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GENERAL BIOLOGY

The First Finding of a Rhinoceros of the Genus *Stephanorhinus* in Arctic Asia

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Abstract—The first skull of a rhinoceros of the genus *Stephanorhinus* has been found above the Arctic Circle on the middle Chondon River (Yakutia, Russia). This is the northernmost finding that extends significantly the genus range and provides additional information about the diet and environment of a genus representative. Plant remnants from the maxillary tooth cavities were identified as belonging to trees (*Larix, Betula*), shrubs (Ericaceae), mosses (*Aulacomnium* sp., *Polytrichum* sp.), herbs (Dicotyledones) and grasses (Poaceae), but not to sedges (*Cyperaceae*). The pattern of attrition of teeth and marks on the chewing surface enamel indicate diverse nourishment. Chondon rhinoceros lived in under Arctic-like climatic conditions, with rather limited food resources.

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Large extinct rhinoceroses of the genus *Stephanorhinus* (*S. kirchbergensis, S. hemitoechus, S. etruscus, S. hundsheimensis, S. yunchuchenensis,* etc.) inhabited the Eurasian area in the Pliocene–Pleistocene period. Only one of these species, *S. kirchbergensis* Jäger, 1839, originally known as Merck's rhinoceros, has been found in Russia [1–3]. Reconstructed area of this species covers most of Europe and much of Asia, except its southern and northern regions [3] (Fig. 1). *S. kirchbergensis* remains have been mostly found in interglacial deposits. Its diet, restored on the basis of plant residues from dental cavities of the skull found in Western Europe, is believed to be foliage and bushes [4], like the diet of the modern black African rhinoceros *Diceros bicornis* Linnaeus, 1758. The front of the skulls of *S. kirchbergensis* and *Diceros bicornis* Linnaeus, 1758 is similar and therefore the ways of feeding too. According to the most recent data [5], a variable pattern of microdamages of dental enamel in the fossil rhinos of different taxa testifies to the shift of diet in response to environmental changes even in species with food specialization.

In summer 2014, a rhinoceros skull with the narrow nasal part and complex structure of the occipital ridge has been found on the middle Chondon River at the foot of littoral uncovering (the Chondon rhinoceros, CR) (Fig. 2). In the find site, the shore is 12 m high and composed of loose icy permafrost deposits of the Middle and Late Pleistocene age. The sample belongs to the Museum of the Ice Age; collection number F-4160.

The following features of this skull indicate that CR belongs to the genus *Stephanorhinus*: the skull is massive, wide in the zygomatic archs, with extremely prominent parietal bone exostoses; the nasal part is strongly narrowed; the post-orbital narrowing between the frontal-parietal ridges is extremely narrow; the occipital crest is divided at the highest point onto two projections, which distinguishes CR skull from those of the woolly rhinoceros *Coelodonta antiquitatis* Blumenbach, 1799 and some members of the genus *Stephanorhinus* (e.g., *S. hemitoechus*) [4]; the orbital cavities are medium-sized, slightly protrudent, and set high; the supraorbital process is poorly expressed; the zygomatic arch under the eye orbit is extremely massive and has no clear inflexion in the lower part behind the orbit; in the middle part of the zygomatic arc, it is very wide though not thick; the nasal notch is oval and elongated; in the skull distal part, the osseous septum that connects the nasal and premaxillary bones, is extremely narrow, which is typical of *Stephanorhinus*; the nasal septum itself, ossified in the live rhinoceros, was only partly preserved in the

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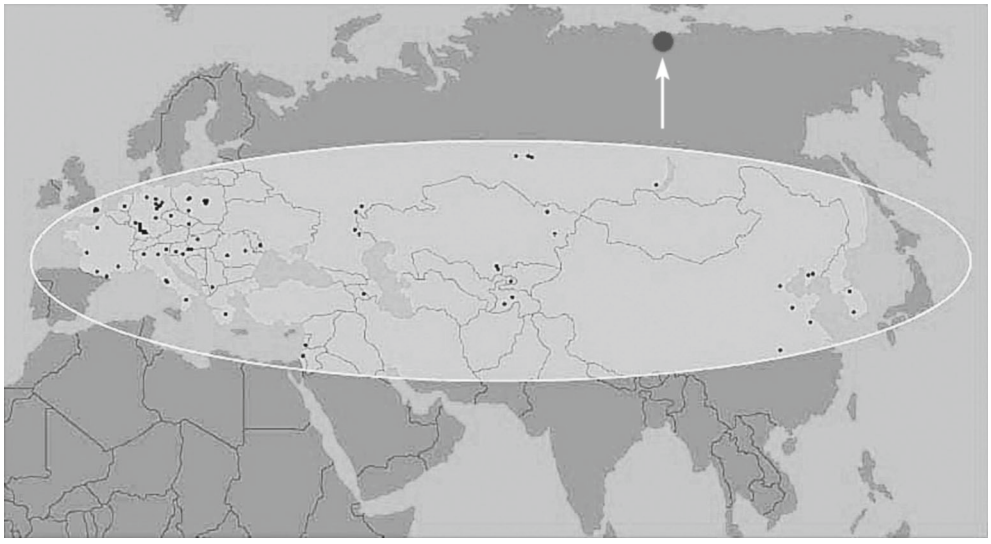

Fig. 1. The range of Chondon Rhinoceros (*Stephanorhinus kirchbergensis*) as reconstructed according to data of [3], and the site of the skull detection (indicated with an arrow) (Chondon River, Northern Yakutia, Russia).

front of skull; as judged by its fragment in the skull base, it was solid or nearly solid, as in *C. antiquitatis*; the relatively large occipital condyles were located wide apart; the occipital bone was of a complex configuration in contrast to the simple nearly rectangular bone and closely spaced condyles of *C. antiquitatis* and *S. hemitoechus*; the skull base was much less massive than that of *C. antiquitatis*; the teeth were very big, and their buccal part was markedly larger than the lingual one.

In the skull cavity, there were large well-rounded flattened gravel and dark-gray pebbles up to 1.8 cm in diameter, as well as fine-grained sand of grayish-yellow color, which were indicative of staying in active aquatic environment. Tooth sinuses, in addition to plant detritus, contained well-sorted fine-grained sand. The skull parts were not rounded, but the greenish patina on some of them (the signs of microorganism activity) suggests accidental staying under subaerial conditions, probably, after thawing out of permafrost.

Fig. 2. The skull of Chondon Rhinoceros, specimen F-4160. The dorsal and lateral sides. Scale, 10 cm.

Judging by the state of cranial sutures, compact, strongly worn tooth crowns and the number of annual rings in the first molar root cushion, CR was an adult specimen that died at an age of about 20 years.

Crowns and chewing surface of the four molars and premolars of CR skull studied were damaged by attrition of teeth and abrasion of food and soil particles grasped along with it; these traces were indicative of the animal diet as it proved for the ungulate [6–10]. The relief of the crown chewing surface and the ratio of polymorphic scratches, pits, indentations and large grooves on the tooth enamel (Fig. 3) suggested that CR diet included the grass, foliage, trees, and shrubs.

Indeed, in addition to grasses (Poaceae), herbs (Dicotyledones), mosses (*Aulacomnium* sp., *Polytrichum* sp.), constituting up to 20% of the residues in dental cavities, there were individual branchlets (aged from 4 to 15 years) of willow *Salix* sp., birch *Betula* sp., heather (Ericaceae), and numerous large bark and twig fragments of larch *Larix* sp. At the same time, the residues of sedges (Cyperaceae) have not been identified although they are known to constitute a significant part of the diet of the Late Pleistocene herbivores [11, 12].

In some larch shoots, the latewood has been formed in the outermost annual ring (Fig. 4), which indicates that plant destruction (probably, because of eating by the rhino) occurred in the middle or at the

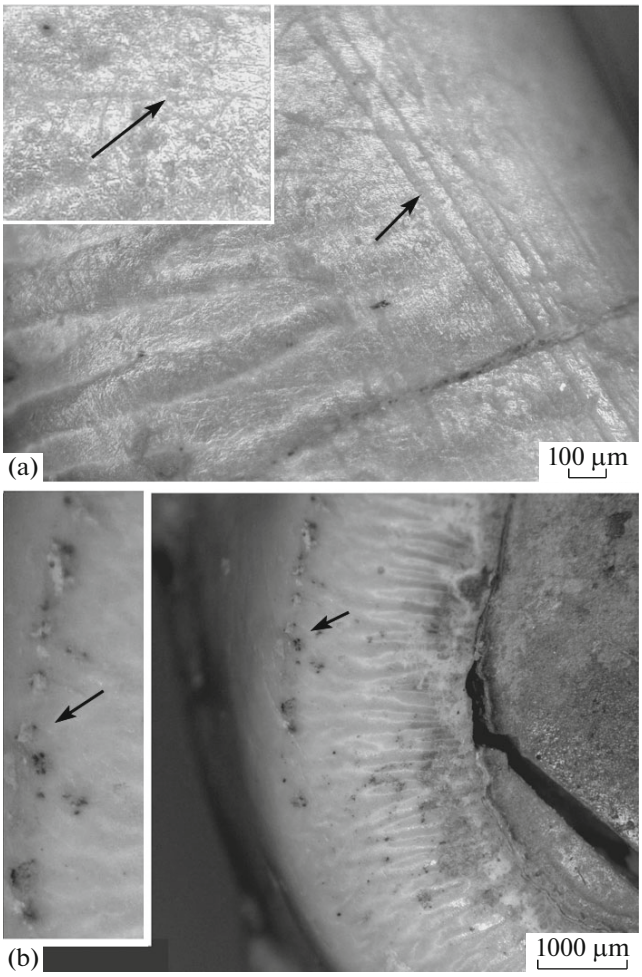

Fig. 3. Polymorphic microdamages (indicated with arrows) on the chewing surface enamel of the teeth of Chondon rhinoceros: (a) large parallel grooves; the inset shows small randomly arranged and crossed strokes; (b) the inset shows large pits and chips located in the arc form. Micrograph.

end of the growing season or in winter. Note that, in larch, the annual ring width varied from 0.05 to 0.2 mm. Such a strong variation of this parameter in the conifer shoots is indicative of significant fluctuations in climatic conditions during the tree life, while an insignificant radial gain suggests the adverse growth conditions, in particular, the short and cold vegetative season [13].

Thus, our study leads to the following conclusions.

The first skull of an ancient rhinoceros of the genus *Stephanorhinus* that has been found above the Arctic Circle makes it possible to expand the boundaries of the reconstructed range of this extinct genus far to the north of Asia.

The living conditions and diet of a member of the genus *Stephanorhinus* in Arctic Yakutia have been represented for the first time on the basis of tooth enamel

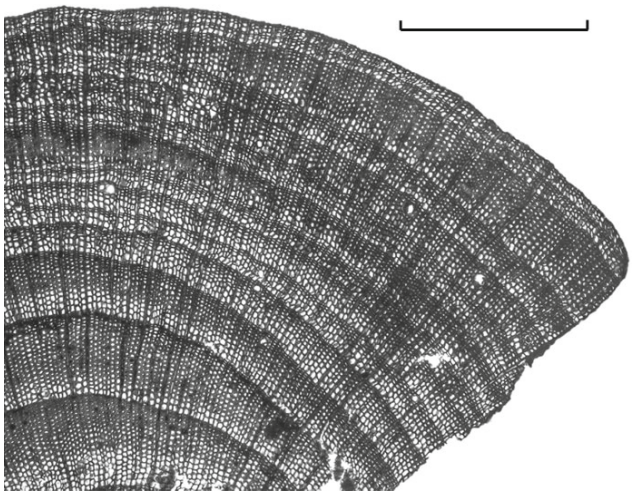

Fig. 4. Cross-section of a *Larix* sp. shoot with clearly distinguishable annual rings and non-uniform growth gain, which were derived from tooth cavity of the Chondon rhinoceros. Scale, 1 mm.

damages and the vegetable food remnants from CR dental cavities.

The composition of the vegetative food remnants from tooth cavities and the marks on dental enamel enabled us to assign CR to the ungulates with mixed diet that included both grass and foliage and trees and bushes.

Judging by an uneven and small annual gain of the conifer shoots and the moss abundance in tooth cavities, CR lived under the Arctic climatic conditions with the limited food resources and it has died, probably, in the cold season.

Dicotyledonous herbs, grasses and mosses indicate the presence of meadow communities in CR habitats while the ericaceous and mosses are the markers of acidic soils and moisture.

Sedge, which is typical of wet biotopes, is a highly nutritious and preferable animal food; however, we have not identified sedge among the remnants in CR tooth cavities. It is unlikely that CR ignored nutritionally valuable sedge to prefer mosses with low nutritional properties in addition to grasses and shrubs. This question remains to be answered due to the new findings of the members of the genus *Stephanorhinus* in the Arctic zone or special palaeography studies in this area. One can assume that the last pastures where the CR was before its death contained no sedge or it was out of reach of the herbivorous animals, for example, under the deep snow or embedded in ice.

Further studies of the CR are required by the methods of molecular genetics and species identification, as well as radiocarbon analysis can determine the skull absolute age.

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