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# Possibilities for reconstructing the paleoclimate of the paleogene and neogene based on the study of fossil flora (using the example of the paleoflora of the Uly-zhilanshik river)

**Abstract.** *The article provides an analysis of Cenozoic floras collected and studied at different times in the valley of the Uly-Zhilanshik River (South Torgai Depression, Kazakhstan), and also discusses the prospects for reconstructing the Cenozoic paleoclimate based on the study of fossil floras. The Uly-Zhilanshchik River valley is a key area for understanding the processes of environmental change in the Paleogene and Neogene. These studies of these paleofloras make it possible to reconstruct paleogeographical conditions: paleolandscapes and climate change. It was shown that floras of the same age were not of the same type and had their own regional characteristics. Floristic composition represented in floras from sediments of different ages along the river. Uly-Zhilanshik, allows us to trace the stages of retreat of the Chegan Sea and further aridization of the territory.*
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**Key words:** *Uly-Zhilanshik, paleoflora of the Torgai type, fossil floras, Paleogene, Neogene, localities*

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## Introduction

Southern Torgai is a necessary area for the transformation of the processes of formation and development of the steppe and desert zones of Eurasia [1]. It is located in the central part of the Kazakh shield, separating the West Siberian and Turanian plates. In this territory, from the beginning of the Cenozoic, a continental regime was established with landscapes of denudation conditions and low highlands, which served as a kind of buffer between the marine regime in the western part of Kazakhstan and the purely continental regime in the eastern part. On the territory of Central Kazakhstan, Cenozoic deposits are well exposed and contain rich paleontological material, on the basis of which it is possible to determine both the relative age of the deposits and its paleogeographic characteristics and climate.

Studying and identifying the direction of development of paleofloras of Central Kazakhstan is fundamentally important for understanding the general direction of change in the composition of ancient and modern floras of Eurasia, since they reflect the characteristics of the vegetation of Western Kazakhstan, Central Asia and Western Siberia, being a connecting link and one of

the main sources of flora migration. Within the framework of the grant project AP19677563 "Research of the paleoflora and climate of Central Kazakhstan at the boundary of the Oligocene and Miocene and the initial stage of desertification of the region" (2023-2025), extensive geological and paleontological material was collected, allowing for a review of previously completed studies of the fossil floras of Central Kazakhstan and Turgai and highlighting the most interesting areas in paleogeographical terms.

An unique object for studying the diversity of Paleogene and Neogene paleoflora is the Turgai trough, where thick Cenozoic continental deposits with a high saturation of these strata with organic, and in particular plant remains are developed and exposed in many places [2].

The Uly-Zhilanchik River (Kazakh: Uly Zhylanshyk) is located in the eastern part of the South Turgai Plain, in the Kostanay region, Amangeldinsky and Dzhangeldinsky districts, formed at the confluence of the Dulygaly and Ulken-Zhilanchik rivers, which in turn originate in the Ulytau Mountains. In Russian-language (Soviet) sources it may also be called Zhylanshy and Zhilanchik.

Uly-Zhylanshyk flows to the northwest, then turns to the southwest. It flows into the drainless salt lake Akkol. The territory of the Uly-Zhilanchik arc (cliffs of the bank of the Uly-Zhilanchik River and adjacent territories) is interesting because continental Paleogene-Neogene deposits with unpredictably rich plant remains are exposed here in many places. These include such well-known locations of fossil plants as Nausha, Bolattam, Tortmola, Myneskesuek, Sarysay, Altyn-zhar, Erzhilansai, Kushuk.

In the composition of these paleofloras, a large number of fossil species new to science and endemic to the Turgai trough have been identified. Myrica turgaica Kornilova was first known from Tortmola, and Lindera ovata Kolakovski was first established on the territory of Kazakhstan from here. In Myne`skesuek, along with the flora, M. D. Biryukov collected the remains of the skeleton of pristinotherium. The flora includes, along with the usual cosmopolitan species of Turgai floras, Cassia phaseolites Ung., Weinmannia microphylla Heer. The composition and paleoflora of the Akmola (Bolattam) location is interesting. From there the following were identified for the first time: Cedrus kazachstabica Bud., Acer monoides Kirich., Schap., Tilia multinervis Kornilova, Cercis turgaica Usn. Imprints of flowers of Carpenteriantus turgaicus Bors were collected from the Naush locality. The Lower Miocene Burdigalian flora of Kushuk is represented by small-leaved mesoxerophytic species, among which there are also many new to science - Peryploca kryshofovichii Kornilova, Sorbaria callicomaefolia Kornilova, Vaccinium paiaeoretusum Kornilova, Trapa vassiljevii Kornilova and many others.

Floristic complexes studied from these places make it possible to reconstruct the history of the development of the Kazakh flora from the early Oligocene to the Miocene, as well as to establish the stages of gradual climate aridization, which subsequently led to the desertification of this region [3].

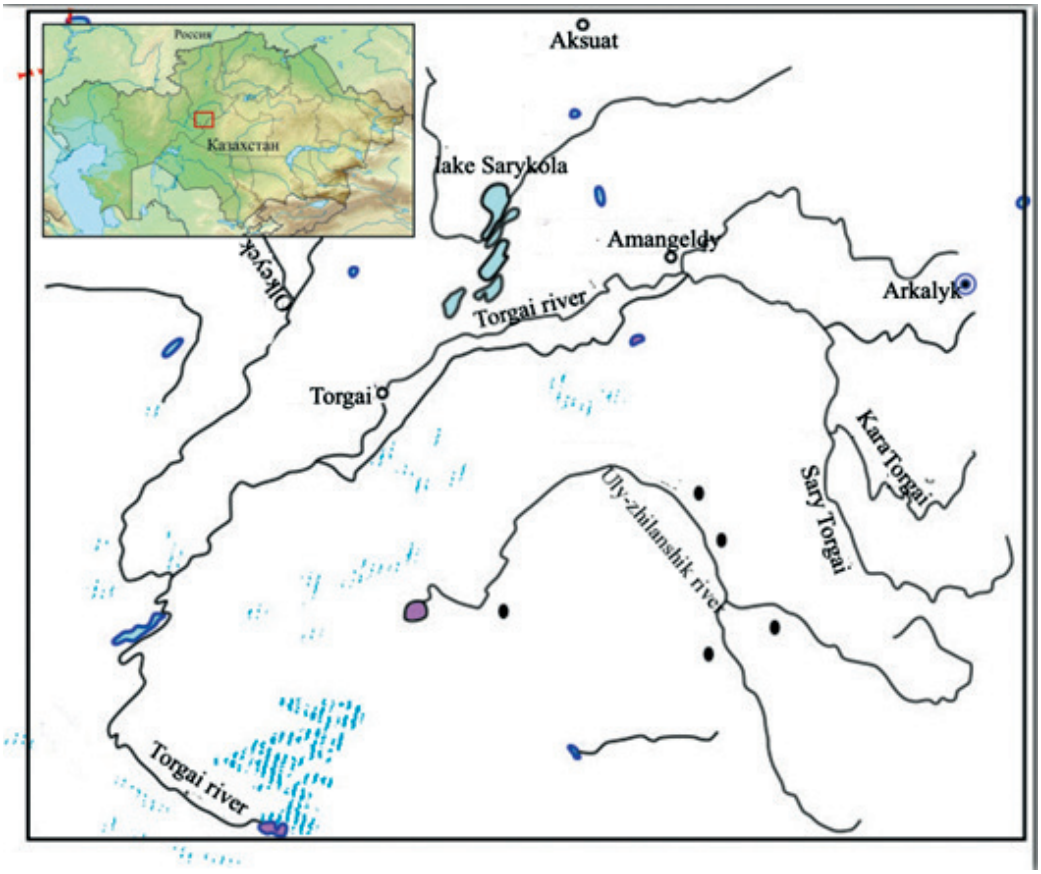


Figure 1. Map of the Torgai region

**Objects and methods of research**

Plant remains "imprints" are cavities formed as a result of plant parts getting into the rock and its further hardening. Moreover, in the hardened rock the process of smoldering of organic residues continues, as a result only a cavity remains, which in its shape corresponds to the original part of the plant. One such print then consists of two parts - a print and a counterprint, as they are not entirely correctly called, which correspond to the top and bottom sides of the sheet. In rare cases, under special conditions of fossilization, remains of phytoleims are preserved.

Fossil plant sites are rock outcrops or outcrops where imprints of leaves, fruits, stems, falling shoots, cones, and inflorescences of higher plants are preserved.

Comparison of the size of the leaf blade, its shape, the shape of the apex and base of the leaf, the type of serration and venation with previously studied fossils, as well as modern species, allows us to establish the systematic affiliation of the specimen. To determine the ecological appearance, paleoecological methods are used:

the method of Bailey and Sinnott, based on the study of the ratio of leaves of simple and complex, with smooth and serrated edges, with pinnate and palmate venation, since all these characteristics are associated with climatic conditions [4];

the method of Axelrod and Bailey, supplementing the above with an analysis of the size of the leaf blade, since a reduction in leaf size usually indicates a water deficit [5].

To the history of studying the issue. The study of fossil plants on the territory of the Turgai trough has a history of almost a century and a half and, despite the seemingly sufficient knowledge, at the present stage remains very promising for paleobotanical research, clarification of the conditions of climate change and the environment. The first collections of plant remains

in the Turgai trough were made by A.I. Antipov in 1856-57, when he discovered signs of coal content in the form of deposits of brown coal and lignite in the Zhar-Kue (Yar-Kue) tract [6]. The selected plant imprints were identified by the Swiss paleobotanist O. Geer and identified 11 species of woody plants: Taxodium dubium Heer, Sequoia langsdorfii Heer, Carpinus grandis Heer, Corylus insignis Heer, Fagus antipovii Heer, Quercus nimrodii Ung., Q. drymeja Heer, Ficus populina Heer, Dryandra Ungeru Ett., Ziziphus tiliaefolius Heer, Liquidambar sp. [7, 8]. O. Geer compared the Turgai collection with the tertiary plants of Switzerland, which had been well studied by that time, and concluded that the fossil flora of the "Kyrgyz steppe" was preserved in freshwater deposits of the Oligocene, which correspond to the lower freshwater mollas of Switzerland.

By the end of the 40s of the 20th century, more than 60 species of fossil plants were known in the fossil floras of the Turgai trough.

From 1946 to 1958 On the territory of the Turgai trough, in connection with widespread geological exploration work, a complex geological and paleontological expedition of the Academy of Sciences of Kazakhstan carried out work. Research was carried out on various paleobotanical objects: L.Yu. studied plant macroremains. Budantsev, A.I. Kirichkova, V.S. Kornilov, spores and pollen were analyzed by R.Ya. Abuzyarova, E.P. Boytsova, Z.K. Zhuchenko, T.V. Pogodaeva, I.M. Pokrovskoy, L.N. Rzhannikova, fruits and seeds were determined by P.I. Dorofeev. During this time, many new localities of fossil flora and fauna were discovered [9-12].

In the work of S.G. Zhilin, a new approach to dating the floras of Western Kazakhstan and Turgai was proposed [13]. Thus, he attributed the paleofloras of Shintuzsay, Murunchik, Zhaman-Kaindy to the Middle Oligocene (Ruppel), the floras of Bolattam, Zharkuye Zhilin S.G. dates back to the Upper Oligocene (Hattian), and Erzhilansai and Nausha to the Early Miocene (Aquitanian). This dating by S.G. Zhilin proposed based on the results of comparison with paleofloras of Northern Ustyurt, dated paleofaunistically.

Comparison of the paleoflora of the river Uly-Zhilanshchik and paleogeography of the time of their existence. The territory of the Turgai trough and adjacent regions of Western and Eastern Kazakhstan is very interesting and favorable for learning the history of the development and evolution of flora and climate of the Cenozoic era.

P.V. Shilin [14] believed that during the Paleocene and Eocene there was a radical restructuring of floras. The beginning of this stage corresponds to the time of development and formation of thermophilic subtropical flora, which is characterized by the almost complete absence of ferns, weak participation in plant groups of conifers, single occurrence of monocots, tree and shrub species of various families of angiosperms, mainly with tropical and subtropical habitats, are predominant. The entire plant complex is characterized by quite distinct thermophilicity [15].

In Eastern Kazakhstan [15, 16] it corresponds to the Kiin-Kerish stage. Its beginning corresponds to the time of development of thermophilic flora, in which, as I. A. Ilyinskaya emphasized [17], various species of extinct genera are noted, conditionally attributed to the family Platanaceae-Protophyllim, Protoacerophyllum, Zaissania. At the same time, "a significant increase in the subtropical Gelinden element is observed" [16], in particular, the genus Dryophyllum appears and achieves great diversity. At the end of the Romankol-Karasor and Kiin-Kerish stages, natural taxa develop predominantly; they account for 70% of all genera and 76% of species known in the flora.

Since the Oligocene, which marks the beginning of the Late Cenophyte, a radical restructuring of the flora took place in the territory under consideration. The subtropical Eocene flora is replaced by a fundamentally different mesophilic flora of the Turgai evolutionary-time stage. Its composition involves mainly natural taxa, modern analogues of which now live within two continents - America and Eurasia.

The floras of the beginning and end of the Turgai stage have some peculiarities. The first of them (the beginning of the Middle Oligocene) covered the time of development of taphofloras, well known from the Shintuzsay, Tortmola, Zhaman-Kaindy and Myneske-Suek localities. The beginning of the stage is characterized by a mixed flora of subtropical and a small number of

temperate broad-leaved elements. As noted by V.S. Kornilova [3], on the territory of the Turgai trough in the early-middle Oligocene, the participation of evergreen elements in floras was constantly decreasing, and the diversity of broad-leaved trees was increasing. As a result, the floras of the early Middle Oligocene were already dominated by deciduous forms of temperate and warm-temperate climates, although individual elements of subtropical floras were still preserved: Cinnomomum, Palibinia, Lomatia, etc. The most ancient taphocenoses of this time were forest: coniferous-deciduous, with the participation of evergreens and mesoxerophilous. Myrica species are found everywhere; apparently, they were part of plant groups on the sea coast, and then on other bodies of water.

The flora of the beginning of the Turgai stage from the Shintuzsay locality has been the most studied [18-21]. The following species are noted in its composition: Salvinia natanella Schap., Taxodium dubium Heer, Populus grandifera Heer, Populus sp., Pterocarya paradisiaca Iljinskaja, Lautus primigenium Ung., Laurophyllum sp., Cinnamomum scheuchzeri Heer, Cinnamomum sp., Sassaftas turgaicum Kornilova, Cercidiphyllum crenatum (Ung.) Brown., Liquidambar europeaum A. Br., Cercis cf. turgaica Uan., Aser angustilobum Heer, Ziziphus tiliaefolius Heer, Pistacea oligocenica Mar., Andromeda protogea Ung., A. vacciniaefolia Heer, Dryandra sp. [20]. It consists of 22 species, one species of ferns (Salvinia natanella Schap.), one of gymnosperms (Taxodium dubium Heer.) and 20 species of angiosperms. Ferns and gymnosperms have not yet been established in the Tortmoly flora. Ferns, of which there are 23 species, are represented by both warm-temperate species (Cercidiphillum crenatum, Zelkova zelkovifollia, Pterocarya paradisiaca, Magnolia inglefieldii), and evergreen and xerophilous elements, possible relicts of the Eocene time - Cinnamomum schuchzerii Heer, Laurus primigenia Ung., Phus turcomanica (Krysht ) Kornilova, Partenocissus duligalensis Tokar, Leoconthoe protogea Ung.

In the adjacent territory of the Northern Aral Sea region, the stratigraphically most ancient flora of the Turgai evolutionary-time stage is the Kumbulak flora on the coast of Butakova Bay, the remains of which are preserved in clayey silts and clays of the Kutanbulak formation [22]. Judging by the systematic composition, the same picture of the development of the flora of the beginning of the Turgai evolutionary-time stage is observed. Eocene relics are also preserved here, among which, according to G.S. Rayushkina [23], some can be considered as edificators of coasts (Myrica) and coastal areas (Sequoia, Cinnamomum). Characteristic forest formations were redwood, broadleaf slope and valley forests of zelkova, maples, elms, sassafras, oak, with brown laurel in the understory.

A completely similar flora developed in other regions of Kazakhstan, in particular in the Zaisan depression, where in general it is more diverse.

Already in the second half of the Middle Oligocene, the flora of the Shintuzsay type, which characterized the beginning of the stage, was replaced by a purely mesophilic forest, in which Eocene relicts were practically absent. This time marks the beginning of the second half of the Turgai evolutionary-temporal stage, covering the development of Early Miocene floras known in the territory of the Turgai trough. Their main feature was the almost complete disappearance of evergreen and subtropical elements. Ferns are rare. Among them are Osmunda doroschiana Goepp., O. heeri Gaud et Strozzi, Woodwardia sp., Asplenim tenerum Lesq., Lygodium sp., Dryopteris sp. [20]. At that time, aquatic ferns of the genus Salvinia reached a significant flourishing on the territory of Kazakhstan; 5 species grew here: Salvinia natanella Shap., Salvinia paleopilosae Shap., Salvinia cerebrata Nikit (megaspores), Salvinia sp. (megaspores) [15, 24]. All species diversity was concentrated in the Turgai trough region. According to V.S. Kornilova, the reservoirs of the Turgai Plain after the retreat of the Chegan Sea became one of the centers of species diversity of aquatic ferns, especially salvinia in Northern Asia [18]. Conifers are also rich, among which the most typical are species of the Taxodiaceae family from the genera Taxodium, Metasequoia, Glyptostrobus, and some genera of other families: Cedrus, Pseudolarix, Pinus and others [21].

Noteworthy is the generic and species diversity of flowering plants: Cercidiphillum crenatum, Lequidambar europea, Fagua antipofii, Quercus alexeevii, Quercus antipofii, Carpinus

subcordata, Carpinus grandis, Corylus jarmolencoi, Pterocarya paradisiaca, Phellodenrdon grandifollium, Carpenteriantus turgaicus, Sassafras ferretianum, Cerci s turgaica, Aser monoides , Aser tricuspidatum, Ulmus carpinoides, Ulmus drepanodonta, Fraxinus nigrifolia, Populus latior, Populus balsamoides. Apparently, in the late Oligocene and early Miocene times, swampy forests with swamp cypress (Taxodium), rich coniferous-deciduous forests with metasequoia, cedar, beech, oaks, maples and many other woody plants existed everywhere in Kazakhstan around numerous flowing and still water bodies. watersheds.

The floras of Kazakhstan, uniform in type, were not completely identical and had regional characteristics in the western and eastern parts. Only in Western Kazakhstan plant complexes were the species Fraxinus dubia Budans., Sorbus praetorminalis Krysht. et Baik., Aser kinjakense Zhilin, Cotinus lavrovii Budans. According to G.S. Rayushkina [25], these differences are explained by paleogeographical features, but we believe that along with the geographical factor of the time of development of Oligocene floras, there was also a paleogeographical factor of the previous evolutionary stages (Romankol-Karasor in the west and Kiinkerish in the east of the country). And, probably, the differences in the floras of the Turgai stage are inherited from previous floras.

Outside of Kazakhstan, these floras are close to the Sarmatian flora of the Ambrosievka locality [26], located on the territory of Ukraine, in the river basin. Krynki. The number of common species reaches 8, and the number of common genera of these floras is 15. There are absolutely no gymnosperms in the floristic complex of Ambrosievka. Monocots are numerous, mainly representatives of the family Cyperaceae; evergreen forms are included in the composition of angiosperms. The paleoflora of Erzhilansai is somewhat older than that of Ambrosievo, which explains these differences [27].

The floristic complex of Erzhilansai shows a noticeable similarity with the flora of the Ciscarpathian region [28]. Along with the general species, of which there are 11, the flora of the Ciscarpathian region also includes representatives of genera not found in Erzhilansai, such as Salix, Myrica, Carya, Fagus, Celtis, Aristolochia, Parrotia, Podogonium, Rhus, Rhamnus, Berchemia, Cornus. In the composition of the flora of the Ciscarpathian region, the participation of subtropical elements characteristic of the floras of the Poltava ecological appearance is quite significant. The absence of such in the Erzhilansai paleoflora is its main difference from the typical European floras of the Turgai ecological type of the Ciscarpathian region.

A noticeable similarity between the types of floras appears with the paleofloras of the Far East and Primorsky Krai. The Aquitanian flora of Erzhilansai has 8 common species with the Paleogene flora of Sakhalin [28]. All of them are typical representatives of the Turgai ecological floras. Along with them, this flora includes species of the genera Myrica, Castanea, Celtis, Fecus, Ribes, Corylopsis, Platanus, Vaccinium, etc.

By the end of the Turgai evolutionary-time stage, the composition of forests becomes significantly depleted due to the loss of coniferous and many broad-leaved species. The flora is becoming increasingly xerophytic, depleted of elements of forest tree species of warm-temperate and humid climates, being replaced by mesoxerophilic species, and shrub and herbaceous communities are widespread. With the expansion of mesoxerophilic formations, a radical restructuring of the entire flora occurs and a new Kushuk stage of its historical development begins. The remains of plants from this stage are preserved in the Kushuk locality. The Kushuk stage is characterized by xerophytic, ancient Mediterranean (according to V.S. Kornilova) flora with a predominance of mesoxerophytic species - especially oaks. Some species included in its composition indicate continuity from more ancient floras of Western Kazakhstan: Salvinia mildeana Goepp., Populus latior A. Br., Pterocarya paradisiaca Iljinskaja, Betula subpubescens Goepp., Ulmus carpinoides Goepp., Zelkova zelkovifollia Buzek et Kotlaba, Peryploca kryshtofovichii Kornilova. Another group includes plants known in Kazakhstan so far only from the Kushuk locality. These are Salvinia kryshtofovichiana Shap., Salix integra Goepp., Sorbatia callicomifollia Kornilova, Gleditsia allemanica Heer, Mirtus minor Ung., Trapa vassiljevi Kornilova, Vaccinium palaeoretusum Kornilova, Fraxinus praedicta (Goepp.) Heer. As noted by

V.S. Kornilov, flowering plants, with few exceptions, are represented by deciduous small-leaved forms. The place of mesophilic large-leaved plants of the Turgai stage was taken by mesoxerophilic forms, modern analogues of which now live in Western Asia and the Mediterranean [19].

The Early Miocene flora of Aktau is dominated by black poplars, numerous legumes, tree-trees, elms, and xerophytic oaks and pistachios are known [30].

How the flora developed later can be judged from the plant remains preserved in the Middle Miocene deposits of Kazakhstan outside the Turgai trough. For example, (data from V.S. Kornilova [18]) in the younger, mid-late Miocene floras of the Kochkor and Tekessoy depressions of the Tien Shan, more than 50 species have been established. Among them, the willow family stands out for the number of prints and the largest number of representatives. The zonal type of vegetation of this time was probably forests and xerophilous woodlands, consisting of juniper, Caracas, barberry, almond, legumes, etc. Tugai forests were dominated by turanga poplars and coastal communities with reeds, which is also characteristic of the features of the modern landscape.

The locations of leaf imprints from the end of the Neogene and Quaternary periods of the Cenozoic era in Kazakhstan and in particular in the Turgai trough were practically unknown until recently. Therefore, information about the formation of modern flora of lowland areas is very scarce. They are based on data from studying the remains of spores and pollen, from which it is possible to establish only the genus, and not the species.

**Conclusion**

In conclusion, we note that the development of the flora of the Turgai evolutionary-temporal stage was characterized by the development of the indricotherium (Turgai fauna). It was studied for the first time from the territory of the Turgai trough by A. A. Borisyak, who described the hornless rhinoceros Indricotherium from this area, typical of the Turgai fauna. The indricotherium (Turgai) vertebrate fauna is represented by a complex of predominantly mammalian animals that inhabited mainly the vast expanses of Central Asia. One of the main elements of the Turgai fauna were odd-toed ungulates, chalicotherium, some rodents, and predators; of artiodactyls, the pig-like Entelodon, Anthrocoterium, etc. 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 locality.

Thus, the analysis of paleofloras allows us to establish that during the Oligocene - Miocene there was a gradual drying of the climate, especially along the watershed, where open spaces began to form already at the beginning of the Miocene.

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## Қазба флорасын зерттеу негізінде палеоген мен неогеннің палеоклиматын қайта құру мүмкіндіктері (Ұлы-жыланшық өзенінің палеофлорасын мысалға ала отырып)

**Аңдатпа**. Мақалада Ұлы-Жыланшық өзенінің алқабында (Оңтүстік Торғай ойпаты, Қазақстан) әр уақытта жинақталған және зерттелген кайнозой флорасына талдау жасалған, сонымен қатар қазбалы флораларды зерттеу негізінде кайнозой палеоклиматын қалпына келтіру перспективалары қарастырылған. Ұлы-Жыланщик өзенінің аңғары палеоген мен неогендегі қоршаған ортаның өзгеру процестерін түсінудің негізгі аймағы болып табылады. Бұл палеофлораларды зерттеу палеогеографиялық жағдайларды: палеоландшафтарды және климаттың өзгеруін қайта құруға мүмкіндік береді. Бір жастағы флоралардың бір типке жатпайтыны және өзіне тән аймақтық ерекшеліктері бар екені көрсетілді. Өзен бойындағы әртүрлі жастағы шөгінділерден алынған флорада ұсынылған флористикалық құрам. Ұлы-Жыланшық Шеген теңізінің шегінуі және аумақты одан әрі аридизациялау кезеңдерін байқауға мүмкіндік береді.

Мақала AP19677563 «Олигоцен мен миоцен шекарасындағы Орталық Қазақстанның палеофлорасы мен климатын зерттеу және аймақтың шөлейттенуінің бастапқы кезеңі» (2023–2025) гранттық жобасын іске асыру барысында дайындалған.

**Түйін сөздер:** Ұлы-Жыланшық, Торғай типті палеофлора, қазбалы флора, палеоген, неоген, елді мекендер

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## Возможности реконструкции палеоклимата палеогена и неогена по данным изучения ископаемой флоры (на примере палеофлоры р. Улы-Жиланшик)

**Аннотация.** В статье приведен анализ кайнозойских флор, собранных и изученных в разное время в долине реки Улы-Жиланшик (Южно-Торгайская впадина, Казахстан), а также рассмотрены перспективы реконструкции палеоклимата кайнозоя по данным изучения ископаемых флор. Долина реки Улы-Жиланшик является ключевым районом для понимания процессов изменения окружающей среды в палеогене и неогене. Данные изучения этих палеофлор позволяют восстановить палеогеографические условия: палеоландшафты и изменения климата. Показано, что одновозрастные флоры не были однотипными и имели свои региональные особенности. Флористический состав, представленный во флорах из разновозрастных отложений по р. Улы-Жиланшик, позволяет проследить этапы отступления Чеганского моря и дальнейшей аридизации территории.

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**Ключевые слова**: Улы-Жиланшик, палеофлора торгайского типа, ископаемые флоры, палеоген, неоген, местонахождения.

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