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Article *in* Stratigraphy and Geological Correlation · May 2001

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Zonal Subdivisions of the Quaternary in Eastern Europe Based on Small Mammals

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Received May 25, 1999

Abstract—A scheme of small mammal (vole) zones is proposed for the Quaternary of Eastern Europe. The zonation is based on the evolutionary appearance of new forms in the *Borsodia–Prolagurus–Lagurus, Mimomys–Arvicola*, and *Allophaiomys–Stenocranius* lineages. The defined units represent the regional range or concurrent range zones. Eleven zones, four of which are subdivided into subzones, are distinguished.

Key words: *Quaternary, mammals, stratigraphy, zonal subdivision, Eastern Europe.*

INTRODUCTION

Since the moment, when Gromov (1948) distinguished successive assemblages of the Pliocene and Quaternary mammals, they were used as a basis for the subdivision and correlation of continental deposits throughout the former USSR. At about the same time, similar biostratigraphic units of the Neogene and Quaternary were defined in Western Europe and North America. In recent decades, however, biozonation gains the increasing significance in practice of subdivision of the Late Cenozoic. Zonal units originally were defined in marine sediments on the basis of fossil plankton, and the mammal zones were subsequently distinguished in continental deposits. For instance, Mein (1975) was first to propose the widely known Neogene zonation of mammal faunas, and then it was elaborated for the Quaternary (Guerin, 1982; Agusti *et al.*, 1987; Feifar and Heinrich, 1990; and others).

Unfortunately, the Quaternary mammal zones did not gain much recognition among paleontologists as some of them had poorly substantiated zonal boundaries, while others were of the comparatively wide ranges. It should be noted that the latest progress in understanding the small mammal evolution, especially of voles, enables a considerably more detailed subdivision and correlation of the Quaternary continental sediments than it was possible before. In this work, we suggest a version of the Quaternary mammal zonation in Eastern Europe.

MATERIALS AND METHODS

Paleontological records that are used as a basis for the proposed zonation are described in works by Agadzhanyan (1972, 1976, 1992), Aleksandrova (1976), Kazantseva (1987), Markova (1982, 1992), Rekovets (1994), and Tesakov (1995, 1998). The works of special significance are those by Krasnenkov and Iosifova who contributed much to a search of new localities, to collecting faunas, and to geological characterization of bone beds (*Opornye razrezy...*, 1984; *Verkhnii pliotsen...*, 1985).

We analyzed data on 51 localities of Eastern Europe (Fig. 1). Some of them are of the multilayer structure. Actually, the bone localities are much more abundant in the study region, but we focused attention on those, which are most precisely correlated with stratigraphic horizons. The taxonomic composition of voles from these localities is characterized in the table. Faunas from some localities were revised by Tesakov.

The proposed zonation is based on new forms appearing in certain phyletic lineages. Using a single lineage, we can distinguish no more than four or five range zones in the Quaternary. Since the appearance levels of new forms in different phyla do not coincide in time, several phyletic lineages that are used considerably enlarge the number of the distinguishable range or concurrent range zones. When elaborating zonation, we considered the most common and widespread forms of three phyletic lineages: *Borsodia–Prolagurus–Lagurus, Mimomys–Arvicola*, and *Allophaiomys–Microtus (Stenocranius)* (Fig. 2). Zonal boundaries are placed at the appearance levels of new species in a certain lineage. We defined the first occurrence level of a new species just where the abundance rate of an advanced morphotype in the assemblage is as high as 75%. It should be emphasized that the accepted value is a matter of convention and agreement. Some zones were subdivided into subzones according to the same principle with due consideration of forms belonging to other phyletic lineages. Zones and subzones are named after their index species. In addition, they are designated by the literal-numeric indices, for instance, by

MQR1, where M means mammals, Q—Quaternary, R—Russia, and the Arabic numeral is the zone number counting downward from the top. Subzones are designated by the Latin capital letters (A, B, C) in the downward succession from the top as well. When we had to subdivide a subzone, the resultant units were indicated by Arabic numerals once again downward from the top. The accepted designation system is like that of magnetic subdivisions in the latest magnetochronological scales.

The age of zonal boundaries was defined in accord with the locality position in the stratigraphic, magnetochronological, and oxygen isotope scales. The zonal boundary datums are of different reliability within certain intervals of the Quaternary. Their confidence depends on the reference locality position relative to the boundaries of paleomagnetic units, and on the validity of correlation between stratigraphic horizons and stages of the oxygen isotope scale.

POSITION OF REFERENCE LOCALITIES IN THE STRATIGRAPHIC, MAGNETOCHRONOLOGIC, AND OXYGEN-ISOTOPE SCALES

It is a customary practice to place the lower boundary of the Quaternary continental deposits at the first occurrence of rootless voles *Allophaiomys*. The Kryzhanovka 4, Tizdar 1, and Tiligul sites (Fig. 3) that yield *Allophaiomys* remains are most ancient in Eastern Europe. The Zhevakhova Gora 5 and 9, Chortkov, and Tizdar 2 localities are somewhat younger and reveal association of archaic *Allophaiomys* form with *Lagurodon arankae* and *Prolagurus ternopolitanus*. All these localities are assigned to the Zhevakhova Gora Horizon in the stratigraphic scheme by Nikiforova and Aleksandrova (1991). In their scheme, the Zhevakhova Gora Horizon is placed just below the Jaramillo Subchron, though it seems to be older than the Olduvai Subchron, because the Tizdar 1 and 2 sites are localized at the Kuyal'nik level, and the Kuyal'nik–Gurian boundary runs in the middle of the Olduvai Subchron (Pevzner, 1989; Pevzner *et al.*, 1998).

A group of localities, e.g., the Korotoyak 3a, Akkulaevo (the Dema and Davlekanovo horizons), Uspenka, and Log Denisov, yield the *Allophaiomys* form intermediate between *A. deucalion* and *A. pliocaenicus*. The exact stratigraphic position of the localities is unknown. They fall in the interval between the Olduvai Subchron and the Nogaisk Horizon base. The younger Tarkhankut locality that yields the more advanced *Allophaiomys pliocaenicus* is referred to the same stratigraphic interval.

The next group of localities is assigned to the Nogaisk Horizon included by Nikiforova and Aleksandrova in their scheme. The lower boundary of the horizon coinciding with that of the Taman' faunal assemblage (nomenclature by Gromov) is dated back to 1.2 Ma (Vangengeim *et al.*, 1991). The base of the hori-
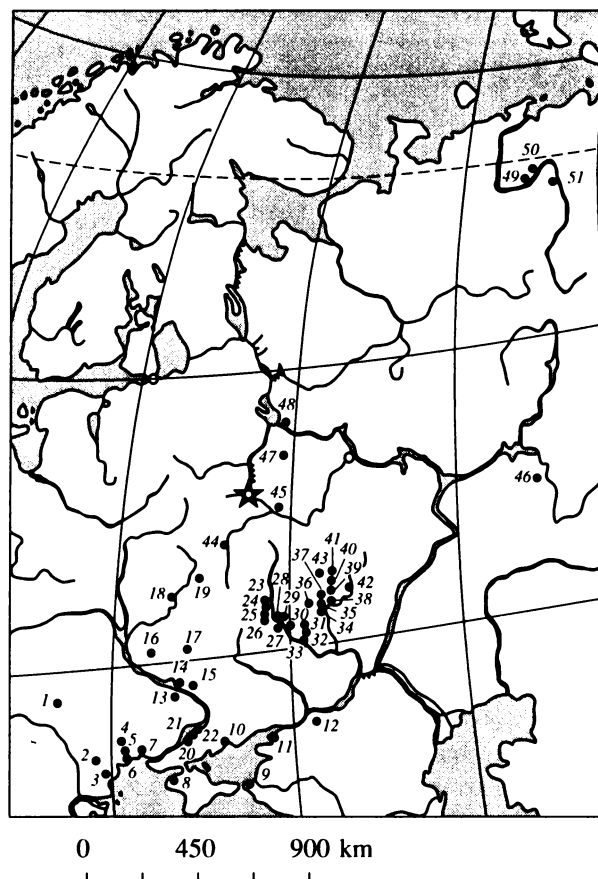

Fig. 1. Geographic map of mammalian reference localities: (*1*) Chortkov; (*2*) Kolkotova Balka; (*3*) Roksolany; (*4*) Morozovka; (*5*) Zhevakhova Gora; (*6*) Kryzhanovka; (*7*) Tiligul; (*8*) Tarkhankut; (*9*) Tizdar; (*10*) Nogaisk; (*11*) Port-Katon; (*12*) Shamin; (*13*) Chigirin; (*14*) Pivikha; (*15*) Gun'ki; (*16*) Priluki; (*17*) Gadyach; (*18*) Arapovichi; (*19*) Khotylevo; (*20*) Zapadnye Kairy; (*21*) Ushkalka; (*22*) Karai-Dubina; (*23*) Strelitsa; (*24*) Verkhnyaya Emancha; (*25*) Bogdanovka; (*26*) Uryv; (*27*) Veret'e; (*28*) Korotoyak; (*29*) Uspenka; (*30*) Klepki; (*31*) Il'inka; (*32*) Log Denisov; (*33*) Petropavlovka; (*34*) Novokhopersk; (*35*) Kuznetsovka; (*36*) Zherdevka; (*37*) Vol'naya Vershina; (*38*) Korostylevo; (*39*) Moiseevo; (*40*) Posevkino; (*41*) Perevoz; (*42*) Melik; (*43*) Rasskazovo; (*44*) Chekalin; (*45*) Alpat'evo; (*46*) Akkulaevo; (*47*) Cheremoshnik; (*48*) Chermenino; (*49*) Chulei; (*50*) Kipievo; (*51*) Akis'.

zon is defined by the appearance of *Prolagurus pannonicus*, and its top is marked by the appearance of *Stenocranius ("Pitymys") hintoni* and *Clethrionomys glareolus*. The most ancient Nogaisk and Korotoyak 3c localities of the group are situated in uppermost beds of the Uspenka Formation, where *Prolagurus pannonicus* appears among voles.[1] The Zapadnye Kairy, Ushkalka,

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[1] We should emphasize that Topachevskii (1965) described the new lagurid form *Prolagurus praepannonicus* at the Nogaisk site. Subsequently, Rekovets (1994) showed that this form fits completely the intraspecific variability of *P. pannonicus* described from Hungary by Kormos. He considered *P. praepannonicus* as a synonym of the latter and transferred the more archaic subspecies *P. praepannonicus ternopolitanus* of Topachevskii into the rank of species *P. ternopolitanus*.

Voles from reference localities of Eastern Europe

Horizon	Localities	Mimomys intermedius	M. pusillus	Clethrionomys sokolovi	Pliomys	Borsodia	Allophaiomys deucalion	Lagurodon arankae	Prolagurus ternopolitanus	Allophaiomys pliocaenicus	Eolagurus argyropuloi	Prolagurus pannonicus	Eolagurus simplicidens	Stenocranius hintoni	Clethrionomys glareolus	Pallasiinus protoeconomus	Microtus arvalinus	Microtus middendorffi-hyperboreus	Terricola arvaloides	Lagurus transiens	Stenocranius gregaloides	Pallasiinus oeconomus	Stenocranius gregalis	Eolagurus luteus	Dicrostonyx simplicior	Arvicola mosbachensis	Microtus arvalis	Lagurus lagurus	Dicrostonyx gulielmi-henseli	Arvicola terrestris	Dicrostonyx torquatus
Holocene															•			•				•	•	•			•	•		•	•
Ostashkovo	Khotylevo 2																					•	•						•	•	
Monchalovo	Arapovichi																					•	•	•			•	•	•		
Kalinin	Gadyach																						•					•			
Mikulino	Cheremoshnik														•								•							•	
Moscow	Kipievo 2																						•						•		
	Chulei,																								•						
	Alpat'evo,																					•	•		•			•			
	Kipievo 1																					•		•							
Odintsovo	Strelitsa,														•				•			•	•	•		•	•				
	Verkhnyaya Emancha														•				•			•	•			•	•	•			
Dnieper	Akis'																					•			•						
	Chermenino																						•		•	•					
	Chekalin (u.b.)														•								•		•			•			
Likhvin	Pivikha														•				•	•		•	•	•		•	•				
	Priluki																			•			•								
	Gun'ki														•					•		•	•	•		•	•				
	Chigirin														•				•	•		•	•	•							
	Chekalin (m.b.)														•			•				•	•	•							
Oka	Chekalin (l.b.)														•							•	•		•						
Muchkap	Tiraspol' (Vorona)																					•	•								
	Vol'naya Vershina	•													•		•	•	•	•		•	•								
	Kuznetsovka,	•													•			•	•	•	•	•									
	Perevoz,																		•	•		•									
	Posevkino,																		•	•	•	•									
	Kolkotova Balka	•													•		•		•	•	•	•									
	Zherdevka,	•													•			•	•			•									
	Korotoyak 4	•													•		•		•	•	•	•									
Don	Bogdanovka	•													•	•			•		•	•									
	Moiseevo 3,														•	•			•		•	•									
	Klepki	•											•		•				•		•	•									
Il'inka	Novokhopersk 2	•	•											•	•		•	•	•			•									
	Moiseevo 2,		•											•	•				•			•									
	Korostylevo		•											•	•		•	•	•			•									
	Novokhopersk 1	•	•															•	•			•									
	Melik,													•	•			•	•												
	Veret'e,	•	•											•	•				•	•		•									
	Il'inka	•	•												•				•	•		•									

Table. (Contd.)

Horizon	Localities	*Mimomys intermedius*	*M. pusillus*	*Clethrionomys sokolovi*	*Pliomys*	*Borsodia*	*Allophaiomys deucalion*	*Lagurodon arankae*	*Prolagurus ternopolitanus*	*Allophaiomys pliocaenicus*	*Eolagurus argyropuloi*	*Prolagurus pannonicus*	*Eolagurus simplicidens*	*Stenocranius hintoni*	*Clethrionomys glareolus*	*Pallasiinus protoeconomus*	*Microtus arvalinus*	*Microtus middendorffi-hyperboreus*	*Terricola arvaloides*	*Lagurus transiens*	*Stenocranius gregaloides*	*Pallasiinus oeconomus*	*Stenocranius gregalis*	*Eolagurus luteus*	*Dicrostonyx simplicior*	*Arvicola mosbachensis*	*Microtus arvalis*	*Lagurus lagurus*	*Dicrostonyx gulielmi-henseli*	*Arvicola terrestris*	*Dicrostonyx torquatus*
Pokrovka	Uryv 3a	●	●								●	●		●		●		●	●												
Petropavlovka	Shamin	●									●			●		●	●														
	Petropavlovka,	●										●		●		●															
	Karai-Dubina	●									●	●		●		●	●														
Morozovka	Morozovka 1	●	●				●				●	●		●		●															
Nogaisk	Moiseevo 1									●			●																		
	Port-Katon	●	●	●						●			●																		
	Korotoyak 3c	●	●	●						●			●		●																
	Zapadnye Kairy,	●		●						●	●		●																		
	Ushkalka,		●				●			●			●																		
	Roksolany	●					●			●			●																		
	Korotoyak 3b,	●	●		●					●	●		●																		
	Nogaisk	●		●			●			●			●																		
	Tarkhankut	●		●				●	●	●	●																				
	Korotoyak 3a								●	●					●																
	Log Denisov	●		●					●	●																					
	Uspenka	●	●	●	●				●	●																					
	Akkulaevo (D + D)	●	●	●					●	●																					
Zhevakhova Gora	Chortkov,		●	●			●		●																						
	Zhevakhova Gora 5, 9	●		●			●	●	●																						
	Tizdar 2		●	●			●	●																							
	Kryzhanovka 4,			●		●	●																								
	Tizdar 1,		●			●	●																								
	Tiligul	●		●		●	●																								

Note: (l.b.), (m.b.), (u.b.) – lower, middle, and upper bone beds; (D + D) – the Davlekanovo and Dema horizons.

and Roksolany localities are close, though somewhat younger in age, as they reveal presence of more advanced of *Allophaiomys* morphotypes. In the magnetochronological scale, these localities should be placed below the Jaramillo Subchron, because the latter is recorded above the bone bed of the Roksolany locality (Dodonov *et al.*, 1998). The Korotoyak 3c locality that associates with the lower part of the Ostrogozhsk Formation lacking paleomagnetic characteristics (Iosifova *et al.*, 1992) can be placed near the lower boundary of the Jaramillo Subchron or just below it, because the upper part of the formation section shows the normally polarity and is correlated with the Jaramillo Subchron. The younger Port-Katon locality still localized within the Nogaisk Horizon can be placed above the Jaramillo Subchron, since the bone-bearing deposits reveal the reversed polarity. The somewhat younger Moiseevo 1 locality also should be assigned to the Nogaisk Hori-
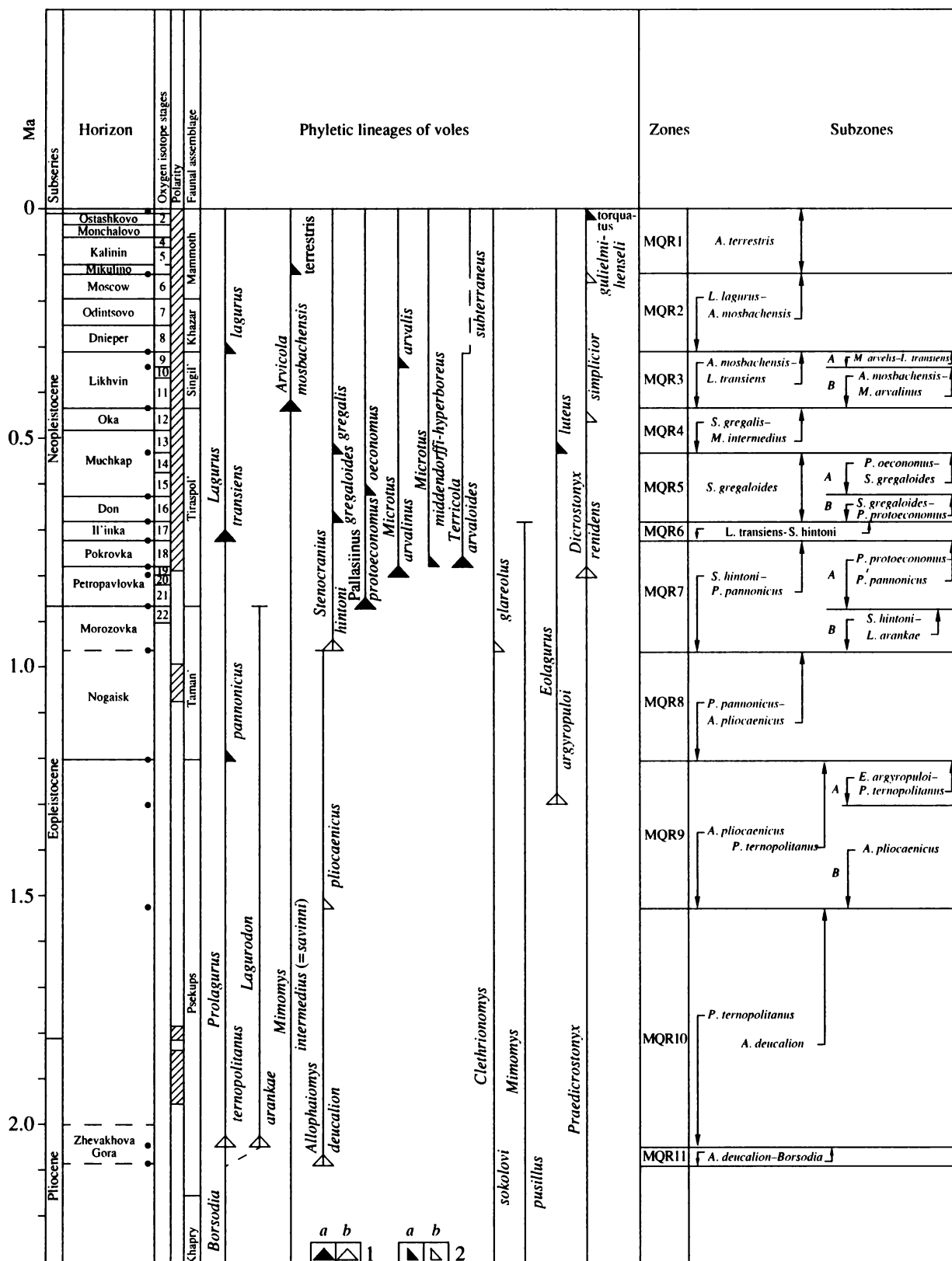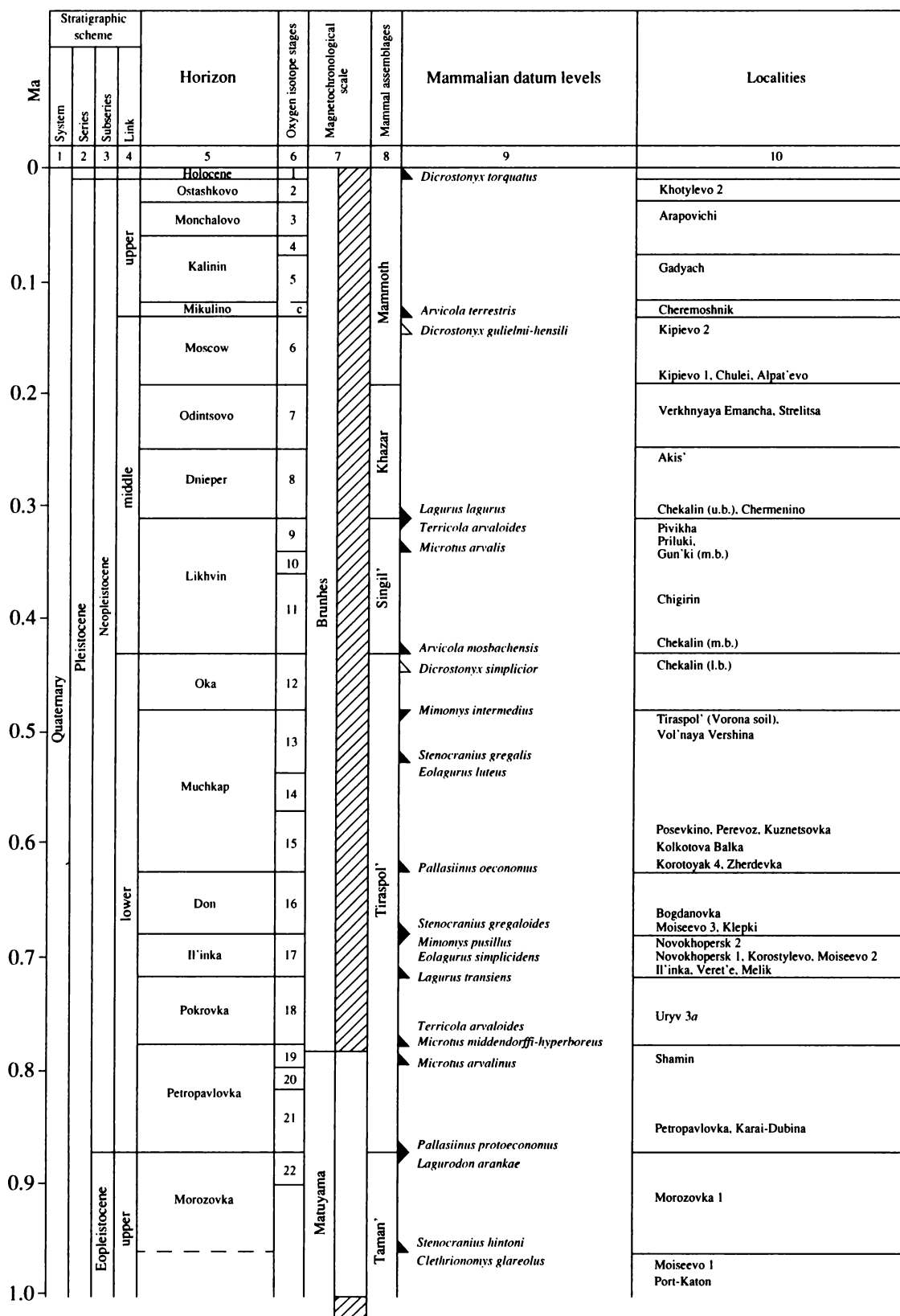
Fig. 2. Biozones and subzones of the Quaternary voles in Eastern Europe: (1) the appearance levels of vole genera related to the horizon boundaries (*a*), or of unknown precise position relative to horizons (*b*); (2) the appearance levels of new species related to horizon boundaries (*a*), or of unknown precise position relative to horizons (*b*).
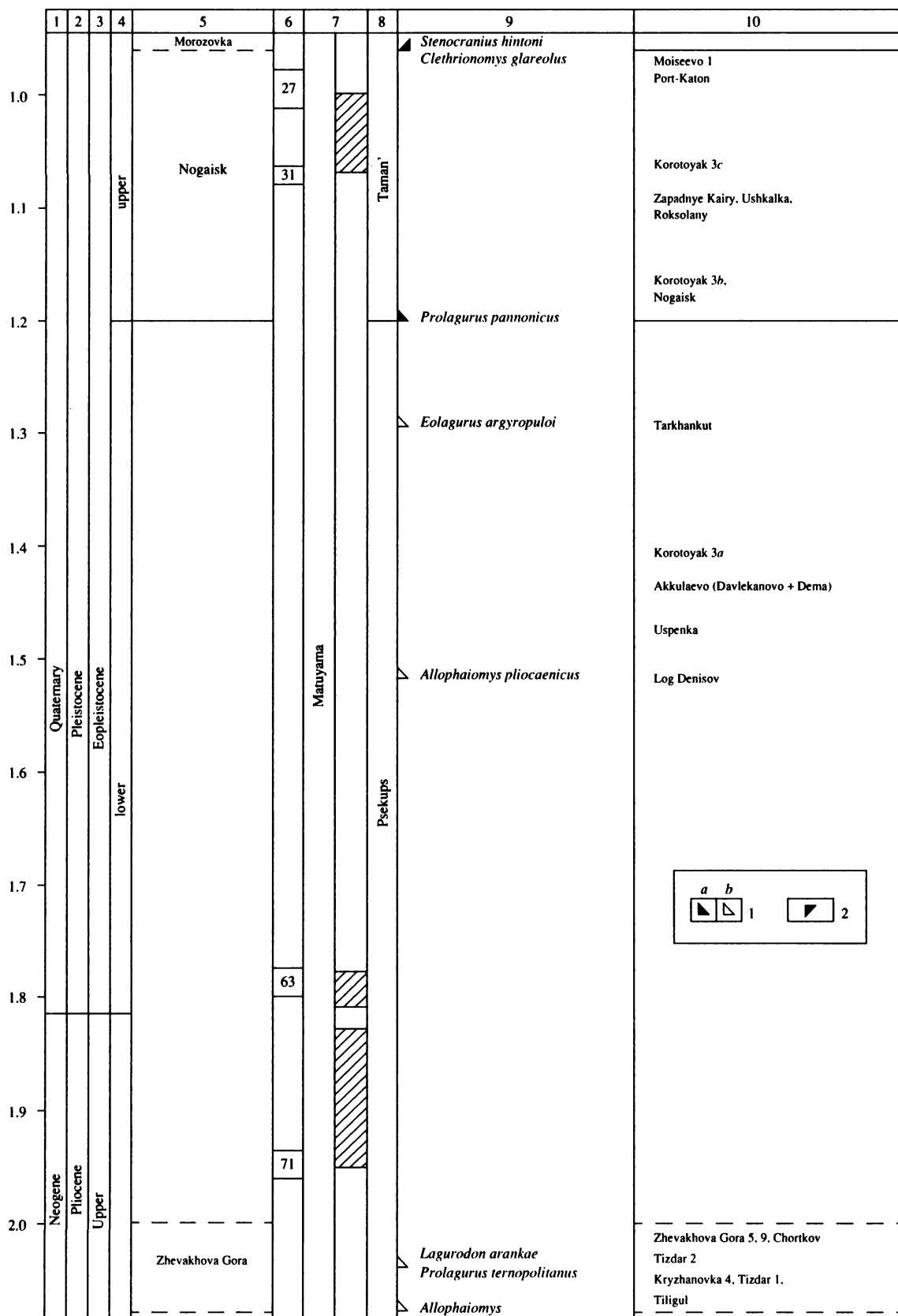
ZONAL SUBDIVISIONS OF THE QUATERNARY

Ma	System	Series	Subseries	Link	Horizon	Oxygen isotope stages	Magnetochronological scale	Mammal assemblages	Mammalian datum levels	Localities
1	2	3	4		5	6	7	8	9	10
0	Quaternary	Pleistocene			Holocene	1	Brunhes	Mammoth	▲ *Dicrostonyx torquatus*	
			upper		Ostashkovo	2				Khotylevo 2
					Monchalovo	3				Arapovichi
0.1					Kalinin	4 / 5				Gadyach
					Mikulino	c			▲ *Arvicola terrestris* / △ *Dicrostonyx gulielmi-hensili*	Cheremoshnik / Kipievo 2
			middle		Moscow	6		Khazar		Kipievo 1, Chulei, Alpat'evo
0.2		Neopleistocene			Odintsovo	7				Verkhnyaya Emancha, Strelitsa
0.3					Dnieper	8		Singil'	▲ *Lagurus lagurus* / *Terricola arvaloides* / *Microtus arvalis*	Akis' / Chekalin (u.b.), Chermenino / Pivikha / Priluki, / Gun'ki (m.b.)
0.4					Likhvin	9 / 10 / 11				Chigirin / Chekalin (m.b.)
					Oka	12			▲ *Arvicola mosbachensis* / △ *Dicrostonyx simplicior*	Chekalin (l.b.)
0.5						13			▲ *Mimomys intermedius*	Tiraspol' (Vorona soil), / Vol'naya Vershina
			lower		Muchkap	14		Tiraspol'	▲ *Stenocranius gregalis* / *Eolagurus luteus*	
0.6						15			▲ *Pallasiinus oeconomus*	Posevkino, Perevoz, Kuznetsovka / Kolkotova Balka / Korotoyak 4, Zherdevka
					Don	16				Bogdanovka / Moiseevo 3, Klepki
0.7					Il'inka	17			▲ *Stenocranius gregaloides* / *Mimomys pusillus* / *Eolagurus simplicidens* / ▲ *Lagurus transiens*	Novokhopersk 2 / Novokhopersk 1, Korostylevo, Moiseevo 2 / Il'inka, Veret'e, Melik
					Pokrovka	18			*Terricola arvaloides* / ▲ *Microtus middendorffi-hyperboreus*	Uryv 3a
0.8					Petropavlovka	19 / 20 / 21	Matuyama		▲ *Microtus arvalinus*	Shamin / Petropavlovka, Karai-Dubina
0.9		Eopleistocene	upper		Morozovka	22		Taman'	▲ *Pallasiinus protoeconomus* / *Lagurodon arankae*	Morozovka 1
1.0									*Stenocranius hintoni* / *Clethrionomys glareolus*	Moiseevo 1 / Port-Katon

Fig. 3. Position of small mammal reference localities and datums in the magnetochronological and stratigraphic schemes: (1) the appearance levels of new species related to horizon boundaries (a), or of unknown precise position relative to horizons (b); (2) levels of species extinction. Letter symbols (l.b.), (m.b.), and (u.b.) denote lower, middle, and upper bone beds.

1	2	3	4	5	6	7	8	9	10

Column 5: Morozovka — Nogaisk — Zhevakhova Gora

Column 6: 27, 31, 63, 71

Column 4: upper / lower

Column 7: Matuyama

Column 8: Taman' / Psekups

Column 1: Quaternary / Neogene
Column 2: Pleistocene / Pliocene
Column 3: Eopleistocene / Upper

Scale (left): 1.0, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 2.0

Column 9:
- *Stenocranius hintoni*
- *Clethrionomys glareolus*
- *Prolagurus pannonicus*
- *Eolagurus argyropuloi*
- *Allophaiomys pliocaenicus*
- *Lagurodon arankae*
- *Prolagurus ternopolitanus*
- *Allophaiomys*

Column 10:
- Moiseevo 1
- Port-Katon
- Korotoyak 3*c*
- Zapadnye Kairy, Ushkalka, Roksolany
- Korotoyak 3*b*, Nogaisk
- Tarkhankut
- Korotoyak 3*a*
- Akkulaevo (Davlekanovo + Dema)
- Uspenka
- Log Denisov
- Zhevakhova Gora 5, 9, Chortkov
- Tizdar 2
- Kryzhanovka 4, Tizdar 1,
- Tiligul

Legend box:
a   b
   1   2

Fig. 3. (Contd.)

zon, because Agadzhanyan (see in *Verkhnii pliotsen...*, 1985) attributed here all vole remains of the *Allophaiomys–Stenocranius* lineage to the forms transitional between *Allophaiomys* and "*Pitymys*" (= *Stenocranius*).

The Morozovka 1 locality is the stratotype section of the Morozovka Horizon. It is characterized by the first occurrence of *Stenocranius hintoni* and *Clethrionomys glareolus*. The boundary between the Morozovka and overlying Petropavlovka horizons coincides with the lower boundary of the Neopleistocene in the general stratigraphic scheme of the Quaternary in Russia (resolution of the Interdepartmental Stratigraphic Commission, February 2, 1995) and with the boundary between the Taman' and Tiraspol' faunal assemblages. In the West European schemes, this level corresponds to the lower-middle Pleistocene boundary and to the Cromerian base that is correlated with the base of oxygen isotope stage 21. In such a case, the Matuyama-Brunhes inversion inside the oxygen isotope stage 19 (Shackleton, 1995) should be in the upper part of the Petropavlovka Horizon. This is exactly the case in the stratotype Petropavlovka section, where that inversion is recorded in the fossil soil developed on the Petropavlovka alluvium (*Verkhnii pliotsen...*, 1985).

The lower boundary of the Petropavlovka Horizon is marked by extinction of *Lagurodon arankae* and by first occurrence of *Microtus (Pallasiinus) protoeconomus*.[2] The Karai-Dubina locality and corresponding stratotype section are recognized in the lower part of the horizon. The Shamin locality in deposits of the reverse polarity is characterized by the first occurrence of *Microtus arvalinus* thus being slightly younger.

The lower boundary of the Pokrovka Horizon corresponds to the appearance level of *Microtus (Terricola) arvaloides* and *Microtus* ex gr. *middendorffi- hyperboreus* that are known from the Uryv 3a stratotype section. Deposits of the horizon are characterized by palynological spectra of the periglacial type and by occurrence of cold-resistant mollusks (*Opornye razrezy...*, 1984). These characteristics allow us to correlate the Pokrovka Horizon with the oxygen isotope stage 18.

The evolutionary level of voles from the Novokhopersk 1 and 2, Korostylevo, Moiseevo 2, Veret'e, and Melik localities is almost identical to that characterizing the Il'inka stratotype section. The mentioned localities are attributed to the Il'inka Horizon, the lower boundary of which is defined by the first occurrence of *Lagurus transiens*. Sediments of the horizon reveal presence of thermophilic mollusks and tortoise remains (Breslav *et al.*, 1992), according to

which the Il'inka Horizon can be correlated with the warm stage 17. Faunas of the Bogdanovka, Moiseevo 3, and Klepki localities are close in composition to those from localities mentioned above. They are younger however and include *Stenocranius gregaloides* but lack *Mimomys pusillus* and *Eolagurus simplicidens* characteristic of more ancient faunas. Although the last localities occur below the Don moraine being referred by the majority of researchers to the Il'inka Horizon, we place them in the basal interval of the higher Don Horizon. This decision is based on the species composition that is somewhat impoverished as compared to that characterizing the preceding group of localities. Moreover, lemming bones occurring at the Bogdanovka site and abundant remains of *Microtus* ex gr. *middendorffi-hyperboreus* in all three localities indicate a comparatively cold climate during accumulation of burials. In addition, the deposits of the Moiseevo 3 and Klepki localities enclose pebbles of crystalline rocks that likely point to the onset of the Don glaciation (Udartsev *et al.*, 1979).

The lower boundary of the Muchkap Horizon is marked by the first occurrence of *Microtus (Pallasiinus) oeconomus* (Rekovets, 1994). In middle courses of the Don River, the Posevkino, Perevoz, Kuznetsovka, Korotoyak 4, and Zherdevka localities are referred to the lower part of the Muchkap Horizon. The two former are localized in the fossil soil of the Vorona pedocomplex immediately above moraine of the Don glacial tongue; and other sites are known in alluvial deposits also overlying this moraine. All the localities are characterized by the presence of *Stenocranius gregaloides* among shrub voles. We place the Kolkotova Balka site of the Dniester River region at the same stratigraphic level according to the fauna composition and evolutionary level of voles. The biometric age of elephants from the Kolkotova Balka locality is 590 ka (Vangengeim and Pevzner, 2000), and this, along with absence cold-resistant taxa, permit the correlation of the site with the oxygen isotope stage 15. Accordingly, the lower part of the Muchkap Horizon corresponds to the same stage 15, and the Don Horizon cannot be younger than the stage 16.

The Vol'naya Vershina locality, the Muchkap Horizon stratotype, and the Tiraspol' site (the Vorona soil) are obviously younger than the previous group of localities, because *Stenocranius gregaloides* is replaced in this case by more advanced *S. gregalis*. *Eolagurus luteus* appears at the same level instead of *E. argiropuloi*. The molluscan assemblage of the Muchkap Horizon stratotype suggests origin under warm climatic conditions, and we correlate the horizon with the oxygen isotope stage 13.

The lower fluvioglacial sediments left by of the Oka glaciation at the Chekalin locality are referred to the Oka Horizon and correlated with the oxygen isotope stage 12.

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[2] The early form of the *Microtus (Pallasiinus)* lineage usually known in Russian publications as *M.* ex gr. (cf.) *oeconomus* was distinguished by Rekovets (1994) as the particular species *M. protoeconomus*.

We consider the Likhvin Horizon in a wide range of 11 to 9 stages of the oxygen isotopic scale. The corresponding fauna is known as the Singil' assemblage. *Arvicola mosbachensis (= A. cantianus)* appeared at the base of the horizon, whereas the upper boundary of the latter is marked by appearance of *Lagurus lagurus* and by extinction of *Terricola arvaloides. Mimomys intermedius*, the direct ancestor of *Arvicola*, is unknown in faunas younger than the uppermost Much-kap Horizon. The middle lacustrine lens (stratotype of the Likhvin interglacial) at the Chekalin locality is referred to the lowermost part of the Likhvin Horizon and to the oxygen isotope stage 11. The Chigirin fauna is close in age. The group of younger localities is known from the upper part of the Likhvin Horizon. According to succession of *Lagurus lagurus* and *L. transiens* morphotypes, these localities can be arranged in the following order according to the age decrease: the Gun'ki (middle bed), Priluki, and Pivikha sites. *Microtus arvalis* appeared first in the Gun'ki site.[3] The spore and pollen assemblages point to a warm climate in the corresponding period (Markova, 1982), and we place the indicated localities at the level of oxygen isotope stage 9.

The upper fluvioglacial bed of the Chekalin locality and alluvial sediments of the Chermenino site, where they underlie the Dnieper moraine second from the top, are referred to the lowermost part of the Dnieper Horizon. Judging from the evolutionary advancement of *Dicrostonyx* forms, the localities are of the same age (*Razrezy otlozhenii...*, 1977; Agadzhanyan, 1976).

At the Akis' locality, deposits that overlie the second moraine from the top are attributed to the upper portion of the Dnieper Horizon. The comparative morphology of *Dicrostonyx* teeth shows that this locality is somewhat younger than the upper bone bed at the Chekalin site (Guslitser and Isaichev, 1983). *Arvicola* forms of the Verkhnyaya Emancha and Strelitsa sites are of a similar evolutionary level but more advanced as compared to *Arvicola* species from the Gun'ki and Pivikha localities. The molluscan fauna from the Strelitsa site suggests a warm climate during its lifetime, and we feel it possible to attribute the Verkhnyaya Emancha and Strelitsa localities to the Odintsovo Horizon and to correlate the latter with the oxygen isotope stage 7.

Sediments underlying the upper moraine at the Kipievo 1 and Chulei sites, are referred to the lower part of the Moscow Horizon. According to the relationship of *Dicrostonyx* morphotypes, the Alpat'evo locality is close in age to them (Markova, 1982). Deposits overlying the upper moraine at the Kipievo 2 locality are correlated with upper strata the Moscow Horizon, as lemmings are represented here by the more advanced *Dicrostonyx* ex gr. *gulielmi-henseli*.

The lower boundary of the Mikulino Horizon is determined by the appearance of *Arvicola terrestris*. The Cheremoshnik locality, where the mammalian fauna was collected from the Mikulino peat deposits (Agadzhanyan, 1972), is attributed to this horizon. The majority of researchers correlates the Mikulino interglacial with the oxygen isotope stage 5e, placing the Dnieper and Moscow horizons at the levels of stages 8 and 6, respectively.

The Gadyach locality of the steppe mammalian fauna is referred to the Kalinin Horizon. The Arapovichi locality in the Bryansk soil yields *Dicrostonyx* ex gr. *gulielmi-henseli* and is placed in the Monchalovo Horizon corresponding to the oxygen isotope stage 3. The Khotylevo 2 locality of 23600 ± 270 years old according to ^{14}C date (Markova, 1982) is attributed to the Ostashkovo Horizon. At this site, lemmings are still represented by *D. gulielmi-henseli*, whereas the more advanced *D. torquatus* is known from numerous localities of the Holocene age (*Stratigrafiya SSSR...*, 1982).

REGIONAL MAMMAL ZONES OF EASTERN EUROPE

Eleven range and concurrent range zones of vole species were distinguished within the analyzed time range (Fig. 2). The zones are characterized below from the basal one upward.

MQR 11: the *Allophaiomys deucalion-Borsodia* concurrent range zone with the base determined by the first appearance datum (FAD) of the genus *Allophaiomys*; the FAD of the genera *Lagurodon* and *Prolagurus* define its upper limit.`

Characteristic taxa are *Allophaiomys deucalion, Mimomys intermedius (= M. savini), M. pusillus*, advanced forms of *Borsodia*, and archaic *Clethrionomys*.

Type locality: Tizdar 1, and **other localities** are Tiligul and Kryzhanovka 4.

Ages of lower and upper boundaries cannot be established precisely. Both boundaries are older than the Olduvai Subchron.

MQR 10: the *Prolagurus ternopolitanus–Allophaiomys deucalion* concurrent range zone, the lower boundary of which corresponds to the FAD *Prolagurus* genus, and the upper one to the last appearance datum (LAD) of *Allophaiomys deucalion*.

Characteristic taxa are *Allophaiomys deucalion, Lagurodon arankae, Prolagurus ternopolitanus, Mimomys intermedius, M. pusillus*, and archaic *Clethrionomys*.

Type locality is Zhevakhova Gora 5 and 9. **Other localities** are Tizdar 2 and Chortkov.

The age of upper boundary is not established. The boundary is somewhat above the Olduvai Subchron.

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[3] In opinion of Rekovets (1994), this form having index values of AL > 55 and d/e < 25 differs from ancestral *M. arvalinus*.

MQR 9: the *Allophaiomys pliocaenicus–Prolagurus ternopolitanus* concurrent range zone; its lower boundary corresponds to the FAD of *Allophaiomys pliocaenicus*, and the top to the LAD of *Prolagurus ternopolitanus*.

Characteristic taxa are *Allophaiomys pliocaenicus, Prolagurus ternopolitanus, Lagurodon arankae, Mimomys intermedius*, and *M. pusillus*. The first appearance of *Eolagurus argiropuloi* is recorded in the upper part of the zone.

Type locality is Uspenka. **Other localities** are Akkulaevo (the Dema and Davlekanovo horizons), Log Denisov, Korotoyak 3a, and Tarkhankut.

The age of the upper boundary is 1.2 Ma. This datum coincides with the boundary between the Psekups and Taman' faunal assemblages and with the base of the Nogaisk Horizon.

The zone is subdivided into two **subzones**. The lower *Allophaiomys pliocaenicus* subzone (**MQR 9B**) spans the interval from the *A. pliocaenicus* FAD to the *Eolagurus argiropuloi* FAD. The upper subordinate unit **MQR 9A** is defined as the *Eolagurus argiropuloi–Prolagurus ternopolitanus* concurrent range subzone. Its interval is between the *E. argiropuloi* FAD and the *P. ternopolitanus* LAD.

MQR 8: the *Prolagurus pannonicus–Allophaiomys pliocaenicus* concurrent range zone with the lower boundary defined by the FAD of *Prolagurus pannonicus*; the upper boundary is marked by extinction of the genus *Allophaiomys*.

Characteristic taxa are *Allophaiomys pliocaenicus, Prolagurus pannonicus, Lagurodon arankae, Mimomys intermedius, M. pusillus*, and *Clethrionomys sokolovi*.

Type locality is Nogaisk. **Other localities** are Korotoyak 3b, c, Roksolany, Ushkalka, Zapadnye Kairy, Port-Katon, and Moiseevo 1.

The zone corresponds to the Nogaisk Horizon. The age of the upper boundary is slightly younger than the Jaramillo Subchron.

MQR 7: the *Stenocranius hintoni–Prolagurus pannonicus* concurrent range zone, the base of which is placed at the FAD of *Stenocranius hintoni*; the top corresponds to the LAD of *Prolagurus pannonicus*. At the lower boundary of the unit, *Clethrionomys sokolovi* is replaced by *C. glareolus*.

Characteristic taxa are *Stenocranius hintoni, Prolagurus pannonicus*, and *Mimomys intermedius*. Abundance of *M. pusillus* decreases. The extinction of *Lagurodon* and the FAD of *Pallasiinus protoeconomus* are recorded in the lower part of the zone. *Microtus arvalinus, Terricola arvaloides*, and *Microtus* ex gr. *middendorffi-hyperboreus* appeared in the upper part of the zone.

Type locality is Karai-Dubina. **Other localities** are Morozovka 1, Petropavlovka, Shamin, and Uryv 3a.

The upper limit corresponds to the boundary between the oxygen isotope stages 18 and 17, i.e., to about 715 ka. The Matuyama-Brunhes inversion is recorded in the upper part of the unit.

The zone is subdivided into two subzones. The lower concurrent range subzone of *Stenocranius hintoni* and *Lagurodon arankae* is designated as **MQR 7B** and ranges from the *S. hintoni* FAD to the extinction level of *Lagurodon*. The subzone corresponds to the Morozovka Horizon. Its top coincides with the boundary that separates the Taman' and Tiraspol' faunal assemblages, and also the oxygen isotope stages 22 and 21; the boundary age corresponds to ca. 865 ka. The upper unit **MQR 7A** or the *Pallasiinus protoeconomus–Prolagurus pannonicus* concurrent range subzone is identified between the *P. protoeconomus* FAD and the *Prolagurus pannonicus* LAD. The subzone is correlative with the Petropavlovka and Pokrovka horizons.

MQR 6: the *Lagurus transiens–Stenocranius hintoni* concurrent range zone; its lower and upper boundaries are defined by the *L. transiens* FAD and the *S. hintoni* LAD, respectively.

Characteristic taxa are *Mimomys intermedius, Lagurus transiens, Stenocranius hintoni, Pallasiinus protoeconomus, Microtus* ex gr. *middendorffi-hyperboreus*, and *M. arvalinus* associated with last *Mimomys pusillus* and *Eolagurus simplicidens*.

Type locality is Il'inka. **Other localities** are Veret'e, Melik, Novokhopersk 1, 2, Korostylevo, and Moiseevo 2.

The zone corresponds to the Il'inka Horizon and to the oxygen isotope stage 17. The upper boundary **age** is about 680 ka.

MQR 5: the *Stenocranius gregaloides* total range zone; its top is marked by first appearance of *Eolagurus luteus*.

Characteristic taxa are *Lagurus transiens, Stenocranius gregaloides, Clethrionomys glareolus, Microtus arvalinus, and Microtus* ex gr. *middendorffi-hyperboreus*. The genus *Mimomys* is represented by *M. intermedius* only. Species *Terricola arvaloides* are abundant. *Pallasiinus protoeconomus* appears in the lower part of the zone to be subsequently replaced by *P. oeconomus* in the upper part.

Type locality is Kolkotova Balka. **Other localities** are Klepki, Moiseevo 3, Bogdanovka, Korotoyak 4, Zherdevka, Posevkino, Perevoz, and Kuznetsovka.

The upper boundary is inside the Muchkap Horizon and coincides with the base of the oxygen isotope stage 13 dated back to 530 ka.

Two **subzones** distinguished within the unit are separated by the boundary that marks the evolutionary transition from *Pallasiinus protoeconomus* to *P. oeconomus*. The boundary coincides with basal levels of the Muchkap Horizon and the oxygen isotope stage 15 (about 625 ka). The lower subdivision **MQR 5B** or

the *Stenocranius gregaloides–Pallasiinus protoeconomus* concurrent range subzone is correlative to the oxygen isotope stage 16. The upper *Pallasiinus oeconomus–Stenocranius gregaloides* concurrent range subzone (**MQR 5A**) spans the interval of stages 14 and 15.

MQR 4: the *Stenocranius gregalis–Mimomys intermedius* concurrent range zone; the unit is bounded by the *Stenocranius gregalis* FAD at the base and by the extinction level of the genus *Mimomys* at the top.

Characteristic taxa are *Stenocranius gregalis, Eolagurus luteus, Clethrionomys glareolus, Microtus* ex gr. *middendorffi-hyperboreus, Terricola arvaloides,* and *Pallasiinus oeconomus.*

Type locality is Vol'naya Vershina. **Other localities** are Tiraspol' (upper bed, the Vorona soil) and Chekalin (lower bed).

The top of the zone coincides with the boundary that separates the Tiraspol' and Singil' faunal assemblages and the Oka and Likhvin horizons. This level corresponds to the base of the oxygen isotope stage 11 and is about 430 ka old. It should be noted here that the extinction time of *Mimomys* forms is not determined with precision. Neither *Mimomys intermedius* nor its direct descendant *Arvicola mosbachensis* are known from the Oka Horizon. Accordingly, the time of the *Mimomys–Arvicola* transition is unclear. This event could take place at any level of the Oka Horizon.

MQR 3: the *Arvicola mosbachensis-Lagurus transiens* concurrent range zone with the lower boundary defined by the *Arvicola mosbachensis* FAD; its upper limit corresponds to the *Lagurus transiens* LAD.

Characteristic taxa are *Arvicola mosbachensis, Lagurus transiens, Clethrionomys glareolus, Stenocranius gregalis,* and *Pallasiinus oeconomus* associated with *Microtus arvalis* in the upper part of the zone.

Type locality is Chigirin. **Other localities** are Chekalin (middle bed), Gun'ki, Priluki, and Pivikha.

The zone corresponds to the ranges of the Likhvin Horizon and Singil' faunal assemblage, and also to the summary interval of 11 to 9 oxygen isotope stages. The upper boundary is dated back to ca. 310 ka.

The zone is subdivided into two **subzones. MQR 3B** or the lower *Arvicola mosbachensis–Microtus arvalinus* concurrent range subzone has upper boundary corresponding to the transition from *Microtus arvalinus* to *Microtus arvalis* and to the base of the oxygen isotope stage 9 at the level of about 340 ka. The upper *Microtus arvalis–Lagurus transiens* concurrent range subzone (**MQR 3A**) is correlative to the stage 9.

MQR 2: the *Lagurus lagurus–Arvicola mosbachensis* concurrent range zone with the *Lagurus lagurus* FAD at the base and the *Arvicola mosbachensis* LAD at the top.

Characteristic taxa are *Lagurus lagurus, Arvicola mosbachensis, Stenocranius gregalis, Pallasiins*

oeconomus, and *Dicrostonyx simplicior* that is succeeded by *D.* ex gr. *gulielmi-henseli* in the uppermost part of the zone.

Type locality is Alpat'evo. **Other localities** are Chekalin (the upper bed), Chermenino, Akis', Kipievo 1, 2, Chulei, Verkhnyaya Emancha, and Strelitsa.

The zone corresponds to the three horizons distinguished in the second half of the middle Neopleistocene. **The age** of the upper boundary is about 135 ka (the base of the oxygen isotope stage 5).

MQR 1: the *Arvicola terrestris* total range zone.

Characteristic taxa are *Arvicola terrestris* and *Dicrostonyx* ex gr. *gulielmi-henseli,* the latter replaced by *D. torquatus* across the lower Holocene boundary. Other voles are represented by modern species.

Type locality is Khotylevo 2. **Other localities** are Cheremoshnik, Gadyach, and Arapovichi.

The zone corresponds to the summary range of the upper Neopleistocene and Holocene.

CONCLUSION

The proposed biostratigraphic zonation of Quaternary small mammals is much more detailed than the subdivision scheme based on faunal assemblages distinguished by Gromov. In particular, the Psekups faunal assemblage corresponds to two zones and two subzones, the Taman' assemblage to a zone and subzone, the Tiraspol' fauna to two zones and three subzones, and the Singil' assemblage to two subzones. The Neopleistocene subdivisions are most detailed. Their time ranges are from 30 to 75 thousands years. At the current state of knowledge, the distinguished Eopleistocene subdivisions are less detailed. Their mean duration is about 270 thousands years.

The presently accepted datums that separate zonal units may be changed subsequently, when stratigraphic positions of reference localities wiN be refined and more precisely correlated with the oxygen isotope stages, or when the stage ages proper will be revised, etc. However, regardless the possible changeability of the stratigraphic and zonal boundary ages, the succession of distinguished zones will be invariable, as it depicts the directional and irreversible evolution of mammals. This is the major advantage of stratigraphic subdivisions based on distribution mammal remains as compared to those obtained with the help of climatostratigraphic methods, because the identical climatic situations may repeat with time.

In our opinion, basic objectives of future investigations could be formulated as follows: (1) the more detailed subdivision of the Eopleistocene (necessary prerequisites are known); (2) the understanding of spatial continuation of the distinguished zones in the northern Palearctic; (3) the refinement of zonal boundary ages; and (4) the recognition and thorough examination of new phyletic lineages, which may be used for a more detailed subdivision.

ACKNOWLEDGMENTS

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