Ruscinian and Lower Villafranchian: Age of Boundaries and Position in Magnetochronological Scale

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Received November 10, 2004; in final form, January 19, 2005

Abstract—Analysis of magnetostratigraphic records and taxonomy of mammalian remains from localities of the terminal Miocene-middle Pliocene in Europe, West Siberia, Mongolia, and China revealed a significant faunal reorganization at about 6 Ma ago close to the C3An/Gilbert paleomagnetic reversal. The Turolian-Ruscinian boundary should be placed therefore below the Miocene-Pliocene boundary adopted at present. Zone MN14A preceding Zone MN14 is suggested to be the lowermost subdivision of the Ruscinian. The Ruscinian-Villafranchian boundary is close to the Gilbert-Gauss reversal and to the lower-middle Pliocene boundary. The top of the lower Villafranchian corresponding to the end of the Gauss Chron is slightly older than the middle-upper Pliocene boundary. Range of the lower Villafranchian inferable from fauna of large mammals coincides with Zone MN16 of rodent scale, typical of which is the Uryv assemblage of small mammals in the Russian Plain.

Key words: Ruscinian, Villafranchian, Miocene, Pliocene, mammals, magnetostratigraphy, mammalian zones.

INTRODUCTION

The so-called "continental stages" of the Mammal Faunal Units or Land Mammal Ages, i.e., the Ruscinian and Villafranchian or Villanyian, correspond to the Pliocene and lowermost Pleistocene of the International Stratigraphic Scale. To a first approximation, the Ruscinian is correlative with the lower Pliocene, Villafranchian with the middle-upper Pliocene and lowermost Pleistocene, and Villanyian with the middle-upper Pliocene. The Villanyian corresponds to the lower and middle Villafranchian (Ginsburg, 1975; Azzaroli *et al.*, 1986; Fejfar *et al.*, 1998). The continental stages are subdivided into MN zones (abbreviation MN means mammals of the Neogene). The Ruscinian and Villafranchian include zones MN14-17. Recently Mein (1989) included the lower part of Zone MQ18 of Guerin (Guerin, 1982) into the last MN zone.

Ages of the Ruscinian and lower Villafranchian boundaries and their position in the magnetochronological scale are controversially interpreted by researchers (Fig. 1). This is connected with different assessment of subdivision ranges, on the one hand, and with ambiguous interpretation of paleomagnetic data on mammal localities, on the other. There is also disagreement with respect to correlation of Villafranchian substages with MN zones of the mammalian scale and to correspondence of some localities to a certain zone.

Our objective is to discuss paleomagnetic data on mammal localities in the CIS, Mongolia, China, and certain sites in Europe, as they can likely help to overcome controversies in dating the Ruscinian and lower Villafranchian boundaries and positioning them in the magnetochronological scale.

To establish stratigraphic succession of mammal localities, we consider in this work, besides geologic and paleomagnetic records, the hypsodonty degree of voles and ages of localities determined by biometric method (Pevzner and Vangengeim, 1994). As it is known, hypsodonty of voles has been growing irreversibly with time. The development of dentine tracts of molars is a good indicator of hypsodonty. The hypsodonty of Ruscinian voles *Promimomys* is defined as sum of heights of three dentine tracts in the first lower molar. The time succession of lower Villafranchian localities is controlled by the hypsodonty degree of first lower molars or by the HH-index (Rabeder, 1981) of species in three lineages of large *Mimomys, Pitymimomys,* and *Borsodia*. It should be mentioned that hypsodonty coefficients calculated for a limited number of teeth should be regarded with caution, since they not always represent the true mean value of the parameter. Having insufficient amount of m1, we used data on other teeth in a jaw. The biometric method of dating is based on exponential law of time-dependent evolutionary changes of important morphological parameters in a single lineage. With known ages of three reference localities, it is possible therefore to determine age of intermediate sites using interpolation of parametric morphological values, e.g., of hypsodonty degree of voles, as we did in this work.

THE RUSCINIAN

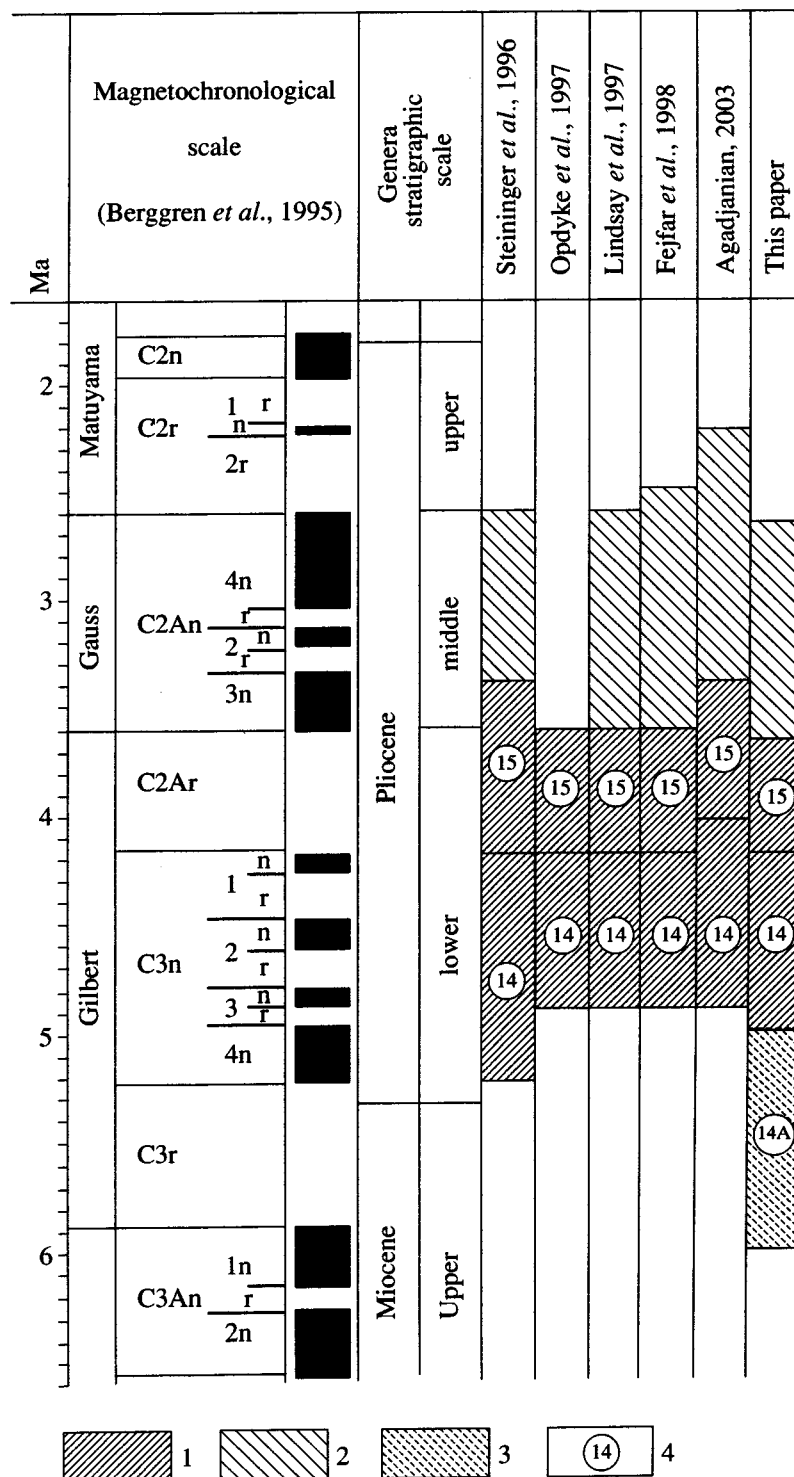Originally the mammalian scale for continental Europe was developed regardless of marine zonations

Fig. 1. Position of the Ruscinian and lower Villafranchian in the magnetochronological scale according to various authors: (1) Ruscinian; (2) lower Villafranchian; (3) new zone distinguished in the Ruscinian; (4) Ruscinian MN zones.

and was based on stages in fauna evolution. Faunal criteria of boundaries between the stages were formulated more or less clear. According to Fejfar (Fejfar *et al.*, 1997, p. 262), the Ruscinian corresponds to "temporal interval of the concurrent range of the genera *Trilo-* *phomys* and *Ruscinomys*. Lower boundary: FAD[1] of *Trilophomys*. The upper boundary is given by the FAD of *Borsodia* defining the beginning of the Villanyian. Moreover, the onset of the Ruscinian is characterized

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[1] First Appearance Datum or the first occurrence of a taxon.

by the FAD of number of new rodent taxa such as *Celadensia, Promimomys,* and *Baranomys* as well." In eastern Spain, the base of the Ruscinian is defined by first occurrence of the genera *Celadensia, Eozapus, Micromys,* and *Rhagapodemus* (Opdyke *et al.,* 1997, p. 144). According to the large mammal fauna, the base of the Ruscinian was placed at the appearance level of the genera *Paracervulus, Sus, Tapirus, Arctomeles,* and *Pliohyaena (=Pliocrocuta)* (Mein, 1989; *Biochronologie...,* 1997, and others).

Taking into account the considerable paleozoogeographic, paleolandscape, and paleoclimatic differences between biological provinces of the vast Palearctic territory, it is impossible to formulate a single faunal criterion for the lower boundary of a given unit. However, one can define certain criteria for every province and figure out connecting markers for adjacent provinces. In the last case, it is necessary to use fauna-independent methods in order to establish synchronism of faunal boundaries. The paleomagnetic method is the most important in such a case.

There is a tendency of recent years to make the Turolian-Ruscinian boundary coincident with the Miocene-Pliocene boundary identified in marine sediments. Faunal criteria of the Ruscinian lower boundary become unclear therewith, and certain mammal localities of the boundary interval transit from the Ruscinian to Turolian only because of their Miocene age.

At present, researchers date the Ruscinian lower boundary at 5.3 Ma, if they believe it to be coincident with the Miocene-Pliocene boundary (Steininger *et al.,* 1996; Azanza *et al.,* 1997; Mein, 1989), or define it between the Thvera and Sidufjall subchrons at 4.9 Ma (Opdyke *et al.,* 1997; Lindsay *et al.,* 1997; Fejfar *et al.,* 1998, and others). According to one more viewpoint based on data from the Asian part of Russia, Kazakhstan, and Mongolia, this boundary is assumed to be about 6 Ma old, falling into the upper part of Chron C3An (Pevzner *et al.,* 1982, 1996).

Position of Some Reference Localities of the Uppermost Turolian in the Stratigraphic and Magnetochronological Scales

According to faunal composition, the localities La Alberca and Fuente del Viso of Spain are placed in the Turolian, close to the Turolian-Ruscinian boundary (de Bruijn *et al.,* 1992; Opdyke *et al.,* 1997). They are of basic importance for solving the age problem of the Ruscinian lower boundary. The *La Alberca* locality is associated with the Messinian sediments bearing planktonic foraminifers of Zone N17 after Blow (de Bruijn *et al.,* 1975) or Zone Mt10 after Berggren (Berggren *et al.,* 1995). The latter is estimated as ranging in age from 7.2 to 5.6 Ma. Thus, the La Alberca locality is not younger than 5.6 Ma. Aguilar and Michaux (1997) placed it below the Messinian evaporites. The Messinian salinity crisis commenced at 5.8 Ma (Berggren

et al., 1995), and the La Alberca locality is therefore older than 5.8 Ma.

The *Fuente del Viso* locality (Cabriel basin of Spain, South Cabriel section) is associated with lacustrine deposits. The bone bed is in the section interval of reversed polarity (Magnetic Polarity Zone R5 is recognized in two samples), which is correlated with the interval of reversed polarity between the Thvera and Sidufjall subchrons (Fig. 2, II). According to these data, the Ruscinian lower boundary is dated here at 4.9 Ma (Opdyke *et al.,* 1997), since the base of Sidufjall Subchron is estimated at 4.89 Ma. The faunal assemblage includes *Apodemus gorafensis* Ruiz Bustos *et al.* that is characteristic of the Ruscinian according to Martin Suarez and Mein (1998).

The great age difference estimated for localities of similar faunal composition (Fuente del Viso 4.9 Ma old and La Alberca older than 5.8 Ma) is surprising. If both localities are close to the Turolian-Ruscinian boundary, then what faunas can fill the in-between gap of about 1 Ma? The contradiction disappears, if we accept the interpretation of paleomagnetic records originally suggested by Opdyke *et al.* (1989), according to which the section interval with the Fuente del Viso fauna was correlated with Chron 5 (C3An) and Gilbert Chron basal part, while the locality was placed close to the C3An/Gilbert reversal. The slightly older fauna of the Venta del Moro locality (MN13) was correlated with the middle of Chron 5 (C3An2n/1r boundary).

It should be noted that Sierro and co-authors who studied the Abad section in southeastern Spain found a level of reversed polarity in the middle of Subchron C3An1n. They believe that if it is not an artifact associated with diagenesis, there should be a cryptochron of reversed polarity within Subchron C3An1n, the more so that the level of a reversed (?) polarity is also recorded within this unit at the ODP Site 845A, Leg 138, in the eastern equatorial Pacific (Sierro, *et al.,* 2001). It is possible that Magnetic Polarity Zone R5 in the South Cabriel section also corresponds to this cryptochron. Then the Fuente del Viso locality can be at the middle of Subchron C3An1n. In any case, the Turolian-Ruscinian boundary is older than 4.9 Ma and close to the C3A-Gilbert reversal.

The *Baccinello V3* locality in Italy contains the Ruscinian characteristic taxa *Celadensia, Tapirus* cf. *arvernensis, Dicerorhinus* cf. *megarhinus,* and *Sus.* The bone bed occurs in the uppermost Messinian lacustrine sediments overlain by the Pliocene marine deposits (Rook, 1992; Rook and Torre, 1995). De Bruijn *et al.,* (1992) and Fejfar *et al.,* (1997) placed this locality in the Ruscinian, but at the Congress "BiochroM'97" in Montpelier it was displaced into the Turolian since "belongs to the end of the Miocene" (*Biochronologie...,* 1997, p. 799).

The *La Tour* locality in southern France known as bearing the oldest *Trilophomys* is in the upper part of the Miocene Valensole molasse (Unit I), immediately
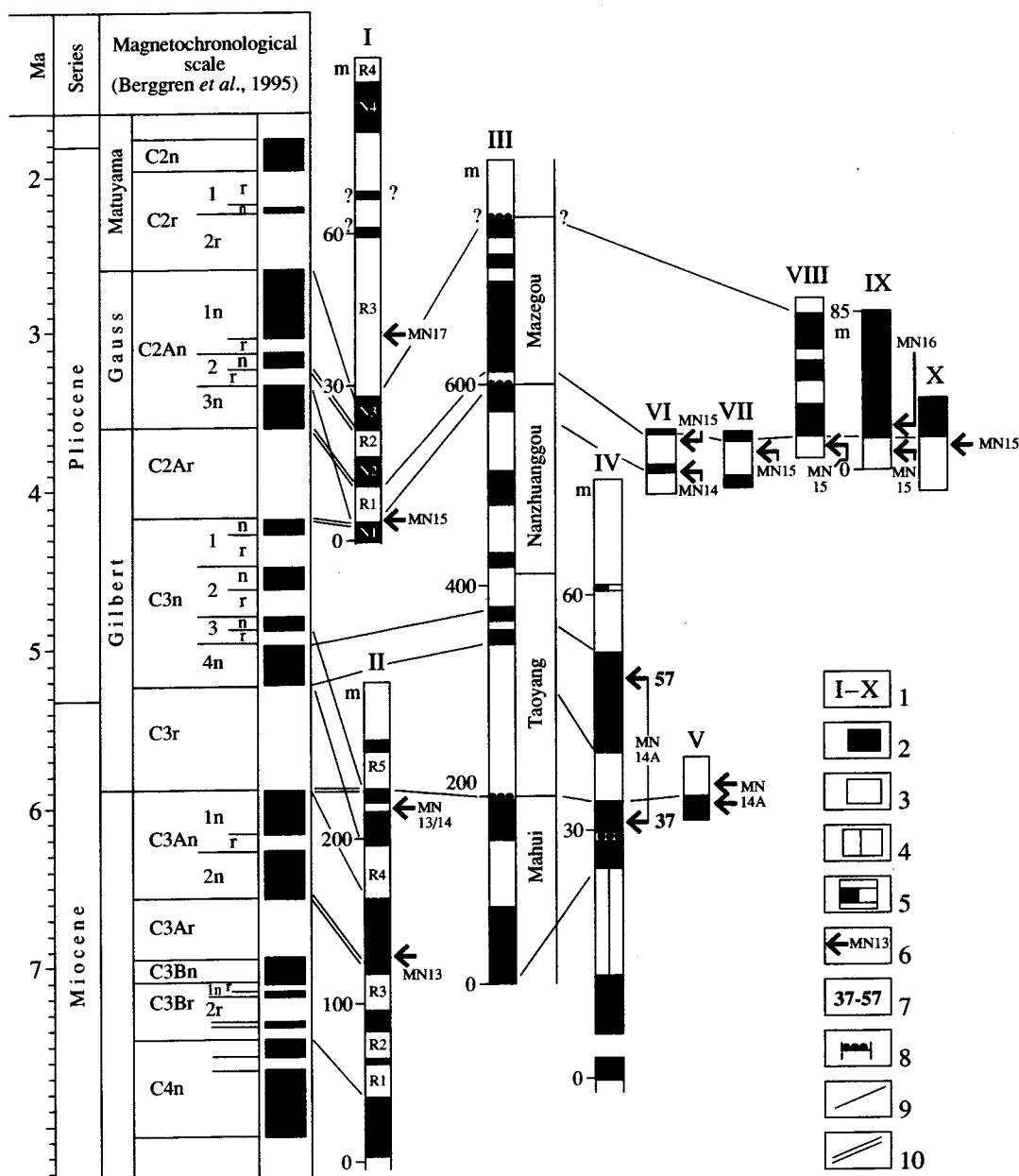
Fig. 2. Paleomagnetic characteristics of the Ruscinian and early Villafranchian reference localities: (1) locality number; (2) zones of normal polarity; (3) zones of reversed polarity; (4) zone of presumably reversed polarity; (5) zone of presumably normal polarity; (6) position of faunal beds and MN zones; (7) taphonomic levels in the Khirgis-Nur 2 section; (8) hiatuses; (9) lines of correlation with magnetochronological scale; (10) correlation with magnetochronological scale proposed for localities Galera (I) and Fuente del Viso (Cabriel south) (II) (see also Opdyke *et al.*, 1989). Localities by names: I, Galera (Garcés *et al.*, 1997); II, Fuente del Viso (Cabriel south) (Opdyke *et al.*, 1997); III, Yushe basin (Tedford *et al.*, 1991); IV, Khirgis-Nur 2 (Pevzner *et al.*, 1982); V, Novaya Stanitsa (Zykin *et al.*, 1991); VI, Orrios; VII, Villalba Alta Rio; VIII, Villalba Alta; IX, Escorihuela, X; Loma del Castillo (VI–X: Opdyke *et al.*, 1997)

below the "Messinian erosion surface" overlain by the Pliocene sediments of the Valensole Formation (Unit II) (Aguilar *et al.*, 1989; Clauzon *et al.*, 1990). Martin Suarez and Mein (1998) placed this locality at the Turolian-Ruscinian boundary.

The *Kalmakpai* locality in Kazakhstan containing fauna of the terminal Turolian (uppermost MN13) is known from deposits of the Karabulak Formation. Sed-

iments enclosing the bone bed are of normal polarity (Yakhimovich *et al.*, 1993) and we correlate them with Subchron C3An2n (Vangengeim *et al.*, 1993). The fauna contains typical Turolian taxa *Adcrocuta eximia* (Roth et Wagn.), *Hyaenictitherium, Plesiogulo crassa* (Telh.), *Cervavitus novorossiae* Khomenko, and others.

A section of the Yushe River basin, Shanxi Province, China, has been well studied in magnetostratigraphic

aspect (Tedford *et al.*, 1991; Flynn and Wo, 2001). The lowermost part of the section is composed of bone-bearing sediments of the Mahui Formation yielding remains of the typical Turolian mammals *Adcrocuta, Indarctos, Machairodus,* and others. This sequence part of normal polarity is correlated with Chron C3An. It is followed with a hiatus of about 0.1 m.y. by sediments of the Gaozhuang Formation, which are mostly of reverse polarity and correlated with the Gilbert Chron (Fig. 2, III). The mammalian fauna from the lower, Taoyang member of the formation includes *Proboscidipparion, Plesiohipparion, Pliohyaena,* and *Sus.* It has much in common with the Ertemte fauna of Inner Mongolia being considered as identical in age (about 5.5 Ma) and corresponding to the lower part of the Gilbert Chron (Flynn, 1997).

The Ertemte fauna lacks species typical of European assemblages. The correlation is based in this case on evolutionary grade of genera, which is comparable with that known from the European and Chinese localities, "provided that such evolutionary grades are about contemporaneous over large geographic areas..." (Storch, 1987, p. 404). The Ertemte taxa are more archaic than their analogues from the Węze (MN15) and Podlesice (MN14) localities in Poland and more advanced than taxa from the early Turolian of Spain, Eichkogel (MN11) site in Austria, and from the Lufeng (MN12) locality of China. Representatives of some genera from the Ertemte site, which are also known from the Ruscinian in Europe, as, for instance, *Micromys* and *Orientalomys,* are more primitive than all the species described by now. Based on this evidence, the Ertemte fauna is referred to the uppermost interval of Zone MN13 (Wu, 1991; Qiu, 1991). The Harr Obo-2 site located nearby is considered as somewhat younger, corresponding to the Turolian-Ruscinian boundary time or to Zone MN14. This locality contains *Rhagapodemus* forms similar to the oldest Ruscinian species of Europe (Storch, 1987).

Position of Some Ruscinian Reference Localities in the Magnetochronological Scale

In the continental scale of Europe, the Ruscinian includes zones MN14 and MN15. The *Celleneuve* and *Vive-2* localities in southern France are attributed to the initial Ruscinian and respectively to Zone MN14. In both sites, the bone beds show reversed polarity being correlated with Chron C3r, i.e., they are older than 5.23 Ma (date of the Thvera Subchron base) (Steininger *et al.*, 1996). The Vive-2 locality is associated with the continental sediments, which grade into marine facies of the lower Zanclean Zone MPL1 (Clauson *et al.*, 1989). The upper boundary of Zone MPL1 is in the lower part of the Thvera Subchron being dated at about 5.18 Ma (Van Couvering *et al.*, 1998). These inferences contradict the above date of 4.9 Ma estimated for the Ruscinian lower boundary.

Fejfar *et al.* (1998) correlated the *Promimomys insuliferus* biozone with Zone MN14 of the initial Ruscinian. Until present, the species first occurrence has not been dated by isotopic and magnetostratigraphic methods. However, the circumstantial age of the *P. insuliferus* FAD can be estimated in several localities of the CIS.

The *Novaya Andriashevka* locality in Moldova bearing *Promimomys insuliferus* Kow. (Fig. 3) is associated with sediments of the so-called Kuchurgan Gravel (Vangengeim *et al.*, 1995). The age of the locality is estimated at 4.4 ± 0.06 Ma by means of biometric method using the CK92 scale, and its position is close to the Sidufjall Subchron (Pevzner and Vangengeim, 1994). This age value recalibrated versus the CK95 scale (Berggren *et al.*, 1995) is 4.76 Ma.[2] Mammal remains from the Kuchurgan gravel are known as the Kuchurgan faunal assemblage.

It should be noted that the Podlesice site in Poland, the type locality for *P. insuliferus,* and the Novaya Andriashevka locality are almost concurrent, as one can judge from the hypsodonty indexes for m1. This parameter is 0.436 ± 0.025, σ = ±0.056 (*n* = 5) for the last site and 0.441 ± 0.039, σ = ±0.087 (*n* = 5) for the Podlesice locality.

The *Antipovka* and *Chugunovka* localities located south of Voronezh in the Don River upper reaches also yield *P. insuliferus* remains. Bone remains are confined here to alluvial deposits of the buried ancient terrace of the Don River (Agadjanian and Kowalski, 1979; *Upper Pliocene...*, 1985). Their exact stratigraphic position relative to the Novaya Andriashevka fauna cannot be established without a thorough morphological examination of the *P. insuliferus* teeth. However, voles from Novaya Andriashevka look somewhat more advanced than comparable taxa from the Don River sites. Paleomagnetic data on the Antipovka bone-bearing sediments (*Upper Pliocene...*, 1985) permit the latter to be placed in the interval of reversed polarity below the Sidufjall Subchron (Fig. 3).

The *Nurnus* locality bearing *P. insuliferus* and situated in the Razdan River valley of Armenia was encountered in the Nurnus Formation of clay–diatomite deposits, which show reversed polarity. The formation is stratigraphically above rhyolites dated in 1983 by the K–Ar method back to 4.8 ± 0.5 Ma. The bone bed is correlated with the interval between the Sidufjall and Nunivak subchrons (Melik-Adamyan, 2003). However, rhyolites should be actually older by 8.7% because of age discrepancy between boundaries of paleomagnetic units in the CK95 and earlier scales (Berggren *et al.*, 1995) thus being 5.2 ± 0.5 Ma old. In such a case, the Nurnus locality likely corresponds to an earlier interval of magnetostratigraphic scale between the Thvera and Sidufjall subchrons. It is possible to infer from reported

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[2] Dates obtained for localities by biometric method using the CK92 scale (Pevzner and Vangengeim, 1994) are reported further on as recalibrated versus the CK95 scale (Berggren *et al.*, 1995).
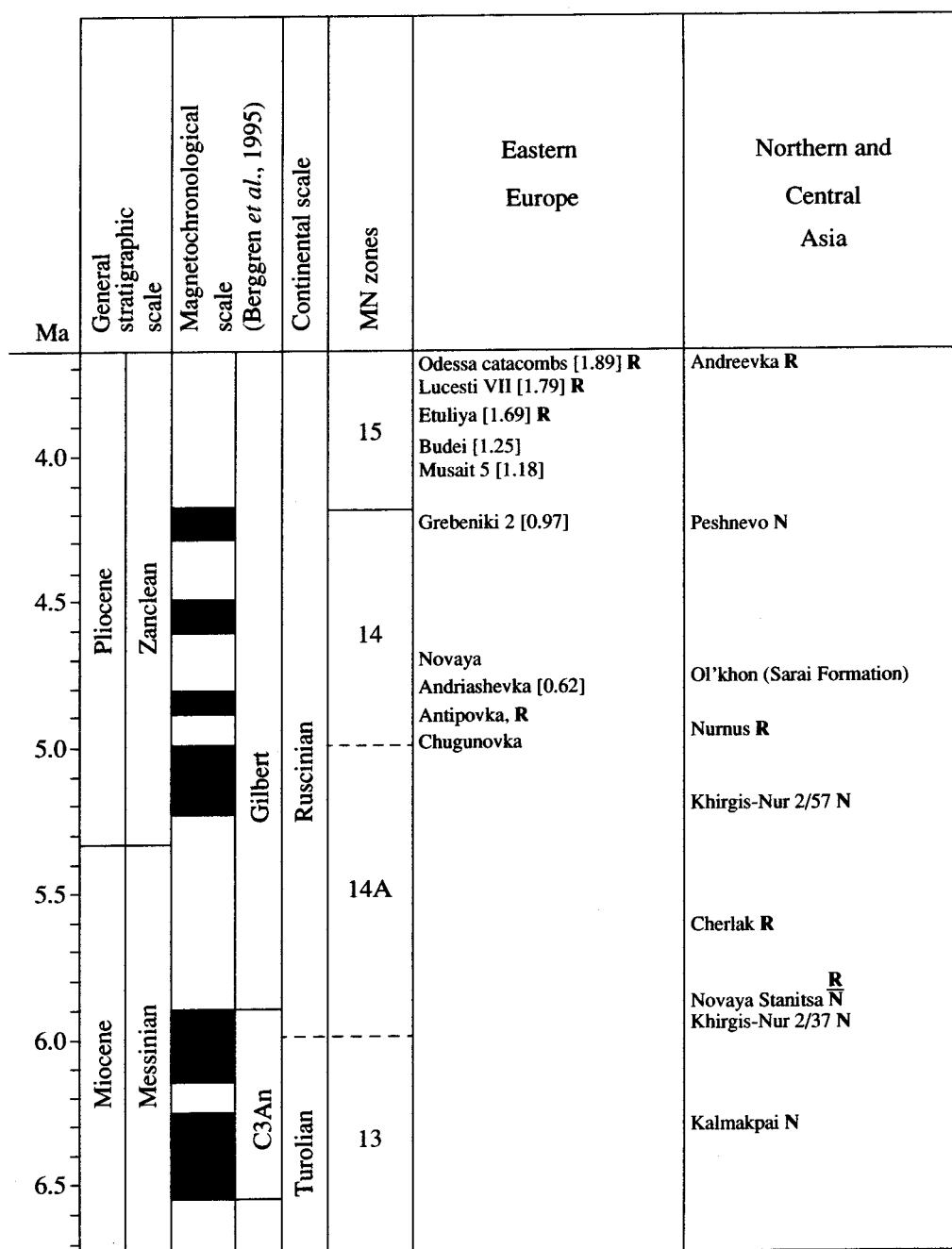
Ma	General stratigraphic scale	Magnetochronological scale (Berggren et al., 1995)	Continental scale	MN zones	Eastern Europe	Northern and Central Asia
4.0	Pliocene / Zanclean	Gilbert	Ruscinian	15	Odessa catacombs [1.89] R Lucesti VII [1.79] R Etuliya [1.69] R Budei [1.25] Musait 5 [1.18]	Andreevka R
4.5				14	Grebeniki 2 [0.97] Novaya Andriashevka [0.62] Antipovka, R Chugunovka	Peshnevo N Ol'khon (Sarai Formation) Nurnus R
5.0						Khirgis-Nur 2/57 N
5.5	Miocene / Messinian			14A		Cherlak R
6.0		C3An	Turolian	13		Novaya Stanitsa $\frac{R}{N}$ Khirgis-Nur 2/37 N Kalmakpai N
6.5						

Fig. 3. Position of the terminal Turolian and Ruscinian localities in magnetochronological and stratigraphic scales; (R) reversed and (N) normal polarity; in square brackets are hypsodonty indexes of voles.

data that *Promimomys insuliferus* appeared not later than 4.9 Ma ago. Remains of this taxon are also known from the Ol'khon Island, the Baikal Lake, but reliable paleomagnetic data on this locality are unavailable (Pokatilov, 1985).

The *Obukhovka* locality in the Don River low reaches and *Grebeniki 2* site in the Kuchurgan gravel of Ukraine contain vole remains similar to *Promimomys moldavicus* Korm. known from the *Malusteni* site of Romania, and relevant faunas are referred to the upper-most zone MN14 (Topachevskii *et al.*, 1988; Vangengeim *et al.*, 1995). Biometric age of about 4.25 Ma obtained for the Grebeniki 2 locality implies that it corresponds to the Cochiti Subchron. The *Peshnevo* locality in the Petropavlovsk Ishim region of West Siberia contains *Promimomys antiquus* Zazhigin. The species is found in sediments of the Peshnevo Formation (Zykin *et al.*, 1991), which reveal normal polarity and can be referred to the same stratigraphic level.

In Europe, the boundary between zones MN14 and MN15 at the level of the Cochiti Subchron is distinct in numerous localities of the Teruel basin, Spain (Fig. 2, VI, VII). In the *Orrios* and *Villalba Alta Rio* localities, terminal faunas of Zone MN14 occur in deposits displaying normal polarity and correlated with the Cochiti Subchron, whereas sediments of reversed polarity corresponding to Chron C2Ar contain faunas of Zone MN15, which are typical of the *Orrios, Villalba Alta, Loma del Castillo,* and *Escorihuela* localities (Fig. 2, VI, VIII, IX, X) (Opdyke *et al.*, 1997).

In the southern Russian Plain, faunas attributed in this work to the late Ruscinian (Zone MN15) are known from the *Budei, Musait 5, 7, Lucesti VII,* and *Etuliya* (lower and middle beds) sites on the right bank of the Bol'shaya Sal'cha River, Moldova, from western coast of the Yalpug Lake, and from the *Kotlovina* site (lower bed) in Ukraine. They all are confined to sediments of alluvial plain, which are known as the Karboliya Beds. According to the evolution grade of voles *Promimomys* ex gr. *moldavicus*, the age succession of localities within the zone is as follows (Fig. 3): Musait 5 (biometric age 4.085 Ma), Budei (4.045 Ma), Musait 7, Lucesti VII (3.864 Ma), Etuliya (middle bed, 3.855 Ma), and Kotlovina (Pevzner and Vangengeim, 1994; Vangengeim *et al.*, 1995; Pevzner *et al.*, 1996).

Paleomagnetic characteristics of the Karboliya beds have been studied at the Novaya Etuliya, Lucesti, and Musait 5 localities (Khubka *et al.*, 1983; Sadchikova *et al.*, 1986). According to the date obtained, the Karboliya Beds of reversed polarity and the corresponding mammalian localities are in the interval of the Gilbert Chron ranging from the Cochiti Subchron to the Gilbert-Gauss reversal (Chron C2Ar). Biometric ages of the localities are well consistent with their position in the magnetochronological scale. Mammalian faunas of the Karboliya Beds are known as the Moldavian faunal assemblage ("Moldavian Roussillon").

The diverse mammalian fauna of transitional Ruscinian–Villafranchian type (characterized by the *Homotherium* FAD) is known from fill of karst sinkholes in the lower Pontian limestone of the Odessa catacombs and corresponds to an uppermost part of Zone MN15. The red-colored bone beds bearing *Pliomys* ex gr. *kowalskii* Shevtschenko show reversed polarity and are correlated with the uppermost Gilbert Chron, whereas the overlying yellowish sandy clays barren of bones correspond to either the initial Gauss or Brunhes chrons of normal polarity.

In West Siberia, the *Andreevka* locality at the Om' River is encountered in the reversed polarity interval of alluvial deposits of the Livenka Formation. The locality bearing the extremely archaic cemented form of *Mimomys* is referred to the end of the Gilbert Chron and respectively to zone MN15 (Zazhigin and Zykin, 1984; Zykin *et al.*, 1991).

Thus, the mammal localities of Zone MN15, which are known in the southern Russian Plain, West Siberia

and Western Europe, occupy the same position in the magnetochronological scale, namely, within Chron C2Ar.

Localities Older Than the Promimomys insuliferus Zone

Between the terminal Turolian Kalmakpai fauna and those bearing *P. insuliferus* in the Asian part of Russia, there are known at least two stratigraphic levels containing the *Promimomys* forms more archaic than *P. insuliferus*. These are levels of the Novaya Stanitsa (Fig. 2, V) and Cherlak localities in the Omsk region of the Irtysh River basin. The relevant faunas are characterized by the first occurrence of *Baranomys* and by a considerable diversification of Soricidae (Storch *et al.*, 1998).

The *Novaya Stanitsa* locality is associated with the lacustrine deposits of synonymous formation overlying with a hiatus sediments of the Ishim Formation that is attributed to the lower half of the upper Miocene. Of two bone-bearing beds occurring in the lacustrine sequence the lower one is in the interval of normal polarity, while sediments of the upper bed show reversed polarity immediately above the reversal (Vangengeim *et al.*, 1984). According to Zazhigin, faunas from both beds are identical and contain "new *Baranomys* and *Promimomys* species indicative of a new, previously unknown stage of the Ruscinian" (Zazhigin and Zykin, 1984, p. 33). The level separating two polarity zones in the section is correlated with the C3An-Gilbert reversal. The *Cherlak* locality bearing *Promimomys* sp. slightly more advanced than specimens of the Novaya Stanitsa fauna is confined to deposits of the Rytovo Formation. According to the reversed polarity of sediments, this formation is correlated with the early Subchron C3r of the Gilbert Chron (Vangengeim *et al.*, 1984; Zazhigin and Zykin, 1984; Gnibidenko, 1990; Zykin *et al.*, 1991, 1995).

In the Great Lakes depression of northwestern Mongolia, the *Khirgis-Nur 2* locality (upper subformation of the Khirgis-Nur Formation, level 37–57; Fig. 2, IV) bears an assemblage of mammal taxa dominated by high-crowned hamsters, *Orientalomys*, and *Hipparion houfenense* Teilh. et Young.[3] Zazhigin and Zhegallo attributed this assemblage to the Ruscinian (Pevzner *et al.*, 1982). Fauna from the upper Khirgis-Nur Subformation contains species in common with the Ertemte fauna: *Lophocricetus pusillus* Schaub, *Dipus fraudator* (Schlos.), *Pseudomeriones abbreviatus* (Teilh.), *Brachyscirtetes wimani* (Schlos.), *Microtodon atavus* (Schl.), and *Orientalomys*. According to Zazhigin, the Novaya Stanitsa and Cherlak faunas also contain genera common with the Ertemte fauna. These are

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[3] According to Forsten (1997), this is a caballoid hipparion, somewhat smaller than the type species *Hipparion houfenense*. In opinion of Zhegallo (personal communication), this is an early form of *Hipparion houfenense*.

genera *Lophocricetus, Paranourosorex, Microtodon, Prosiphneus,* and *Zelceina,* the latter known from the Cherlak assemblage only (Pevzner *et al.,* 1982; Zazhigin and Lopatin, 2000, 2001, 2002; Zazhigin *et al.,* 2002; Storch, 1987; Storch and Zazhigin, 1996). In the magnetochronological scale, faunas of the Novaya Stanitsa locality and upper Khirgis-Nur Subformation occupy the same position: the uppermost part of Chron C3An and basal interval of the Gilbert Chron. Lower beds of the Gaozhuang Formation (Taoyang member), which contain fauna of the Ertemte type, and the Cherlak locality correspond to the lowermost interval of the Gilbert Chron (Fig. 2, III, IV, V). Similar taxonomic composition of mammal remains and identical position in magnetochronological scale imply that the considered localities characterize a single stage of mammal fauna evolution in the Eastern Palaearctic.

Age of the Ruscinian Lower Boundary

Like Zazhigin, Fejfar (Fejfar *et al.,* 1997, p. 269) believed that the Novaya Stanitsa and Cherlak faunas (evidently together with Khirgis-Nur, Ertemte, and Taoyang assemblages) belong to the new earliest zone of the Ruscinian (MN14a) that is below the first occurrence of *Promimomys insuliferus.* We agree with this standpoint but propose to designate this zone as MN14A. Repenning *et al.* (1990) suggested to term the interval of Ertemte-type faunas as the separate subdivision Ertemtian, although they defined it not at the very beginning of the Ruscinian. The Ventian Stage intermediate between the Turolian and Ruscinian was distinguished by Aguirre in 1977, and later on Alberdi and Bonadonna (1988) refined its stratigraphic range. In their understanding, the the Ventian lower boundary is immediately above the last Messinian evaporite event, and the upper boundary is defined at the appearance level of typical Ruscinian taxa. As it has been thought, characteristic of the Ventian fauna is joint occurrence of certain Turolian and Ruscinian taxa. The Baccinello V3 was suggested to be the stage reference locality. The lowermost Ruscinian zone discriminated in this work is very close in range and stratigraphic position to the Ventian.

Based on data characterizing localities considered above, we place the Ruscinian lower boundary close to the reversal C3An/C3r in the uppermost Subchron C3An1n. Accordingly, it is between 6.137 Ma and 5.89 Ma (dates of the subchron boundaries) that is consistent with the Turolian-Ruscinian boundary age in the La Alberca (> 5.8 Ma) and Fuente del Viso (the middle of Subchron C3An1n after Opdyke *et al.,* 1989) localities. In Western Europe, the interval between this boundary and basal Zanclean at least is evidently lacking localities with exactly known geologic position. A series of the terminal Messinian sites, which have been attributed alternately to zones MN13 and MN14, most likely correspond to this interval. The final solution of the problem needs additional data and magnetostrati-

graphic research. In Eastern Europe, namely in the northern Black Sea region, the interval from the terminal early Pontian to mid-Kimmerian corresponds to a significant break of continental sediment accumulation. This is a consequence of active erosion likely associated with a low sea-level stand in the late Pontian and Kimmerian basins. The lower Pontian sediments are caped here by a thick red-colored weathering crust.

We preliminary suggest the following faunal criteria indicative of the beginning of the Ruscinian *s.l.* in the northeastern Palaearctic: FAD of *Micromys, Orientalomys, Baranomys, Arctomeles, Sus,* FAD of caballoid hipparions, and increased diversity of Insectivora.

Some criteria, e.g., FAD of *Sus,* diversification of Insectivora, and, likely, FAD of caballoid hipparions, may be valid for the northwestern Palaearctic as well. The question what evidently global causes resulted in such a considerable rearrangement of mammal fauna in the terminal Miocene, still remains open.

LOWER VILLAFRANCHIAN

The first occurrence of *Leptobos, Acinonyx, Homotherium,* and *Megantereon* among large mammals (Mein, 1989), of *Borsodia* and *Villanyia* among rodents, and a wide dispersal of *Mimomys* s.l. with well developed cement on teeth (Fejfar *et al.,* 1997) used to be regarded as faunal criteria signifying beginning of the Villafranchian (Villanyian).

Azzaroli (1977) distinguished several faunal units in the Villafranchian. The lower Villafranchian included the Triversa and Arondelli faunas (type localities) and the Montopoli fauna that contains first *Equus* and *Archidiskodon* forms. The Saint Vallier site in France, which has no analogues in Italy, was suggested to be the type locality of the middle Villafranchian. The upper Villafranchian included three faunal units Olivola, Tasso, and Farneta. Azzaroli correlated the Triversa-Arondelli fauna with Subzone MN16a, the Montopoli fauna with Subzone MN16b, and the Saint Vallier assemblage with the Zone MN17 (Azzaroli *et al.,* 1986). Subsequently some researchers referred to the middle Villafranchian the faunas of Subzone MN16b bearing first elephants and true horses and correlated Zone MN17 with the upper Villafranchian (*Biochronologie...,* 1997; Fejfar *et al.,* 1998; etc.).

The Ruscinian-Villafranchian boundary is defined controversially: close to the Gilbert-Gauss reversal at 3.58 Ma according to mammal localities in the Teruel basin of Spain; or in the uppermost part of the Gilbert Chron in the Triversa locality of Italy (Opdyke *et al.,* 1997; Lindsay *et al.,* 1997;[4] Fejfar *et al.,* 1998; etc.); or in the lower part of the Gauss Chron between 3.58 Ma and 3.33 Ma in the Galera site of the Guadix-Baza

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[4] In this work, there is suggested to attribute the Triversa site (type locality of the early Villafranchian!) to the Ruscinian, because it is correlative with the upper part of the Gilbert Chron.

Basin in Spain (Garces *et al.*, 1997; Steininger *et al.*, 1996).

Within Zone MN16, Fejfar and Heinrich (1989) originally distinguished two rodent biozones of *Mimomys hajnackensis* (MN16a) and *Mimomys polonicus* (MN16b), but subsequently they established that *M. hajnackensis* Fejfar is a junior synonym of *Mimomys hassiacus* Heller (Fejfar and Storch, 1990). As the stratigraphic range of *M. hassiacus* exceeds the early Villafranchian and spans the terminal Ruscinian as well, the concurrent range zone *M. hassiacus-M. stehlini* was recognized for the early Villafranchian (Fejfar *et al.*, 1998). The *Mimomys pliocaenicus* biozone corresponds to Zone MN17 in the scale of Fejfar and Heinrich .

Taxonomic Remarks

Remains of *M. hassiacus* in the Heller's type collection from Gundersheim and additional material from the Gundersheim 4 locality of similar age, which are illustrated by Fejfar and Storch (1990), considerably differ in the anteroconid morphology from the other known large *Mimomys* forms of the *M. polonicus-pliocaenicus* lineage. Young and heavily worn m1 specimens of the former have a deep insular reentrant and a small rounded enamel island. In addition, the only known M3 specimen (Fejfar and Storch, 1990, Fig. 110) has a deep posterolingual reentrant filled with cement and not closed up in an enamel island. In distinction, the other known members of the *polonicus* group are characterized by a compact subtriangular anteroconid m1 with a large stretched enamel island oval in shape (Agadjanian, 1976; van Kolfschoten *et al.*, 1998; Mörs *et al.*, 1998) and by M3 with a posterior enamel island formed by reduction of a posterolingual reentrant. At the same time, the revised type series of *M. hassiacus* includes an illustrated specimen completely similar in morphology to the typical large *Mimomys* ex gr. *polonicus* (Storch and Fejfar, 1990, figs. 1, 2). This specimen is also characterized by significantly higher dentine tracts, which resemble those of *Mimomys polonicus*. Thus, the Heller's type series represents most likely a mixture of heterogeneous forms, and name *M. hassiacus* cannot be used therefore without additional revision of *M.* ex gr. *polonicus* specimens from the first half of the early Villanyian and subzone MN16a. Judging from the original description, *M. hajnackensis* is actually characterized by a lower degree of hypsodonty than the typical *M. polonicus* from the Rebielice Krolewskie 1 locality. In the present-day situation, it seems more reasonable to use name *M. hajnackensis* Fejfar, 1961, to characterize Zone MN16a. The degree of hypsodonty of m1 corresponding to the HH-index of 2.5, can be accepted as the boundary between two species (Tesakov, 2004).

Early Villafranchian Reference Localities in the Magnetochronological Scale

We consider the lower Villafranchian in the range of Zone MN16 established in the Triversa and Arondelli type localities, including the *Mimomys hajnackensis* (MN16a) and *Mimomys polonicus* (MN16b) biozones of Fejfar and Heinrich (1989) (see the above taxonomic remarks). Following recommendations of the Congress "BiochroM'97," we attribute faunas bearing first elephants and true horses to the middle Villafranchian, including them into Zone MN17 of the Saint Vallier type locality, i.e., we exclude the Montopoli fauna from Subzone MN16b and refer it, along with the Saint Vallier fauna, to Zone MN17. The upper Villafranchian is considered here in its original range suggested by Azzaroli.

The *Triversa* type locality (Fornace RDB) in Italy, one of the most ancient in the lower Villafranchian is correlated, according to Lindsay *et al.* (1997), with the upper part of the Gilbert Chron, whereas the *Hajnacka* site in Slovakia bearing *Mimomys hajnackensis* Fejfar (HH-index is 1.66) is correlated with the lowermost part of Gauss Chron (Fig. 4). In the *Escorihuela* section of Teruel basin in Spain, bone beds bearing faunas of zones MN15 (Escorihuela B) and MN16 (Escorihuela A) occur exactly below and above the Gilbert-Gauss reversal, respectively (Fig. 2, IX) (Opdyke *et al.*, 1997).

Based on paleomagnetic records of the Galera locality in the Guadix-Baza basin, Spanish researchers determined age of the Villafranchian lower boundary at 3.4 Ma, in the lowermost Gauss Chron (Garces *et al.*, 1997; Agusti *et al.*, 2001). In the lower part of the Galera section (Fig. 2, I), they established three zones of normal polarity N1, N2, and N3 (from the base upward), which are separated by two intervals R1 and R2 of reversed polarity. Mammalian fauna of Zone MN15 was encountered in the lowermost Polarity Zone R1. It is believed that the section spans the Gauss Chron that has a hiatus or condensed sedimentary interval about 300 thousand years long in Subchron C2An1n and the incomplete Subchron C2An3n. Polarity Zone N1 is correlated with Subchron C2An3n. The hiatus is likely in the upper part of the alluvial member that separates the lower and upper lacustrine sequences. In our opinion, paleomagnetic records can be interpreted in the other way (Fig. 2, I, double line). Polarity Zone N1 can be correlated with the Cochiti Subchron and zones N2 and R2 with two lower subchrons C2An3n and C2An2r of the Gauss Chron. Zone N3 may correspond to the rest of the Gauss Chron with the hiatus spanning subchrons 2An1r and, partly, 2An1n (upper part of the alluvial member). In this interpretation, position of the fauna-bearing bed in Zone MN15 is consistent with data on other localities, for instance, on those in the Teruel basin, and with position of the Ruscinian-Villafranchian boundary close to the Gilbert-Gauss reversal (Opdyke *et al.*, 1997).

General stratigraphic scale	Ma	Magnetochronological scale (Berggren et al., 1995)	Continental scale	MN zones	Rodent zones (Fejfar, Heinrich, 1989)	Localities	HH-index		
							Mimomys ex gr. hajnackensis-polonicus	Pitymimomys	Borsodia
Pliocene — Piacenzian — Gelasian	2.3	Matuyama	Villafranchian (lower)	17 (middle)	M. pliocaenicus	Kryzhanovka 3 R	4.25 ± 0.07 (3)		3.60 ± 0.13 (12)
	2.4								
	2.5					Kryzhanovka 2 R			3.23 ± 0.10 (4)
	2.6					Stranzendorf D R	4.0 (2)	3.42 ± 0.18 (4)	>2.5 (1)
		Gauss			M. polonicus	Stranzendorf C N	3.78 (1)		
						Veselovka N			3.07 ± 0.10 (14)
	2.7					Akkulaevo		3.23 ± 0.12 (22)	2.01 ± 0.06 (21)
	2.8			16b		Simbugino	3.21 ± 0.06 (21)	3.02 ± 0.08 (19)	1.75 (1)
	2.9					Rebielice Krolewskie 1	3.06 ± 0.08 (10)		
						Kushkuna N	3.05 ± 0.06 (21)		
	3.0					Deutsch Altenburg 21	2.78 (1)	2.68 ± 0.06 (8)	
						Korotoyak 2a R / Uryv 2 R			
	3.1					Deutsch Altenburg 20	2.52 (1)		
						Frechen N	2.47 (2)		
	3.2				M. hajnackensis	Hambach	2.40 (3)		
	3.3			16a		Rebielice Krolewskie 2	2.25 ± 0.05 (12)		
						Shirokino	2.24 ± 0.18 (4)		
	3.4					Ripa Skortsel'skaya N	1.88 ± 0.14 (6)	1.58 ± 0.06 (3)	
	3.5					Korotoyak 2 N / Arondelli			
Zanclean	3.6	Gilbert	Ruscinian	15		Hajnacka N / Escorihuela A N / Triversa R / Korotoyak 1 R	1.66 (3)		
	3.7					Escorihuela B R			
	3.8								
	3.9								

Fig. 4. Position of lower and lower middle Villafranchian localities in magnetochronological scale and HH-indexes of voles; (**R**) reversed and (**N**) normal polarity; in brackets number of measured specimens.

In Russia, the *Korotoyak 1* locality of the Don River upper reaches contains *Mimomys hajnackensis* Fejfar more archaic than the type species from the Hajnacka site. The locality is confined to the interval of reversed polarity in alluvial deposits of the Korotoyak Formation. Above there is the 5-m-thick interval of normal polarity spanning the upper part of the Korotoyak Formation and lower Uryv Subfomation. Basal horizon of the latter corresponds to the bone bed of the *Korotoyak 2* locality bearing *M. hajnackensis* similar to the type species (Agadjanian and Glushankova, 1988; Agadjanian, 2003; Iossifova and Semenov, 1998). In our opinion, these localities can be respectively correlated with the upper Gilbert Chron and lowermost Gauss Chron. Consequently, the lower boundary of *M. hajnackensis* biozone of the scale by Fejfar and Heinrich is in the

| Ma	Magnetochronological scale (Berggren et al., 1995)		General stratigraphic scale		Stratigraphic scale of the Eastern Paratethys	Continental scale		MN zones	Age of boundaries	Duration
2	C2n		Upper	Gelasian	Apsheronian	Villafranchian	upper		~2.0–2.2	
	C2r 1 r / n; 2r						middle	17		0.4–0.6
3	C2An 1n; 2 r/n/r; 3n		Middle	Piacenzian	Akchagylian		lower	b / 16 / a	2.6 / ~3.1	~1.0
4	C2Ar		Lower	Zanclean	Pantikapei	Ruscinian		15	~3.6 / ~4.2	~0.6
5	C3n 1 n/r; 2 n/r; 3 n/r; 4n				Kamysh-Burun / Kimmerian			14		~0.8
	C3r							14A	~5.0	~1.0
6	C3An 1n; r; 2n		Miocene	Upper / Messinian	Azov				~6.0	
7	C3Ar; C3Bn; C3Br 1r/2r				Pontian	Turolian		13	~7.1	~1.1

Fig. 5. Boundary ages, duration, and position of MN zones in magnetochronological and stratigraphic scales.

uppermost part of Gilbert Chron and coincides with the base of the lower Villafranchian defined by remains of large mammals (Triversa).

In the *Ripa Skortsel'skaya* locality of Moldova, *Mimomys hajnackensis* (HH-index = 1.88, Fig. 4) was found in the interval of normal polarity correlated with the lower part of the Gauss Chron (*Putevoditel'...,* 1982). The *Shirokino* site in the northern Azov region, which contains *M. hajnackensis* with a greater hypsodonty index (2.24), is stratigraphically higher. Almost the same index is characteristic of voles from the *Rebielice Krolewskie 2* locality in Poland. Paleomagnetic data on the latter two sites are unavailable. Biometric age calculated for the Shirokino locality is 3.286 ± 0.09 Ma, and the locality is correlative therefore with Subchron C2An2r (Mammoth).

In the Don River upper reaches, the upper Uryv Sub-formation contains locality *Uryv 2* that bears remains of a large vole, which is intermediate between *M. hajnack-ensis* Fejf. and *M. polonicus* Kow. according to its evo-lutionary grade (Agadjanian, 2003). Fejfar *et al.*, (1997, p. 276) identified this form as *M. hassiacus* (= *M. hajnackensis*). The *Korotoyak 2a* locality in the lower interval of reversed polarity of the overlying Belogor'e Formation (Selyavnovka sequence) contains *M. poloni-cus* similar to the type species from Rebielice Krolews-kie 1 (Agadjanian, 2003; Iossifova and Semenov, 1998). In our opinion, the interval of reversed polarity with bone-bearing sediments can be correlated with Subchron C2An1r (Kaena).

The *Kushkuna* locality in Azerbaijan yields *M. polonicus* Kow. with the HH-index of 3.05 ± 0.06 (*n* = 21). The locality is in the normal polarity zone of the middle Akchagylian deposits. The bone bed is slightly above an ash horizon dated by fission-track method at 2.88 ± 0.24 Ma (= 3.03 when calibrated against CK95, see above) (Ganzei, 1987). Biometric age of the locality is 2.90 ± 0.03 Ma and it may be placed in Subchron C2An1n. *Mimomys polonicus* from the Kushkuna site is almost identical with the type species from the *Rebielice Krolewskie 1* site (HH-index is 3.06 ± 0.08, *n* = 10), and both sites are concurrent therefore. *M. polonicus* from the *Deutsch Altenburg 21* locality in Austria is characterized by a lower HH-index of 2.78 (Rabeder, 1981), and we place it stratigraphically below the Kushkuna level.

According to data considered above, the boundary between the *M. hajnackensis* and *M. polonicus* bio-zones of the scale by Fejfar and Heinrich (MN16a-MN16b) is about 3.1 Ma old and close to the base of Subchron C2An1r.

In this connection, we should discuss magnetochro-nological position of the Reuver Clay in the *Frechen* and *Hambach* localities in Germany (Reuver B, unit 11). The major sequence of the Reuver Clay (unit 11) in the Fortuna quarry is characterized by normal polarity of sediments, and reversed polarity is established here in the uppermost beds only. The sequence is correlated with the upper part of the Gauss Chron (Boenigk *et al.*, 1979). A large vole from the Frechen locality is identi-fied as *Mimomys* cf. *polonicus* (Kolfschoten *et al.*, 1998) and as *M.* hassiacus (= *M. hajnackensis*) at the Ham-bach site (Mörs *et al.*, 1998). After examination of the specimens, Tesakov referred both voles to *M. hajnack-ensis,* presumably to the latest form occurring close to the boundary between *M. hajnackensis* and *M. poloni-cus* zones according to the calculated hypsodonty index. Considering that boundary position in the mag-netochronological scale, we can correlate the normal polarity interval of the Reuver Clay with Subchron C2An2n of the Gauss Chron. Tapir remains found in the Tiglian A at the Maalbeek site of the Netherlands rep-resent a form that is unknown outside the early Vil-lafranchian (Westerhoff *et al.*, 1998), i.e., an indirect

evidence in favor of the above age estimate. The Tiglian is stratigraphically above the Reuver.

According to Yakhimovich *(Fauna and Flora...,* 1977), the *Simbugino* locality with *M. polonicus* is con-fined to the Kumurly beds of the Akchagylian in the Bashkirian Cis-Urals and lacks a reliable paleomag-netic characterization. The HH-index of *M. polonicus* equal to 3.21 is higher than that of vole from the Kush-kuna site (3.05). Biometric age of the locality is 2.828 ± 0.03 Ma, and we place it in the middle of Subchron C2An1n. Stratigraphically higher in the Akkulaevo Beds of the middle Akchagylian, there is the *Akkulaevo* locality (lower horizon) also containing *M. polonicus (Fauna and Flora...,* 1972). According to the HH-index of *Pitymimomys* (3.23), this locality is younger than the Simbugino locality (3.02). The same difference in hyp-sodonty indexes is characteristic of *Borsodia* forms (2.01 versus 1.75 at the Akkulaevo and Simbugino localities, respectively; Fig. 4).

The *Veselovka* locality in the Tamanskii Peninsula is in the normal polarity zone of the lower Kuyal'nik thus being correlative with the upper part of the Gauss Chron. Above there is recovered interval of reversed polarity in the Akchagylian sediments of the Tamanian Horizon (Zubakov, 2000). The HH-index of *Borsodia* from the Veselovka site (3.07) is significantly higher than index characterizing this form from the Akkulaevo site (2.01).

Age of the Upper Boundary of the Lower Villafranchian

In the *Stranzendorf* locality Austria, the bone beds C and D bearing *Mimomys praepliocaenicus* Rabeder, an intermediate form between *M. polonicus* and *M. plio-caenicus,* occur below and above the Gauss-Matuyama reversal, respectively (Rabeder, 1981). In the scale by Fejfar and Heinrich, the replacement of *M. polonicus* by *M. pliocaenicus* s.l. defines boundary between rodent zones MN16 and MN17. If *M. praepliocaenicus* can be referred to *M. pliocaenicus* s.l., then this bound-ary is older than 2.58 Ma according to position of first *M. praepliocaenicus* in the uppermost part of the Gauss Chron. The hypsodonty index of *Borsodia* from Stran-zendorf D, being calculated for all the teeth (Rabeder, 1981), is higher than that of *Borsodia* from the Veselovka site (HH-index = 3.07). The *Borsodia* speci-mens from the Kryzhanovka 2 locality, which are found in sediments of the reversed polarity interval correlated with the lower part of Matuyama Chron (Pevzner, 1989), are also more advanced (HH-index = 3.23).

There is the only work reporting on the *M. polonicus* tooth fragment found in sediments penetrated by De Meern Borehole in the Netherlands and correlated with the lower part of the Matuyama Chron (Gibbard *et al.*, 1991). However, this fragment could have been rede-posited or transferred in the core from older deposits in the course of drilling.

Based on remains of small mammals from the *Uryv* and Korotoyak localities in the Don River upper reaches, Agadjanian (2003) distinguished the *Uryv* faunal assemblage of the Russian Plain considering it as typical of the Zone MN16. However, the estimated age of the assemblage and, accordingly, the inferred range of Zone MN16 (from 3.3 to 2.2 Ma) differs from our assessments. Despite the paper title: "*Middle Pliocene Small Mammals…*" (emphasis is our), the *Uryv* assemblage range, in opinion of Agadjanian, spans the greater part of the middle and a significant part of the late Pliocene. The above data on stratigraphic distribution of mammal species throughout zones MN16 and MN17 in Russia, central and Western Europe contradict this inference. As we believe, the Uryv faunal assemblage actually corresponds to Zone MN16, i.e. to the *Mimomys hajnackensis* and *M. polonicus* biozones of Fejfar and Heinrich, and does not occur outside the middle Pliocene of the General Stratigraphic Scale. Numerous localities attributed by all the researchers to Zone MN17 are correlated with the lower part of the Matuyama Chron (Steininger et al., 1996).

We place the bone bed of the *Montopoli* locality in Italy, which yields first *Archidiskodon* and *Equus* forms, in Zone MN17 immediately above the Gauss-Matuyama reversal (Lindsay et al., 1980). Faunas of similar age, which contain archaic true horses and are correlative with the lowermost interval of reversed polarity in the Matuyama Chron, are known from a series of localities. These are the lower beds of the *Liventsovka* locality in southern Russia, the parastratotype of the Khapry faunal assemblage, lower beds of the *Kryzhanovka* locality in Ukraine (Pevzner, 1989), and the *Kuruksai, Obigarm, Karamaidan,* and *Tutak* sites in Tajikistan and *Southern Adyrgan* site in eastern Kazakhstan, Central Asia, (Dodonov, 2002).

In the *Kairakkum* locality of the West Fergana region, Uzbekistan, remains of *Archidiskodon gromovi* are found at the boundary between intervals of normal and reversed polarities, which is correlated with the Gauss-Matuyama reversal (Tetyukhin et al., 1980). Fauna with *Equus* ex gr. *stenonis* is known from the normal polarity zone of the *Zil'fi* section (Tajik depression) that is about 30 m thick. Sediments overlying the bone bed correspond to zone of reversed polarity. Dodonov (2002) correlated the normal polarity zone with the Olduvai Subchron, which implies the upper Villafranchian level of the fauna. However, an extremely archaic character of horse remains implies that fauna is not younger than the initial middle Villafranchian. Evidently, bone-bearing sediments of the normal polarity zone should be correlated with the uppermost part of the Gauss Chron.

In other regions of Europe and northern Asia, remains of *Archidiskodon* and *Equus* are also correlative with the uppermost interval of the Gauss Chron. In the *Yushe* basin of China for instance, the normal polarity interval in the upper part of the *Mazegou* Formation

is correlated with the Gauss Chron and yields the *Archidiskodon* remains (Flynn et al., 1997). In the *Nihewan* basin (Hongya Nangou) *Equus* sp. first found in China is associated with deposits, which are also correlated with the upper part of the Gauss Chron (Du et al., 1995). In Romania, *Archidiskodon rumanus* (Stefanescu) is described from the *Tuluceşti* locality correlated with the second half of the Gauss Chron (Radulescu and Samson, 2001). In the *Rincon 1* locality of Spain, remains of *Equus* are confined to the section interval corresponding to the Gauss Chron uppermost part (Agusti and Oms, 2001).

According to large mammals, the boundary between zones MN16 and MN17 is also in the Gauss Chron uppermost part, close to the Gauss-Matuyama reversal. Thus, ranges of Zone MN16, in other words, of the lower Villafranchian, coincide being defined based on large and small mammals.

CONCLUSION

Data considered in this work lead to the following inferences:

(1) The Ruscinian fauna replaced the Turolian one at the end of Chron C3An1n close to the C3An1n-Gilbert paleomagnetic reversal. The Ruscinian lower boundary is estimated to be about 6 Ma old, and the stage duration is nearly 2.4 m.y. (Fig. 5). The date accepted for the Ruscinian base reduces duration of Zone MN13, or of the late Turolian (7.1–6 Ma), down to 1.1 versus 1.8 or even 2.2 m.y. (the unit top respectively at 5.2 or 4.9 Ma see above). In our interpretation, the Ruscinian base (6 Ma) is older than the Miocene-Pliocene boundary at 5.3 Ma. However, it is close to previous assessments based on zonal scale for oceanic sediments, where the Miocene–Pliocene transition is defined at the first occurrence of *Globorotalia margaritae* (Bylinskaya et al., 2002). FAD of this species is estimated at 6–6.4 Ma (Berggren et al., 1995).

(2) Within the Ruscinian, between the Turolian upper boundary and *Promimomys insuliferus* Zone, we distinguish the additional Zone MN14A in understanding of Zazhigin and Fejfar (Zazhigin and Zykin, 1984; Fejfar et al., 1997) or the analogue of Ertemtian in understanding of Repenning et al., (1990). A close analogue of the proposed unit is the Ventian discriminated by Alberdi and Bonadonna (1988). The zone is about 1 m.y. in duration. It corresponds to the uppermost Messinian and lowermost Zanclean or to the middle part of the lower Kimmerian in the scale of Eastern Paratethys.

(3) The lower boundary of Zone MN14 (*P. insuliferus* biozone, MN14a) is dated at about 5 Ma. In the southern Russian Plain, Zone MN14 is characterized by the Kuchurgan mammalian assemblage. The zone duration is approximately 0.8 m.y. The unit is correlative with the middle Zanclean or with the terminal lower and middle Kimmerian in the Eastern Paratethys.

(4) Boundary between zones MN14 and MN15 is placed at the top of the Cochiti Subchron thus being about 4.2 Ma old. In the southern Russian Plain, Zone MN15 yields the Moldavian mammalian assemblage ("Moldavian Roussillon"). It is about 0.6 m.y. in duration, correlative with the terminal Zanclean or with the upper Kimmerian of the Eastern Paratethys.

(5) The Ruscinian-Villafranchian boundary can be placed at the top of Gilbert Chron and dated at 3.6 Ma. It almost coincides with the lower-middle Pliocene boundary being close to the base of the Akchagylian (Kuyal'nik).

(6) The upper boundary of the lower Villafranchian (interface between the *Mimomys polonicus* and *M. pliocaenicus* biozones) is close to the top of Gauss Chron and slightly older than 2.58 Ma, i.e., than the middle-upper Pliocene boundary. In the Eastern Paratethys, it corresponds to the level of the Akchagylian transgression maximum. In such interpretation, the lower Villafranchian in the scale of large mammals corresponds completely to the rodent Zone MN16 and to the range of the Uryv mammalian assemblage from the Russian Plain. The lower Villafranchian and Zone MN16 are about 1 m.y. in duration. Both units closely correspond to the Piacenzian and to the lower and, partly, middle Akchagylian.

(7) Boundary between subzones MN16a (*Mimomys hajnackensis*) and MN16b (*M. polonicus*) is close to the base of Subchron C2An1n being about 3.1 Ma old.

(8) Successions of localities within every MN zone can be established quite reliably based on hypsodonty indexes of voles.

(9) Certain faunal events dated based on the magnetostratigraphic scale took place more or less simultaneously within vast territories. These are the appearance events of several characteristic taxa. *Promimomys insuliferus* appeared about 5 Ma ago from the Lake Baikal region to Western Europe. Rooted voles having tooth cement developed at the end of the Gilbert Chron from West Siberia to Western Europe, and first occurrence of elephants and horses is confined to the termination of the Gauss Chron in a vast territory from China to Spain. Within the Pliocene, synchronism of the events can be estimated with the accuracy of 100–200 thousands years. Magnetostratigraphic examination of a greater number of localities containing mammal remains is perspective for discovery of other synchronous faunal events, which can solve problems of distant correlations and help in developing of general biostratigraphic scale for the Late Cenozoic continental deposits of the whole Palaearctic.

ACKNOWLEDGMENTS

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