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Quaternary zonal subdivisions of Eastern Europe based on vole evolution

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ABSTRACT – A vole zonal scheme is proposed for the Quaternary of Eastern Europe. The scheme is based on the evolutionary appearance of forms in the Borsodia-Prolagurus-Lagurus, Mimomys-Arvicola, *and* Allophaiomys-Stenocranius *lineages. Eleven range and concurrent range zones were distinguished (downward from MQR1 to MQR11). Zones MQR9, MQR7, MQR5, and MQR3 each are subdivided into 2 subzones. The Psekups faunal assemblage corresponds to the MQR11- MQR9 zones; the Taman' one to the MQR8 zone and the B subzone of the MQR7 zone; the Tiraspol' assemblage to the A subzone of the MQR7 zone and to the MQR6- MQR4 zones; the Singil complex to the MQR3 zone; and the Khazar and Mammoth assemblages to the MQR2 and MQR1 zones. The most detailed subdivisions, ranging from 30 to 75 thousand years, were developed for the middle Pleistocene.*

RIASSUNTO – [Zonatura del Quaternario dell'Europa orientale in base all'evoluzione degli arvicolidi] – *Viene proposta una suddivisione del Quaternario dell'Europa orientale, sulla base a comparse evolutive di nuovi taxa sulle linee* Borsodia-Prolagurus-Lagurus, Mimomys-Arvicola, *e* Allophaiomys-Stenocranius. *Vengono distinte undici zone di distribuzione e concomitanti (da MQR1 a MQR11). Le zone MQR9, MQR7, MQR5, e MQR3 sono a loro volta divise in due subzone. Il complesso faunistico Psekups corrisponde alle zone MQR11-MQR9; il complesso faunistico Taman alla zona MQR8 e alla subzona B della zona MQR7; il complesso Tiraspol alla subzona A della MQR7 ed alle zone MQR6- MQR4; il complesso Singil alla zona MQR3; infine i complessi Khazar e Mammoth alle zone MQR2 e MQR1. Le suddivisioni con maggior risoluzione, da 30 a 75000 anni, si hanno durante il Pleistocene medio.*

INTRODUCTION

Since the distinction by V.I. Gromov (1948) of the Pliocene and Quaternary faunal assemblages of large mammals, they are the basis for the subdivision and correlation of continental deposits throughout the former USSR. In recent decades zonal units found increasing use for the subdivision of the Late Cenozoic (among others, Azzaroli, 1970; Azzaroli *et al.*, 1988; Mein, 1975; Guerin, 1982; Agusti *et al.*, 1987; Feifar & Heinrich, 1990). It should be noted that the latest progress in the study of small mammal evolution, especially of voles, permits a considerably more detailed subdivision and correlation of the Quaternary continental sediments of Russia.

The present paper suggests a variant of the Quaternary zonation for Eastern Europe. The records that provided the basis of the proposed zonation are available in the papers of Agadzhanyan (1976,1992), Aleksandrova (1976), Kazantseva (1987), Markova (1982, 1992), Rekovets (Rekovets & Nadachowski, 1995), Tesakov (1995, 1998), and Shik (1984, 1985). The analysis includes data on 61 localities of Eastern Europe. The taxonomic composition of voles from these localities is presented in Table 1. Faunas from some localities were revised by A.S. Tesakov.

The proposed zonation is based on three phyletic lineages of the most common and widespread voles: *Borsodia-Prolagurus-Lagurus, Mimomys-Arvicola,* and *Allophaiomys-Microtus (Stenocranius)* (Text-fig.1). Zonal boundaries were established according to a new species appearance in a certain lineage. The first appearance level of a new species was defined by the occurrence of a progressive morphotype in 75% of the population. We emphasize that this number is a matter of convention and agreement. In some cases the zones were subdivided into subzones according to the same principle, though using forms of other phyletic lineages.

Zones and subzones are named for certain index species, and additionally they are designated by letter/number indexes, for instance, MQR1, where M means mammals, Q = Quaternary, R = Russia, and the Arabic numeral is the number of the zone (downward from the top). Subzones are designated by capital Latin letters (A, B, C) downward from the top as well.

The age of the zonal boundaries was defined by the position of localities within the stratigraphic, magnetochronological, and oxygen isotope scales (Vangengeim *et al.*, in press). The reliability of zonal boundary datums is different for certain intervals of the Quaternary. It depends on the position of reference localities in relation to the boundaries of paleomagnetic units and on the more or less valid correlation of stratigraphic horizons with oxygen isotope stages.

REGIONAL MAMMAL ZONES OF EASTERN EUROPE

Eleven range and concurrent range zones of vole species are distinguished within the studied time span

horizon	localities	*Mimomys intermedius*	*M.pusillus*	*Clethrionomys hintonianus*	*Borsodia*	*Allophaiomys deucalion*	*Lagurodon arankae*	*Prolagurus tenopolitanus*	*Allophaiomys pliocaenicus*	*Eolagurus argyropulol*	*Prolagurus pannonicus*	*Stenocranius hintoni*	*Clethrionomys ex.gr. 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 guilelmi-henseli*	*Arvicola terrestris*	*Dicrostonyx torquatus*
Holocene													•			•				•	•	•			•	•			•
Ostashkovo	Khotylevo 2																			•	•					•	•		
Monchalovo	Arapovichi																			•	•	•				•	•		
Kalinino	Gadyach																				•					•	•		
Mikulino	Cheremoshnik												•								•							•	
Moscow	Kipievo 2																				•						•		
	Chuley,																			•			•						
	Alpatievo,																			•	•		•			•			
	Kipievo 1																			•			•						
Odintsovo	Strelitsa												•				•			•	•	•		•	•				
	Verkhnyaya Emancha												•				•			•	•			•	•	•			
Dniepr	Akis'																			•			•						
	Cheremnino																				•		•	•					
	Chekalin (u.b.)												•							•			•			•			
Likhvin	Pivikha												•				•	•		•	•	•		•	•				
	Priluki																	•			•								
	Gunki												•					•		•	•	•		•	•				
	Chigirin,												•				•	•		•	•	•		•	•				
	Chekalin (m.b.)												•		•					•	•			•					
Oka	Chekalin (l.b.)												•							•	•		•						
Mikhkap	Tiraspol (voronsky)																				•	•							
	Volnaya Vershina	•											•		•		•	•		•									
	Kuznetsovka,	•											•			•	•	•	•	•									
	Perevoz,																•	•		•									
	Posevkino,																•	•		•									
	Kolkotova Balka	•											•		•		•	•	•	•									
	Zherdevka,	•											•			•	•	•		•									
	Korotoyak 4	•											•		•	•	•	•	•	•									
Don	Bogdanovka	•											•	•		•		•	•										
	Moiseevo 3,												•	•		•		•	•										
	Klepki	•								•			•	•		•	•	•	•										
Il'inka	Novokhopersk 2	•	•							•		•		•	•	•													
	Moiseevo 2,		•							•			•	•		•		•											
	Korostylevo		•							•			•	•	•	•		•											
	Novokhopersk 1	•	•							•		•	•	•	•	•		•											
	Melik,									•			•	•	•	•		•											
	Veretie,	•	•							•		•	•	•		•	•	•											
	Il'inka	•	•							•		•			•	•	•	•											
Pokrovka	Uryv 3a	•	•							•	•	•		•		•	•												
Petropavlovka	Shamin	•								•		•		•	•														
	Petropavlovka,	•									•	•		•															
	Karay-Dubina	•								•	•	•	•	•															
Morozovka	Morozovka 1	•	•				•			•	•	•	•																
Nogaisk	Moiseevo 1								•		•																		
	Port Katon	•	•	•					•		•																		
	Korotoyak 3c	•	•	•					•	•	•																		
	Zapadnye Kaity,	•		•					•	•	•																		
	Ushkalka,		•				•		•		•																		
	Roksolany	•					•		•		•																		
	Korotoyak 3b,	•	•						•	•	•																		
	Nogaisk	•		•			•		•		•																		
	Tarkhankut	•		•			•	•	•	•																			
	Korotoyak 3a							•	•	•																			
	Log Denisov,	•		•				•	•																				
	Uspenka,	•	•	•				•	•																				
	Akkulaevo (d+d)	•	•	•				•	•																				
Zhevakhovsky	Chortkov,		•	•		•		•																					
	Zhevakhova Gora 5,9,	•		•		•	•	•																					
	Tizdar 2		•	•		•	•																						
	Kryzhanovka 4,			•	•	•																							
	Tizdar 1,		•		•	•																							
	Tiligul	•		•	•	•																							

Tab. 1 - Voles from reference localities of Eastern Europe. L.b. = lower bone bed; m.b. = middle bone bed; u.b. = upper bone bed; (d+d) = Demsk and Davlekanovo horizons.

(Text-fig. 1). A characterization of the zones upward from the bottom is presented below.

MQR11 is a concurrent range zone of *Allophaiomys deucalion* and *Borsodia.* The bottom of the zone is defined by the first appearance datum (FAD) of the genus *Allophaiomys,* and the top by the FAD of genera *Lagurodon* and *Prolagurus.*

Type locality: Tizdar 1. Other localities: Tiligul and Kryzhanovka 4.

The age of the zone boundaries is not established precisely. Both boundaries are older than the Olduvai Subchron.

MQR10 is a concurrent range zone of *Prolagurus ternopolitanus* and *Allophaiomys deucalion.* The lower boundary is defined by the FAD of *Prolagurus,* and the upper by the last appearance datum (LAD) of *Allophaiomys deucalion.*

Type locality: Zhevakhova Gora 5, 9. Other localities: Tizdar 2 and Chortkov.

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

MQR9 is a concurrent range zone of *Allophaiomys pliocaenicus* and *Prolagurus ternopolitanus.* The bottom of the zone corresponds to the FAD of *Allophaiomys pliocaenicus,* and the top to the LAD of *Prolagurus ternopolitanus.*

Type locality: Uspenka. Other localities: Akkulaevo (Demsk and Davlekanovo horizons), Log Denisov, Korotoyak 3a, and Tarkhankut.

The age of the upper boundary is 1.2 Ma. It coincides with the boundary between the Psekups and Taman' faunal assemblages and with the bottom of the Nogaisk horizon.

The zone is subdivided into two subzones. The lower one (*MQR 9B*) is an interval subzone of *Allophaiomys pliocaenicus* ranging from the FAD of *A. pliocaenicus* to the FAD of *Eolagurus argyropuloi.* The upper subzone *MQR 9A* is a concurrent range subzone of *Eolagurus argyropuloi* and *Prolagurus ternopolitanus.* It is distinguished in the interval between the FAD of *E. argyropuloi* and the LAD of *P. ternopolitanus.*

MQR8 is a concurrent range zone of *Prolagurus pannonicus* and *Allophaiomys pliocaenicus.* The lower boundary is defined by the FAD of *Prolagurus pannonicus,* and the upper by the extinction of the genus *Allophaiomys.*

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

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

MQR7 is a concurrent range zone of *Stenocranius hintoni* and *Prolagurus pannonicus.* The bottom of the zone is placed at the FAD of *Stenocranius hintoni* and the top at the LAD of *Prolagurus pannonicus.* At the lower boundary, *Clethrionomys sokolovi* is replaced by *C. glareolus.*

Type locality: Karai-Dubina. Other localities: Morozovka 1, Petropavlovka, Shamin, Uryv 3a.

The top of the zone corresponds to the boundary between oxygen isotope stages 18 and 17 (about 715 ka). The Matuyama/Brunhes boundary is recorded in the upper part of the zone.

The zone is subdivided into 2 subzones. The lower concurrent range subzone *MQR 7B* (*Stenocranius hintoni-Lagurodon arankae*) is identified from the FAD of *S. hintoni* to the extinction of *Lagurodon.* The subzone corresponds to the Morozovka horizon. The top of the subzone coincides with the boundary between the Taman' and Tiraspol' faunal assemblages and corresponds to the boundary between oxygen isotope stages 22 and 21 with an age of about 865 ka. The upper concurrent range subzone *MQR 7A* (*Pallasiinus protoeconomus- Prolagurus pannonicus*) is identified from the FAD of *P. protoeconomus* to the LAD of *Prolagurus pannonicus.* The subzone corresponds to the Petropavlovka and Pokrovka horizons.

MQR6 is a concurrent range zone of *Lagurus transiens* and *Stenocranius hintoni.* The lower boundary is defined by the FAD of *Lagurus transiens,* and the upper by the LAD of *Stenocranius hintoni.*

Type locality: Il'inka. Other localities: 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 age of the upper boundary is about 680 ka.

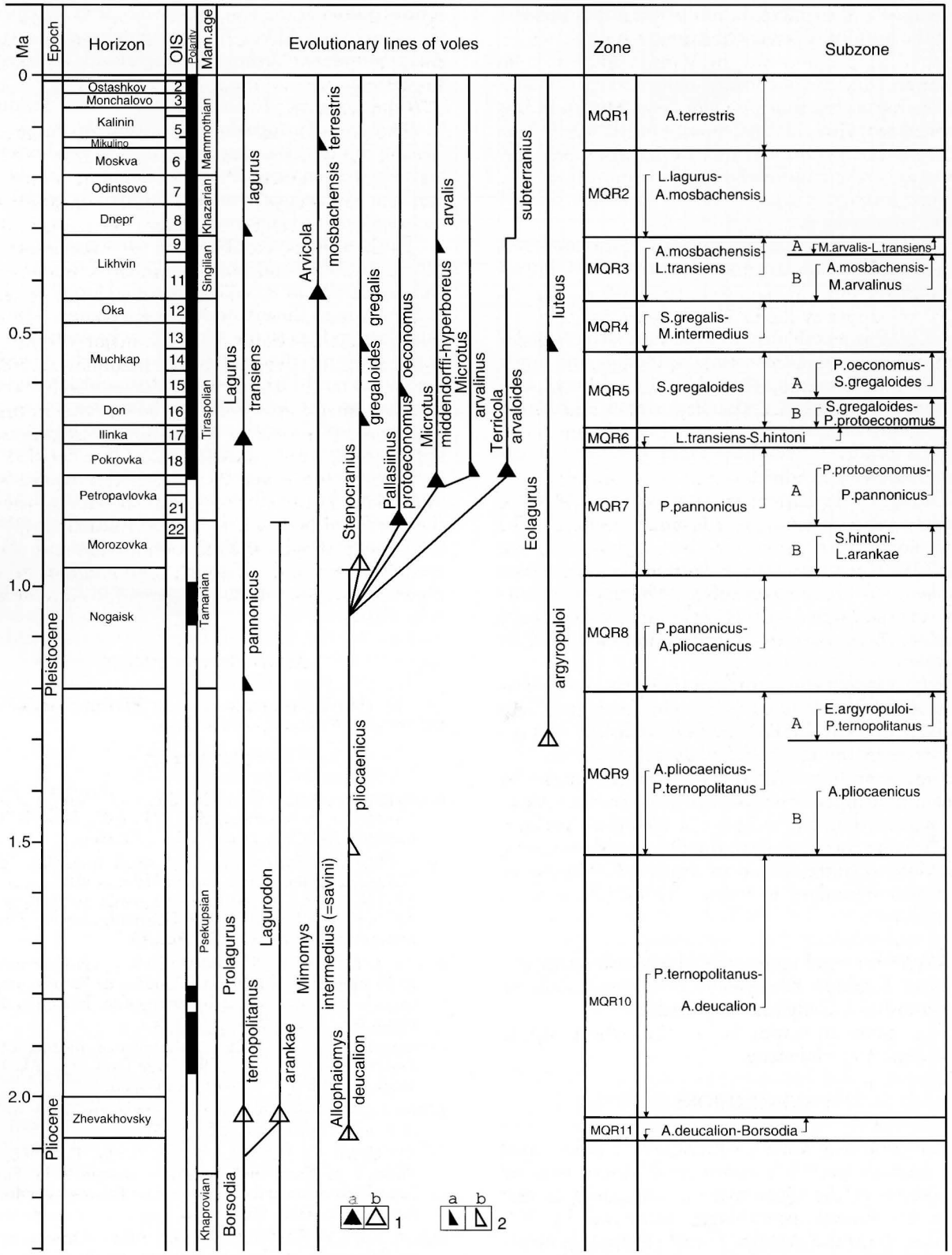
MQR5 is a total range zone of *Stenocranius gregaloides. Eolagurus luteus* has its first appearance at the top of the zone.

Type locality: Kolkotova Balka. Other localities: Klepki, Moiseevo 3, Bogdanovka, Korotoyak 4, Zherdevka, Posevkino, Perevoz, Kuznetsovka.

The upper boundary of the zone is within the Muchkap horizon and coincides with the base of the oxygen isotope stage 13 dated at 530 ka.

Two subzones are distinguished within the zone with the boundary placed at the evolutionary transition from *Pallasiinus protoeconomus* to *P. oeconomus.* It coincides with the bottom of the Muchkap horizon and with the base of stage 15 (about 625 ka). The lower concurrent range subzone *MQR 5B* (*Stenocranius gregaloides-Pallasiinus protoeconomus*) corresponds to the oxygen isotope stage 16. The upper concurrent range subzone *MQR 5A* (*Pallasiinus oeconomus-Stenocranius gregaloides*) corresponds to stages 14 and 15.

MQR4 is a concurrent range zone of *Stenocranius gregalis* and *Mimomys intermedius.* The lower boundary is defined by the FAD of *Stenocranius gregalis* and the



Text-fig. 1 - Zones and subzones of voles for the Quaternary of Eastern Europe. 1) appearance levels of vole genera: a = related to the boundaries of horizons; b = precise position within a horizon is not determined; 2) appearance levels of new species of voles: a = related to the boundaries of horizons; b = precise position within a horizon is not determined. OIS = oxygen isotope stages by Shackleton (1995). Position of mammalian localities in the stratigraphic, magnetochronologic and oxygen isotope scales is after Vangengeim *et al.* (in press).

upper one by the extinction of the genus *Mimomys.*

Type locality: Vol'naya Vershina. Other localities: Tiraspol' (upper horizon, the Voron soil), Chekalin (lower horizon).

The top of the zone coincides with the boundary between the Tiraspol' and Singil faunal assemblages and between the Oka and Likhvin horizons, and corresponds to the base of the oxygen isotope stage 11 (about 430 ka).

MQR3 is a concurrent range zone of *Arvicola mosbachensis* and *Lagurus transiens.* The lower boundary of the zone is defined by the FAD of *Arvicola mosbachensis* and the upper by the LAD of *Lagurus transiens.*

Type locality: Chigirin. Other localities: Chekalin (middle horizon), Gun'ki, Priluki, Pivikha.

The zone corresponds to the Likhvin horizon in the range of oxygen isotope stages 11-9 and to the Singil faunal assemblage. The upper boundary is dated at 310 ka.

The zone is subdivided into two subzones. The lower one is a concurrent range subzone *MQR 3B* of *Arvicola mosbachensis* and *Microtus arvalinus.* The upper boundary is defined by the transition *Microtus arvalinus-Microtus arvalis* and corresponds to the base of stage 9. Its age is about 340 ka. The upper concurrent range subzone *MQR 3A* (*Microtus arvalis-Lagurus transiens*) corresponds to the oxygen isotope stage 9.

MQR2 is a concurrent range zone of *Lagurus lagurus* and *Arvicola mosbachensis.* The bottom of the zone is defined by the FAD of *Lagurus lagurus* and the upper one by the LAD of *Arvicola mosbachensis.*

Type locality: Alpat'evo. Other localities: Chekalin (upper horizon), Chermenino, Akis', Kipievo 1, 2, Chulei, Verkhnyaya Emancha, Strelitsa.

The zone corresponds to the Dnieper, Odintsovo, and Moscow horizons and to stages 8-6. The age of the upper boundary is about 135 ka (the base of stage 5).

MQR1 is a total range zone of *Arvicola terrestris.*

Type locality: Khotylevo 2. Other localities: Cheremoshnik, Gadyach, Arapovichi.

The zone corresponds to the whole upper Pleistocene and Holocene.

CONCLUSIONS

The proposed zonal biostratigraphic units based on mammals permit a considerably more detailed subdivision of the Quaternary as compared to that based on faunal assemblages proposed by V.I. Gromov. Thus the Psekups faunal assemblage corresponds to two zones and two subzones, the Taman' assemblage to a zone and subzone, the Tiraspol' complex to two zones and three subzones, and the Singil' assemblage to two subzones. The most detailed subdivision is applied to the middle Pleistocene. Time spans of the units distinguished range from 30 to 75 thousand years. Less detailed subdivision is possible for the lower Pleistocene in the present state of knowledge. Mean duration of its faunal units is about 270 thousand years.

The presently accepted datums of the boundaries between zonal units may be changed subsequently as a result of refinement of the stratigraphic positions of reference localities, of their refined correlation with oxygen isotope stages, or of revision of ages of the stages themselves, etc. However changeable the ages of stratigraphic and zonal boundaries may be, the succession of zones will be invariable, as it results from the directional and irreversible evolution of mammals. This accounts for the major advantage of subdivision of deposits using mammal records as compared to climatic stratigraphic methods, because similar climatic situations may be repeated in time.

The basic problems for future investigations, in our opinion, are as follows: (1) the more detailed subdivision of the lower Pleistocene (prerequisites are available); (2) the elucidation of spatial extension of the distinguished zones in the Palearctic; (3) the refinement of ages of zonal boundaries; and (4) the establishment and thorough examination of new phyletic lineages, which may serve for more detailed subdivision.

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