Analysis of Palaeoecological Factors in Shaping Modern Landscape of Republic of Kalmykia

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Abstract. This paper examines environmental issues from the point of view of historical geology and geocology. The territory of the Caspian region has undergone many geological and geographical changes for more than 180 million years. The waters of the Tethys ocean covering the entire region gradually regressed. One of the remnants of the ocean is the Caspian (Khazar) sea. The Caspian Sea has also undergone many changes. If in the Quaternary period it washed the Ergeninsky upland, then now it has gone 300 km south of the coastline. The history of the Caspian Sea is very interesting and entertaining. The tribes that lived on the territory of the Caspian Sea, from the Scythians to the descendants of Genghis Khan, were mainly engaged in cattle breeding. They mainly bred horses and sheep intended for long-distance raids on this territory. At different times and eras, the livestock in the studied area varied, it was about 2 million or more animal units. For more than 30,000 years, the soil layer has been destroyed. If 2000 years ago the territory of the Caspian lowland and especially the territory of the Republic of Kalmykia were blooming, then for more than 2-3 centuries this zone has changed a lot. The peak of degradation of the soil layer occurred in the 1960-1980s. One of the reasons for the destruction of the natural balance is the system of land reclamation, widely carried out in the 20th century. The purpose of this research is to analyze the process of soil degradation, landscape changes, and gully-girder system over the past 30 centuries. To solve this problem, we used the materials of archaeological expeditions conducted by scientists of the Kalmyk University, as well as information available in open sources. The hypothesis accepted for the study was the system of nature variability with consideration for the influence of other factors. The destruction of the soil layer and its degradation led to the formation of the Sahel belt on the territory of the Republic. Another part of the accepted hypothesis was the system of equilibrium in nature, entropy. Any of these disruptions can lead to adverse consequences.
Such consequences are not yet fully understood. The obtained data will allow us to assess the current environmental status of the study area.

1. Introduction
The Caspian region and in particular the territory of the Republic of Kalmykia (RK) is located in a complex extreme continental geographical zone [18]. More than 20% of the territory is now a desert. This is the largest desert in the South-Eastern part of Europe. A peculiar Sahel belt was formed on the territory of Kalmykia [21].

The purpose of this paper was to analyze the creation of the desert, illiquid lands on the territory of the Republic of Kazakhstan from the point of view of ecology, geology and geography as well as paleontology and the history of the region.

To solve this problem, the material of expeditions conducted by both scientists of the Kalmyk University and other researchers were studied [9, 14-16, 26]. The issues of land degradation and erosion are considered in the research of Krasichkova V. P. [10], Baktasheva N. M. with co-authors [4] and other university scientists [20,23,24].

This paper considers the research conducted by scientists from Russia and neighboring countries on ecology, historical ecology and geography, paleoecology, geochemistry of soil formation and decomposition of the lithosphere layer, etc. [1,2,3,25]. The methodological base of research and data on geomorphology are taken into account separately [5,6]. A comparative analysis of the data obtained with results from other equivalent regions was carried out [7,8].

Over than 180 million years, the territory of the former ocean floor has significantly changed. There have been many changes, primarily tectonic. All of the above has led to the rise and fall of the junction of tectonic plates related to the tip of the Caspian basin of the East European platform [18,20,24].

Due to tectonic changes, there were changes in the relief, landscape of the territory, the formation of the gully-girder system of the Caspian Sea and its environment [18,20,23].

2. Materials and methods
The paper considers the materials of conferences held at different levels with the participation of students, undergraduates and employees of the faculty of engineering and technology of the University [11].

The consequences of environmental impact on the landscape of the Republic of Kalmykia (RK) as a result of human activity can be traced back to the stone age [13,24]. According to archaeological data, nomad sites were located everywhere on the territory of the Caspian lowland, especially since the climate and geographical location of the region contributed to the development of nomadic and semi-nomadic lifestyle among the tribes of that time. Table 1 provides information about the presence of ancient man on the territory of the Republic of Kazakhstan [12]. Figure 1 shows a map of the sites of ancient men in the Republic of Kazakhstan during the transition from the Eneolithic to the bronze age. Figure 2 shows archaeological finds discovered during excavations of ancient men sites from the Mesozoic period.
Figure 1. Ancient human sites on the territory of the Republic of Kazakhstan during the transition from the Eneolithic to the Bronze Age 4,000–2,500 BC.

Table 1. The existence of an ancient man on the territory of the Republic of Kazakhstan [25].

| No. | Era/century | Period/archaeological culture/Dating | Location of an ancient man on the territory of the Republic of Kazakhstan | Actual archaeological sites, the main type of activity of the population (based on the results of finds) |
|-----|-------------|-------------------------------------|--------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------|
| 1   | Stone age   | Paleolithic/40,000–35,000 BC         | The existence of an ancient man on the territory of the Republic of Kazakhstan was not proved | No archaeological sites were found on the territory of the Republic of Kazakhstan. Stone tools, scrapers for finishing leather, knives for cutting animal skin and butchering carcasses were found. The main activity of the population is hunting, fishing, and gathering. |
| 2   | Mesolithic   | 13,000 BC                           | The following sites were found: Kharba village (Justinsky district), Tavn-Gashun village (Yashkulsky district), Yergeni village (Southern slope). | Stone tools, scrapers for finishing leather, knives for cutting animal skin and butchering carcasses were found. The main activity of the population is hunting, fishing, and gathering. |
| 3   | Neolithic    | 10,000–5,000 thousand BC            | Sites discovered: Yasta-Khuduk (Chernozemelsk region), Jangar (Oktyabrsky region), the natural boundary Kanat. | Stone and bone hooks for fishing, harpoons. Stone millstones for grinding, etc. The main activity of the population is hunting, fishing, farming, and cattle breeding. |
| 4   | Chalcolithic | Eneolithic/4–3,000 BC               | Sites were discovered along the shores of now | Mounds erected at the burial sites of local |
|   |   |   |
|---|---|---|
|   |   | dry lakes, on the slopes of the Yergeni hills or in the basins. leaders, finds in the form of stone scepters and other signs of power; the main activity is hunting, fishing, farming, cattle breeding. |
| 5 | Bronze age  | Yamnaya culture/3500-2500 BC | Not far from Elista numerous funerary monuments of the yamnaya culture were discovered Flint and bronze arrows, scrapers and knives for cutting meat and dressing leather, awls, beads and bracelets, as well as ceramic flat-bottomed vessels for cooking and storing food were found in the burials. The main type of activity is agriculture and cattle breeding. |
| 6 |   | Catacomb culture/2000-1600 BC | Settlements of this period were found near the settlements of Yashkul, Beloe Ozero, Tavn-Gashun, etc. In the catacomb-type burials, there are exhibits of four-wheeled carts, household items in the form of ceramic dishes of various shapes, often covered with ochre. The main activity is mainly agriculture, cattle breeding. |
| 7 |   | Srubnaya culture/1500-1000 BC | Burial in the Northern part of the territory of Kazakhstan: Bolshoy Tsaryn, Guwa II, Jangar, Zahanati, Zergenta I, Iki-Zegista, Kermen Tolga, Ultan Tolga, Tsagan-Nur, Sholmun-Tolga. In the graves there are items that represent the deceased's position on the social ladder, as well as to his or her profession: bronze maces, arrowheads and spears, ceramic kitchen utensils, women's jewelry in the form of earrings, beads, etc. The main activity is mainly cattle breeding. |
| 8 | Iron age  | Cimmerian archaeological culture/800-700 BC | Burial Savromato-Sarmatian type. More than 600 were found on the territory of the Republic of In the graves were found household utensils and military equipment, ceramic and wooden dishes, |
As can be seen from the table, the main areas of the Republic of Kazakhstan were inhabited by ancient people during the Mesolithic period. However, the absence of discovered archaeological finds confirming the existence of primitive people in the Paleolithic does not prove the existence of the Ergeninsky upland being inhabited by ancient people during this period, for example, separate settlements built by natives of the Caucasus. According to [9], such primitive sites could have taken place as a result of the migration of ancient people from Transcaucasia to the middle Volga region, and it is proved by a site of ancient people on the Sukhaya Mechetka river, located in (Volgograd region), [22].

The anthropogenic factor that has a negative environmental impact on the lands of the Republic of Kalmykia was present in all periods of the existence of ancient man. Solid household waste (MSW) formed as a result of the emergence and activity of primitive settlements took place in the studied periods, starting from the middle stone age of the Mesolithic 10,000-13,000 BC [18,19]. The prerequisites for the populating of the Republic of Kazakhstan during this period were the climate change in the Caspian lowland in the Quaternary period. Indeed, the transition from the Pleistocene to the Hologene was accompanied by numerous changes in the level of the Caspian sea due to tectonic processes, as a result of which the climate, geographical position of the Republic of Kazakhstan and relief became similar to what we see today [11,14]. The formation of a chain of Sarpinsky lakes as a

| Kazakhstan.          | iron knives, weapons were mainly short iron swords akinaki, spears, bronze and iron arrowheads. |

Figure 2. Silicon archaeological finds of the Neolithic period (district of Yasta-Kuduk, Chernye zemli).
result of changes in the general course of the Volga river contributed to the development of this territory in the late Mesolithic. In the heyday of the Eneolithic, about 4,000 BC, the number of settlements (sites) of ancient man grew significantly. We can judge this from the archaeological findings (see the map on Fig. 1). The discovered Neolithic sites were located mainly in the Chernozemelsky district of the Republic of Kazakhstan [17]. An example of a Neolithic settlement is the finds discovered in 1950 [26] in the Yasta-Khuduk Urochische. Based on the obtained archaeological data of the microlitic industry, the territorial areas of settlement by the ancient people of the Republic of Kazakhstan were identified.

There are practically no materials that indicate the relationship of the ancient inhabitants of Kalmykia with their environment, however, studying the geographical location of modern settlements in comparison with the paleoecological principles of actualism, which in this case are considered as indirect signs of a convenient place for stationary sites of ancient people in the past (analysis of the terrain at the expense of non-flooded areas on terraces in floodplains, gentle descents to the water, etc.) can be very relevant. Moreover, due to the fact that since the Mesolithic the Caspian Sea level did not undergo major changes, topography from the point of view of convenient human life on the territory of Kazakhstan has been preserved to a greater extent, therefore, modern settlements are often founded in the sites of ancient settlements.

The actual material accumulated during the existence of ancient sites that could affect the balance of the ecosystem of the Republic of Kazakhstan can be judged by the state of garbage, which during the Mesolithic period mainly included fragments of ceramic utensils, bones of various animals, fragments of stones from which silicon crafts were made, etc. Such accumulations of debris were found during archaeological excavations of ancient sites, which, as a rule, were concentrated in pits, ditches and natural depressions near the location of the sites. It should be noted that the so-called "ancient garbage pits", according to scientists [26], were located along the perimeter of the site. This indicates a reasonable approach of the ancient inhabitants to the ecological component of the habitat. Archaeological research also shows that another rational approach of the ancient inhabitants of the Republic of Kazakhstan was that elements of metallurgical production, even in the early bronze age, were located in the ravines and natural depressions closest to the sites in order to protect residential settlements from acrid smoke [16].

3. Results

Thus, based on actual archaeological data and the principles of actualism, we can establish the reasonable approach of the ancient inhabitants of the Republic of Kazakhstan to their environment. If this concept is expressed in modern language, the ancient population of the Republic of Kazakhstan sought to preserve the ecosystem around them [26].

4. Discussion

4.1. Forecast of the current status of the environment in the Republic of Kazakhstan in relation to paleogeoeocological factors

The environmental situation in the Republic of Kazakhstan in relation to paleogeoeocological factors is based on methods that allow determining the composition of natural components in accordance with the relief and landscape sphere of past eras. The tectonic structure reflected in the relief significantly affects the nature of sedimentation, the depth of ground water, as well as the soil and vegetation cover of the territory [15].

Based on paleogeocological factors, it is possible to determine the patterns of development of a particular region in the studied historical and geological periods [17].

For the Republic the definition of the period of formation of "landscape areas" is particularly relevant, since geographically, Kazakhstan is included in a high risk zone of aridity and complex interaction of these three major components of the geosphere: atmosphere, hydrosphere and lithosphere in the context of filling biotic content may provide insight into the evolutionary
geochemical processes of the formation the modern landscape in Kalmykia [10]. Paleoecological methods for predicting the current state of the landscape sphere are based on certain studies in various fields of science and technology with the basic methods presented in the diagram (Figure 3).

While ecology studies the relationship between the landscape sphere and its biotic content, paleoecology examines the same patterns, but in relation to the geological history and the organic world that inhabits the geosphere of the studied territory in a certain chronological period of its development.

![Figure 3. Paleoecological research methods.](image)

Until recently, the study of paleontological remains of animals and plants was the most reliable method for researching paleoecological factors [5,7]. Nevertheless, the study of fossil remains by a paleontologist provides an understanding of the evolutionary processes that took place during the studied period and the species systematics of fossils. It also considers the species distribution within the chronological period when describing paleontological objects. This data is a prerequisite for constructing the stratigraphy of sedimentary rocks and determining the geological age of the studied sections. Paleoecological characteristics are determined by indicators, which are the morphology of fossil organisms, the habitat and conditions for the formation of sedimentary rocks, geographical distribution and, consequently, the climatic conditions of the time period.

A set of indicators in paleoecological studies makes it possible to restore the cycle of existence of a single chronological fragment of an ecosystem, to restore its biotype. In this case, paleontological research methods for the restoration of the paleoecological system are a priority based on a set of analytical methods that include a set of approaches within the geosystem. In the modern interpretation of the geosystem, there is both a planetary and a regional factor. The study of natural and geographical conditions of the Pleistocene and early Holocene periods using systematic approaches of paleoecology makes it possible to represent the development of the regional geosystem of the Republic within the studied geological time [23].

Reference sections of different geological periods of the Pleistocene and early Holocene were studied on the scale of the Eastern slopes of the Ergeninsky upland in the Republic of Kalmykia [4]. The accumulated desktop material on fossils of terrestrial and aquatic plants together with the data of
terio – and microfauna made it possible to characterize the natural environment taking into account its historical geology [20]. Based on geological and morphological data, the central geosystem of the Caspian region is divided into so-called sub-geosystems, which are equated to the main collection basins. The interrelation of climate change in the Caspian region depending on natural processes occurring in different geological periods was studied. There is a pattern in the study of local objects of past ecosystems and global climate change that led to the current arid state of the soils of the Republic of Kazakhstan [20].

On the territory of the Republic of Kalmykia, the most ancient rocks are the Permian-Kungur deposits, which are based on rock salt deposits. Then deposits pass into rocks of Triassic, Jurassic, and Cretaceous periods, and the Paleogene in the South of the Republic of widely developed Absheron and Achkagalyk quaternary sediments, whose thickness reaches up to 100 m. These deposits are mainly represented by carbonate silty clays of mainly gray color, typical for the South of Kalmykia, rich in macroflora and microfauna [1]. From the point of view of stratigraphic descriptions Achkagalyk sediments belong to the upper Pliocene. Figure 4 shows diatom fossils in Achkagalyk deposits of the South of Kalmykia.

Figure 4. Fossilized diatoms in Achkagalyk deposits of the South of Kalmykia.
The peculiarity of sedimentation in the Caspian lowlands and especially in the territories of the Republic of Kalmykia is the alternation of moraine and continental sedimentation, which is undoubtedly associated with the periods of raising levels of the Caspian Sea and the formation of the Khvalyn sea on the territory of the Republic.

To study Pleistocene deposits in order to determine the genesis of their formation, the spore-pollen method is used [2]. Palynological analysis allows us to identify patterns of changes in plant communities depending on climate and landscape changes in the studied geological time period [6]. Palynology reveals qualitative and quantitative climate changes. To study the sedimentation of continental sediments in palynology, the method of wood-grain precipitation is used, and to study marine sediments, the method of diatom analysis is used [8]. Both of these methods in paleogeoeocological studies are quite informative for building a map of changes in the natural environment in different geological eras and predicting the current state of climate and terrain using the example of the Republic of Kazakhstan. To explore the moraine deposits characteristic of the Republic of Kazakhstan in geopaleontologic are also widely used methods of paleocarpological (the study of the remains of aquatic plants) and malacofaunas analysis (the study of fossilized shells of crustaceans and mollusks), Figure 5 shows fossilized crustaceans and mollusks in Achkagalyk moraine deposits in Kalmykia Republic.

Geopaleoecological data obtained by palynological methods, including diatom analysis, helps assess the ecological and biological state of sediments formed during geological evolution and predict the current state of the landscape and soil composition features [3].

1 - Coscinodiscus grani Gough, 2 - C. asteroidus Ehr., 3 - Thalassiosira coronifera Pr.-Lavr., 4 - T. subsalina Pr.-Lavr., 5 - T. variabilis Makar., 6 - Thalassionema nitzschioides Grun. var. nitzschioides, 7 - Rhaphoneis maeotica (Milov.) Sheshuk. et Gles., 8 - Coscinodiscus lacustris Grun. var. lacustris

Figure 5. Fossilized shellfish in Achkagalyk moraine deposits in Kalmykia Republic.
At the present level of development of reproduction in the Republic of Kalmykia, processes of superimposition of anthropogenesis and technogenesis on the fragile natural environment occur everywhere. In the Republic of Kalmykia, this phenomenon often manifests itself both locally and generally. The processes of aridization of soils in some areas of Kalmykia, for example, Chernye zemly, have reached a massive scale, more than 1 million hectares of soil have been transformed into moving sand.

These phenomena are confirmed as a result of paleoecological studies and are fully recorded by chemical, physical and physico-chemical methods of analysis. Today, the composition of the atmosphere in the Republic of Kalmykia is changing due to the greenhouse effect, smog (this is especially evident in oil and gas fields). The upper layers of the lithosphere undergo geochemical anomalies, an increase in exogenous processes in the Republic, and the transformation of complex rocks into silicates and feldspars increases the risks of aridity in the region. The hydrosphere also changes its mineral composition due to an increase in the total salinity of surface waters. The state of surface waters in the Republic in the ecological and biological aspect sufficiently reflects the processes in the natural environment in the geosystem as a whole. This is related to air mass transfer and precipitation, diffusion, leaching and mineralization processes, etc.

It is well known that the state of ground water is directly related to underground water, which is connected by hydraulic processes. The Republic of Kalmykia is severely suffering from the lack of drinking water [18]. Therefore, it is particularly important to improve the system of control over the environmental and biological state of surface waters in the Republic of Kazakhstan based on geoecological factors. Monitoring of the state of biotic factors in comparison with paleogeoeocological factors will help to identify the degree of crisis in terms of the irreversibility of processes. Such a systematic comprehensive study established that the predicted scientific facts corresponding to paleogeoeocological studies are reliable and complete [18].

The most important thing for understanding the current state of the ecological situation in the Republic of Kalmykia is the data obtained during paleoecological studies, the understanding that the ecosystem of the past period does not return to the previous level after passing a certain threshold of trophic development, i.e. it passes the point of "no return" and this process is consistent and natural.

5. Conclusions

Article I. This paper presents for the first time a description of palaeoeocological factors and their importance in shaping the modern landscape of Kazakhstan, considered in detail the stages of development of the science of palaeoecology.

Based on open laws and developments of the 19th and 20th centuries, the author analyzed how the science of paleoecology was created and its significance for the establishment of fundamental paleoecology factors.

Based on the analysis, the specific features of paleoecological factors in the Republic of Kazakhstan were determined and the areas for further research were identified. All areas of geopaleontologic studies provide relatively complete material for a reconstruction of ecosystem transformation of the object in the chronological geologic period from the times of the ancient biota to predict the formation of modern landscapes.

The special features of paleoecological factors in the Republic of Kalmykia is associated with the features of landscape formation in this region, knowledge of which allows us to see the integrity of the development of the natural, geographical and geological environment, geochemical and geophysical processes in the historical aspect and the transformation to the current state of the geoecological situation in the Republic, including the human factor.

To study the paleoecological factors inherent in the Republic of Kazakhstan, the principle of actualism was considered, which makes it possible to analyze the stages of evolution of a specifically selected ecosystem of the studied object on the territory of the Republic of Kalmykia. This is especially true for the specific geological and geographical conditions of the region associated with finding large areas of arid land.
In the course of the geological development of the Caspian territory as a whole, in particular, there were geological processes, the formation and transformation of the composition and properties of various rocks and groundwater. Knowledge and understanding of the patterns of the geological conditions formation, the development of the biota of the studied territory to a significant extent allows you to reveal and predict, and in some cases prevent the development of unfavorable processes and phenomena from an environmental point of view.

Based on the principle of actualism, a model of transformation of the natural conditions in the Caspian Sea, as well as the relief formation in the Republic of Kazakhstan, was made, considering geoeological factors that are directly related to exogenous, erosive, aeolian, and anthropogenic processes. The disintegration of rocks in the Republic of Kazakhstan, along with desertification, is a typical case for this region. For the European part of Russia, the processes of land degradation in Kalmykia on this scale are an isolated case.

The processes of complex influence of exogenous factors of rock destruction in the Republic of Kazakhstan were revealed, as well as the specifics of relief formation by zoning in relation to specific territorial objects.

The paper provides information about the possible impact of the ancient man who lived on the territory of the Republic of Kalmykia since the Mesolithic on modern geoeological processes. The location of ancient man in the Republic of Kalmykia from the Paleolithic period (40,000 BC) to the iron age (Cimmerian archaeological culture, 800–700 BC) was studied. The anthropogenic factor that has a negative environmental impact on the lands of the Republic of Kazakhstan was present in all periods of the existence of ancient man. Solid household waste (SHW) formed as a result of building and living in primitive settlements took place in the studied periods, starting from the Middle Stone Age of the Mesolithic 10,000–13,000 BC.

Forecasting the current state of the environment in the Republic of Kalmykia in connection with paleoecoeological factors identifies patterns of development of a particular region in the studied historical and geological periods. For the Republic of Kalmykia the definition of the period of formation of "landscape areas" is particularly relevant, since geographically the Republic is in a high risk zone of aridity and complex interaction of these three major components of the geosphere: atmosphere, hydrosphere and lithosphere in the context of filling biotic content may provide insight into the evolutionary geochronological processes of forming the modern landscape of Kazakhstan. These processes are completely recorded as a result of paleoecological studies using chemical, physical and physico-chemical analysis methods.

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