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Paleogeographical reconstruction of the late neogene in the north-eastern part of Central Kazakhstan (The «Goose Passage» Site)

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Abstract. The study and identification of regularities of geological and paleogeographic development of Central Kazakhstan in the Cenozoic is fundamentally important for understanding the geological processes of Eurasia as a whole, as they were reflected in the marine and continental landscapes of the adjacent regions of Western Kazakhstan, Central Asia and Western Siberia. Practically from the beginning of the Cenozoic, a continental mode of sedimentation was established here, with landscapes of denudation plains and low highlands. Organic remains make it possible to dissect the Cenozoic continental strata and reconstruct the stages of landscape development from typically tropical and subtropical in the Paleocene and Eocene to steppe and savannah landscapes by the beginning of the Quaternary. The Goose Flight fauna locality is a stratotype of the Pliocene Pavlodar Formation. It is one of the largest localities of Miocene Hipparion fauna of Eurasia, located in the north-eastern part of Central Kazakhstan, on the Irtysh River, within the city limits of Pavlodar. The location «Goose flight» is comparable to such widely known localities of Hipparion fauna as Taralyk-Cher and Kholu (Russia, Tuva), Baode fauna in Shansi province in China, Grebeniki and Berislavsky in Ukraine, Taraclia in Moldova. The locality needs protection and defence as it is destroyed due to erosion of the banks of the Irtysh River and uncontrolled sampling. The article provides a description of the Pavlodar Formation sediments, its geological and palynological characteristics, as well as the history of the study of the Goose Flight locality, the most complete list of fossils, gives their environmental characteristics and concludes on the conditions of accumulation of the Pavlodar Formation strata.

Keywords: *Hipparion fauna, Pavlodar Formation, Late Miocene, paleogeography, Central Kazakhstan.*

1. Introduction

The study and identification of patterns of geological and paleogeographic development of Central Kazakhstan in the Cenozoic is fundamentally important for understanding the geological processes of Eurasia as a whole, since they were reflected in the marine and continental landscapes of the adjacent regions, being a connecting link and one of the main sources of sedimentary material removal. Practically from the beginning of the Cenozoic, a largely continental sedimentation regime had established here, forming the landscapes of denudation plains and low highlands.

The study of organic remains allowed reconstructing the changes in the geological situation, climate and biological diversity in Cenozoic times, as well as tracing the stages of landscape development from typically tropical and subtropical in the Paleocene and Eocene, to steppe and savanna by the beginning of the Quaternary. The study of the remains of Cenozoic flora and fauna is of great importance for the division and correlation of continental sediments. At the same time, each site adds new data to the mosaic reconstruction picture of the past environment.

Currently, on the territory of Central Kazakhstan, mainly in its western part, a large number of sites of leaf flora (imprints) and fauna of Oligocene vertebrates have been identified. The macroorganic Miocene sites occur in much smaller quantities, and the Quaternary ones are still unknown. Particularly well represented are the Oligocene and Early Miocene deposits, which contain rich paleontological material, on the basis of which the relative age of the deposits was determined and the past paleogeographic conditions were reconstructed. At a later time, the accumulation of sediments with remains of flora and fauna occurred much less frequently and more fragmentarily, which is associated both with a change in the type of vegetation (from mixed-deciduous forests in the Paleogene to steppes and deserts of the Quaternary), and with the general aridization of the climate and changing sedimentation conditions.

Late Neogene deposits, reflecting the initial stage of desertification of the territory of Kazakhstan, are widely represented in Central and North-Eastern Kazakhstan and are classified as the Pavlodar Suite. Its age is established as late Miocene. The stratotype of the Pavlodar Suite are sediments with a complex of classical hipparion fauna, exposed on the right bank of the Irtysh River, within the city of Pavlodar area (north-eastern part of Central Kazakhstan). One of the largest in Eurasia sites of hipparion fauna titled «Goose Passage» is located here, on the cliff of the floodplain terrace (Figure 1).

The site needs due protection and guarding, as it is being destroyed by the erosion of the Irtysh River banks and by uncontrolled sampling.

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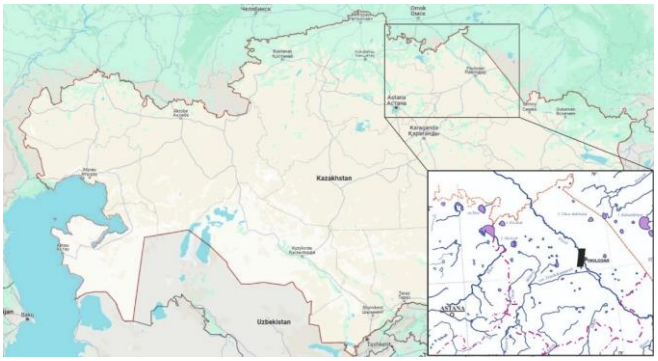

Figure 1. The location of the «Goose Passage» hipparion fauna site

Analysis of the compositional features of the «Goose Passage» fauna, as well as of the lithological, sedimentological and palynological characteristics of the host sediments, enables to reconstruct the paleoecological environment of the time of accumulation of these strata, the stages of development of the Neogene climate of Central Kazakhstan and replenish the paleobiogeographic materials.

2. Materials and methods

The proposed article rests on the paleontological materials previously obtained by B.U. Baishashov, as well as on data acquired during the study of numerous paleontological collections of different years at the «Goose Passage» site and stored mainly in the funds of the Institute of Zoology at the RK MES, as well as in the Pavlodar City Museum and the Paleontological Museum at the Russian Academy of Sciences (Moscow). For paleontological study, the taxonomic affiliation of the material was determined by measuring and comparing distinctive features with previously described reference samples.

Methodology consists in itinerary studies of the right bank of the Irtysh River, a layer-by-layer description of the section. The bones of vertebrates are deposited in red-brown clays with interlayers of greenish-brown dense sandy clays, in places turning into dense sandy loam. During field work, samples were taken for palynological analysis. Because of the site's location in the city park, the samples were taken out not from the cleared section, but from small clearings. For palynological analysis, samples were taken from the layers containing vertebrate bones and from the underlying and overlying sediments.

Also, materials acquired during the 2022-2023 field studies were utilised in the article in order to study sections of red-colored late Miocene clays commonly spread in Central, Eastern and South-Eastern Kazakhstan.

Palynological analysis of the samples was carried out in the palynological laboratory of the K.I. Satpayev Institute of Geological Sciences (Almaty), using generally accepted chemical processing techniques [40]. The method provides for the following sequence of work: 1) samples are treated with a 10% HCl solution to remove carbonates; 2) the samples are treated with a 5% solution of $Na_4P_2O_7$ H_2O to free them from clay particles, then are washed in distilled water; 3) the resulting sediment was centrifuged in a solution of heavy liquid [K2(CdI4)] with a specific gravity of 2.25-2.4 to separate the mineral and organic fractions. The macerate was treated with HF to remove silicate minerals. The resulting macerate was placed for storage in test tubes with glycerin. The macerate was not subject of sieving. The collection of palynological preparations is stored in the laboratory of Mesozoic and Cenozoic geology of the K.I. Satpayev Institute of Geological Sciences.

The study of palynomorphs was carried out with the Axiostarplus optical microscope (CarlZeiss) at a working magnification of ×400 and ×600. isolated from the red sediments were few amounts of palynomorphs, therefore all encountered specimens were counted: spores and pollen of plants, green algae, and fungi. Plant spores and pollen were identified to genus or family (in case of poor preservation).

2.1. The site study history and its current state

The study of this section has a history of more than a century [24]. In 1928, Yu.A. Orlov, on the territory of the city of Pavlodar, discovered one of the largest sites of the hipparion fauna of Eurasia, later called «Goose Passage». In 1929-1930, during excavations, employees of the Paleontological Institute of the USSR Academy of Sciences (now the A.A. Borisyak Paleontological Institute of the Russian Academy of Sciences) collected several thousand bone remains of vertebrates [35-39]. A special exhibition was created in the Paleontological Museum of the USSR, occupying a separate room, where the collected skeletons of hipparions, rhinoceroses and other animals were placed.

Since 1950s, the excavations were carried out by paleontologists of the Institute of Zoology at the Kazakh SSR Academy of Sciences, however, the found representative materials were scanty. In 1976, B.U. Baishashov, an employee of the Institute of Zoology, organized a special expedition and large excavations (Figures 2, 3, 4) using machinery. As a result, for the first time, more than 10 skulls of the rhinoceros Chiloteria alone and many bones of other mammals were obtained in the form of monoliths. This material allowed identifying distinctive features and describing a new species for science - Chilotherium orlovi Bayshashov, 1982 [5]. Most often in these deposits are the bones of hipparions, extinct equine mammals. They were widespread in the Miocene, and therefore the fauna was called hipparionic.

Figure 2. The bone-bed clearing at the «Goose Passage» site, 1976 (the B.U. Baishashov archive)

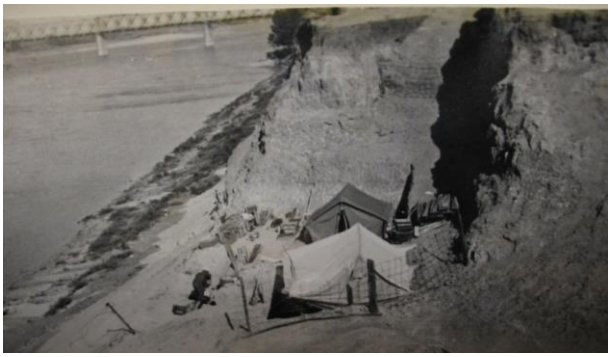

Figure 3. Excavation in progress, 1976 (the B.U. Baishashov archive)

Figure 4. B.U. Baishashov at the opening of bones and preparation of the monolith, 1976 (the B.U. Baishashov archive)

As a result of many years of research by specialists from Russia and Kazakhstan (B.U. Baishashov, F.A. Tleuberdina, V.V. Lavrov, L.L. Gaiduchenko and many others), more than 60 species of vertebrates of the hipparion fauna were identified at the «Goose Passage» site.

The question of the need for protection (geoconservation) of the «Goose Passage» site has been repeatedly raised by the scientific community since the mid-1950s. On December 7, 1971, the site of the hipparion fauna «Goose Passage» was declared a natural monument of republican significance and taken under state protection. In 1979, the Institute of Zoology of the Academy of Sciences of the Kazakh SSR and the Central Council of the Kazakh Society for Nature Conservation took the initiative to create the «Open Air Museum – «Goose Passage» to preserve this natural monument as a national treasure of the Republic of Kazakhstan, which represents a prototype of the fauna of African savannas with a variety of representatives of the ancient animal world.

In 1988, a decree was issued prohibiting spontaneous excavations on the territory of the «Goose Passage» natural monument without the appropriate permission.

In 2002, in the course of joint work carried out by employees of the Institute of Zoology (Almaty) and the Toraigyrov Pavlodar State University (Pavlodar), a number of measures were proposed to preserve this unique site [8].

Figure 5. The «Goose Passage» site. General view at present

To this day, the monument, despite repeated excavations, is far from being exhausted. Every year, after the Irtysh river floods and the collapse of the coastline caused by spring floods, a bone-bearing horizon is getting exposed here. Currently, for scientific purposes, quite a large amount of material has been acquired to the collections of the Paleontological Institute of the Russian Academy of Sciences (Moscow) and the Institute of Zoology of the Ministry of Education and Science of the Republic of Kazakhstan (Almaty) and there is no need to conduct new excavations. Scientific processing of available material, showing the importance of this unique site in reconstructing the landscape and climatic conditions of the past, is going on [10]. Despite the adopted statutory measures, actually the natural monument «Goose Passage» remain neglected and left to deteriorate.

3. Results and discussion

3.1. Geological description of the section

The Pavlodar Formation ($N_{1\text{-}2}$ *pv*) was identified in 1951 by V.V. Lavrov. The stratotype is described from deposits of the «Goose Passage» site, with the remains of a hipparion fauna. The age is determined by the vertebrate fauna and spore-pollen complexes as in the Upper Miocene - Lower Pliocene, Messinian-Zanclean stages.

The formation sections in the area are quite similar and are represented by lithologically homogeneous clays of brownish tints. They lie under Quaternary sediments of different ages. They are often separated from the underlying formations by a basal interval represented by sandy clays with gravel and pebbles. The thickness of the formation is 30-40 m.

Deposits of the Pavlodar formation are widespread and correlate with the sequence of the same name in the West Siberian Plain and Turgai [29]: it overlies the Aral (Kalkaman) (Bayshashov et al., 2015) formation and has a two-member structure, where sands lie at the base, above clay. The most typical rocks are red-brown clays. It is a carbonate formation with abundant marl nodules and interbeds. The deposits are saturated with fine-silty carbonates and also include calcareous-marly and, less commonly, gypsum nodules ranging in size from 3 to 7 cm. Sand in clays is noted both in a dispersed form and in the form of interlayers and lenses. Sandy-gravel deposits with pebbles often occur at the base of the formation. The paleontological characteristics are also similar, with common main species of animals and pollen of herbaceous plants, with a slight admixture of pollen of tree forms.

The Pavlodar Suite section. Compiled by B.U. Baishashov upon the 2022 filed work.

According to the European stratigraphic scale, this is the Turolian fauna of the late Miocene.

Middle-Upper Miocene. Serravalian - Messinian stages. Kalkaman Suite ($N_1^{2\text{-}3}$*kl*). It is represented by green gypsum-bearing clays of montmorillonite-hydromica composition, containing large druses of gypsum, interlayers of marls, dark gray clays, sands, and silts (40 m). The age is based on the vertebrate fauna in the adjacent area (along the Irtysh River).

Upper Miocene - Lower Pliocene. Messinian - Zanklian stages. The Pavlodar Suite ($N_{1\text{-}2}$ *pv*) is represented by deposits of different genesis, dominated by red-brown and green clays with interlayers of sand, loam, sand and gravel material, and characterized by calcareous-marly nodules (20-30 m). The age of the formation is established based on the mammal fauna.

Upper Pliocene. Piacenza Stage. The Irtysh Suite (N_2^2*irt*) is represented by bluish and brownish silty clays with sand interlayers (50 m). Irtysh Suite in outcrop near the village Lebyazhy along the river Irtysh and contains a fauna of mammals, freshwater mollusks and ostracods, which allows parallelizing it with the Bitekey Suite of the upper Neogene [4].

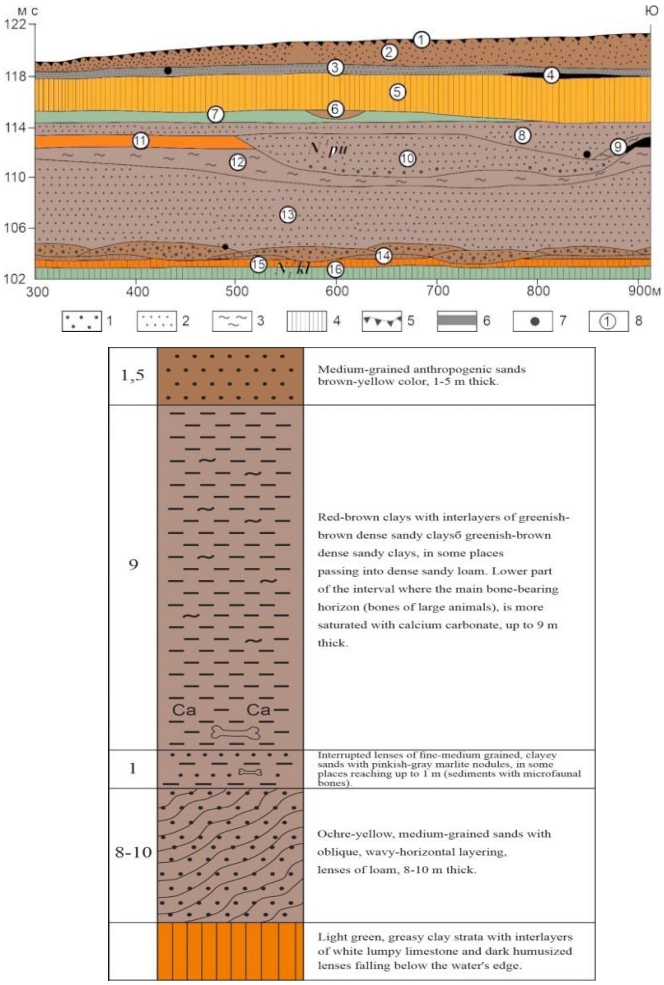

Figure 6. The section of the Pavlodar Suite according to [Zykin, 1982]

Figure 7. The «Goose Passage». Decaying bones

Figure 8. The «Goose Passage». Bones along with the rock material are exposed and washed away from the cliff wall

3.2. Palynological study

Clays of the Pavlodar suite contain single grains of pollen of xerophytic plants, and only small quantities of tree pollen are present: Betulasp., Alnussp., Corylussp., Pinusstrobus, R.sibirica.

In the lower part of the section (palynocomplex 1, 2), encountered were pollen of the oak Quercussp., hornbeam Carpinussp., hazel Corylussp., and the pollen of herbaceous forms is characterized by the dominance of pollen of cereals and wormwood.

The upper part of the section (palynocomplex 3) contains mainly pollen of herbaceous plants: wormwood, goosefoot and grasses, which indicates the development of treeless steppe landscapes on watersheds.

Palynocomplex 1:

Arboreal pollen 4-16%: Pinus, Betula, Ulmus, Alnus, single Carpinus, Quercus, Salix.

Herbaceous: 83-96%: pollen dominated by Poaceae (78%), Chenopodiaceae, Artemisia.

Palynocomplex2:

Arboreal ones make up 21-47% of all pollen forms encountered: a relative increase in the proportion of Pinus (50-80% of all arboreal ones), Betula (12-38%) and Picea, Corylus, Alnus, Quercus are also present.

Herbaceous species make up 53-79%: Artemisia and Chenopodiaceae predominate, forbs are represented by pollen of Asteraceae and cereals of Poaceae.

Palynocomplex3:

Arboreal ones make up 2-10%, mainly Pinus and Betula pollen.

Herbaceous-shrubs dominate in the spectra -95-100%, Artemisia predominates among them (80%) and also present are Chenopodiaceae, Asteraceae, Poaceae.

The composition of pollen and spores indicates the development of xerophilic vegetation and the existence of floodplain temperate-deciduous forests in river beds. These are probably elements preserved from earlier, heat-loving floras of the «Turgai ecological type», which became widespread in the late Oligocene-early Miocene and are well studied from leaf prints from the sites of Turgai, Central and Eastern Kazakhstan: Tortmola, Shintuzsky, Tortmola, Akmola, Nausha, Kenkous, Altyn-Shokysu, Kumsuat, Kintykche, Ashutas, etc. [Popova at all 2018, 2019, Nigmatova, 1998].

In the palynospectra of the Eocene-Oligocene deposits of the Takyrsor, Shintuzsay, Nausha, Erzhilansai sites (Turgai trough, Aquitanian), pollen grains of chenopods, amaranthaceae, wormwood, cereals and ephedra were found in small quantities (Abuzyarova, 1954, oral communication by Nigmatova S.A.), which also suggests that small steppe areas could have existed on the watersheds even in the Paleogene, which in the late Miocene, due to aridization, significantly expanded the area, displacing moisture- and heat-loving species.

5.3. Fauna analysis

The entire complex of widespread hipparion fauna has been established at the «Goose Passage» site. This fauna is special by the presence of sea pinnipeds *Semantormacrurus* [37-39] and turtles Chelodoniidae [33]. This is explained by the fact that the ancestral Irtysh river in the Miocene may have been connected to the sea.

By composition, the vast majority of large mammals are inhabitants of forest-steppe areas: giraffes *Samotheriumirtyshense* [18], *Sivatheriumsp., Palaeotragusasiaticus* [18-19]; deer *Cervavitusorlov* Flerov, 1950, *Tragocerusirtyshense, T. frolovi*, [1]; gazelles *Gazelladorcadoides* Schlosser (Dmitrieva, 1974), *G. deperdita*, *Procapreolus sp*.; mastodons *Mastodonsp.* [37-39] and inhabitants of coastal areas the rhinoceroses *Chilotherium orlovi* (Baishashov, 1993). Steppe forms are represented by long-legged hipparions *Hipparion longipes* [20, 22] classifies the hipparion *H. elegans* as an inhabitant of forest-steppe areas. Carnivores are represented by the typical companions of the hipparion fauna: hyenas *Hyaenictitheriumvenator, Ictitheriumhipparionum, I.robustum, Crocutaeximia*; *Machairodusirtyschensis* the saber-toothed tiger, mustelids *Plesiogulocf. crassa* Teilhard, *Martespaleosinensis* Zdansky. Collections of institutes in different countries contain fragmented materials, which prevents from accurate counting of specimen and bones of large vertebrates. Only collections of the Institute of Zoology at the RK MES preserve more than a thousand samples of bone remains.

Among small vertebrates, amphibians and rodents predominate. All previously known fragments of toad bones from this site, according to N.V. [21], belong to one species, Mongolian *Bufo raddei*. Out of this, K.I. Iskakova defined lizards, snakes, and frogs; G.D. Hisarova identified fish *Liciopterca sp., Perca sp*.; freshwater turtles *Sakya sp.* [48]; and birds *Struthiochersonensis, Sushkina pliocaena* [45].

By species, P.F. Savinova 1959, 1960 and 1976 (1988) and L.A. Tyutkova (2003, 2005), established the presence of the following rodents: Clirinaegen.?, Ruscinomyinaegen.?, *Microtoscoptes praetermissus* Schaub, 1934, *Spermophilus cf. orientalis* Qiu, 1991, *Sinocricetus zdanskyi* Schaub, 1930, *Nannocricetus mongolicus* Schaub, 1934, *Sicista bagajevi* Savinov, 1970, *Lophocricetus vinogradovi* Savinov, 1970, *L. afanasievi* Savinov, 1970, *Paralactaga (=Proalactaga) varians* Savinov, 1970, *Brachiscirtetes robustus* Savinov, 1970, *Scirtodipus kazakhstanica* Savinov, 1970, *S. kalbica* Savinov, 1970, *Rhinoceromys savinovi* Tyutkova, 2005. Lagomorphs *Proochotonacf. eximia* Chomenko, 1914.

The species composition of small mammals also indicates the forest-steppe landscape of the region. Some of them: shrews *Similisorex orlovi, Crocidura pavlodarica*, possibly hamster-like animals *Microtoscoptes sibiricus*, etc. are inhabitants of river floodplains. There are also forest inhabitants: squirrels *Eutamias sp.*, Myoxinae gen. indet. According to [44], the composition of the goosepassagean microtheriocomplex is dominated by hamsteriformes (54%), followed by jerboas *Lophocricetus* (14.5%), *Proalactaga* (8.5%), *Scirtodipus* (7.3%). Modern creepers and jerboas of Kazakhstan mainly inhabit steppe areas, but in the past, their ancestors could well have lived in the forest-steppe zone.

Table 1. The systematic composition of the hipparion fauna at the «Goose Passage» site

Class	Subclass	Order	Suborder	Family	Subfamily	Genus	Species	Habitat
OSTEICHTHYES (bony fish)	ACTINOPTERYGII (ray-finned)	PERCIDA (perciformes)	PERCOIDEI (perciformes)	Percidae Bonaparte, 1831		Perca Linnaeus, 1758	Perca sp.	Water
AMPHIBIA (amphibians)		ANURA (tail-less)	PROCOELA (procoelous)	Bufonidae Fitzinger. 1826		Bufo Laurenti, 1768	Buforaddei Strauch, 1876	Amphibious
			OPISTHOCOELA (opistho-coelous)	BombinidaeFitzinger. 1826				
				Bombinidae gen. indet.				
				PelobatidaeBruch, 1861				
				Pelobatidae-gen. indet.				
			DIPLASIOCOELA (diplasio-coelae)	Ranidae Linnaeus, 1758				
				Ranidae gen. indet.				
REPTILIA (reptiles)	TESTUDINATA (testudinata)	CHELONIA (sea turtles)		Platysternidae Gray, 1870		Sakya Bogachev, 1960	Sakua sp.	Water
	LEPIDOSAURIA (scaly)	LACERTILIA (lizards)	SCINCOMORPHA	Lacertidae Fitzinger, 1826				
				Lacertidae gen. indet.				
			IGUANIA (iguaniformes)	Agamidae Gray,1827				
				Agamidaegen. indet.				
		OPHIDIA (snakes)	Colubroideafam. indet.					
AVES (birds)		STRUTHIONIFORMESLATHAM, 1790 (ostriches)		Struthionidae Vicords,1825		Stuthio Linnaeus,1758	Struthio sp.	
		ACCIPITRIFORMESSAVIGNY, 1809 (diurnal predators)		Falconidae Anonymou, 1820		Sushkinia Tugarinov, 1935	Sushkinia pliocaena Tugarinov, 1935	Forest-steppe

		GALLIFORMES TEMMINCK,1820 (chicken)		Gallidae Illiger, 1811		Palaeoperdix Milne-Edwards, 1871	Palaeoperdix sp.	
		RALLIFORMES REICHENBACH, 1849 (rails)	GRUES BONAPARTE, 1854 (cranes)	Ergilornithidae Kozloa, 1960		Amphipelargus Lydekke, 1891	Amphipelargus sp.	
		PASSERIFORMES LINNAEUS, 1758 (passerines)		Motacillidae Vigors, 1825		Anthus Bechstein, 1805	Anthusseductus, Kurochkin, 1985	
							Anthussp.	
				Emberizidae gen.indet.				
				Alaudidae gen. indet.				
MAMMALIA (mammals)		INSECTIVORA BOWDICH, 1821 (insectivore)		Soricidae Fischer vonWaldheim, 1817		Similisorex	Similisorexorlovi, Stogov et Savinov, 1965	Foreststeppe
				Crocidurini Stirton, 1930		Crocidura Wagler, 1832	Crocidura pavlodarica Stogov et Savinov, 1965	
				Erinaceidae Fischer vonWaldheim, 1817		Schizogalerix Engesser, 1980	Schzogalerix sp.	
		RODENTIA BOWDICH,1812 (rodents)		Cricetidae Fischer vonWaldheim, 1817	MicrotinaeCope, 1891	Microtoscoptes Schaub, 1934	Microtoscoptes praetermissus Schaub, 1934	Foreststeppe
				Sciuridae Gray, 1821	XerinaeOsborn, 1910	Spermophilus Brandt, 1852	Spermophilus cf. Orientalis Qiu, 1991	Foreststeppe
					MarmotinaePocock, 1923	Tamias Illiger, 1811	Tamias (Eutamias) sp.	
				Gliridae Thomas, 1807	Glirinae (=Mioxinae) Thomas, 1807			
					Glirinaegen. indet.			
				Dipodidae Waterhouse, 1842	Sminthinae Murray,1866	Sicista Gray, 1827	Sicista bagajevi Savinov, 1970	Foreststeppe
					LophocricetinaeSavinov, 1970	Lophocricetus Schlosser, 1924	Lophocricetus vinogradovi Savinov, 1970	Foreststeppe
							Lophocricetus afanasievi Savinov, 1970	Foreststeppe
					AllactaginaeVinogradov, 1925	Paralactaga Young, 1927	Paralactaga (=Proalactaga) varians (Savinov, 1970)	Foreststeppe
						Brachiscirtetes Schaub, 1934	Brachiscirtetes robustus Savinov, 1970	Foreststeppe
					DipodinaeVinogradov, 1925	Scirtodipus Savinov, 1970	Scirtodipus kazakhstanica Savinov, 1970	Foreststeppe

							Scirtodipus kalbica Savinov, 1970	Forest-steppe
				Tachyo-ryctoididae Schaub, 1958		Rhinoce-romys Tyutkova, 2005	Rhinocero-mys savinovi,Ty utkova, 2005	Forest-steppe
		LAGOMORPHA BRANDT, 1855 (Lagomorpha)		Lagomyidae Lilljeberg, 1866	Lagomyin-aeLilljeberg, 1866	Proochoto-na Khomen-ko, 1914	Proo-chotonacf. Eximia Chomenko, 1914	Forest-steppe
		CARNIVORA BOWDICH, 1821 (carnivores)	FISSIPEDIA BLUMENBACH , 1791 (true carnivores)	Mustelidae Swainson, 1835	MustelinaeGill, 1872	Martes Frisch, 1775	Martes paleosinen-sis Zdansky, 1925 ?	Forest-steppe
						Plesiogula Zdansky, 1924	Plesiogula cf. Crassa Teilh. De Chard., 1945	Forest-steppe
				Hyaenidae Gray, 1869	HyaeninaeMi-vart, 1882	Crocuta Kaup, 1828	Crocuta (=Percrocut a) eximia Roth et Wagn., 1855	Forest-steppe
					Ictitheriinae-Touessart, 1897	Ictitherium Wagner, 1848	Ictitherium hipparionum Gervais 1846	Forest-steppe
							Ictitherium robustum Gervais, 1850	Forest-steppe
						Hyaenic-titherium	Hyaenic-titherium venator	Forest-steppe
				Felidae Gray, 1821	MachairodontinaeGill, 1872	Machairo-dus Kaup, 1883	Machairo-dus ir-tyschensis Orlov, 1936	Forest-steppe
		PERISSODACTYLA OWEN, 1848 (peris-sodactyls)	HIPPOMORPHA WOOD, 1937	Equidae Gray, 1821		Hipparion de Chris-tol, 1832	Hipparion longipes Gromova, 1952	Steppe
							Hipparion elegans Gromova, 1952	Forest-steppe
		CERATOMORPHA WOOD, 1937		Rhinoce-rotidae Owen, 1845	Acera-theriinaeDoll, 1885	Chilotheri-um Ring-strom, 1924	Chilotheri-um orlovi (=schlosseri) Bayshash-ov, 1982	Forest-steppe
					RhinocerotinaeOwen, 1845	Sinotheri-um Rhig-strom, 1922	Sinotherium sp.	
		ARTIODACTYLA OWEN, 1848 (artio-dactyls)	RUMINANTIAS COPOLI, 1777 (ruminants)	Cervidae Gray, 1821	CervinaeBaird, 1857	Cervavitus Flerov, 1950	Cervavitus orlovi Flerov, 1950	Forest-steppe
					Obo-coileinaePococ, 1923	Procapreo-lus Schlosser, 1924	Procapreo-lus sp.	Forest-steppe
				Girafidae Gray, 1821	Palaeotragi-naePilgrim, 1911	Palaeotra-gus Gaudry, 1861	Palaeotragus asiaticus Godina, 1975 ?	Forest-steppe
						Samotheri-um F. Major, 1888	Samotheri-um ir-tyshense Godina, 1962	Forest-steppe

					Sivatheriina-eZittel, 1893	Sivatheri-um Fal-coner et Cautley, 1835	Sivatherium sp.	Forest-steppe
				Bovidae Gray, 1821	BovinaeGill, 1872	Tragocerus Gaudry, 1861	Tragocerus irtyshense Abdrach-manova, 1974	Forest-steppe
							Tragocerus frolovi M. Pavlova, 1913	
						Mi-otragoce-rus Stro-mer, 1928	Miotragoce-rus cf. pannoniae, Kretzoi, 1941	
					Antilop-inaeBaird, 1857	Gazella Blainville, 1816	Gazella dorcadoides Schlosser, 1903	Forest-steppe
							Gazella deperdita Gervais, 1848	
					Hippotragi-naeBrooke, 1876			
					Hippotraginae-gen. indet.			
		PROBOSCIDEA ILLIGER, 1811 (proboscidian)	ELEPHANTOIDEA OSBORN, 1921	Mastodonti-dae Girard, 1852		Mastodon G.Cuvier, 1806	Mastodon sp.	Forest-steppe
		PINNIPEDIA (pinnipeds)		Semantoridae Orlov, 1931		Semantor Orlov, 1931	Semantor marcrurus Orlov, 1931	Marine water

In regard to species, about 60% of the vertebrate fauna of the «Goose Passage» relate to the forest-steppe zone, 17% to aquatic and amphibians, 9% to the steppe, 8% to inhabitants of coastal areas, 6% to inhabitants of forests.

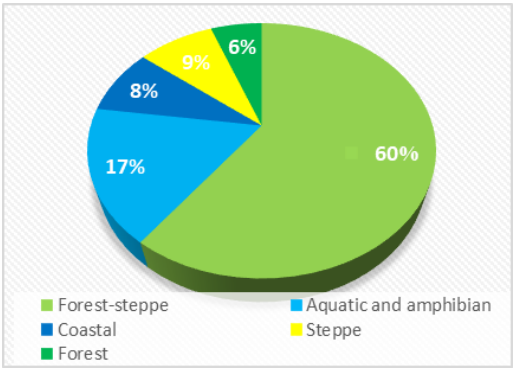

Figure 9. Ratios of major species by ecological habitat zones

Hipparions are one of the forms of horses, linking small Eocene inhabitants of wetland forests (with four toes on the forelimbs and three toes on the hind limbs (*Hyracotherium*)) to modern steppen, single-toed forms (*Equus.* Hipparions); they lived during the second half of the Miocene to the second half of the Pliocene, when a change happened in landscapes from warm-temperate forest zones to arid forest-steppe and steppe zones. [20] divides hipparions into two ecological types: one lived in a more forested landscape with moist soil, soft and succulent vegetation, and the other lived under more xerophilic conditions.

The second most numerous vertebrates after Hipparion at the «Goose Passage» are Rhinoceros Chiloteria. Accounting for known distinctive features of the Chinise *Chiloteri-umanderssoni* and the Ukrainian Grebeniki and Berislava *Chilotherium schlosseri*, *Ch. sarmaticum*, this species of rhinoceros was described as *Chilotherium orlovi* [5], named so after the discoverer of this site, Yu.A. Orlov.

Ringstrom T. [42], describing rhinoceroses of the genus *Chiloterium*, considered them to be inhabitants of steppe biotopes, pointing to development of hypsodont teeth, the position of incisors in the lower jaw and the elongation of middle fingers relative to the lateral ones. According to E.I. Belyaeva [15], Chilotherium, like other short-legged rhinoceroses, lived in low-lying, wet and swampy places. V.I. Gromova (Gromova 1954) noted some features of convergence in the structure of limbs of chilotheriums and swamp rhinoceroses (wide shoulder blade, shortened limbs, widened and inactive hands and feet, etc.). E.L. Korotkevich (1970) allowed the existence of some later forms in steppe zones, and Sarmatian chilotherium, in her opinion, lived in coastal wooded-swampy biotopes. Hypsodontism of their teeth could have developed due to the grinding of hard marsh vegetation.

B.U. Baishashov, based on structural features of the skeleton of *Ch. Orlovi* believes that they lived in low-lying, coastal areas with abundant vegetation and, apparently, spent most of their time in shallow bodies of water. Perhaps this, to some extent, served as their protection from predators. Being in low, swampy places or water bodies, Chilotherium fed on abundant coastal plants and therefore did not need to tilt its head down much. Short limbs also contributed to this.

By size and some signs of evolutionary development, all chilotheria can be divided into groups:

– the small form (*Ch. sarmaticum*) - with weakly molarized, relatively narrow high teeth, less adapted to coastal areas, known from Sarmatian deposits of the Berislav site in Ukraine;

– the middle form (*Ch. anderssoni* and *Ch.schlosseri*) with well-molarized front molars, adapted to living in coastal areas, known from the Maeotic deposits of the Shanxi site of China and the Maeotic deposits of south-eastern Europe;

– the large form (*Ch. orlovi*) with relatively wide, more molarized front molars, with a long and wide symphysis, more adapted to the coastal, aquatic habitats, from Pavlodar.

Figure 10. The skeleton of a hipparion in the paleontological museum of Almaty

Figure 11. The skeleton of a chylotherium rhinoceros (Ch. orlovi) in the paleontological museum of Almaty

Another group of Pavlodar rhinoceros, *Sinotherium* (Ringstrom, 1922), is poorly studied, because their remains are extremely rare. These rhinoceroses were the ancestors of steppe Elasmotheriums, probably still in the stage of transition from wet forest-steppe to steppe biotopes. They were first described in China, from the Maeotic site of Shanxi. So far, only minor fragments of bones of the post-cranial skeleton have been found in the «Goose Passage». Much better material in the form of a fragment of the skull and some bones of the limbs was discovered in Kazakhstan from the deposits of the Karabulak Suite of the Zaisan depression, Kalmakpai site [6, 9], which belongs to another, later species.

Analysis of the data shows that the classic hipparion fauna of Pavlodar, reflecting the heyday of its biodevelopment and distribution, belongs to the upper part of the MN 12 biozone and the beginning of the MN 13 biozone. It should be noted that according to V.S. Zazhigin et al. (2002), «Goose Passage» rodents show an age of MN 12.

The Pavlodar fauna correlates with the Kalmakpai fauna (Karabulak Suite) at the Kalmakpai site (Eastern Kazakhstan, Lake Zaisan). However, the Kalmakpai fauna (Karabulak) is younger than that of Pavlodar. The fauna of the Karabulak Suite with a late Hipparine faunal complex belongs to the end of the MN 13 biozone and the first half of the MN 14 biozone.

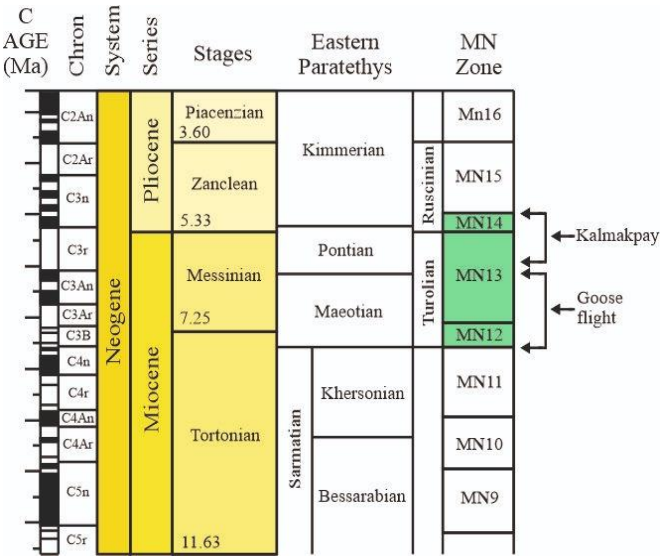

Figure 12. Stratigraphic distribution of the hipparion fauna at «Goose Passage» and Kalmakpai sites

The probable gap in absolute age between these two deposits of hipparionic faunas is 1-1.5 million years.

Thus, analysis of data on the oryctocenosis of the hipparion fauna of the «Goose Passage» site shows that at the end of the Miocene this territory had a vast forest-steppe zone, rich in vegetation, with lake-river sites.

4. Conclusions

The Miocene (23.0–5.3 million years) marked the last period of warm climate at the planetary level. The warm climate and abundance of precipitation on the territory of Eurasia in the Lower-Middle Miocene favoured development of forests, extremely diverse and rich in taxonomic composition (Popova at all 2018, Florent Rivals at all, 2024, N. V. Zelenkov et al., 2022), with domination of deciduous trees: various types of walnut, elm and beech; evergreen plants (myrtle, laurel, magnolia), lianas were widespread, and preserved among conifers were taxodiaceae (Kornilova, 1966, Nigmatova, 1998). Such flora is known in the literature as the warm-temperate flora of the Turgai ecological type. The Late Oligocene-Early Miocene was characterized by the development of the indricotherium (Turgai) fauna. It was studied for the first time in the territory of the Turgai trough by A.A. Borisyak (1915), who described the hornless rhinoceros Indricotherium from this area, typical of the Turgai fauna. One of the main elements of the Turgai fauna were odd-toed ungulates, chalicotherium, some rodents, and predators; among artiodactyls, the pig-like Entelodon, Anthrocoterium, swamp (aminodont) rhinoceroses, as well as tapiroids. In addition, the indricotherium fauna included insectivores, predators, ancient lagomorphs, rodents and others. Among the artiodactyls there were representatives of Cetancodontamorpha (anthracotherium and entelodons), as well as primi-

tive ruminants - short-legged (Lophiomeryx) and long-legged (Prodremotherium) deer. In addition to mammals, the Turgai fauna included birds, turtles, fish, insects and mollusks. The vast space inhabited by this fauna was heterogeneous in composition.

Later, the warm-temperate flora of the Turgai ecological type gave way to the more xerophytic, «Mediterranean», flora of the Kushuk site [Kornilova, 1964], with predominance of narrow-leaved forms. As noted by V.S. Kornilova, flowering plants, with few exceptions, are represented by deciduous small-leaved forms, modern analogues of which now live in Western Asia and the Mediterranean.

In the early Miocene, a radical restructuring of the mammal fauna occurred. Within the Turgai trough, the so-called gomphotherian fauna developed, its remains were first collected in the Kushuk site. This is so far the only site characterized by rhinoceroses - Aceratherium deperetiBoriss., Brachiopoterium aurelianensevar. gailitiBoriss., in addition, the earliest large proboscideans for Eurasia were established here: mastodons MastadonatavusBoriss., serridentinusBoriss. etBel.

In the late Miocene (~10–9 million years ago), the zone of continuous forests was divided into separate massifs, gradually decreasing in size. Forest broad-leaved vegetation gradually retreated from the plains to mountainous areas, and into the wide valleys of numerous rivers, losing the most vulnerable heat-loving elements. In the central and western parts of the territory, lakes (often salty) and quickly drying oxbow lakes were preserved, facilitating the survival of remains of the flora and fauna.

In the open spaces between river valleys, sparse woods were replaced by dry savannas.

In the temperate latitudes of continental Eurasia in the late Miocene, due to the degradation of broad-leaved woods, steppe associations formed with wormwood-grass vegetation. In Central Europe, in the south of Eastern Europe, in Kazakhstan, Mongolia, began the «process of great steppezation» [34], the reason for this was the neotectonic activation of the earth's crust at the Paleogene-Neogene boundary (23 million years ago), «expressed in the general uplift of the continent and the formation of modern mountain systems. The consequence of these processes is a powerful regression of the Paleogene epicontinental seas, orographic isolation and a sharp increase in the continental climate of the interior regions of Eurasia» [1]. At the same time, the forest-steppe zone became isolated as a transitional type. As aridization intensified, semi-deserts and deserts with saxaul, ephedra, etc. appeared in temperate latitudes.

The diversity of landscapes has contributed to the emergence of different ecological niches for herbivores and predatory mammals.

In the second half of the Miocene, valley and lowland forests transformed from subtropical swamps into broad-leaved forests. At the same time, in the interfluve spaces, open forest gives way to savanna-steppe, first meadow and then dry. Landscapes are becoming increasingly open, with grassy cover, which favors the existence of ungulates. In the forest-steppes and steppes of Eurasia, the anchitherium fauna (genus Anchitherium - a small horse with three-toed limbs) developed, which has ecological differences in the arid and humid regions of Eurasia. In addition, this included a variety of rhinoceroses, mastodons, tragulids, muntjac deer, pig-like animals, gazelles, large chalicotheriids, rodents, and turtles (Bazhanov, 1955).

In Central Kazakhstan, Mongolia, and China, it included a variety of forest and forest-steppe animals: muntjac deer, mastodons, gazelles and rodents, which enabled V.S. Bazhanov to identify a more xerophilous variant of the anchiterium fauna into a special «muntjac complex» that lived in a forest-steppe landscape [16].

In Kazakhstan, remains of vertebrate anchiterium fauna are known in Torgai, Central Kazakhstan, North-Eastern Ustyurt on the coast of the Aral Sea, in the Pavlodar Irtysh region, in the Zaisan depression.

The direct trans-Mediterranean contact between Europe and Africa, which appeared in the mid-Miocene, facilitated widespread animal migration. From Africa come elephants, mastodons, giraffes, hippos, and hyenas. The emergence of open landscapes in Beringia, until that time exclusively forested, determines the wide migration routes of the steppe fauna of Asia and America. From America come herbivorous (that is, not leaf-eating) horses, felines, and canine predators, and from Asia - bulls and antelopes.

Communities of forest mammals of the anchiterian fauna were gradually replaced by animals adapted to life in open spaces. It also contains giraffes, rhinoceroses, mastodons, deer, antelopes, gazelles, ostriches, numerous rodents and true predators: saber-toothed tigers (mahairods), bears, hyenas, oth. By the end of the Tortonian age (~7.2 million years ago), on the territory of Central Kazakhstan, an ecosystem is being formed that is most similar to the ecosystem of the modern African savanna.

In the late Miocene and early Pliocene, the next phase of rapid cooling and continentalization of the climate begins. Geobotanical zoning becomes even more contrasting and complex. At the end of the Miocene, due to the onset of a drier climate, almost universal development of steppe vegetation is observed; vast spaces covered in the Paleogene and in the first half of the Neogene by subtropical forests take on the character of steppes and forest-steppes, the area of the latter also increases and due to the increase in land mass due to the partial liberation of continents from the seas that covered them.

Due to the general advance of the steppe into forests, the living conditions of some of its inhabitants are deteriorating, some of whom are dying out, others are migrating, following the remnants of forest flora in river valleys and into the mountains. At the same time, thanks to the strong development of herbaceous vegetation, the ungulate fauna that inhabited the steppes and forest-steppes quickly flourishes and widely spreads, and the hipparion fauna starts to blossom.

The largest sites of hipparion fauna amaze with the accumulation of some animals: giraffes, rhinoceroses, hipparions. In Kazakhstan, such sites include, in addition to «Goose Passage», the Tulkisai ravine in Torgai near the city of Arkalyk, the Kalmakpai mountains in the Zaisan region, on the shore of Lake Karabastuz in the Semipalatinsk's Irtysh region, in the Almaty region near the village of Saty (the Bota-Moinak pass) and in the Esekartkan ravine in the Tekes depression. However, in regard to number of species and abundance of bone remains, the fauna of «Goose Passage» is the most representative.

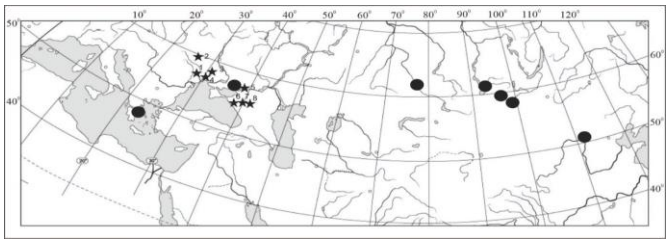

Figure 13. The diagram of the distribution of the hipparion fauna sites in Eurasia

The climate of the late Pliocene had, preserved to this day, the characteristic features of a continental climate, which was determined by the position of Kazakhstan within the Eurasian continent.

In most of the territory of modern Kazakhstan, a mild monsoon climate developed and there were open, mostly flat, shallow-hill spaces with the participation of cereals in the northern part (savanna type), with deciduous forests of elm, poplar, willow, linden, walnut, and oak in the floodplains of numerous rivers and with the dominance in the southern part and on the watersheds of wormwood, goosefoot, cereals, fruit and nut groves in the river valleys [3]. Only in the very south did low mountains rise, covered with pine and spruce trees and fruit forests in the foothills.

The open savannah spaces were inhabited by the Auvergne mastodon, the southern forest elephant, Stenon's one-toed horse (later the Sanmien horse), gazelles, goitered gazelles, giant camels and Prebactrian camels, as well as ostriches of the genus Struthio. The wooded interfluves were inhabited by the southern elephant (the Ili faunal complex, analogous to the Khaprovsky one) [17].

Thus, the study of the hipparion fauna of the «Goose Migration» allows reconstructing the development of forest-steppe and steppe landscapes of the temperate zone, complementing the holistic picture of the development of the arid climate of Eurasia. This is an important geological and paleontological site, comparable to such well-known sites of hipparion fauna as Taralyk-Cher and Kholu (Russia, Tuva), the Baode fauna in Shanxi Province in China, Grebeniki and Berislavsky in Ukraine, Chobruchi, Tudorovo, Taraclia in Moldova [27, 28, 49].

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Орталық Қазақстанның солтүстік-шығыс бөлігіндегі (Қазғұш өткелі аймағы) соңғы неоген дәуірінің палеогеографиялық реконструкциясы

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Аңдатпа. Орталық Қазақстанның кайнозой дәуіріндегі геологиялық және палеогеографиялық дамуының заңдылықтарын зерттеу мен анықтау Еуразияның геологиялық процестерін түсіну үшін өте маңызды, өйткені бұл процестер Батыс Қазақстан, Орталық Азия және Батыс Сібірдің көршілес аймақтарындағы теңіз және құрлықтық ландшафттарда көрініс тапқан. Кайнозой дәуірінің басынан бастап мұнда шөгінділердің континенттік режимі қалыптасып, денудация жазықтары мен аласа таулы аймақтардың ландшафттары басым болды. Органикалық қалдықтар кайнозой дәуірінің құрлықтық қабаттарын жіктеп, палеоцен мен эоцен кезеңдеріндегі тропикалық және субтропикалық ландшафттардан бастап төрттік дәуірдің басындағы дала және саванна ландшафттарына дейінгі кезеңдердің дамуын қайта қалпына келтіруге мүмкіндік береді. Қазғұш өткелі фаунасы орны – плиоцен кезеңінің Павлодар формациясының стратотипі болып табылады. Ол Орталық Қазақстанның солтүстік-шығыс бөлігінде, Ертіс өзенінде, Павлодар қаласының аумағында орналасқан Еуразиядағы миоцен кезеңінің гиппарион фаунасының ең ірі орындарының бірі.

«Қазғұш өткелі» орны Ресейдің Тува аймағындағы Таралық-Чер және Холу, Қытайдың Шаньси провинциясындағы Баодэ фаунасы, Украинаның Гребеники және Бериславский, сондай-ақ Молдованың Тараклия сияқты кеңінен танымал гиппарион фаунасы орындарымен салыстыруға болады. Бұл орын қорғауды қажет етеді, өйткені ол Ертіс өзенінің жағалауының эрозиясы және бақылаусыз үлгі жинау салдарынан бұзылуда. Мақалада Павлодар формациясы шөгінділерінің сипаттамасы, олардың геологиялық және палинологиялық ерекшеліктері, сондай-ақ Қазғұш өткелі орнын зерттеу тарихы, қазба қалдықтарының ең толық тізімі, олардың экологиялық сипаттамалары беріледі және Павлодар формациясы қабаттарының жиналу жағдайлары туралы қорытындылар жасалған.

Негізгі сөздер: *гиппариондық фауна, Павлодар формациясы, кеш миоцен, палеогеография, Орталық Қазақстан*.

Палеогеографическая реконструкция позднего неогена в северо-восточной части Центрального Казахстана (место «Гусиный переход»)

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Аннотация. Изучение и выявление закономерностей геологического и палеогеографического развития Центрального Казахстана в кайнозое имеет фундаментальное значение для понимания геологических процессов Евразии в целом, поскольку они нашли отражение в морских и континентальных ландшафтах прилегающих регионов Западного Казахстана, Центральной Азии и Западной Сибири. Практически с начала кайнозоя здесь установился континентальный режим осадконакопления с ландшафтами денудационных равнин и низких возвышенностей. Органические остатки позволяют расчленить континентальные отложения кайнозоя и реконструировать этапы развития ландшафтов - от типично тропических и субтропических в палеоцене и эоцене до степных и саванных ландшафтов к началу четвертичного периода. Фаунистическая местность «Гусиный перелет» является стратотипом плиоценовой Павлодарской формации. Это одно из крупнейших местонахождений гиппарионовой фауны миоцена Евразии, расположенное в северо-восточной части Центрального Казахстана, на реке Иртыш, в черте города Павлодар. Местность «Гусиный перелет» сопоставима с такими широко известными местонахождениями гиппарионовой фауны, как Таралык-Чер и Холу (Россия, Тыва), фауна Баодэ в провинции Шаньси (Китай), Гребеники и Бериславский (Украина), Тараклия (Молдова). Это местонахождение нуждается в охране, так как разрушается из-за эрозии берегов Иртыша и неконтролируемого отбора образцов. В статье приводятся описание отложений Павлодарской формации, их геологические и палинологические характеристики, а также история изучения местонахождения «Гусиный перелет», наиболее полный перечень фауны, их экологические характеристики и сделаны выводы об условиях накопления отложений Павлодарской формации.

Ключевые слова: *гиппарионовая фауна, Павлодарская формация, поздний миоцен, палеогеография, Центральный Казахстан.*

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