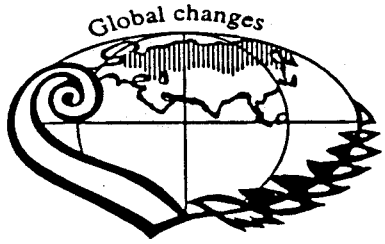
Stratigraphy and Geological Correlation, Vol. 1, No. 2, 1993. Translated from Stratigrafiya. Geologicheskaya Korrelyatsiya, Vol. 1, No. 2, 1993, pp. 38 - 45.



Evolution of the biosphere

On the Age of Mammalian Fauna from the Karabulak Formation of the Kalmakpai River (Zaisan Depression, Eastern Kazakhstan)

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Manuscript received July 2, 1992

Abstract – The study of fossil mammalian fauna from the Kalmakpai River locality (Karabulak Formation deposits) indicates that this fauna must be referred to the Turolian of the European stratigraphic scale, i.e, to the terminal Miocene, and not to the Ruscinian, as was previously supposed. The bone bed is correlated with the beginning of polarity Chron 5 of the magnetochronologic scale.

INTRODUCTION

The study of the Cenozoic deposits in the Zaisan Depression has a long history. It was most intensive at the end of the 1950s and the beginning of the 1960s. B.A. Borisov (1963) generalized the geological data on this region according to the results of the geological survey performed by the Leningrad group of the Altaian Expedition (East Kazakhstan Geological Department) from 1956 to 1961. The suggested stratigraphic scheme included many subdivisions, characterized paleontologically using different groups of the biota.

The Neogene section along the Kalmakpai River was subdivided into the middle Miocene Zaisan Formation, the middle-upper Miocene Sarybulak, the lower-middle Pliocene Kalmakpai, and the middle-upper Pliocene Karabulak Formations.[1] In 1960, hipparion remains were found in the middle part of the Karabulak Formation, as well as enamel fragments of a hypsodont tooth, originally considered as belonging to an elephant. V.E. Garutt and L.K. Gabuniya determined the age of the remnants as middle-late Pliocene. Afterwards, the remnants proved to be tooth fragments of *Sinotherium* (*Elasmotheriini*). Nevertheless, the first identification led to the overstating of the age up to the middle-late Pliocene (Borisov, 1963).

In 1961, 1966, and 1968, scholars of the Paleontological Institute, Russian Academy of Sciences, made excavations that provided essential osteological data.

In 1966, V.I. Zhegallo published a preliminary list of mammals. He determined the middle Pliocene age of the Kalmakpai fauna (Karabulak Formation), considering that the underlying Kalmakpai sediments corresponded to the lower Pliocene Pavlodar Formation, whereas the fauna was somewhat more progressive than that of Pavlodar. This age was also adopted later (Vangengeim *et al.*, 1972); however, it was stated, "According to the generic spectrum, the large mammalian fauna in this stage of evolution was rather similar to the preceding Pavlodar one" (p. 59).

The excavated remnants were thoroughly studied by different investigators. E.L. Dmitrieva (1977) described from this locality the *Gazella dorcadoides* Schlosser and referred it to the lower-middle Pliocene. V.I. Zhegallo identified two hipparion species *Hipparion hippidiodus* Sefve and *H. elegans* W. Grom. and referred the fauna from this locality to the Ruscinian, the beginning of the middle Pliocene (Kimmerian), considering its age as post-Pavlodar. A.Ya. Godina (1979) described a new subgenus and species of the giraffe *Palaeotragus* (*Yuorlovia*) *asiaticus* and dated it as the Early Pliocene. Yu.A. Semenov (1989) described the ictithere remnants as *Hyaenictitherium hyaenoides orlovi*. M.V. Sotnikova (1992) identified a new species *Machairodus kurteni* and *Adcrocuta eximia* (Roth et Wagner).

[1] These ages are corrected according to the Interregional Stratigraphic Committee scheme (1956), in which the Pontian corresponds to the lower Pliocene.

Table 1. Comparison of the Kalmakpai fauna with Turolian faunas of Pavlodar and China

Kalmakpai	Pavlodar	Turolian faunas of China
Vormela sp.	–	–
Adcrocuta eximia (Poth et Wagner)	+	+
Hyaenictitherium hyaenoides orlovi Semenov	*H. venator*	*H. hyaenoides*
Martes palaeosinensis Zdansky	+	+
Melinae gen. indet.	–	–
Plesiogulo crassa Teilhard	cf.	+
Indarctos sp.	–	+
Machairodus kurteni Sotnikova sp. n.	*M. irtyschensis*	*M. gr. tingii-palanderi*
Hipparion hippidiodus Sefve	–	+
Hipparion elegans W. Gromova	+	–
Chilotherium sp.	+	+
Sinotherium zaisanense Bajshashov	sp.	*S. lagrelii*
Cervavitus novorossiae Chomenko	–	+
Procapreolus latifrons Schlosser	sp.	+
Gazella dorcadoides Schlosser	+	+
Tragocerus sp.	+	+
Palaeotragus (Yuorlovia) asiaticus Godina	+	+
Samotherium cf. irtyshense Godina	*S. irtyshense*	3 species

Additionally, the collection of the Paleontological Institute yields remnants of *Chilotherium* sp., *Sinotherium* sp., *Cervinae*, *Tragocerus* sp., and *Vormela* sp.

In 1981 - 1983, the excavations in this locality were conducted by paleontologists from the Institute of Zoology, Kazakh Academy of Sciences (Tleuberdina, 1988). The investigations supplemented the previous list of mammals with *Melinae* gen.?, *Indarctos* sp., *Plesiogulo crassa* Teilh., *Cervavitus* sp., and *Procapreolus* sp. B.U. Baishashov (1986) referred the *Sinotherium* remains as a new species *Sinotherium zaisanensis* Baish. It appears that *Hipparion houfenense* was erroneously mentioned in this list with the reference to V.I. Zhegallo's (1978) paper. These authors determined the age of the Kalmakpai fauna as the Kimmerian and assigned it to the Ruscinian.

In the regional overview on Eastern Kazakhstan (Stratigrafiya SSSR, 1986), the Kalmakpai Formation was referred to the lower Pliocene (Pontian), whereas the Karabulak Formation, including the bone bed, to the middle Pliocene (Kimmerian). In the same volume, L.K. Gabuniya (p. 325) erroneously assigned the mammal remnants from the Karabulak Formation to the Kalmakpai Formation and dated them as the end of the Early or beginning of the middle Pliocene (Pontian-Kimmerian).

Therefore, the paleontologists' opinions on the age of the Kalmakpai mammalian fauna vary. They place it in the Pontian, i.e., the lower Pliocene, at the lower-middle Pliocene boundary, or finally, in the Kimmerian (the middle Pliocene), but the majority of investigators, however, correlate it with the West European Ruscinian.

It should be remembered that according to the European stratigraphic scale of continental deposits, the second half of the Miocene is divided into the Vallesian and Turolian stages, corresponding to the upper Serravalian, Tortonian, and Messinian, whereas the Pliocene stages are the Ruscinian and Villafrancian (lower and middle). The upper Villafrancian is referred to the Quaternary.

During the last decade, intensive study of the Neogene mammalian fauna throughout almost all the Palaearctic revealed general regularities of its evolution and allowed the stratigraphic range of many taxa to be defined more precisely. In accordance with modern views on the Neogene history of the Palaearctic fauna, we had to revise our opinion on the place of Kalmakpai fauna in the general stratigraphic system.

COMPOSITION AND STRATIGRAPHIC DISTRIBUTION OF TAXA FROM THE KALMAKPAI FAUNA

The list of taxa, identified from the Kalmakpai locality, is represented in Table 1, and their stratigraphic distribution is shown in Fig. 1.

Martes palaeosinensis Zdansky was recorded in the Paote Formation, Shansi Province in China. Yu.A. Orlov (1941) described *Martes* sp., from the Pavlodar locality, with features characteristic of *M. palaeosinensis*. A similar species *M. andersoni* is known from the Ertemte locality that is dated as the terminal Turolian and the beginning of the Ruscinian. E. Anderson (1970) considered these forms to be synonymous. Therefore,

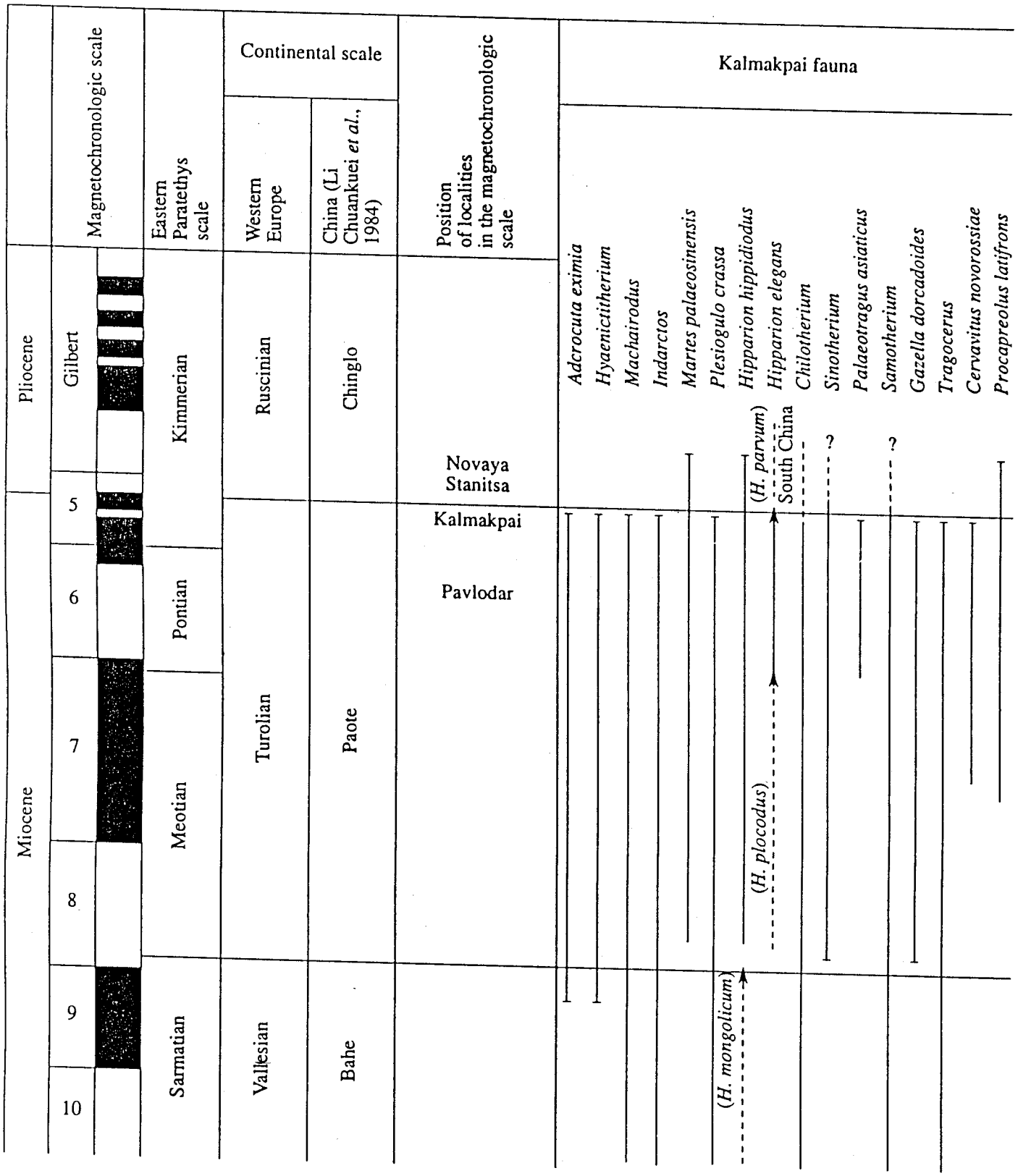

Fig. 1. *Stratigraphic distribution of mammals from the Kalmakpai River locality and its position in the magnetochronologic scale.*

the stratigraphic range of *M. palaeosinensis* covers the Turolian and the beginning of the Ruscinian.

Fossil remnants of the genus *Vormela* occur very rarely. Its lower stratigraphic limit is unknown.

The Neogene glutton *Plesiogulo crassa* Teilhard was widely distributed in the Chinese Turolian (the Paote Formation). It was considered to be a characteristic form of Central Asia. Recently, however, the occurrence of the Neogene glutton was recorded in Europe. *P. crassa* was recorded in the upper Turolian Cherevichnoe locality in the northern Black Sea region (Korotkevich and Semenov, 1975), the lower Turolian Vathylakkos locality in Greece (Koufos, 1982), and the upper Messinian Baccinello locality in Italy (Rook, 1990). Remains of this form were also found in the sediments of the Dhok-Pathan Formation in India. Yu.A. Orlov (1941) recorded *Plesiogulo brachygnathus* in the Pavlodar. B. Kurten (1970), revised the genus *Plesiogulo* and ascribed this species to *P. crassa*. Thorough study shows the Pavlodar form to be rather small and closer to *P. brachygnathus*, according to its dimensions. Nevertheless, its main morphological features are similar to those of *P. crassa*, and thus we assign it to *P. cf. crassa*.

Adcrocuta eximia (Roth et Wagner) is known in Eurasia from the end of the Vallesian (second half of the MN 10 zone) to the terminal Turolian. It was especially widely distributed in the second half of the Turolian from China to Western Europe and Libya. It was also recorded in Pakistan.

Hyaenictitherium hyaenoides (Zdansky) was an important faunal component in the Chinese Turolian and most likely inhabited Turkey (Semenov, 1989). From the Kalmakpai locality, Yu.A. Semenov (1989) described a new subspecies *H. hyaenoides orlovi*, which "differs from the nominal subspecies by less massive canines, relatively narrower premolars, and weaker reduction of last molars" (p. 126). It is not clear whether this is a geographical difference or it indicates younger age.

In Eastern Europe, this genus is represented by another species *H. venator* Semenov that is known since the end of the Late Sarmatian (Late Vallesian) and was especially characteristic of the second half of the Meotian (Middle Turolian). This genus was not recorded after the Turolian.

The genus *Machairodus* is known in Eurasia since the beginning of the Vallesian. A new species *M. kurteni* Sotnikova was recorded in the Kalmakpai locality. The arrangement of the incisors of this form has some special features peculiar to the later genus of serrate-toothed cats *Homotherium*. This makes the Kalmakpai form different from the typical Turolian sabre-toothed cats of the *M. giganteus* group, and it can be considered as the latest representative of the genus *Machairodus*.

Two hipparion species were recorded, *Hipparion hippidiodus* Sefve and *H. elegans* W. Gromova. *H. hippidiodus* was absolutely dominant. This species appeared as a result of the Turolian adaptive radiation of *Hipparion mongolicum* Schlosser, which was characteristic of the Vallesian analogues in Central Asia. *Hipparion hippidiodus* is attributed to the unique group of hipparions without a fore-eye socket. Its first representatives migrated to Europe and Africa from Central Asia in the Turolian and initiated the appearance of *H. platigenis* and *H. turcanense*. Late forms of *H. hippidiodus* are typical for the Chinese Paote Formation (the Turolian), but they were also recorded in its Asian analogues of the Early Ruscinian, e.g., the Leijiahe locality in China (Li Chuankuei, 1984).

Hipparion elegans is very rare, in contrast to the Pavlodar locality, where it dominates. It is a characteristic form of the Late Turolian, being phylogenetically connected with the Early Turolian *H. plocodus*, and in the beginning of the Pliocene, it initiated a new evolutionary stage of *H. parvum*, the smallest among Asian hipparions.

The rhinoceroses are represented in Kalmakpai by two genera, the *Sinotherium* and the *Chilotheruim*. Both groups have an Asian origin. They have roots in the Oligocene, at the beginning of the habitat redistribution among *Rhinocerotidae*, which replaced hyracodonts.

Sinotherium is known only in the Asian part of the Palaearctic. It existed for certain in the Turolian, Late Miocene. A long hiatus between *Sinotherium* and its probable descendant elasmothere, known since the end of the Pliocene, does not offer the possibility of valid stratigraphic interpretation of the *Sinotherium* find in the Kalmakpai locality. Nevertheless, it is important that *Sinotherium*, as a constant component of fossil assemblage, occurs with one exception only in the Miocene and is not known for certain stratigraphically higher than the Ertemte level (Inner Mongolia).

The form established in Kalmakpai was considered by B.U. Baishashov (1986) as a new species *Sinotherium zaisanensis*, but it has no reliable difference from *S. lagrelii*, a common species in the Turolian faunas of China.

The genus *Chilotherium* appeared in South Asia in the Agenian. In the Palaearctic, it was common in Vallesian and Turolian faunas. It is a rather morphologically stable genus. Its earliest and latest species sufficiently differ in the degree of hypsodonty, but the morphological distinctions between the synchronous or near synchronous species are fairly relative. The latest chilothere remnants are known from the base of the Pliocene in the localities of South China (Gansu) and Western Mongolia (Chirgis Nuur 2).

Deer are represented by *Cervavitus novorossiae* Chomenko and *Procapreolus latifrons* Schlosser. The former was widely distributed in the first half of the Turolian among the northern Black Sea region faunas. The species was recorded in the Grebeniki, Tarakliya, and other localities. In China, it is known from the Paote fauna of the Henan and Shansi Provinces, e.g., the localities Paote, Yushe, zone I, and others (Teilhard, 1937; Zdansky, 1925).

The distribution of *P. latifrons* appears to have been limited to Central Asia. It was recorded in the Olan-Chorea and Ertemte localities of Inner Mongolia and China (Schlosser, 1924), which yielded fauna transitional between the Turolian and Ruscinian. In China, this form was also common in the earlier faunas of the Paote Formation. It was also recorded in the Turolian of Mongolia (Dzachso-Chairchan 1).

Gazella dorcadoides Schlosser is a characteristic form of the Turolian fauna in China. It is known in the localities of Chirgis Nuur 2 in Mongolia (member A, Turolian) and Ortok in Kirgizia. A form close to *G. dorcadoides* was recorded in Pavlodar (Dmitrieva, 1977).

The Kalmakpai fauna yields two giraffe genera, *Palaeotragus* and *Samotherium*. The genus *Palaeotragus* occurred extremely widely in the Eurasian hipparion faunas, whereas the distribution area of the subgenus *Yuorlovia* was mainly limited by the Asian part of the Palaearctic. The most eastern occurrence of the giraffe, which can possibly be related to this subgenus, was recorded in the eastern Azov region (Godina and Baigusheva, 1985). Except for the Kalmakpai locality, *Palaeotragus* (*Yuorlovia*) *asiatica* Godina is known from the Pavlodar, Ortok, and Chinese Turolian faunas (Godina, 1979). *Samotherium* was also common enough in the Turolian of Eurasia. Reports on its remains in younger localities require a more accurate approach.

Representatives of Tragocerini appearing in the Middle Miocene, namely, in the Astaracian (Korotkevich,1981), flourished in the Late and middle Turolian. Toward the end of the Turolian, their number decreased greatly, and in the Ruscinian localities they were not found.

TAPHONOMY OF THE LOCALITY AND ECOLOGICAL CHARACTERISTICS OF THE FAUNA

The Kalmakpai fossil assemblage is enclosed in a pluvial lens inside the proluvial-deluvial sedimentary complex. The proluvial channel is not clearly seen in the section, and its thalweg can be recorded only by erosional pockets in the middle of the sequence. The flood running along the thalweg was constant enough to produce the channel-line facies, represented by pure gravel, and the flood-plain facies, composed of poorly sorted deposits containing remnants of small vertebrates (Ochotonidae indet.). Therefore, the fossil assemblage was formed near a more or less steady flood that provided the riverside vegetation resources sufficient for the numerous chilotheres, as follows from the excavation data. At the same time, the fossil assemblage position at the piedmont of the proluvial-deluvial train and the complete absence of alluvial facies in the Karabulak Formation clearly indicate the low humidity of extravalley biotopes of that time.

The dominance of *Hipparion hippidiodus*, an inhabitant of the open landscapes and an obligatory herbivorous form, as well as the sparse occurrence of the browsing *H. elegans* and the presence of gazelle with higher hypsodonty, also confirm the conclusions about the xerophytic landscape during the time of the Kalmakpai fauna.

PALEOZOOGEOGRAPHIC CHARACTERISTICS OF THE FAUNA

Thorough study of the Kalmakpai fauna taxonomic spectrum indicates its striking resemblance to the Turolian hipparion fauna of Northern China (Table 1). In 1903, M. Schlosser distinguished in Northern China two paleozoogeographical provinces, the forest area in the south and the steppe in the north. Each of them, together with common forms, yields certain peculiar mammalian species. B. Kurten (1952) called them the "gaudry" (with a typical representative being *Gazella gaudryi*) and "dorcadoides" (with *Gazella dorcadoides*) faunas, respectively. The former inhabited the territories of Henan, Hebei, and the southeastern Shansi provinces, and the latter, the Gansu and northwestern Shansi. The transitional zone (part of Shansi and Shensi), with mixed, according to Kurten, fauna, occurred between those paleozoogeographical provinces.

The genera and some species of the Kalmakpai locality, equivalent to the North Chinese fauna forms, were distributed in the Kurten's fauna-provinces as follows: *Sinotherium* occurred only in the dorcadoides fauna; *Samotherium*, *Chilotherium*, *Tragoceros*, *Indarctos*, and *Plesiogulo*, in the dorcadoides and transitional faunas; *Hipparion hippidiodus* and *Gazella dorcadoides* had the same distribution; *Hyaenictitherium hyaenoides* was present in the dorcadoides and transitional faunas and occurred in the single Hung-Kou locality of the gaudry fauna.

Adcrocuta eximia (= *Hyaena variabilis* in Chinese lists) was most characteristic in the dorcadoides, rarely occurring in the transitional and being found only once in the gaudry fauna. The genus *Procapreolus* is known from the transitional and gaudry fauna localities.

Palaeotragus was abundant in the Palaearctic hipparion faunas, whereas the distribution area of subgenus *Yuorlovia* occurred only in the eastern Palaearctic. *P. (Y.) asiaticus* was found in the dorcadoides and transitional faunas (Godina, 1979).

GEOLOGICAL AGE OF THE KALMAKPAI FAUNA

As cited above, the Kalmakpai fauna is evidently recorded in the same paleozoogeographical province as the Northern Chinese hipparion dorcadoides fauna. The majority of the Kalmakpai forms does not exceed the Turolian bounds (Fig. 1).

In the former USSR territory, the Kalmakpai fauna is most similar to the Gusinyi Perelet fossil assemblage near the Pavlodar (Pavlodar Formation deposits, Table 1). These faunas have the following common

forms: *Adcrocuta eximia*, *Hipparion elegans*, *Chilotherium*, *Sinotherium*, *Samotherium*, *Palaeotragus* (*Yuorlovia*) *asiaticus*, *Gazella dorcadoides*, *Tragocerus*, and *Procapreolus*.

The genus *Hyaenictitherium* is represented in the Gusinyi Perelet locality by another species, *H. venator*. The Turolian age of the Pavlodar fauna is beyond any doubt. Nevertheless, the complete synchronization of the Kalmakpai and Gusinyi Perelet faunas appears to be invalid. For example, the Kalmakpaian gazelle is more hypsodont than that of the Pavlodar fauna. This indicates a more arid environment and, most likely, a younger age.

Giraffes also have some differences. The Kalmakpaian *Palaeotragus* is more long-legged. However, these differences most likely can lie within the intraspecific variability or be connected with somewhat different areas of inhabitation. Teeth of the Kalmakpaian *Samotherium* have narrower crowns than those of the Pavlodar form.

The dominance of *Hipparion hippidiodus* in the latter locality, characteristic of the terminal Turolian faunas, may serve as indirect evidence of the age difference between the Gusinyi Perelet and Kalmakpai localities. Accordingly, we can correlate fauna from the Karabulak Formation of the Kalmakpai River with the very end of the Turolian and consider it to be younger than the Gusinyi Perelet fauna.

The paleomagnetic record also indicates the age difference of these localities. In the Gusinyi Perelet section, the bone beds are associated with reversely magnetized deposits that correlate with polarity Chron 6 and the Pontian of the Eastern Paratethys.

According to V.L. Yakhimovich[2] (oral communication, Yakhimovich *et al.*, 1990), deposits at the top of the Karabulak Formation show a reversed polarity; the bone bed is associated with the normal polarity zone (about 7 - 10 m thick); the lower, greatest part of the upper subdivision of the Karabulak Formation (about 17 - 20 m) is reversely magnetized; the lower subdivision is associated with the zone of predominantly normal polarity. Deposits at the base of this formation are reversely magnetized.

Two zones of reversed and normal polarity were distinguished in the Sarybulak Formation sediments.

Yakhimovich correlates the Karabulak Formation with the Gilbert paleomagnetic epoch, attributing the bone bed to the Cochiti event and the upper part of Chron 5; the Kalmakpai Formation, with the beginning of Chron 5 and Chrons 6, 7, and 8; and the Sarybulak Formation, with Chrons 12 and 13. She supposes the presence of a considerable hiatus between the Kalmakpai and Sarybulak Formations.

According to the data of M.A. Pevzner and E.A. Vangengeim (1986), the Turolian-Ruscinian boundary in the European continental stratigraphic scale must be placed within Chron 5 and almost coincides with the Miocene-Pliocene boundary. In the Eastern Paratethys stratigraphic scale, it is placed in the lower Kimmerian.

Basing on the pre-Ruscinian age of the Kalmakpai fauna, the paleomagnetic section on the Kalmakpai River can be interpreted in the following way (downward from the top).

Normally magnetized deposits with the bone bed, most likely correspond to the lower part of Chron 5 (basal Kimmerian); the reversed polarity zone, underlying the bone bed, to Chron 6, i.e., to the Pontian and Gusinyi Perelet beds of the Pavlodar Formation; normally magnetized deposits of the lower subdivision of the Karabulak Formation and top of the Kalmakpai Formation, to Chron 7, i.e., the Late Meotian. The Kalmakpai Formation sediments correlate with the beginning of Chron 7, Chrons 8 and 9, and the end of Chron 10 and correspond to the lower half of the Meotian and Late Sarmatian. The Sarybulak Formation can be correlated with Chrons 10 and 11, i.e., with the middle and part of the Early Sarmatian. The characteristic Astaracian forms *Anchitherium* sp. and *Amphicyon* sp., from the base of the Sarybulak Formation, agree well with this dating, suggested by L.K. Gabuniya ("Stratigrafiya ...," 1986). Regarding such interpretation of the paleomagnetic record, we consider that the section on the Kalmakpai River is free of large hiatuses, in particular, that between the Kalmakpai and Sarybulak Formations, which was supposed by V.L. Yakhimovich to correspond to the Early-middle Sarmatian. Accordingly, the stratigraphic volume of the Kalmakpai Formation becomes wider, whereas that of the Sarybulak Formation decreases.

CONCLUSIONS

The study of the taxonomic composition of the fossil mammalian fauna from the Kalmakpai River locality and correlation with the paleomagnetic record enables us to draw the following conclusions.

The Kalmakpai fauna is referred to the Turolian, i.e., we should place it in the terminal Miocene of the European stratigraphic scale. In the magnetochronologic scale, it corresponds to the lower part of Chron 5 and is stratigraphically younger than the fauna of the Gusinyi Perelet locality, which corresponds partly to the level of the Pavlodar Formation. The latter is correlated with Chron 6. The Novaya Stanitsa locality of the Irtysh River, with the lower Ruscinian fauna (Fig. 1), takes place at the boundary between polarity Chron 5 and the Gilbert epoch (Vangengeim *et al.*, 1984; Zykin *et al.*, 1989) and has a stratigraphically higher place than the Kalmakpai locality.

In Central Europe, the upper Turolian Baltavar locality in Hungary has the same position in the magnetochronologic scale as the Kalmakpai fauna. Deposits bearing fossil mammalian remnants (beds with *Unio wetzleri*) show a normal polarity and overlie the Pon-

[2] The authors are very grateful to V.L. Yakhimovich for permission to use her unpublished data on the paleomagnetic record of the Kalmakpaian section.

tian sediments that contain mollusks (Pevzner and Vangengeim, 1986). In Western Europe, the Messinian localities Baccinello and Brizighella in Italy may also be analogous, according to the carnivore mammal species (Rook, 1990).

The most essential change in the previous dating of the Kalmakpai fauna concerns its correlation with the European continental scale: it should be referred not to the Ruscinian, but to the Turolian. As for correlation with the Eastern Paratethys stratigraphic scale, the position of bone beds can now be defined more accurately: they correspond to the basal Kimmerian only.

The Kalmakpai fauna is not only one of the latest Turolian faunas in Asia, the richest among the precisely dated fossil assemblages of that period, but also marks the final Turolian stage of the last precrisis hipparion faunas preceding the Ruscinian.

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