ISSN 0012-4966, Doklady Biological Sciences, 2011, Vol. 436, pp. 23–25. © Pleiades Publishing, Ltd., 2011.
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GENERAL BIOLOGY

Study of Pollen and Spores from the Stomach of a Fossil Woolly Rhinoceros Found in the Lower Reaches of the Kolyma River

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Received August 27, 2010

DOI: 10.1134/S0012496611010017

As was reported earlier [1, 2], in June 2007, a frozen mummy of an adult female woolly rhinoceros (*Coelodonta antiquitatis,* Blum., 1799) was found at a goldmine near the Cherskii settlement of the Nizhnekolymskii raion of the Republic of Sakha (Yakutia) (68°46′N, 161°38′E). A study of the stomach contents of the fossilized rhinoceros using palynological methods with the aim of establishing the particularities of its diet and re-creating the paleofloristic conditions of the period of its existence was of great interest.

A sample of the remnants of the stomach lump of the woolly rhinoceros was characterized by a high concentration of pollen and spores (more than 1700 micrograins in one preparation). Most pollen grains were very well preserved.

In the general spectrum, the pollen of grass plants predominates (98.5%). Pollen from trees and bushes accounts of 0.9%, and 0.6% are represented by spores (Table 1). The grass pollen composition is mainly accounted for by the pollen of Gramineae (45.9%) and Compositae (40.6%), in which wormwood pollen dominates (40.1%). Up to 10 varieties of pollen can be distinguished in the Gramineae pollen by morphological characteristics. They differ in size, grain shape, pore, and exine structure, etc. It is very difficult to classify the Gramineae pollen down to the species level, and this has not been done yet. Nonetheless, judging by the morphological particularities of the pollen, it can be assumed that it belongs to different Gramineae species. Wormwood pollen is also represented by various species; on the basis of its morphology, we assume that it is composed of *Artemisia* cf. *arctica, A. borealis, A.* cf. *macrantha, A.* cf. *scoparia, A.* cf. *tilesii*, etc.

The pollen of motley grasses identifies steppe and meadow plants, among which Caryophyllaceae account for 3.4% (*Selene repens, Stellaria* sp., *Lichnis sibirica*, etc); Rosaceae, for about 3.2% (Rosaceae gen. sp., *Sanguisorba officinalis, Potentilla* sp., *P.* cf. *nivea, Rubus chamaemorus*); Plantaginaceae, for 2.3% (*Plantago* cf. *lanceolata, P.* cf. *media, Plantago* sp.). Small amounts of the pollen of the following families have been found: Papaveraceae; Ranunculaceae (*Ranunculus* cf. *borealis, R.* cf. *repens, Thalictrum* sp., etc); Polygonaceae (Polygonaceae gen. sp., *Rumex* cf. *sibirica*); Cruciferae; Chenopodiaceae; Leguminosae (cf. *Lathyrus humilis*, cf. *Astragalus* sp., *Vicia cracca, Oxytropis adamsiana*); Polemoniaceae (*P.* cf. *boreale, P.* cf. *acutiforum, Phlox sibirica*); Valerianaceae (*Valeriana capitata, V. officinalis*); Cichoriaceae; Asteraceae; and Cyperaceae (table).

The content of tree and bush pollen is extremely low: single pollen grains of fir trees (*Picea* sp., *P. sect. Omorica*), pine trees (*Pinus diploxylon* type and *P. haploxylon* type), and willows. The pollen of fir trees and pine trees is very ill preserved, which indicates that it is of more ancient age and, apparently, got into the animal's stomach accidentally.

The spore group is not numerous either. Single spores of liverworts, horsetail, northern spike moss (*Selaginella sibirica*), and *Lycopodium pungens* are present.

Apart from pollen and spores, snatches of green algae colonies of the *Pediastrum* genus are found, as well as various small fungi and remnants of plant fibers.

The established spore–pollen spectrum indicates that the leading place in the diet of the woolly rhinoceros was occupied by various species of cereals and a rich array of motley grasses. The presence of an insignificant amount of wormwood pollen implies that some species of these plants were also included in the

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Spore and pollen species and their number in a sample from the stomach contents of a woolly rhinoceros (Kolyma River)

No.	Spore and pollen species	Number of grains	Content, %
	Trees and bushes		
1	*Picea* sp.	1	0.1
2	*Picea* sect. Omorica	1	0.1
3	*Pinus* s/g *Haploxylon* (mineralized)	1	0.1
4	*Pinus* s/g *Haploxylon* (old)	3	0.2
5	*P. pumila* (Pall.) Rgl.	3	0.2
6	*Pinus* s/g *Diploxylon* (old)	1	0.1
7	*Salix* spp.	1	0.1
	Total	11	0.9
	Grasses		
8	*Papaveraceae* gen. sp.	1	0.1
9	*Ranunculaceae* gen. sp. (*Ranunculus* sp., *R.* cf. *repens* L.), *R.* cf. *borealis* Trautv., *Thalictrum* sp.	11	0.7
10	Chenopodiaceae gen. sp.	2	0.1
11	*Caryophyllaceae* gen. sp. (*Stellaria* sp., cf. *Selena repens*) Patr, cf. *Cerastium* sp., cf. *Lychnis sibirica* L.	59	3.4
12	*Polygonaceae* gen. sp. (*Rumex* cf. *sibiricus* Hult)	4	0.3
13	*Cruciferae* gen. sp.	1	0.1
14	*Rosaceae* gen. sp. (*Sanguisorba officinalis*, *Potentilla* sp.), *P. nivea* L., *Rubus chamaemorus*	55	3.2
15	*Leguminosae* gen. sp. (cf. *Lathyrus humilis* Tisch ex DC), *Astragalus* sp., cf. *Vicia cracca* L., *Oxytropis adamsiana* (Torutv) Vass.	11	0.7
16	*Polemoniaceae* gen. sp. (*Polemonium boreale* Adams., *P. acutiforum* Willd., *Phlox sibirica* L.)	6	0.3
17	Umbelliferae gen. sp.	5	0.3
18	*Plantago* cf. *lanceolata* L., *P.* cf. *media* L.	40	2.3
19	*Cichoriaceae* gen. sp.	5	0.4
20	*Asteraceae* gen. sp.	3	0.2
21	*Valerianaceae* gen. sp. (*Valeriana officinalis* L., *V. capitata* Pall.)	4	0.2
22	*Artemisia* sp., *A.*cf. *macrantha* Ledeb., *A.* cf. *arctica* Less., *A.* cf. *scoparia* Waldst., *A.* cf. *tilesii* Ledeb	730	40.1
23	*Poaceae* gen. sp.	820	45.9
24	*Cyperaceae* gen.sp.	3	0.2
	Total	1740	98.5
	Spores		
25	*Hepaticae*	1	0.1
26	*Riccia* sp. (mineralized)	2	0.1
27	*Lycopodium pungens* La Pyl.	1	0.1
28	*Selaginella sibirica* (Milde) Hieron	4	0.2
29	*Equisetum* sp.	1	0.1
	Total	9	0.6
	Total of grains	1760	100

diet of the animal. Part of wormwood pollen sometimes got into the food with other grasses because wormwood has elevated pollen productivity and in the palinospectra of steppe and steppified areas, wormwood pollen often dominates, outnumbering the pollen of the main edificators of cenoses: cereals and motley grasses.

In terms of its taxonomic composition, the obtained spectrum fits well the spore–pollen spectra established from friable deposits, which contained the remnants of the woolly rhinoceros and the soil mass stuck to the fur of the rhinoceros [1]. Predominance of the pollen of grass plants, with cereals and wormwoods prevailing and rich motley grass composition, is characteristic for all spectra. At the same time, in the spectrum of the content of the stomach of the rhinoceros, the motley grass content is higher and its composition is more varied, especially with respect to Gramineae, Artemisia, Caryophyllaceae, Rosaceae, Plantaginaceae, and Ranunculaceae. In the spectra of the bearing strata and the soil stuck to the coat of the rhinoceros, the content of tree and bush pollen is higher (*Larix, Betula, Alnaster*, and *Salix*). No doubt the last spectra reflect landscapes and nature–climatic conditions of the time of the animals' existence more fully, whereas the spectrum obtained from the stomach of the animal mainly reflects the composition of vegetation that the animal consumed.

Thus, spore–pollen analyses of the stomach content of the woolly rhinoceros show that during the existence of the woolly rhinoceros, steppe and meadow–steppe groups were widespread among the plant growth of this territory. The tundra element is not pronounced in the vegetation. The core of the steppe groups consisted of cereal–motley grass, wormwood–carnation–motley grass, and sedge–motley grass associations. Open spaces probably combined with rare larch woods, dwarf birch, willow, and alder thickets, most developed on the slopes of the northern exposition. On the whole, the plant composition meets the severe and comparatively dry climatic conditions of the late Neopleistocene.

Radiocarbon dating of the rhinoceros mummy to 39 140 ± 390 year ago [2] and the results of palynological analysis indicate that the time of the existence of the woolly rhinoceros was in the second half of the Karginski interglacial period of the late Neopleistocene, a period with arid continental climate and hot summer periods. This time corresponds to the middle of the relatively warm sea isotopic stage 3 (MIS-3) [3].

Similar spore–pollen spectra were established by Tirskaya [4] in the stomach content of the Churapchinskii rhinoceros. The same spectra composition with the pollen of cereals predominating over the wormwood and motley grasses pollen was determined by Metel'tseva [5] in the remains of food extracted from the teeth of the Kholbuiskii rhinoceros found on the bank of the Bytantai River.

Such rare findings of corpses of animals from the ice age with the content of the gastrointestinal tract make it possible not only to establish the particularities of their diet but also supply the material, which allows us to reconstruct the paleoecological conditions of the periods of their existence.

ACKNOWLEDGMENTS

This study was supported by the regional initiative project of the Russian Foundation for Basic Research–Far East no. 09-04-98568.

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