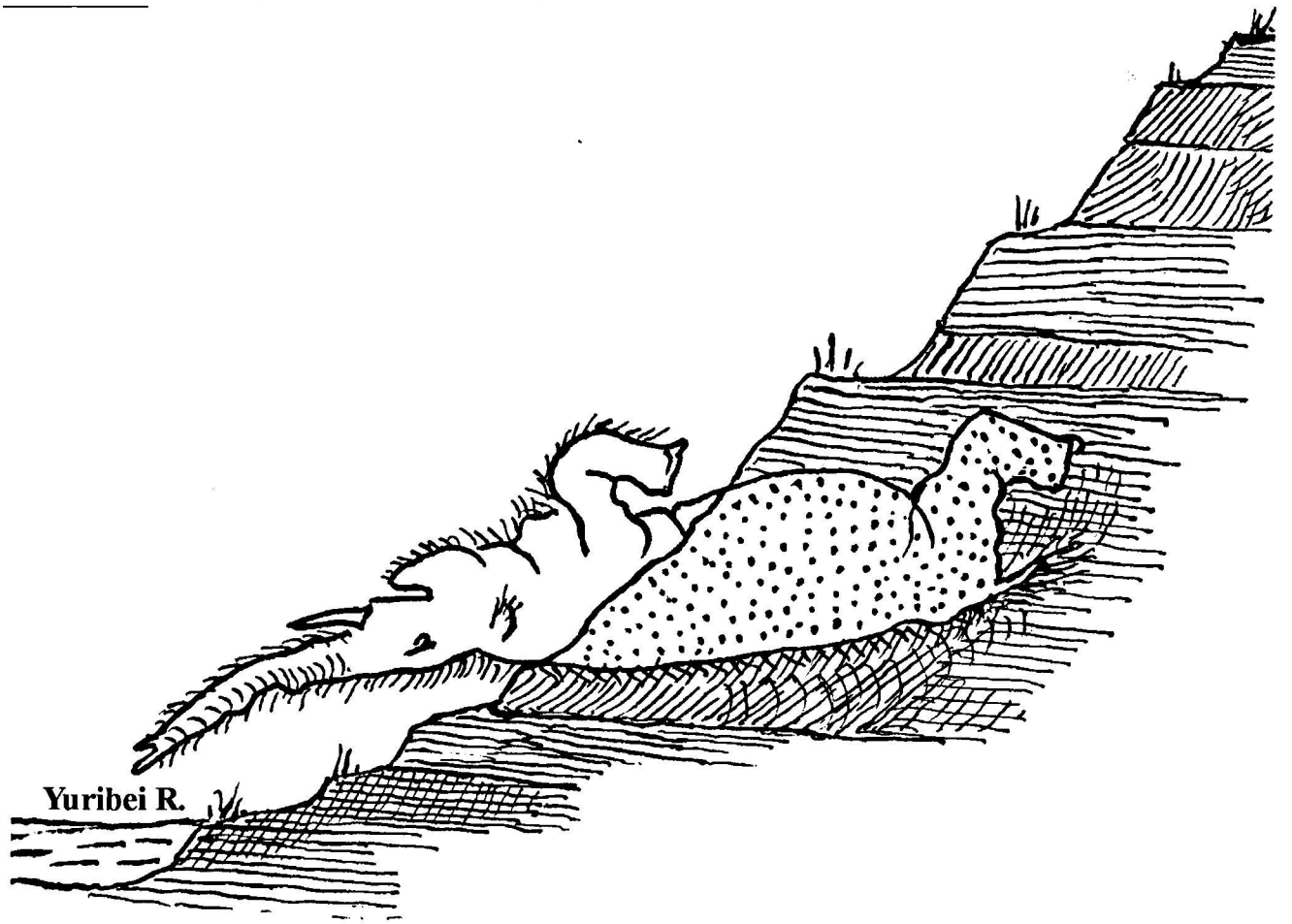

Fig. 32 Situation of the carcass of the Yuribei female mammoth in a lake-alluvial sediment, 1979.

Fig. 32 Houding van het karkas van de Yuribei mammoetkoe in meersedimenten, 1979.

Fig. 33 A taphonomical discussion at the place of discovery of the Magadan baby mammoth. Susuman, 1977. From left to right: A. Nikolaev, N. Nioradze, I. Dubrovo, and A. Ryabchun.

Fig. 33 Een tafonomische discussie op de vindplaats van de Magadan baby mammoet. Susuman, 1977. Van links naar rechts: A. Nikolaev, N. Nioradze, I. Dubrovo, en A. Ryabchun.

from its primary locality by a flood. The baby mammoth was mummified. The trunk, tail, and left ear had been lost. The posterior side of the right ankle was severely damaged, as though by a laceration, with shredded, blackened sinew fibres. This injury may have been the cause of death.

Measurements (in cm) of the Yamal baby mammoth are: height at withers = 67, at the breast = 38, at the elbow = 29; length: overall (base of nose to tail) = 135, slant, of the body = 80, of the head = 43, of the neck along the outer edge = 14, of the spine from the withers to the tail = 77, of the ear, vertically = 15.5. The weight is approximately 40 kg.

The legs are short and those of the right side are slightly tucked under those on the left side. The vertical length of the front leg is 30 cm, length of the hind leg (up to the knee joint) is 28 cm. Measurement of the soles of each front foot is 12 × 11 cm, while the soles of each hind foot measure 10 × 8 cm. The soles' surfaces have small dimples. Along the frontal edge of each sole are traces of three sloughed hooves; these hooves

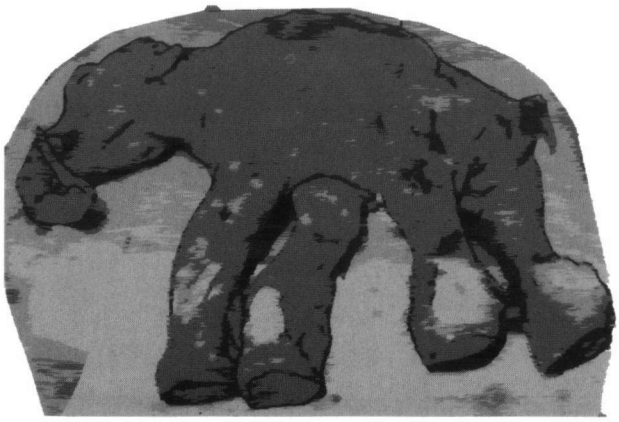

Fig. 34 Carcass of the Magadan baby mammoth prior to embalming.

Fig. 34 Het karkas van de Magadan baby mammoet voor preparatie.

on the front feet measure 15 × 26 mm and on the hind feet measure 18 × 27 cm.

Two milk tusks each had a length of 5 cm. The distance between their ends measured 8 cm. In x-ray view, three upper and lower premolars were visible: dP 2/2 possessing five plates that had not begun to wear; dP 3/3 with eight plates that were one half erupted; and dP 4/4 with nine plates in place. Obviously, the baby was still nursing.

The skin on the head and neck was notably destroyed. The subcutaneous muscle and fat had a white colora-

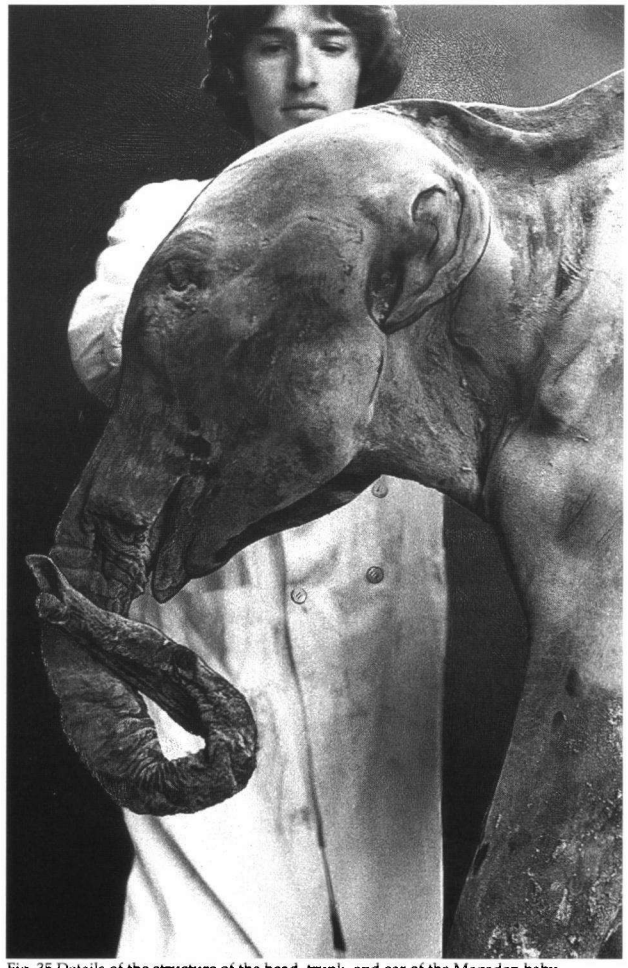

Fig. 35 Details of the structure of the head, trunk, and ear of the Magadan baby mammoth.

Fig. 35 Details van het hoofd, de slurf en het oor van de Magadan baby mammoet.

tion, and a friable and greasy texture. On the bare skin of the shoulders, sides, and legs a film of vivianite was deposited. The hair covering, probably foetal considering the age of the individual and only slightly grown in, readily falls off. It was preserved in isolated patches on the head, neck, lower sides, hips, shins, wrists, and on the perineum. The length of preserved hair on the sides [neck, hips and lower sides] is 25 - 30 mm; the longest hair, occurring over the posterior portion of the tibia, reaches 80 mm in length.

Macro- and microscopic structure of the woolly covering

Macrostructure

The general picture of the structure and distribution of the woolly hair coat and its coloration on adult mammoths, judging from carcasses of individuals that died during the warm season, is as follows:

Head

The top of the head and the forehead of mammoths was covered by a "bonnet" of coarse tangled hair with a length of 15 - 20 cm hanging in the form of a fringe down to the eyes and to the base of the trunk. This "bonnet" was reminiscent of a similar woolly covering appearing on the North American bison. The cheeks and ears were covered by strands or locks of light brown hair, which appeared as though they had been combed.

Trunk

The upper, front facing side of the trunk from the eyes to its terminal tip of beak and lip was covered with short, thick brown or chestnut hair, streaming forward or downward, having a length of up to 7 - 10 cm. In addition there was an underwool 5 - 6 cm long that entirely hid the annulated skin folds. From the sides and from the lower part of the trunk, particularly in its upper third, hung a fringe of longer hair, up to 12 - 14 cm in length. The end of the trunk and the edges of the terminal beak and lip had a dark slate grey coloration.

Withers

Coarse, short light brown guard hairs covered the shoulder hump and the dorsum, hiding a thick ashy-yellow underwool. The length of the guard hairs was 20 - 25 cm and longer.

Tail

The body of the tail, from its base to its termination, bore a plume of brown or sometimes yellow guard hairs 50 - 60 cm or more in length. These guard hairs hung from the tail to the level of the knee or even as low as to the lower third of the shin.

Neck and body

The lower neck and dewlap were covered with thick locks of black and brown hair with a length of 30-40 cm. The shoulder portions of the body, as well as the sides and hip, were covered with very long cutting guard hairs, with black to brown and straw-coloured

Fig. 36 The Yamal baby mammoth at the site of its discovery, September, 1988.

Fig. 36 De Yamal baby mammoet op zijn vindplaats, september, 1988.

shades. These hairs, up to a meter and more in length [!], hung down like a skirt. A similar "attire" is typical of the wild and domesticated yaks of Tibet.

Legs

The legs, from the elbow and knee to the edges of the soles of the feet, were covered by shaggy, dark brown hair up to 20 cm and more in length, streaming downwards towards the ground. We remind the reader that on the Magadan baby mammoth the hair covering the wrists and ankles attained a length of 14 cm.

Underwool

The underwool, hidden under the strands of cutting or other guard hairs, was not uniform in thickness or coloration but varied on different portions of the body. When observed primarily on the sides, the underwool reached a length of 6 to 16 cm, comprising in the whole up to 70% or more of all hair fibres. Underwool was always lighter in colour than guard and transitional hairs, varying from brown to straw-coloured as well as light violet. Some fading probably occurred, specifically due to degradation of the pigment in the frozen strata, especially during thawing. However, studied material indicates primarily a dark hair colour for both young and adult individuals. Up to the present, instances of true albinism have not been recorded for mammoths although it would be quite natural for animals in arctic areas, in response to Gloger's rule, which states that "within any one species, colors tend to be darker in warm, moist climates and lighter in cold, dry climates." (Simpson et al., 1957)

Skin

The skin of mammoths was primarily light brown or cream-coloured. The skin of the hairless or only lightly hair-covered tip of the trunk as well as the lips and the perianal folds was dark grey.

Microstructure

Histological studies of the hair coat of the mammoth began in the previous century. In 1892 Möbius, for example, compared the hair of the mammoth with the hair of the African and Asian elephants and did not find overall structural differences. He distinguished two types of hair, downy hairs (Flaumhaare) and guard or bristle hairs (Grannehaare). According to Möbius the diameter of the hair shafts comprising the underwool, or down varied from 0.064 to 0.08 mm; the diameters he reported for shafts of the guard hairs were 0.28 - 0.48 mm. The underwool did not possess a medulla canal with its softer, amorphous cells and air spaces.

The Academician V. V. Zalenski (1909a) subdivided the hairs of the mammoth into three categories: (1) short, fine hairs of the underwool lacking a medulla canal; (2) long, more or less light rather than dark coloured guard hairs possessing round shaft cross-sections approximately 0.28 - 0.4 mm in diameter, with a single tube of medullary matter situated in the central part of the hair; (3) very long black bristly hairs, situated primarily on the tail, having a flattened or oval shaft cross-section up to 1 mm in the long diameter, having numerous tubes comprising the medullary matter scattered within a cortex.

Treating the hair of the Berezovka mammoth with a caustic alkali, Zalenski discerned "light, flattened epidermal cells of cuticle, fusiform-like cells of cortex substance without nuclei." Later he discovered that the "plural canals" of bristly hairs were actually the result of cell expansion of the cortex layer, under the influence of the alkali treatment.

Among the topographically indeterminable hairs of the Berelekh mammoths three types are distinguished: underwool (down), transitional hairs, and guard hairs having typical macro- and micro metrical indices (Vereshchagin, 1977). Cuticle cells of the squamose layer had been partly destroyed. As observed on gelatinous microscopic sections and in SEM photomicrographs, the surface of the shafts of down and guard hairs appears to be irregular, as though excavated, in a manner reminiscent of a lunar landscape (Figs. 37, 38). The outlines of individual preserved cells of cuticle lack well-defined boundaries or are slightly dentate.

Transverse shaft cross sections prepared from the underwool show these hairs to be regularly rounded. Similar transverse sections of the transitional hairs are circular or, less frequently, slightly oval, while guard hairs have irregularly-rounded outlines. An axial medullary canal was not observed in any type of hairs. Grains of brown and yellowish pigment were distributed more or less uniformly in the matrix of the cortex of the underwool; in strands of transitional and guard hair varieties, pigment grains are primarily concentrated as small clusters in the centre.

The hair coat of the Magadan baby mammoth, on the basis of studies reported by Sokolov and Sumina (1981), is subdivided into cutting guard hairs and downy fibres. They are of reddish-golden coloration and possess circular or slightly flattened shaft diameters. A few cutting hairs have longitudinal grooves and medullary canals, which are usually discontinuous. The diameter of the cutting hairs at the base is 0.1 - 0.2 mm; in the middle, 0.09 - 0.17 mm; and at the ends, 0.02 - 0.03 mm. The cuticle cells are flat and tile-like, rather than ring-like, with roughly indented, or notched free (upper) edges.

Three types of hair were distinguished on different regions of the body of the Yuribei Mammoth, the young female from the Gyda Peninsula: underwool, transitional hairs, and guard or cutting hairs. On all parts of the carcass the strands comprising the underwool had shaft diameters of from 0.03 - 0.06 mm. The transitional hairs, with shaft diameters of 0.1 - 0.18 mm, possessed partially destroyed cuticle scales. The cutting hairs are coarse and thick, with shaft diameters of from 0.11 to 0.32 mm. The cuticle cells of the cutting hairs are not ring-like in form and are very closely compressed on each other. A portion of these cutting fibres have a discontinuous medullary canal with porous, amorphous

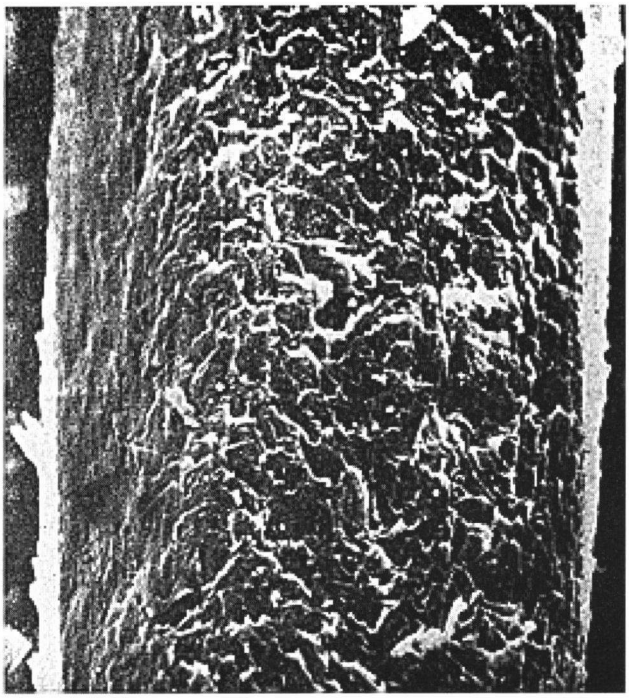

Fig 37 Outlines of preserved cuticle cells of the squamous layer of the Magadan baby mammoth: a) guard hair, middle portion, x 800, b) underwool, x 2000. Stereoscan by V.E. Sokolov and E.B. Sumina, 1981.

Fig. 37 SEM-foto's van haarcellen van de Magadan baby mammoet: a) middenstuk van dekhaar, x 800, b) onderwol, x 2000. Scan door V.E. Sokolov en E.B. Sumina, 1981.

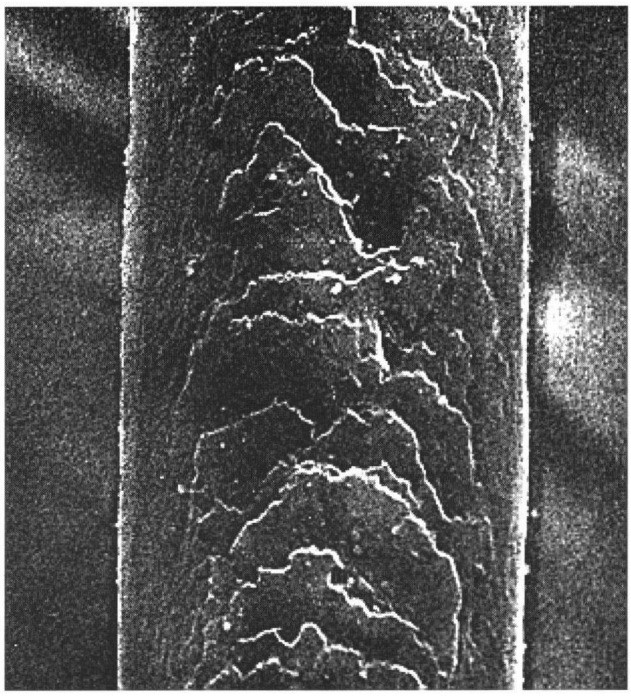

Fig. 37 b.

cells. The shaft cross sections are oval or irregularly rounded. The coloration of the downy hairs is lighter than the other varieties; they are weakly pigmented, of light red colour. The cutting and transitional hairs vary in colour from light red to chestnut (Sokolov and Sumina, 1981). The correlation of varieties of hair in strands and as fleece in general was extremely heterogeneous on different parts of the body. The usual ratio of strands comprising the guard hair to those of the underwool (down) on the sides varies from 1:3 to 1:5, i.e., the number of down hairs reached 70 - 80% of the total hair strand sample.

The generalized characterization of the structure of the woolly covering of mammoths on the basis of the fibre types we distinguished (Fig. 39) is:

Fibres of the underwool (= down)

Underwool fibres are round in shaft cross-section, with ringlike cuticle, and without medullary canals. Grains of pigment are dispersed more or less uniformly in the matrix of the cortex layer. Less frequently, grains of pigment are absent. Shaft diameters = 0.015 - 0.07 mm.

Transitional hair fibres (= intermediate hair)

Transitional fibres are round, irregularly rounded, or oval in shaft cross-section. The cuticle is not ring-like and medullary canals are absent. Grains of pigment are concentrated primarily in the centre of the cortex layer or, more frequently, are diffusely dispersed. Shaft diameters = 0.08 - 0.2 mm.

Fibres of the guard hair (= directing, cutting, and bristle hairs)

Guard hairs are streaming and bristly. Guard hair fibres are irregularly rounded, oval, or subangular in shaft cross-section. The cuticle is not ringlike, rather it is flat and less frequently tile-like; interrupted medul-

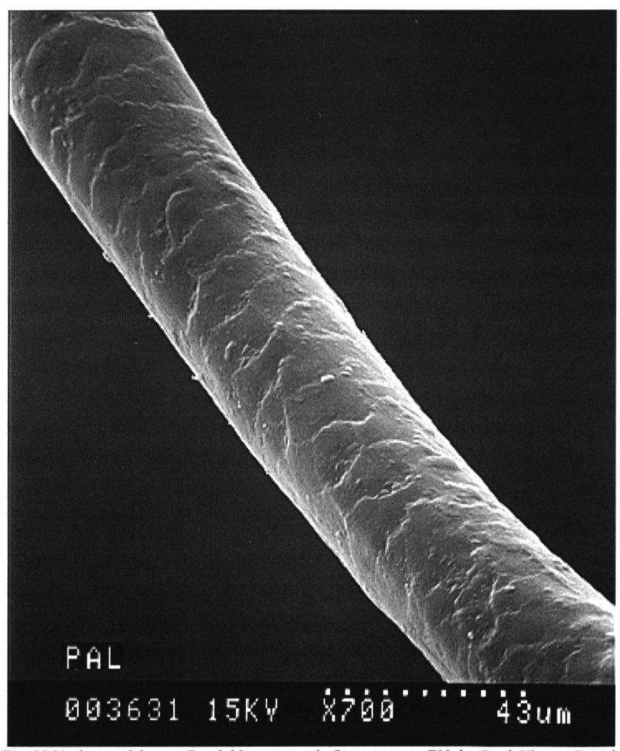

Fig. 38 Underwool from a Berelekh mammoth. Stereoscan, x 700, by Prof. Kloger, British Museum (Natural History).

Fig 38 Onderwol van een Berelekh mammoet. Scan, x 700 door Prof. Kloger, British Museum (Natural History).

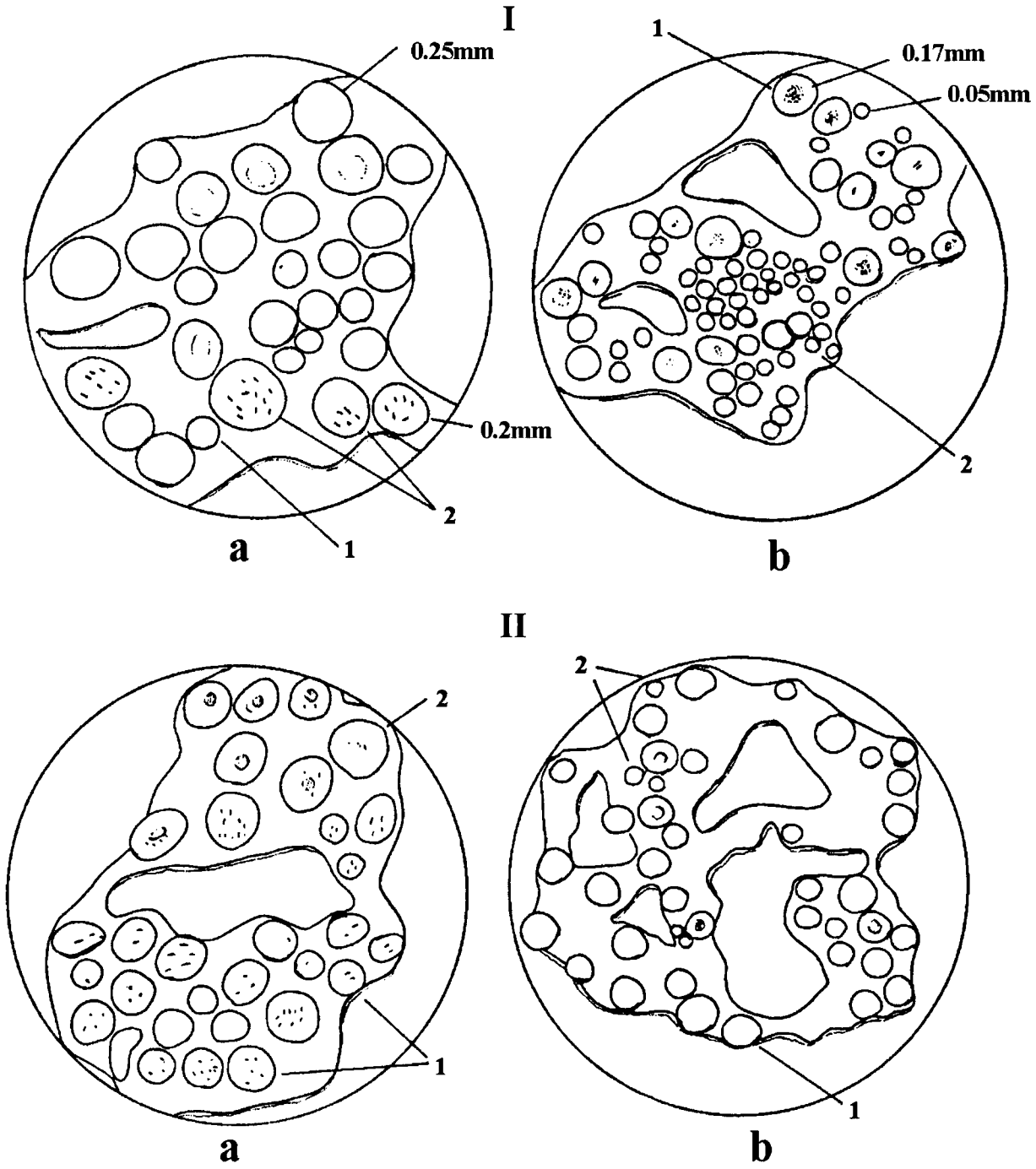

Fig. 39 Cross-sections of hairs: Top row (Yuribei mammoth 12 - 14 years old): a) light yellow strand from the hip, 1) intermediate hair, 2) guard hairs with pigment cores; b) pale yellow strand from the side, 1) intermediate hair, 2) underwool. Bottom row (Taimyr mammoth 40 - 45 years old): a) dark brown hair strand, middle section, 1) intermediate hairs, 2) guard hairs with core ducts; b) light yellow strand, middle section, 1) intermediate hairs, 2) underwool. Drawings of 72x magnification.

Fig. 39 Doorsneden door haren: bovenste rij (Yuribei mammoet 12-14 jaar oud): a) licht gele lok van de heup, 1) overgangshaar, 2) dekharen met pigment kernen; b) bleek gele haren van de zij, 1) overgangshaar, 2) onderwol. Onderste rij (Taimyr mammoet 40-45 jaar oud): a) donkerbruine lok, middelste gedeelte, 1) overgangsharen, 2) dekharen met kern kanalen; b) licht gele lok, middelste gedeelte, 1) overgangsharen, 2) onderwol. Afbeelding 72 x.

lary canals are present. Grains of pigment are concentrated as nonuniform clusters in the central portion of the cortex layer. Shaft diameters = 0.13 - 0.37 mm. Length of guard hairs on the tail are up to 1 m [!].

Baby mammoths that were born in the spring, in April or May, were covered by a juvenile coat of brown-yellow guard hairs with a light underwool. The guard hairs grew by the winter, attaining a length of up to 20 - 30 cm on the body and up to 14-15 cm on the legs (Vereshchagin and Mikhel'son, 1981).

As a rule, the natural colour of all varieties of hair fibres, somewhat faded in burial and mummification, varied from pale yellow and ashy to dark brown and

coal black. Downy hairs always possessed a lighter colour than either the transitional and guard hairs.

From Blumenbach's first assignment of the species name *Elephas primigenius*, (on the basis of colossal bones) in 1799, nearly 200 years have passed. Since that time, Academician V.V. Zalenski (1909:40) more precisely defined the species description, including data from the animal's exterior, on the basis of his study of the skeletons and other remains of the Lena, Berezovka, Sanga-Yuryakh, and Lyakhovskii mammoths. Zalenski noted "Mammoths were trunked mammals, having a more awkward body than elephants (their height relative to the length of their body was less than that of elephants), a larger head than elephants (the head was as long as half of the body), and a short tail. The body was covered with thick wool, especially well developed along the sides of the lower parts of the body, where it formed a hairy fringe composed of long hair. The [upper] incisors (tusks) were huge, and spirally curving with their apices directed inwards and upwards. Both pairs of legs had four toes and three toenails. [In fact, the fifth toe of all feet is clearly discernible on skeletons; it has two relatively small phalanges.] The tail, adorned at the end with a large bundle of long, black, bristly hairs, was short.[Indeed, the entire free portion or body of the tail was covered with hair.] The anal apparatus was more developed than that of elephants."

Such a general characterization is certainly insufficient for the reconstruction of the true appearance of our animal. However, in articles and in photographs, Zalenski first provided far more varied and exact details of the morphology and structure of the woolly outer coat and skeleton of mammoths than is apparent in the diagnosis cited above. He was the first to confirm the extreme aseriality of the structure of the fore foot [carpus] of the mammoth, a feature characteristic in differing degrees for all of the elephantids. The essence of this structure in the mammoth lies in the fact that the wide intermedium bears down on carpals 2 and 3 and that the radial is moved inside [medially] and is joined with carpals 1 and 2. It is thought that such a phenomenon strengthened the mammoth's fore foot [carpus], lessening the probability of dislocation. The compactness of the carpals and tarsals, in addition, favors the locomotion of elephants (and presumably mammoths) on sticky, boggy ground. The compactness is attained by the relative flexibility of the subcutaneous tissue and skin of the feet, under which conditions the foot, if submerged into the pliant substratum, expands for support in the region of the sole, and during extraction it shrinks [collapses] and does not remain mired in the boggy stratum.

Here we present a more precise sketch of the mammoth's figure, or a species diagnosis of the mammoth based on appearance of our study materials.

Form of the body and morphological details

The mammoth was a massive, moderately long-legged animal, with a height at the withers of 3 - 3.5 m for males and up to 2.8 m for females. The index of size, i.e., slant length of the body/height-at-the-withers × 100, in mammoth calves on the basis of carcasses is 74%; in adult mammoths, on the basis of skeletons this index is 78% while on the basis of ancient representations it is 81.3%. The index of sloping of the hindquarters, i.e., slant length of the body/height-at-the-sacrum × 100, in calves is 75.5%, in adult mammoths, on the basis of skeletons the index of sloping is 98.6% and on the basis of ancient representations it is 103.8%. Old males were characterized by possessing a neck inlet or "saddle" behind the head.

The head of the mammoth is larger than that of present day elephants. It was characteristic that the rostral portion was narrow; the alveoli of the tusks were closely opposed, and the base of the trunk rested upon them. The index of head length is the length of the head/height-at-the-withers × 100. In calves this index is 48%, in adults, on the basis of skeletons it is 43% and on the basis of ancient representations, 46.7%.

The length of the trunk, with the end reaching to the ground, terminated with finger-like dorsal and ventral proboscideal processes. In Flerov's view (1931), the dorsal process, somewhat beak-like, was 9 - 12 cm in length; the ventral process, more lip-like, was 4 - 6 cm in length. The tusks were larger than those of Asian and African elephants, with the replacement of the deciduous set by the permanent series occurring at one year of age. Tusks of old males 70 - 75 years of age attained the greatest size, based on lengths of up to 3.8 - 4 m and diameters at the alveoli of 16 - 18 cm. Tusks of females, correspondingly, were up to 2 - 2.2 m in length, with diameters at the alveoli of 8 - 10 cm. In males, the tusks curved into a gently twisting heteronomous spiral, i.e., the left tusk twisting toward the right and the right toward the left. In females they sloped sabre-like in a single plane. The tips of the tusks were always worn on the outer surface. As the spiral developed in males, the worn area also moved medially.

The ears were not large, and in form were similar to those of a human's. They laid against the rear portion of the head, were oval, elongated, and had measurements, in adults, of 30 × 15 cm, having one-fifth to one-sixth the area of Asian elephant ears and 1/15th to 1/16th the area of African elephant ears.

The torso of old males was humped at the withers, with a sloping, cascading rump and lowered hindquarters; in females, the hump and lowering of the hindquarters was more weakly developed. The legs were massive, five-toed, pillar-like and straight during standing, flexing only while in gait motion. The soles were rounded, with a diameter of 13 - 15 cm in calves up to a year old, and 40 - 45 cm in old males. There were three and occasionally four hooves on the front and hind feet.

The body or dock of the tail was short, with a hair covering reaching halfway down the hip. In calves up to a year old, the exterior features of the adults, especially those of the adult males, were muted or "concealed" in the juvenile attributes, and in the latter the dorsal outline of the head and back formed one weakly convex arch.

The mighty woolly coat, covering the entire body, was composed of three types of hair: underwool or down, transitional hairs, and the cutting or guard hairs. The topography and coloration of the wool was relatively uniform on males and females. The region from the top of the head to the forehead carried a "bonnet" of black, forward-streaming coarse hairs having lengths of 15 - 20 cm. The top or anterior portion of the trunk was covered with brown wool up to 7 - 8 cm in length; on the sides and bottom of the trunk this covering was up to 12 - 14 cm in length. The annulations of the trunk were entirely hidden in the underwool; the guard hairs along the sides of the trunk formed a sparse beard-like cascade.

The ears, pressed against the head near the neck, were entirely covered with brown wool, with the long strands extending down to the earlobes. Under the lower jaw and the dewlap hung locks of brown wool with a length of up to 49 cm and more.

The body was covered with brown, light brown, or yellow-brown and brown with an admixture of straw-coloured guard hair up to 20 - 25 cm in length. From the sides, shoulders, belly, and hips hung a "skirt" of brown or light brown locks, with the length of the guard hair attaining a meter or more in length. The guard hairs in these locations hid a thick, twisted underwool of yellowish-straw or ashy colour, having a length of up to 15 cm and more.

The shoulders and the lower legs were hidden under brown guard hairs having a length of up to 30 - 40 cm. On the wrists and ankles this type of hair reached 14 - 20 cm. The soles of the feet in old individuals were very corneous, and their outer layer was fissured. The tail, from the base of the body to its termination, had a bundle of coarse brown and dark brown guard hairs. These hairs had a length of up to 60 cm and more. The colour of the skin of the body was light yellow or brown. On exposed areas free of wool (e.g., the end of the trunk, the lips, and the anus), the skin exhibited dark-pigmented spots.

The exterior and living conditions of mammoths

The realistic notions of the adaptive and functional importance of the external morphological characters of mammoths are revealed by means of comparison of the same characteristics in modern elephants. These notions, however, are conditioned with a knowledge of the ecology of extinct and extant animals in the distinct ecological conditions of northern Eurasia in the late Pleistocene, versus the tropics of the Old World.

The configurational differences of the three types of elephants is illustrated in the outline drawings shown in Fig. 40. The basic features distinguishing mammoths from African and Asian elephants include: (1) a splendid furry "attire" (woolly covering) over the entire body; (2) a more prominent head with a narrow rostrum (nasal part); (3) a more proportional (well proportioned) build, especially of the torso and the extremities (observed when the woolly covering has been removed); (4) prominently curved, hyperdeveloped tusks representing the extreme of tusk development in elephants; (5) lengthened proboscideal processes, small ears, and an abbreviated tail; and (6) feet primarily with three hooves.

Woolly covering

The robust, differentiated fur covering of the mammoths is their most distinguishing feature when compared with elephants living today. Clearly the main function of the covering was heat retention. This is confirmed by the specific topography of the fur covering, including the presence of a distinctive bonnet of tangled hair on the forehead and on the crown of the head, analogous to the covering on the heads of North American bison, living on the blizzard-prone prairie; the thick, hairy drape or beard at the base of the trunk, on the cheeks, and covering the dewlap; the "skirt" of dangling locks of long hair on the sides and underbelly, analogous to the covering of the yak, living on the cold plateaus of Tibet and the Himalayas. There was presumably a spring moulting, lest the mammoths would have perished in the summer from overheating under their enormous arctic insulation. The distinctive hair types and their patterning that we have enumerated were necessary for the animal's survival under conditions of dry, sharply continental climate. One of the reasons for the extinction of the mammoths was perhaps the unsuitability of such a covering, its propensity for wetting and icing under the variable weather conditions–thaws, frosts, and blizzards–marking the end of the Valdai glaciation and the beginning of the Holocene, around 13,000 - 10,000 years ago (Vereshchagin, 1971). Southern populations of mammoths, for example those in the Crimea and Transcaucasia, probably were less hairy than contemporary mammoths occupying subarctic habitats.

The fur of mammoths was primarily brown and light-brown in colour. Possibly fur coloration lightened in winter, as evidenced by the thick growth of lightly coloured guard hairs over the spine and on the sides of mammoths acquiring their winter covering.

Elephants of low temperate and tropical latitudes, especially those of Africa, although having extremely bristly and sparsely distributed hair (as adults), are, compared to the mammoths, relatively hairless. Sparse, bristly hair covers the head, throat, belly, and spine of the Asian elephants. In Sumatra, adult individuals also occur that possess a woolly covering. The adaptive advantage of a woolly coat in the cold climate of the subarctic is indisputable.

Head

The relatively large head proportions in mammoths are in part a function of the development of the powerful tusks. Head length (rostrum - occiput) equalled up to one half the height of the individual at the withers. In the African elephant head length measured along this line equals only 40% of the individual's height at the withers. The placement of the mammoth's relatively long (and thin) tusks in parallel or converging alveoli is more mechanically advantageous for their survival during employment than would be the case were they placed in diverging alveoli, which would have directed them to the side. The facial nasal portion of the mammoth's head is also narrower.

Proportions of the body and the paired extremities

From comparisons with modern elephants, mammoths had builds of different proportions. This is seen in properly mounted skeletons and is shown through the index of size and gait. In a morpho-functional sense, these proportional differences can be explained by the requirement of great mobility in mammoths, i.e., their ability to move over vast expanses of open habitats during long seasonal migrations along river valleys. Greater mobility was also conditioned by decreased biological productivity in the subarctic, compared with the tropics. In other words, in order to gather equivalent forage in a cold climate the expenditure of more energy was demanded.

Paired extremities.

The legs of mammoths, like those of elephants, are characterized by straightness of the levers formed from their constituent bones. The legs were straight or pillar like when the animal was at rest and exhibited flexure at the elbow-knee and ankle-wrist only during gait motion.

The soles of mammoth feet were flat and rounded. The edges were supplied in the front with two, more often with three, and rarely with four, flat hooves. This contrasts distinctly with the condition in elephants, which possess four or five prominent hooves. The strands of coarse hair in the foot region, bordering on the soles, are worn thin and trodden down, but the toenails do not exhibit evidence of having been sorely worn, such as by showing traces of hangnails. This fact convinces us that mammoths did not use their feet to push snow aside in search of forage, a behaviour often portrayed in the images of present day artists.

The extreme degree of aseriality in the arrangement of the mammoth's wrist bones is sometimes viewed to be a consequence of adaptation to the "unstable ground of the tundra" (e.g., Garutt, 1952) because of this arrangement's apparent strengthening of the wrist joint. There have been no anatomical (myological) or mechanical calculations in support of such a conclusion. Therefore the tendency for the development of aseriality, the commencement of which is attributed to the southern elephants in the late Pliocene, should be regarded as an example of non-adaptive evolution in the Order Proboscidea.

With the diameter of the sole of the six month-old Magadan baby mammoth being 15 cm, the load on the trace was equal to 141.5 g/cm^2; for the old Khatanga mammoth with a sole diameter of 45 cm, the trace load was equal to 663.2 g/cm^2. In comparison with other animals of the subarctic zone (Kuzmina, 1977: 42), these loads were not large: approximately that of the horse but one and one half times smaller than the load of primitive bison.

The tusks and their function

The development of huge curved tusks having external wear of their ends (with the formation of wear zones), sharply differentiates mammoths from modern elephants. In a series of tusks of African elephants it can be observed that in a continuum of wear some examples exist having their ends worn more or less evenly into a cone. African elephants actively use their tusks for the uprooting of trees, destruction of the trunks of baobab trees to gain access to stored water, and for altercations with its own kind as well as for defence against predators. Modern Asian elephants also apply their tusks in work tasks, for example carrying logs. In the Kalimantan region of Indonesia and elsewhere, and in Africa, elephants create niches on the sides of hills and on the walls of caves with their tusks in their quest for salt.

Mammoths, however, are a different matter. Pfitzenmayer (1939), after participating in the excavation of the Berezovka mammoth, presumed that mammoths wore their tusks distinctively in the procurement of food, for example grasses beneath the snow. This hypothesis was accepted by many writers and became widely established in the literature and contemporary artwork. At that time it was not well known that the wear of tusks began in mammoth calves at a stage when the tusks were far too short to reach the surface of the ground. The discovery of broken tusks with reworn, rounded ends (up to 4% in samples) demonstrated that these teeth were used by mammoths for very heavy work (or possibly in aggressive activities) (Fig. 41). According to S. V. Tomirdiaro, tusk breakage such as this resulted primarily from the rigid pressures of applying the tusk to frozen cracks of the ground, and on ice-covered walls of riverine banks and precipices.

Hypertrophy of the mammoths' tusks is sometimes seen as one of the factors in their extinction but venerable large males with very large tusks frequently contradicts this idea.

The trunk, its purpose

The functions toward which the elephant's trunk are applied are numerous and diverse. It is a special arm, used in the acquisition of plant food, sand (for dusting), and water; for tactile exploration; for the seizure of antagonists; and for the infliction of mighty blows. The trunk, twisting in a peculiar way, like a snake, is

suited to many manipulations. Such multipurpose functions of the trunk, its ability to compress abruptly and to extend, was enabled by its annulated surface, the presence in relief of transverse folds of thick skin. In the Asian and African elephants these transverse trunk annulations are 35 to 40 in number, in the baby mammoth, up to 76 [!].

The tip of the trunk, a region supplied with very sensitive lip and finger-like processes, is capable of the most delicate and crucial operations. In spite of the relatively simple structures comprising the end of the African elephant's trunk, it is able to pluck leaves and bark from trees, and to grasp small fruits and nuts (as is well known to visitors of zoos).

The structure of the end of the mammoth's trunk, with its terminal processes, is nearer to that of the Asian than to the African elephant. Judging from the better development of the processes at the end of the trunk,

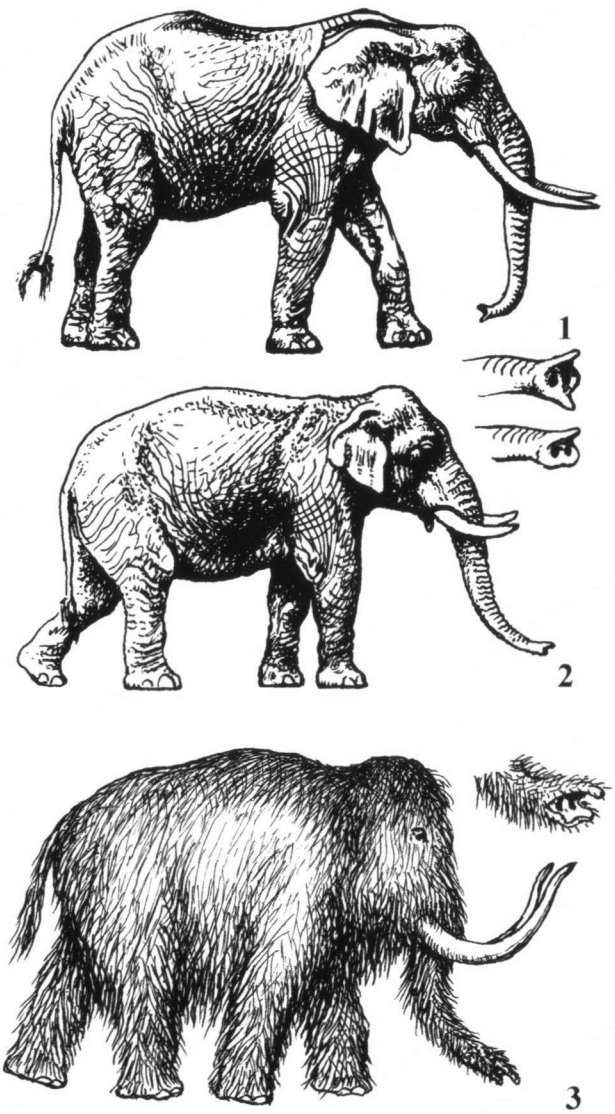

Fig. 40 Figures of adult males: 1) African and 2) Asian elephants (drawings by V.A. Gorbatov); 3) mammoth (drawing by N. K. Vereshchagin).

Fig. 40 Afbeeldingen van volwassen mannetjes: 1) Afrikaanse olifant, 2) Indische olifant (tekeningen V.A. Gorbatov); 3) mammoet (tekening N.K. Vereshchagin).

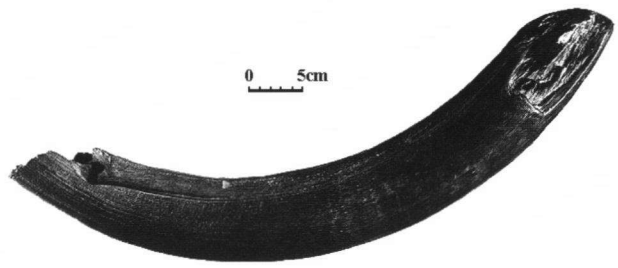

Fig. 41 A tusk broken during the life of the mammoth, with secondarily worn and polished tip.

Fig. 41 Tijdens het leven gebroken stoottand van een mammoet, met een secundair afgesleten en gepolijste punt.

mammoths possessed a greater ability for capturing and collecting small plants such as grasses and leaves (see, for example, Fig. 40) as compared with modern elephants. The presence of such small plants as foxberry, mosses, and miscellaneous herbs in the food mass in the stomach of the Shandrin mammoth corroborates once again the herbivorous nature of these animals and their habit of foraging in meadows and, primarily, in river valleys and bottom lands, i.e., the basins of thermokarst lakes of the Pleistocene subarctic.

Ears

A basic comparison of the area of the external ear of the mammoth with the ear of modern-day elephants shows that for a size of 300 - 400 cm^2, it is 5 - 6 times smaller than the area of the Asian elephant's ear and 15 - 16 times smaller than the African elephant's.

In a tropical climate, the ears of the African elephant perform a distinct heat regulating function. Supplied with a branching network of blood vessels, the ears prevent overheating in the sun. Through swinging of the ears slowly from front to back, like a fan, the animals cool their head and neck regions, and at the same time discourage insect pests. The peculiar "locator" role of the ears of these elephants is also great. The keen hearing of elephants in the African bush is confirmed by many hunters. In Asian elephants, similar receptor and thermoregulatory functions of the ears are apparently much weaker.

The small external ears of the mammoth, fully covered by and half concealed in the wool, adjoin the neck as a consequence of natural adaptation to the rigid cold of the Pleistocene subarctic. In the widely open, expansive landscapes typical of the harsh Pleistocene steppe, the mammoth's ears, in comparison with the acuity of hearing in modern elephants, were probably less sensitive to transmitted sound.

The hump on the withers

Paleolithic artists regularly represented mammoths as humpbacked, possessing a large shoulder hump posterior to the neck inlet. Such a hump may have been the result of the development of powerful muscles on the excessively developed dorsal spines of the anterior thoracic vertebrae, as also seen in bison. In addition, the hump could be a result of fat deposits such as in zebu cattle and camels, or could be merely the representation of a mane of hair developed behind the neck and over the shoulders. Although the dorsal spines of the thoracic vertebrae of the bison are proportionately one and one half times as long as the mammoth's, their function is especially for support of the powerful musculature of the spine and anterior, shoulder portions of the front extremities. Fat plays no role in the prominence of the bison's hump, unlike the humps of the camel and the zebu, which are skin supported fat containing sacs not associated with extreme spinous development, analogous in many ways to the fatty tails of some sheep. Large deposits of subcutaneous fat do not occur in elephants inhabiting the tropics but this analogy can not be extended to mammoths. The dorsal spines on the anterior thoracic vertebrae of the African and Asian elephants are similar in length to the mammoth's. Until the discovery and thorough study of the entire carcass of an adult mammoth, it remains to be established whether a winter accumulation of fat occurred, beneath the skin and in the internal organs, and we therefore continue to ascribe the humped back appearance in representations of mammoths in representations to the presence of a developed mane.

The tail

The tail of mammoths sharply contrasts to that of elephants living today. A long free tassel of coarse and thick hair on the tail of African and Asian elephants extends from the end of the appendage downwards. Such a tail is effective for driving off bothersome insects from the hips and perineum. It is more appropriate to compare the fluffy tail of the mammoth with the tail of yaks and bison. The smaller length of the mammoth's free tail is accounted for by reduction in the number of vertebrae, to 20 or 21, as opposed to 23 or 24 for modern-day elephants. The most probable general morphological differences of adult and baby mammoths are illustrated in Fig. 42.

Our morphological inferences and deductions support present-day reconstructions of the ecology of the Pleistocene arctic biome. Briefly, they are as follows:

Mammoth populations flourished in the subarctic for a period of 50 - 60 thousand years during the last glacial stage of the late Pleistocene epoch (= Würm, = Valdai, = Wisconsinan stages) in a very dry, strongly continental climate. The habitation zone of mammoths (the "hyperzone" of Pleistocene periglacial tundra-steppe, in central and southern Europe, northern Asia, and Alaska) underwent extreme intra-soil freezes. These imposed a peculiar complex of ecological features, the so-called region of "permafrost".

Extremely low temperatures and the absence of a snow cover in winter, and high levels of insulation during the hot summers typified the open landscape during this period. These conditions resulted in the thriving of meadow grasses in river valleys, on the slopes of hills, and in dry lake depressions (Velichko, 1973; Tomirdiaro, 1980; Hopkins et al., 1982; Kontrimavichus, 1976). These river valleys with their flood plains, oriented in N - S directions, including riverine forests and shrub thickets, were the primary habitats of mammoths and their "satellites". They provided pastures for fattening-up, river-beds for seasonal wandering, as well as places of spontaneous death in floods and on thin ice (Vereshchagin and Baryshnikov, 1980).

Estimates of basic biological data for mammoths were also formed on the basis of these materials, including: the evident seasonality of their reproduction, i.e., the birth of young in April or May; the beginning of sexual maturity at 18 - 25 years of age; a sex ratio of 1:1; and a maximum life span of 75 - 80 years with an average

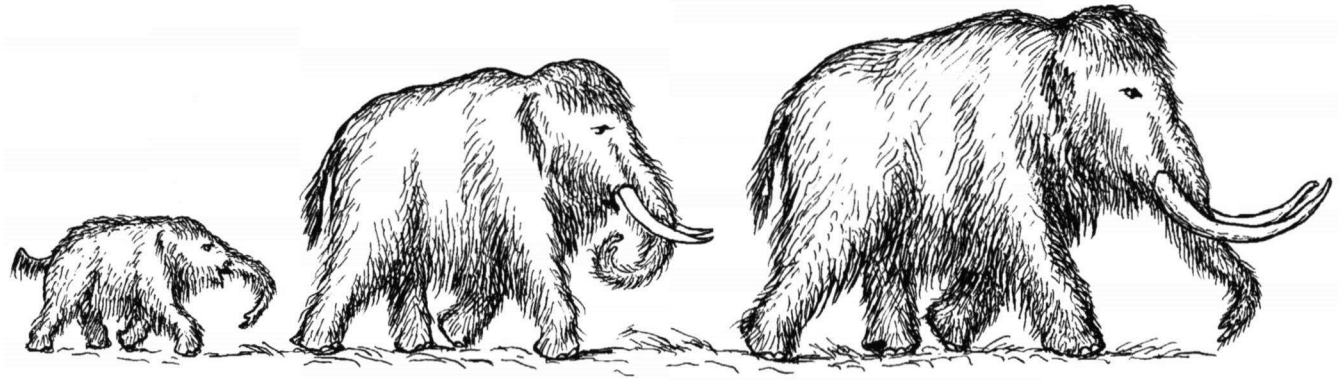

Fig. 42 Adult male, female, and yearling mammoths. Drawing by N.K. Vereshchagin.

Fig. 42 Volwassen stier, koe en jonge mammoet. Tekening N.K. Vereshchagin.

longevity of 45 - 50 years (Vereshchagin and Mikhel'son, 1981). These new data, obtained by us, also include information on mammoth mortality (Fig. 43).

Problems of the study of the mammoth fauna

The following is presented on the basis of material in a report by N. Vereshchagin presented at the Fourth Convention of Theriologists of the USSR in Moscow, January 28, 1986 and at the Twenty-second Session of the Paleontological Society in Tallinn, January 29, 1986. While it departs from the theme of the mammoth's exterior, it has implications for additional understanding.

Wild and domestic mammals make up the primary resources of protein necessary for the nutrition and well-being of people throughout the world. The study of the origination and development of the mammal fauna is necessary for the reasoned assimilation and conservation of this resource.

The modern fauna of northern Eurasia appears today as only a vestige of the richer fauna of the glacials and interglacials of the Pleistocene period, of which the most striking representatives were the woolly mammoths. Therefore, the fauna of this period is also called the mammoth fauna.

The mammoth fauna was formed throughout a number of great glaciations and brief interglacials characterizing the Earth's most recent geological history. In the realm of study of late Quaternary mammals, many organizational, methodological, and

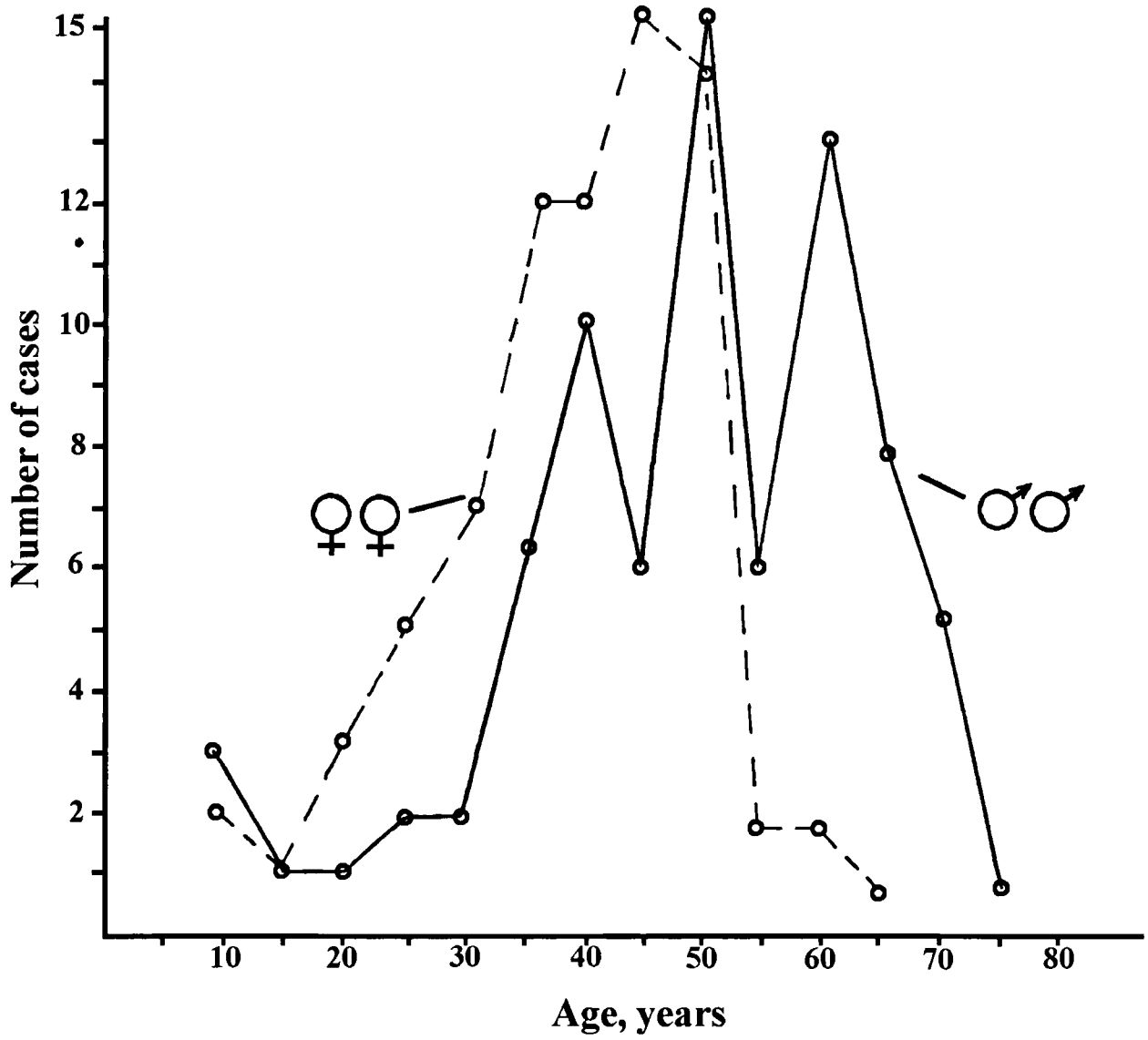

Fig. 43 Age of mammoths at death, on the basis of tusks collected from the continental shelf of the Dmitriya Lapteva Strait.

Fig. 43 Leeftijd van overlijden van mammoeten bepaald aan de hand van stoottanden verzameld op het continentaal plat van de Dmitriya Lapteva Straat.

theoretical problems have accumulated. It is now appropriate to summarize these and to touch on the prospects for their resolution.

In the span of the last 70,000 years of the Quaternary period, during Riss-Würm (Dneipr-Valdai) interglacial and the Würm (Valdai) glacial stages, the mammoth fauna achieved its greatest flowering and then, approximately 10,000 years ago, quickly vanished.

Today there are known to us more than 80 species of large and small animals, the populations of which were formerly distinguished by high numbers. This is shown by the abundance of their fossil remains discovered in sediments of different types and genesis deposited throughout the Quaternary period. The origin of the mammoth fauna extends into the earlier part of the Quaternary period, i.e., as far back as 800,000 years before the present and even into the Pliocene.

The mammoth fauna presents biologists, and in particular the mammalogists, the opportunity to study and understand the late stages of phylogenesis, the ecological environments of this epoch, the characters and high rates of morphological transformations of organisms, and the boundaries of their distributions in time and space, their migrations, and to clarify the essence of modern geographical variability. Finally, study of their remains leads to understanding some of the causes of the extinction of this fauna.

From study of frozen carcasses of mammoths, rhinoceroses, horses, bison, and musk-oxen recovered from thick permafrost deposits, geneticists hope to obtain a view of their ancient genomes from preserved forms of DNA; physiologists intend to solve problems of the duration of suspended animation of tissues and cells, the evolution of animal proteins, and the preservation of fatty acids; microbiologists attempt to understand the nature of immunity and to discover new forms of fossilized microbes and viruses.

For anthropologists and archaeologists this mammal fauna and its composition in different regions of Eurasia, are important from point of view of knowledge its provides regarding available foods for contemporary groups of human foragers as well as their habitats, their hunting methods and tools, and sources and inspiration of their decorative art. For geologists, paleogeographers, taphonomists, and paleoclimatologists, the remains of animals of the mammoth fauna appear to be a source of abundant information for the construction of geomorphological, biostratigraphical, and paleogeographical models and conclusions. The connections of paleozoology with neighbouring disciplines are thus enduring.

Conditions and organization of field investigations

The Committee for the Study of Mammoths and the Mammoth Fauna [now the Mammoth Committee] was created on the initiative of the Academician E. N. Pavlovski in 1948 at the Presidium of the Academy of Sciences USSR. The basic goal at its creation was rapid response to information concerning important finds of frozen mammoths and their scientific assimilation. Today, the Committee unites approximately 200 corresponding members, representing scientists at academic institutes and museums. Comprising the whole, which includes many specialities, there are primarily zoologists, paleozoologists and archaeozoologists (45%), Quaternary geologists (25%), and archaeologists (12%). A regional, Republic Commission for the Study of Mammoths and the Mammoth Fauna was formed in Yakutsk under the direction of the main Committee. The Committee has a working group of 21 members comprising colleagues from the leading institutes of the country's centre and periphery.

The office of the Committee is in St. Petersburg, in the Zoological Institute of the Russian Academy of Sciences, where the largest collection of Quaternary mammal remains in the country is concentrated. During the past 20 years the Committee organized four All-Union conferences and produced six collections of works and two popular science booklets. Fifty two scientists from the former Soviet Union and the USA collaborated in a book reporting results of investigations of the Magadan baby mammoth.

The most significant recent field and laboratory work of the Committee includes the following: excavations in caves along the Suchan River in Primorskii Territory (1968 - 1975); investigations of the Berelekh mammoth "cemetery" in Yakutia (1970 - 1980); detailed studies of the Selerikan horse (1968 - 1974) and the Shandrin mammoth (1974); excavation of the skeleton of the Churapchin rhinoceros (1973); and excavations of partial carcasses of the Khatanga (1978) and Yuribei (1979) mammoths. In addition, skeletons of a southern elephant and an elasmotherium found in the lower Quaternary sands of Pyatigorye were mounted with Committee participation in the Stavropol Museum. Also, the long standing scientific ties with archaeology continue, as for example in the collection and study of bone materials from Paleolithic sites on the Russian Plain and in the Caucasus.

Other beneficial activities undertaken by the Committee included: lectures presented on "Yorkshire Television" in England by Vereshchagin (1979) and the creation of a special film based on these; exhibit of the mummy of the Magadan baby mammoth in London at an industrial trade exhibition (1979) and in Turin (1980); as well as special "All About Mammoths" exhibits in Japan (1980-81), Finland (1985), Sweden (1991, 1994), U.S.A. (1992), and Germany (1994 - 1995). In three cities of Japan, over two years, 1.5 million people visited this exhibit and in Finland, over two months, it was visited by 150,000 people. In the U.S.A. the mammoth exhibition was viewed by numerous visitors in Houston and Minneapolis.

Work is organized in Russia and the former republics to conduct surveys in locations supporting known

sites of remains of mammoth fauna. The results of these surveys are published for distribution to colleagues in Russia and adjoining regions.

The primary problem in organizing new field research is without doubt obtaining the funds for systematic scientific searches for burials and for the gathering of timely information from the discovery areas of valuable frozen carcasses of mammoths and their "satellites." In a sense, the carcasses of "satellites" perhaps now are even more desirable–for example, the carcass of a musk-ox, a cave lion, or a cave bear would be of special great interest. Our attempts to influence the course of discoveries through print, radio, and the publication and distribution of special leaflets have to the now provided only scanty results. This is partly due to the absence of an incentive for the first people on a site to report their discovery. In the districts of the gold mines, for example, according to evidence provided by Siberian geologists, frozen carcasses of various animals, including mammoths, are revealed annually, but, as a rule, they are hurriedly buried again in the mine tailings terraces. The arrival of scientists can delay work and complicate the mining of gold. The gold-digging work teams are not always composed of individuals of such high cultural standards as the miners at Susuman who in 1977 found and saved the carcass of the Magadan baby mammoth. Losing a few "gold-days" due to the influx of reporters, scientists, and curious on-lookers, the work-teams and bulldozer crews at Susuman received "compensation," i.e., thanks from the President of the Academy of Sciences. In hindsight this turned out to be a very curious and absurd situation, as shortly thereafter, once transported to Leningrad, the Magadan mummy was insured for ten million roubles and sent on exhibition to London. Later, during the 1980s, the Magadan baby mammoth was the highlight of the show at large international exhibitions. In addition to paleontological specialists, many non-paleontological staff of the USSR Academy, including entomologists, ichthyologists, and fresh water biologists, as well as carpenters and secretaries, were provided an opportunity to travel with the display of this one baby mammoth mummy and other exhibit components to Japan, Finland, and Sweden.

On two occasions the Committee for the Study of Mammoth and the Mammoth Fauna succeeded in obtaining, from the Presidium of the USSR Academy of Sciences, the apportionment of gilded watches (each with a value of 40 roubles) for discoveries of the crania and tusks of two mammoths, but it should be obvious to everyone that for such a reward, a hunter, fisherman, or reindeer breeder (be they Nenet, Dolgan, Yakut, or Evenk) hesitates to travel a hundred kilometres to send a telegram to the Presidium of the Academy reporting the discovery of the body of a mammoth. As during the last century, it is much simpler for him to chop off the tusks and receive 200 - 400 roubles without cares or trouble, or simply to use the tusks for carving and to feed the meat of the mammoth to the sled dogs or to leave it for the polar foxes. The conviction of a few financier-bureaucrats from the Academy, that the first discoverers of the bodies and skeletons of wild extinct animals ought to be happy with the very fact of discovery and "obligated," thus abandoning their business to go a hundred kilometres to notify scientists, reveals only their complete misunderstanding and ignorance of the physical (ecological) conditions of the tundra and taiga of Siberia. For in this region in fact the life of a person often hangs by a thread.

The next problem is the presence of a possibility for quick response to the notice of a discovery of a frozen carcass. To facilitate this, constant and free reserves of supplies are required for an urgent expedition to the discovery site in the tundra, and also, of course, a qualified team of accompanying scientists. The fact is, that skeletons or frozen carcasses of wild animals frequently show up on the frozen cliffs of the shores of rivers and lakes in all for only a few days, rarely for a whole season, and soon after their exposure they are typically covered in a landslide of thawed material or are carried away in flood-water or by ice. Such processes of erosion of the tundra ground proceed rapidly during warm and rainy weather.

Excavations and recovery of frozen carcasses of the beasts should be thorough, attracting specialists in various fields, for example biologists, microbiologists, taphonomists, and geologists. But on expeditions to the tundra and taiga is it not possible to bring along "ballast" people, who are unsuited for the field. In the excavations of skeletons and carcasses, paleontologists take into account the smallest facts and traces connected with the origin and nature of the burial, as well as assume the obligation to record and sketch the proceedings. It happens, however, that specialists of different kind go on such expeditions, i.e., searchers for whole mammoths who are incapable to evaluate even the most rudimentary taphonomic facts and therefore destroy the burials. It is extremely important to preserve the find in a frozen condition and not to let it thaw.

Washing out the skeleton of the Shandrin mammoth with a motorized pump in 1972, a team from the Institute of Geology of the Yakutian Branch of the Academy of Sciences pulverized the frozen organs of the thorax with jets from the water pump that penetrated between the ribs. In addition to the skeleton, only the intestines and part of the stomach, filled and fixed with frozen chewed grass, were thus preserved for science.

No less tragic was the history of the Khatanga mammoth, which was found lying on the left bank of the Bolshaya Rassokha River, 150 km north of the center of the Khatanga region in 1977. Sent for its protection to the Taimyr Peninsula, a party headed by Dr. P.P. Gambaryan, instead of the preservation of the skeletal and soft tissue remains by shielding it from thaw, unexpectedly started an amateur excavation. Not only did this party allow the skin and flesh of the head to thaw, but also mangled the trunk of this ancient mammoth into pieces, and subsequently abandoned these

around the site. This was the fourth mammoth trunk lost to science. And so once again the Russian proverb is confirmed: "There's trouble if the shoemaker begins to bake pies and the baker to make shoes." But even more lamentable, from science's point of view, is the history of assimilation of a complete carcass of a large mammoth in the Gyda Peninsula in the spring of 1987. In brief the history is as follows:

In the fall of 1986, a reindeer-breeder/team leader from the collective farm "The Dawn of Taimyr," Tesedo Yavoli, discovered the body of a mammoth in the bank of Yekaryauyakha River, which flows into the Yenisei Gulf. Having been removed from the body by ice flows, the head was lying in the water. Four men were unable to retrieve it; perhaps it was stuck or frozen in place. The tusks, which were underwater, were sawn off and later were used for carving. Tesedo informed the Public Prosecutor of the Ust-Yenisei region, Yu. A. Baklanov, about his discovery and Baklanov immediately contacted the Presidium of the Academy of Sciences.

The organization of the research of this discovery was entrusted to the Zoological Institute in Leningrad. Nonspecialists, however, were sent to the site of discovery and their attempts to recover and document the remains were bungled. As a result the body, removed from the sediments and left lying in the sun at a temperature of +30° C, collapsed at the beginning of July 1987 onto the river ice and together with the head that had previously been dislodged and now frozen in ice, was carried away by flood waters to the Yenisei Gulf. This happened perhaps only a few days or perhaps even hours before the arrival of a second team of researchers on July 14.

This kind of organization of expeditions and responses to a discovery, it is understood, did not promote the progress of our science and discredited the very idea of search by and obtaining information from the indigenous inhabitants of the tundra.

At the beginning of the present decade, things are going very badly with the preservation of remains of Quaternary animals in state-supported collections in the country and especially so in regional museums. Regional museums usually do not keep inventories or catalogues, and very valuable collections are often in the basement or in the attic, or are simply treated like refuse. These were the circumstances, for example, in Baku with the unique collection from the Binagad Bitumen and with the collection of the Taman fauna held by the Temriuk Museum.

Finally, our unilateral scientific connection with foreign scientists has materialized as the infamous "absurd" situation. In essence, over the past ten years western scientists, for example Swedes, Danes, West Germans, Canadians, Americans, and the English come to us at the Zoological Institute to examine our fossil collections of horses, rhinoceroses, primates, and mammoths, and for the past ten years our scientists have been denied the possibility to work at museums in Germany, France, England, and America, and to see their representative specimens. To the Novosibirsk Islands–"please", but the Institute's zoologists are "not allowed" in the British Isles! Happily, this situation is rapidly changing in the 1990s.

We turn now to scientific results and problems. Here we have discussed work on large animals of the mammoth fauna, since the small mammal specialists, the "mouse-men", have many of their own achievements and problems. Mammoth research problems, in addition to being pursued in institutes in St. Petersburg and Moscow, are also more or less successfully elaborated in centres and branches in Belarus, Moldova, Ukraine, Georgia, Azerbaijan, Uzbekistan, Tadjikistan, Kazakhstan, Siberia and the Far East. A review of the results of this work of the various centres deserves separate presentation.

Achievements of the paleozoologists

Thanks to the wide paleozoological survey within the boundaries of the former USSR, we have succeeded in revealing and publishing a number of patterns in the evolution of distribution ranges of Quaternary mammals, and, utilizing radiocarbon dating, in tracing this evolution in both absolute and relative temporal terms.

The Zoological Institute is preparing for publication an atlas of maps of Quaternary mammals of the former Soviet Union. The chronological dates of the latest finds permit us to follow the evolution of distribution ranges of threatened species, to recognize areas of the last refuges of a number of animals against the background of ecological factors of the environment, and to understand the probable causes of extinction of various species. Working copies of maps such as those for the mammoth, woolly rhinoceros, musk-ox, and river beaver have already been prepared for publication. The centres of distribution of animals that were abundant in numbers and the last "refuges" or "sanctuaries" of the above-mentioned species, i.e., where their populations have survived the longest, are clearly shown on these maps.

In the goals of the paleozoologist and zoogeographer, great achievements were produced in the 1970s in the southwestern and northeastern portions of the country. New genera of early Pleistocene horned ruminants–the antelope *Pontocerus* from the Taman and Tiraspol faunas and the ox *Adjiderebos* from the Upper Pliocene of Transcaucasia–were described .

In the lower Kolyma Valley, along the Chukochya and Krestovka rivers, mammal faunas dating to the early and middle Pleistocene have been discovered. Species of wolf-like dogs, wolverines, the sheep-like zorgelia, *Praeovibos*, broad-fronted moose, and *Trogontherium* beaver were described. In addition distribution maps of populations of small and large cave bears of the subgenus *Spelaearctos* have recently been refined. These

cave bears, it is now recognized, lived not only in Europe but also in southern Siberia and Central Asia.

Taphonomical studies

The study of the nature of burial (taphonomy) of the remains of Quaternary mammals provides a foundation for paleoecological discussion and explanation. Taphonomical observations in the valleys of rivers of the Russian Plain and in the tundra of Siberia as well as in the caves of the Caucasus allowed us to trace and understand the nature of burial of animal remains in sediments of different types and genesis.

As is well known, discovery of frozen carcasses of giant animals in northeast Siberia was for a long time enigmatic to both scientists and the general public. In this regard there sometimes was reported theoretical and frequently absurd conjectures by people unfamiliar with taphonomy. First of all, the carcasses: the reason why their soft parts were preserved in the Arctic was that the animals lived and died in a cold climate, on ground frozen for many years. As soon as the body of the animal was buried by fluidized ground deposited as a landslide, or in an icy gully or fissure, or in flowing sand or silt of a river-bed, that is, in a flood plain lake or ravine, then it had the chance of being preserved for thousands of years at a temperature of -4 to -10° C. This occurred if the body was buried sufficiently rapidly and subsequently remained frozen. The majority of carcasses of animals that died of old age in a watershed, and of those that died in rivers or lakes, and collapsing there on the fragile ice or into the water, have decomposed. Only their skeletons, with occasional scraps of skin, tendons, and hair fibres remain. Numerous skeletal remains of mammoths at the famous Berelekh "cemetery" in northern Yakutia can be attributed to the carcasses of drowned animals that were carried to backwater pools on ephemeral creeks, and, later decomposing, were covered over by alluvial deposits and frozen.

Ecological-morphological studies

For rational representations and interpretations of the ecology of the mammoth fauna in northern Eurasia, different methodological approaches have been used. These include discussions of faunal composition; research on the biological features of extinct species and their external morphologies; taphonomical observations and data integrated from neighbouring sciences such as paleobotany, permafrost studies, and paleography. I. E. Kuzmina (1977) presented a critical review of opinions regarding the history of formation of the mammal fauna of the Arctic tundra, based in part on her personal observations in the Anabar Valley. Vereshchagin and Baryshnikov (1983) reported paleoecological studies of the mammoth fauna of northern Eurasia and compared it to the large mammal fauna of the African savannah. The conclusion was reached that in ecological essence this was a fauna of the steppe, meadow-steppe, and tundra-steppe inhabiting an extremely severe, sharply continental climate on an open landscape with compact ground. Its characteristic inhabitants were mammoth "satellites," e.g., horses (the kulon, or Mongolian wild ass, *Equus hemionus*), saiga, bison, and yaks. These were steppe forms that did not inhabit and do not inhabit marshes or forests, but foraged and conditioned themselves not only in the open landscape but also in the low riverine valley forests. An ecological vicariate existed–the huge consumers of vegetation on the cold tundra-steppe of Eurasia during the Pleistocene compared favourably with the herbivorous animals of the modern hot African savannah.

Recent research conducted on carcasses of frozen animals, for example the Selerikan horse, Churapchin rhinoceros, Sutorokh bison, and the Shandrin, Khatanga, and Yuribei mammoths, confirm that all were grass-eating animals and to a lesser degree browsers of such foods as tree branches. Moreover, all possessed a thick woolly covering. Study of a large series of mammoth tusks (approximately 200 specimens) from the intertidal zone of the Laptev and East Siberian seas and from the Berelekh mammoth "cemetery" enable a determination of basic life history data for the species. These data, presented here, when reported were new: (1) ratio of sexes, approximately 1:1; (2) longevity, 75 - 80 years; (3) attainment of sexual maturity at 18 - 25 years; and (4) most intensive growth of tusks occurred during the interval of 25 - 40 years.

According to our understanding, the tusks served the mammoths for stripping the bark off of trees–willows, poplars, larch and *Chosenia arbutifolia*, the Far Eastern willow. Possibly, they used their tusks to break the loose ice from cracks in the ground to quench their thirst, when, in the absence of water sources and snow cover in the maritime plains and with temperatures of -50 to -60° C, critical situations arose. The 3 - 4% incidence of tusk breakage, followed by remodelling of the tip by wear over the lifetime of some individuals, provides evidence of this.

Our paleoecological conclusions corroborate the excellent research of the paleogeographers and permafrost specialists, especially Velichko (1973), Tomirdiaro (1980), and others.

Many new data on morphology and other features were obtained through study of the Magadan baby mammoth. Multidisciplinary investigations demonstrated the well-preserved state of the fatty acids, for example, lipids of the brain, as well as details of the anatomy of the circulatory system, including the heart, and other internal organs of the mammoth. It caused a sensation when American collaborators discovered, with the aid of an electron microscope, well preserved complex albumen proteins in the blood, that corroborated through serological reaction the opinion that mammoths are more closely linked genetically to Asian than to African elephants. If amateurs had not been amusing themselves with the thawed carcass of

the baby mammoth at the Susaman gold mine, and if there had not been summer weather already in late June of 1977 above the Okhot Range, the baby mammoth, with its tissues still fresh-frozen, would have told us much more.

A small atlas presenting microphotographs of the hair of the mammoth, the Chersky horse, the woolly rhinoceros, and primitive bison has been assembled. This atlas is based primarily on our studies and on those of the Academician V. E. Sokolov. The atlas was compiled to assist biostratigraphers in the field with the early recognition of these organic remains in sediment samples from drill cores.

The sketch of the figure of young and adult mammoths, which is presented here (Fig. 42), assists present day artists and sculptors to henceforth avoid caricature-like representations of these remarkable animals.

On the problem of extinction of the quaternary fauna

In 1984 in the United States a world-wide review on the problem of extinction of Quaternary mammals and birds was published by the University of Arizona press, edited by the scientists P. S. Martin and R. G. Klein. Wide application of radiocarbon analysis to the problem of extinction refined conclusions about the dates of last appearances of a series of species of mammals and birds (from the mastodont to the moa) on all islands and continents. In his contributions P. S. Martin maintains his earlier view (1965 - 67), which is the extinction of animals in the Holocene was from the direct and indirect influence of arriving human populations. The fauna of Africa suffered the fewest losses. A review of the extinction of animals during the Quaternary period in northern Europe was presented by Vereshchagin and Baryshnikov in the Martin and Klein volume. They concluded that extinctions were not of the same kind in different systematic groups and regions. Mammoths and their "satellites," the woolly rhinoceroses, gigantic deer, primitive bison, etc., perished at the end of the last glaciation, about 10,000 years ago, as a result of an ecological catastrophe: the change from a sharply continental climate to a climate of more humid type, and from the resultant thawing of the meadow- and tundra-steppes of the Arctic and subarctic. In the southern regions of the former Soviet Union surviving populations of these species persisted but were gradually eliminated by Mesolithic, Neolithic, and later hunters. A number of large, ungulate species, for example antelope, kulon, and yaks, survived in the mountainous steppes of Mongolia and Tibet until the nineteenth century–as is well known from the period of the travels of I. M. Przhewalskii. These ice age survivors lived on until the assimilation of Tibet by China in the 1950s. For example, large, hoofed, wild yaks survived for a long time in the mountains of Central Asia, due in part to absence of humans, but also due in part to the severe, cold climate and little snow that presents the possibility of year-round pasturage in an area of scant forage without the requirement of long migrations. However, the woolly rhino, the horse, the mammoth, the cave hyena, and the cave lion were already gone from Tibet. A significantly larger population density of hoofed animals, already extinct in the nineteenth century, was apparently required for the survival of predators.

What is the prognosis of the fate of the current large mammal fauna in the near future? The probable fate of the remainder of the mighty fauna of the Ice Age of Eurasia is not a happy one. It is possible to say with assurance, that this fate will be completely dependent on the nature of the assimilation of natural resources by people. If these resources, the landscapes, flora, and fauna of deserts, steppes, forests, tundra, and the maritime coast, are assimilated rapidly and carelessly, rapaciously, one-sidedly, and ecologically ignorantly as has been the case up to this time further impoverishment of the populations and species of the northern fauna will be much more intensive than it has ever been in all of the past ages and millennia. Reserves for the conservation of flora and fauna are of little help as these conserve specimens, but not the general communities and ecosystems of nature.

It is well known that we have nearly lost, absolutely and irrevocably, the rich mammal fauna of the south-Russian and south-Siberian steppe known from the late Middle Ages. Out of the powerful steppe group of hoofed animals–horses, deer, aurochs, bison, etc.–only the saiga, deer, and the steppe sheep survived to the present. In the taiga, despite the rapacious felling of the forests, the brown bear and the elk will probably survive, but the forest reindeer will disappear from the destruction of the reindeer moss and the coniferous forests. In the tundra and the forest-tundra, possibly the greatest numbers of wild tundra reindeer will be preserved if, instead of the chaotic destruction of the herds from the air, on land, and in the water, there is successful regulation of reasonable exploitation through hunting and preservation of the migration routes. It is necessary to preserve the herd's pastures from destruction by land rovers and acid rain. Partial amelioration of the tundra into a condition more suitable for the large fauna is possible through a program of draining tundra lakes and using their bottoms as meadows.

The preservation and development of natural plant and animal resources at present requires a radical restructuring of the consciousness of our people and the introduction of ecological ideas into all production groups of the population, including our planning agencies and governmental bodies.

The next scientific and practical tasks

Field and laboratory research of the mammoth fauna undoubtedly will continue on national, regional, as

well as international levels. It is necessary for paleozoologists to develop and strengthen co-operation with paleogeographers, specialists in permafrost research, and archaeologists. In a parallel way, with the organization of information collected from the sites, it is necessary to begin a purposeful search for and study of frozen carcasses and skeletons of Pleistocene animals on the basis of predictive models of finds of baby and adult mammoths, formulated importantly on taphonomical characteristics of their places of discovery. An intensive study of mass "cemeteries", similar to the Berelekh locality, may yet provide new details on the ecology of Pleistocene animals and the assimilation of the northern latitude by prehistoric hunters. This is shown by ever-emerging new data from finds on the eroded river banks of the north Arctic Coast and the islands of the Laptev Sea.

It is necessary to regulate the preservation of paleontological collections in the biological institutes of the country. In a practical, utilitarian, sense it is necessary to improve the organized collection of mammoth tusks not only in the tundra but also on the banks of the water bodies of the taiga zone. One should give thought to methods of mass extraction of tusks from submerged parts of the Laptev Sea and from the bottom of promising portions of rivers.

The task of primary importance ought to be the publication and wide dissemination, in reindeer-breeding, hunting, fishing, and gold-mining settlements, of colourful leaflets noting high premiums for information about discovery of whole skeletons and especially of frozen carcasses. Considering the high demand for the frozen carcasses, skulls, and skeletons of animals of the mammoth fauna, and the high prices these materials command, it makes sense to encourage the organization of prospectors who specialize in such a distinctive trade.

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