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Morphometric Study of the Skull of a Late Pleistocene Mummy of the Bilibino Horse from the Western Chukchi Peninsula

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Abstract—The skull of a mummy horse from the Late Pleistocene of the western Chukchi Peninsula is described. This is the seventh horse mummy recorded during the past 150 years in the Pleistocene permafrost of Siberia. Because of unique preservation (the skeleton is covered by soft tissues and skin) and young individual age (1–1.5 years of age), it is presently impossible to provide its correct species allocation of this specimen. Morphological features of the skull proportions and dentition of the Bilibino horse apparently reflect both species and individual characteristics of the structure and development.

Keywords: *Equus*, Bilibino horse, mummy, Late Pleistocene, western Chukchi Peninsula.

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INTRODUCTION

Remains of large Quaternary mammals are frequently well preserved in the permafrost of northeastern Siberia. Mummified horse remains are relatively rare; from the 1870s, only six almost complete corpses (Chersky, 1891; Vas'kovsky, 1959; Garutt and Yur'ev, 1966; Vereshchagin and Lazarev, 1977; Lazarev, 2002, 2008) and two limb fragments of horses (Popov, 1948; Belolyubskii et al., 2008) have been recorded in this region. All specimens belong to the species *Equus lenensis* Russanov, 1968, which occurred in Eastern Siberia at the end of the Pleistocene–beginning of the Holocene.

The mummy under consideration was found in the winter 2004–2005 in permafrost deposits of a gold mine on the Angarka River, 200 km southwest of the village of Bilibino (66°48′ N, 164°01′59′′ E) in the western Chukchi Peninsula (Sher et al., 2007). It was transported in frozen condition to the Museum of Glacial Period (Moscow), where it is presently stored (no. F-200) at a constant temperature of –18°C. The mummy was damaged during excavation, apparently, by a bucket of the excavator. The anterior body part (head, neck, and shoulder girdle with both limbs) are only preserved. Organs of the thorax are partially preserved (to ribs 5–6); heart, stomach, organs of abdominal cavity, and hind limbs are absent. The fur cover is partially preserved on the withers and distal regions of limbs. All tissues are extremely strongly dried, the skin looks like thin parchment. The anatomical study of the mummy was performed on the right side. In the region of the right humerus, there are traces of damaged tissues and intense hemorrhage (hematoma about 10–15 cm in size) resulting from a strong impact. This probably caused the death of the animal. This specimen is a young horse (1–1.5 years of age).

To preserve the specimen for exposition of the museum and because of its young individual age, the skull and postcranial skeleton were incompletely prepared, soft tissues were partly retained. Bone elements were measured on the assumption of the minimum thickness of soft tissues.

Radiocarbon dating provided the following estimates of the absolute age of the Bilibino horse: 31.700 ± 1.300 (GIN-12770), 36.550 + 400–350 (GrA-46005), and more than 58.500 (OxA-14713). We believe that the horse existed 37–31 ka.

The purpose of the present study is identification of the mummy to species. We consider cranial features of the Bilibino horse in comparison with other Pleistocene horses of northeastern Siberia, the Przewalski horse, and domestic horses of aboriginal breeds of the eastern group.

MATERIAL AND METHODS

Taking into account individual age of the Bilibino horse, the initial comparative sample of extant and Pleistocene horses included skulls of two age groups: 1–1.5 and over 5 years of age. The age was determined

† Deceased.

based on the standard technique (Korneven and Lesbr, 1932; Dyurst, 1936; Krasnikov, 1977). The sex was only determined for the adult skulls.

A total of 60 skulls of three horse species have been measured.

(1) Group of Young Horses (1–1.5 Years of Age)

Lena horse (*E. lenensis*), lower jaw: Museum of Glacial Period, Moscow (MLP), nos. F-123 and F-2444; Geological Museum of the Institute of Geology of Diamond and Noble Metals of the Siberian Branch of the Russian Academy of Sciences, Yakutsk (ZM IGABM), no. 5601.

Przewalski horse (*E. przewalskii* Poljakov, 1881), skull: Scientific Museum of the Biosphere Nature Reserve Askania Nova, Ukraine (BZAN), nos. 435, 593, 594, 1056, 1096, 1116; Zoological Institute of the Russian Academy of Sciences, St. Petersburg (ZIN), nos. 512, 5215, 5217, 7201, 24095, 27029, 27090; Zoological Museum of Moscow State University (ZM MGU), no. S-153503.

Domestic horse (*E. caballus* Linnaeus, 1758), Yakut breed, skull: Yaroslavsky Yakut State Museum of History and Culture of Northern Peoples (YaGMIKNS), without no.; ZIN, no. 12618, without lower jaw; ZM MGU, no. S-186095, without lower jaw; lower jaw: ZM IGABM, no. 5833.

Domestic horse (*E. caballus*), Kazakh breed: skull: ZM MGU, no. S-177846.

Domestic horse (*E. caballus*), Tuvinian breed, skull without lower jaw, ZM MGU, no. S-186100.

Domestic horse (*E. caballus*), Bashkir breed, skull, ZM MGU, no. S-184630.

(2) Group of Adults (over 5 Years of Age)

Lena horse (*E. lenensis*), skull: MLP, nos. F-2431, F-2442, F-254, F-2530; ZM IGABM, nos. 33/82, 1715, 3715, 5059, 6730; Mammoth Museum of the Institute of Applied Ecology of the North of the Academy of Sciences of the Sakha Republic (Yakutia), Yakutsk (MM IPES), no. 7096.

Przewalski horse (*E. przewalskii*), skull: Zoological Museum of Tomsk State University (ZM TGU), nos. 3525, 3526; BZAN, no. 288/120; ZIN, nos. 5212, 5213, 5214, 5216, 5218, 27089; ZM MGU, no. 1772.

Domestic horse (*E. caballus*), Yakut breed, skull: YaGMIKNS, no. 7658, two skulls without nos.; MM IPES, no. MBK1; ZM IGABM, nos. 5, 6, 8, 9, 10, 17, 33, 34, 1931-32, 1933-34, 1944.

Comparative analysis was based on 13 measurements of the axial skull and 21 measurements of the dental system, which follow the generally accepted technique (Gromova, 1949; Eisenmann, 1980; Eisenmann et al., 1988). Individual teeth were described and compared based on elements of the grinding surface according to the standard technique (Gromova, 1949; Eisenmann, 1981).

Data processing included the following standard statistical methods: multivariate analysis of variance (MANOVA, model III), principal component analysis (based on correlation matrix), multidimensional scaling (based on matrix of correlation distances), stepwise ascending discriminant analysis (estimation of Mahalanobis distances D^2 between centroids of groups, posterior probability of specimen identification). Comparisons were performed between individual specimens and between mean group values; in the second case the Bilibino horse was taken as a separate group. Taking into account the small sample sizes, effects were accepted as significant at $p < 0.01$ in the case of analysis of variance and as correct at $p > 0.75$ in discriminant analysis of posterior identification; in the models of multivariate analysis used here, scores of the first and second axes of were considered. The effect of the age factor on differences between specimens was excluded using Burnaby's data transformation based on the first principal vector of the covariance matrix, estimated for the age effect using analysis of variance (Burnaby, 1966). This method allowed simultaneous comparison of cranial characters of adult and young animals and, hence, inclusion in analysis of Pleistocene horses which are only represented by adult skulls.

For more detailed analysis of similarity and differences in individual characters between the horses under study, the method of profiles was used. For this purpose, the mean value of each measurement was calculated for the entire sample based on mean-group values, and deviations of particular groups from this sample mean were calculated and presented in the *character profiles* of each group.

Data processing was performed using the program STATISTICA for Windows (version 8.0).

CHARACTERISTICS

Skull (Pl. 14, fig. 2) of the Bilibino horse is large, the parietal region is 482 mm long (Table 1). The individual is distinguished by the skull proportions: the occipital region is strongly extended, the ratio between the anterior and posterior orbital lines is 130.5%. The facial skull region is narrow, the width between the facial crests is 121.5 mm, and its relative size (index of the width between anterior points of the facial crests to the parietal length) is 25.2%; the distance between anterior orbital points is 138 mm, its relative size (index of the width between anterior orbital points to the parietal length) is 28.6%; at the anterior orbital borders, 146.5 mm, the relative size (index of the width at the anterior orbital borders to the parietal length) is 30.4%. The relative forehead width at the posterior orbital border is narrow and the braincase width is intermediate (Table 2). The diastema is relatively short, 17.9% of the parietal length, but wide

Table 1. Skull measurements of young horse group (1–1.5 years of age), mm; designations: (*n*) number of specimens, (*M*) mean value, (min) minimum value, (max) maximum value, and (*SD*) standard deviation

Measurement no	Measurement	Bilibino horse (no. F-200)	Przewalski horse (n = 14)				Domestic horses of aboriginal breeds			
			M	min	max	SD	Yakut	Tuvinian	Bashkir	Kazakh
7	Diastema length at alveolar edges from I^3 to P^2	**86.3**	84.6	71.6	101	7.9	71.2	83.2	101.8	90.8
8	Length of upper deciduous premolars at alveolar edges	**97**	104.1	99.7	109	3.1	105	98.9	97.2	97.6
15	Anterior orbital line from prosthion to extreme point of projecting posterior orbital border	**287**	346.7	320.2	384.3	19.5	312	330.3	353.5	327
16	Posterior orbital line from extreme point of projecting posterior orbital border to middle of occipital crest (acrocranion)	**220**	175.9	162.7	189	9.1	166.2	171.5	188.8	169.5
19	Parietal length from acrocranion to prosthion	**482**	476.8	451	526	22.7	438.9	462.5	505.5	461
30	Diastema width at its narrowest part	**67.2**	47	35.5	55.7	5.8	44	46.5	46.2	47
42	Width between anterior points of facial crests (crista facialis) on the dorsal side in projection	**121.5**	141.3	127.5	155	9.4	130.2	140.5	137	128.2
43	Width between anterior points of facial crests (crista facialis) on the dorsal side in projection	**138**	145.3	131.2	155.8	8.6	143.2	147	149.2	140
44	Width between anterior points of orbits on the dorsal side in projection	**146.5**	163.1	137	176.2	12.4	154.5	162.5	164.5	150.2
45	Interorbital width between nearest upper points of orbits on the dorsal side in projection	**150**	124.4	110	136	8.7	145	144.3	142.7	139
46	Forehead width at posterior orbital borders in line with the zygomatic processes of the frontal (processus zygomaticus ossis frontalis) on the dorsal side in projection	**178.5**	185.4	164.5	199	10.9	187.3	183	188.2	179.9
47	Braincase width at the postorbital narrowing along external frontal crests (crista frontalis externa) in the middle part of the frontal on the dorsal side	**92.2**	85.2	79.8	91	3.4	88.9	86.6	91	78.9
49	Skull width at external edges of glenoid fossae at external points of the zygomatic process of the temporal on the dorsal side	**179**	182.6	163.2	193.8	9.8	187.2	180	193	178
66	Length of lower deciduous premolars at alveolar edges	**98.3**	99.4	94.3	108.6	4	92.7		96.5	93.5

Plate 14

Explanation of Plate 14

Figs. 1–4. *Equus* (*Equus*) sp., Museum of Glacial Period, Moscow, no. F-200; female, 1–1.5 years of age; the village of Bilibino (Western Chukchi Peninsula), Russia; Upper Pleistocene: (1) anterior part of the horse body, including the head, neck, shoulder girdle, and two limbs, lateral view; (2) head, with removed right lower jaw, lateral view; (3) right tooth row of upper deciduous teeth dP^2–dP^4, M^1, grinding surface; (4) right tooth row of lower deciduous teeth dP_2–dP_4, M_1, grinding surface.

Table 2. Relative cranial measurements in the young horse group, % (for measurement nos., see Table 1)

Indices	Bilibino horse	Przewalski horse (M, $n = 14$)	Domestic horses of aboriginal breeds			
			Yakut (M, $n = 2$)	Tuvinian	Bashkir	Kazakh
Anterior orbital line/posterior orbital line (15/16)	**130.5**	197.1	187.7	192.6	187.2	192.9
Diastema length/parietal length (7/19)	**17.9**	17.7	16.2	18.0	20.1	19.7
Premolar row length/parietal length (8/19)	**20.1**	21.8	23.9	21.4	19.2	21.2
Anterior orbital line/parietal length (15/19)	**59.5**	72.7	71.1	71.4	69.9	70.9
Posterior orbital line/parietal length (16/19)	**45.6**	36.9	37.9	37.1	37.3	36.8
Diastema width/parietal length (30/19)	**13.9**	9.9	10.0	10.1	9.1	10.2
Width between anterior points of facial crests/parietal length (42/19)	**25.2**	29.6	29.7	30.4	27.1	27.8
Width between anterior points of orbits/parietal length (43/19)	**28.6**	30.5	32.6	31.8	29.5	30.4
Width at anterior orbital border/parietal length (44/19)	**30.4**	34.2	35.2	35.1	32.5	32.6
Interorbital width/parietal length (45/19)	**31.1**	26.1	33.0	31.2	28.2	30.2
Forehead width at posterior orbital borders in line with the zygomatic processes of the frontal/parietal length (46/19)	**37.0**	38.9	42.7	39.6	37.2	39.0
Braincase width at postorbital narrowing/parietal length (47/19)	**19.1**	17.9	20.3	18.7	18.0	17.1
Skull width at external edges of glenoid fossae/parietal length (49/19)	**37.1**	38.3	42.7	38.9	38.2	38.6

(67.2 mm), possibly because of measurements involving soft tissues. The premolar row is relatively short (20.1% of the parietal length) (Table 2). The dorsal outline of the skull is straightened. The skull width at the external edges of the glenoid fossae is relatively small.

The skull is still covered by soft tissues, preventing examination in more detail.

Teeth. The upper jaw contains deciduous premolars dP^2-dP^4, the first molar (M^1) is in the state of eruption (the paracone and protoconule are seen on the gum surface). A wolf tooth (dP^1) is absent. The description concerns primarily the third and fourth deciduous premolars, as least changeable in tritor structure.

The facets are rectangular (extended along the tooth axis), with a slightly waving edge. The protocone is long; in dP^3, it is 30.7% of the tooth length; in dP^4, it is 24.6% (Table 3). The relative width of the protocone of dP^3 and dP^4 is 15.1 and 16.9%, respectively. The protocone is boot-shaped, with ventrally extending, slightly narrowing, rounded anterior and posterior ends. In dP^2, the protocone is elliptical, with rounded ends. The lingual wall of the protocone is gently concave; in dP^2, it is convex, without an incisure. The buccal wall of the protocone is convex into the internal valley, oblique strongly posteriorly. The protocone is displaced strongly anteriorly relative to the tooth axis and sharply asymmetrical and shifted posteriorly relative to the neck. The protocone neck is moderately wide. The internal valley is wide, expanding, square in the tooth center, with a well-developed long and wide spur (Pl. 14, fig. 3).

The ectoloph is biconcave; in dP^4, it is concave or slightly concave. The parastyle is square, wide, slightly extended, slightly anteriorly oblique. The mesostyle is rounded, undivided, wide in dP^2 and dP^3 and moderately wide in dP^4, extended, slightly anteriorly oblique. The metaslyle is absent or poorly developed.

The hypocone is moderately wide, rounded extended, slightly pointed. The protocone projects slightly lingually relative to the hypocone (Pl. 14, fig. 3).

The upper teeth have moderately plicate enamel.

The lower jaw has deciduous premolars dP_2–dP_4, the first molar (M^1) has erupted, remaining unworn (only the metaconid and metastylid have weak wear traces). The premolar row is 98.3 mm long.

The double loop is asymmetrical, with a more rounded metaconid and triangular metastylid. The relative length of the double loop of dP_3 is 58.4% and that of dP_4 is 58.6% (Table 3). The metaconid and metastylid are similar in size. The metaconid is extended, with a rounded expansion in the anterior part, as though having a stalk; the base is moderately wide. The metastylid is triangular or extended triangular, with a narrow base and rounded apex; the lingual wall straight or slightly concave. The linguaflexid is

Table 3. Absolute and relative measurements of teeth in the young horse group, mm. Designations: (*n*) number of specimens, (*M*) mean value, (min) minimum value, (max) maximum value, (*SD*) standard deviation

Measurementsindices	Bilibino horse	Przewalski horse					Lena horse					Domestic horses of aboriginal breeds							
												Yakut					Kazakh	Tuvinian	Bashkir
		n	*M*	min	max	SD	*n*	*M*	min	max	SD	*n*	*M*	min	max	SD			
Upper teeth																			
dP^2 tooth length	**38**	14	41.1	39.3	43	1.1						2	40.7	39.7	41.6	1.3	39	40.1	39.2
dP^2 tooth width	**22.5**	14	23.0	21.3	25	1.1						2	21.7	21.3	22	0.5	22	20.8	20.5
dP^2 protocone length	**8.2**	14	7.7	6.8	9.0	1.1						2	8.0	7.0	9.0	0.9	6.7	6.8	7.4
dP^2 protocone width	**4.1**	14	4.5	4.5	4.6	1.1						2	5.0	4.0	6.0	0.8	5.4	5.1	5.6
dP^2 protocone index	**21.6**	14	18.7	17.3	20.9	1.1						2	19.6	17.6	21.6	0.8	17.2	16.9	18.9
dP^3 tooth length	**29.3**	14	30.2	28.1	33	1.2						2	29.4	28.6	30.2	1.1	28.6	28.9	29.2
dP^3 tooth width	**22.5**	14	25.7	23	27.6	1.4						2	22.7	22	23.4	1.0	24	23.2	22.2
dP^3 protocone length	**9**	14	9.0	7.3	10.4	1.1						2	8.5	8.5	8.6	0.5	8	6.9	7.8
dP^3 protocone width	**3.4**	14	4.3	3.6	4.7	1.2						2	4.3	4.3	4.4	0.7	4.8	5.3	4.4
dP^3 protocone index	**30.7**	14	29.9	25.9	31.5	1.2						2	29.1	28.5	29.7	0.5	28.0	23.9	26.7
dP^4 tooth length	**34.5**	14	32.1	28.8	35.2	1.9						2	33.3	33.1	33.5	0.3	30.3	31.3	29.5
dP^4 tooth width	**22.5**	14	25.1	22.6	26.7	1.2						2	22.2	22	22.4	0.3	23.6	22.3	22.9
dP^4 protocone length	**8.5**	14	11.2	10	12.3	0.7						2	10.4	9.7	11	0.9	9.8	9.3	9.8
dP^4 protocone width	**3.8**	14	4.1	4.0	4.3	1.1						2	4.4	4.3	4.5	0.7	4.2	5	4.3
dP^4 protocone index	**24.6**	14	34.9	34.7	34.9	1.2						2	31.1	29.3	32.8	0.9	32.3	29.7	33.2
Lower teeth																			
dP_2 tooth length	**33.5**	14	34.2	31.5	36	1.4	3	34.6	34.1	35.5	0.8	2	35.3	33.7	36.8	2.2	34.3		34.4
dP_2 tooth width	**14**	14	14.4	12.4	16.7	1.0	3	13.2	12.5	14.5	1.1	2	14.3	14	14.5	0.4	13.7		12.2
dP_2 double loop length	**19.3**	14	15.9	15.3	16.4	1.2	3	18.4	17.8	19	0.9	2	17.2	16.8	17.7	0.9	17.5		17.5
dP_2 double loop index	**57.6**	14	46.5	45.6	48.6	1.2	3	53.2	52.2	53.5	0.8	2	48.7	48.1	49.8	1.0	51.2		50.9
dP_3 tooth length	**30.5**	14	30.9	27.8	34	1.5	3	30.3	29.4	30.8	0.8	2	28.5	26.7	30.3	2.5	29		30
dP_3 tooth width	**14**	14	15.3	13	17.3	1.2	3	15.8	15.3	16.7	0.8	2	15.1	14.8	15.4	0.4	14.6		14.8
dP_3 double loop length	**17.8**	14	14.0	13.5	15	1.2	3	17.6	16.3	18.8	0.8		18.0	17.9	18.1	0.8	15.5		17.2
dP_3 double loop index	**58.4**	14	45.3	44.1	48.6	1.1	3	58.1	55.4	61.0	0.9	2	63.0	59.7	67.0	0.8	53.5		57.3
dP_4 tooth length	**34.3**	14	34.7	31.7	38.6	2.2	3	32.0	31.2	32.5	0.7	2	35.5	32.9	38	3.6	31		32.2
dP_4 tooth width	**14.7**	14	15.3	13.6	17	1.1	3	15.8	15	17	1.0	2	15.1	14.5	15.6	0.8	14.3		14.2
dP_4 double loop length	**17.7**	14	13.8	13.3	14.5	1.2	3	15.0	14.5	15.6	0.8	2	20.0	19.5	20.5	0.7	15.5		16.2
dP_4 double loop index	**51.6**	14	39.8	37.6	41.9	1.1	3	46.9	46.5	48.0	0.9	2	56.3	53.9	59.3	1.5	50		50.3

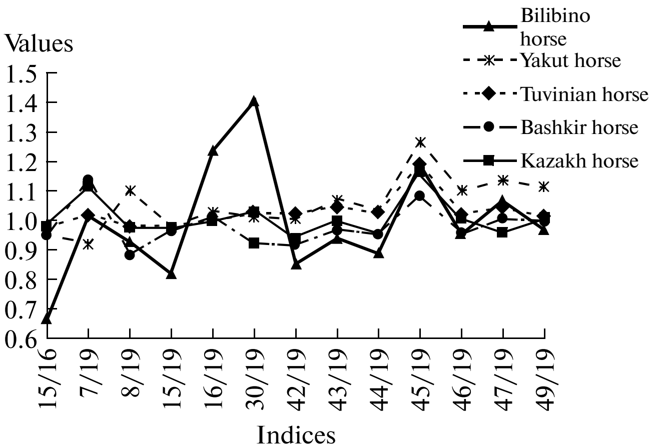

Fig. 1. Ratios of skull measurements of the Bilibino horse and domestic horses of aboriginal breeds (for designation of indices, see Table 2).

small, wide, slightly pointed towards the center. The neck of the double loop is narrow.

The protoconid and hypoconid are rectangular, extended along the tooth axis. The external walls of the protoconid and hypoconid are flattened, parallel to the longitudinal tooth axis, wavy (Pl. 14, fig. 3).

The entoconid is large, rounded; in dP_2, it anterior edge is sharpened. The anterior internal valley is moderately long and wide, displaced slightly posteriorly relative to the neck, parallel or slightly inclined towards the longitudinal tooth axis; the edges are rounded; the lower wall is straight or slightly concave. The posterior internal valley is long, moderately wide, slightly asymmetrical relative to the neck, and slightly oblique relative to the longitudinal tooth axis; the edges of the valley are rounded sometimes extended; the lower wall is convex, wavy.

The ectoflexid is wide, deep, narrowing towards the center, with a well-pronounced pli caballinid fold.

The lower teeth have weakly plicate enamel.

COMPARISON

The young individual age of the Bilibino horse sharply restricts the opportunity of a thorough comparison. The comparative sample of skulls of similar age includes only the Przewalski horse and domestic horses of eastern breeds (Tables 1–3). Pleistocene horses of northeastern Siberia lack specimens of similar individual age (except for three lower jaws of the Lena horse).

Skull. The Bilibino horse has a large skull compared to horses of the same age; it is only inferior in size to domestic horse of the Bashkir breed. The diastema length of the Bilibino horse occupies an intermediate position; it is longer than in Yakut and Tuvinian horse breeds and the Przewalski horse and shorter than in Bashkir and Kazakh domestic horses (Tables 1, 2). The length of the deciduous premolar row in the Bilibino horse is less than the mean-group value; all species and breeds included in analysis have larger teeth, except for the small-tooth Bashkir domestic horse (Table 2).

As mentioned above, the skull proportions of the Bilibino horse are rather unusual in having an elongated occipital part. In the Bilibino horse, the ratio between the anterior and posterior orbital lines is the smallest (130.5%); in other groups analyzed, it ranges from 187.2 to 197.1% (Table 2; Fig. 1). In the Bilibino horse, the ratio of the anterior orbital line to the parietal length is the smallest (59.5% versus 69.9–72.7%) and the ratio of the posterior orbital line to the parietal length is the greatest (45.6% versus 36.8–37.9%) (Table 2). The facial skull region of the Bilibino horse is narrow, as distinguished from other horses; the relative skull widths at the anterior points of the facial crests (index 42/19), at the anterior points of the orbits (index 43/19), and at the anterior orbital borders (index 44/19) are the smallest (Table 2). At the same time, the braincase width of the Bilibino horse is close to the values in the horse groups included in comparison. The relative interorbital width (index 45/19) in the Bilibino horse is similar to that in the Tuvinian breed, greater than in the Bashkir and Kazakh breeds, much greater than in the Przewalski horse, and less than in the Yakut horse. In the index of the forehead width at the posterior orbital border (46/19), the specimen described is the smallest; in particular, it is considerably smaller that the extant domestic Yakut horse and most similar to the Bashkir breed. The relative braincase width at the postorbital narrowing (index 47/19) in the Bilibino horse is greater than in the other groups, except for the domestic Yakut horse. The relative skull width at the external edges of the glenoid fossae (index 49/19) in the Bilibino horse is the smallest (Table 2; Fig. 1).

The dorsal skull outline of the Bilibino horse is straight, as in the Yakut and Kazakh domestic horses and some Przewalski horses. In the Tuvinian breed, this outline is concave at the level of orbits; in the Bashkir breed, it is convex.

Upper teeth. In the structure of upper deciduous premolars, the Bilibino horse is very similar to the living Yakut horse. The relative protocone length in the specimen described is the greatest in dP^2 and dP^3 and the least in dP^4, as compared with the Przewalski horse and four aboriginal breeds of domestic horse (Yakut, Kazakh, Tuvinian, and Bashkir breeds) (Table 3).

The protocone structure of the Bilibino horse differs from that of the Yakut aboriginal breed of domestic horse only in the more rounded and less extended anterior end; the buccal wall of dP^4 is more convex into the internal valley and is more strongly posteriorly oblique in dP^3 and dP^4. The spur is better developed and longer. The ectoloph of dP^4 is less concave, the parastyle is wider, the mesostyle is more rounded, the metaslyle is less developed. The hypocone is wider and less pointed, the protocone projects lingually to a lesser extent. The upper teeth are more strongly plicate.

The Bilibino horse differs from the Kazakh aboriginal breed of domestic horse in the boot-shaped protocone (which is extended ovate in the Kazakh breed). The protocone edges are more narrowed and extended, the lingual wall is more concave, not wavy; the buccal wall is more convex into the internal valley; the protocone is more asymmetrical relative to the tooth axis and neck. The internal valley expands at the central end; the spur is wider. The mesostyle is more rounded, not doubled, less inclined anteriorly; the metaslyle is less developed and less pointed. The hypocone narrows to a greater extent.

The Bilibino horse differs from the Tuvinian aboriginal breed of domestic horse in the protocone shape (rounded ovate in the Tuvinian breed), its narrower and more extended edges, more concave lingual wall; the buccal wall is more convex into the internal valley and more strongly oblique relative to the longitudinal tooth axis; the protocone is displaced more strongly anteriorly relative to the tooth axis; the protocone neck is wider. The internal valley expands at the central end; the spur is wider and longer. The parastyle is less oblique relative to the longitudinal tooth axis, not doubled. The mesostyle is more rounded, wider in dP^2 and dP^3, not doubled, less oblique anteriorly; the metaslyle is less developed, less extended. The hypocone is wider; the protocone projects lingually to a lesser extent. The enamel is more strongly plicate.

The Bilibino horse differs from the Bashkir aboriginal breed of domestic horse in the protocone shape (ovate or extended ovate in the Bashkir breed). The protocone edges are more narrowed and extended; the lingual wall is more concave, smooth; the buccal wall is more convex into the internal valley of dP^4; more strongly oblique relative to the longitudinal tooth axis; the protocone is displaced more strongly anteriorly relative to the tooth axis, and more asymmetrical relative to the neck in dP^4; the protocone neck is wider. The internal valley is wider, more expanded, more square at the central end; the spur is wider and longer. The parastyle is less oblique relative to the longitudinal tooth axis, not doubled in all deciduous teeth. The mesostyle is more rounded, wider in dP^2 and dP^3, not doubled; the metaslyle is less developed. The hypocone is more narrowed and pointed. The enamel is more plicate.

The Bilibino horse differs from *E. przewalskii* in the extended corners of the protocone; the more concave lingual wall of the protocone, particularly, in dP^4; in the convex and posteriorly more oblique buccal wall of the protocone; the more asymmetrical protocone relative to the tooth axis and neck; the protocone neck is wider. The internal valley is widened towards the center, the spur is better developed, narrower, and longer. The mesostyle is wider, without a trace of bifurcation in all teeth; the metaslyle is less developed. The hypocone is wider and less pointed. The enamel is more plicate.

Lower teeth. In the structure of lower deciduous premolars, the Bilibino horse is most similar to the Yakut aboriginal breed of domestic horse. In the relative length of the double loop of dP_3, the specimen described is similar to the Lena horse and exceeds the values in the Kazakh and Bashkir breeds, considerably exceeds the values in the Przewalski horse, and is considerably inferior to the Yakut breed. The relative length of the double loop of dP_4 of the Bilibino horse is greater than that of all horse species and breeds included in comparison, except for the Yakut domestic horse (Table 3).

The Bilibino horse differs from the Kazakh aboriginal breed of domestic horses in the more asymmetrical double loop of dP_3. The metastylid is more extended, has a more pointed apex; the linguaflexid is smaller. The entoconid is larger, more rounded. The anterior internal valley is less asymmetrical relative to the neck, the posterior edge is more rounded, the anterior edge is not extended downwards. The posterior internal valley is longer and wider, more oblique relative to the longitudinal tooth axis; the valley edges are more rounded, more extended; the lower wall is more convex. The ectoflexid is deeper; the pli caballinid fold is better developed.

The Bilibino horse differs from the Bashkir aboriginal breed of domestic horse in the more asymmetrical double loop. The metastylid is more extended, has a more pointed apex; the lingual wall more straight; the linguaflexid is smaller. The external walls of the protoconid and hypoconid are not oblique relative to the longitudinal tooth axis nor concave. The entoconid is larger. The anterior internal valley is less asymmetrical relative to the neck, the posterior edge is more rounded. The posterior internal valley is longer and wider, less symmetrical relative to the neck; the valley edges are more rounded; the lower wall is more convex. The ectoflexid is deeper; the pli caballinid fold is better developed.

The Bilibino horse differs from *E. przewalskii* in the more asymmetrical double loop. The metaconid is more extended, with a wider anterior part; the metastylid is more extended, more pointed at the apex; the lingual wall is more concave; the linguaflexid is smaller. The neck of the double loop is narrower. The entoconid is larger, more rounded, with a nonextended anterior lower corner of dP_3. The anterior internal valley is less asymmetrical relative to the neck, the edges are more rounded. The posterior internal valley is longer and wider, less symmetrical relative to the neck, more oblique relative to the longitudinal tooth axis. The ectoflexid is wider and deeper.

DISCUSSION

The small sample size impels us to use complex statistical methods for detailed comparison of different horse species irrespective of individual age.

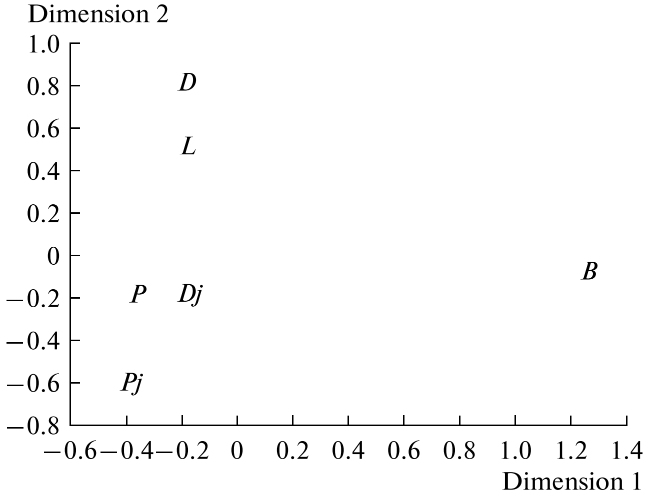

Fig. 2. Distribution of the horse groups examined in the space of the first and second axes of multidimensional scaling. Designations: (*B*) Bilibino horse, (*L*) Lena horse, (*P*) Przewalski horse (adult), (*Pj*) Przewalski horse (young individual), (*D*) Yakut horse (adult), and (*Dj*) domestic horses (young individual).

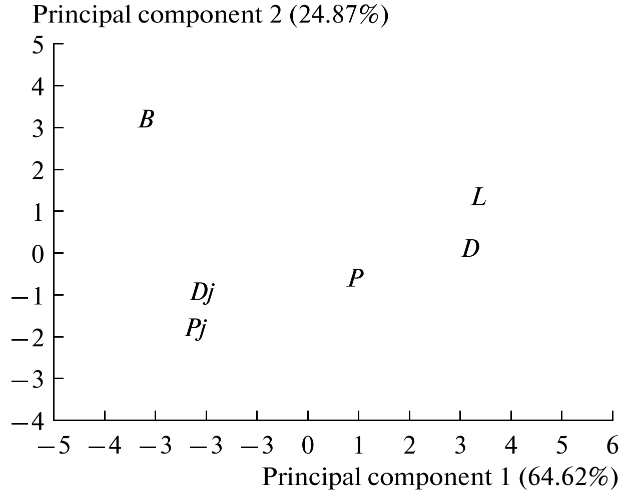

Fig. 3. Distribution of the horse groups examined in the space of the first and second principal components (for designations of groups, see Fig. 2).

In the characters of the axial skull, the intergroup differences are statistically significant (F ranges from 6.9 to 21.3) in seven characters: the diastema length, premolar row length, diastema width, interorbital width, forehead width at the posterior orbital border, braincase width at the postorbital narrowing, and the skull width at the external edges of the glenoid fossae. Age differences are highly statistically significant for the overwhelming majority of characters; sexual differences are statistically nonsignificant and excluded from consideration. In the dental measurements (in young and adult horses), the intergroup differences are statistically nonsignificant with reference to the factors *group, age*, and *sex*. Based on this, these characters were excluded from further analysis.

The analysis of similarities in mean-group values of particular characters in the initial sample, using the methods of multidimensional scaling (MS) and principal components (PC) gave generally similar results, with minor difference in relative position of the Bilibino horse (Figs. 2, 3). It occupies a distinctly detached position relative to other groups. In the case of multidimensional scaling, the Bilibino horse is clearly distinguished by the MS1 axis, which is correlated mostly with the measurements of the anterior orbital line and, particularly, with the diastema width. In the space of the first and second principal components, PC2 (mostly correlated with the posterior orbital line and diastema width) distinguishes the Bilibino horse from young domestic horses and the Przewalski horse. The comparison of individual specimens by the same two methods gives similar distributions, which in general confirm the previous results and show significant differences of the Bilibino horse from other animals. The axes distinguishing it are highly correlated with the following characters: MS2 with the diastema width, width between the facial crests, and width at the anterior orbital borders; and PC2 with the diastema width and braincase width at the postorbital narrowing.

Stepwise discriminant analysis was based on both initial measurements and residuals in two models; in the first case, the learning sample included all groups of adult and young individuals; in the second case, it only included groups of adults. In the first case, the groups of young and adult horses are distinguished most clearly by the first canonical variable, with the greatest contribution being made by the width between the anterior orbital points, interorbital width, and the forehead width at the posterior orbital borders. Note that the diastema width, which distinguishes the Bilibino horse, is not included in the discriminant function, since this character has a nonsignificant effect. Among adults, Yakut and Lena horses are most similar; in the scatter diagram, their groups overlap completely, the Mahalanobis distance is minimum ($D^2 = 11.9$); young Przewalski horses are more similar to young domestic horses ($D^2 = 18.4$) than adult individuals of respective species ($D^2 = 34.7$). The analysis on values transformed according to the Burnaby's method has displayed a similar distribution of groups in the space of canonical variables. The most similar groups were, on the one hand, young and adult Przewalski horses ($D^2 = 5.9$) and, on the other hand, young domestic and adult Lena ($D^2 = 4.9$) and Yakut horses ($D^2 = 7.8$). In both comparisons, the skull of the Bilibino horse falls into the group of young domestic horses.

Discriminant analysis, in which the learning sample consists only of adult horse groups, provides the following results. As the initial measurements are used, the Lena horse is most similar to the Yakut breed

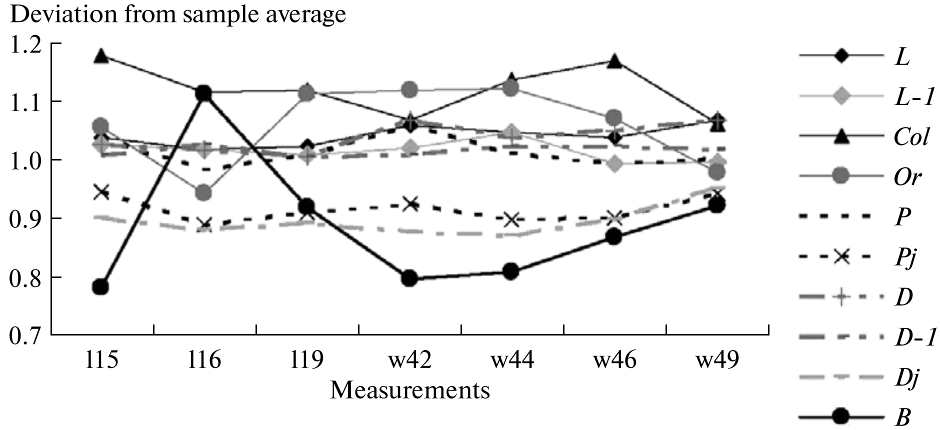

Fig. 4. Character structures for all horse groups, including *E. coliemensis* and *E. orientalis* (for measurement nos., see Table 1). Designations of groups mostly the same as in Fig. 2; Measurements: (*L-1*) Lena (*Col*) Kolyma, (*Or*) eastern, and (*D-1*) Yakut horses (after Lazarev, 1980).

($D^2 = 21.1$), the Przewalski horse is more similar to the Lena horse ($D^2 = 23.1$) than to domestic horses ($D^2 = 52.9$). Posterior probabilities allocate all young Przewalski horses to the group of adults of this species, while domestic horses and the Bilibino horse are close to the Lena horse. As transformed characters are used, the structure of similarities between the groups of adults remains essentially the same (values of D^2 are 17.1, 18.1, and 41.2, respectively). Posterior probabilities for young horses provide the following identification: of 14 young Przewalski horses, seven are referred to the group of adult *E. przewalskii*, three are identified as the domestic Yakut breed, and the positions of others are uncertain; of four young domestic horses, three are referred to the Lena horse and one, to the group of adult Yakut horses; the Bilibino horse is also referred to the Lena horse.

The analysis of character profiles (Fig. 4) shows the following: the diastema length and, to a lesser extent, the interorbital width distinguish the groups of adult Yakut and Lena horses from all others. The parietal length, the width between the facial crests, width between anterior orbital points, width at the anterior orbital borders, and, to a lesser extent, forehead width at the posterior orbital borders, skull width at the external edges of the glenoid fossae distinguish between the groups of adult and young horses. The anterior and posterior orbital lines and, particularly, the diastema width distinguishes the Bilibino horse from all other groups; at the same time, the character “anterior orbital line” clearly divides the latter into adult and young horses. Other characters do not show obvious distinctions.

As our data are compared with the data on extinct Pleistocene horses of Yakutia (Lazarev, 1980), additional characters are used, which have shown the most significant distinctions in previous analyses, i.e., the anterior orbital line, posterior orbital line, parietal length, width between the facial crests, width at the anterior orbital borders, forehead width at the posterior orbital borders, and skull width at the external edges of the glenoid fossae. The correlation distances between all groups (excluding the Bilibino horse) range from 0.006 to 0.742 and, according to our and published data, the distances in the groups of Lena and domestic horses are 0.067 and 0.046, respectively.

The distribution of all these groups in the space of the first and second principal components (Fig. 5) generally corresponds to the results previously obtained in respect to the position of Lena, Przewalski, domestic, and Bilibino horses. At the same time, it displays an isolated position of the Kolyma (*E. coliemensis* Russanov, 1968) and eastern (*E. orientalis* Russanov, 1968) horses relative to each other and other

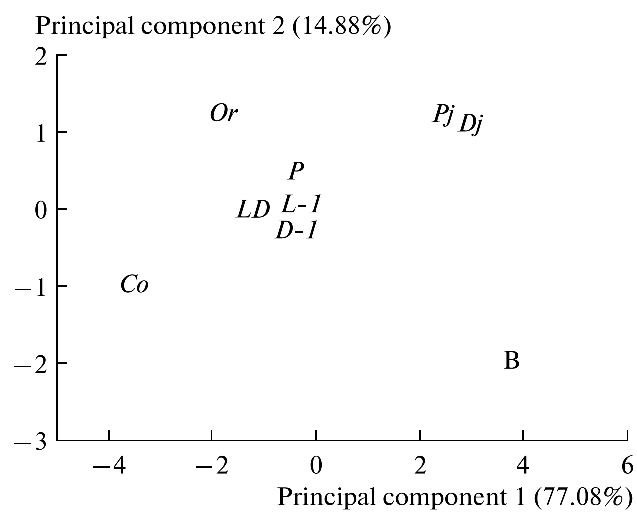

Fig. 5. Distribution of the horse groups examined, including *E. coliemensis* and *E. orientalis*, in the space of the first and second principal components (for designations of groups, see Figs. 2 and 4).

groups examined. This distribution also distinctly shows well pronounced isolation of the Bilibino horse; however, it is similar to *E. coliemensis* in the posterior orbital line (which also distinguishes them from other horses).

The results obtained suggest the following preliminary conclusions about the character of distinctions in cranial characters between the groups of wild and domestic horses and about the position of the Bilibino horse.

For a meaningful analysis of these distinctions, it is required first of all to point out the age-dependent characters. These are primarily the anterior orbital line, length parietal, width between the facial crests, width at the anterior orbital borders, forehead width at the posterior orbital borders, skull width at the external edges of the glenoid fossae, the mean values of which are always lower in young horses than in adults. It is possible to supplement this list with characters such as the posterior orbital line and diastema width, which are the smallest in young domestic and Przewalski horses and maximum in the Bilibino horse. The diastema length and premolar row length distinguish adult Lena and domestic horses from all others; interestingly, in this case, young Przewalski horses are grouped with adults. This result displays differences and similarities in terms of *adult* and *juvenile* cranial features of horses.

The Bilibino horse is most distinct among the groups considered in the ratio of adult and juvenile cranial features. On the one hand, the anterior orbital line and skull widths in the orbital region (width between the facial crests, width between the anterior points of the orbits, width at the anterior orbital borders) of this horse are the smallest among young individuals; in these characters, it is possible to regard this skull as *superjuvenile*. On the other hand, the posterior orbital line and, particularly, the diastema width, which, in domestic and Przewalski horses are generally greater in adults than in young individuals, in the Bilibino horse are maximum; these characters are regarded as superadult, although the skull in question belongs to a young animal. It should be noted that, in the posterior orbital line, the Bilibino horse is most similar with the Kolyma horse and this character differs considerably the two horses from others.

The sharp difference of the Bilibino horse in a set of cranial characters, which displays its specificity, is shown by the methods of multidimensional scaling and principal component. Discriminant analysis has not revealed this segregation because other horse groups differ nonsignificantly in the characters strongly distinguishing this skull. As comparison is based on discriminating characters, the Bilibino horse is most similar to either domestic or Lena horses. This uncertainty of results of discriminant analysis indirectly confirms the specificity of the Bilibino horse in skull proportions from other horse groups, although it may partly be accounted for by the small sample size.

CONCLUSIONS

Despite well-pronounced specificity of the Bilibino horse in skull proportions and dental structure, it is premature to make a conclusion about its taxonomic status. Perhaps, we deal with an individual anomaly caused by unusual growth and development of this animal. If distinctive features of skull structure are characteristic of a certain horse group from the Late Pleistocene of northeastern Siberia rather than result from abnormal individual development, this group deserves at least species taxonomic rank. However, this statement requires additional confirmation.

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