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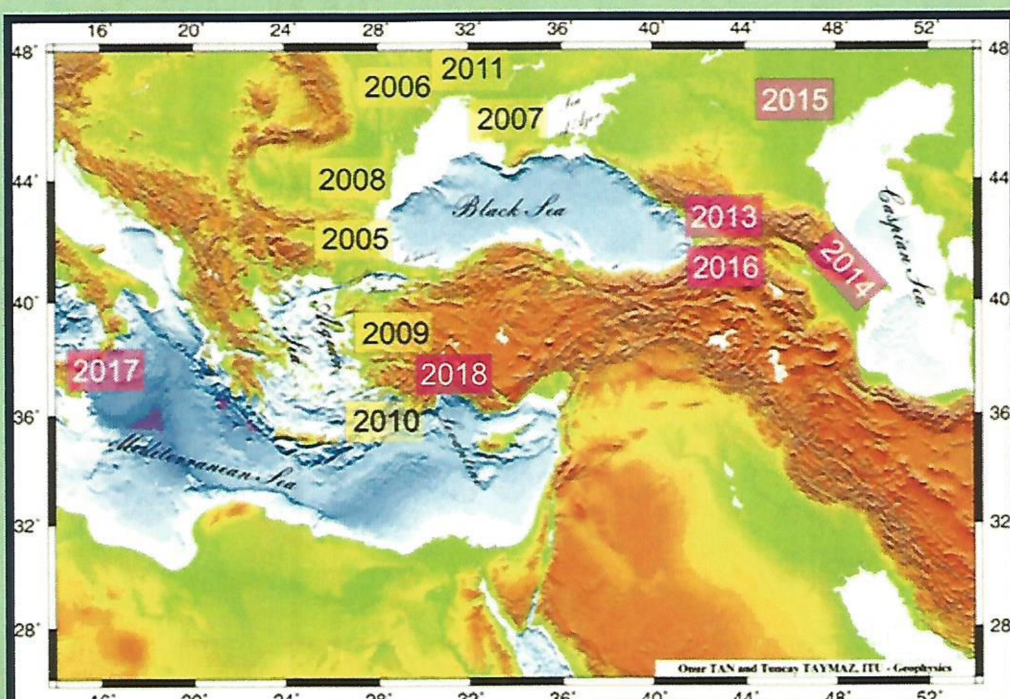

PROCEEDINGS

IGCP 610 "From the Caspian to Mediterranean: Environmental Change and Human Response during the Quaternary" (2013 - 2018)

INQUA IFG POCAS "Ponto-Caspian Stratigraphy and Geochronology" (2017-2020)

CLIMATE AND ENVIRONMENTAL CHANGES IN THE NORTHERN CASPIAN SEA REGION DURING THE HOLOCENE

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Introduction

Changes in landscape conditions in the northern Caspian Sea during the last 10,000 years are associated with climate change and fluctuations in the level of the Caspian basin. Using data on geology, geomorphology, history, archaeology, and malacology, as well as results of radiocarbon (^{14}C) dating, P.V. Fedorov, O.K. Leontyev, G.I. Rychagov, S.I. Varushchenko, A.A. Svitoch, and others have defined coastline hypsometry and the ages of a hierarchy of multiple transgressions and regressions of the Caspian Sea during the Holocene.

Climatic conditions and plant communities of the littoral areas during the Mangyshlak regression, during the maximum of the New Caspian transgression, and during different phases of the Late Atlantic period have been reconstructed from palynological analyses of Caspian Sea bottom sediments and from analyses of lake, alluvial, and subaerial deposits of the northwestern and northeastern sectors of the Caspian region by T.A. Abramova (1980, 1985), V.A. Vronsky (1980, 1987), V.L. Yakhimovich et al. (1986), and others.

A holistic understanding of vegetation and climate evolution during the entire modern interglacial epoch has been hampered by a lack of data for the Caspian sequences that possess the full representation of Holocene sediments, sufficient palynological characteristics, and a series of ^{14}C dates. In the late 1980s, the first results were obtained (Bolikhovskaya, 1990) from a comprehensive palynological study of sediments that were fully dated by ^{14}C, and this allowed us to reconstruct a continuous sequence of changes in vegetation and climate of the Lower Volga during the Holocene. Using materials from our subsequent research, we compared Holocene climatic and vegetation successions from the Volga-Akhtuba floodplain and the Volga delta, and identified patterns of landscape and climatic changes that have been occurring in the study area over the last 10,000 years (Bolikhovskaya and Kasimov, 2008, 2010).

This publication presents the main results of detailed reconstructions of changes in zonal vegetation types and the transformation of the zonal and intrazonal plant communities in the Holocene landscapes of the Lower Volga region that occurred under the impact of global climate fluctuations and changes in edaphic conditions. These reconstructions were based on a comprehensive palynological analysis and radiocarbon dating of paleogeographic sequences that were the most informative regarding the Holocene period. The reconstructed paleoclimatic events were correlated with the Caspian Sea transgressive-regressive phases of the Holocene. A detailed periodization scheme of individual paleoclimatic events has been developed, and this scheme can now serve as a framework for subsequent climato-stratigraphical and paleogeographical studies of the Northern Caspian region during the Holocene. The reconstructed chronological paleo-boundaries of vegetation, landscape, and climate change phases may serve as a climato-stratigraphical framework for subsequent paleogeographical studies of the Holocene in the Caspian basin. Furthermore, these findings may help to understand the magnitude of the transformation in Holocene landscapes of the Northern Caspian region during various transgressive and regressive epochs.

Materials, methods, study area

The main object of these research efforts was the Northern Caspian Sea region, specifically the Volga-Akhtuba floodplain, as it is the most indicative in palynological respect. Its vegetation (as shown by the results of this study) actively responded to climate change and the congruent Caspian Sea level fluctuations. A spore-pollen analysis of sediments from two sections near the site of Solenoye Zajmishche (47°54' N, 46°10' E; about -19-20 m asl — i.e., above sea level — and 5 km south of the city of Chernyi Yar, Astrakhanskaya oblast) was performed. Section 1 was a 5-meter thick layer uncovered by a well at a dry oxbow lake developed on the surface of a high floodplain. A detailed climato-stratigraphical interpretation was performed using palynological analysis of 50 samples taken at 10-cm intervals and ^{14}C dating of five samples (Table 1). It appeared that the process of accumulation of oxbow-lake clays continued through the entire Holocene. In the outcrop of the sediments, Section 2 uncovered a high floodplain towering 6-7 meters above the river's edge. Representative data have been obtained for the upper 3 m of the exposed sequence. On the basis of pollen assemblages, it can be dated to the late Subboreal and Subatlantic periods of the Holocene.

Table 1. Radiocarbon and calendar dates for Holocene sediments from sections at Solenoe Zajmishche

Sample Number	Depth, m	^{14}C dates, yrs BP	Calendar (calibrated) dates, BP (ca. ^{14}C yrs BP)
1	4.75–5.00	9560±60	11060–10970
2	4.50–4.75	8500±100	9500
3	2.25–2.50	3200±60	3440–3400
4	2.00–2.25	2540±130	2620
5	0.30–0.50	900±60	900–800

Palynological data were also derived from a 10-m thick layer penetrated by borehole N22 in the littoral area of the Volga Delta (45°43' N, 47°55' E) (-22 m asl) at the Damchik site of the Astrakhan Nature Reserve. The absolute age of this section's sediments was determined by our colleagues in an international project from six ^{14}C AMS dates; they varied from 7287 ± 44 to 3316 ± 34 BP. The Holocene geological record in the sequences of the Volga delta (Kroonenberg and Hoogendoorn, 2008) is incomplete, which has been confirmed by rigorous palynological and algological investigation of four sections from the delta carried out by K. Richards (2018; see also Richards et al., 2014).

Results and conclusions

A detailed climato-stratigraphical subdivision of the sediments studied and a description of 26 phases in the development of vegetation and climate during the Holocene in the Lower Volga region were performed using the palynological data and results of ^{14}C dating obtained in this study (Table 2).

Table 2. Climatic stages of the Holocene in the Lower Volga Region, their characteristics and ages according to pollen analysis and ^{14}C dating of the deposits from Solenoe Zajmishche

Holocene Subdivisions	^{14}C ages of climatic stages, years BP		Zonal vegetation	Climate
	Conventional	Calibrated		
SA-3	200 – 0	250 – 0	Semi-desert	Relatively warm and arid
	400 – 200	500 – 250	Semi-desert	Temperature fall, humidification
	700 – 400	670 – 500	Semi-desert	Temperature rise, humidification
	900 – 700	840 – 670	Semi-desert	Temperature fall, aridization
	1100 – 900	1030 – 840	Dry steppe	Cool and arid
SA-2	1300 – 1100	1270–1030	Steppe	Temperature rise, humidification
	1500 – 1300	1400–1270	Dry steppe	Temperature fall, aridization
	1700 – 1500	1600–1400	Steppe	Relatively warm and relatively humid
	1800 – 1700	1720–1600	Steppe	Warm and arid
	2100 – 1800	2080–1720	Steppe	Relatively warm and relatively humid
SA-1	2300 – 2100	2340–2080	Dry steppe	Temperature fall, continentalization
	2500 – 2300	2600–2340	Steppe	Temperature fall, humidification
SB-3	2700 – 2500	2780–2600	Steppe	Relatively warm and arid
	3500 – 2700	3770–2780	Forest-steppe	Relatively warm, humidification
SB-2	3700 – 3500	4040–3770	Dry steppe and semi-desert with Chenopodiaceae -	Temperature fall, aridization

			Artemisia assemblages	
	4200 – 3700	4770–4040	Forest-steppe; mixed forests with broad-leaved, birch, and conifer stands	Warm and humid climate (III climatic optimum)
SB-1	4800 – 4200	5540–4770	Forest-steppe	Temperature fall and humidification rise
	5000 – 4800	5740–5540	Forest-steppe	Temperature fall, aridization
AT-2	6100 – 5000	6970–5740	Forest-steppe; mixed forests with hornbeam, beech, elm, lime, birch, and conifer stands	Warm and humid (II – main - climatic optimum)
	7400 – 6100	8240–6970	Steppe	Warm and relatively arid
AT-1	7600 – 7400	8400–8240	Dry steppe with Chenopodiaceae - Artemisia assemblages	Temperature fall, aridization
	8000 – 7600	8900–8400	Steppe	Warm and relatively humid
	8300 – 8000	9350–8900	Steppe	Temperature fall, continentalization
BO-2	8500 – 8300	9500–9350	Forest-steppe; mixed forests with hornbeam, elm, lime, birch, and conifer	Warm and humid (I climatic optimum)
BO-1	9200 – 8500	10250–9500	Steppe with Chenopodiaceae assemblages, park pine forests	Cool, continentalization
PB-2	10000–9200	11500–10250	Forest-steppe dominated by Picea, Pinus, Abies	Relatively cool and humid

We correlated the reconstructed paleoclimatic events to the Caspian Sea level fluctuations defined according to geological, geomorphological, malacological, and other studies. The research presented herein established the following dependencies in landscape-climatic changes in the Lower Volga region and in climate-dependent sea-level fluctuations of the Caspian Sea during the Holocene.

1) Over the past 10,000 years (11,500 cal yrs), there were several changes in the vegetation cover and climate of the Lower Volga region. Palynological data indicate at least 26 phases in the evolution of the Holocene landscapes and climate of this territory. During the Early and Middle Holocene, in the interval ~10,000–2500 BP, forest-steppe and steppe landscapes dominated under a more favorable and humid (compared to modern time) climate in the study area. These landscapes underwent seven forest-steppe and seven steppe non-consecutive phases during their development. In the Late Holocene, in the interval ~2500–900 BP, there were eight phases that reflect the transformation of zonal and intrazonal phytocoenoses. During the last 900 years, the territory of the Lower Volga became the area of development of desert-steppe and desert landscapes, for which at least four climato-phytocoenotic alternations were identified; these phases reflected fluctuations of heat and moisture availability.

2) The main feature of the evolution of climatic processes in this region during the Holocene was expressed in the distinct climatic optima that corresponded to the maxima of heat and moisture supply. The Late Atlantic optimum (~6100–5000 BP) was the main optimum and the time of development of forest-steppe landscapes. The amount of thermophilic arboreal pollen in the pollen assemblages that represent this period reached 31%. Mixed oak forest with an admixture of common and Caucasian hornbeam (Carpinus betulus, C. caucasica), oriental beech (Fagus orientalis), different species of elm (Ulmus laevis, U. foliacea), linden (Tilia cordata), birch, and other trees, and coniferous forests comprised the forest belt of the Lower Volga floodplain. The Late Boreal (~8500–8300 BP) and the Middle Subboreal (~4200–3700 BP) optima were close in character and characterized by a lesser heat availability and greater moisture supply. They were both marked by the dominance of forest-steppe and, in some phases, of steppe landscapes. However, they differed from the Atlantic optimum by less favorable conditions for the growth of broad-leaved tree stands and by less participation of broad-leaf species in the forests. The amount of pollen from broad-leaf species in the pollen assemblages that describe these periods did not exceed 21–23%. It is possible to correlate these three phases to the maximal transgressive stages of the New Caspian basin with a high degree of confidence.

3) The existence of the transgressive stages of the Caspian Sea is also supported by the phases of cold and relatively humid climate. First, this is expressed in the presence of the forest-steppe phase in the interval ~10,000–9200 BP, which corresponds to the Sartass stage when, within the part of the Northern Caspian region free from the sea, there were widespread sparse pine forests and isolated forest stands dominated by spruce and fir. The phases of cooling and humidization were also identified in the intervals ~4800–4200, 2500–2300, and 400–200 BP. Transgressive stages of the sea correlate also with the phases of warming and humidization of climate in the intervals ~8000–7600, 3500–2700, 2100–1800, 1700–1500, 1300–1100, and 700–400 years BP.

4) Regressions of different ranks may correspond to the reconstructed minima of heat and moisture (the periods of cold and dry climate), as well as to the intervals of significant warming and aridization (the periods of relatively warm and dry climate). Two of the most significant minima of heat and moisture availability correlate with the Early Subboreal sub-period and to the first half of the Late Subatlantic sub-period. The first minimum corresponds to the time of the Mangyshlak regression of the Caspian Sea (~9200–8500 BP), while the second minimum corresponds to the Derbent regression (1500–700 BP). Within the interval 8500–1500 BP, there was one phase of rapid warming and aridization of climate (~2700–2500 BP) and five phases of sharp cooling and aridization of climate (in the intervals ~8300–8000, 7600–7400, 5000–4800, 3700–3500, and 2300–2100 BP) that may correspond to a short-term but pronounced drop in the Caspian Sea's level. The most significant decrease relates to the intervals ~7600–7400 and 3700–3500 BP. All phases of cooling and aridization

of climate were marked by the prevalence of dry steppes and semideserts within the study region; there, xerophitic Artemisia and Chenopodiaceae communities dominated the vegetation.

5) Based on the reconstructed climatic and vegetation successions, two paleogeographic models of the Caspian Sea in post-Mangyshlak time may be proposed. The first model is based on the fact that the Late Subatlantic interval, characterized by the dominance of semidesert and desert landscapes, is very different in phytocenological and climatical respect (with the exception of the last phase of the Subboreal period ~2700–2500 BP) from the entire preceding part of the Holocene. It should be also noted that the last (the newest) 700-year-long phase of development of the Caspian basin is closer to regressive than transgressive in paleo-climatic respect. The alternative model is close to the models developed by O.K. Leont'ev and G.I. Rychagov (1982), and A.N. Varuschenko et al. (1980), except for the interpretation of a regressive phase in the interval of ~5000–3500 BP. We suggest that this phase was developing as a pulse regressive phase (as determined from the palynological data) ~5000–4800 BP. This phase was replaced by a transgressive phase ~4800–3700 BP followed by a new pronounced pulse decrease in the Caspian Sea level ~3700–3500 BP.

Acknowledgments

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