

Ecological-Historical Stages of Marine Vegetation Formation in the European Zone

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Abstract

The purpose of this work is to study the peculiarities of formation and space-temporal spreading of vegetation cover in the European desert during the Tertiary and The Quaternary periods. The authors have revealed three ecological-historical stages: Ancient Caspian, New Caspian and Newest Caspian, which correspond to the periods of main fluctuations in the Caspian Sea, as well as to global climate changes, which periodically caused the changes of different types of vegetation. Ecotone type of landscape has been observed in the European desert. Ecotone of the first class has been traced in the Precaspian Lowland, ecotone of the second class – in the vegetation of the Ancient Caspian terraces and the third class – in the transitional zones between terraces. Each terrace corresponds to an exact geological epoch: Early Khavlynian, Late Khvalynian and New Caspian. Vegetation as an indicator of ecological conditions reflects landscape evolution in the Precaspian region. Ecological-dynamic rows, laying on each terrace, reveal regularity of succession process from the Caspian Sea coast to zonal vegetation. Criteria of evaluation are as follows: decrease of ground waters level and saline degree of soil.

Keywords: European desert; North-western precaspian; Ancient Caspian terraces; Early Khvalynian; Late Khvalynian; New Caspian; Ecotone; Ecological-dynamic rows; Succession; Vegetation; Caspian fluctuation.



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1. Introduction

On the European continent, zonal desert and semi-desert landscapes are situated in the north-western part of the Precaspian lowland formed on the Caspian coast. As the biggest geo-morphological area, Caspy appeared in an ancient tectonic hollow (Leontiev *et al.*, 1977). During the Tertiary period (about 70 million years ago), the Ponto-Caspian basin separated from the Tethys Ocean and further, at the end of the Pontian period (10 million years ago), it fell apart into several pieces. One of them transformed into a distinct basin – the Caspian Sea (Kazmyn *et al.*, 1987; Rytchagov, 1997). At present time, it is the biggest continental sea-lake situated on the border of Europe and Asia. The sea borders of five countries lie across Caspy: Russia, Kazakhstan, Turkmenistan, Azerbaijan and Iran. According to the Convention regarding the legal status of the Caspian Sea, its northern and north-western parts are located on the European continent and belong to the Russian Federation (V Intergovernmental Summit of the Precaspian Countries' Leaders, 2018).

Formation of botanical diversity has been tightly connected to the history of the Caspian Sea level fluctuation, climate changes, solar impact and tectonic processes taking part at the bottom of the sea. Different altitudes have been noticed on its coast: from +45-+50 m to -29 m of absolute altitude (Leontiev *et al.*, 1977; Rytchagov, 1997; Swytotch and Yanina, 1997; Varushenko *et al.*, 1987). According to paleobotanical materials, marks of flora species in the North-Eastern Precaspian are situated in the Pliocene and Pleistocene blankets of the Caspian Sea (Dorofeev, 1960; Grytchuk, 1960; Vronsky, 1980). Each of them has its own peculiarities, impacting modern geo-ecological situation of the region.

The goal of the research is to study the succession direction of vegetation cover in the European desert of North-Western Precaspian and its space-temporal allocation.

2. Methods

Collection of ferine materials took place during forwarding expedition of the Botanical Faculty of Kalmyk State University and the Faculty of Biology and Geography of Lomonosov Moscow State University.

Observations were conducted on 18 model grounds situated on the Late Caspian terraces. The connection of vegetation and natural environmental factors was estimated according to the composition of ecological matrix based on the following indicators: saline level of soil and ground waters occurrence (Gennadiev *et al.*, 1994). We used a concept of block organization of ecotone “water – land” (Dzhalalova, 2009; Novikova, 2006; Zalyetaev, 1997). Method of ecological-dynamic profiling helped to define the mechanism of the succession process taking place in the Ancient Caspian terraces and lake watersides. The discovered ecological levels corresponded to the zonal distribution of communities: hydromorphic, semi-hydromorphic, auto-morphic (Myalo and Malkhazov, 2000; Ramensky, 1938; Vyktorov, 1974). Processing of geobotanical descriptions was conducted according to Whittaker (1979) and Lebedeva *et al.* (1999) works.

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3. Results

For reconstruction of vegetation cover evolution in North-Western Precaspian, we distinguished three ecological-historical stages: Ancient Caspian, New Caspian and Newest Caspian, which correspond to the main periods of the Caspian Sea fluctuations (Lazareva *et al.*, 2011; Leontiev *et al.*, 1991; Swytotch, 2016) (Table 1).

As the biggest enclosed basin, Caspy appeared during the Preaktchagyl age. Alternation of marine and continental phases influenced the emerging of the Ancient Caspian terraces and vegetation cover development, corresponding to secular phylogenesis according to Sukatchov (1942). They took place in the context of multiple successions (primary, secondary) and as a result, several species with vital strategy could survive and they represent the exact stages of these successions (Rabotnov, 1982). Modern vegetation communities represent a progressive historical continuum.

We consider Pliocene transgression and regression over the Tertiary period as a starting point of Precaspian. The Aktchagyl transgression flooded a huge territory: up to Iran in the south, and to Kazan city in the north. During the Apsheron age, progressive shortening of water area resulted in drainage of large territories at the sea bottom and affected plants forthcoming (10 million years ago). We estimate this period as the beginning of vegetation cover development on the Caspian coast but also as a formation of succession types from pioneer annual communities to sustained arboreal, shrubby, suffruticose, pluriannual gramineous phytocenosis (Lazareva, 2003).

In order to describe the ecological and historical stages in the formation of vegetation in the region, we rely on our own geobotanical descriptions of modern vegetation cover in Ancient Caspian terraces finding in them the relict elements by dominant ecological-phytocenosis principle in syntaxones volume: aggregation — formation — vegetation type. Psamphyte, halophyte and meadow phytocenosis were noticed in vegetation cover of researched terraces. These types of phytocenosis indicate its succession character and incompleteness, proceeding during the current historical stage (Table 1).

Table-1. Ecological-historical vegetation formation stages in Ancient Caspian terraces of the European desert (Grytchuk, 1954; Nikolayev *et al.*, 1997)

Ecological-historical stages (age/period/epoch)	Geological age	Mark (m absolute height)	Impact factors: sea, climate	Ecological background	Vegetation type
Ancient Caspian: Apsheron, Aktchagyl age /Tertiary period/ Pliocene epoch	10 million years	+80-+90 m	Transgression, sea regression, humid and breezy climate	Sea blanket	Coniferous, temperate, foliar forests of partially grassy type. Steppe areas with herbs and shrubs emerge. Their quantity reaches up to 15-20%.
New Caspian: Baku age/ The Quaternary period/ Early epoch	400-500 thousand years ago	+17 m above the Volga River line	Transgression, sea regression, humid and breezy climate	Continental sea blanket	Taiga type forests, wet meadows.
Hazard Age/ The Quaternary period/ Middle epoch	250-90 thousand years ago	from -15--20m to -10--5 m above the sea level	Transgression, sea regression, climate	Sea, deltaic, river, liman blanket	Dry steppes with the presence of xerophytes and halophytes.
Newest Caspian: Khvalynian age/ The Quaternary period /Late epoch	18-9 thousand years ago	+50--19	Transgression, sea regression	Sea, liman, wind-laid blanket, chocolate clay	1. Taiga type forests; 2. Forest-steppe; 3. Steppe.
Early Khvalynian age	18-11 thousand years ago	+48-+50	Transgression, sea regression	Sea, liman blanket, chocolate clay, flat-plain landscape	1. Taiga type forests; 2. Forest-steppe.
Late Khvalynian age	11-9 (approximately 9) thousand years ago	0--15, -19	Transgression, sea regression, continental climate, rather breezy, precip. 380-400 mm.	Sea, liman, wind-laid blanket, slightly hilly and knobs landscape	Steppe, semi-desert, negligible presence of forests.
Modern, New Caspian age	Approximately 8 thousand years ago (19-21 centuries AD)	-20--25, -25--29	Transgression, sea regression, rather humid and less continental climate	New Caspian Sea, liman, wind-laid blanket, ridgy-knob landscape	Steppe with a partial presence of board-leaved forests.

Ancient Caspian ecological-historical stage. During the research of flora and vegetation of this period, we relied on the data of sporo-pollen analysis (SPA), which showed the domination of forest flora. It is clearly seen in the Apsheron blanket on the territory of the Sarpinskaya Lowland. According to Gubina (1954), on this territory, pollen of birch, alder, pine and other trees was found, but also some pollen of meadow-steppe herbs of Asteraceae, Apiaceae families, and in saline soils – Chenopodiaceae family and others. Tschiguryaeva *et al.* (1988) considers that at that time in the Precaspian region, there were coniferous, temperate and foliar forests, partially steppe areas of the suffruticulous type with the presence of thrift and ephedra. Typha, water plantain, arrowhead and other hygrophilous plants grew around water basins. Breezy and humid climate influenced the structure of the landscape.

New Caspian ecological-historical stage. During the Quaternary period, the most important were the following transgression phases: Baku, Hazard, Khvalynian and New Caspian.

At the Baku age, the Caspian Sea flooded up to +17 m above the sea level. This transgression took 100-120 thousand years (Swytotch and Yanina, 1997; Swytotch, 2016). Paleobotanic research of the blanket at that time shows that on the Southeast of the European part of Russia, the climate was breezy and humid with the dominance of the taiga type forestlands. Thermophilic families of hazel, which were present in Apsheron, were absent in this era. As for Chenopodioideae, they were represented by *Kochia prostrata*, *Salsola foliosa*, *Chenopodium glaucum* and others. Pydromorphic alkaline soils disappeared. According to SPA, grassland vegetation took from 30% to 68% of the territory (Dorofeev, 1960; Grytchuk, 1960; Vronsky, 1980).

During the Hazard age, the marks of transgressive epoch were layers of deltaic-sea and river-born blanket. At this period, maximum absolute marks were reached –15–20 m, the minimum were –10–5 m above the sea level (Nikolayev *et al.*, 1997). Thermoluminescent analysis (TLA) showed that Hazard transgression was the longest and took about 91-340 thousand years (Swytotch and Yanina, 1997). By the end of it, the Sarpinskaya Lowland and the biggest part of black soils had dried. Taiga forests were replaced by, humid meadows, while lakes and moors were replaced by dry steppes. Elements of taiga flora disappeared from the vegetation composition. As for sporo-pollen, it was represented by the pollen of birch, oak and elm. Herbal plants were dominated by the Chenopodioideae family (31 types, 12 classes). We also found seven types of vegetation (Chenopodium chenopodioides, Suaeda confusa, *S. corniculata*, *Salicornia europaea*, *Halimione verrucifera* and others), on sodic and alkaline soils – 12 types (*Artriplex tatarica*, *Kalidium foliatum*, *Anabasis aphylla*, *Salsola soda*). Wild grasses were represented by the steppe type herbs from following families: Fabaceae Ranunculaceae, Caryophyllaceae, Apiaceae, Brassicaceae. Hydriphytes were represented by *Typha*, *Potamogeton*, *Sparganium*. Climate aridisation impacted the disperse of saline soils and formation of desert-steppe landscapes with xerophytes and halophytes in the composition (Grytchuk, 1954).

Newest Caspian ecological-historical period. After short Hazard regression in Precaspy, mostly modern type of steppe vegetation was established during this time. New, Early Khvalynian transgressive phase was the biggest in the history of the Caspian Sea. Its coastline has reached the foot of the Ergeny and risen up to +48–50 m above the sea level (Dorofeev, 1960; Leontiev *et al.*, 1991; Markov *et al.*, 1965; Tschiguryaeva *et al.*, 1988). During the regressive phase, shortening of basin area was irregular with long breaks. In the northern part of the region under study, Early Khvalynian sea blanket lies directly on the surface. Its thickness varies from 10 to 20 m. Thinly laminated, platy, chocolate clays dominate in the composition (Markov *et al.*, 1965).

According to SPA, in the territory under study at the Khvalynian age, three periods of change are observed in terms of vegetation cover: during the first period, the vegetation was composed of taiga type forests with firs, Siberian cedar, pine and other coniferous trees. It is evident that further, they joined with the forests of the Caucasus. The second period was represented by mesophile and xeromesophile communities with steppe herbs partially alternated with coniferous and parvifoliate forests (Baktasheva, 2000; Shiffers, 1953). The third period was marked by the domination of steppes. The data of SPA taken from the Barmantsak Lake indicate that pollen of arboreal plants made only 4%, herbal – 92%, among which plants of Poacea family – 3%, Chenopodiaceae – 67%, *Artemisia genius* – 19% (Grytchuk, 1954).

Unlike Early Khvalynian, Late Khvalynian sea was shallow. In the area of black soils, the depth of the sea reached 10-20 m. The coastline was characterized by brusque unevenness with numerous liman lows. The lithological composition of the Late Khvalynian layers, situated on the Early Khvalynian ones, is not uniform. Liman lows are characterized by clay blanket, while watershed lows have closed-grained sandy clays and light clay loams with thickness level up to 5 m (Markov *et al.*, 1965; Nikolayev *et al.*, 1997; Poroshina, 1989).

With the development of the Early Khvalynian transgression, the sea salinity raised from low (approximately 5‰) to rather high (approximately 13‰) and then reached its maximum, which was followed by a drop of about 4-5‰ at the regressive stage. The salinity of the Late Khvalynian basin was less significant – about 10‰ (Swytotch and Yanina, 1997). Welling up of the Caspian Sea caused affluence of the Volga waters, which led up to the formation of the Sapinskaya Lowland in the Volga arm. Its flows and delta currently are represented by a set of branching hollows. At the end of the Late Khvalynian age, the sea level significantly dropped. This was accompanied by a noticeable drying of climate, which resulted in the wide presence of windborne processes and vast hummocky plains.

New Caspian transgression took place about eight thousand years ago. Its coastline is traced at the altitude of –15–20 m (Swytotch, 2016; Varushenko *et al.*, 1987). The capacity of the New Caspian basin was increasing towards the sea. The blanket included fine sands and a large amount of smashed shells (Nikolayev *et al.*, 1997).

Consequently, during the geological historical process on the territory of the European desert, transitional fields – “ecotones” were formed. Having a specific structure, these fields serve as the place of biodiversity development. The active dynamic process has been noticed on these ecotone fields, which gives them the main role in evolution process (Dzhalova, 2009; Novikova, 2006; Zalyetaev, 1997).

In modern Precaspy, soil-vegetation cover reflects both stages of secular succession in the Ancient Caspian terraces and stages of the last transgression. These processes are aimed at dealkalinizing hydromorphic saltings through semi-hydromorphic to automorphic soils. This process has been noticed on ecological and dynamic rows. Research shows that on New Caspian terrace it starts from hygrophytic flux flows, replaced by halophyte desert communities. This dynamic row terminates by xerophyte, desert-steppe phytocenosis on Early Khvalynian terrace. The changes in vegetation communities in accordance with their remoteness from the sea can be considered a result of long hologynic succession (Lazareva, 2003). The mechanism of this succession develops in a different way

depending on the ecological stage of the dynamic array. Each terrace (Khvalynian and New Caspian) has its own peculiarities.

The low ecological level of the New Caspian terrace is characterised by glycophyte reed-typha flux flows of the ground waters level (GWL) – 0.0 m; the Late Khvalynian – 0.0-0.5 m, represented by halophyte communities, growing on very saline soils (1.0–2.0%) of the heavy mechanical composition. On the Early Khvalynian this corresponds to alkali-reed communities with the presence of *Limonium suffruticosum* on medium saline soils (0.5-1.0%) with GWL – 0-1.0 m.

The medium ecological level of the New Caspian terrace is marked by halophyte meadow communities, where soil salinity level gets to 0.25-0.5% with GWL – 0.0-0.5 m; on the Late Khvalynian – *Artemisia santonica* and *Artemisia pauciflora* semi-shrub phytocenosis on saline soils (0.5-1.8%) with GWL – 1.0-3.0 m. On the Early Khvalynian, xerophyte, *Artemisia lerchiana*, *Artemisia pauciflora* and haloxerophyte phytocenosis are dominant on medium saline soils (0.25-1.0%) with GWL – 1.5-4.0 m.

At the high ecological level, progressive transformation of ephemeral *Artemisia santonica* phytocenosis into the desert on New Caspian terrace with the increase of land age and landscape roughness is observed. The same phytocenosis transforms into desert and desert-steppe on Late and Early Khvalynian terraces. In addition, an increase of habitat diversity complicates the horizontal structure: complexity in zonal desert-steppe areas and the combination of different type of vegetation in azonal areas (Lazareva *et al.*, 2011) (Table 2).

Table-2. Environment of the Ancient Caspian terraces in the European desert (Lazareva *et al.*, 2011; Swytotch, 2016)

Environment	Ancient Caspian terrace in the Precaspian Lowland		
	Early Khvalynian	Late Khvalynian	New Caspian
Duration of continental development, thousand years	18-11 (11-12)	11-9 (approximately 9)	8 (19-21 centuries AD)
Maximum sea level rise, m absolute height	+48 – +50; +5 – +7	0 – –15; –19	–20 – –25; –25 – –29
Soil materials	Chocolate clays	Sabulous and sandy sea blanket, in holes – lake type, in liman lows– clay and loamy, on hummocky plain – sandy and sabulous	Sandy sea blanket with an accumulation of mollusc shells and detritus, sandy sea and liman blanket
Landscape	Flat plain	Slightly billowy, hillock-billowy	Ridge-hillocky
Soils	In northern and north-western parts– light-chestnut, alkaline, complex, in eastern part – brown	Brown, desert-steppe, sandy, sabulous, rare complex with alkali soils, meadow-brown soils; in the south-east – salines, dispersed sand	Brown sabulous and sandy primitive combined with salines, meadow – saline soils
GWL, m	0 – 10; more15	about 6 – 15; 0 – 6	3 – 5; 0 – 2,5
Level of soil layer salinity 0-30 cm, in %	0,1 – 0,2; 0,1 – in highlands, 4,4 – in lake blanket	0,3 – 0,4; 0,3 – in highlands; 2,4% – in lake lowlands	0,8 – 1,0; 0,2 – next to the sea line; 0,8 – 1,7 – distance - 10 km from sea
Salinity type	Cl, Cl-SO ₄	SO ₄ -Cl; Cl-SO ₄	SO ₄ ; Cl-SO ₄
Vegetation	Steppe zone Precaspian southern (desert) steppes, pollen-sod grasses on light-chestnut soils. (<i>Stipa sareptana</i> , <i>Agropyron desertorum</i> , <i>Festuca valesiaca</i> , <i>Artemisia lerchiana</i>)	Desert zone Precaspian northern deserts on sabulous and brown soils. Semi-shrub (<i>Artemisia lerchiana</i>), gramineous-semi-shrub (<i>Artemisia taurica</i> + <i>Poa bulbosa</i> , <i>Artemisia pauciflora</i> + <i>Poa bulbosa</i>), complexe.	Desert zone Precaspian northern deserts on brown sandy soils. Semi-shrubs (<i>Artemisia lerchiana</i>), gramineous-semi-shrub (<i>Agropyron fragile</i> , <i>Artemisia arenaria</i>) psammophyte combined with vegetation of sands and salines. In coast zone reed-typha flux flow, halophyte meadows

4. Conclusions

The mentioned ecological-historical stages in the European desert formed the ancient ecotone of the first class. Level fluctuations of Caspy during the last 18-20 thousand years led to the development of three Ancient Caspian terraces, corresponding to the ecotone of the second class. The ecotones of the third class are represented by the transitional zone situated in accordance with the decrease level of ground waters, as well as digression of soil saline level. Zonal and regional factors are the most significant and we can notice this from wetland communities on the cost of the Caspian Sea through suffruticulose deserts of the Late Khvalynian terraces to the desert steppes of the Early Khvalynian terraces. They present the result of the vegetation cover evolution of the Precaspian Lowland from ancient times to modern epoch (Dzhalalova, 2009; Ramensky, 1938).

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