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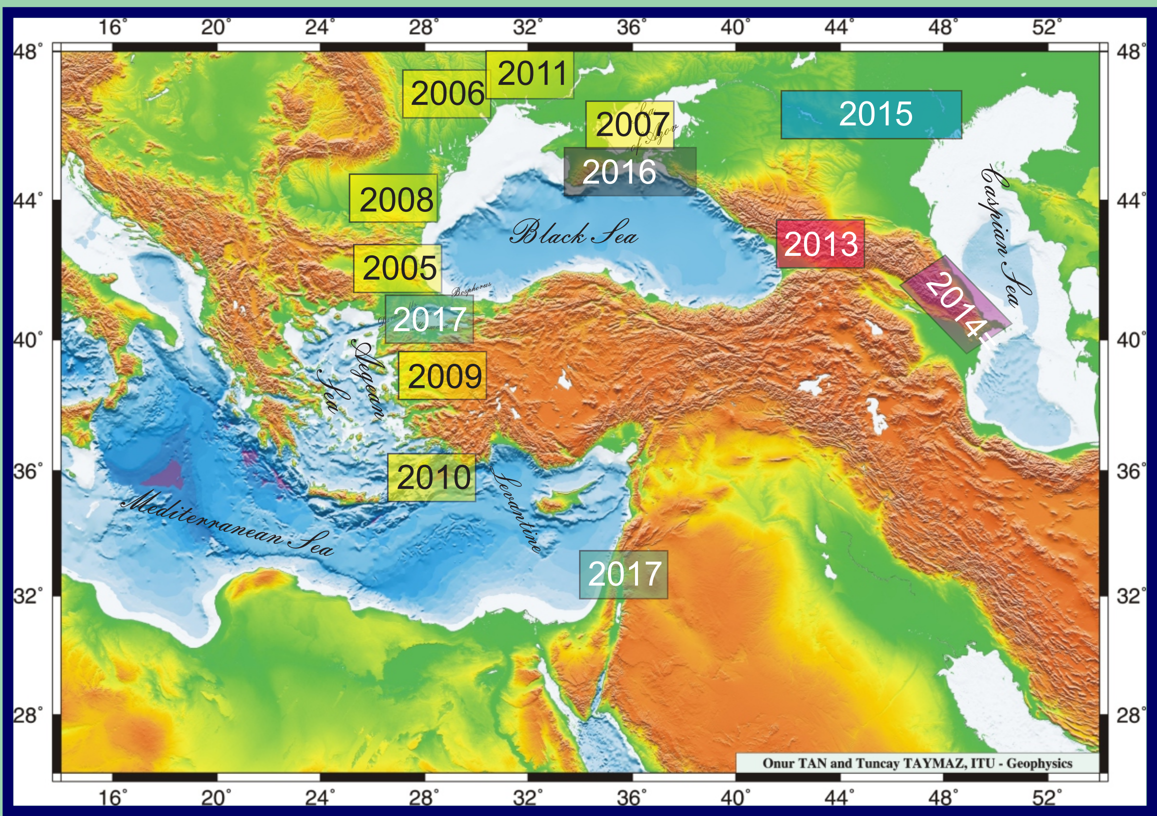
Institute of Earth Sciences of the Georgia Ilia State University, Tbilisi, Georgia

12-19 October 2013

INTERNATIONAL GEOSCIENCE PROGRAMME



Proceedings of the First Plenary Conference

IGCP 610 “From the Caspian to Mediterranean: Environmental Change and Human Response during the Quaternary” (2013 - 2017)

http://www.avalon-institute.org/IGCP

IGCP 610 First Plenary Conference and Field Trip, Tbilisi, Georgia12-19 October 2013

PROCEEDINGS

Organizers

Institute if Earth Sciences,

Ilia State University, Georgia

Avalon Institute of Applied Science,

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Ilia State University, Georgia

Avalon Institute of Applied Science,
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Ilia State University

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AIMS AND SCOPE

This Project will investigate the influence of environmental change on the development of humankind for the entire Caspian-Black Sea-Mediterranean Corridor ["CORRIDOR"] that encompasses the Eurasian intercontinental basins of the Caspian, Black, Marmara, Aegean, and Eastern Mediterranean seas with their connecting straits and coasts (Fig. 1). During the Quaternary, these basins were repeatedly connected and isolated from each other. This predetermined their environmental conditions and hydrologic regimes and imposed specific impacts on diverse biological populations, including humans inhabiting the coastal domains.

The Project's goal is to provide cross-disciplinary and cross-regional correlation of geological, archaeological, environmental, and anthropological records in order to (a) explore interrelationships between environmental change and human adaptation during the Quaternary, (b) create a networking and capacity-building structure to develop new interdisciplinary research initiatives, and (c) provide guidance to heritage professionals, policy makers, and the wider public on the relevance of studying the "CORRIDOR" for a deeper understanding of Eurasian history, environmental changes and their relevance, and likely future impact on humans.

This Project succeeds IGCP 521 "Black Sea-Mediterranean Corridor during the last 30 ky: sea level change and human adaptation" (2005-2010) that collected, integrated, and analyzed much scientific data and established a strong international team of multidisciplinary scientists from 32 countries.

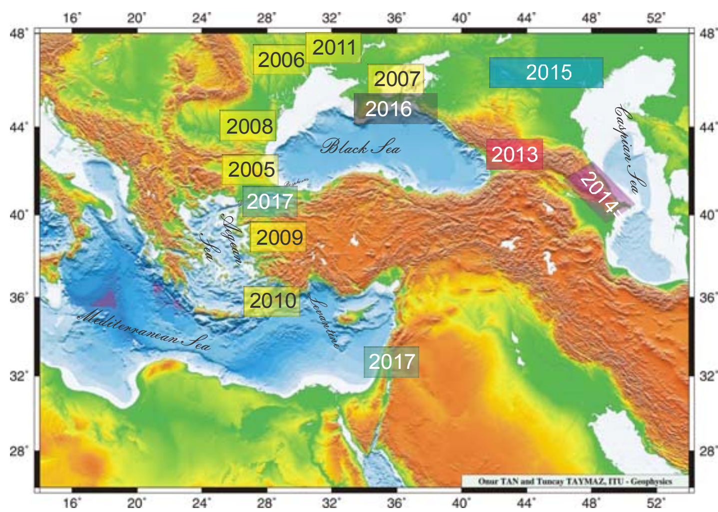

Figure 1. The Caspian-Black Sea-Mediterranean "CORRIDOR": in yellow are the locations of IGCP 521-INQUA 501 meeting and field trip sites (2005-2011); in other colors are sites to be studied by the proposed project: 2013 – Tbilisi, Georgia; 2014 – Baku, Azerbaijan, and Derbent, Dagestan (Russia); 2015 – Astrakhan' (Volga delta) and the Manych Valley, Russia; 2016 – Sevastopol (Crimea), Ukraine, and the Taman Peninsula, Russia; 2017 – Haifa, Israel, and Istanbul, Turkey.

The First Plenary Meeting and Field Trip will focus on the Eopleistocene geological sequence of Tsvermaghala Mountain that represents a stratotype of the Gurian Chauda; it possesses a thickness exceeding 1000 m deposited prior to the Matuyama-Brunhes Reversal (i.e., 780 ka BP) as well as archaeological sites of Lower to Upper Paleolithic age that include Dmanisi, Mashavera Gorge, Tetritskaro, Tsalka-Bedeni Plateau, Faravani Lake, Akhalkalaki, Diliska, Chiatura, Bondi Cave, Undo Cave, Djruchula Gorge, as well as the Neolithic site Samele Cave and Medieval-Roman site Vardzia Cave.

The meeting will cover seven days. Two days (13-14 October) will be spent in plenary sessions, and four days (15-18 October) will be dedicated to the field trips.

WELCOME

On behalf of the Organizing and Executive Committees as well as the Ilia State University, Georgia, and Avalon Institute of Applied Science, Canada, we are delighted to welcome you to the IGCP 610 First Plenary Conference and Field Trip being held on 12-19 October 2013 in Georgia.

This conference is the first in a series of IGCP 610 Plenary Conferences and Field Trips. It is expected that IGCP 610 conferences will bring together multidisciplinary scientists from all over the world and in the process enhance West-East scientific dialogue by providing a supportive background for collaboration regarding the correlation and integration of discoveries on the influence of climatically/tectonically induced sea-level changes and coastline migration on humanity. This is an area of strategic importance not only for all coastal countries but also for at least 17 other countries sharing a drainage basin that is one-third the size of the European continent.

The First Plenary Conference and Field Trip has been organized by the Institute of Earth Sciences of the Ilia State University, Georgia, and Avalon Institute of Applied Science, Canada, and sponsored by the Ilia State University, Georgia, and the Avalon Institute of Applied Science, Winnipeg, Canada; with very moderate financial contributions from IGCP.

We are happy to welcome to Georgia distinguished specialists and students in the Humanities, Earth, and Life Sciences from countries around the world.

We wish you a very pleasant stay in Georgia.

Sincerely,

Organizing and Executive Committees of IGCP 610 First Plenary Meeting and Field Trip

VENUE

The conference will be held under the auspices of the Ilia State University, Tbilisi, Georgia (www.iliauni.edu.ge). Tbilisi is the capital and the largest city of Georgia, lying on the banks of the Kura River. The name is derived from an early Georgian form ‘T'pilisi’, and it was officially known as Tpilisi (in Georgian) or Tiflis (in Russian) until 1936. The city covers an area of 726 km2 and has 1,480,000 inhabitants. Founded in the 5th century by Vakhtang Gorgasali, the monarch of Georgia's precursor Kingdom of Iberia, Tbilisi has served, over various intervals, as Georgia's capital for nearly 1500 years and represents a significant industrial, social, and cultural center of the country. Located on the southeastern edge of Europe, Tbilisi's proximity to lucrative east-west trade routes often made the city a point of contention between various rival empires throughout history, and the city's location to this day ensures its position as an important transit route for global energy and trade projects. Tbilisi's varied history is reflected in its architecture, which is a mix of medieval, classical, and Soviet structures. Historically, Tbilisi has been home to peoples of diverse cultural, ethnic, and religious backgrounds, though it is now overwhelmingly Eastern Orthodox Christian. Notable tourist destinations include cathedrals like Sameba and Sioni, classical Freedom Square and Rustaveli Avenue, medieval Narikala Fortress, the pseudo-Moorish Opera Theater, and the Georgian National Museum.

Ilia State University is one of the flagship public research HEIs and the first HEI in Georgia to base its core undergraduate curriculum on the principles of liberal education. ISU was established in 2006, based on the union of several different institutions. 25 research institutes and laboratories are actively engaged in research and graduate teaching. ISU strives to provide high-quality education and facilitate rigorous research through innovative initiatives and policies. ISU believes that this approach will contribute to the creation of a society possessing global knowledge and capable of developing sustainable solutions for the challenges of the 21st century.

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ACKNOWLEDGEMENTS

We gratefully acknowledge the support and hospitality of the Georgian organizers, the Institute of Earth Sciences of Ilia State University for hosting the IGCP 610 First Plenary Conference and Field Trip, and providing us with their facilities to convene this conference. Support has also been received from the Avalon Institute of Applied Science, Canada. Financial contributions to underwrite the travel costs for young scientists from developing countries and countries in transition were kindly provided by IGCP.

We are indebted also to Prof. Dr. Gigi TEVZADZE, Rector of Ilia State University, Prof. Dr. Zurab JAVAKHISHVILI, President of the Conference and Head of Administration, and Avtandil OKROSTSVERIDZE, Head of the Geological Department for their extraordinary efforts in organizing the conference and field trips. Particular appreciation is extended to Mikhais KAKABADZE, Mikhail ELASHVILI, Nikoloz TUSHABRAMISHVILI, Zurab JANELIDZE and Lasha SUKHISHVILI, for arranging the Field Trips and preparing the Field Trip Guide.

We gratefully gratefully acknowledge the assistance of Tinatin GHVINIASHVILI, Executive Secretary of the Conference.

We gratefully recognize the assistance of Prof. Allan GILBERT together with Prof. Dr. Valentina YANKO-HOMBACH for editing and layout of the Conference Proceedings.

To the Scientific Committee, we offer sincere thanks for evaluating submissions and managing the abstract review process. The Scientific Committee, in turn, wishes to thank the anonymous reviewers for their efforts in providing useful comments on submitted papers.

For her prompt action, we extend our appreciation to the Administator of the Project, Dr. Irena MOTNENKO. We are indebted to Prof. Dr. Peter HOMBACH of Osorno Enterprises, Winnipeg, Canada, and Dr. Irena MOTNENKO for the project website design; and we acknowledge assistance provided toward this goal by Sealevel Special Projects (http://sealevel.ca/).

We are also very grateful to the journal *Quaternary International*, which has kindly invited us to publish the Georgia conference proceedings within their pages, just as it did for the IGCP 521 and INQUA 0501 projects.

Prof. Dr. Valentina Yanko-Hombach

Co-Leader of IGCP 610 and Executive Director of the Conference

PROCEEDINGS

ON THE POSSIBILITY OF FORECASTING ELBRUS ERUPTIONS: THE STRUCTURE OF SNOW - THE PARAMETER OF TECTONIC ACTIVITY

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Keywords: glacier, fumarole, chemical composition, aerosol emissions

Introduction

Mount Elbrus is the largest mountain in Europe and the Caucasus. Today, it is a sleeping volcano, but according to radiocarbon data as well as descriptions from Strabo, eruptions occurred in the 1st-2nd centuries BC (Bogatikov et al., 1998; Laverov, 2005). In fact, satellite images of Mount Elbrus show traces of catastrophic rock-ice avalanches and rapid movements of glaciers Kukurtlu and Ullukam that occurred at that time (http://www.igem.ru).

If it were to happen, a present-day eruption of Mount Elbrus would be a catastrophe for the Caucasus and the Black Sea coast because (1) incandescent lava would melt the ice cap, (2) the ice strength would decrease due to the influence of abundant volcanic gases, aerosols, and mineral water, and (3) the glaciers would flow down into the river valleys, such as the Kuban, causing mudslides and flooding in heavily urbanized, industrialized, and populated territories (Alekseev, 2007).

Study area

The study area extends from the peak to the foot of Mount Elbrus, including the glacier Garabashi (with a glaciated area of about 5 km^2 and a length of 4.09 km). Snow masses that contain various admixtures of chemical elements originating from volcanic eruptions or gaseous emanations are blown off the mountain peak and accumulate on the saddle below the glaciers and snowfields.

Materials and methods

Samples were collected throughout the study area from the peak to the foot of Mount Elbrus (Fig. 1) and brought to the laboratory of the Russian Research Center "Kurchatov Institute," where they were investigated by atomic emission spectrometry with inductively coupled plasma [ICP-AES] (Alekseev, 2007).

A strong fumarolic plume was observed on the eastern slope of the eastern peak of Mount Elbrus when, after the solar eclipse in March of 2006, it could be clearly seen against the background of a cloudless sky and looked like steam from a factory chimney. This fumarolic area (Fig. 2) was chosen for investigation by hydrogen survey as well as by georadar and lidar methods.

Figure 1. Mount Elbrus and the upper reaches of the glacier Garabashi.

Figure 2. Fumarolic area on the eastern peak of Mount Elbrus (elevation, 5590 m).

It is quite difficult to compare the concentration of elements but more convenient to compare Coefficients of Enrichment (K_e) that represent the ratio of a given element's concentration to the concentration of Fe in the sample normalized to the ratio of the clarke content of the given element in the Earth's crust.

Results

The K_e of chemical elements in the snow samples collected on the peak and slopes of Mount Elbrus in 2007 are shown in Table 1.

Table 1. K_e of chemical elements determined from snow samples collected within the uppermost 0-5 cm of surface snow in different places on the western side of Mount Elbrus on 28 June 2007.

№	Location	Na	Mg	Al	Si	S	K	Ca	Ti	V	Mn	Cu	Zn	Sr	Ba
1	Western peak, elevation 5642.7 m	bd*	bd	0.93	bd	1900	15	43	bd	bd	7	bd	210	61	bd
2	Saddle, elevation 5366 m	bd	bd	0.45	bd	2400	30	54	bd	bd	5.0	bd	570	61	bd
3	Pastukhov' cliff, elevation 4538 m	bd	bd	0.56	bd	3800	74	220	bd	bd	5.5	17	390	180	bd

* bd = below detection limit.

It can be seen that, similar to Avachnikiy volcano (Alekseev and Alekseeva, 1989; Alekseev et al., 1991), the snow samples contain Al, S, K, Ca, Mn, Zn, Sr, and in some places Cu, showing the influence of fumarolic gases. The values of K_e for the same chemical elements vary in samples collected from different places on Mount Elbrus. The highest values of Zn S, and Sr are present in samples from Pastukhov' cliff. We consider them as bench mark elements (in bold) of volcanic activity similar to the fumarolic activity on the Avachinskiy volcano (Alekseev and Alekseeva, 1989).

Comparing the K_e of the bench mark elements Zn, S, and Sr in Table 1 and 2, we can conclude that (1) the highest K_e of S was obtained on the eastern peak and Pastukhov' cliff; (2) the highest K_e of Zn was obtained on the saddle and eastern peak; and (3) the highest K_e of Sr came from the saddle and Pastukhov' cliff. The highest K_e is obtained for Zn was close to the fumarolic area. The eastern side of Mount Elbrus is the most active; here, values for K_e are almost twice as high compared to the other sampled sites.

Table 2. K_e of chemical elements determined from snow samples collected within the uppermost 0-5 cm of surface snow in different places of eastern side of Mount Elbrus on 30 July 2012.

№	Location	Na	Mg	Al	Si	S	K	Ca	Ti	V	Mn	Cu	Zn	Sr	Ba
1	Eastern peak, elevation 5621 m	44	11	0.85	1.8	3200	16	104	2.1	5	15	35	3300	131	30
2	Fumarolic cave, elevation 5590 m.	22	6.3	0.55	2	1500	12	41	1.0	4	7.3	37	300	103	30
3	Fumarolic area, elevation 5590 m	3.4	2.9	0.97	1	260	2.6	4.1	0.4	2	1.9	2.5	150	16	8.3
4	Snow crystals on stones, elevation 5450 m	8.5	0.8	0.10	0.15	260	2.1	0.8	0.1	0.4	2.2	1.9	380	7.8	4.2
5	Elevation 5400 m	4.7	1.0	0.09	0.52	200	2.0	3.1	0.4	2.6	1.7	2.3	56	11	5.9
6	Saddle, elevation 5366 m	7.2	23	0.75	0.91	540	7.3	2.8	0.4	1.7	2.8	2.6	200	390	7.2
7	Elevation 5200 m	4.6	1.4	1.2	0.87	370	5.0	2.5	0.6	1.6	2.5	3.6	110	15	11
8	Elevation 5200 m	0.8	0.4	0.09	0.16	34	0.6	1.1	0.1	1.3	8.6	2.5	21	3.3	3.0

Snow crystals on stones (Fig. 3) are formed by water vapor from the atmosphere as well as sublimation on the sharp margins of the stones. Therefore, it is not surprising that concentrations of some chemical elements and their corresponding K_e are the smallest compared to other sampling sites.

Figure 3. Snow crystals on stones of the eastern peak of Mount Elbrus, elevation 5450 m.

Conclusions

This study enabled us to choose particular sites for regular observations of tectonic activity on Mount Elbrus in order to monitor its recent condition and prognostigate on possible eruptions. It appears that the site located on Pastukhov' cliff should be monitored continuously for aerosol emissions. Similar observations are recommended for other dangerous localities, such as volcanoes and earthquake-prone areas.

We have shown previously that, in historical context, volcanic eruptions of Mount Elbrus have occurred at the lowest levels of the Caspian Sea (Alekseev et al., 2009). Consequently, the possibility of the next eruption can be expected when the level of the Caspian Sea is again close to its minimum. Therefore, we recommend monitoring chemical elements in snow samples as possible indicators of volcanic eruptions from Mount Elbrus.

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THE IMPACT OF DANUBE FLOODS ON THE SEDIMENTOGENESIS OF THE BLACK SEA LITTORAL ZONE

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Keywords: delta, hydrologic conditions, hydro-chemical parameters, seasonal changes, sedimentological conditions

Introduction

As is well known, deltas are sedimentary systems formed by the deposition of detrital material carried by rivers to their mouths in either marine or lacustrine basins (Panin, 1989). The Danube delta is a unique area. It is one of the most rapidly accumulating parts of the Black sea shelf. The solid matter component of the inflow represents 133 million tons of debris added to the Black Sea every year. Of this amount, the Danube inputs 83 million tons (Shyisky, 2003). These processes of sedimentation and deposition have been ongoing in the study area for several thousand years and have led to the creation of a huge mineral mass. The present paper presents actual data on the changes in sedimentation conditions for the Danube Delta during different seasons. Investigations of the sedimentation process require simultaneous examination of varied environmental factors. In this paper, data on water depth, salinity and temperature conditions, oxygen content, pH, and grain characteristics of the deposits were considered. As weather varies over the course of a year, time series analysis was proposed to show the changes over different seasons in hydro-chemical, hydrologic, and sedimentary characteristics, which are definitely very important in the entire process of sedimentation within the study area.

Study area

Preliminary studies were conducted in three stages: in the spring (May), summer (July), and autumn (October). Sampling of sediment and water was carried out in the Kilia Danube Delta in the mouth of Bistry channel, and in two more sections—seaside of the Vostochny and Starostambulsky branches (20th isobaths). In Fig. 1, the research area is indicated within the rectangle.

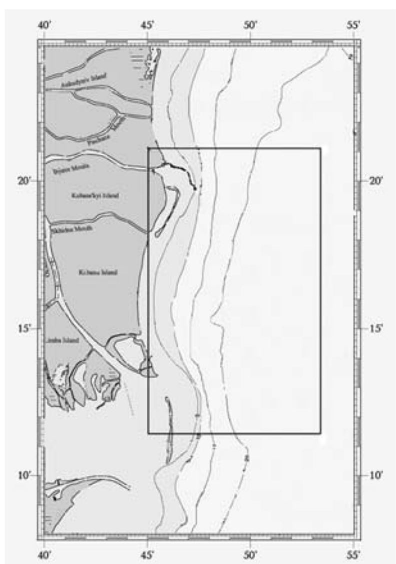

Figure 1. Research area.

Materials and methods

During May sampling have been examined 18 stations; 34 water samples were collected to determine hydro-chemical parameters, and 16 samples of deposits were obtained to determine grain size distributions. In July, 24 stations were sampled; 49 water samples were collected to analyze for hydro-chemical parameters, and 20 sediment samples were taken to study grain size characteristics. In October, 25 water samples for hydro-chemical examination and 14 samples of deposits for the grain size analysis were retrieved from 18 stations. During the sample collection, the bathometer of Molchanov was used for water sampling and the Petersen grab (0.1 m^2) for collecting sediments (Bordovskii, Ivanenkov, 1978). Sample collecting was conducted by UkrSc in 2010. Salinity determination, dissolved oxygen, pH, and temperature measurements were made using the WTW - Conductivity meter LF 318, Oximeter LF 420, and pH-320 in the laboratory of the Ukrainian Scientific Center of the Ecology of the Sea. Sediment analysis employed a combined method. Determination of the moisture level of the deposits was followed by a sieve analysis using mesh sizes of 4, 2, 1, 0.5, 0.25, 0.1, and 0.05. After this, the decanting method—based on Stokes's Law, according to which the velocity of free fall of fine, spherical particles through a liquid will be different for different sizes (Hjulström, 1935). Data from the mechanical analysis of the samples were arranged on the phi scale, such that the Wentworth grade is equal to one phi unit (Krumbein, 1939). Cumulative curves were drawn for each sample, using phi as the independent variable. The median and quartiles were read directly in the phi notation. For statistical purposes, the median was chosen as an average value, and sort level ratio was expressed by using the "Quartile method," where the sorting level ratio can be found as $So = \sqrt{Q1/Q3}$ (Trask, 1932).

Results

Sampling in the spring was performed during a strong 10 m/s wind blowing from northern, eastern, and southern compass points. The wind and upwelling were impeded suspension transfer and as a result suspension was discharged in the wellhead area with the water depth of about 15 m. The maximum transfer of suspension to the sediments was observed in Bistry channel. In the spring, the formation of hydro-chemical conditions in the research area was due to an additional supply of water, the transformation of the Danube hydrologic conditions of the region, and the development of productive-destructive processes. According to the results of satellite data (NOAA-19), the entire coastal area from the Cape of Saint George to the Odessa Gulf was under the influence of coastal upwelling. However, the places of greatest upwelling were confined to the wellhead areas of the Danube Delta. The water temperature in these areas of local upwelling on the northern seaward side of Kilia lobe of the Danube Delta was 11-13°C. The temperature at the riverine beach of the estuary was 18.8 to 19.0°C. Thus, warm river water was being discharged into the narrow coastal zone. On the seaward part of the area, local upwelling activity was observed. This led to a significant spatial heterogeneity in the thermal characteristics of the seawater (the difference is significant: 11.4 to 19.0°C).

The cold water areas on the surface have a higher salinity—more than 14 ‰—and at depths of 5-20 m—more than 17‰. This indicates that cold water masses of marine genesis were brought in as countercurrents under the pressure of the flow of fresh river water. The water was stratified by the salinity parameter because of the upwelling phenomenon. According to the hydro-chemical indicators, the strong front between the river water and the area of divergence caused by the upwelling contributed to the formation of two water masses with different hydrologic and hydro-chemical indicators. The amount of dissolved oxygen in the water varies from 8.12 to 11.0 ml/dm^3. The content of dissolved oxygen and pH value indicate the active development of photosynthetic processes (Garkavaya et al., 2006).

Visual imagery from NASA (USA) of the Danube region in the summer showed that the flow out from branches south of the Kilia delta was almost unidentifiable as separate streams. This was caused by the strong flow of the river, which filled because of positive rainfall anomalies over the European continent. The thermal regime of the water in the surface layer of Kilia delta in midsummer was different, leading to a spatial inhomogeneity in the water. The temperature of river water was 2-3°C lower than the surrounding seawater, and this is generally characteristic of the winter and spring periods. The maximum water temperature (about 26°C) was found in the southeastern sector of the study area.

The thermocline lay was found at the water depths near 10-15 m. As a result, at these depths was situated natural thermal front. To the west, in shallow water, an almost complete uniformity of water temperature at about 20-13°C was found, and to the east, the bottom water temperature dropped to near 10-11°C. Distribution of salinity to the seaward side was not typical for July because this is the season of low water in the Danube. All this month nto the Danube, a high level arose, which is often greater than the critical flood stage level. Furthermore, river water in the delta could be compared with the maximum period of high water (Berlinsky et al., 2006). In this regard, freshened water with a salinity less than 1.5-2.0 ‰ occupied the entire surface horizon of the study area. At a distance of 8 km from the coastline, the salinity of the surface layer was 8.4 ‰, and the bottom water revealed a maximum for the study area: 17.7 ‰. These observations during a period of abnormally high flow for the Danube River showed, broadly, the presence of extremely low levels of salinity in the surface layer and transparency of water. Surface water from the Bistry channel demonstrated the lowest dissolved oxygen content in absolute values: <5.6 ml/dm^3. At the same time, in the eastern part of the study area, the content of O_2 varied from 7.5 to 10.5 ml/l cc. The same pattern was observed in the spatial distribution of its saturation. Near the 20th isobath, the level of hypoxia was only 2.7-3.2 ml/dm^3. This area was under the direct influence of surface stream flows from the Bistry and Starostambulsky channels. The surface distribution of pH was low 7: 7 in the wellhead area of Bistry channel and higher values (about 8.5) in the western part of the polygon. Closer to the seaward side, the pH ratio was about 8.0-8.3. In the deeper part of the area, there were lower values of pH (<8) due to the development of hypoxia or conditions which could be created after hypoxia (Popov et al., 2002; Ukrainsky and Popov, 2009).

In the autumn the water temperature on top was about 13-15°C and increased toward the seaward direction. The bottom layer revealed the start of winter vertical circulation; the temperature increased there at a depth of 7 m. The distribution of salinity in the bottom layer was typical for the estuarine zone. The halocline was found almost at the river mouth of the Bistry channel. The content of dissolved oxygen in the surface layer of the seaward side was high, 9.46 ml/dm^3. In the bottom layer, a reduction in dissolved oxygen to about 8.36-7 ml/dm^3 was detected. The distribution of pH, which is dependent on the transformation of river water and the development of biological processes, was changing in the surface layer from 8.84 to 7.91. This decreasing pH was the result of high turbidity as a consequence of dredging work in the Bistry branch. In the bottom layer, pH varied from 8.62 to 7.83. It was also related to the large amount of suspended matter in the area. In the bottom horizon of the northern part of the research area, the minimum pH value of 7.53 was found. This is evidence of adverse conditions for the development of productive processes; it could have been caused by the introduction of marine water because salinity in the surface and bottom layers was 17.38-17.80 ‰.

Sediments

When all samples of bottom deposits were plotted as cumulative curves on a single sheet, the figure resembled a wide, dark band with several lighter zones within it. These zones roughly differentiate three types of sediments within the environment (Krumbein, 1939): very fine and fine sands, sands with “tails” of silt and shells, and clay with “tails” of silt and very fine and fine sand.

The first type consists mainly of clay and has a tail of silt, very fine, and fine sand. These curves are not symmetrical. The grain size median values average about 0.004 mm. The samples are well sorted. This kind of sediment is typical of all seasons. In the maps, it corresponds to the underwater continuation of the Bistry branch, and it reaches almost the 20th isobaths after which it turns to the south and proliferates along the coastline.

The second band of curves is typical of all seasons as was the first, but in contrast, it is predominantly sandy and consists of more than 50 % very fine and fine sand. Additionally, it has a tail of coarse sand with an insignificant percentage of shells. Thus, the grain size median average is about 0.12 mm in October and 0.25 mm in July and May. The sediments are very well sorted. This kind of sediment proliferated between the 10th and 15th isobaths.

The third type began to form in July and shows much greater development in October. This type includes more than 60 % sand but also contains silt and some shells. The median average of the grain size is about 0.15 mm. The sediments are poorly sorted. They proliferated from the 20th isobaths o the seaward; obviously, these are marine sediments that were affected by river suspension.

Conclusions

In the spring, the formation of hydro-chemical conditions on the seaward side was caused by additional water supply and the transformation of the Danube waters, hydrological conditions of the region, and the development of productive-destructive processes. The main feature of 2010 was an unusually protracted period of high water and high levels in the Danube, which affected the hydrological structure of marine water in the summer. Distributions on the seaward side were not typical. Transformed Danube water with salinity above 2.00 ‰ occupied the surface layers to the 15th isobath, at a distance of 8 km from the coastline, salinity was 8.4 ‰. In the bottom layer, seaward salinity varied from 2 ‰ (at a depth of 10 m) up to 17.7 ‰ at a depth of 20 m. The distribution of suspended matter along the coast of the Danube Delta was due to its removal from the river flow (abnormal for this autumn season) and hydrological conditions of the surrounding area. In the surface horizon, high level turbidity covered the entire coastal half of the study area to the 15 m isobaths. In autumn, a strong wind in the landfill area created two different freshwater mass structures with a salinity of about 1‰, and other with the values of salinity 2-16 ‰. Formation of the geochemical regime in the seaward area in October 2010 was due to the high level of water in the Danube and a significant turbidity, which hampered the development of productive processes.

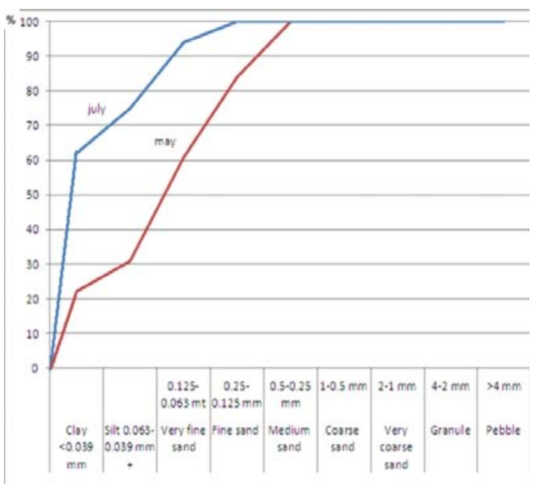

Figure 2. Typical cumulative curves for sediments sampled in July and May 2010 near the coastline.

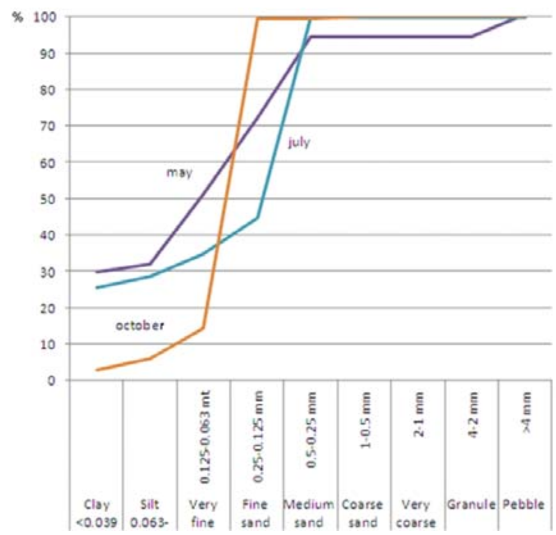

Figure 3. Typical cumulative curves for sediments sampled in May, July, and October 2010 near the 30th isobaths.

The sediment content also differed depending on the season. There are two curves in Figure 2. One is typical for spring and one for summer. This sediment was collected from the same stations near the 5th isobath. We can see that the content of clay had increased enormously by 40 % during the summer flood. Furthermore, in Figure 3, we can see 3 kinds of curves typical for each of sampling seasons. These samples were collected in the marine part of delta, at the same stations but in different seasons. According to this graph, the bottom deposits became coarser with distance from the coastline. Thus, we can say that the strong flood and the removal of large amounts of material from the river in summer 2010 were reflected in the bottom deposits. However, the composition of the debris removed from the Danube also depends on the distance from the shoreline. This is a consequence of the Danube's influence on the sediment composition of the coastal area of the Black Sea.

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ON THE AGE OF THE KHVALYNIAN TRANSGRESSION IN THE CASPIAN SEA ACCORDING TO 14C AND 230TH/234U METHODS

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Keywords: Caspian Sea, late Pleistocene, Khvalynian transgression, age, paleogeography

The Khvalynian transgression was the most important event in the Pleistocene history of the Cas-pian Sea. But the age of the transgression is under discussion. Since 1978, 38 samples of mollusk material from Khvalynian deposits of the Caspian region were dated by 14C and 230Th/234U methods in the Laboratory of Paleogeography and Geochronology at St. Petersburg State University. Results are given in Tables 1 and 2.

More detailed data about these dated samples and the chronology of Khvalynian deposits are contained in Arslanov et al. (1978, 1988); Yakhimovich et al. (1986); Arslanov and Yanina (2008); Chepalyga et al. (2008); Svitoch et al. (2008); and Yanina (2012). Analysis of the sections and sampling was carried out by the authors of the listed papers. Sample dating was conducted using index-fossils: Didacna praetrigonoides from the upper Khvalynian (hv2) deposits and *D. parallella, D. protracta*, and *D. ebersini* from the lower Khvalynian (hv1) deposits (Yanina, 2005). Dating of the "total composition" of samples and the index-fossils from them showed a substantial divergence in age caused by the presence of redeposited shells (LU- 5853, 5852, 5855, 5903).

It was previously established that thin (often small) shells from hv1 deposits give, in most cases, a rejuvenated 14C age (Arslanov et al., 1978, 1988; Arslanov and Yanina, 2008; Chepalyga et al., 2008). Data from the tables show this 14C age rejuvenation from hv1 deposits: 17 samples out of 26 dated shells reveal overly young 14C ages ranging from 10900±200 (LU-5952) to 12270±140 years BP (LU-7021). Such an age is characteristic of hv2 shells lying stratigraphically higher. Only 9 samples of hv1 mollusks have ages ranging from 12480±230 (LU-6848) to 13320±360 years BP (LU-6846). 14C ages obtained from 9 dated samples of the thick bivalve *D. praetrigonoides* from hv2 deposits range from 11340±100 (LU-479V) to 12650±160 years BP (LU-5801). This age inter-val is synchronous with the Allerød-Bølling interstadials (14C age from 11000 to 12400 years). Additional confirmation of this upper Khvalynian chronology is seen in the close values of the corrected radiocarbon age of two samples of the thick bivalve *D. praetrigonoides* with age defined uranium-thorium method (Table 2, LU-423B and LU-479B).

The rejuvenated 14C age of the thin bivalves from hv1 deposits and the more reliable age of the thick bivalve *Didacna praetrigonoides* have geochemical justification: contamination of the thin shells happens very quickly by isotope exchange between the crystal structure of the $CaCO_3$ in the shells and dissolved younger carbonates in the ground water. At the same time, diffusion of con-taminating younger carbonates into the thick shells happens much more slowly.

The age interval for hv1 mollusks is synchronous with the stages of degradation of the late Val-dai glaciation. The Scandinavian and Laurentian glaciations reached a maximum at 17000 cal. years ago (Bassinot et al., 1994). The data obtained show that the degradation of the late Valdai glaciation occurred very quickly, and it was apparently one of the main reasons for the Early Khva-lynian transgression. According to T. Yanina (2012), the low temperatures of the Early Kvalynian basin produced the small sizes and fragility of the Early Khvalynian mollusks. According to pollen analysis data, the Early Khvalynian was accompanied by a cool climate whereas the Late Khvalynian witnessed a general warming (Abramova, 1974; Yakhimovich, et al., 1986). The mollusks *D. subcatillus* and *D. protracta* from cores in the Northern Caspian Sea were dated by us too; they yielded 14C ages of 30360 ± 610

(LU-6884) and 29200±1220 (LU-5953) years, therefore belonging to the beginning of the Early Khvalynian transgression, when sea level was close to that of the modern Caspian Sea (Svitoch et al., 2008).

Table 1. Age determinations for Khvalynian mollusks by the ^{14}C method

Lab. number	Species of mollusks, sections	^{14}C age	Calibrated age
LU-5725	*Didacna protracta*, hv_1 deposits, Zunda-Tolga, +26 m	10670±140	12570±170
LU-5726	*D. ebersini* from the same layer	13320±220	16390±560
LU-5768	*Hypanis plicatus*, hv_1 deposits, +25 m, East Manych	11470±180	13360±180
LU-5769	*D. protracta*, hv_1 deposits , +20 m, Lake Manych	10930±370	12760±450
LU-5800A	*D. praetrigonoides*, hv_1 deposits, +18 m, Mangyshlak	12020±130	14000±210
LU-5800B	Inner side of the same shells	12550±210	14850±380
LU-5853	"Total composition" of samples, hv_1 deposits, +35 м, Manych	19330±240	23090±320
LU-5952	*D. trigonoides*, the same deposits	10900±200	12870±160
LU-5854	Debris of the shells from the archeological site in the hv_1 deposits, +13 m, San-Manych	11210±130	13100±130
LU-6020	*D. protracta*, hv_1 deposits, +10 m, Aral-Sor, Nothern Caspian	11270±140	13170±130
LU-6021	*D. protracta*, hv_1 deposits, +25 m, Chogray, Manych	12150±900	14180±190
LU-6022	*D. protracta*, *D. trigonoides*, hv_1 deposits, +35 m, Ergeni	13180±340	16140±680
LU-6834	*D. protracta*, hv_2 deposits, –10 m, Kalmykiya	12130±140	14170±250
LU-6835	*D. protracta*, hv_1 deposits, +18 m, Cherniy Yar, Lower Volga	12010±200	14050±310
LU-6836	*H. plicatus*, hv_1 deposits, +20 m, Cherniy Yar, Lower Volga	11810±120	13710±120
LU-6846	*D. protracta*, hv_1 deposits, Tsagan-Aman, Lower Volga	13320±360	16270±680
LU-6847	*D. protracta*, *D. delenda*, hv_1 deposits, +15 m, Cherniy Yar	12550±280	14920±570
LU-6848	*D. protracta*, hv_1 deposits, +20 м, Cherniy Yar, Lower Volga	12480±230	14710±420
LU-6873	*D. ebersini*, *Hypanis plicatu*, hv_1 deposits, +18 m, Raigorod, Lower Volga	11040±460	12860±550
LU -6874	*D. protracta*, hv_1 deposits, +23 m, Raigorod, Lower Volga	13030±630	15750±105 0
LU -6917	Dreissena polymorpha, Dr. rostriformis, Monodacna caspia, hv_1 deposits, –2 m, Kopanovka, Lower Volga	11870±370	13960±500
LU -6918	*Dreissena polymorpha*, hv_1 deposits, –3 m, Tsagan-Aman	12690±440	15390±930
LU -6919	*D. protracta*, *D. subcatillus*, *Hypanis plicatus*, hv_1 deposits, +22 m, Raigorod, Lower Volga	11630±530	13760±680
LU -6884	*D. subcatillus*, hv_1 deposits, core, 19-20 m, Northern Caspian	30360±610	35590±520
LU -5953	*D. subcatillus*, *D. protracta submedia*, hv_1 deposits, core, 31.5-31.7 m, Northern Caspian	29200± 1220	33860±149 0
LU -5954	*D. praetrigonoides*, *D. parallella*, hv_2 deposits, 0 m, «Nadezhda», Dagestan	11420±160	13320±170
LU -5855	"Total composition", hv_2 deposits, 0-+2 m, Temirgoe	26110±470	30790±290
LU -5903	*D. parallella*, the same deposits	12650±160	12900±120
LU -5856	*Didacna*, hv_2 deposits, –12 m, Almalo	11960±120	13880±150

LU -5801	*D. praetrigonoides*, hv_2 deposits, +2 m, Sangachal, Azerbaijan	12650±160	15010±300
LU -6019	*D. ebersini*, hv_1 deposits, –5 m, Selitrennoe, Lower Volga	11000±160	12930±140
LU -7021	*D. praetrigonoides*, hv_2 deposits, –10 - –12 m, Kalmykiya	12270±140	14330±250
LU -7022	*D. praetrigonoides*, hv_2 deposits, –10 - –12 m, Kalmykiya	11730±160	13610±170
LU -7023	*D. praetrigonoides*, hv_2 deposits, –10 - –12 m, Kalmykiya	11670±160	13560±170
LU -7024	*D. praetrigonoides* from hv_2 deposits, –10 m, Kalmykiya	11480±110	13390±120

Note: (1) Values of the calibrated age are given on the basis of the CalPal calibration program of 2006 (www.calpal.de). (2) A – external side of a shell, B – internal side of a shell.

Table 2. Age determinations for Khvalynian mollusks by ^{14}C and $^{230}Th/^{234}U$ methods

Lab number	Species of mollusk, sections	^{14}C age BP	Calibrated age	$^{230}Th/^{234}U$ age BP
LU -424A LU -424B	*D. parallella, D. cristata, D. praetrigon-oides*, hv_1 deposits, Turali, Dagestan	13100±490 12720±400	15920±870 15440±880	13350±440 13800±440
LU -426A LU -426B	*D. parallella*, hv_1 deposits, +25 m, Manas, Dagestan	11600±400	13620±480	12700±450 12500±300
LU -841	*D. protracta*, *D. subpyramidata*, hv_1 deposits, Inder lake, Lower Ural	11490±330	13420±330	14100±500
LU -846	*D. protracta*, hv_1 , Chapaev, Lower Ural	11830±200	13770±230	15240±600
LU -423B	*D. praetrigonoides*, hv_2 deposits, –2 m, Shirvan, Azerbaijan	12330±140	14450±310	14440±400
LU -479A LU -479B	*D. praetrigonoides*, hv_2 deposits, –12 m, Azerbaijan	11210±90 11340±160	13120±90 13250±160	11800±350 12900±350

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OGURCHINSKY ISLAND OFF THE COAST OF TURKMENIA IS ONE PROOF OF THE AMU-DARYA RIVER'S CONFLUENCE INTO THE CASPIAN SEA IN THE MIDDLE AGES

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Keywords: palegeography, Uzboy, delta, Derbent regression, sea-level oscillations, ancient settlements

Reliable data on Ogurchinsky Island off the Turkmen coast have been known for 14 centuries. Previously, there were several islands, some of them were joined, and others have been flooded. Two large islands, eventually joined into one, were known to ancient geographers as Ogroicha and Ogus. The same islands were known as Ogurchinsky; by the end of the 19th century, it had a width of about 3 km and a length of about 45 km.

The island, as well as other islands in the northern Caspian Sea, lies near the 15-20 m isobaths. From these depths, a steep slope extends. Between the island and the eastern Turkmen coast, the depth is no greater than 15-16 m, the same as in the northern Caspian Sea. The depth here increases gradually, with a slope of 0.005. Now, the maximum width of Ogurchinsky is about 2 km, and the minimum is about 60 m. In the northern part of the island, a lagoon 3 km in length and up to 400 m in width was formed as a result of the last sea-level rise of more than 2 m (between 1977 and 1995). There are many dunes, and in the middle of the island their maximum height is 3-5 m.

The island consists of Novocaspian and modern marine deposits. The high terrace occupying the central part of the island is divided by solonchaks into western and east parts, and in different directions it is bordered by a lower surface. Then, there is the so-called terrace of 1929. Essential changes took place even in comparison with the map of 1964 (Nikiforov, 1964). Now, the northeastern part of the island is even more wedged to the east, and a new, smaller island appeared there.

Ogurchinsky Island is situated on an extensive shoal, with a width of more than 150 km, which is similar to the northern Caspian Sea where big banks (Bolshaya and Malaya Zhemchuzhnaya, Bezymyannaya, and others) and islands (Kulaly and Tuleny) are located. It was earlier proven that these accumulative forms are coastal bars that formed on the edge of the Volga and Ural deltaic plains during the Derbent regressive stage of the Caspian Sea (Badyukova et al., 1996).

Ogurchinsky Island, as well as other accumulative forms in the northern Caspian Sea, represents the conserved fragments of a coastal deltaic plain, built upon transgressive coastal bars and aggregated subsequently into one island. The central high part of island was not flooded by the sea (the maximum height in 1836 was about 3.5 m). Comparison of the island's coordinates in 1850 with today's shows that the island gradually moved toward the land at the expense of a redistribution of its deposits after erosion and change of length and configuration (the last is visible from comparison with the maps). The greatest role in this process belongs to eolian processes, as according to Nikiforov (1964), from one meter of beach, 5 kg of sand are carried inland each hour at a wind speed of 4.9 km/s.

The indirect demonstrations of the subaerial position of the island are the presence of fresh water (the best water of the entire east coast as was described in writing by travelers of the 18th-19th centuries) and rather fertile soils. Turkmen came here from Cheleken (previously Hazar) and sowed wheat, cotton, and grew watermelons and melons. On the island, which nomads occasionally visited, horses, and herds of sheep, goats, and camels grazed.

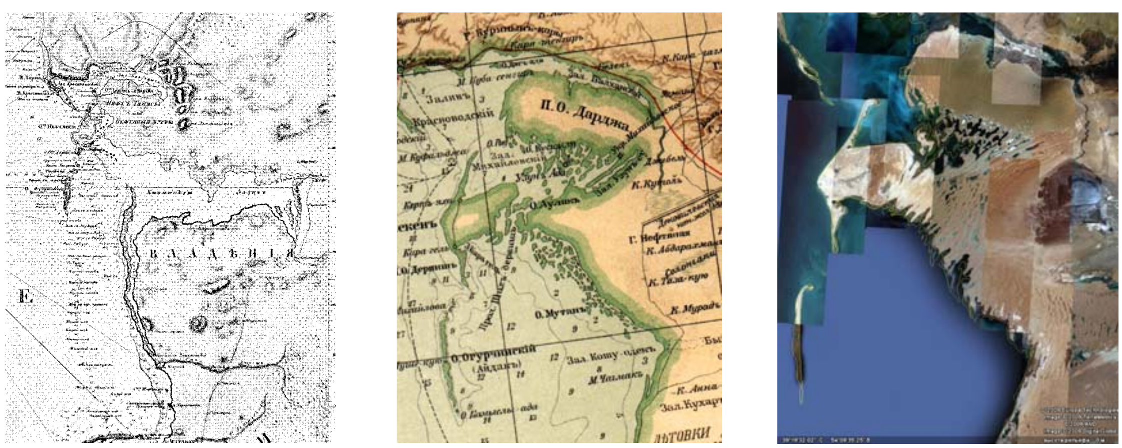
Numerous historical data indicate that during the 9th to 13th centuries, life on the coastal plain flourished. According to these data, the Amu-Darya flowed into the Caspian Sea. Research in the 20th century has shown that there was a Derbent regression when the sea level dropped to -35 and even to -48 m during the 9th-10th centuries (Hoogendoorn et al., 2005). It is obvious that explorers did not know in the 19th century that the sea-level decline was 15-20 m, therefore, many disagreed that the Amu-Darya ran into the Caspian Sea in historical time, as they did not find any signs on the Turkmen coastal plain of either the river's mouth or its delta.

But it is necessary to consider that the coastline at that time lay many tens of kilometers to the west from the modern one, and accordingly the river delta was located there as well. On the deltaic plain of that time according to the historical evidence, there were many settlements, vineyards, and fields, and vessels on the river. The subsequent sea-level rise led to catastrophic consequences: flooding of the huge coastal and delta plain, reduction of erosive processes and, as result, infilling of the arms of the river with fluvial and eolian deposits. The edge of the deltaic plain at sea-level rise was transformed into coastal bars which were gradually displaced towards land, and then disappeared due to erosion. As a result, the deltaic plain and mouth of the Amu-Darya have been transformed into a large lagoon (as, for example, the Curonian and Vistula lagoons bordering the Baltic Sea), and then into the extensive Mikhailovsky Gulf.

Like many explorers of the 18th to 19th centuries, this author considers that the Amu-Darya (or its separate arm) flowed into the Caspian Sea during the Middle Ages. Besides historical evidence, it is possible to confirm this conclusion with some geological and geomorphologic data. As is known, all large deltas settle within submergence areas. Ogurchinsky Island is not bound to any rising tectonic structure, and it is dated to the Kyzylkumsky trough (Richter, 1965), testing intensive submergence. It is not an underwater bar which afterwards appeared on the subaerial surface as Nikiforov (1964) considered.

The Mikhailovsky Gulf to the east of Ogurchinsky Island looks like the delta of a big river: showing the same branched, narrow waterways streaming between underwater spits. Together with the Balkhansky Gulf, the Mihailovsky Gulf probably represents a mouth of the Amu-Darya, running here through three main arms. On maps of the 18th-19th centuries, south of Balkhansky Gulf is Khivisky Gulf (width more than 40 km, length more than 100 km).

The gulf penetrated into the continent and stabilized opposite Ogurchinsky Island. One of the arms flowed down into it (Fig. 1a). At present, Khivinsky Gulf is completely filled by deposits, and its surface consists of high barchans; it lacks any form reminiscent of an arm. Only the extensive Kel'kor solonchak, where the irregularly functioning Uzboy River flowed, is conserved (Fig. 1 b, c).



a **b** **c**

Figure 1. Significant alteration of the Turkmen coast over about two centuries (a = map by Kolodkin, dated 1826; b = map from an atlas of 1910; c = Google map).

So, the mouth of the Uzboy River valley is a former valley of the Amu-Darya, which in many, but not all parts, was inherited by the Uzboy. When this stream could not overcome a barrier, such as detrital fans or barchans, it laid another path. The valley possesses 3 terraces and a flood plain. It is very wide, sometimes as much as 20 km in width, and a dry arm in places reaches 2-3 km. It is obvious that the waterway periodically emanating from the Sarykamyshsky depression during periods of overflow by river water, was unable create so developed a valley. The existence of a much bigger river than the Uzboy is also indicated by the large radii of the meander belts. According to the geometry of the meanders, measured using remote sensing, the runoff was quite significant and corresponded to a modern Amu-Darya runoff or even one discharging 1.5 times more (!) (Mamedov and Trofimov, 1986).

The wide mouth of the Uzboy valley cuts coastal bars of a maximum Novocaspian transgression—according to Kroonenberg et al. (2007), it was about 2600 BP—i.e., the river was in this region later. Filled with deposits at the subsequent transgression, the arm can be traced even now on aerial photographs within the Kel'kor solonchak up to the town of Nebitdag (now Balkanabat). In boreholes from the western part of the solonchak, under the latest transgressive marine deposits are dissected alluvial deposits with freshwater fauna (Volkov, 1958).

Spores and pollen analysis confirm the existence of a shallow, intensively growing freshwater basin: many seeds of plants typical for the modern Amu-Darya delta are found. There is also a flora that is propagated only in the mountain areas and in the modern delta of the Amu-Darya (Samsonov, 1961).

Thus, Caspian Sea level rise after the Derbent regression led to catastrophic consequences: flooding of the seaside plain and destruction of villages and cities. In the 19th century, some ruins were conserved at higher hypsometric relief, in particular, the settlement of Kune-bazar along the Adzhaib arm. Turkmen named it a city, "being underground." The Amu-Darya has stopped flowing into the Caspian Sea; there were several causes which, along with Holocene paleogeography of the Uzboy, Sarykamysh, and Aral, will be considered in subsequent publications.

Acknowledgments

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GEOMORPHOLOGY AND PALEOGEOGRAPHY OF THE IRANIAN COAST OF THE CASPIAN SEA IN THE LATE QUATERNARY

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Keywords: Pleistocene, Holocene, transgression, regression, stratigraphy, lithology.

Introduction

The Iranian coast of the Caspian Sea stretches 620 km from Astara to Gumishan. The width of the flat part fluctuates between 1 km in the central regions to 60 km in areas of river deltas of the Sefidrud and Gorgan. In the western part, where research was conducted, the plain is called Giljan. There have been many studies devoted to the constitution of the Iranian coast of Caspian Sea (Ehlers, 1971; Kazancı et al., 2004; Lahijani and Sharifi, 2005; Khoshraftar, 2006; Moghaddam et al., 2006; Svitoch and Yanina, 2006; Danehkar et al., 2007; Mousavi Rohbaksh, 2008; Lahijani et al., 2009, 2010), however, the geomorphology and history of its development in the Neopleistocene and Holocene remains insufficiently investigated. During the expedition in 2011, a detailed geomorphologic description of the seaside plain and Giljan coast was conducted with the collection of mollusk shells. In addition, detailed study of the Novocaspian and modern deposits in outcrops was done. In total, 64 fields were described.

Geomorphology of the coast and coastal plain of Giljan

The modern coastline within the Iranian littoral of the Caspian Sea is very smooth; points are formed only by old and modern deltas of the river Sefidrud. To a lesser degree along the Giljan coast, deltaic points are expressed, but the rivers are not so large. Small rivers distribute to irrigation canals or they run into small coastal lagoons.

The geomorphologic analysis of the coast has not shown dominating drift along the shore in an eastern direction, as was written (Lahijani and Sharifi, 2005; Lahijani et al., 2009, 2010). Moreover, sediment drift was often observed both to the west and to the east, as was indicated by O.K. Leontev (1987). The character of the southern coast of the Caspian Sea reveals a prevalence of transversal movement of deposits.

Along the Giljan shoreline are coastal types that can be subdivided into abrasion and accumulative (the latter can be further subdivided into accumulative retreating when the coastal bar moves inland, and erosion accumulative). Accumulative retreating coasts are often accompanied by lagoons (Badyukova et al., 2004) as they are along the Dagestan shore.

Despite the drop in sea level of 0.6 m after 1995 and its modern stabilization, erosion is observed now on many coasts. Cliffs in sandy deposits of Novocaspian terraces have developed. Underlying the Novocaspian and modern deposits, there are often coarse pebbles: alluvial deposits of the numerous rivers formed during the Mangyshlak regression.

During the Novocaspian transgression, the coastal bar descended and overlapped the lagoon. At the mouth of the Havig River (N 16 on the Fig. 1), the series of Novocaspian deposits that overlie those of the lagoon are dissected.

On this part of coast, there is erosion, as well as to the north of the Karganrud River delta (N 26), where the small ship from the time of Peter I was "dug out" of Novocaspian sand deposits. Active erosion proceeds, and in the eastern part of Giljan, stubs of trees which had earlier been growing on a regressive terrace are conserved on the beaches. Fragments of the regressive terrace have been preserved, and at the mouth of the Hotbessara River (N 20), a considerable quantity of coarse alluvial material (including boulders up to 1 m in diameter) has been brought down during high waters and floods.

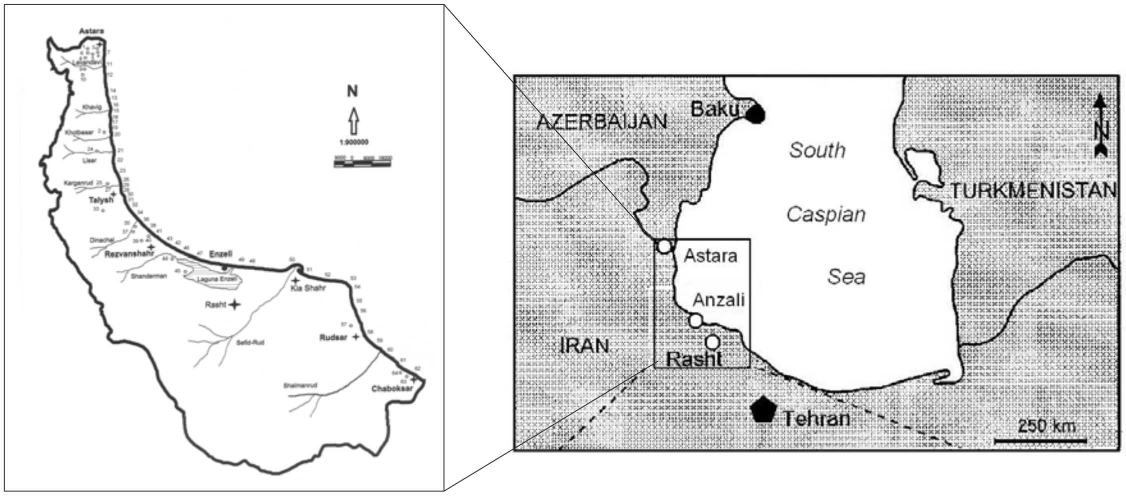

Figure 1. Area of investigations indicating points where detailed field work was conducted..

An erosion type coast exists south of the mouth of the Lisar River (N 21) passes into an accumulative, sandy beach that continues on some kilometers. A bar 250 m in width isolates an extensive lagoon. South of the Karganrud River delta (N 28, 29), the coastline forms a smooth arch. Directly on a beach, stubs of trees were observed, which indicates that the regressive terrace has been washed away. It borders with Novocaspian terrace, which stretches along the coast. Here, it adjoins a former high cliff (-14 to 16 m) consisting of coarse alluvial deposits that form a sharp contact with the underlying grey clays. Such series of the deposits are peculiar to the majority outcrops in the coastal plain. On higher hypsometric locations, the grey clay is replaced by brown clay and silt. According to the hypsometric position of this clay and silt roof, they are to be dated to the Early and Late Khvalynian ages.

To the southeast of the Shafadrud River, the bar separating the lagoon of Enzeli (length about 30 km; width up to 10 km) begins. The average depth of the lagoon is 2.5 m; its maximum depth is 6 meters (Khoshraftar, 2006). The lagoon has freshwater, as about 25 rivers run into it. During the last regressive stage of the Caspian Sea, the lagoon had been almost completely isolated from the sea; now, it is connected by one canal, yet several centuries ago, there was one more. The bar represents a high (to 18 m) and rather wide (1-2 km) accumulative form and consists of sand and pebbles with detritus. In the central axial part, low (3-5 m) overgrown dunes meet in places; as a whole, such conditions are rare along the coast.

Stages of development

In the one of seven open mines the eolian and the marine deposits composing a bar are exposed. From above, the sequence includes eolian sand, then there are marine sand, small rubble and detritus with two layers of paleosols; this means that formation of the bar separating the lagoon of Enzeli occurred over several stages.

According to remote sensing, the bars around the lagoon of Enzeli were formed earlier. The most ancient of them, stretching almost 10 km to the south of the modern coastline, was formed at nearly 6000 BP (Golamreza, 2003). Younger coastlines are consistently located closer to the modern shoreline. Their formations are linked to the transgressive stages of the Caspian Sea, as that is when bars are formed (Badyukova et al., 2004). One of these coastlines exists in the form of fragments of a wide bar; it was preserved as the western (N 45) and eastern parts of the Enzeli lagoon. According to the radiocarbon dates for the deposits there were three high levels of the Caspian Sea at the end of the Holocene along the Iranian coast – 2500 BP, 900 BP, and 500 BP. The level of the Caspian Sea stood then, respectively at -22, -24, and -25 m (Lahijani et al., 2009).

By this time, a significant part of the Enzeli was filled by lagoon alluvial deposits. Formation of the lagoon occurred together with a sea-level rise, a scenario characteristic of all Caspian Sea lagoons. At transgression, there was a flooding of the low deltaic plain and simultaneous formation of a transgressive bar at the edge of the plain, i.e., the Enzeli lagoon never was a sea gulf that was fenced off subsequently by a spit. Data of cores from bore holes into the bar and lagoon confirm this conclusion (Fig. 2).

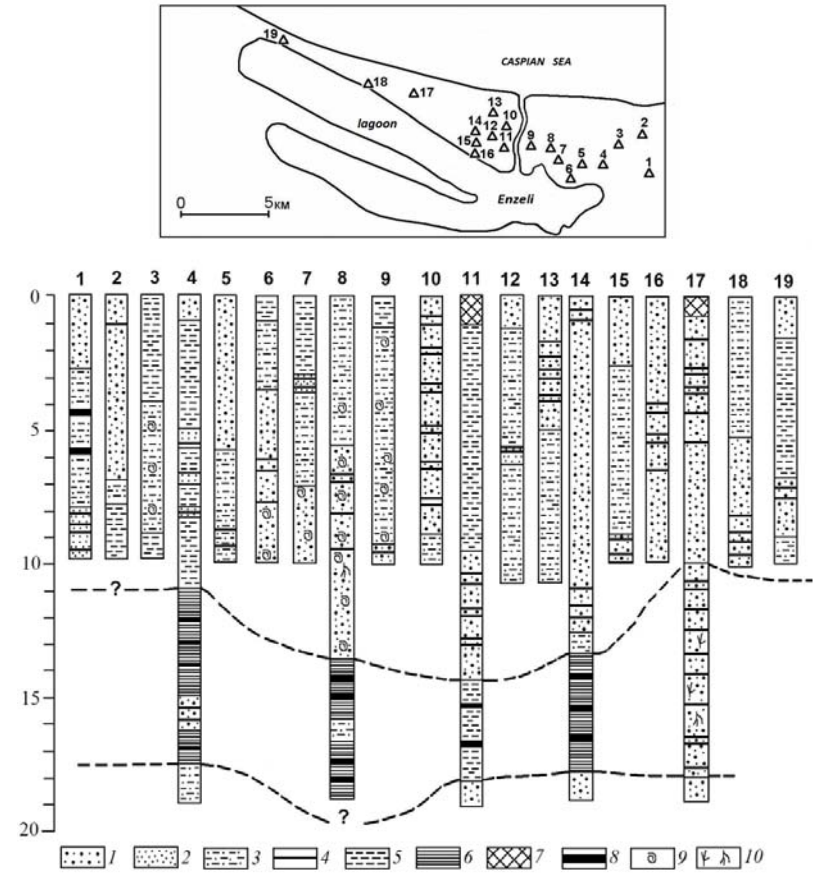

Figure 2. Character of the deposits composing the bar and lagoon of Enzeli (Kazancı et al., 2004). 1 – coarse and fine-grained sand; 2 – fine-grained sand; 3 – grey silty sand; 4 – layers of brown silt; 5 – grey sand and silt; 6 – brown clay; 7 – anthropogenic dumps; 8 – organic layers; 9 – mollusk shells; 10 – plant residues.

To the east of the bar, the mouth of the largest river of the Iranian coast, the Sefidrud, is located. The northern part of its delta, more than 80 % of its area, was generated during the Holocene (Khoshraftar, 2006). During this period, the river changed a direction six times. The greatest movement of its mouth (20 km) occurred about 500 years ago when the formation of the modern delta (Krasnozhon et al., 1999) began to the west of the old delta. The ancient delta formed an alluvial fan, and the coastline changed its direction southward. Now, there is active erosion observable and beach material moves to the south up to the mouth of the Shalmanrud River (N 56), where wide beaches are formed.

Alluvial-fan deposits have been laid down at elevations from -20m to 0 m and above, up to the foot of the mountains, and they occupy almost all of the coastal plain. Unlike Elersa (Ehlers, 1971) that evolved on the plain terraces at -17, -12, and 0 m. Our research could confirm only the level at approximately 0 m, where small fragments of the presumably Late Khvalynian terraces were mapped. There are no Early Khvalynian terraces on the plain, as they are overlapped by the powerful slopes of thick alluvial-fan deposits. So the presence of such deposits on the coastal plain represents the distinctiveness of the Iranian coast of Caspian Sea.

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PLEISTOCENE CLIMATOSTRATIGRAPHY AND ENVIRONMENTS OF THE TEREK-KUMA LOWLAND (NW CASPIAN SEA REGION), BASED ON PALYNOLOGICAL, PALEOMAGNETIC, AND RODENT FAUNA ANALYSES OF THE OTKAZNOYE KEY SECTION

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Keywords: Quaternary climate and landscapes, multidisciplinary study, East Ciscaucasia

The object and methods

The thickest, most continuous, and most stratigraphically complete sequences of Pleistocene deposits in the southern regions of European Russia are located in the middle reaches of the Kuma River (western Terek-Kuma Lowland). They were studied by the authors collectively together with a number of specialists: A.A.Velichko, V.P. Udartsev (field study of lithology); D.R. Morozov, T.D. Morozova (paleosoils); N.S. Bolikhovskaya (palynology); S.S. Faustov, E.I. Virina† (paleomagnetism); A.A. Markova (small mammals); N.I. Chikolini†, S.N. Timireva (granulometry, mineralogy). The ~160 m thick section of Quaternary strata was studied in natural exposures and penetrated by boreholes on the interfluve and on the Kuma valley slopes and terraces near the Otkaznoye Village (44°19' N, 43°51' E).

Detailed palynological and paleomagnetic analyses were carried out for two vertical profiles (Bolikhovskaya, 1995; Faustov and Virina, 2001). The longest profile (Profile I) shows deposits ~140 m thick penetrated by a borehole on the interfluvial plateau (at ~245.5 m a.s.l.). There are exposed sediments of three sedimentary cycles. The first cycle contains alluvial deposits (126.2-136.4 m) and a subaerial member including three well-developed paleosols (115.8-126.2 m), the second cycle contains alluvium (112.6-115.8 m) and subaerial formations with two paleosols (107.35-112.6 m). In the third cycle, there is an alluvial-proluvial series (64.9-107.35 m) and a thick member of loessial deposits that contain 6 paleosol complexes (PC) (1.4-64.9 m). The Matuyama-Brunhes reversal (~0.783 Ma) was found at 75 m a.s.l. The Jaramillo subchron has been recognized within the Matuyama zone in the 104.7-113.0 m interval; it is dated approximately to 1.053-0.986 Ma (Singer et al., 1999). According to pollen data, deposition of this interfluvial series took place during the Early to Upper Pleistocene and ended in the formation of a thick upper loess, the latter being formed during Dnieper glacial time and the first half of the Mikulino (Eem) Interglacial. The results obtained from Upper Pleistocene deposits studied in this profile are complemented by analysis of the Valdai sediments of lower terraces of the Kuma River.

Profile II is located near the Otkaznoye reservoir dam, on the upper part of the Kuma valley slope (at ~217.8 m a.s.l.). A more than 50 m thick sequence exposed in a quarry wall is attributed to the third sedimentary cycle. Palynological data enable us to identify Middle Pleistocene horizons below the modern soil. The Brunhes-Matuyama boundary has been also found in the upper part of the alluvial-proluvial series (at 37.5 m).

Rodent fauna from the PC III and IV exposed in Profile II was collected during the fieldwork by Dr. Victor Udartsev. Screening and washing were used for separating the bone materials. A. Markova identified the species composition (Table 1), as well as reconstructed the age and environments of the habitats of these fauna.

Table 1. Species composition of rodent fauna from Paleosol Complexes III and IV

Taxa		Number of bones
Latin name	English name	
Paleosol Complex III		
Rodentia	Rodents	
Spermophilus pygmaeus Pallas	Little suslik	6
Eolagurus luteus volgensis Alexandrova	Yellow steppe lemming	1
Lagurus sp.	Steppe lemming	1
Microtus obscurus (Eversmann)	Altai vole	4
Microtus arvalis Pallas	Common vole	5
Paleosol Complex IV		
Spermophilus pygmaeus Pallas	Little suslik	33
Spalax sp.	Mole rat	25
Cricetus cricetus Linnaeus	Common hamster	2
Cricetulus migratorius Pallas	Grey hamster	3
Eolagurus luteus volgensis Alexandrova	Yellow steppe lemming	18
Lagurus lagurus Pallas	Steppe lemming	6
Microtus obscurus (Eversmann)	Altai vole	6
Microtus arvalis Pallas	Common vole	7

Paleoenvironments and climatostratigraphy

The little suslik, yellow steppe lemming, and steppe lemming are habituated within steppes and semi-deserts. Voles of the genus *Microtus* prefer grasslands. All the species found in Paleosol III indicate open landscapes near the section. Fauna discovered in Paleosol IV are richer in species composition and quantity of remains. The remains of steppe lemming (*Lagurus lagurus*) include the lower first molars, which are a very indicative marker for stratigraphy. These remains permit a correlation of this horizon with the Likhvin Interglacial or later Middle Pleistocene intervals. This species appeared only during the Likhvin Interglacial and existed with small changes in morphology until modern times. *Lagurus transiens*, which was the indicator for the earlier Oka Glaciation and Muchkap Interglacial is absent from the Otkaznoe fauna (Markova, 2007). The richer fauna from Paleosol IV also includes the typical open landscape rodents, namely mole rat, common hamster, and grey hamster. The abundant quantity of remains from mole rat, which maintains an underground habitat, indicates a well-developed chernozem soil and rich steppe vegetation.

Pleistocene palynoflora recovered from the Otkaznoye section include pollen and spores belonging to more than 150 taxa (46 species, 37 genera, and more than 70 families) of trees, shrubs, dwarf shrubs, herbs, and grasses. The detailed stratigraphic subdivision of the studied sequence is based on historical and floristic materials obtained by analysis of species and genera of arboreal and non-arboreal plants in Pleistocene interglacial floras in terms of the presence of Neogene relicts and changes in the relationship among various geographical groups of dendroflora. The data thus obtained, when compared with results of palynological studies of Late Cenozoic sequences in adjacent regions, permits one to specify the boundaries between stratigraphic units (interglacials, glacials, interstadials, stadials) within the Brunhes Chron (Bolikhovskaya, 1995).

Comprehensive palynological information provided a means for reconstructing the evolution of flora, vegetation, and climate for all 15 interglacial and cold stages of the Brunhes Chron, that is ~780 ka (Fig. 1). For most of this period, the Terek-Kuma Lowland was occupied by interglacial forest-steppes or by periglacial forest-steppes. For the first time in Middle Pleistocene history, steppes became dominant here during one of the phases of the Likhvin Interglacial (MIS 11), during which time Paleosol Complex IV was formed under steppe and forest-steppe environments. Dry steppes and semi-deserts that appeared occasionally in the Middle Kuma basin at various warm Early Pleistocene intervals assumed dominant importance during the Middle-Late Pleistocene, first at the cryoxerotic stage of the Dnieper ice age (~MIS 6), and later at the same stage of the Valdai glacial epoch (~MIS 4-2); the vegetation at those stages bore all the characteristics of periglacial vegetation. Dominance of forest landscapes was established with certainty for five intervals. At the Muchkap Interglacial (~MIS 15), broad-leaved forests prevailed with a considerable participation of subtropical species. Broad-leaved forests (mesophytic or xerophytic) occupied the region during the interglacials corresponding to ~ MIS 9, MIS 7, and MIS 5. Individual phases during the Kaluga cold epoch (~MIS 10) were marked by the dominance of forests containing spruce and Siberian stone pine. The five named "forest" periods correspond to the maximum climate-induced rises of Caspian Sea level during the Middle-Late Pleistocene.

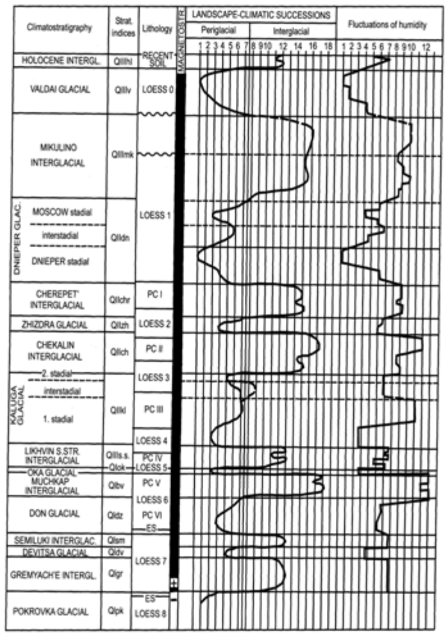

Figure 1. Climatostratigraphy and changes of vegetation and climate in the Middle Kuma basin during the Middle-Late Pleistocene (based on palynological data from the Otkaznoye sequence).

- *Landscape-climatic successions*: 1 = periglacial semi-desert and dry steppe; 2 = periglacial steppe; 3 = periglacial forest steppe; 4 = birch and coniferous-birch open woodland; 5 = extraglacial forest steppe; 6 = extraglacial birch open woodland; 7 = extraglacial spruce and cembra pine-spruce forests; 8 = birch open woodland with broad-leaved arboreal species; 9 = birch forests with broad-leaved arboreal species; 10 = coniferous-birch and birch-coniferous forests with broad-leaved arboreal species; 11 = forest steppe; 12 = steppe; 13 = piedmont forest steppe; 14 = shrub hornbeam groves; 15 = elm-oak, oak, hornbeam-oak forests; 16 = hornbeam forests; 17 = oligo- and polydominant broad-leaved forests; 18 = polydominant broad-leaved forests with subtropical taxa.
- *Fluctuations of humidity curve*: 1 = periglacial semi-desert and dry steppe (annual precipitation <250 mm); 2 = interglacial desert and semi-desert (250 mm and less); 3 = periglacial steppe (280-300 mm); 4 = periglacial forest steppe (300-450 mm); 5 = interglacial steppe (300-450 mm); 6 = periglacial open woodland (400-500 mm); 7 = interglacial forest steppe (400-650 mm); 8 = interglacial open woodland (600-700 mm); 9 = interglacial oak forest (550-700 mm); 10 = interglacial hornbeam forests (700-800 mm); 11 = extraglacial spruce and cembra pine-spruce forests (up to 800 mm); 12 = oligo- and polydominant broad-leaved forests under interglacial temperate climate (up to 1500 mm); 13 = polydominant broad-leaved forests under interglacial subtropical climate (>1500 mm).

At the present time, the palynological characteristics of deposits below the Brunhes-Matuyama boundary are fragmentary and permit reconstructions only for some stages of the Early Pleistocene. Specifically, two phases of vegetation evolution are recognized in layers dated to the Jaramillo subchron. The first phase corresponds to climatic cooling and increasing aridity, with *Betula* sect. *Fruticosae*, *B*. sect. *Nanae*, and *Alnaster* represented in the dominant grass steppes. The second phase was distinguished by warming and increasing humidity. During that phase, broadleaf forests existed here. The principle aim of future research is to obtain representative pollen assemblages from the all strata of the Matuyama Chron sediments.

Acknowledgments

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DYNAMICS OF THE BLACK SEA BELT BENTHIC BIOCOENOSIS AND ITS CONNECTION WITH THE EARTH'S PLANETARY AND SOLAR CYCLES

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Keywords: biocoenosis, Black Sea, dynamics, ecology, facies, Earth's rotation, solar cycles

Introduction

In the second half of the 20th century, biotic communities of the Black Sea (BS) experienced significant changes. This period is characterized by increased eutrophication of the water body and, as a result, excessive development of phyto- and zooplankton, which resulted in a significant decrease in water transparency. This fact led to the suppression and even death of biocoenoses over large areas. Eutrophication of BS water masses led to a significant degradation of the ecosystem and its ecological communities and was intensified by human activities. The negative human impact is not limited to excessive additional supply of biogenic elements. Radioactive and chemical contamination of water, ground dumping, the extraction of sand from the sea represent an incomplete list of anthropogenic influences (Emelyanov, et al., 2004). The emergence of invasive species dangerous to the BS ecosystem also occurred via human activity. Coincidence in time of the dramatic changes in the BS ecosystem and the maximum in industrial and agricultural activity in the region convinced the scientific community that human factors are crucial in the degradation of biocenosis.

Analysis of the leading biocoenoses and associated species dynamics as well as the reasons for changes over a 100-year period allowed us to establish cyclicity in their development. Comparison of these data with the results of research on global climate processes and astrophysical phenomena has shown in phase synchrony between biological and geophysical processes. This makes it possible to establish causal links between them and thus gain a measure of predictability about the development of biocenoses.

Materials and methodology

Quantitative data and the qualitative characteristics of the leading species of the BS general facies for the last 100 years were compared with published results of global climate and astrophysical research.

Results and discussions

In the Black Sea just off the coast of Crimea, about 50 macrozoobenthic biocoenoses were observed, each identified by the leading, or dominant, species. Only 3 species form biotic communities, which are called "belt zoned," as they have a circum-basin distribution, but confined to a specific area by depth, temperature, and a certain type of bottom sediment, the distribution of which is also subject to belt zoning. These three species belong to two families of bivalve mollusks: Mytilidae and Veneridae. The mytilids are *Mytilus galloprovincialis* Lam., 1819 and *Modiolula phaseolina* (Philippi, 1844), and the venerid is *Chamelea gallina* (L., 1758). They perform the important ecological function of biological water treatment, and the status of their populations largely determines the state of the Black Sea ecosystem. As a species-edificatory, they determine the face of the elementary ecosystem, creating not only a biocenosis, but determining the appropriate facies.

<u>Fam. Mytilidae biocoenoses</u>. *M. galloprovincialis* is the most effective of the Black Sea benthic filter feeders. Populations with a high density can filter up to 31410 l/m² per day, thus depositing on the bottom up to 47 g of processed suspension. Usually, two ecomorph mussels are recognized: rocky and muddy ones in accordance with the type of substrate they inhabit. Coastal rock surfaces usually are traced to a depth of about 10 m, rarely to 15 m, and in some cases up to 32 m. The distribution of mud mussels is usually limited to within isobaths 20-53 m, but in some areas, it is found at shallower depths. Maximum biocoenosis development for muddy *M. galloprovincialis* reaches depths of 40 m (Kiseleva,

1981). The most complete set of data to establish the characteristics of *M. galloprovincialis* dynamics exist for the rocky ecomorph (Fig. 1).

The resulting curve (Fig. 1) indicates cyclicity in the development of mussel populations. The complete cycle between adjacent peaks of the curve is approximately 70 years, which leads us to expect a new peak of mussels in 2038. The cyclical nature of the changes in biomass indicates the presence of mussel population waves in the development of the species, which may result from the influence of external factors, which are also cyclical in nature.

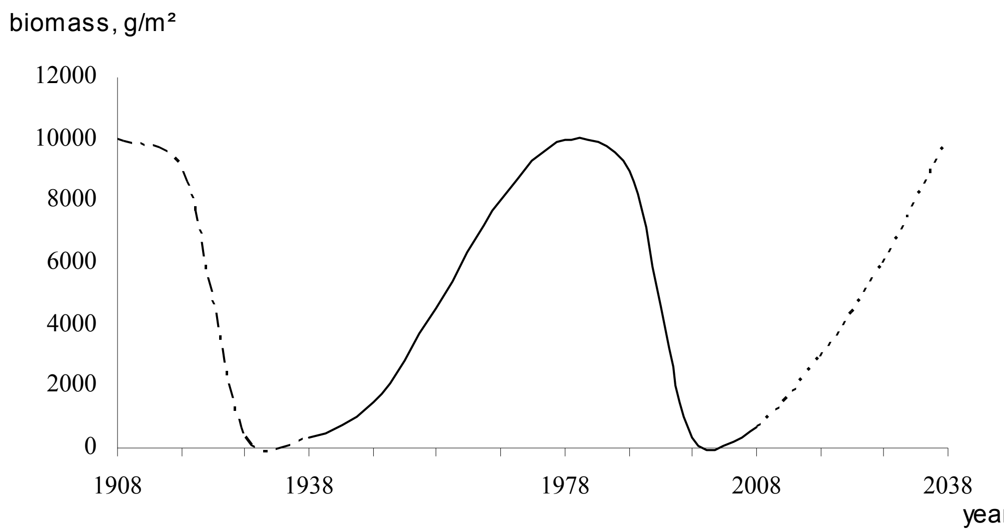

Figure 1. Variations in *M. galloprovincialis* biomass (g/m²) on the Crimea littoral in the XX to the beginning of the XXI centuries. Solid line based on data from Sharonov (1952), Synegub (2004), and Kovaleva et al. (2012); dashed and dotted line (retrospective branch) after Andrusov and Zernov (1914) and Zernov (1908, 1913); dotted line - perspective (predictive branch).

Population dynamics for mud mussels in various areas of the Black Sea are generally consistent with the trends shown for rocky mussels, but there is a weaker amplitude in the changes in indicators of development.

Modiolula phaseolina is a species of boreal origin, which determines its ability to carry out its full life cycle in the BS only at a constant temperature below 8ºC. Such conditions exist within the cold intermediate layer (CIL), which is located on the continental shelf at depths of 45-50 m up to 100-120 m (Bondarev, 2012). Insignificant seasonal and long-term fluctuations of temperature and other parameters in the CIL are reasons why there are no obvious cyclical changes in the values of *M. phaseolina* in the ecological community as a whole, which are characteristic for *M. galloprovincialis* biocenoses.

Fam. Veneridae biocoenoses. Members of the family Veneridae form biotic communities at depths of 1m to 55 m, but the main range is 7 to 30 m. The most widely distributed are the two dominant species: *Chamelea gallina* (L., 1758) (= *Venus gallina*) and *Gouldia minima* (Montagu, 1803); much less common is *Pitar rudis* (Poli, 1795). Fluctuations in biomass for *Ch. gallina* are very significant, while the rate of biomass formation in *G. minima* is variable to a much lesser extent (Fig. 2).

Biomass variations of *Ch. gallina* demonstrate the same 70-year cycles as *M. galloprovincialis.* That means there exists a common stimulus to cause these basal BS facies for leading species.

Analysis of the state of the BS ecosystem for the period from 1928 to 2004 shows the connection between a certain type of atmospheric circulation and an increase or decrease in biological productivity (Bryantsev, 2010). Analysis of the population dynamics of many commercial species in the oceans shows a similar cycle with a periodicity of 60-70 years. Cyclical development of fish is associated with fluctuations in temperature background (Klyastorin and Lyubshin, 2005). For the BS, it is noted that beneficial conditions for the development of pelagic commercial species are created together with a specific type of atmospheric circulation. The latter, in turn, depends on the performance of the thermal background of the Black Sea, which is synchronous with the change in the rate of rotation of the Earth (Bryantsev, 2010). The rate of the Earth's rotation has a 70-year periodicity with a maximum in the mid-1930s and a minimum in the mid-1970s (Sidorenkov, 1980) hanging the speed of the Earth's rotation affects the intensity of the circulation of the water masses. The indicator of the thermal background of the Black Sea (Bryantsev, 2010) is also synchronous with changes in the Earth's rotation and the maximum warming in 1935, with a gradual cooling up to 1975, indicated in the monograph by M.I. Budyko (1974). These phases are synchronous changes in development parameters of *M. galloprovincialis* (Fig. 1) and *Ch. gallina* (Fig. 2).

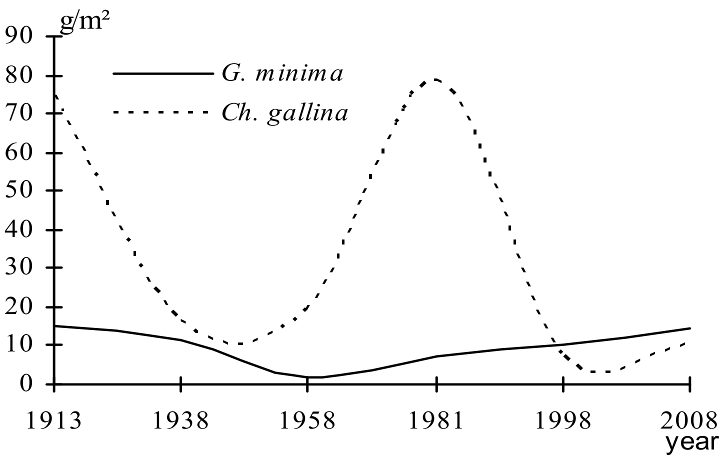

Figure 2. Biomass (g/m²) variations of the dominant species in the ecological community of sand from 1913 to the 2008s. Data for 1913 from Zernov (1913); data for 1938 to 1981 from Kiseleva (1992): 1938 - by M.Yu. Beckman (1952), 1957 - by G.V. Losovskaya (1960); data from 2008 from Mazlumyan et al. (2009).

The timing of the period of growth indicators for the leading species (Fig. 2) with an increase in the overall yield of the Black Sea ecosystem, marked by the mid 1930s to the 1970s (Bryantsev, 2010), indicates the existence of general regularities of ecosystem development associated with global and cosmic factors. A graph of the Earth's speed of rotation over the period from 1700 to 1970 (Nazarkin, 2006) shows that its maximum deceleration occurs at the beginning of the 1900s, which confirms the validity of the peak in mussel productivity shown on Figures 1 and 2 in this period as well as the accuracy of the retrospective part of our plots. Data recently obtained (Kovaleva et al., 2012) give reason for further increase in the biomass of Black Sea mussels and indicate the peak values for this indicator at the end of 2030s, under favorable regional background conditions.

Conclusions

The natural environment is a dynamic system that develops according to specific internal laws, while submitting to regional, global/planetary, and astronomical processes. These processes can occur with certain cyclicity.

For the Black Sea shelf, biocoenoses correspond to the 70-year cycle of solar activity, which involves the solar "wind" effect on the Earth's magnetic field, periodically accelerating or slowing its rotation. This process implies a change in the temperature of the Earth and the background of dynamic processes in the hydrosphere, which affect the overall productivity of the Black Sea ecosystem and affect the dynamics of benthic indicators.

The greatest impact of these dynamic processes of various sizes and origin is on the coastal biotic communities. The maximum oscillation parameters are reconstructed for the development of the rocky mussel ecological community. In response to external influences, the mud mussel biocoenosis has similarly, undergone fluctuations in development, but of smaller amplitude. Planetary cycles are not likely for be reflected in the *M. phaseolina* biocenosis because its distribution is confined to the CIL zone within which the variations in parameters of the water column, and above all temperature, are the smallest for the entire shelf area.

The cyclical development of coastal ecological communities, correlated with phenomena of planetary and cosmic scale, can provide an optimistic forecast for their future development. A prospective peak of littoral biotic communities should be reached by about 2038. The degree of their development will depend on a set of processes, a significant part of which belongs to the anthropogenic influence.

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THE SUBMERGED CHALCOLITHIC LANDSCAPE OF TARASCHINA: IMPLICATIONS FOR HUMAN SETTLEMENT WITHIN THE DANUBE DELTA

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Keywords: Danube delta, Chalcolithic, submerged landscape, sea level, Romania

Introduction

From 2008, survey and excavation by a Franco-Romanian team in and around the upper Danube delta has allowed refinement of the chronology of Chalcolithic occupation. In particular, the area close to Mila 23 has been the target of intensive fieldwork (surveying, excavation, and coring). Data collected in and around the Chalcolithic settlement of Taraschina (Mila 23 district) has documented the last evolutionary phase of a blocked delta and its transition to the prograding stage, together with its possible consequences on early human settlement within the Danube delta. Additional information collected on a newly discovered Gumelniţa settlement to the south of Taraschina (Haralambie) provides new data that constrain human occupation within the Danube delta.

Methodology

The methodology was based on a coupled study of classic archaeological excavations and a set of in-site and out-site coring. Excavation data allowed us to define both the chronology and the economy of the site. Archaeozoological data were also used to refine knowledge of the Chalcolithic landscape around the site. In the absence of preserved pollen, phytolith data were used to reconstitute the vegetational landscape. In addition, 17 mechanical cores ranging from 3 to 7 m deep were extracted in and around the site. They allowed us to reach the first level of occupation, which is now flooded beneath the water table, and to date it while defining the paleotopographical and geological context of the settlement.

Results

After the Black Sea reconnected to global ocean, the upper Danube delta prograded into a fresh water lagoon isolated from the Black Sea and developed in a context of sea-level rise. This scenario agrees with former reconstructions (Spratt, 1856; Antipa, 1915) which postulated the existence of a baymouth barrier. Evidence from former drilling (Panin, 1972) and new paleoecological data also support this scenario. During the reconnection phase around 8.4 ka BP to 6.0 ka BP, aggradation dominated the deltaic evolution, controlled by rapid sea-level rise. Danube delta evolution could be regarded as a “bay head transgressive delta" *sensu* Nicols and al. (1997) separated from the Black Sea by the Letea-Caraorman spit. Our work has allowed dating of the Letea-Caraorman spit from at least 6.4 ka cal BP, though it may be older. Decrease in the rate of sea-level rise initiated a stage of rapid progradation of the delta and the beginning of the St George lobe formation. This phase is well documented by a series of cores around the Chalcolithic site of Taraschina, and it had a huge influence on human settlement occupation.

During the period comprized between 6.5 ka to 6.0 ka BP, rapid aggradation occurred in the lagoon (mean sedimentation rate ~5.5 mm an^{-1}), then stopped abruptly. This period corresponds to the end of occupation for the Taraschina settlement, which is now largely silted. During the last stage of occupation, the surrounding loessic terrace supporting the settlement was progressively silted and fossilized under fluvio-lagoonal deposits. Paleoecological data, in particular phytolith analysis, provide evidence of cereal cropping during the site occupation, i.e. from 6.5 ka to 6.0 ka BP, within the present-day Danube delta. Natural vegetation (reed like) reclaims after 6.0 ka BP.

From these data, we proposed a paleogeographical reconstitution of the settlement and surrounding area during the interval of 6.5 ka to 6.0 ka BP. The site was built at the edge of a loessic terrace recognized in cores and correlated with other Pleistocene deposits within the delta. This terrace probably constituted the southern extent of the Bugeac plateau and sloped gently to the east. Between 6.5 and 6.0 ka BP, a highly variable fluvial regime is indicated. Two phases of high fluvial regime (i.e., Flood Dominated Regime) are recorded between 6.4 and 6.3 ka BP and between 6.1 to 5.9 ka BP, separated by hydrological quiescence (i.e., Low Water Regime). There is a synchronicity between hydrological regime and settlement occupation, implying rapid adaptation of the Chalcolithic societies to environmental changes.

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NEW DATA ON OLDOWAN MIGRATION TO EUROPE VIA THE NORTHERN BLACK SEA CORRIDOR IN THE LIGHT OF THE LATEST DISCOVERIES IN THE NORTHERN CAUCASUS AND DNIESTER VALLEY

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Early Paleolithic cultural layers with tools of Oldowan type were discovered in the northern Caucasus (Dagestan) by Kh. Amirkhanov in 2006 (Amirkhanov, 2007) and in the Dniester valley by N. Anisyutkin in 2010. During the last few years, these Paleolithic sites were studied by complex methods, led by A.L. Chepalyga, including geology, geomorphology, paleontology, palynology, sedimentology, mineralogy, paleomagnetism, etc. (Chepalyga and Anisyutkin, 2012).

In Dagestan's Akusha region, a group of Early Paleolithic sites were located in the upstream area of Sulak (Akusha-Usisha rivers). Study has shown numerous cultural layers with tools and bones included within stratified clastic sediments.

Akusha formation

The Akusha geological formation was named after the Akusha River. The spatial distribution of tool-containing sediments was studied along the interfluvial ridge between the Akusha and Usisha rivers, where it extends for 4 km (Fig. 1a, b).

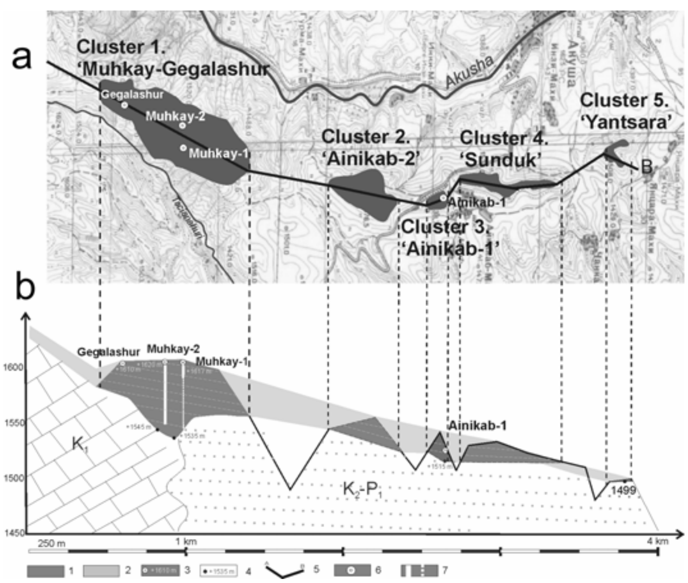

Figure 1. a - Distribution of Akusha formation clusters in the Akusha-Usisha interfluve. 1 = Akusha formation sediments; 2 = Akusha formation, eroded sediments; 3 = highest point asl of the Akusha formation surface; 4 = highest point asl of the Akusha formation basement; 5 = transversal profile along the Akusha-Usisha interfluve; 6 = Paleolithic sites (Oldowan); 7 = excavated trench and as yet unexcavated trench. b - Transversal section through the Akusha formation sediments along the Akusha-Usisha interfluve.

The total area of the Akusha formation is 0.78 km^2 (78 ha). Regarding its geologic background, cover sediments are absent, and younger Pleistocene sediments are represented by river terrace alluvium. The surface of the sediments reaches 1650 m asl (possibly higher) and it descends northwards to 1500 m asl. The basement of Mesozoic limestone and sandstone drops northwards from 1570 to 1499 m asl. Contact with this basement appears with discordance, erosion, and basal conglomerates.

The Akusha formation is divided by post-sedimentary erosion into 5 separate clusters.

Stratotypes. The proposed holostratotype of the Akusha formation is the section of the site Mukhkay-2, which reveals layered sediments 75 m in thickness excavated from 1620 to 1545 m asl (basement). Parastratotypes proposed are in excavated trenches at the sites of Ainikab-1,2; Mukhkay-1,2; Gegalashur; and Sunduk. Inclination of the layers is to the north at 1-2º.

The **geological age** of the Akusha formation was established in the section at Mukhkay-2 (Figs. 2-4) by several methods (paleontology, palynology, and paleomagnetism) as Eopleistocene = Early Lower Pleistocene (0.8-1.8 million years).

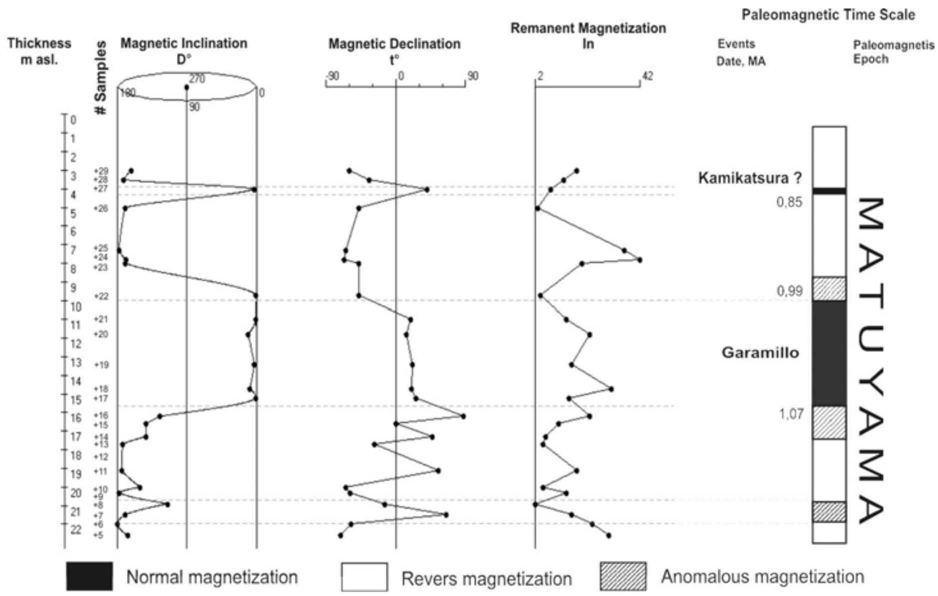

Figure 2. Paleomagnetic characteristics of the Akusha formation (Mukhkay-2 site).

According to paleomagnetic studies (Figs. 2, 3), this section is characterized by the reversed polarity of the Matuyama epoch (0.8-2.6 myr). The normal polarity Jaramillo (0.99-1.07 myr) subchron is recorded in the upper part of the section at the depth interval of 9-16 m. Another normal magnetization event found somewhat higher at 3.5 m is possibly the Kamikatsura event (0.85 myr). Some short intervals of anomalous magnetization were found below and above the Jaramillo subchron (transition zones).

These data allow us to determine the isochrones of some absolute ages: 0.85 myr (3.5 m depth), 0.99 myr (9.5 m depth), and 1.07 myr (15 m depth). The estimated age of the main cultural layer was calculated by the rate of sedimentation at 1.4-1.5 million years. These dates are confirmed by paleontology (Psekupsean = Odessa mammal complex).

Lithology and sediment genesis

The Akusha formation represents an intercalation of coarse grained (sand, gravel, pebbles, and boulders) and fine sediments (clay, aulleuroclay, and loam, mainly carbonated). Coarse sediments have lagoonal, nearshore, proluvial, and alluvial origins and are accompanied by mammal bones, tools, and land mollusk shells. Fine clay sediments up to 10 m in thickness reflect a water basin environment that was relatively deep and contained nannoplankton (*Spiniferites ramosus*, *Spiniferites* sp. *Panonean* type) typical of Caspian-type, isolated brackish basins (Apsheronean, Akchagylean).

Clay packages contain **authigenic glauconite**, which formed during the time of sedimentation. This suggests an isolated nearshore marine basin environment. At this time in the Caspian depression (30 km from the Akusha sites), the Apsheronean basin contained brackish water. Possibly, the Akusha formation sediments were deposited in lagoons belonging to this basin.

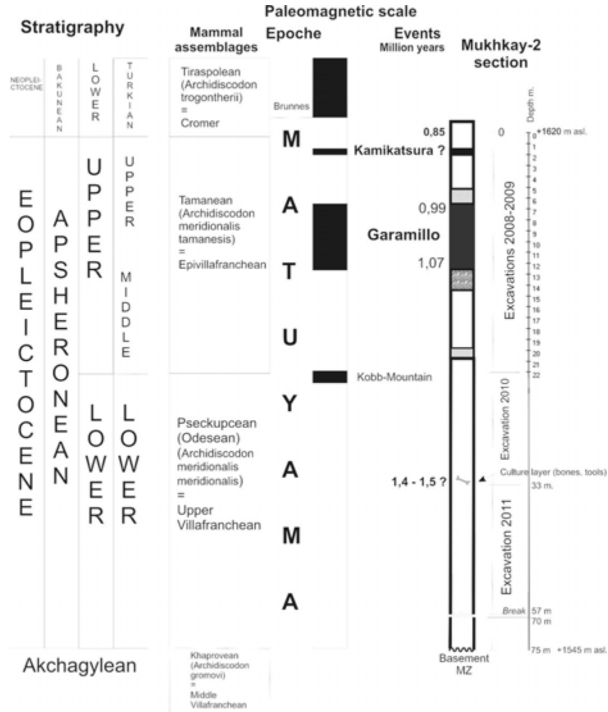

Figure 3. Stratigraphic position and age of the Akusha formation.

Palynological studies of the upper 35 m of sediments recovered vegetation changes with 13 palynocomplexes reflecting alternation of climatic oscillations (aridization – humidization, cooling – warming). During the cooling stages, parvifoliate (*Betula*) and dark coniferous (*Picea*, *Tsuga*) trees predominate; warming stages were accompanied by thermophile timber (*Magnolia*, *Ostrya*, *Pterocaria*, and *Cryptomeria*) and an absence of dark coniferous and parvifoliate species.

Environmental reconstruction

First human settlements appeared on lower slopes of the Caucasus foothills and nearshore environments possibly facing the Apsheronean basin with its sea-level oscillations. Coarse sediment accumulation is an indicator of regressive stages of the basin; the territory studied was then covered by a terrestrial landscape with broadleaf vegetation containing thermophilous elements, a Psekupsean mammal complex, and hominins using Oldowan-type tools. The accumulation of fine clayey sediments reflects transgressive stages and sea-level rise, wherein the water basin deepened and flooded previously terrestrial landscape that supported a human population. During the next 1.0-1.5 ma, this territory was raised 1.0-1.5 km by tectonic uplift eventually reaching its current mountain level.

Dniester Valley (Dubossary town)

The Early Paleolithic site of Bairaki, discovered by N.K. Anisyutkin in 2010, was occupied on alluvial and covering beds of the VII Dniester terrace (Lower Eopleistocene) (Chepalyga and Anisyutkin, 2012). At the same time, it was studied by A.L. Chepalyga for determination of age and environmental reconstruction (Chepalyga et al., 2012). The Dniester River alluvial terrace system near Dubossary town was studied and its description updated. Five high terrace systems (fig. 4) were represented by: three terraces (VIII, VII, VI) Eopleistocene in age with artifacts, and three terraces (VI high, VI low, V) Early Neopleistocene in age. These were all investigated. The paleomagnetic Jaramillo event (0.98-1.07 mya) was found in the stratotype section of Chitskany terrace in the upper alluvium of terrace VII. This date was supported by RTL dates (1.1 ±0.25 mya and 0.940 ±0.2 mya) and an associated Tamanean complex of mammals (Epivillafranchean). The age of the oldest Oldowan tools from alluvial pebbles is 0.8-1.2 mya. This is one of the oldest Early Paleolithic sites in Europe (Anisyutkin et al. 2012). Fossil soils and pedosediments were also studied. Three fossil soils were identified. Palynological analysis identified some palynozones with forest (oak, beech, hornbeam, elm, linden, hazel, etc.) and steppe vegetation. The climatic environment was reconstructed.

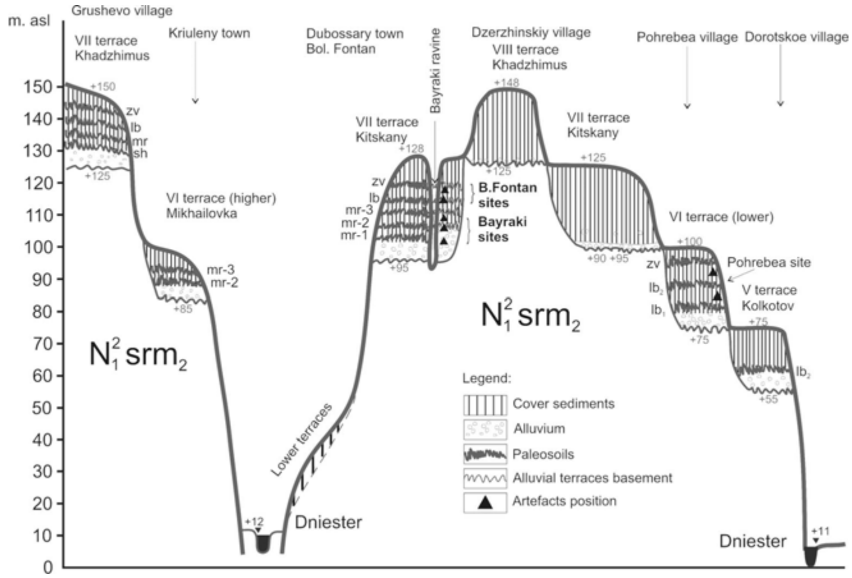

Figure 4. Terrace profile of the Dniester Valley near Dubossary town and stratigraphic position of Early Paleolithic sites

Migrations

The new data of the oldest Oldowan sites located in the Caucasus and Dniester Valley allow us to define a new migration route for hominins from Africa to Europe. The main migration routes took place along the sea coasts: Red Sea, Mediterranean Sea, Black Sea, Caspian Sea, and in the valleys of the great rivers: Danube, Dniester, and Southern Bug (Fig. 5).

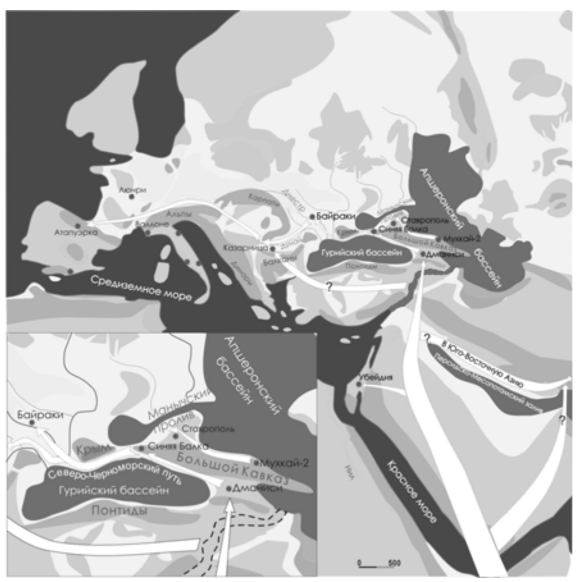

Figure 5. Map of hominin migration from Africa to Europe via the Caucasus and the Dniester Valley.

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OF THIS COMPLEX STRATIGRAPHY AND PALEOGEOGRAPHY OF THE FINAL PLEISTOCENE AND PALEOLITHIC OF THE DNIESTER AND BUDZHAK VALLEYS

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Keywords: epoch of extreme inundations, paleohydrology, palynology, Roxolany section

Within the temperate belt of Eastern Europe, immediately after the LGM (20-18 ka BP), an intense warming started (17-11 ka BP) followed by degradation of the ice shield and permafrost and, consequently, extreme inundations: river floods, marine transgressions, lake formation on interfluves, and solifluction processes. This time span is regarded as the epoch of extreme inundations (Chepalyga et al., 2012; Panin et al., 2011, 2012). In this paper, the following contributions to the problem are presented: (1) the first results of the study of the uppermost part of the Roxolany section (18-10 ka BP)—this interval had not been investigated during the former study of the section by Gozhik et al., Heller et al. , T. Gendler et al., A. Dododnov et al., etc; (2) stratigraphy of the coeval alluvial deposits and terrace levels; and (3) preliminary correlation with the loess-soil stratigraphy of Ukraine and Russia.

The uppermost part of the Roxolany section consists of the following beds sequentially from the top: (1) the Holocene soil – chernozem (0.0-0.5 m); (2) loess-like loam which differs from typical loesses by darker color and coarse grain-size composition (0.5-1.8 m)—it is presently regarded as the local Ovodiopol loess unit which is possibly correlated to the Prychernomorsk unit of the Ukrainian Quaternary framework; (3) incipient soil (1.8-2.4 m) consisting of B soil horizon (pale-brown, 0.3 m thick) and C_{ca} horizon (most intense carbonate accumulation, 0.3 m thick)—the soil is presently regarded as the local Roxolany unit, which is possibly correlated with the Dofinivka soil unit in the Ukrainian stratigraphy; (4) loess bed (2.4-4.9 m) which by its typical loess properties is similar to the Bug loess unit; and (5) pedocomplex of two soils (4.9-6.3 m)—the upper soil of this comple[was ^{14}C-dated at 26-27 ka BP (Dodonov et al., 2006) and is correlated with the Bryansk soil of Velichko's framework, or with the Upper Vytachiv soil of Ukraine, which has similar dates (Gozhik et al., 2001; Gerasimenko, 1999). According to its stratigraphic position and pedomorphology, the Roxolany soil can be correlated with the Trubchevsk soil (A. Velichko), the Pushchino soil (L. Gugalinskaya), the Zarayskaya soil (Ch. Amirkhanov), and the Kamenno-Balka soil (N. Leonova). Presently, it cannot be excluded that the Roxolany soil might be correlated with the incipient soil within the Prychernomorsk unit of the Ukrainian stratigraphy.

The pilot pollen study of the Roxolany soil (Simakova, 2008) has shown an increase in *Pinus* pollen and the appearance of single grains of *Picea* and *Tilia* against a background of pollen dominated by steppe plants. Palynomorphs of mesophytic herbs became as abundant as those of herbal xerophytes. This indicates an increase in humidity as compared to the time of the loess formation. The recent pollen study of the Roxolany soil (sampling frequency 5 cm) enables the following paleoenvironmental reconstuctions. Prior to the soil formation, slopes of the Dniester river valley were covered by typical grassland with significant participation of xerophytic herbs. The low pollen percentages of *Pinus* indicate that this genus did not grow in the area studied, which was completely treeless. The climate was arid. Nevertheless, in the uppermost loess beds (directly below the C_{ca} soil horizon), the *Pinus* pollen percentages give evidence that pine groves had already appeared in the region, as well as some willow and birch trees. The frequency of mesophytic herbs also increased, and the grassland started to transform into a forbs-Poaceae steppe. This obviously was incurred by a decrease in aridity. During the formation of the material of the C_{ca} horizon (calcium carbonates are secondary products of the following pedogenesis), the area was occupied by forest-steppe (presently it is covered by the typical grassland). This is a definite indication that the climate was wetter than nowadays. Frequent occurrence of pine groves is confirmed by the presence of palynomorphs of plants that are typical for pine grove undergrowth (Ericaceae, Lycopodiaceae, and Polypodiaceae). Alder and birch occurred in the second layer of the forest. None of these boreal plants presently grow in the region studied. This indicated that the humid climate of this phase was much cooler than nowadays. On the other hand, it was noticeably warmer than during the preceding time of loess formation. Steppe bush *Rhamnus cathartica* and steppe herb *Scabiosa*, of which the pollen was present in the spectra, do not grow in periglacial environments. Thus, the stadial had been replaced by a cool interstadial ('interphasial'). The appearance of a few pollen grains of broad-leaved trees is connected with their long-distance transport from the refugia, which existed in the foothills of the Carpathian Mountains (Willis et al., 2000) or in the hills of Moldova. Pollen productivity of these trees possibly increased under the warmer climate of the phase described.

During the formation of the B horizon of the incipient soil, forested areas first became smaller, but later on, they increased again marking the second maximum in humidity during the interval studied. Forest-steppe landscape existed in the area during the entire period of soil formation: the arboreal vegetation was represented by birch-pine groves, whereas the steppe was mesophytic. A few pollen grains of broad-leaved trees and *Pinus cembra* occur at some depth levels, and they possibly indicate long-distance pollen transport with the westerly winds. On the other hand, a few palynomorphs of *Corylus* are constantly present in the soil material. This might indicate that this warm-loving bush could already occur in the vegetation composition, and thus, the climate was of a south-boreal type (relatively warm and rather wet). The phase between the two optima in humidity was somewhat cooler because spores of boreal plants *Huperzia* and *Botrychium* occur in the corresponding deposits. It is suggested that the earlier maximum in humidity might correspond to the Lascaux interstadial (18-17 ka BP), whereas the late maximum fits the Raunis interstadial (15-14.5 ka BP).

During the formation of the lowermost bed of the overlying loess, the forest-steppe initially existed, but arcto-boreal species of *Betula* appeared, and the proportion of xerophytes increased in the steppe. At the same time, *Corylus* still occurred. The landscapes were in transition from an interstadial to a stadial. The climate became much cooler later when grassland dominated the landscape, forest areas shrank, and shrub birches spread more extensively than earlier. The climate was not arid: hygrophytic Cyperaceae plants became a prominent part of the non-arboreal vegetation. The increase in humidity during the formation of the incipient soil and its overlying bed occurred in the area presently occupied by grassland under an arid climate. Thus, this humid period might be related to the epoch of extreme undulations (see above).

The stratigraphy and paleogeography of the transition from the Pleistocene to the Holocene was studied in the Budzhak area (the Belolesye island site discovered by D. Kiosak in 2011). The section consists of the following units (palynologically characterized by G. Shilova): (1) the Holocene soil – a chernozem (0.0-0.6 m), forbs-Poaceae steppe; (2) DR-III − flood-plain alluvial loams, re-worked by C_{ca} horizon of the modern soil (0.6-1.3 m), Poaceae and *Artemisia*-Poaceae steppe with few *Betula humilis*, the Final Paleolithic cultural layer (uncalibrated ^{14}C-data 8900±110 BP possibly underestimates the age); (3) AL − sandy loams and cryosuspensites (1.3-2.0 m), tree stands of *Pinus* (dominated) with admixture of *Picea*, *Abies*, *Quercus*, *Tilia*, *Acer*, *Carpinus*, and *Corylus*; (4) DR II (?) – alluvial sands and sandy loams (2.0-2.3 m), dry steppe and a few pine groves with arcto-boreal *Selaginella* in the valley. On interfluves, these alluvial deposits are replaced by the following facies: DR-III – loess-like loam; BO-AL – the Budzhak pedocomplex from soddy-meadow soil at the base (BO) and cambisol at the top (AL), separated by loess-like loam DR-II; DR-I − loess-like loam; the Roxolany soil − incipient soil described in the Roxolany section. The similar loess-soil successions are related (and dated) to the Final Pleistocene in the sections at Parkany (the Dniester valley), Beglitsa (the northern coast of the Sea of Azov), and Divnogorye (the Don valley).

In the Dniester valley, the alluvial phases of the Final Pleistocene are found within the so-called proterrace (a transitional level between the floodplain and the 1st terrace). It was earlier described as the 1st Parkany terrace by L. Lungersgauzen, or the "0" Ternovka terrace by Chepalyga. The terrace deposits consist of specific alluvia (cryosuspensites by Chistyakova and Lavrushin) represented by an unsorted mixture of sands, loams, and sandy loams. They originated as a result of permafrost melting on the slopes of the river valley during the epoch of extreme inundations. Three levels of this accumulative proterrace have been described in the river valleys of southeastern Europe: (a) high (14-15 m), (b) medium (9-10 m), and (c) low (3-4 m). The last is represented in the Budzhak section.

This new study makes it possible to subdivide the period between the LGM and the Holocene into nine climatic phases: three phases of Roxolany soil formation, two phases of the DR-I, three phases of the Budzhak pedocomplex formation (BO – DR-II – AL), and DR-III.

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COQUINITE ON THE WESTERN BLACK SEA COAST OF TURKEY (ŞILE, ISTANBUL): POSSIBLE EVIDENCE FOR HIGHER SEA LEVEL DURING MIS 3

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Introduction

The Black Sea exhibits a complicated relative sea-level history during the Late Pleistocene and Holocene. Available evidence on secular trends in sea level and the magnitude of fluctuations during glacial and interglacial periods is relatively incompatible with that of the global oceans (Algan et al., 2007). When Late Pleistocene levels of this anoxic water body are considered, available data have attested to dramatic changes after the Karangatian transgression, coinciding with the so-called Eemian (Mikulinian) interglacial. This interglacial is known to have been followed by the post-Karangatian regression that occurred between 72 and 45 ka BP and then by the Surozhian (a later synonym of Tarkhankutian) transgression, represented by sea levels of -60 m and -10 +/-1 m, respectively (Chepalyga, 1984).

Methodology

Our study area lies about 13 km west of the Şile district of Istanbul, NW Turkey. The coquinite beds with a maximum width of 30 m are exposed for 150 m along the foreshore. This sandy beach is backed by a coastal dunefield that rests on a 3 m-thick eolianite. In a preliminary attempt, two bulk samples of bivalvia rich in *Mytilus* sp. were tested using radiocarbon dating. Subsurface imaging was also carried out using electrical resistivity tomography (ERT) to determine subsurface geometry of the cemented coquina. Quantitative elemental analyses of the finer materials filling inter-grain pore spaces of tightly-packed bivalvia fragments were made using Energy Dispersive X-ray Spectroscopy. Interior parts of the cemented materials were scanned using Scanning Electron Microscopy to examine the micro-fabric of the samples. Total carbonate contents were measured using a Scheibler calcimeter. For the micro-paleontological investigation, 10 g of sub-sampled sediments were treated with 10% H_2O_2 for 24 hr then wet-sieved through a 63 μm sieve. The benthic foraminiferal fauna were identified and counted in the sediment fraction above the 63 μm mesh size.

Preliminary Results

The coquinite beds at Şile extend along a 40 m-wide sandy beach with a sprinkle of shell debris. Submerged beds are followed up to 10 m offshore and terminate at -1 m below modern sea level. ERT images show the existence of coquinite bodies buried under the beach sands. The thickness of the beach material is about 9-10 m, covering resistive (>500 ohm-m), rugged bedrock at the bottom. The thicknesses of the coquinite beds under loose beach sands are not more than 5 m. Beds are composed of current-induced laminae of trough cross beds with a total thickness of 1.1 m. Four sets of cross-beds were determined at a few typical sections from bottom to top, separated from each other by nearly horizontal planes. Albeit in broken forms, various benthic foraminifera were defined in the bottom level, such as *Ammonia parkinsoniana*, *A. tepida*, *Ammonia* sp., *Elphidium* sp., *Haynesina* sp., and *Polymorphina* sp. The top level also includes various species, such as *E. crispum*, *Ammonia* sp., *A. compacta*, *A. parkinsoniana*, *A. tepida*, *E. macellum*, *E.* cf. *pulverum*, *Elphidium* sp., *Haynesina* sp., *Quinqueloculina* sp., *Porosononoin subgranosum*, and *Porosononoin* sp. These trough cross beds are indicative of deposition under bi-directional flow conditions along a wave-dominated high-energy shallow marine environment.

The calibrated age ranges of 30610 to 30250 BP and 26950 to 26250 BP for the lowermost and topmost samples were determined, respectively. With regard to the late Pleistocene sea-level dynamics of the Black Sea, this time span is contentious and lacks background information. Based on available knowledge provided by Russian researchers compiled by Yanko-Hombach (2007), these ages coincide with Surozhian, a later synonym of Tarkhankutian that occurred at 40-25 ka BP. At 31 ka BP of this highstand, the Mediterranean waters were in connection with the Black Sea (Chepalyga, 2002). Amongst other evidence regarding this event are submerged coastal bars on the northwestern and Romanian shelves and the quantity of Mediterranean foraminifera (Yanko-Hombach, 2007) as well as a co-mixture of Mediterranean mollusks with those of the Caspian Sea (Nevesskaya and Nevessky, 1961). If we assume that the Black Sea was near -30 m below the present during this highstand, the present position of the coquinite beds could only be explained by tectonic uplift of about 1 mm^{-1}. This appears unreasonable in the lack of any tectonic-induced evidence throughout the coastal zone. At this stage, we presuppose that the loose coquina materials might have accumulated in the studied shoreface zone, requiring a sea level similar to the present.

Acknowledgments

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NEW EVIDENCE FOR A POSSIBLE LATE HOLOCENE TSUNAMI IN SW MARMARA SEA, SOUTHERN MARMARA ARCHIPELAGO, NW TURKEY

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Keywords: tsunami, Hasır Island

In this paper, we discuss the main depositional characteristics, subsurface structure, and radiocarbon ages of a fossil-rich deposit of possibly tsunamigenic origin on the coast of Hasır Island (40° 29' North; 27° 34' East), Southern Marmara Archipelago, SW Marmara Sea, Turkey.

The studied sequence is found on the west coast of the island (0.016 km^2), one of the small islands of the Southern Marmara Archipelago (Arnold, 2008) that comprises 24 islands and cays with a total area of 165 km². These islands, rising on southwest shelf of the Marmara Sea, form part of the Kapıdağ Peninsula and are composed of granite, granodiorite, marble, and schist (Ardel and Kurter, 1973). Samples of fossil shells were collected for AMS radiocarbon dating and stable isotope ($\delta^{13}C$ and $\delta^{18}O$) measurements.

Along transects taken perpendicular to the coastline, electrical resistivity imaging was conducted to reveal the subsurface nature of the sequence and its contact relationship with the underlying unit. Foraminiferal contents were also investigated.

From a depositional viewpoint, the studied sequence represents a high-energy event. It lies behind beds of submerged beachrock and covers an undulating surface cutting the underlying metamorphic basement. The fossil-laden layer with a thickness up to 0.75 m overlies an unconsolidated colluvial unit and is also overlain by similar weathered material. The underlying unsorted unit has an erosive base on green schists and contains angular rock fragments and unsorted sands and granules with poor internal arrangement. The fossiliferous unit in question with similar grain size and internal characteristics is composed largely of *Cerithium vulgatum* and lesser amounts of *Gibbula albida*, *Patella vulgata*, *Pecten maximus*, and *Cardium edule*. These species are known to be abundant in the Pleistocene raised coastal deposits of the so-called Marmara Formation (Sakınç and Yaltırak, 1997; Yaltırak et al., 2002). Albeit in limited amounts, various benthic foraminifera such as *Elphidium aculeatum* (d'Orbigny, 1846), *Elphidium crispum* (Linnaeus, 1758), *Elphidium macellum* (Fichtel and Moll, 1798), *Elphidium* sp., *Rosalina* sp., and *Quinqueloculina* spp. were also defined.

The abnormal and disordered accumulation of marine gastropods and shells within a sandy and muddy matrix including benthic foraminifera is likely typical of a tsunamigenic event since this level does not show any stratigraphic transition either upwards or downwards. The AMS ^{14}C ages fall in the range between 2340 and 1870 years cal BP and are suggestive of the period for the proposed Late Holocene tsunamigenic event.

Acknowledgments

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A METHOD FOR SEPARATING THE EUSTATIC AND TECTONIC COMPONENTS OF LOCAL SEA-LEVEL CURVES

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Keywords: Holocene, Mediterranean sea-level change, vertical coastal movements, eustatic curve

In articles (Esin et al., 2013, 2013) and in a report (Esin, 2011), we have shown that each local curve of sea-level change is the sum of the vertical displacement of the earth's crust, the eustatic sea-level change, and the effects of random processes. In these papers, a method of calculating eustatic sea-level change was suggested. The theoretical curve of eustatic change in the level of the Mediterranean Sea during the Holocene was found using 7 local curves from this sea. In this study calculations have been completed using 9 local curves of sea-level change in the Mediterranean (Fig. 1).

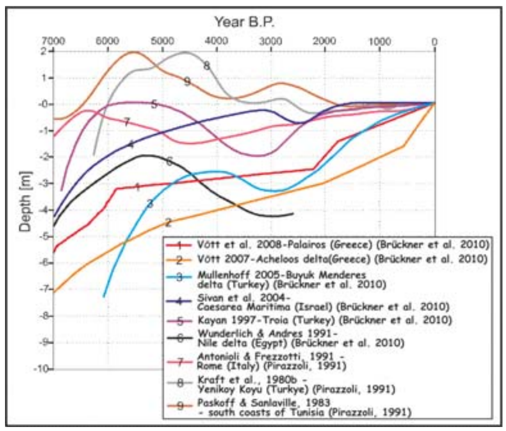

Figure 1. Local curves of sea-level change in the Mediterranean during the Holocene.

Results of the eustatic sea-level change calculation are presented in Figure 2.

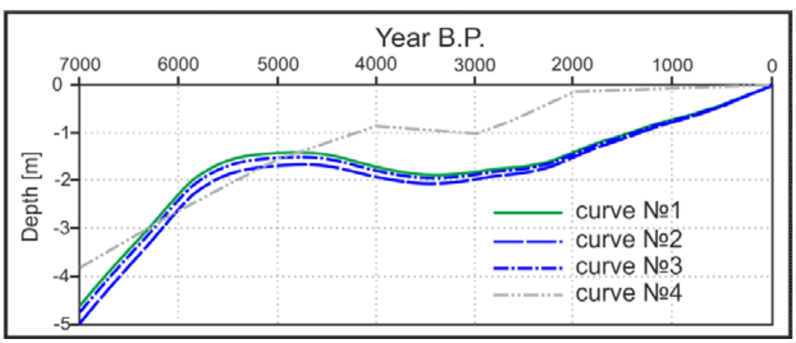

Figure 2. Theoretical curves of Mediterranean eustatic change. Curve no. 1 is the arithmetical mean between the real local curves. Curves 2 and 3 are calculated using the method presented in Esin (2011) and by using the identification points [-6000 year; -2.57 m] and [-5000 year; -1.5 m], respectively. Curve 4 is the sea-level change according to Rohde (Rohde, 2007).

As can be seen, 3 curves of Mediterranean eustatic sea-level change differ from each other by a few centimeters. The shapes of these curves are similar to the Rohde (2007) curve of World Ocean eustatic change. The theoretical local curves are calculated using these 4 curves, and they are shown in Figure 2. The comparison of theoretical and real local curves provides an opportunity to evaluate the accuracy of the calculations. The comparison shows that the average deviations of the theoretical local curves from the real local curves are equal to 0.57 m for curve no.1, 0.62 for curve no. 2, 0.58 for curve no. 3, and 0.83 for the Rohde curve.

If the ordinates of the eustatic sea-level curve (curve no. 1) are subtracted from the ordinates of each real local curve, then we obtain the graphs of the velocity change in vertical crustal movement of the earth (or exogenous processes).

The calculations of vertical crustal movement during the last 7 thousand years in 9 locations of the Mediterranean Sea coast are presented in Figure 3. As can be seen, they are quite different; this could be concluded earlier based on the diversity of local curves.

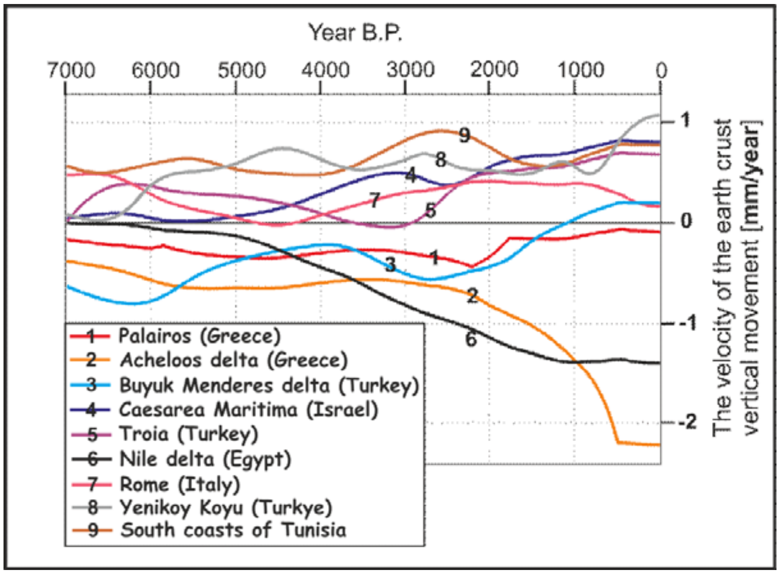

Figure 3. The graphs of the earth's vertical crustal movement velocities, calculated for different parts of the Mediterranean coast where the local curves of sea-level change are known.

The data describing the contemporary vertical crustal movements are presented in various publications. According to results of research (Ferranti et al., 2006) conducted on the coast of Rome, Italy corresponds to curve 7 (Fig. 3), the velocity of this uplifting coast is 0.17 mm/year. According to our data, this velocity is close to 0.16 mm/year (Fig. 3). The last uplifting of the earth's crust in the area of the ancient city of Troia began 3000 years ago. The bottom of the sea has risen nearly 2 m, and the shoreline has moved seaward several kilometers.

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MATHEMATICAL MODELING OF THE BLACK SEA COAST AND SHELF EVOLUTION DURING THE QUATERNARY PERIOD

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Keywords: abrasion, cliff, bench, profile of the shelf

The current coast and shelf of the Black Sea were formed mainly during the Quaternary period. Glacial eustatic sea-level fluctuations, vertical movements of the earth's crust, and the process of wave-based destruction made major contributions to Black Sea basin expansion and the creation of raised marine terraces on the coast. The curve of Black Sea transgression according to P.V. Fedorov (1978) shows that the velocity of the transgression was almost constant for a long time. Our research (Esin, 1980; Esin, et al., 1980) has shown that the abrasion process occurs with constant parameters (speed and bottom slope) when the velocity of the transgression is constant. In this case, if the profile of the coastal slope is described by curve $y = f(x,t)$, then the following equation is correct (Esin, et al., 2011):

$$\frac{dy}{dt} = \frac{tg\beta}{1 + |A|} \qquad (1)$$

where $A = \frac{V_y}{u}$, u is the velocity of sea-level rise at the point of cliff and bench intersection, A is the abrasion number, and V_y is the velocity of dredging in the surf zone. The number A characterizes the abrasion intensity: the greater A is, the smaller will be the angle at which the sea cuts the land.

Equation (1) allows us to reconstruct the evolution of the coast and the shelf as a broken line using the parameters of the present abrasion process and the known curves of sea-level change. The evolution of marine transgressions can be recovered by sequentially calculating the effects of each subsequent transgression. The experience of such reconstruction is presented in Esin et al. (1986) and Esin et al. (1989). Equation (1) allows us to obtain a full profile of the shelf and coast at different stages of their development. The numerical methods are the main way to solve it.

In rare cases, it is possible to obtain an analytical solution. For example, if the level change can be approximated as the relation:

$$y = L\,(1 - \cos\omega t\,),$$

where L is the amplitude of the vertical level displacement $\omega = \frac{\pi}{T}t$, and T is the period of the level fluctuation. Then, we get the equation to find the profile of the coast and shelf (Esin et al., 2011):

$$\frac{dy}{dx} = \frac{\omega\sqrt{2Ly - y^2 tg\beta}}{\omega\sqrt{2Ly - y^2 tg\beta} + V_y} \qquad (2)$$

Its solution is the function:

$$x = \frac{1}{\omega}V_y\pi ctg\beta + yctg\beta + \frac{1}{\omega}V_y\pi ctg\beta \cdot \arcsin\left(\frac{y}{L} - 1\right) \qquad (3)$$

Curve (3) is close to a straight line in its central part, and it shows the formation of flat areas at the beginning and at the end. The shapes of current shelf profiles in the Black Sea differ from Curve (3) because they were formed after successive transgressions of the Black Sea. The real profile of the coast and shelf can be obtained by sequentially applying the results of the coastal destruction of each subsequent transgression to the previous situation.

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A SIMPLE APPROACH TO PROJECTING CLIMATE CHANGE EXTREMES: A CASE STUDY OF THE BLACK SEA AND THE SEA OF AZOV

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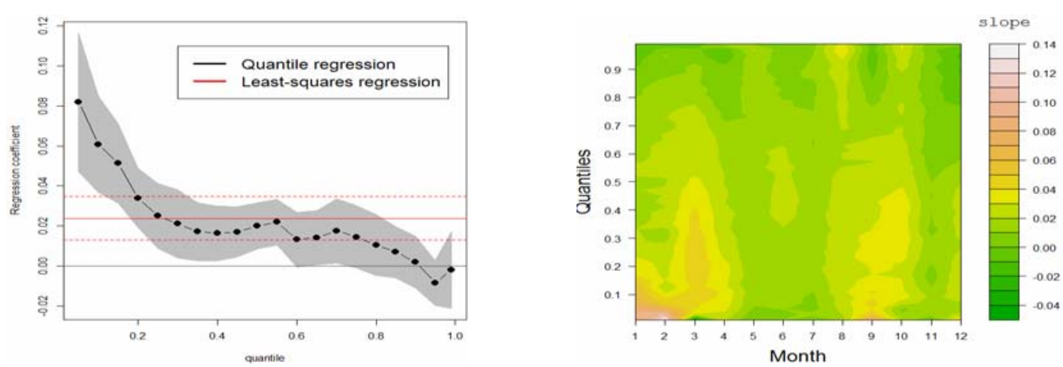
Keywords: global climate change, extremes, quantile regression model, air temperature, uncertainty

Understanding the role of extremes in changing climate is one of the main topics in contemporary climatology, as extreme events have a strong impact on economic and ecological systems (e.g., IPCC, 2007). Predicting these impacts is of great importance, and that is why climate studies over the last decade have focused on weather and climate change extremes both in the future and in the past. Global climate models (GCMs) are effective tools for studying climate change. Their output as a rule provides a realistic representation of large-scale features of climate in time and space, but extremes are not the case due to their spatial and temporal localization. Although CMIP5 simulations recently demonstrated promising results in projecting extreme trends into the future according to SRES and RCP scenarios of greenhouse gases emission (Sillmann et al., 2013a,b), nevertheless, the problem of consistent projection is still motivating researchers to make a comprehensive statistical description of probable changes in climate extremes in addition to GCM simulations.

Extreme events are defined as rare events requiring investigation of the tails of the probability density function associated with the variable of interest (air temperature, precipitation, etc.) (Beniston, 2009). In practice, 10% and 90% percentiles are often considered as special threshold levels for extreme low/high values, though other percentiles could also be used.

In the case of future projections and modeling of extremes, it is reasonable to pose the question whether changes in the mean climate can cause shifts in extremes (Beniston, 2009). In order to answer the question, we computed daily air temperature trends of different quantiles using the quantile regression method (Koenker, 2005) for sites along the Ukrainian coastal zone of the Black and Azov seas. Trends were calculated for each month separately and compared to trends in monthly-mean values. It is clear from Fig. 1 that the distribution of trends with respect to different months and quantiles differs much, especially for extreme temperatures—more (less) than 90% (10%) quantile; hereafter Ta90 (Ta10). Thus, special treatment of extreme ranges should be implemented.



a **b**

Figure 1. Quantile trends and their confidence intervals for daily temperatures at the Eupatoria site for January (a), and quantile trends map for all months (b).

In this work, we developed a simple approach to extreme climate change treatment using the technique of uncertainty estimation of hydrological forecasts (Weerts et al., 2011). The method does not consider temporal dependency but instead considers relationships between monthly-mean value for a variable and one of quantiles of daily values (e.g., Ta10 and Ta90). This relationship can be expressed in the following functional form:

$$\Delta T_q = T_q - \overline{T} = f\left(\overline{T}\right) \qquad (1)$$

where T_q and $\overline{T}$ stand for daily values of a certain quantile, q, and monthly-mean value, respectively. Such a relationship is specific to each site under consideration, thereby requiring calibration using a historical dataset. Let us demonstrate this approach with air temperatures. To increase sample size and improve reliability of the calibration procedure, all months should be included. In general, Equation (1) is nonlinear and imposes constraints on the statistical properties of the sample. In order to preserve the objectiveness and simplicity of the method, we applied Normal Quantile Transformation (NQT) to map Equation (1) onto a Gaussian domain (Bogner et al., 2012). In order to make the procedure robust, a quantile linear regression of median values in the Gaussian domain was applied (Koenker, 2005) for estimation of possible values of Ta10 and Ta90. An important issue here is uncertainty of estimation. At this point, a quantile linear regression for quantiles 5, 25, 75, and 95% was applied to construct 50% and 90% confidence intervals for the NQT transformed Ta10 and Ta90 estimation. Inverse NQT transformation enables one to get absolute values of Ta10 and Ta90 and their confidence intervals.

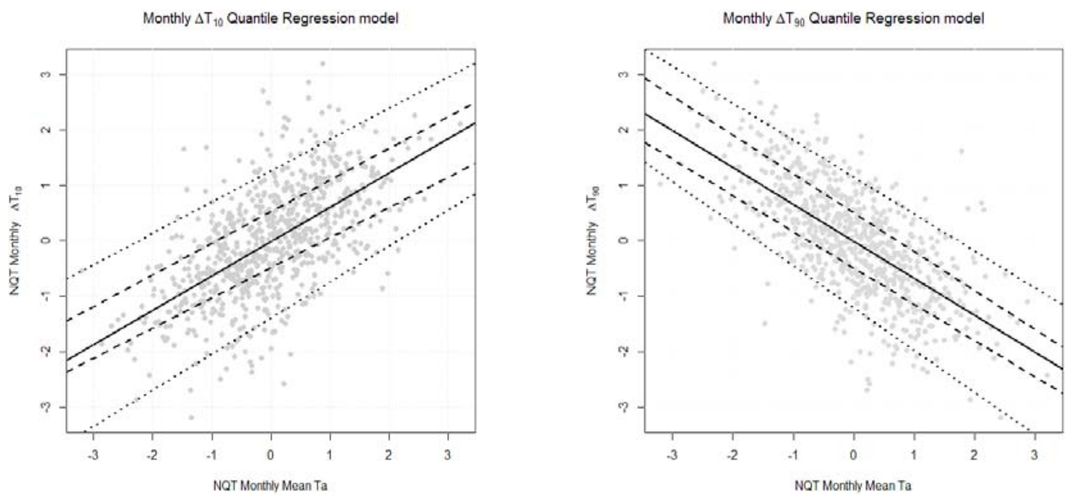


Figure 2. Quantile linear regression model for NQT values of Ta10 (a) and Ta90 (b) for Eupatoria.

The proposed method has been validated on records for 16 sites of the Black and Azov seas using the period of 1936-2000 for calibration and 2001-2012 for validation. This approach shows promising results that allow one to project climate change extremes using the ensemble of GCM outputs for a monthly-mean variable. A special issue to be addressed is treatment of GCM uncertainties.

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THE AEGEAN ROUTE: AN ALTERNATIVE ROUTE FOR THE NEANDERTHALS AND ANATOMICALLY MODERN HUMANS (AMHS) TRAVELLING FROM ASIA TO EUROPE AND *VICE VERSA*

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***Keywords:** coastal palaeo-configuration, human dispersal, north-eastern Mediterranean*

Introduction

One of the most debated issues in archaeology is when, why and how humans first ventured into seagoing. The first humans to develop seafaring capabilities were the Neanderthals, who crossed the waters from the Hellenic peninsula to reach the southern Ionian islands of Zakynthos and Kefallinia in the Middle Palaeolithic, sometime between 110 and 35ka BP (Ferentinos *et al* 2012). AMH's travelled the waters from southeastern Asia to Australia no earlier than 45ka BP and probably as early as 55ka BP. In retrospect the earliest evidence of AMH's seafaring in Europe comes from Sicily in 30ka BP, Sardinia between 22 and 18ka BP and Cyprus between 13 and 11ka BP (Broodbank 2006). Recently, Strasse *et al* (2011) based on the presence of stone tools in the Island of Crete dated between 130 and 45 ka BP and implying the likely insularity of Crete during the same period, suggested that seafaring was started much earlier by pre-Sapiens hominins.

The objectives of this paper are to (i) shed light on human mobility from the Hellenic peninsula and Anatolia to the Aegean islands and *vice versa* during the Middle and Upper Palaeolithic from Marine Isotopic Stage (MIS) 4 to 3 (74 to 23 ka BP), (ii) examine whether humans had walked to the islands using land-bridges or had developed seafaring capabilities for their movements, and (iii) the Aegean Archipelago was one of the routes used by the Neanderthals and AMHs to travel from Europe to the Middle East and *vice versa* during MIS-4 and MIS-3.

Methodology

For achieving the aforementioned objectives a chrono-cultural framework for MIS-4 and MIS-3 is established for the Hellenic Peninsula and the Aegean Sea, and compared to those from the Levant, Anatolia and central/eastern Europe. Furthermore, the palaeo-shoreline configuration of the Aegean Sea is established over the same time span, taking into consideration the sea-level evolution in relation to the eustatic, isostatic and tectonic changes in the area, to examine the insularity of the Aegean islands.

Data pesentation

The technological-typological analysis of the lithic industries found in the Hellenic peninsula has shown the presence of the following litho-complexes: a Mousterian, a Final Middle Palaeolithic, an Initial Upper Palaeolithic, an Early Aurignatian (Aurignatian I), an evolved Aurignatian (Aurignatian II) and a Gravettian (Pope *et al* 1984, Runnels, 1988, Runnels *et al* 1994, Koumouzelis *et al* 2001, Panagopoulou *et al* 2001, Panagopoulou *et al* 2002-2004, Kopaka and Mantzanas 2009, Douka *et al* 2011). Comparing the chrono-cultural framework of the Hellenique peninsula to that of the central/eastern Europe, Anatolia and the Levant the following are concluded: The Uluzzian and Szeletian-like type lithic industries in the Hellenic peninsula are contemporaneous with the Italian Uluzzian and the Bohunician in Tzechia, respectively. The former is dated between 44.5 and 40 cal ka BP (34-32 ka BP) and the latter between 46 and 40 cal ka BP (39-35 ka BP) (Joris and Street 2008). The IUP lithic industry in the Hellenic peninsula dated between 44.5 and 38.2 cal ka BP is synchronous with those found in the Levant, Anatolia and central/eastern Europe, which are dated at between 43 and 41.3 cal ka BP (Joris and Street 2008). The Early Aurignatian (Aurignatian I) in the Hellenic peinsula, dated between 39.3 and 36.3 cal ka BP and the Evolved Aurignatian (Aurignatian II), dated at around 36.5 and 35.3 cal ka BP Douka *et* *al.* 2011), are contemporaneous with those in Europe dated between 39.8 and 33.8 cal ka BP (Joris and Street, 2008).

The study of the Aegean Sea configuration during MIS 4 and MIS 3 shows that the Aegean islands that time were insular (Fig. 1).

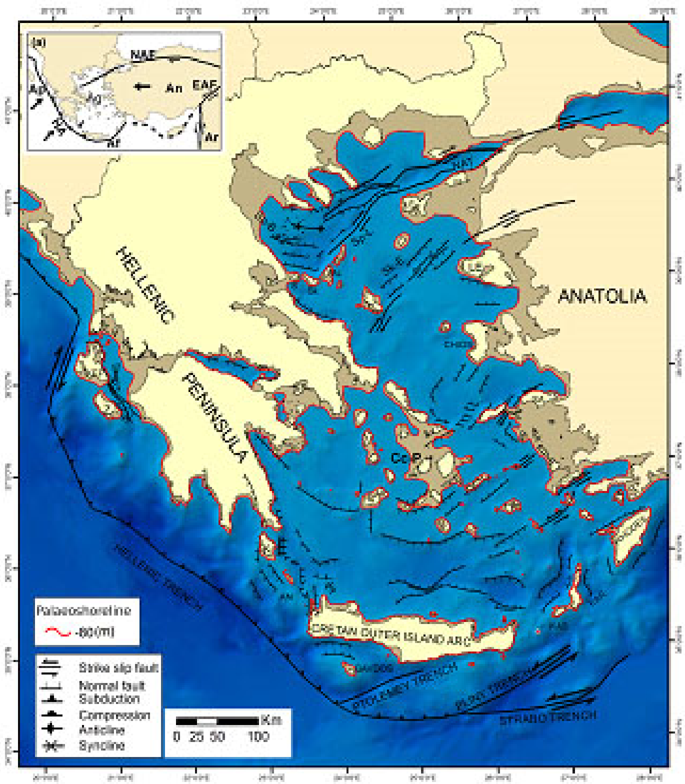

Figure 1. Aegean Sea map showing: (i) the major morpho-tectonic provinces, (ii) the major fault lines, (iii) the present day shoreline configuration and (iii) the shoreline configuration when the sea-level was -80m below present during MIS 4 and MIS 3 (74 to 22 ka BP).

Conclusion

The data presented offers substantial evidence that: (i) the Hellenic peninsula was used by the Neanderthals as a refugium during MIS 4 and MIS 3, (ii) Neanderthals and AMHs co-existed in the Hellenic peninsula at around 40 cal ka BP (35ka BP), (iii) the max. time-span of the Neanderthals and AMHs co-existence in the Hellenic peninsula may extend from 44 to 33 cal ka BP., (iv) Neanderthals and AMHs were seafaring in the Aegean Sea, the former from around 60 to 35 ka BP and probably from 120 to 35 ka BP, the latter from 35 ka BP and onward, (v) Neanderthal and AMHs in their movement from the Hellenic peninsula to the Anatolia and *vice versa* had established a coastal route via the Aegean Archipelago, “the Aegean route” using the islands as stop over and (vi) the “Aegean route” might have been used as an alternative route to the Bosporus land-bridge by the Neanderthals and AMHs in their movement between the Levant, Anatolia and Europe during MIS 4 and MIS 3 (74 to 23 ka BP) (Fig. 2).

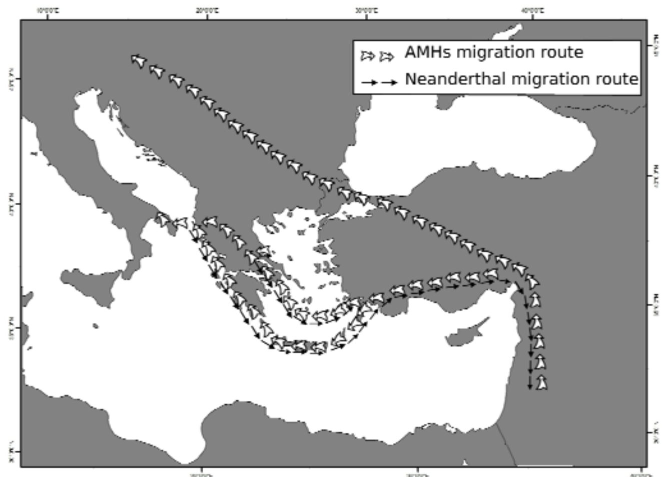

Figure 2. Map showing an alterative coastal route via the Aegean Archipelago used by the Neanderthals and AMHs in their movement from Europe to the Levant and *vice versa*.

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RECENT DEFORMATION PROCESSES AND ECOLOGICAL CONSEQUENCES ON LONG-TERM DEVELOPED PETROLEUM FIELDS

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Key words: depleted petroleum fields, pressure drop, reservoir compaction, ground subsidence, underflooding, induced seismicity, damage to infrastructure

Introduction

It is known that long-term development of petroleum fields removes great volumes of oil, gas, and formation water from the substrate. This leads to an essential pressure drop in reservoirs (Mes, 1990; Xie et al., 2003) that can reach up to 50-80% below hydrostatic pressure (Xie et al., 2003). A drop in formation pressure in reservoirs tends to increase effective pressure, which reduces porosity and permeability of rocks, while it stimulates additional compaction (Abasov et al., 1997; Vanhasselt, 1992). This process changes the ecological situation in the field and brings about substantial consequences. Ground subsidence develops (Holzer and Bluntzer, 1984; Martin and Serdengecti, 1984; Vanhasselt, 1992; Fielding et al., 1998), territories flood (Pratt and Johnson, 1926), "induced" seismicity appears (Plotnikova et al., 1990; Adushkin et al., 2000; Sze et al., 2005), and finally, infrastructure is damaged—e.g., breakdown of wells, platforms, pipelines, bridges, etc. (National Research Council, 1991; Van der Kooij et al., 1995), restoration of which requires significant capital investments (National Research Council, 1991).

This presentation will assess the drop in formation pressures within petroleum fields that have been developed over long periods on the Absheron peninsula (Azerbaijan) and consider the accompanying ecological consequences.

Results

The richest oilfields on the Absheron peninsula have already been worked for more than a century. Industrial development first began here in 1871 on the Balakhany-Sabunchi-Ramana field. During their active period, the Absheronian fields produced more than a billion tons of oil (without taking into account accompanying gases and formation waters) from the substrate, and at present all fields are essentially depleted. It has been established that primary formation pressures in fields of the Absheron peninsula as a whole (according to data from about 15 fields) were equal to the hydrostatic pressure. The lengthy period of development, however, has led to dropping formation pressures in reservoirs (Fig.1).

In the depleted reservoirs, both elastic and plastic deformation processes have developed; plastic deformations are more significant than elastic. The irreversible process of rock compaction leads to declining porosity and thus a reduced permeability in the rocks, leading to decrease of oil production. The compaction of reservoir rocks negatively influences the environment. Ecological consequences of this phenomenon are: (1) intensive (up to 47 mm/year) subsidence of the ground in the area of the petroleum fields (Balakhany-Sabanchi-Ramana, Surakhany, Garachukhur, and Bibi-Eybat), (2) flooding of these areas, and (3) the occurrence of induced seismicity (Surakhany earthquake in 1937).

The diagram of Figure 2 reflects the appreciable correlation between average annual rate of downward vertical ground movement with an increase in average annual oil recovery from fields on the Absheron peninsula.

Processes of ground subsidence on the Absheron peninsula were accompanied by negative ecological consequences: an intensive rising in the level of groundwater correlated with areas of ground subsidence. For example, in the central part of the peninsula, from 1955 to 2006, areas with a groundwater depth of >10 m have decreased 21.4 %, and areas with a groundwater depth of 3-5 m have increased 10.3 % (Israfilov, 2012).

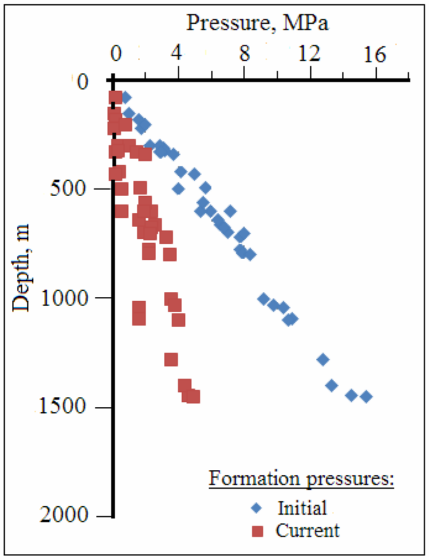

Figure 1. Initial and current (on 01.01.2009) formation pressures vs. depth of petroleum reservoirs in fields of the Absheron peninsula.

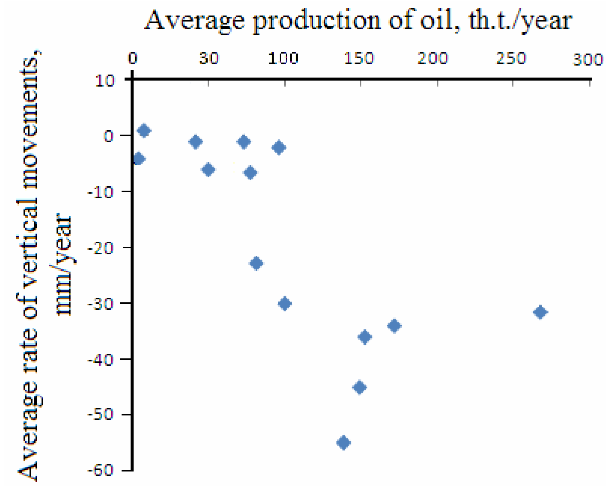

Figure 2. Average annual production of oil from fields on the Absheron peninsula vs. rate of recent vertical ground movements (prepared using data of Yashenko, 1989).

Abnormal subsiding near the crest of anticlines within the oldest fields (Sabunchi, Surakhany, Ramana, and Bibi-Eybat) has reached 1 to 2.5 m over the past 50 years (Bulanzhe and Nikonov, 1973; Lilienberg, et al., 1980), and over the past 80 years, the central part of the Absheron peninsula has fallen more than 3 m (Yashenko and Yanbayev, 2006). The consequences of anthropogenic deformation processes have led to frequent incidences of curved boreholes, breaks in oil, gas, and water pipelines, and sudden kicks of water and sand.

Abnormal rates of subsidence in the area of the Surakhany field (about 47 mm/year) triggered an earthquake in 1937 near the village of the same name.

Conclusion

Technogenic activation of local tectonics has been caused by humans, and so it seems that humans can and should also regulate this process; unlike natural tectonic activity, controlling induced seismicity is quite possible and necessary. To minimize ecological and economic damage, providing future extractive applications with a system of seismic and geodynamic control is crucial for forecasting the development of tectonic processes.

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EAST MEDITERRANEAN ENVIRONMENTAL CHANGE AND HUMAN DISPERSAL FROM CAVE DEPOSITS

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Keywords: Dead Sea, speleothem, paleoclimate, stromatolite, Neanderthal

The climatic reconstruction discussed here is based primarily on the most straightforward paleohydrologic records. These terrestrial proxies convey direct paleoenvironmental signals of effective precipitation. The two main proxies we use are periods of deposition/non-deposition of speleothems in the Dead Sea region, and temporal changes in terminal lake levels within the Dead Sea basin.

Speleothem ages (using U-Th) from two caves on the Dead Sea Fault Escarpment and two caves from arid rain-shadow areas surrounding the Dead Sea span the last three glacial cycles between ca. 354 to 12 ka (Fig. 1). They suggest increased infiltration of meteoric waters into the caves mainly during the glacial periods of Marine Isotopic Stages (MIS) 6 and 4 to 2 (Lisker et al., 2010).

Figure 1. Speleothems from a Dead Sea escarpment cave and their U-Th age. Photo: S. Lisker.

U-Th ages of stromatolites (Fig. 2) deposited in the Late Pleistocene Lake Lisan and preserved in caves of the Dead Sea Fault Escarpment suggest high lake levels during the last glacial period, and particularly high during the late part of MIS 3 lasting until middle MIS 2, as well as at the MIS 5.1 to 4 (interglacial-glacial) transition (Lisker et al., 2009; 2010).

The speleothem deposition periods spanning the 38.4±0.5 to 16.4±0.3 ka time interval, i.e., late MIS 3 to early MIS 2, represent moist periods in the lake area, coeval with regional high precipitation/evaporation ratios inferred by the stromatolite record. A direct connection is thus implied between local and regional climate at the latest Pleistocene based on correlation between the two independent data sets. In general, the last two glacial periods in the central Levant experienced high precipitation/evaporation ratios, making the climate more temperate. The last two interglacials, MIS 5, and the Holocene generally experienced low precipitation/evaporation. Therefore, in the southern Levant, more water was available for the ecosystem during glacial periods than during interglacials, at both local and regional scales. Other records, such as stable isotopes, if interpreted correctly, correspond well with these two direct proxies. It is thus inferred that climatic belts have migrated southward during the glacial periods. Beyond the general mean glacial/interglacial climate suggested here, variations occurred at several temporal scales throughout the glacial or interglacial periods.

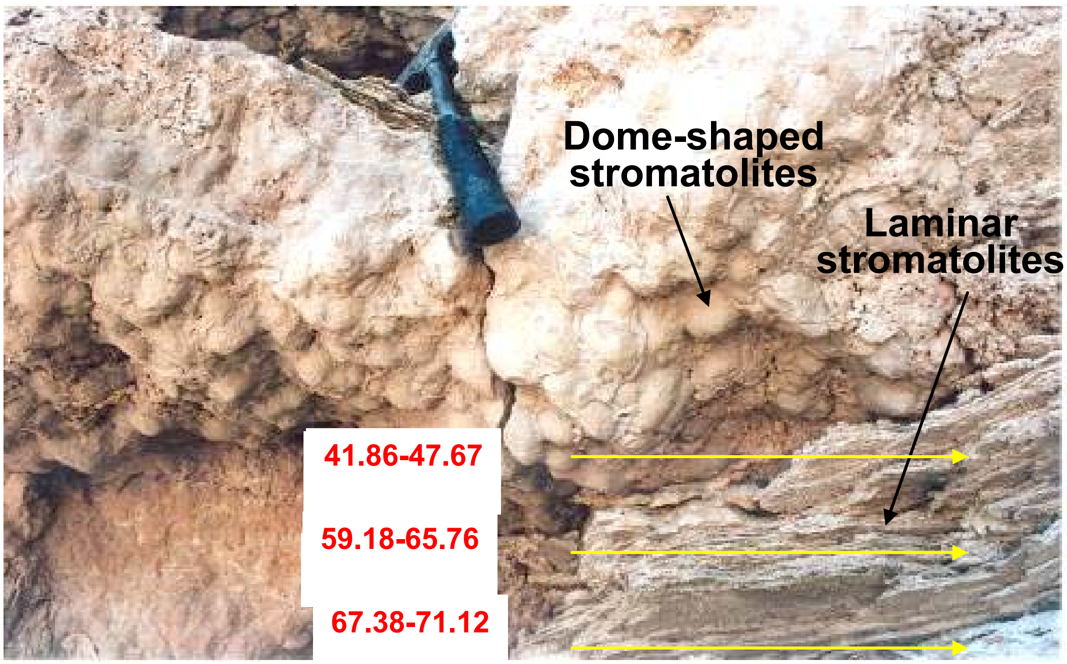

Figure 2. Stromatolites in a Dead Sea escarpment cave and their U-Th age range in ka. Photo: S. Lisker.

The major glacial/interglacial paleohydrologic variations of this region and the Sahara had probably affected human migration routes across the southern Levant. Neanderthals dispersed into the eastern Mediterranean during the onset of cold and wet conditions of the early glacial period (MIS 4) (Frumkin et al., 2011). On the southern side, Anatomically Modern Humans apparently migrated out of Africa during wetter spells in the desert belt (Vaks et al., 2007).

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OBSERVATIONS ON LATE PLEISTOCENE FLOODING OF THE EURASIAN CONTINENTAL INTERIOR AND POSSIBLE ALLUVIAL ORIGIN OF LOESS

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Keywords: Caspian Sea, Black Sea, paleohydrology, deluge, radiocarbon, Azerbaijan, Bulgaria

Fluctuations in the level of the Caspian Sea have greatly influenced coastal communities for millennia. This is due in part to a dynamic balance between regional climate, temperature, rainfall in the catchment areas of the rivers feeding the basin (principally the Volga), and evaporation from the surface of the sea. As an endorheic basin (i.e., having no outflow), and evaporation estimated to be around one meter per year, the Caspian Sea level will either rise or fall depending on climate and rainfall. Currently, the level is around minus 28 m relative to average sea level (asl). In the present era, fluctuations are on the order of only a few meters, and while significant to those living near the coastline, this is minor compared to the dramatic regressions and transgressions associated with the Ice Ages (Mamedov, 1997).

In the last ice age, it is acknowledged that global sea level fell below -100 m asl as ice sheets developed on land and in polar waters. Then with deglaciation, meltwater inundated the northern watershed areas to drain via river systems into the low lying basins of the Aral, Caspian, and Black Seas. During the transgression, maximum water levels rose to around 50 m above mean sea level. This is the current understanding of Quaternary Eurasian water balance (Grosswald, 1998; Rudoy, 1998; Mangerud et al., 2001, 2004; Baker, 2007; Komatsu and Baker, 1996; Komatsu et al., 2009). However, the author believes that rainfall and river inputs have largely been overlooked and that sea/lake levels in reality were much higher (Gallagher, 2011).

The realization of massive flooding during the Ice Age came about as a result of natural history and archaeological forays into the Azerbaijan countryside to search for evidence of early man (i.e., rock shelters, stone circles, cart ruts, burial mounds, rock art, etc.). Flooding was hinted at due to settlement remains at the edge of old sea beds. More obviously, it became apparent that the Caspian Sea had to have been much higher due the presence of raised terraces and relatively unweathered strandlines in valleys and on mud volcanoes. With terraces in excess of 100 m above mean sea level, and strandlines in sheltered valleys in excess of 200 m asl, it seemed improbable these could be attributed to tectonic uplift. With no obvious explanation for the flooding, this encouraged a search for organic remains to determine the age of the flooding, and possibly identify a mechanism for its cause.

In explaining this, it is important to consider that as Arctic ice fronts advanced onto mainland Russia, the north-flowing rivers (Yenisei, Ob, Pechora, Dvina, and possibly Lena) which supply most of the freshwater to the Arctic Ocean became blocked by ice dams. In consequence, rivers were incrementally diverted into the Ponto-Caspian region during the Pleistocene and would have persisted for millennia to create a huge lake. This may also be the reason why stepped terraces are to be found in Azerbaijan with terrace tops correlating to spillway heights (Gallagher, 2011). Of further importance and for topographic reasons, the deluged landscape was not able to drain floodwater as the Dardanelles and Bosporus channels were then closed. This is evidenced by a single borehole study in the Aegean Sea dating from 16,000 years BP, which showed no outflow from the Black Sea/lake up until 10,000 BP (Aksu et al., 2002).

In consequence, large ice-dammed lakes formed between the ice sheet in the north and the continental water divides to the south. These lakes overflowed toward the south, and thus the drainage of much of the Eurasian continent was reversed. The result was a major change in the water balance on the continent, with decreased freshwater supply to the Arctic Ocean, and increased freshwater flow to the Aral, Caspian, Black, and Baltic seas. In effect, a massive endorheic body of water had to have formed within the continental interior.

Proving this to the author's satisfaction involved finding and dating organic remains. With perseverance, it was possible to collect mollusks at elevated locations in the region of the Gobustan archaeological reserve in Azerbaijan (a remarkable site depicting over 6000 petroglyphs, several of which were of multi-oared rowing boats). Test bulk shell samples were sent to Beta Analytic in Florida for radiocarbon dating. Initial results confirmed water levels in excess of 80 to 126 m asl with dates around the end of the LGM. While inaccuracies in dating might be anticipated due to fossil washout, and jumbled seabed shells accumulating over a longer timescale, sufficient information was obtained to suggest the possibility of an Ice Age deluge.

To test this theory further, it was important to determine the spatial extent of the inland water body. Logically, such a massive body of water should be detected around the Black Sea coastline. Using *Google Earth*, the terraces and cliffs of the Thracian coastline in Bulgaria were identified as a possible location to find mollusk remains, which proved to be the case. Samples were collected and analyzed from sites ranging from 33 to 126 m above the Black Sea. Two samples, at 77 m and 126 m asl, provided radiocarbon dates of 39200 +/- 490 BP and 29010 +/- 170 BP, respectively, with other results in excess of 43 ka, i.e., towards the limit of the radiocarbon dating method. The former results supported the Late Pleistocene dating from Azerbaijan and provided evidence for widespread flooding. Selected results include are shown in Table 1.

Table 1. Radiocarbon age of selected samples

Country	General location (GPS coordinates available)	Elevation asl m	Measured age BP	13C/12C ‰	Conventional age BP
Azerbaijan	Gobustan at 8m	8	26,110±180	+2.5	26,560±190
	Gobustan 18 to 30m	18 - 30	28,520±210	+1.1	28,950±220
	Gobustan 80 to 85m	80 - 85	14,310±70	+1.6	14,750±80
	Terrace top near Gobustan	100	32,460±480	+2	32,910±510
	Gobustan 125m	125	16,770±100	+1.6	17,210±100
	Qobu terrace near rock shelter	140	40,730±530	+1.1	41,160±530
Bulgaria	Thracian Cliffs	33	n/a	+3.8	> 43500
	Thracian Cliffs	46	n/a		> 43500
	Thracian Cliffs	77		+2.7	39,650±490
	Thracian Cliffs	110			> 43500
	Thracian Cliffs	126	29,010 +/- 170	+2.8	29,470±170

With this limited data set, it is not possible to determine the actual water-level fluctuation timeline, as many more data points are needed. However, assuming that there are no errors in radiocarbon analyses and tectonic uplift is not a significant factor, it may be inferred that Eurasia was indeed deluged for much of the late Pleistocene. The release of meltwater upon deglaciation would of course later raise floodwater level much higher, possibly beyond the 200 m asl mark, as indicated by Azerbaijan's strandlines, such that discharge would be to the North Sea and English Channel. Meltwater may even have played a part in carving open the Bosporus and Dardanelles waterways.

With flood levels in excess of 100 m asl, Eurasian geography would obviously be greatly affected, and this would have significant implications for regional climate, biogeography, and human demographics. From an archaeological perspective, it may even be inferred that intercontinental navigation was possible for millennia during mankind's prehistory. The flooded landscape and the eventual disappearance of the waterways during the Holocene would also surely have influenced mankind and prehistory at the start of the earliest civilizations. Curiously, in other research, Upper Paleolithic settlement sites are to be found only on higher ground, above the floodwaters.

In considering the physical impact of a massive body of water, it is likely that there is sedimentary evidence to be found. Deltas and alluvial fans would be displaced upriver and fine silt widely dispersed throughout the sea/lake, enhanced by spring floodwaters.

In exploring this idea to work out the scale of the water body, a reasonable assumption was to use the dominant 60 km long raised terrace in Azerbaijan as a benchmark for extrapolation and delineating the contours of the inland sea/lake. With an upper elevation of around 125 m asl, using *Google Earth*, a map of the sea/lake was obtained (Fig. 1). Then, in comparing this to the loess map of Europe (Fink et al., 1977), a close correlation was found. This then raised the question of the origins of loess. Could it be that loess is the result of sedimentation, and that it has alluvial and not aeolian origin?

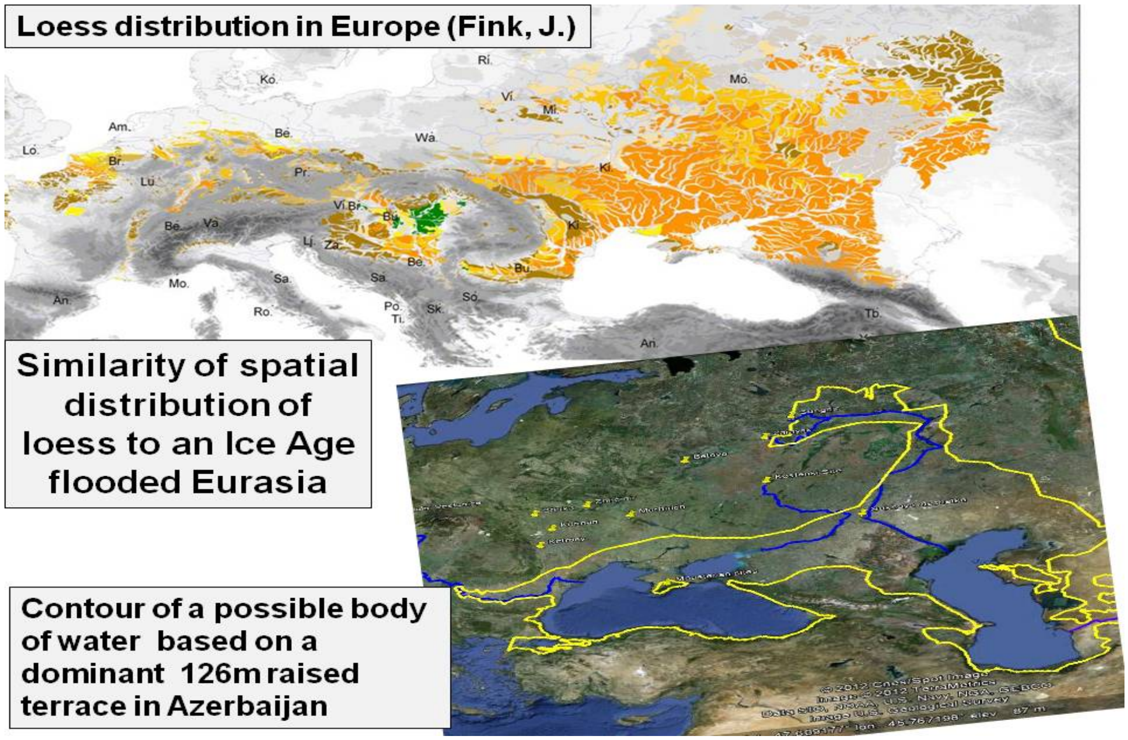

Figure 1. Loess map of Europe (after Fink, 1977) and reconstruction of water body of the Ponto-Capian basin.

Current understanding is that loess is an Aeolian, or windblown, deposit, which originated during drier ice age conditions. Given that the radiocarbon dating evidence suggests low lying areas were under water for much of this time, then (if true) this challenges loess's aeolian origins. And given the likelihood that major rivers contributed fine silts, it further suggests loess may be an alluvial deposit. Subsequent water retreat would expose the unconsolidated sediments to erosion by streams and rivers and to aeolian reworking.

While it may be noted that earlier scientists, including Charles Darwin, once thought that loess had alluvial origins, evidence for this was missing. With limited radiocarbon dating, strandline evidence and a probable flood mechanism suggesting an alluvial origin for loess, researchers may wish to investigate this possibility. If proven, then this would perhaps help pave the way to multidisciplinary investigation of the many fascinating implications inherent in an ice age flooded continental interior.

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PALEOECOLOGY OF THE SCYTHIAN POPULATION IN THE FOOTHILLS OF THE CRIMEAN MOUNTAINS BASED ON POLLEN STUDY OF THE AK-KAYA SETTLEMENT

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Multiple environmental changes during the Late Holocene have been observed in the pollen record obtained from the section of the Ak-Kaya settlement, which is located on the right bank of the Biyuk-Karasu River near the village of Vishenne (Bilogirsk district, Crimea). The section consists of chernozem-like soils and pedosediments that include cultural layers of different periods within Scythian time and the medieval period. The studied area presently is situated in the geobotanical region of mesophytic steppe and oak forests, though the latter are absent near the Ak-Kaya site. The surface pollen spectra adequately represent the modern vegetational composition. They have been used for comparison with fossil spectra from the section during the paleoenvironmental reconstructions.

Before the settlement's appearance (prior to the IV century BC), forests occupied much larger areas than during later times, and the composition of the steppe vegetation was more mesophytic than nowadays (herbs strongly dominated over grasses). The extensive spread of arboreal vegetation could be connected either with a humid climate or with the absence of noticeable human impact, but the complete absence of xerophytic elements and sharp predominance of mesophytic herbs on the steppe give evidence that the climate was wetter than today. The beginning of the Subatlantic (the VI-V centuries BP) is characterized elsewhere by an increase in precipitation (Khotinsky et al., 1991; Gerasimenko, 2007). At the period of settlement initiation (the beginning of the IV century BC), significant changes in vegetational cover occurred. Shrubland spread (*Crataegus* sp., *Rosa canina*, *Pyrus elaeagrifolia*, *Prunus* sp., *Lonicera tatarica*, and *Sambucus* sp.) and grasses dominated over mesophytic herbs on the steppe. Oak forests (with *Fraxinus* and *Cornus mas* in the second layer) occupied much smaller areas than earlier. The climate became drier, though it was still more humid than at present. At the beginning of the settlement's existence, human impact on the vegetation was not significant, as it is not traceable in the pollen records. In the first half of the III century BC, human impact became quite noticeable with the appearance of pollen grains of Cerealia, segetal, ruderal, and pasture weeds. The decrease in arboreal pollen counts at this level can be connected with forest clearings.

Ruderal weeds absolutely thrived at the site during the middle part of the III century BC (a period of fires at the settlement lasted around 20 years). Plants from the Asteraceae, Cichoriaceae, and Brassicaceae families and, in particular, *Cirsium*, *Sonchus*, and *Amaranthus*—all of them indicators of destruction of natural vegetation (Bottema, 1975; Kremenetsky, 1997)—occupied the site. During formation of the cultural layer of the second half of the III to the beginning of the II century BC, a trend toward increasing climatic aridity continued (the further xerophytization of the steppe vegetation). The mesophytic steppe consisting of herbs and grasses was replaced by typical grassland. It is indicated by an increase in Poaceae pollen percentages and the appearance of xerophyte pollen: Chenopodiaceae, *Ephedra*, *Sedum*, and *Limonium*. The role of steppe bushes in the vegetational cover decreased (with the exception of the typical steppe xerophytes: *Rhamnus cathartica* and *Elaeagnus angustifolia*). Thus, prior to the beginning of the II century BC, the climate became drier than at present, but it was the same in terms of warm temperature (the pollen percentages of broad-leaved trees correspond to modern ones). Pollen percentages of Cerealia reached their peak within these layers. This can indicate Cerealia cultivation in terrains around the settlement. Ruderal and pasture weeds (particularly *Cirsium*, *Urtica*, *Sonchus*, *Cannabis*, and *Plantago*) were spread significantly.

After a short break in sedimentation, which corresponds to the hard floor of the settlement, the cultural layer of the II-I century BC appears in the section. During its formation, the role of xerophytic and ruderal plants was firstly significant in the steppe associations: Chenopodiaceae, *Artemisia*, Asteraceae (including *Cirsium*), Cichoriaceae (including *Sonchus*), but later on, the predominance of grasses was re-established. Shrubs of *Crataegu*s sp. and *Rosa canina* occurred. The climate still was drier than at present. Long distance transport of pollen from the Crimean Mountains increased (*Pinus kochiana*, *Pinus sylvestris*, *Carpinus betulus*), indicating the predominance of southern winds. The pollen percentages of Cerealia are not significant. Thus, their cultivation around the settlement was rather limited.

Higher in the section, the bed of limestone plates corresponds to a long sedimentation gap. Above this bed, the Saltiv culture layers were formed (IX-X centuries AD). During this time, the steppe around the settlement was mesophytic, with a great diversity of herbs. At these levels, pollen of 18 families of Herbetum mixtum is represented, whereas only 6 of them occur in the cultural layer of the II-I centuries BC. Oak groves and shrub bushes from the Rosaceae family were widespread. The humid climate of this phase is also indicated by the transport of *Fagus sylvatica* and *Hedera helix* pollen from the Crimean Mountains. At that time, the wet-loving plants spread more extensively (or they had greater pollen productivity) than at present. This wet and warm phase evidently corresponds to the climatic optimum of the Middle Ages (IX-XII centuries AD). The human impact on the vegetation became stronger at this time. Pollen percentages of Cerealia increase, and the segetal weed *Centaurea cyanis* occurs, as well as pastures (*Plantago*, *Euphorbia*, Cichoriaceae) and ruderal (*Urtic*a, *Cannabis*, *Convolvulus*, and Chenopodiaceae) weeds.

Higher in the section, a phase can be traced that is characterized by steppe vegetation consisting of mixed herbs and grasses. Pollen percentages of grasses are significant, whereas pollen of xerophytes (*Artemisia*, *Echinops*, *Ephedra*, and Chenopodiaceae) is not frequent. The areas of broad-leaved tree groves and bushes decreased considerably. Only *Lonicera tatarica*, *Sambucus*, and *Juniper* occurred. A strong drop in pollen percentages from broad-leaved trees indicates that the climate became cooler, and thus, pollen productivity of thermophilous plants decreased. This phase evidently corresponds to the “Little Ice Age” (XIV to the beginning of the XIX century), and, namely, to its first part (prior to the XVI century AD). The climate in the Crimean steppe was not arid then (Gerasimenko et al., 2011). The human impact on the vegetation decreased as compared with the preceding phase (in particular, pollen percentages of Cerealia are much lower). The second half of the “Little Ice Age” is traced in the lower part of the humus horizon of the modern soil which had never been plowed. The area was occupied by grassland with a significant share of xerophytes: Chenopodiaceae, *Artemisia*, *Ephedra*, *Sedum*, *Leontice odessana*, *Echinops*, and *Limonium* (though part of the Chenopodiaceae pollen could belong to ruderal plants). Steppe bushes (*Crataegu*s sp., *Lonicera tatarica*) occurred rarely. Arboreal pollen is represented only by grains from long distance transport: *Pinus*, *Picea*, *Alnus*, and *Betula* (boreal trees). This indicates low pollen productivity from broad-leaved trees in the Crimean mountain forests. The climate was cooler and drier than today.

The beginning of the modern warm phase can be traced in the upper part of the humus horizon of the modern soil (0.5-5.0 cm) by the appearance of pollen from broad-leaved trees and an increase in the pollen percentages of bushes. Then, the grassland had a lower proportion of mesophytic herbs than at present, though diversity of the latter increased as compared with the preceding phase. Oak groves with *Fraxinus*, *Euonymus*, and *Viburnum* in the undergrowth re-appeared. The climate was warm but still drier than nowadays. The human impact can be seen in the presence of Cerealia and *Centaurea cyanis* pollen, as well as in abundance of pollen from pasture and ruderal weeds (particularly Chenopodiaceae).

Thus, in the foothills of the Crimean Mountains, oscillations in temperature and particularly in precipitation occurred during the Subatlantic, though they did not have great amplitude. The “Little Ice Age” (XIV-XIX centuries AD) was the coldest time. The climate was wetter than today at the beginning of the Subatlantic (prior to the III century BC) and during the “Medieval climatic optimum” (namely the IX-X centuries AD). From the end of the III century BC up until the end of the I century BC, and during the second half of the “Little Ice Age,” the climate was drier than at present. During the occupation of the Scythian settlement (IV-I centuries BC), the climate changed progressively from humid to arid: a shrub steppe with a diversity of mesophytic herbs was replaced by steppe with a predominance of grasses over herbs, and finally by typical grassland. Nevertheless, such a strong aridification and vegetational xerophytization (dry *Artemisia*-Poaceae steppe) as happened in the plain area of Crimea during the II-I centuries BC (Gerasimenko, 2007), did not occur in the foothills of the Crimean Mountains. This evidently can explain the lengthy existence of the Scythian population here. These people could live a sedentary lifestyle and practice farming. Paleoenvironmental events reconstructed from the pollen records of the Ak-Kaya site are well correlated with those from the sedimentary archive of Lake Saki, southwestern Crimea (Gerasimenko et al., 2011).

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IS THERE A CORRELATION BETWEEN ARCHAEOLOGICAL AND CLIMATIC CHANGES IN THE MIDDLE TO UPPER PALEOLITHIC TRANSITION? AN EXAMPLE FROM THE HELLENIC PENINSULA

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Keywords: Neanderthals, AMHs, dispersal in southeastern Europe

Introduction

As was recently argued, climatic fluctuations followed by sea level and shoreline changes played an important role in prehistoric movements by land (Mellars, 2006) and by sea (Ferentinos et al., 2012) in the eastern Mediterranean. The same was argued about Neanderthal extinction (Tzedakis et al., 2007) and the expansion of Anatomically Modern Humans (AMHs) (Muller et al., 2011) all over Europe. Other environmental factors, like volcanic ash (Lowe et al., 2012), seem also to have played an important role in these movements. As many long sequences of data are now available from Eastern Europe (Balkans, east European plains, Anatolia, and Italy), the Greek peninsula seems a very promising area of research, as it could be a place of possible overlap or succession between AMH dispersal across Europe and the preceding Neanderthal populations. In this paper, a correlation between human cultural evolution (Neanderthal and AMH) and climatic changes will be examined. The research focuses on archaeological and climatic evidence (lithic and fossil human records) on the Hellenic peninsula during the last part of the Middle and the beginning of the Upper Paleolithic period (OIS 4 from 74 to 59 ka BP and OIS 3 from 59 to 25 ka BP).

Methodology

The reconstruction of paleoclimate will be achieved by the study of 5 cores from the Mediterranean and 3 cores from lacustrine basins in Italy and Greece (Geraga et al., 2005; Muller et al., 2011, Tzedakis et al., 2007). The chrono-cultural framework will be based on work by Runnels (1988), Harvati et al., (2009) and Papagianni (2009) (Fig. 1).

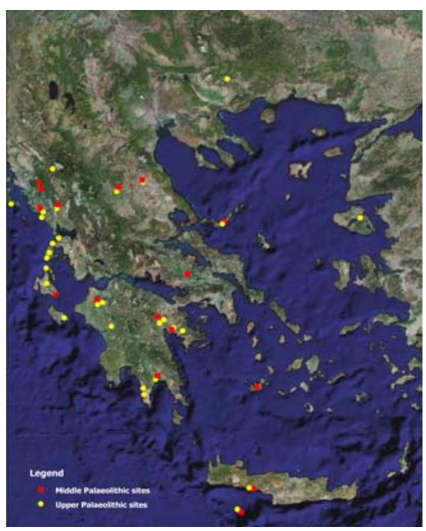

Figure 1. The main Middle and Upper Paleolithic sites on the Hellenic Peninsula.

Results

The paleoclimatic reconstruction shows that during MIS 4 and MIS 3, winter frost conditions were dominant in the Hellenic peninsula, interrupted by mild events: Stadials were characterized by dry steppe environment and interstadials by increased precipitation. The very cold periods around 62 ka BP and

HE5 at 48 ka BP, respectively, seem to have played a role in the future extinction of the Neanderthals. The Campanian Ignimbrite eruption at 40 ka BP during the cold HE4 caused a volcanic winter with the wide spread of ash deposition, but this seems not to have been associated with Neanderthal extinction (Lowe et al., 2012). Finally, the particularly humid period between 55 and 49 ka BP seems to have played an important role in the dispersal of AMH (Muller et al., 2011).

Conclusions

The correlation between archaeological and climatic changes on the Hellenic peninsula during MIS 4 and MIS 3 shows that the transition from Middle to Upper Paleolithic was well correlated with a sequence of stadial (cold) and interstadial (mild) events. This is supported by Muller et al. (2011), who view that "adaptation in abrupt environmental changes was achieved through innovation in both technology and social organization." One can also argue that the Hellenic peninsula's evidence constitutes "a human biological and cultural mosaic in relation to ecological change" as Finlayson and Carrion (2007) point out. Archaeological evidence from the surrounding area, particularly Baco Kiro and Temnata Caves in Bulgaria, Karain, Kanal, and Üçagızlı Caves in Turkey, Grotta del Cavallo in Italy, and the sites of the East European plain, northern Caucasus, and Crimea confirm the above- mentioned picture of prehistoric life in eastern Europe during the establishment of AMHs.

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LATE PLEISTOCENE AND HOLOCENE SEDIMENTS OF T,HE LAZAREVSKY CAPE (CAUCASIAN COAST, BLACK SEA)

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Keywords: Holocene, late Pleistocene, marine sediments, fauna of mollusks, radiocarbon dating

High abrasion shorelines formed by ancient sediments dominate the Caucasian coast of the Black Sea. Low accumulative areas, which are usually associated with the mouths of the relatively large rivers, are extremely rare. One of them is the small Lazarevsky Cape, which adjoins the Psezuapse River mouth. This accumulative form has been created by river and marine-coastal sedimentation. It stretches along the coast for a distance of about 5km, and juts out 0.5km in the direction of the sea relative to the adjacent shores (Arslanov et al., 1977; Izmailov, 1982). In the course of geological work, wells have been drilled up to 50-60m deep along and across the coastline. The most representative profile extends directly along the coast (Fig. 1).

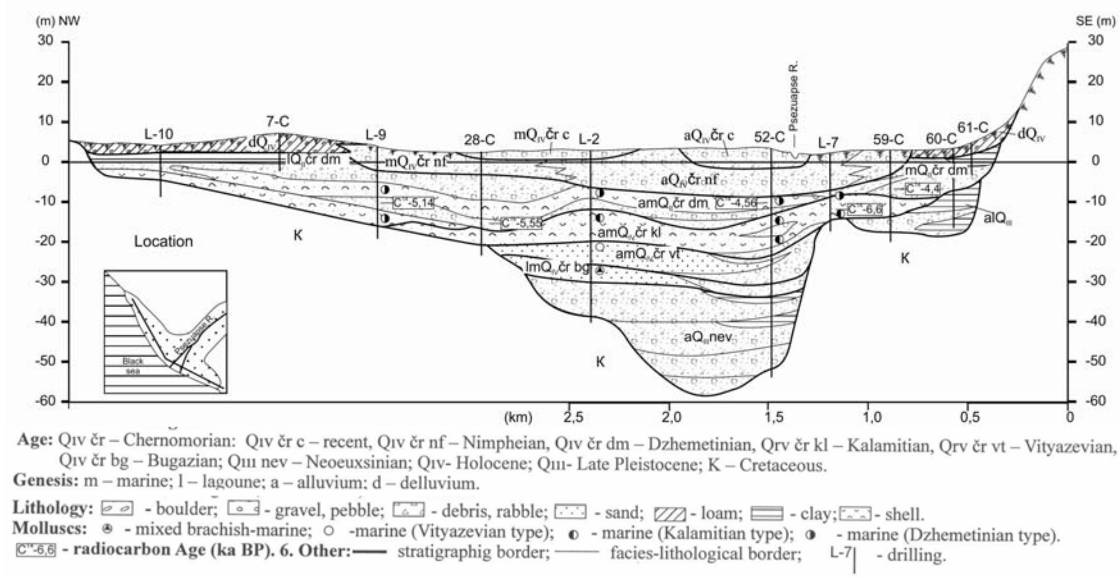

Figure 1. Geological sequence of the Lazarevsky Cape.

Its section has been constructed according to data obtained from 10 wells, the deepest of which is 57 m. 7 out of 10 wells have reached the bedrock, which is represented by Upper Cretaceous flysch. The wells were made by stamping, and thus it was possible to extract the full core. Detailed descriptions of the core, study of the mechanical composition of the sediments, and study of the molluscan fauna at meter intervals (38 tests) have been produced. The material from three of the wells allowed the construction of paleontological diagrams. There are only five radiocarbon dates based on mollusk shells.

Almost all the deposits, which were uncovered along the drilling profile, form a single, clearly defined sedimentary complex, and they are assigned to the last glacial cycle, i.e., the Antian (Neoeuxinian) regression period and the following transgression of the Black Sea. Only at the southeastern end of the profile, in the two wells at 8-18 m bsl , were fragments of older Pleistocene marine sediments found. The maximum depth of the Late Pleistocene-Holocene sediments is 55-58m; the Psezuapse River canyon had incised down to this negative elevation during the regression. The width of the paleo-canyon is 800-1000 m; possibly near the axis of the valley, a narrower recess existed, but it was not observed in the wells.

These complex sediments can be confidently divided into two parts. The lower, Late Pleistocene (Neoeuxinian) part is fully represented by coarse-grained alluvium (boulders and pebbles with gravel-sand filling). An alternation of layers containing coarser and less coarse filler has been observed, and apparently it resulted from fluctuations in river erosion. There are interlayers (up to 2 m) of oxbow clays. The thickness of the lower part of the section reaches 25m. Higher in the section, the alluvial deposits are replaced by more diverse strata from both a lithological and a genetic point of view. There, beach pebbles alternate with coastal-marine sands, as well as with boulder-pebble alluvium interlayers. The total thickness of this part of the section exceeds 30 m. There Bugazian, Vityazevian, Kalamitian, Dzhemetinian, Nymphaean, and modern layers can be identified by the molluscan fauna in the section, as well as by individual radiocarbon dating of the marine sediments.

The Bugazian layers are described at the base of said upper thickness of sediment in the range of -25-33 m bsl. They are characterized by a mixed molluscan fauna: *Corbula mediterranea*, *Cerastoderma glaucum*, *Chione gallina*, *Dreissena rostriformis*, *D. polymorpha*, *Theodoxus pallasi*, and others. The Vityazevian layers have been recovered in different wells at levels minus 20-30 m. In these layers, the above-mentioned semi-freshwater elements almost disappear. The Kalamitian layers (interval minus 8-23 m) are distinguished by the massive expansion of *Chione gallina*, together with *Cerastoderma glaucum*, and *Corbula mediterranea*; there are also *Spisula subtruncata* and others. In well L-7, at the absolute elevation of minus 12.2 m, a date of 6600 ± 120 years (ЛУ-701) was obtained from shell material. The calibrated age is 7490 ± 100 years. The Dzhemetinian layers were highlighted in different wells at the absolute levels of minus 18 to plus 2 m. They were characterized by a maximum diversity of the molluscan fauna. In addition to the above Mediterranean forms, large quantities of *Ostrea edulis*, *Donax venustus*, *D. trunculus*, *Tellina tenuis*, *Divaricella divaricata* and others were sometimes found. The Dzhemetinian layers were characterized by shells yielding the following dates: 5550 ± 380 years (ЛУ-195, 28-C well, - 16.6 m bsl; 5140 ± 90 years (ЛУ-703, L-9 well, -9 m bsl); 4560 ± 160 years (ЛУ-199, 52-C well, - 11.2 m bsl); and 4400 ± 100 years (ЛУ-189, 59-C well, -9.7 m bsl). The calibrated ages respectively are: 6370±430, 5890±110, 5220±220, and 5090±160 years. The Nymphaean and modern marine and alluvial sediments have a total thickness of more than 10m, but they have not been sufficiently studied paleontologically and chronologically because of the weak saturation of shell material.

Paleontological diagrams, as in other areas, point to a gradual increase in the salinity of the Black Sea from the Bugazian to Dzhemetinian layers. However, we noted the unevenness of this process. In the faunal complexes, the rhythmic oscillations are fixed, but there is an overall trend toward increasing diversity upward in the section.

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THE RELATIONSHIP BETWEEN THE HISTORY OF THE ORIGIN OF PALIASTOMI LAKE AND THE FLUCTUATION REGIME OF THE MEAN BLACK SEA LEVEL

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Keywords: geological drilling materials, active hydrological balance

Based on interpretation of a lithological-facies analysis of materials obtained through geological drilling in the area of the Rioni River estuary, an assumption was expressed that the history of the origin and development of Paliastomi Lake (area 1800 km2, maximum depth 3.2 m) located in the same area, was closely related to the Holocene fluctuation regime of mean Black Sea level (Bogolyubova et al., 1989).

The research methodology used to justify such an assumption was based on the following facts:

- Paliastomi Lake is located at a distance of 0.6 km from the coastline,
- The lake surface lies very nearly at sea level or 0.3 meters above sea level,
- The terrestrial surface in the area of the lake is at very low absolute height (no more than 0.1-0.4 m),
- Only silt, clays, and sands are distributed to a depth of 15-20 meters from the terrestrial surface in the area of the lake, and they are characterized by a very weak ability to resist erosion,
- High speed, negative tectonic movements are typical for the area of the lake,
- The lake possesses an active hydrological balance due to excessive atmospheric precipitation within its basin,
- The lake is connected with the sea through the Kaparchina River (Maltakva),
- Peat bogs are located at the northern, eastern, and southern banks of the lake, and the peat has been accumulating constantly over the past 6000 years (Otchet o rezultatakh..., 1978).

At various times, the lake depression was occupied by an embayment of the sea, a lagoon, a freshwater lake, a wetland, and a saline lake. This is evident based on the factors enumerated above as well as facts that have been established by drilling: the order of sediment horizons demonstrates lithological-facies features indicating the presence of a freshwater lake, saline lake, wetland, lagoon, and marine bay at depths of 12-15 m from the bottom of Paliastomi Lake.

If we take into account the location of Paliastomi Lake in close proximity to the coastline, as well as the location of its surface, which is nearly at sea level, and we consider its history of significantly different facies, including lakes and wetlands at different times, we will come to the conclusion that the formation and development of the lake and its active water balance was greatly affected by fluctuations in mean Black Sea level, which was simultaneous in step with the ocean level (Kaplin et al., 1999; Fedorov, 1978; Newman et al., 1980).

The Black Sea level has risen 1-2 meters above its contemporary elevation twice, 4700/5000 years ago and 4200/4000 to 3700/3500 years ago, during the New Black Sea phase of the development of the Black Sea basin (Kaplin et al., 1999; Fedorov, 1978). During these two peaks of the New Black Sea transgression, the Paliastomi Lake depression was occupied first by an embayment of the sea and then by a lagoon. In the second half of the New Black Sea phase, about 4000-3700 years ago, the above-mentioned lagoon was separated from the sea by a newly created line of sandy hillocks along the coast. This gave rise to the development of the freshwater lake. Due to the active hydrological balance of the lake, it was discharging its excessive water through the river running to the sea. About 3500-3700 years ago, during the Black Sea Phanagorian regression, when the Black Sea level dropped by 2 meters on average, the area of the Paliastomi Lake decreased gradually (due to erosion by the Kaparchina River that connected the lake and sea through the coastal hillocks) and the separate sectors became swampy.

In the c. V-IV BC, the wetland stage of development of the Paliastomi Lake depression was transformed into a lacustrine regime, which was caused by the termination of the Black Sea Phanagorian regression and the start of the Nymphaean (Dunkirk) transgression in the next era (Fedorov, 1978).

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THE EVOLUTION OF THE TAMAN PENINSULA: SEA-LEVEL CHANGES, GEOARCHAEOLOGY, AND PALEOGEOGRAPHY

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Keywords: Sea of Azov, Black Sea, Kuban River

Introduction

The Taman Peninsula, situated between the Black Sea and the Sea of Azov, is a sensitive region for sea-level changes, and it plays a key role in the paleogeography of the Bosporan Kingdom. It is the aim of our ongoing project to decipher the paleogeographical and geoarchaeological evolution of the Taman Peninsula in detail with a focus on several key areas and sites (e.g., Taman Liman, Labrys, Krasnaia Oktabr). In addition, these studies represent a valuable contribution to our increasing knowledge about the Greek colonization of the Black Sea region in the 6th century BC.

Methodology

To date, more than 100 vibracorings were carried out on the peninsula, mostly concentrated around ancient Greek settlements and in geoarchives like deltas and spit systems. While preliminary field analyses were conducted, samples were also taken for laboratory studies. There, complementary analyses of micromorphology and microfossil content made it possible to draw conclusions about sedimentary environments. By dating the borders of sediment layers using radiocarbon dating (14-C), a chronostratigraphy was established, reflecting the chronology of facies changes. On the basis of radiocarbon dated sea-level indicators, several local sea-level curves for the past 7,000 years were reconstructed. Finally, the results of the analysis of the geoarchives, with the help of other disciplines like philology and archaeology, allow us to draw new maps of the paleogeography of the Taman Peninsula during the first millennium BC.

Results

As a result of the rapid postglacial sea-level rise, an archipelago was formed in the 6th-5th millennia BC. By then, a second Bosporus, the so-called Kuban Bosporus, had formed in the area of the eastern Taman Peninsula. Later on, when sea-level rise decreased, coastal mechanisms started to form lagoons and large barrier-spit-systems, which can be dated back to the end of the 3rd and the beginning of the 2nd millennium BC (e.g., Kelterbaum et al., 2011).

In several areas (e.g., Golubitskaya, Soleni, and Kuban delta) of the Taman Peninsula as well as on the Kerch Peninsula (Kelterbaum et al., 2012), vibracoring results prove the local sea-level evolution in detail. It is evident that in none of the corings does sea level show major regressional or transgressional cycles (e.g., Brückner et al., 2010; Fouache et al., 2012). In nearly all areas investigated, sea-level rise decelerated around 3000-2000 BC, which led to the formation of lagoons and extended spit and barrier systems all around the peninsula. The detailed results give hints about the local tectonic setting.

Recent results obtained near the easternmost part of the peninsula, ca. 30 km inland at the settlement of Red October (Krasnaia Oktabr) prove the existence of a marine gulf reaching far into the hinterland. This provides evidence of the most inland penetration of Greek colonies in the area of the Sea of Azov and the Black Sea.

Conclusions

There are several main conclusions of the study: (i) During the 6th-5th millennia BC, the Taman Peninsula was an archipelago of four islands; (ii) sea-level changes in the Black Sea do not show any signs of repeated trans- or regressive cycles, only a gradual sea-level rise is detectable, and this is also supported by local tectonics; (iii) a rapid delta growth of the Kuban river since the 1st millennium BC can be proven; (iv) the Greek colonies founded during the 6th century BC around the former Kuban Bosporus had several strategic functions: controlling and surveillance, representation, fortification, and trading. For them the Kuban Bosporus was a major waterway at least until the 4th-5th century AD, when it was cut off by the prograding delta front of the Kuban River.

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HOLOCENE MOLLUSKS OF THE IRANIAN CASPIAN COAST AND THEIR STRATIGRAPHIC IMPORTANCE

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Keywords: Caspian Sea, Iranian coast, Holocene deposits, mollusks, biostratigraphy

Introduction

The Iranian coast of the Caspian Sea is part of the South Caspian Depression, which represents a spacious plain with a subtropical climate bordered to the south by the Elburz mountain system. Its western, central, and eastern parts bear different names: Gilan, Mazandaran, and Golestan plains, respectively. In structural terms, this region represents the Elburz foredeep filled with a thick sequence of Neogene-Quaternary sediments and separated from the Elburz fold system by a deep seated regional fault. During recent years, the structure and developmental history of the Iranian coast have been investigated, and many available publications are dedicated to particular geological aspects. Mollusks from Recent deposits of the Iranian coast, unlike those from other parts of the Caspian coast, remain practically unstudied. Some data on the taxonomic composition of the mollusks from Holocene sediments are listed in the work of E. Ehlers (1971), and in A.A. Svitoch and T.A. Yanina (2006). Systematic descriptions with illustrations of described species were not given, however. The present work partially fills this gap.

Material and methods

The materials discussed in this communication were obtained on the Iranian coast of the Caspian Sea in 2005 in the course of field excursions during the International Scientific Conference “Rapid Sea-level change: Caspian perspective” held in Resht as well as field studies undertaken in 2011 on the Iranian coast. Field study included comprehensive investigation of the Holocene sections. The range of applied methods included: geomorphological, lithologic-facies, malacological, and geochronological analyses. The data thus obtained were used as a basis for interpreting the sediment stratification. Special emphasis was placed on the study of Holocene malacological fauna, including the study of the taxonomy, taphonomy, biostratigraphic distribution, and development of fauna over time. As a result, an extensive collection of mollusk shells was assembled, which was systematically studied in the laboratory setting.

Results

Holocene deposits are rich in fossil material and have a wide distribution on the Iranian coast. Eleven species of mollusk were distinguished (Table 1). Much of the malacological fauna is represented by the family Cardiidae, with the most abundant genera being Didacna Eichw. and Cerastoderma Poli. The former represents the endemic index species for the Caspian Pleistocene. The second is an invader from the Black Sea, a euryhaline species of Mediterranean origin, which settled in the Caspian during the New Caspian epoch of the Holocene. New Caspian mollusk assemblages are distinguished from the isochronous assemblages along other parts of the Caspian coast by the predominance of crassoidal Didacna and low numbers of brackish-water species, co-occurring with Cerastoderma glaucum. The species cited in the Table form the New Caspian molluscan fauna. The analysis of their bed by bed distribution through the section shows that they form three assemblages: Dagestanian, New Caspian, and Recent. The New Caspian assemblage is represented by two subassemblages, which occupy different stratigraphic positions in the section. The different compositions and different rank assemblages combined with complex data on sediment lithology provide the basis for stratigraphic subdivision of sections (Table). The New Caspian horizon consists of Mangyshlakian (without mollusks on the Iranian coast), Dagestanian, New Caspian, and Recent beds; New Caspian beds consist of lower and upper New Caspian layers.

Table 1. Holocene mollusks of the Iranian Caspian coast and their stratigraphic position

Stratigraphic unit / Mollusks	New Caspian horizon			
	Dagestanian beds	New Caspian beds		Recent beds
		Lower New Caspian layers (−24…−20 m)	Upper New Caspian layers (−24…−25 m)	
Didacna crassa				
D. trigonoides				
D. pyramidata				
D. praetrigonoides				
D. cristata				
Monodacna caspia				
Adacna vitrea				
A. laeviuscula				
Cerastoderma glaucum				
Mytilaster lineatus				
Dreissena polymorpha				
Assemblages	*Didacna cristata*	*Cerastoderma - Didacna*		*Mytilaster-Cerastoderma*
Subassemblages		*Didacna - Dreissena*	*Cerastoderma - Didacna cristata*	

1 4

1 –abundant mollusks, 2 – many mollusks, 3 – rare mollusks, 4 – single mollusks

The Mangyshlakian beds, which reflect a significant Caspian Sea regression, are widespread on the Iranian coast and constitute the surficial part of the maritime plain section (upper 0 to –20 m). With respect to their lithological–facies composition, these sediments are dominated by coarse-detrital alluvial and alluvial-proluvial varieties, which fill buried river valleys and form spacious fans overlying the terraced surface of the late Khvalynian plain. Noteworthy are frequent finds of large differently rounded boulders of Elburz bedrock. The subordinate role belongs to loess-like and aeolian facies and buried soils.

The Dagestanian beds of the section are conditionally defined proceeding from their occurrence at the base of the marine Novocaspian sediments and the lack of *Cerastoderma glaucum.* They are represented by gray-lilac sands with whole *Didacna cristata* shells, which grade laterally into compact caked plant remains overlying Mangyshlakian boulder gravel with pebbles.

Lower New Caspian layers are found at hypsometric levels of -24 to -20. They represent a low plain with weakly developed terraces, outcropping in places, where there are no younger alluvial-proluvium and deluvium accumulations. On the coast of Gilan, lower New Caspian deposits build the major part of the spits, separating the Anzali and Amirkelayeh lagoons. In the more complete sections, deposits have a wide variety of lithological and faunal composition. Thus, the reference section of the Iranian Holocene on the left flank of the Khavig estuary is characterized by an increase in mollusk abundance and diversity in the lower layers, and by the absence of shells of *Cerastoderma* at the base. Among lower New

Caspian layers, coarse clastic lithofacies and lagoon sediments are common. They also contain diverse fauna with a predominance of *Cerastoderma*, rarer *Didacna*, and single *Monodacna caspia* and *Adacna.*

Upper New Caspian layers are found in the coastal part on the seaside plain at absolute levels of −24…−25 m, where they build a low marine terrace, made up by a series of beach ridges, well expressed in the relief. Upper New Caspian deposits have a rather complex structure, established as a result of the study of the rear part of the spit, which separates Anzali Lagoon from the sea (Svitoch and Yanina, 2006). Exposed in the section, the rear side of the spit comprises sediments of three accumulation cycles. Upper and lower layers represent shallow water marine formations, based on the faunal composition. It had the normal Caspian Sea salinity of 12–14‰, separated by freshened lagoon sediments with periodic salinization and drying out (traces of soil formation). Structure and composition of the upper part of the New Caspian beds, forming low beach ridges, is less complex. These are poorly sorted sands, with a predominance of well sorted fine-grained varieties, often finely laminated, where lamination is caused by the interlayers of coarse-grained sand, gravel, and fine well-rounded pebbles. In sediments, along with abundant detritus there are whole mollusk shells, among which *Cerastoderma glaucum* predominates. In more complete sections, in the lower parts there are often lagoonal sediments—silty aleurite and grey silty sands with *Cerastoderma glaucum*. In the upper part, sediments underwent weathering. Visible thickness of the upper part of the New Caspian sediments does not exceed 1.5-2.0 m. Fauna from the beach ridges has the lowest diversity, apart from *Cerastoderma*, only *Didacna cristata* is found in noticeable quantities.

Recent beds comprise marine sediments of the low seaside regressive terrace formed between 1929 and 1977 as a result of Caspian sea-level drop, such as beach sediments, estuarine and flood plain alluvial sediments, aeolian, and soil accumulations. The major part of the recent sediment is characterized by variability in lithology and facies composition, and constantly changing accumulation environments. Beach sediments of the modern subassemblage contain abundant and diverse fauna, with *Mytilaster lineatus*, which is not found in older sediments.

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CASPIAN RAPID SEA-LEVEL IMPACT ON THE TEMPORAL AND SPATIAL VARIATION IN GASTROPODS

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Keywords: Caspian Sea, fluctuation, gastropod, Miankaleh

Introduction

Generally, fluctuations in oceans and seas play a major role in the deformation and displacement of shorelines all over the world. Climatologic, tectonic, geologic, and anthropogenic impacts cause these changes in coastal areas (Khoshravan, 2007). The Caspian Sea is largest closed basin in the world, and it has demonstrated a regular cycle of sea-level change between 1930–1996, with a 3 meter variation in water table elevation (Ghanghermeh and Malek, 2005). During the above mentioned interval, several sedimentary basins were affected, and the mouths of rivers, lagoons, gulfs, islands, and channel inlets were modified by Caspian rapid sea-level changes. In this period, chemical properties of the water and substrate sedimentation conditions of the subsedimentary environments were deformed, causing temporal and spatial changes in faunal and floral distribution (Rychagov and Mamedov, 1994). In this research, our attention has been focused on the problem of gastropod species recognition and their frequency and distribution across the region of Miankaleh. We also examine the relationship of bio-indicators to rapid sea-level changes of the Caspian Sea. Measurement of water quality in subsedimentary environments and the sedimentary composition of gastropod habitats were the most effective approaches in obtaining a final conclusion.

The main goals of this research are the determination of the localized frequency distribution of gastropod species in several sedimentary environments of area of Miankaleh and their temporal and spatial variation due to the impact of rapid sea-level changes in the Caspian Sea. Eight transects were selected for measurements along the study area, and from them, 24 sediment samples and 8 water samples were recovered for analysis of biofacies and chemical properties. In addition, the degree of Caspian shoreline deformation and displacement over the course of 38 years was evaluated by remote sensing and GIS modeling. The principal results show that the most important gastropod species include: 10 species associated with 3 genera and 2 families of the Prosobranchia. The correlation of gastropod species distribution with shoreline displacement in the GIS modeling indicates greater variation in the central and eastern part of Miankaleh.

Methods

First, the study area was chosen because of its morphology and geology. Using satellite and aerial image interpretation, 8 transects were selected along the Miankaleh spit. In total, 24 sediment samples and 8 water samples were taken from different parts of the study area that correspond with several subsedimentary environments. Gastropod species were identified microscopically (Moore, 1969). Then, using the calculating method in the GIS software, the amount of displacement in the Caspian Sea shoreline was measured over the 38 year interval (1966- 2004) in the different parts of the study area. Correlating the map of gastropod distribution with vector data for shoreline displacement in Arc-GIS software, the temporal and spatial variation in gastropod bio-indicators was measured against rapid sea-level changes of the Caspian Sea.

Results

Gastropod species

Ten species belonging to three gastropod genera have been identified through microscopy. Among them, the predominant genera are *Pygohydrobia* sp. (72%), *Caspiella* sp. (22%), and *Theodoxus* sp. (6%).

Statistical study of gastropod accumulation and distribution in different parts of the study area showed that there are many index bio-indicators in the subsedimentary environments, such as the Caspian beach zone, Miankaleh lagoon, Khozeini channel, the saline wetland, and Gorgan Gulf (Table 1).

Table 1. Gastropod bio-indicators for subsedimentary environments

Name of Species	Relative frequency %	Sedimentary environments
Theodoxus pallasi	10	Khozeini channel, Gorgan Gulf
Pygohydrobia gemmata	90	Lagoon and Sea (transition Zone)
Pygohydrobia oviformis	30	Beach
Pygohydrobia eichwaldi	30	Lagoon and Gulf
Pygohydrobia gemmata, P. eichwaldi	50	Saline wetland

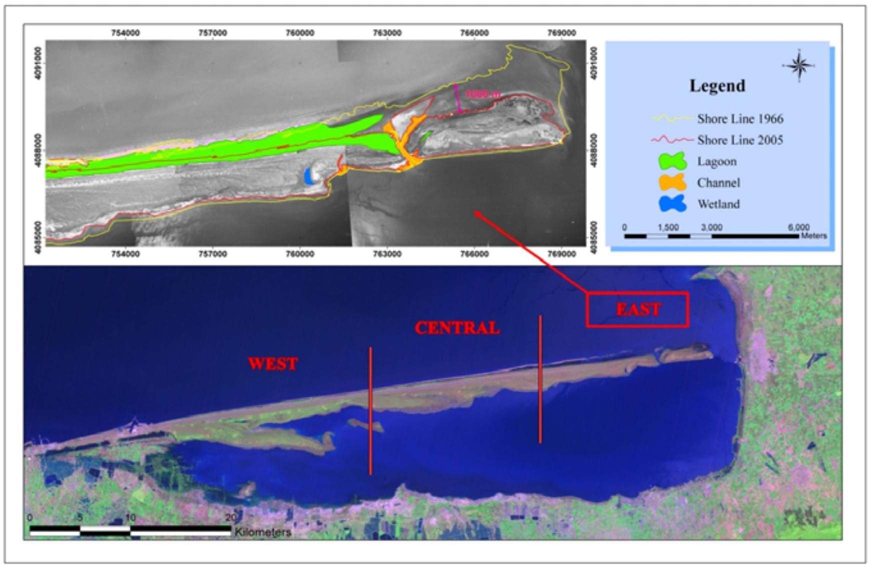

Figure 1. Caspian rapid sea-level changes and shoreline displacement between 1966-2004.

Shoreline displacement rate

Comparison between periodic aerial images of the study area during the 38 years between 1966 and 2004 indicated different shoreline displacement responses in the various parts of study area (fig. 1). The greatest displacement of shoreline has been observed in the eastern end of the Miankaleh sand barrier, parallel to the Caspian Sea about 1000 meters (fig. 1). Other parts of the study area show low shoreline displacement, evaluated to be about 50 to 70 meters. In the eastern part of Miankaleh, more than 80 sq km have been flooded by the last progression of the Caspian Sea (1978-1995). The rate of shoreline displacement along the Gorgan Gulf is low. It is similar to the western part of the Caspian shoreline within the study area.

Conclusion

The most important conclusion produced by this recent research is as follows. Areas vulnerable to high flooding were located near the northeastern side of Miankaleh territory. The Caspian Sea's last progression caused real variation in sedimentary environments, particularly in the Miankaleh lagoon, Khozeini channel, and saline wetland. Five bio-indicator groups of gastropods have been distinguished in the study area. Temporal and spatial variations of index gastropods have been developed in the eastern part of the study area near the Caspian shoreline. The most saline basins were located in the wetlands near the eastern side of the Gorgan Gulf and in the central part of Miankaleh lagoon.

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MODIFIED COASTAL SHORELINE DURING THE HOLOCENE ALONG THE NORTHERN MARMARA, TURKEY: TWO EXAMPLES OF SUBMERGED SETTLEMENT OF BYZANTINE TIMES

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Keywords: Coastal modification, North Anatolian Fault Zone, Istanbul, Prince Islands, K. Çekmece Lake, Byzantine settlements

Complex tectonic structures are observed along the northern coast of Istanbul, extensively modifying the Neogene sequence of the Marmara region (e.g., Koral and Şen, 1995; Barka, 1988). These Neogene units were folded and faulted by neotectonic events, some of which are apparently linked to the North Anatolian Fault Zone (NAFZ). Two submerged sites of ancient settlement provide evidence for parameters influencing the coastal changes along the northern Marmara region (Fig. 1).

A small island named 'Vordonisi' is one the Prince Islands, located 4 km south of the Asian coast of the city of Istanbul in the Marmara Sea. The Prince Islands comprise nine closely spaced islands with unique geological features: five large ones and four rather small rocky masses above sea level (Isbil, 2012). 'Vordonisi' is said to have supported a monastery during Byzantine times, circa 850 AD, which now lies submerged under several meters of water Meriç, 2010).

Likewise, "Bathonea" is named after an ancient settlement that existed on the Lake of Küçük Çekmece through the 3rd-12th centuries. The Küçük Çekmece Lake is a lagoon situated inland on the northern coast of the Marmara Sea. Parts of this settlement and its mole now lie under the water level of the lake. Both sites are either near the NAFZ or its secondary branches.

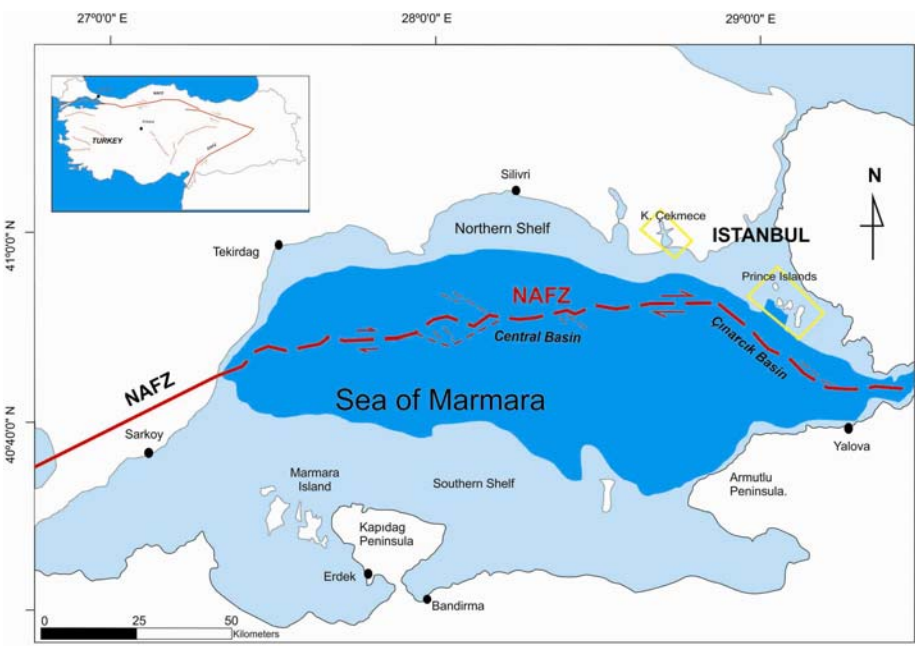

Figure 1. Locations of investigation near Istanbul, Turkey.

The northern Marmara region has been affected by strong historical earthquakes, especially by those of 989, 1509, 1766, and 1894, whose epicenters are considered to have been close by, in addition to events dating to 861, 869, 1011, 1032, 1063, 1296, 1332, 1346, 1419, 1542, and 1556 AD (Ambraseys and Finkel, 1987, 1991). Therefore, coastal changes observed along the fault line during the August 1999 Golcuk (Izmit) (Mw=7.46) and Kaynaşlı (Mw=7.2) events (e.g., Barka, 1999; Herece, 1999; Öztürk, et al., 2000; Koral, 2007) make it plausible to relate the submergence of these Byzantine settlements to seismic activity along the NAFZ.

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ON THE QUESTION OF THE TWO TECHNOCOMPLEXES OF THE LOWER PALEOLITHIC IN THE TISZA-DANUBE BASIN

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The Lower Paleolithic is dated from 2 million to 300 thousand years ago. For this period, two types of industries are characterictic: Mode 1 (technocomplex without handaxes) and Mode 2 (technocomplex with handaxes). From the viewpoint of tool size, the industries can be divided into micro (length <5 cm) and macro (length >5 cm) (Valoch, 1977; Gladilin and Sitlivyi, 1990).

There are two stratified Lower Paleolithic sites in the Tisza-Danube basin: Vértesszöllös (Hungary) and Korolevo I (AH VII and VI) (Transcarpathia, Ukraine).

The **Vértesszöllös** site is located in the small Ataler River valley within travertine deposits. Across the two sectors of the site, 4 levels were found that contain lithic industries, fireplaces, bones, and anthropological finds. The latest remains belong to *Homo erectus*. Artifacts were made from small quartzite, flint, and quartz pebbles. The tool-kit is represented by pebble-tools (choppers), handaxes, bifacially retouched tools, denticulates, flakes with non-regular retouch, etc. The site is dated from 600,000 to 350,000 years ago (Kretzoi and Dobosi, 1990).

The **Korolevo** Paleolithic site is located on two terraces: "Gostry Verkh" (120 m) and "Beyvar" (100 m) of the right bank of the Tisza River. In the main geological profile (12 m) 7 paleosols are distinguished (K-III through K-IX) (Fig. 2 in Haesaerts and Kulakovska, 2006). In the sequence of 10 archaeological levels, the two lowest ones were determined as Lower Paleolithic (Kulakovska, 2001; Kulakovska and Usik, 2011). It should be stressed that in Transcarpathian sediments, there are no organic finds.

AH VII was found in a small pebble alluvium layer under the Brunhes-Matuyama boundary (MIS 23/25). At this time, a forest of temperate type with *Ulmus, Carpinus*, and *Picea* was widespread. For artifact production, the local volcanic raw material andesite—vitrophyric dacite (Rácz, 2013)—quartz and quartzite were used. The main *in situ* collection of Level VII (33 artifacts) originated from sector "Gostry Verkh" and excavation area XIII and included cores, flakes, choppers, and a fragment of a bifacial tool. Primary flaking was represented by simple unidirectional, parallel, and kombewa methods. Additionally, one artifact can be determined as a polyhedron, which is probably a result of the method of core reduction "without hammer." This industry belongs to the so-called Mode I (Fig. 1 B) (Kulakovska et al., 2010).

Cultural Level VI was found in the upper part of the inter-Mindel paleosol K-VII (after P. Haesaerts and Kulakovskaya, 2006) and dated around 550,000 years ago. The paleolandscape matches periglacial forest-steppe. The lithic collection ("Bayvar," excavation area IX) contains more than 5000 pieces. Apart from the main raw material (andesite = vitrophyric dacite), quartzite, quartz, flint, and slate were also used for reduction. The primary flaking is characterized by exploitation of simple unidirectional, parallel, and rare radial methods. Polyhedral artifacts are present, too. In the tool-kit, the following tool-types are present: simple, transversal, and diagonal scrapers with steep retouch; denticulates, etc. A few samples with bifacial retouch by shape and the style of treatment are qute similar to the "Keilmesser" of the Micoquian technocomplex. The industry of Level VI can be attributed to Mode 1 also (Kulakovska et al., 2010) (Fig. 1 A).

The new investigations of Lower Paleolithic stratified sites and detailed analyses of lithic industries have provided evidence for some adjustments to the established understanding of this period. The typology of Lower Paleolithic industries has demonstrated wide variability and a quite "developed" level of tool manufacture, which may change opinions about expected "archaisms" (Derevianko, 2009). The tool collection of Level VI at the Korolevo site supports this opinion.

In contradistinction to typology, the primary flaking demonstrated monotonic examples of reduction and simple technology. In this context, it possible to talk about reduction "without hammer," and simple unidirectional and parallel exploitation of cores with flat working surfaces. The technology of centripetal reduction of non-Levallois flat cores has not developed yet (Kulakovska and Usik, 2010).

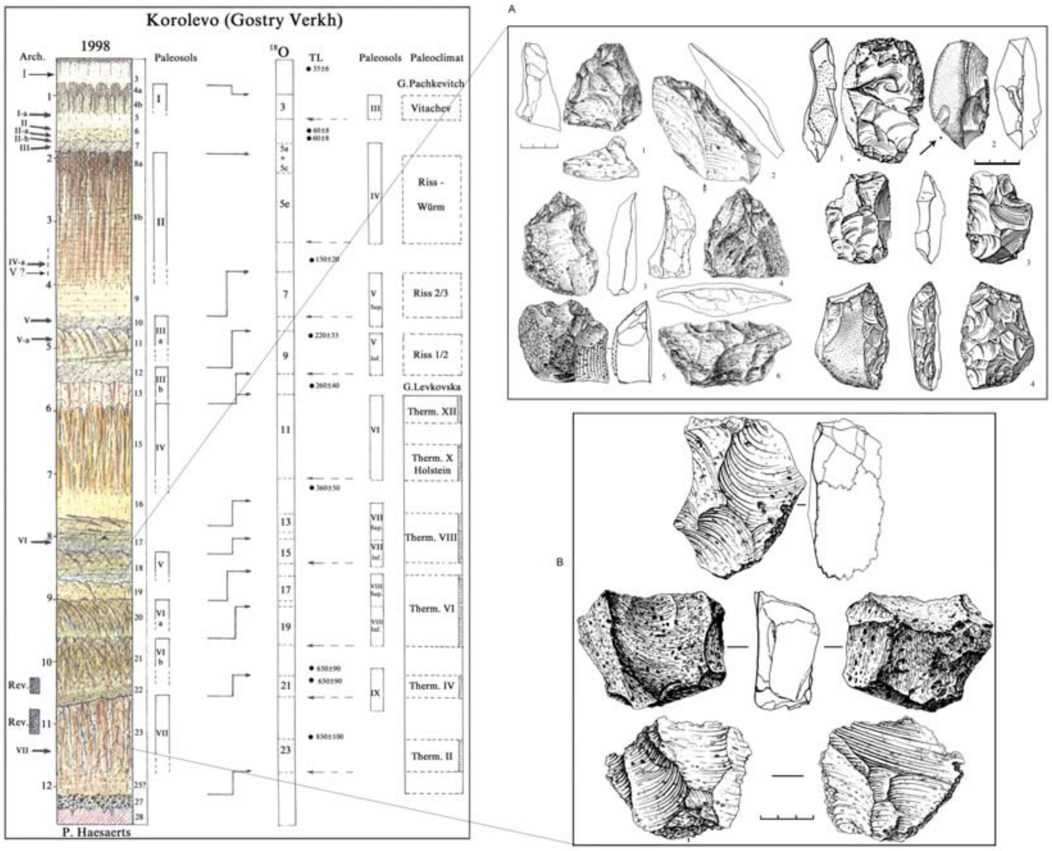

Figure 1. Korolevo. Stratigraphy. A: AH VI; B: AH VII.

For the Middle Paleolithic, the methods of primary flaking are more variable and technologically more complex. The appearence of Levallois methods can be noted, widespread centripetal methods, parallel and convergent methods, and other variants.

Thus, the first traces of the presence of humans for the time of MIS 23/25 in the Tisza-Danube basin are marked by the Mode 1 type industry of the AH VII Korolevo I site. The next wave of human occupation (600-500 ka BP) is represented by the Vértesszöllös micro-industry of Mode 2 and the Mode 1 industry of the AH VI Korolevo I site.

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SEARCHING FOR THE GOLDEN FLEECE – A GEOARCHAEOLOGICAL PROJECT IN THE RIONI DELTAPLAIN

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Keywords: Black Sea, Georgia, paleogeography

Introduction

A new research project has started concerning the paleogeography of the Georgian Black Sea coastline. The main tasks of the project are (i) to reconstruct the landscape of the Rioni deltaplain and several other coastal areas in western Georgia by means of geoscientific methods, and (ii) to trace back the human impact on the landscape evolution and the human adaptation to those changing landscapes. The study area comprises the lower Rioni River in the north, the Pichvnari plain north of Batumi, and further to the south the Roman fortress of Gonio. The evolution of the landscape will be reconstructed with special focus on potential harbor sites.

Methodology and Goals

To solve these tasks, we will use several methods. Essential are vibracore drillings with open and closed tubes in the different geoarchives; OSL-dating will be carried out on the large beach barrier of Poti; 14-C age estimates of organic matter from the cores will clarify the chronostratigraphy of the sedimentological processes; palynological analyses on the peat bogs of the Rioni plain will be done to get a better impression of the landscape evolution in space and time (see also Connor et al., 2007; de Klerk et al., 2009). Moreover, possible sites of the not yet discovered Greek and Roman city of Phasis should be identified by comparing philological with geoscientific data. In addition, this study will try to estimate the past and recent human impact on the sediment balance in the Rioni plain. Since Georgia is a country with a long history, signals of early agricultural and mining activities may be traced in the sediments (XRF scans, ICP-MS; see also Narimanidze and Brückner, 1999). Another aspect is reconstruction of the sea-level curve for the Georgian coastline, which will lead as well to a better understanding of coastal evolution.

First Results

Two OSL-dates for the sand barrier system of Poti gave a first age estimate for the evolution of this extended coastal system. The ages were produced on the contact zone between the barrier sediments and overlying dunes, which evolved on this barrier after its rise above sea level. The two dunes can be dated back to around 1,500 BP; thus, the sand barrier that cuts off the lagoon from the Black Sea, must have evolved much earlier. The Rioni drained into the lagoon, then broke through the sand barrier and has since built its new delta out into the Black Sea.

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FORCING FACTORS ON CASPIAN SEA LEVEL CHANGES IN THE LATE PLEISTOCENE AND EARLY HOLOCENE: CONTRIBUTION FROM PALYNOLOGY

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Keywords: Younger Dryas, Holocene, Caspian Sea, water level, climate, vegetation, hydrology

Introduction

Three Late Pleistocene and Holocene sequences from the south (a deep sea one and a coastal one) and the middle (a deep-sea one) basins of the Caspian Sea (CS) have been studied for their palynological contents in order to reconstruct past vegetation (hence climate) and past water salinities (hence water levels). The aim of this project is to obtain the first complete paleoclimatic sequence from the Allerød to the present.

Methodology

The coastal core (27.5 m) was taken by drilling. The marine cores (10 m) were taken by Kullenberg and piston cores. Palynology (pollen, dinocysts and NPPs) was used to reconstruct past environments. Dating was obtained by the radiocarbon method. The ages were corrected for the amount of detrital if bulk, but when possible the ages were obtained on shells and on organic matter. Then everything was calibrated with marine corrections if adequate only. Each sequence followed a different approach (Leroy et al., 2007, 2013 a, b)

Results

It has been established that the Younger Dryas is well marked by a regional aridification of the climate, but sea level remained high and was still part of the Khvalynian highstand.

The Mangyshlak lowstand in the Early Holocene is characterized by the most brackish waters of the whole south basin deep sequence and a hiatus in the coastal one. No specific vegetation changes are observed. It is suggested that this water level lowering was due to a starvation of water inflow to the CS in response to hydrographic modifications of the main rivers (the Volga River and the Amu Darya) under a climate that remained still very dry at the beginning of the Holocene.

The development of trees was delayed in the deep-sea cores and occurred not until 8.3 cal. ka BP, but hardly any delay was noticed in the coastal one that is located at the foot of the Elburz Mountains which were a refugium during glacial times.

The freshest waters are inferred between 8.3 and ≤4.0 cal. ka BP, linked to a connection of the CS with the Amu Darya, which was fed by the melting of glaciers on the Pamir Mountains.

A sharp drop of water level is finally reconstructed at 3.9 cal. ka BP, before the start of the Neocaspian intermediate water levels.

Conclusions

At present the CS levels are mainly forced by the summer precipitation on the Volga drainage basin. In the past, the drainage basin of the Amu Darya (flowing from the Pamir Mountains) must be considered to understand the CS hydrological budgets. Sea levels have changed at times very rapidly; and humans had to adapt to this.

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CHOCOLATE CLAYS OF THE NORTHERN CASPIAN SEA REGION: DISTRIBUTION, STRUCTURE, AND ORIGIN

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Keywords: Northern Caspian Sea, late Pleistocene, Khvalynian transgression, chocolate clays

Chocolate clays represent one of the most common facies of the Lower Khvalynian sediments of the Northern Caspian Sea and Lower-Middle Volga Region. After more than a hundred years of research, there are still a number of unresolved issues related to the conditions of their bedding, facies structure, and color blending.

Chocolate clays are confined solely to negative landforms of the pre-Khvalynian surface: terraces, paleo incisions, junctions of large tributaries in river valleys, paleoravines of various forms and origins, estuaries, saline-dome depressions (Elton, Baskunchak), and ancient deflation depressions at watersheds in Kalmykiya. Following the general north-south inclination of the Lower Volga and Northern Caspian Sea region, the top surface of chocolate clays generally decreases in the same direction. The highest elevation of this surface in the Caspian depression is usually recorded at +20 to 25 m. To the north, within the Volga River valley, it rises to 35 m and more.

There are two patterns of occurrence for chocolate clays: continuous and intermittent (mosaic). Continuous distribution prevails in the Volga River valley and ancient estuaries and junctions of the Volga's major tributaries: Bol'shoi and Malyi Irgiz, Bol'shoi and Malyi Karaman, Torgun.

Depending on their facies composition, chocolate clays are divided into subfacies: clayey, stratified, sandy-clayey, and silty-clayey. The most common clayey subfacies is a massive unstratified or hidden-stratified dark chocolate brown clay with large block jointing, sometimes intercalating with lighter silty varieties.

The most characteristic feature of chocolate clays is their color, which is produced by different causes. One of them is the provenance of the fine material. There are vast fields of brown-colored moraines related to the Dnieper and Moscow glaciations and Permo-Triassic red terraines in the watershed area of the Ural and Volga rivers.

Molluscan fauna do not appear within chocolate clays, it is always strictly dated for one of sandier pro-layers. The fauna can be represented by the halobionts and the deep-water mollusks (Didacna protracta submedia), and by poorly brackish water groups from Monodacna and Dreissena. Mostly the fauna was rather poor fauna consisted from Didacnas of "trigonoides" and "catillus" groups (D. parallella, D. protracta, D. ebersini), from numerous slightly brackish water mollusks of the genera Monodacna, Adacna, and Dreissena. Absence of malacofauna in chocolate clays, obviously, testifies to a high sedimentation rate and a muddiness of the basin under which conditions the life of benthos would be limited.

The stage of the Khvalynian transgression that deposited chocolate clays was developed in cold (glacial) climatic conditions. Testifying to this are the lithological features of the clays, signs of permafrost (wedges, cryoturbation), data from the palynological analysis (forest-tundra ranges, ac-cording to Moskvitin, 1962), and the small sizes and the thin shells of the mollusks. According to 20 radiocarbon dates, it was the epoch of the late Valdai glaciations of the East European Plain and their degradation. Ages of 11040 to 13030 years ago were determined; their calendar values are calculated in the range from 12860 to 16270 years ago. The dates were obtained from mollusk samples from the sandy pro-layers, having different positions within the thickness of the chocolate clays. Probably, the lithological features of chocolate clays were caused by plentiful input of thin light material from a periglacial environment, under conditions of glacial degradation and perma-frost thawing.

Despite the number of hypotheses that have been proposed, the origin of chocolate clays remains largely unknown. Why did chocolate-like clays not form during other Caspian Sea transgressions of the same scale, same provenance area (moraines, Permo-Triassic red terraines), and relatively similar climatic conditions as the Khvalynian? It is possible that the origin of chocolate clays relates to specific environmental and hydrological developments within the area during the Khvalynian epoch.

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POLLEN-DERIVED BIOMES IN THE CASPIAN-BLACK SEA-MEDITERRANEAN CORRIDOR IN RELATION TO CLIMATE AND VEGETATION

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Keywords: palynology, paleohydrology, biomization, Holocene, climate models

Objectives

An international collaboration was undertaken to obtain a uniform, objectively-based, pollen-derived biomization of modern vegetation throughout the Caspian-Black Sea-Mediterranean Corridor and to apply the results to a reconstruction of past vegetation patterns. We first evaluate how well present-day surface pollen samples reflect modern potential (= “natural”, pre-land clearance) vegetation data obtained from maps and GIS land-cover data. We then examine the potential of the biomization techniques for reconstructing the vegetation patterns throughout the Caspian, Pontic, and Northeastern Mediterranean regions, using for the application, the time-slice 9000−8000 cal yr BP when the Mediterranean and Black Seas were first reconnected in the early Holocene.

Background

The Caspian-Black Sea-Mediterranean Corridor covers a vast territory stretching over 2000 km between latitudes 28^o and 48°N and from the eastern Mediterranean to the Caspian Seas, between 22^o and 62°E. This region of mountains, plains, and inland seas is characterized by a high diversity of environmental conditions and a mosaic of vegetation types which are determined by specific interactions between subregional climate, geography, and floristic affinities. This region of huge diversity is the background setting for studies of human history because it is located at the crossroads of migrating human populations and cultural exchange between Europe and Asia, in both modern and prehistoric times. This vast region has been subject to periodic megafloods associated with the waxing and waning of Siberian and European ice sheets. In determining the potential size of the megaflood events, quantification of regional hydrological budgets has been attempted (e.g., Chepalygya 2007; Hiscott et al., 2007). A required component of these hydrological budgets is the amount of precipitation and/or soil water; this value is usually based on pollen-derived estimates of vegetation type. However, past estimates for postulated flood events at 16−14 ka, 9−8 and 8−7 cal ka used a relatively sparse pollen database not covering the whole region and not uniformly related to paleoclimatological parameters, e.g., mean temperature of the coldest or warmest month, growing degree days, and precipitation to evaporation (P-E) ratios. The IGCP521 WG2 collaboration has allowed the expansion of the pollen database to cover the entire region and to standardize the data to one set of modern vegetation, enabling more reliable estimates of past vegetation and climate parameters as reconstructed from pollen assemblages.

Methods

We apply the biomization approach of Prentice et al. (2000) to 1264 modern pollen samples from the region to reconstruct the distribution of 22 broad vegetation categories (= biomes). This biomization method is a thoroughly tested approach to regional-scale vegetation and quantitative climate reconstruction, and it was used for the collaborative palynology project within the IGCP521 program and the EMBSeCBIO (an acronym for **E**astern **M**editerranean-**B**lack **S**ea-**C**aspian **B**iomes), which established an extensive dataset of modern pollen assemblages from surface samples and pollen traps in addition to a large set of fossil pollen data (Cordova et al., 2009). In the present study, the dataset of surface samples further includes averaged data of 5 years (minimum) of pollen trap data, and core tops of the EMBSeCBIO pollen database. This large database is used to estimate how the potential natural vegetation (i.e., prior to recent land clearance) and current vegetation types are (1) reflected in pollen assemblages, and (2) how these pollen assemblages correspond to macroclimatic conditions within the study region. The accuracy of the results is assessed using two maps of potential vegetation: *Physico-Geographic Atlas of the World* (FGAM) and the European Vegetation Map (EVM). To further test if the accuracy of the reconstructions is significantly affected by local-scale land use, the reconstructed biomes are also compared with land-cover data derived from pollen data in the Global Land Cover dataset (GLC2000: Giri et al., 2005). After these evaluations, the biomization scheme is applied to fossil records from sediment records at 50 locations throughout the study region for the time interval measured by radiocarbon ages as between 9000–8000 cal yr BP.

Results

The biomization scheme yields good reconstructions of the broad-scale patterns of vegetation in the Caspian-Black Sea-Mediterranean Corridor, with 78% of all samples matching the potential vegetation according to the EVM. Furthermore, if we exclude sites where forest biomes are reconstructed in areas of open vegetation (e.g., high-mountain areas, alluvial plains, or azonal vegetation), then the sample matches increase to 89%. This level of predictability is higher than that previously obtained for limited regions within the whole study area (e.g., Tarasov et al., 2000), and it is sufficient to warrant applying the technique to reconstruct past vegetation patterns. We also establish that biomes inferred for surface samples from cultivated areas provide good matches with the distance-weighted land-cover from the surrounding 50 km in 80% of the test cases. This further indicates that the biomization procedure provides a reliable estimate of vegetation when considered at a large-enough spatial scale, even where agricultural use is now widespread.

The large pollen data base and the quantitative biomization methods we have used provide major refinements of vegetation reconstructions for the Caspian-Black Sea-Mediterranean Corridor in the early Holocene, 9000–8000 cal ka BP (Fig. 1).

For this time slice, change is driven primarily by inflow of Mediterranean Sea water rather than by freshwater flooding from inter-linked Caspian-Pontic basin watersheds during early deglaciation. Marine geology evidence suggests that the lake was full and overflowed into the Marmara Sea through the Bosphorus Strait before 13 cal ka. The catastrophic flood model requires that the lake level subsequently dropped at least 60 m below this level during the early Holocene. Such a substantial reduction in lake level in a closed basin could be explained only by extremely low effective moisture (i.e., a low precipitation/evaporation ratio) in the drainage basins at the start of the flood event. Our new reconstruction for the period 9000-8000 cal yr BP shows considerable sub-regional variation related to altitude and montane rain-shadow effects. Our data provide evidence for a wide diversity of moisture levels—from temperate moist conditions supporting evergreen broadleaf trees (TE-MAL-FO) to drought-resistant shrubland (WM-XER-SH)—for the integrated early Holocene time-interval of our study.

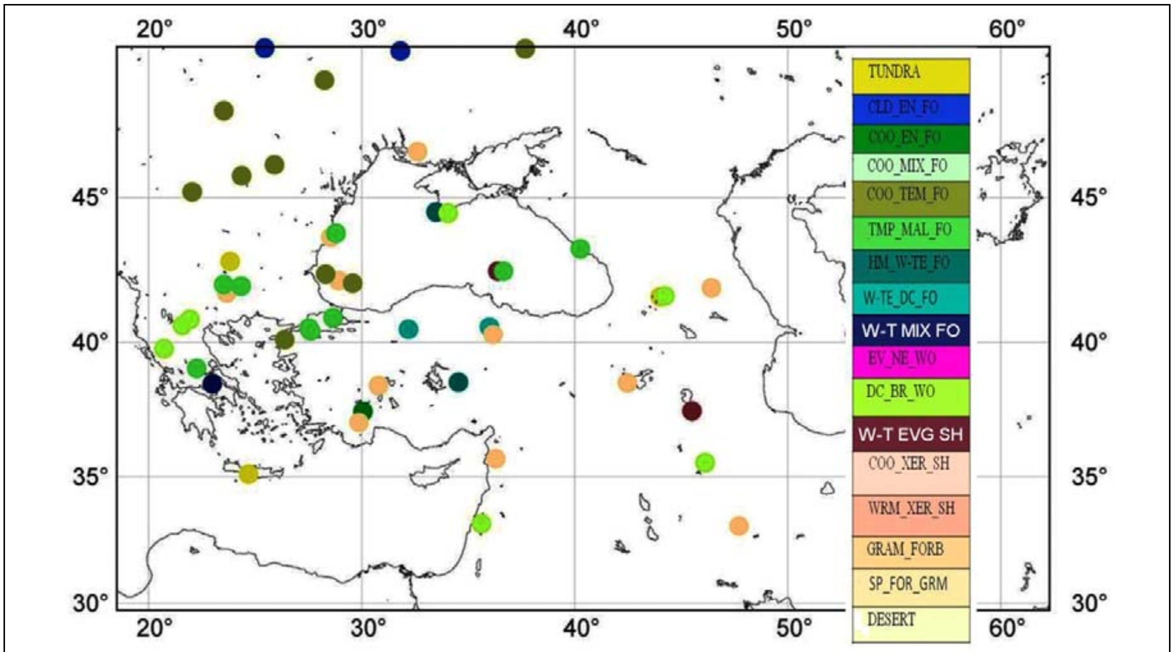

Figure 1. Initial map showing reconstructed biomes for the time interval 9000-8000 cal yr BP inferred from the pollen samples included in the database. Color legend shows 17 vegetation types observed in the modern data set. Legend abbreviations for the 8 types present in the core samples are: CLD – cold, COO – cool, DC – deciduous, EN – evergreen needle, FO – forest, MAL – malacophyll, SH – shrubs, TMP –temperate, W-TE – warm temperate, WO – woodland, XER – xerophytic.

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CLIMATIC CHARACTERISTICS OF THE EXTREMES IN SURFACE TEMPERATURE WITHIN THE CASPIAN - BLACK SEA - MEDITERRANEAN CORRIDOR

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Keywords: climate change, Late Würm, Holocene Optimum, early Sub-Atlantic epoch, Medieval Optimum

Climate played a substantial role in human development. Therefore, analysis of the structure of alternating warm and cold climatic periods may provide opportunities for assessing and understanding the causes of many historic events in different areas of the planet. The scales of variation anomalies in mean annual air temperature are shown in Fig.1-4. Climatic cycles can run for 100-150 ky, warm interstadials periods for 10-20 thousand years (Fig. 1) (Groisman and Lyalko, 2012). In the last warm period of the late Pleistocene (125-122 ka BP), the average annual temperature was higher than that of today by 1-2o C. One image cannot show the different features of change in the mean air temperature at the surface for a season, year, or other significant period of time (Klimenko, 2004).

They give some idea of the structure of the corresponding temperature variability. The Recent climatic situation corresponds to the warm phase, which began about 10,500 years ago. The maximum temperature was reached 6-5.5 thousand years ago (Figs. 1, 2) (Groisman and Lyalko, 2012) (called the Holocene climatic optimum).

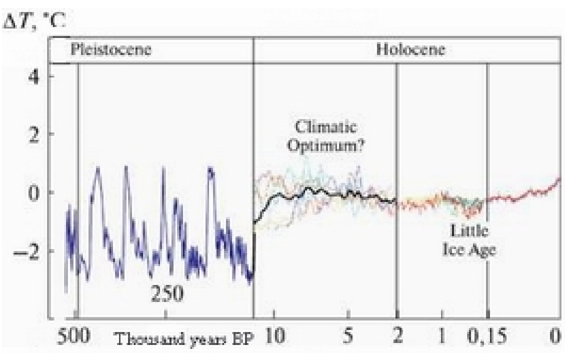

Figure 1 Variation anomalies in mean annual air temperature for the entire globe in the Pleistocene and Holocene (Groisman and Lyalko, 2012).

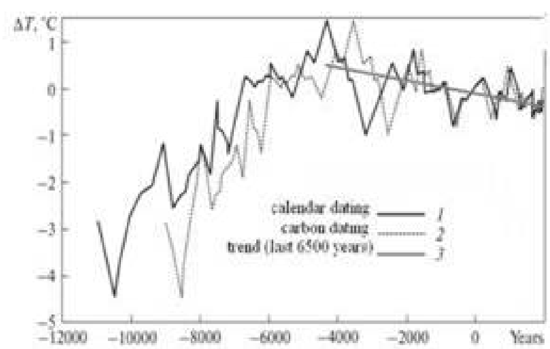

Figure 2 A historical series for the Northern Hemisphere in the Holocene over the last 12 ka (Groisman and Lyalko, 2012).

From this moment, there was a general negative trend in global temperature change (Figs. 2, 3).

In the background of this trend, there is some fluctuation in global temperature, with amplitudes that do not exceed 1-2° C (Figs. 2, 3) (Groisman and Lyalko, 2012; EEA, 2008). The warming of the 20th century takes place unevenly across time and space. The greatest values of global warming, which started in the 1970s, were realized in the last two decades (Fig. 3) (EEA, 2008). It is likely that the anthropogenic factor is the main reason for the trend in the natural course of global temperature change in the last 3-4 decades.

Fig. 4 shows the change in temperature at the meteorological station of Odessa. It can be seen that there was an increase in average annual temperature at the end of the 19th and at the end of the 20th century. But during the years 1900-1940, there was a definite decrease in temperature. A similar trend was observed for the entire northern hemisphere, however, given the background of significant fluctuations in temperature recorded by instrumental measurements (solid black line, Fig. 3), the period of 1900-1960 can be considered relatively stable (Figs. 3, 4). Therefore, climatic anomalies of past epochs were determined by comparison with the standards of the period 1901-1960, presumably substantially free of anthropogenic influence.

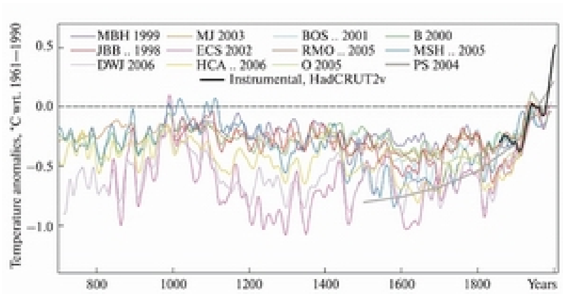

Figure 3. Reconstruction for the Northern Hemisphere over the last 1300 years using multiple climate proxy records and the instrumental record for the last 150 years. Anomalies are the mean value for 1961 and 1990 (EEA, 2008).

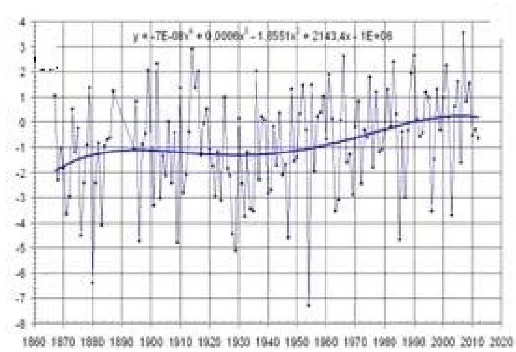

Figure 4 Data from the Odessa meteorological station from 1865 to 2012.

Deviations of the mean temperatures of the air within the Corridor as compared to the present values are shown in Fig.5 (Klimenko, 2001, 2004).

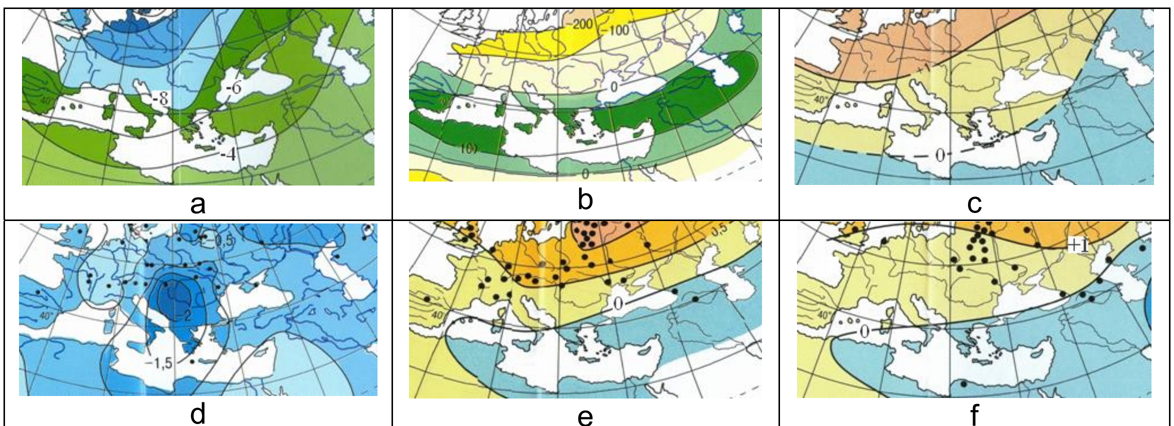

Figure 5. Deviations of the mean temperatures of the air within the Corridor (Klimenko, 2001, 2004): (a) summer temperature (Late Würm, 18 ka BP); (b) deviations of the mean annual precipitation (Late Würm); (c) summer temperatures in the Atlantic Holocene optimum (6-5 ka BP); (d) the maximum summer temperatures in the cooling ESA (about 2.5 ka BP); (e) summer temperatures in the Medieval Optimum (about 1.0 ka BP); (f) summer temperatures in the Medieval Optimum.

The relatively low mean annual air temperature anomalies led to significant changes in the life of civilizations. Simulation of climatic change projections for the next 100 years under different scenarios of human development gives an increase in global temperature of 2 to 8^{o} C. Identifying the causes of global temperature change with the paleoclimatic data can indicate the direction taken by humanity to adapt to climate change.

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ON THE DISTRIBUTION OF RECENT HARD-SHELLED FORAMINIFERA IN THE BLACK SEA

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Keywords: bottom species, hard-shelled and soft-shelled species, geographical distribution

Foraminifera make a significant contribution to the total meiobenthos. They are widely used as indicators of natural and human pollution (Yanko et al., 2000 a, b, c). Meanwhile, the Black Sea area is studied non-uniformly concerning Recent foraminiferal fauna and the bathymetric and geographical distribution of the species.

This study deals with the materials from the open sea area south of the Crimean peninsula (44° N to 34° W) and in the eastern part of the sea (between 43-44° N and 37-39° W) at depths from 7 to 180 m. 26 hard-shelled Recent foraminiferal species were discovered along with some redeposited fossil forms.

Soft-shelled species described in the Black Sea basin (Gooday et al., 2011; Sergeeva et al., 2005, 2010) were not discovered, as the samples were dried, and the fragile soft shells could not be preserved.

The hard-shelled Recent forms could be divided into three groups.

Relicts of the Pontian basin: *Ammonia beccarii*, *Elphidium macellum*, *E. poeyanum*, *Cribroelphidium martkobi*. Some (*A. beccarii*, *E. macellum*) inhabit the Caspian Sea as well. All of them are known from the earlier Cenozoic deposits of Crimea and Caucasus (Didkovski, 1959; Bogdanovich, 1947; Yanko et al., 2000 a-c).

Endemics: *Ammobaculites ponticus, Miliammina rugosa, Lagena perlucida var. basispiculata, L. lateralis var. pontica, Elphidium ponticum*. Black Sea endemic *Trochammina winogradovi* (Didkovsky, 1959) was not found in our materials.

Mediterranean (Atlantic) fauna, which are the richest in number (15 species). Among them *Hippocrepinella hirudinea, Armorella sphaerica, Glomospira gordialis, Starobogatovella hoeglundi* (= *Ammoscalaria runiana* Mikhalevich, 1968), *Trochammina inflata, Quinqueloculina subrotunda, Laryngosigma williamsoni, Ammonia perlucida, Cribroelphidium bartletti* were not identified earlier in this basin.

The genus *Starobogatovella* was separated from the genus *Ammoscalaria* on the basis of its shell morphology (Mikhalevich, 1994).

The introduction of Mediterranean faunal elements into the Black Sea is a young process that is continuing at the present time. It is possible that some of these species are representatives of the latest phases of this introductive process. The lower temperatures and depressed salinity of the Black Sea water obviously influence the selection of the Mediterranean forms, favoring those of more northern origin, which gives the Black Sea foraminiferal fauna its apparent northern character. The representatives of this Atlantic Black Sea fauna were noted in the North Atlantic near the coasts of Norway, Great Britain, Ireland, and Greenland. It is of interest that *Glomospira gordialis* and *Starobogatovella hoeglundi* are always rare in the North Atlantic, but in the Black Sea, they are more abundant and found in significant quantities despite the strong oxygen depletion and high concentrations of hydrogen sulfide of the Black Sea water.

The foraminiferal fauna of the Black Sea can be characterized in general as shallow water and euryhaline. The low salinity caused the shells to be predominantly pure calcareous material, with thin translucent shell walls and weakly developed sculpture. The deficit of lime is compensated by a stronger development of organic matter and the presence of forms with an organic shell wall (*Starobogatovella hoeglundi*).

The richest fauna are found on silty and silty sand substrates, at depths of 27 to 100 meters. On sands and sands rich in seashells, it is poor or fully absent. At depths of 7-8 and 150-180 meters, the fauna are also impoverished; at the shallowest depths, only some exemplars of *Ammonia beccarii* are present, while at the deepest depths, only *Eggerella scabra* and rare *Cribroelphidium* are found.

The foraminiferal species composition of the eastern part is close to that of the western part (south of Crimea), but in the former, representatives of the family Lagenidae are fully absent, though their absence may be accidental as they are rare forms for this basin. However, the quantitative ratio of species from separate groups in both regions differ somewhat. Thus, *Ammobaculites ponticus* prevailing in the east is met only once in the Crimean region, and *Starobogatovella hoeglundi*, while abundant in the western part, is found in the eastern part only in solitary instances, though the shells of this species in the west are more fragile, with thinner organic shell walls. This difference may obviously be explained by the different salinities of both regions: the western part is more desalinated on account of the inflow of the big rivers. Among the miliolids in the eastern part, *Quinqueloculina laevigata* prevails while *Q. subrotunda* is rarer; among elphidiids, representatives of Cribroelphidiinae and *Elphidium peyanum* are common, while *E. macellum* is rare. In the western part, representatives of the Mediterranean fauna are the most abundant: *Armorella sphaerica*, *Starobogatovella hoeglundi*, *Glomospira gordialis*, *Trochammina inflate*, and *Miliammina groenlandica*. This may be explained by the character of the Black Sea water exchange in which there is an annual inflow carrying saline water from the Marmara Sea to the Crimean coast. The influence of these waters is weaker in the eastern part, and its Mediterranean fauna are represented by fewer species and individuals. Nevertheless, some forms of Mediterranean origin, such *as Massilina secans*, *Cribroelphidium depressulum*, and *C. bartletti* obviously found here favorable conditions.

The difference in the foraminiferal composition of the regions investigated could be explained by the difference in their hydrology and perhaps also because of historical reasons.

Some redeposited species (*Globotruncana arca*, *Gumbelina* sp., *Cibicides* sp., *Lagena orbignyana*, and *L. variata*) were present in the material studied.

The data received widen our knowledge of the distribution of foraminifera in the Black Sea.

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EXTREME MARINE EVENTS IN THE NW PART OF THE BLACK SEA, REVEALED BY SEDIMENTOLOGICAL, PALEONTOLOGICAL, AND RADIOCARBON DATA

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Keywords: natural hazard, submarine slides, tsunami-type deposits, breccia, radiocarbon dating

Introduction

With active fault systems and high regional seismicity, the Black Sea basin represents a prime area for natural hazards, as the classical hazard-triggering mechanisms are present: active faults, earthquakes and high seismicity, submarine slides, and gas hydrates. Earthquakes, which usually accompany active tectonic activity, as the North Anatolian Fault or Shabla Fault, represent the main triggering mechanism of tsunami waves and submarine landslides, or of large scale gas-hydrate seepages.

The western Black Sea is characterized by a very large Romanian and Ukrainian shelf area (150-190 km), with low water depths (below 200 m) and low seashore topography, which makes the coastal area highly vulnerable to anomalous hydrodynamic coastal events and poses a high potential danger for coastal communities. There are historically recorded tsunami run-ups in some of the countries surrounding the Black Sea (Turkey, Bulgaria, and Ukraine). Due to its active faults both onshore and offshore, the Romanian Black Sea coast is considered a "coastal area with tsunami potential, located close to tectonically active zones" (Schmidt-Thomé, 2006; Schmidt-Thomé & Kallio, 2006; Tinti et al., 2008) and the written historical data on tsunamis in the Black Sea show important events starting with 1st century AD. For Romania, geohazards related to submarine active structures, such as submarine landslides, are an important element due to the bottom morphology of the shelf area and the coastal geometry.

Based on the tsunami-type events that occurred in the Black Sea during the last 120 years (1868-1997), the recurrence time for a tsunami was estimated at 20 years (Yalçiner et al., 2004). From the 22 major events known in the Black Sea, 9 were recorded in the XXth century. Considering only these events, the Ukrainian and Turkish authors concluded that the recurrence period for the tsunamis in the Black Sea seems to be only 11 years.

For the Romanian Black Sea coast, the oldest mention of a tsunami-type event dates from year 104 AD, when the Greek Callatis citadel was affected by high sea waves (Oaie et al., 2006). In the XXth century, anomalous flooding events in the Romanian Black Sea coastal zone were recorded in May 1958, December 1960, August 1993, and March and May 1995 (Oaie et al., 2008).

This paper presents results of sedimentological, paleontological, and radiocarbon data for sediments sampled from the Black Sea coast, the Danube Delta lagoon complex, and from the continental shelf, whose sedimentological features suggest deposition related to extreme marine (possibly tsunami-type) events.

Methodology

The documented observations are based on visual or instrumental measurements at hydro-meteorological stations along the Romanian seashore. Geohazards generated by active fault structures, like earthquakes and tsunamis, have been studied on the basis of previously collected information (seismic maps, geological tsunami layers, etc.). Direct sedimentological and paleontological investigation was done on the northern Romanian Black Sea coastal area, on sediment cores sampled from the Razelm-Sinoie lagoonal complex, and from the offshore area at stations located in front of the Danube Delta and on the internal Black Sea shelf area (water depths of 10-12 m).

^{14}C dating was done on coquina samples from layers suspected as having been deposited by tsunami-type events. For ^{14}C dating, geological samples were analyzed at the Institute for Cryogenics and Isotopic

Technologies in Râmnicu Vâlcea (Romania), using the direct absorption method and liquid scintillation counting with a IAEA-C6 reference standard, a certified value of 150.61 pMC% (± 0.11%, 1σ), and $\delta^{13}C_{PDB}$ = -10.8‰ (±0.47‰, 1σ), an efficiency of 67.89% and a background of 2.330 CPM.

Results

In the southern part of the Romanian Black Sea coast (Vama Veche – 2 Mai – Corbu area), five types of potential tsunami deposits have been identified (Oaie et al., 2008). The sediments show a lithofacies interpreted as deposited by tsunami-type waves, with the following characteristics: irregular layers resembling a poorly sorted breccia, with sandstone interbeds and often with soil layers, containing a mixture of fossils of different ages originating from various environments (marine, brackish, and lacustrine). The sixth type of possible tsunami layer was identified in a borehole core drilled into Razelm Lake. Sedimentological investigations of the sample show decimetric coarse sand beds, rich in vegetal debris, containing whole or fragmented shells. These beds are underlain and overlain by fine-grained lacustrine sediments (muds, silts).

Seismological studies revealed active hypocenters in the vicinity of the Black Sea basin; high magnitude seismic events are being considered as triggering tsunami-type waves. The presence of coarse intercalations within fine-grained lacustrine strata, as well as the various transport directions (marked by internal laminations), indicate possible accumulations related to extreme marine events, which crossed the beach-ridge located between the sea and the lagoonal complex.

Geological strata suspected to be deposited from tsunami-type waves contain a mixture of fossils showing various geological ages and derived from different environments (marine, brackish, and lacustrine). Micropaleontological analyses were performed on the sediment cores collected from the Black Sea onshore and offshore areas, at water depths of maximum 10-12 m. In the sediment cores analyzed, the ostracod associations represent a mixture of marine (*Leptocythere devexa*, *Xestoleberis decipiens*), brackish (*Leptocythere histriana*, *Cyprideis littorali*), and freshwater (*Darvinula stevensoni*) species. The predominant species within this mixture are typically marine, and only sporadic appearances of the freshwater species *Darvinula stevensoni* were observed. The faunal association can be considered *in situ*, excepting the freshwater species *Ilyocypris bradyi*, *Paracandona albicans*, *Limnocythere inopinata*, *Darwinula stevensoni*, and *Cypria* sp.

The collected cores were also analyzed for calcareous nannofossil assemblages. Smear-slides were prepared directly from untreated samples in order to retain the original composition. The samples yielded nannofloral assemblages with a moderate diversity and abundance, entirely reworked from older Cretaceous, Paleogene, and Neogene deposits. Several samples do not contain any nanofloras, neither *in situ*, nor reworked. The presence of the huge nannofloral reworkings (more than 600-700 specimens/sample) could suggest either a tsunami phenomenon, or an extreme storm, in front of the Danube Delta area.

The five ^{14}C ages obtained range between 3302 (+194/-190) BP (for the 2 Mai sample) and modern times (< 200 years) (for the Corbu sample) (Oaie et al., 2009). Considering the sea-level changes of the Black Sea during the Holocene (Chepalyga, 1984), the deposition of tsunami layers occurred in a regressive phase of the sea.

Conclusions

Recent geological and geophysical investigations have shown thick (>10 cm), chaotic or massive layers, dominated by accumulations of pebbles and cobbles, suggesting depositional processes related to exceptional marine events. Geophysical studies (SEV investigation) confirmed the landward development of the thick layers, suspected to represent the effects of the tsunami waves. Preliminary radiocarbon dating of shells from the tsunami-type layers yielded ages between 3302 (+194/-190) BP and modern times.

Coarse sandy beds from cores within the lacustrine mud sequences of the Razelm-Sinoie lagoonal complex indicate accumulations possibly related to exceptional marine events (including tsunami-type waves) that have crossed the beach-ridge.

The sediment cores from the internal shelf show coarser sediment intercalations, with a mixture of marine, brackish, and freshwater ostracods. The sediment samples from the shelf area are relatively rich in micro- and macrofauna when compared with those from the coastal dunes area. The sediment cores contain mixtures of marine and brackish ostracoda (plus one freshwater species), as well as foraminifera and mollusks of strictly marine origin. The marine fauna are clearly *in situ,* while the freshwater species are clearly allochtonous, thus strongly suggesting the existence of some extreme marine events in the area.

Diagnostic criteria reflect the high energy of the marine events. Some of the possible tsunami sedimentary deposits may have been generated by extreme storms, or by the coupled effects of both tsunamis and extreme storm waves**.**

Acknowledgments

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FIELD INVESTIGATION OF THE MYTHICAL "GOLD SANDS" OF THE COLCHIS KINGDOM (ANCIENT GEORGIA) AND THE PURPOSE OF THE ARGONAUTS' EXPEDITION

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Keywords: the Caucasus, "Gold Sands," the Argonauts, "Golden Fleece"

According to ancient Greek mythology and historical sources, the ancient Georgian kingdom of Colchis, generally located in the Caucasus region of western Georgia, was rich in gold sands. Here, the natives extracted this noble metal by working the gravels in the rivers, using special perforated wooden vessels and sheepskins in a process known today as gold placering. The Argonauts were a band of heroes in ancient Mycenaean myth who, in the years before the Trojan War, accompanied Jason to Colchis in his quest to find the "Golden Fleece" (Urushadze, 1964; Castleden, 2005).

In order to form our own opinion on this subject, we decided to carry out geologic studies in the territory of the ancient Colchis kingdom in order to find those areas where placering or extraction of gold from alluvial placers was, or could have been, possible at the time of the Argonauts. For this purpose, a group of geologists including the authors carried out research for more than 20 years in western Georgia in the following areas: Abkhazia, Samegrelo, Imereti, Svaneti, Racha, Guria, and Adjara. Our work has confirmed that the Svaneti area uniquely fits the likely place that was most important in ancient times for placer gold; this was the likely destination of the Argonauts. In the Svaneti area today, the locals still wash gold from the alluvial placers in domestic, perforated wooden vessels that are identical to those of legend and they still collect the fine gold that passes through the holes , on sheepskins placed beneath the wooden vessels. Alternatively they also place the sheepskins, alone in streams, in order to catch the gold being eroded today from bedrock occurrences.

The geological field work in the Svaneti area was carried out during the years 1998-2008 (Okrostsvaridze and Bluashvili, 2009). The gold concentrations in alluvial placers, and in the outcropping rocks of this region were tested in more than 1000 samples. Gold and other elements were determined by using ICP-MS instrumental analysis at "ACME LABS" (Vancouver, Canada). In addition to the geological material, we also collected a large body of artifacts including wooden vessels (Fig. 1) and sheepskins from this district that were still used by the natives for gold washing.

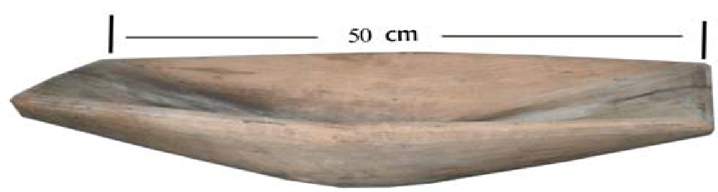

Figure 1. Unique vessel of ash wood from the Svaneti region (Sgurishi village).

Modern geological research conducted by us in the region has shown that the auriferous river gravels in the streams of the Svaneti region, on the south flank of the Greater Caucasus Range, probably represent the principal area in the

ancient Colchis kingdom where it was possible to obtain abundant gold from the mountain rivers (Enguri, Tviberi, Lasili, Arshira, Dolra, Hokrila, Chuberi, and others) by using the special wooden vessels and sheepskin methods that were unique to this area. We think that the gold content of the rocks and the river gravels of this region as determined by our investigations give ample grounds to believe that there was enough reason for the legends which describe Svaneti as a country rich in this noble metal. After examining the results of our own and other modern geological investigations, as well as viewing ancient and modern artifacts of gold and placer equipment, we share the viewpoint of the Roman historian Apian Alexandrine (A.D. 90-170) who related that the so-called myth about the expedition of the Argonauts to the Colchis kingdom in quest of the "Golden Fleece" was a real event. We further suggest that not only was the purpose of the Argonauts' mission to obtain gold but also to obtain knowledge of the local and unique technology for the extraction of gold from the river gravels.

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VARDZIA CAVE TOWN (GEORGIA) AND THE ENVIRONMENTAL PROBLEMS CAUSED BY FIBROUS ZEOLITES

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Key words: Erionite, mordenite, ferrierite, mazzite, volcanic tuffs

The Cave City of Vardzia combines urban, monastic, and defensive complexes and is located in Meskheti (South Georgia), on the left bank cliffs above the river Mtkvari, at an altitude of 1300 meters above sea level. King George III began its construction in the 50s of the 12th century, and it was completed during the reign of his daughter Queen Tamara. The time was a period of Georgian Revival, and this huge fortress-city, carved into the rock (Fig. 1) is monumental proof of this. For nearly three and a half centuries, an intensive economic, scientific, cultural, and educational life was conducted in the fortress-city of Vardzia. Queen Tamara was fond of the city and spent much time; especially, of her early years there.

Figure 1. View of the Vardzia Cave Town, central part.

The complex consists of 13 floors with a total area of over 5,000 m^2. It includes 120 dwellings, 420 pantries, among them 25 special storage facilities for wine (Marani), a pharmacy, and 4 Christian churches. Next to the main church there are springs, and a 3.5 km long water channel was carved into the rock, providing drinking water to the complex. In 1283, after a strong earthquake, the cave complex was severely damaged, but it did not cease its operation. In 1553, the Persian army destroyed it, and in 1578 the Ottoman Empire captured Meskheti, after which the complex was abandoned. In 2007, Vardzia, together with Khertvisi fortress, were designated by UNESCO as World Heritage Sites.

The rocks into which the complex of Vardzia was carved are identified as the Vardzia Horizon (Ustiev and Jigauri, 1971), which represents caked flow tuffs with a thickness that varies from 45 to 60 meters. The Vardzia Horizon is overlain by andesitic tuffs, and in direct contact, a zone of ignimbrites developed, which serves as a natural upper boundary for the Vardzia complex. The Vardzia flow is not graded and mainly consists of medium- and poorly-caked tuffs, the color of which depends on the degree of sintering and varies from pink to white. The size of the tuff debris ranges from 0.1 to 3 cm and is mainly composed of hypersthene-hornblende, rarely of biotitic andesites, in which the average content of

SiO_2 is 61.0%. Together with andesite hornblende, biotitic dacites are marked, in which the average content of SiO_2 corresponds to 65.0%. Binder material basically consists of volcanic ash, which, as a result of low-temperature hydrothermal processes, was transformed into a zeolite, in particular, mordenite. Vardzia flow tuffs are very easily cut with a knife, a fact that was successfully applied by ancient builders, but of course they did not know anything about the geo-environmental hazard posed by the fibrous zeolites in these rocks. The World Health Organization classified fibrous zeolites (erionite, mordenite, ferrierite, mazzite, ofrrerite, and roggiannite) as one of the most carcinogenic natural minerals to human health. According to this classification, erionite is the most dangerous toxic mineral, 50-100 times more toxic than asbestos-chrysotile. Modern research shows that fibrous zeolites caused a regional epidemic of malignant neoplasias (bronchial carcinoma, malignant mesothelioma). The first such epidemic occurred in Cappadocia, Turkey, where the populations of several villages suffered from pleural mesothelioma, and more than 50% of the inhabitants died because of it (Baris et al., 1978).

Zeolites are formed in volcanic ash and pyroclastic rocks as a result of diagenetic and hydrothermal alteration. Erionite and other fibrous zeolites are formed in the mixed environment of volcanic ash and clay. Fibrous zeolites are often found in association with other zeolites, precisely with clinoptilolite and chabazite.

In Southern Caucasus, volcanic formations are widely spread and occupy about 30% of the total area. Zeolites have been studied quite extensively in Georgia (Skhirtladze, 1991), but identification of fibrous zeolites hasn't carried out, as nothing was previously known about their danger. Despite this, zeolites with erionite and mordenite are found in the Mtkvari, Enguri, and Algeti river gorges, at the zeolite deposit of Tedrzami, the barite-polymetallic deposit of David-Gareji, and the copper polymetallic deposit of Abulmulak, and also in the area surrounding the villages of Askana, Vardzia, Bolnisi, Ratevani, Abrameti, Samshvilde, and Nichbisi. Based on the above, these areas most likely represent the greatest "zeolites danger" for the population.

Climatic conditions and petrographic structure of the sintered tuffs of the Vardzia flow, which extends more than 20 kilometers in distance, are very similar to those of volcanic rocks common in the province of Cappadocia (Turkey). This suggests the possibility that the local Cappadocian population is or was getting sick from mesothelioma.

For the investigation of this question, we examined the historical sources of the region (Okrostsvaridze et al., 2011) and discovered that the life expectancy of people living there did not exceed 50-55 years. More information exists about the disease of Queen Tamara. It is known that she died at the age of 53 and was ill only during the last two months of her life (Samushia, 2010). In addition, all her symptoms coincide with those of typical mesothelioma, which was probably caused by her long-term living in Vardzia.

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QUATERNARY GEOLOGY, VOLCANISM, SEISMICITY, AND MINERAL RESOURCES OF GEORGIA, THE CAUCASUS

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Keywords: orogen, Black Sea, sediments, glacial, alluvial

The Caucasus represents a Phanerozoic collisional orogen formed along the Euro-Asian north continental margin. Currently, it extends over 1200 km from the Caspian to the Black Sea and is an expression of continental collision between the Arabian and Eurasian lithospheric plates. Three major units are distinguished structurally in the Caucasian construction: the Greater and Lesser Caucasian mobile belts and the inner Caucasian microplate.

The Caucasian orogen started active exhumation in the late Miocene, and in the Quaternary period, it was formed in its modern shape. Georgia is situated in the western part of this orogen and geologically represents one of its most active segments. As a result, nearly all types of Quaternary sediments are represented here: seashore, glacial, alluvial, lake, subaerial, and volcanogenic.

The lower Quaternary part of the Black Sea shore of Georgia is represented by Chaudian semi compressed sea sediments, which are terraced along the Guria and Apkhazeti seashores (Tsvermagala, Khvarbeti, Ureki, Sokhumi, etc.). Chaudian terraces are situated at 90-150 m asl. In the middle Quaternary, during the late Euxinic transgression, the late Euxinic sea terrace was formed alongside the shore, which is situated at 55-65 m asl. At the end of the middle Quaternary, the Uzunlarian transgression took place, traces of which are represented at 35-45 m asl as a terrace in Guria near the village of Tskaltsminda. In the upper Quaternary, the Karangatian transgression took place. The Karangatian terrace is situated at 25-30 m asl in Guria and Apkhazti. In the Holocene, as a result of the early Black sea transgression, the modern seashore was formed, the age of which has been determined at 4000-6000 years.

Quaternary glacial sediments in Georgia are mainly spread in the high mountainous zone and at a smaller scale in the Lesser Caucasus. Evidence of the Würm, Riss, and Mindel glacial periods is present here (Tsagareli, 1989). The moraines of all the mentioned glaciers are fixed in the central segment of the Caucasus, and glacial trenches formed at the riverheads, which descend from 2000-2200 m asl.

Alluvial sediments are widespread in Georgia and form river terraces in the depressions between the mountains. Their paleontology has not been studied well, and their correlation is based only on geomorphological methods. Contrary to alluvial sediments, Quaternary lake sediments are rare in Georgia. They are mainly formed on the Javakheti volcanic highland (Tsalka depression) and the Kolkheti lowland.

Volcanism

In the Quaternary period, intensive subaerial volcanic activity took place on the territory of Georgia. The genesis of this volcanism is disputed (Chang et al., 2013). A substantial number of geologists consider that it is the result of residual oceanic crust subduction; another group of geologists relate it to mantle plume activity. There were two major volcanic provinces in Georgia in the Quaternary: the Greater and Lesser Caucasian. Kazbegi (5033 m asl) is the best known in the volcanic region of the Greater Caucasus, which is mainly constructed of andesites and last showed activity around 6000 years ago. In the Lesser Caucasus, the Javakheti volcanic highland was formed during the Quaternary; it was formed mainly of 300 m thick basalt lava layers. In this highland, the 70 km long, S-N trending Abul-Samsari volcanic range was formed already in the late Pleistocene-Holocene. The most prominent volcanoes in this range are Didi Abuli (3300 m asl) and Samsari (3284 m asl). The products erupted are mainly lavas (andesite to dacite) and very subordinate pyroclastics. Some isolated volcanic centers with geochemical characteristics and ages similar to the Abul-Samsari range were active in the Bakuriani-Borjomi area, north of the main volcanic chain.

Seismicity

Present day seismicity of the region is defined by the northward movement of the Arabian plate toward the Eurasian plate. The convergence rate is estimated to be about 30 mm/yr, 2/3 of which is likely to be taken up south of the Lesser Caucasus, and it completely vanishes at the Greater Caucasus, forming a complex structure of seismic faults with diffused seismicity (Philip et al., 1989). A smaller portion of the seismic energy is released in the form of earthquakes. Analysis of the historical and instrumental seismological data shows that strong earthquakes with magnitudes up to 7.0-7.5 and macroseismic intensity of 9 (MSK scale) have occurred here during the Quaternary period. The recurring periodicity of such events is on the order of a thousand years (for the same source). The South Caucasus is within the area of high seismic activity, with the risk factor constantly present. The consequences were heavy in the South Caucasus in the 20th and beginning of the 21st century, in particular in the 1980s and 1990s (Faravani, Spitak, Racha) and in 2002 (Tbilisi). The consequences of the powerful earthquakes that occurred in that period in Georgia are felt even today.

Mineral resources

In the Quaternary period, the territory of Georgia was rich in necessary mineral resources for the development of humans. Both Caucasian range systems were rich in freshwater, and caves were formed in the Cretaceous sediments of the southern slope by an intensive net of montane rivers. Besides, numerous obsidian deposits were formed as a result of intensive subaerial volcanism. Thick layers of volcanic ash and tuff were laid down as a result of the same volcanism; thick rows of sand, rocks, and conglomerations were formed as a result of intensive exhumation (it was easy to carve dwelling spaces in both mentioned formations). At the same time, a lot of clay deposits, which were formed as a result of intensive alteration, sea sand, iron deposits (Guria), and alluvial gold (Svaneti, Bolnisi region) are also worth mentioning.

Thus, we can ascertain as a result of the study of the Quaternary geology, volcanism, and seismicity of the Georgian territory, that humans dwelling in this area faced great challenges; they either had to leave powerful volcanic and seismic activity zones or adapt to the environment. As we can see, the living conditions (climate, natural resources) were so good, they choose to stay, and the Georgian autochthonic nation was formed.

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DIAGENETIC CHARACTERISTICS AND OSL CHRONOLOGY OF NORTH CYPRUS BEACHROCKS: IMPLICATIONS FOR LATE HOLOCENE SEA-LEVEL CHANGES

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Keywords: Beachrock, sea level change, Northern Cyprus, Eastern Mediterranean

Beachrock, *sensu stricto*, forms as result of the intertidal cementation of beach sediments with calcium carbonate, and it is frequently used in studies of Holocene sea-level change and neotectonics (Kelletat, 2006; Vousdoukas et al., 2007; Thomas, 2009). Along the coasts of the Mediterranean Sea, where tidal range is nominal, these cemented beaches have a wide distribution (Friedman and Gavish, 1971; Alexandersson, 1972; Bernier and Dalongeville, 1988; Holail and Rashed, 1992). Representing the third largest island in the Mediterranean Sea, Cyprus possesses appropriate conditions with respect to beachrock cementation, such as arid climate, low tidal range, etc. In this study, diagenetic characteristics and OSL dating results obtained from beachrock at 23 different localities are discussed (Fig. 1).

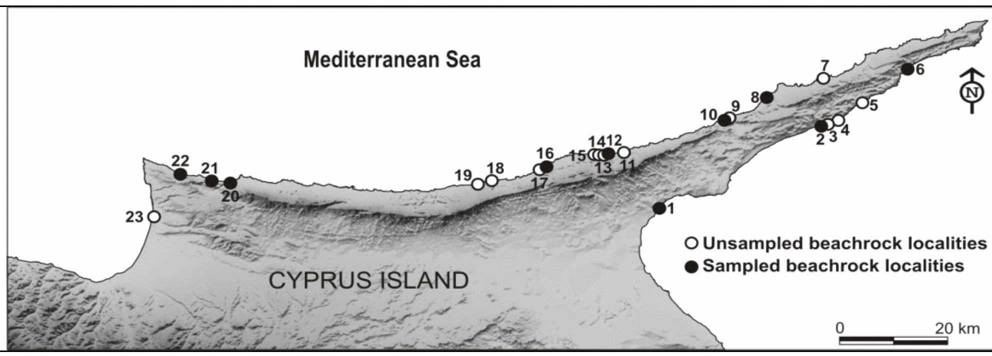

Figure 1. Beachrock localities along the North Cyprus coast.

We surveyed a coastal zone of about 320 km and measured several morpho-stratigraphical features of the cemented beds. A total of 21 samples were collected for petrographic thin sections and scanning electron microscopy (SEM) analyses, as well as optically stimulated luminescence (OSL) dating.

Field observations showed that the length of beds ranges between 20 m and 1.6 km. The beds are 35 m in maximum width and dip toward the sea at angles between 3º and 5º. Composed of alternating beds of conglomerate and lithic sandstone, beachrocks contain a total calcium carbonate content of between 37% and 65%. FTIR spectra show that connective carbonates have similar chemical structures and are composed entirely of calcite based on XRD data. Quartz is a predominant component. Thin sections and SEM images demonstrate the presence of various types of cements, such as meniscus bridges, circumgranular micritic coatings and dogtooth cements. These cements are suggestive of meteoric vadose, marine phreatic, and meteoric phreatic environments (Stoddart and Cann, 1965; Scoffin and Stoddart, 1983; Adams and MacKenzie, 1998; Spurgeon et al., 2003; Rey et al., 2004; Vieira and De Ros, 2006). OSL ages of the beachrocks range between 387±19 ka and 5407±425 ka. Our sea-level curve adapted from these ages shows that beachrock formation took place when sea level was between 0 m and -1 m. This is confirmed by the aforementioned sequential cement fabrics.

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EVOLUTION OF THE DANUBE DELTA COASTLINE IN THE HOLOCENE

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Keywords: natural factors, human intervention, coastal erosion, shoreline dynamics, radiocarbon data

Introduction

With a length of 2857 km and a drainage basin of about 820,000 km^2, the Danube River discharges its sediments into the Black Sea through the Danube Delta through the main three distributaries: Kilia, Sulina, and Sf. Gheorghe. The average multiannual discharge is about 6500 m^3/sec (Almazov *et al*., 1963; Stançik *et al*., 1988; Bondar et al., 1991; Bondar 1993; Bondar and Panin, 2000). As for all major river deltas, the Danube Delta is affected both by natural and anthropogenic factors, as well as by global changes. Large parts of its coast are subject to erosion while shoreline retreat, although a natural phase in the evolution of a delta, has accelerated at high rates in the last decades due to human intervention.

The goal of this paper is to present an overview of the natural and anthropogenic processes controlling the shoreline dynamics of the wave-dominated Danube Delta, based on the corroboration of a large variety of published and unpublished data: geomorphological, sedimentological, mineralogical, geochemical, bathymetrical, hydrological, faunal, radiocarbon dating, etc.

Natural factors controlling the Danube Delta evolution

Sedimentological and mineralogical data indicate that the main types of deposits in the Danube Delta include: marine littoral deposits (type **a** = of littoral drift from the Ukrainian rivers; type **b** = of Danubian origin; type c = of littoral diffusion, resulting from mixed a and b types); lacustrine littoral deposits; fluvial deposits (bed-load and mouth bar, subaequeous and subaerial natural levee, crevasse and crevasse-splay, point bar and meander belt, deposits related to intradeltaic depressions and interdistributary areas); marsh-deposits; and reworked loess (or loess-like) deposits (Panin, 1989).

According to radiocarbon data (Panin et al., 1983; Panin and Jipa, 1998; Oaie et al., 2009), the Danube Delta started to form some 12.000 years ago. The delta evolved from an initial spit (the Letea-Caraorman spit, formed between 11,700 and 7,500 years BP of type **a** sediments), and continued by successive progradation of several delta lobes. With its first beach ridges formed by sandy sediments from the Ukrainian rivers and the last by Danubian sediments of the Sulina distributary, the Sf. Gheorghe I Delta (9,000-7,200 years BP) records an overall progradation of 10 km in 2000 years. It was followed by the Sulina delta (7,200-2,000 years BP), formed when the Sulina paleodistributary became the main branch in the delta for almost 5000 years. The maximum progradation of the Sulina Delta front (10 km offsore from its current position) coincides with the Phanagorian regression, when the sea level was 2-4 m below its present-day level. The northern part of the Sulina Delta was formed initially of ridges of type **a** sediments, while its southern part was built by type **b**, Danubian sediments.

When the Sulina distributary became partly clogged and subject to partial erosion 2,800 years ago (coinciding with the current sea-level rise), the Kilia and Sf. Gheorghe II Deltas of Danubian sediments started to prevail and build their own depocenters N and S of the Sulina Delta. The Kilia secondary Delta is still prograding, favored by the relatively large supply of sediment - more than 50% of the total sediment discharge of the Danube River (Bondar and Panin, 2000). The current phase of the Sf. Gheorghe II Delta is represented by the Sahalin lateral arcuate mouth bar, that started forming after the flooding of 1897; while the Sahalin mouth bar joined the front of the Sf. Gheorghe secondary delta in 1980, today the bar has attained 17 km in length, its southern tip tending to approach the shore in the Ciotic-Zătoane area. In front of Lakes Razelm and Sinoie, the Coşna-Sinoie Delta prograded between 3,500 and 1,500 years BP.

Anthropogenic factors controlling coastal dynamics

Human interventions affecting the Danube Delta coast started in the second half of the XIXth century, with regularization works performed in order to improve navigation and limit periodic floods. Cut-offs of the Sulina distributary meander belts, performed during 1868-1902 by the European Danube Commission, include 9 channel cut-offs with lengths between 0.6 and 9.7 km. The Danube sediment discharge dropped dramatically (by 35-50%) after the building of the Iron Gates I and II barrages (Panin, 1996). Built for navigation purposes, the Sulina jetties also have a profound impact on coastal zone evolution. Successive elongation of the Sulina jetties, in order to avoid or reduce the accumulation of sediments at the seaward opening of the channel, resulted in extension of the navigation canal by 8 km into the sea; the consequence was the almost complete blocking of longshore drift from the north, which in turn resulted in clogging of the Musura Bay north of Sulina and downdrift erosion south of Sulina. Dredging of the mouth bar of the Sulina distributary in order to maintain a minimum depth for navigation is another cause for the "beach starvation" in the Sulina-Sf. Gheorghe area. Being dumped in offshore locations, the dredged sediments leave the nearshore system.

Shoreline dynamics

Studies of the Danube Delta coast have enabled the establishment of a detailed picture of shoreline dynamics in several sections from Sulina to Portiţa (Dan, 2013): retreat of the shoreline in the Sulina-Sf. Gheorghe section (34 km long), characterized by a longshore current toward the south (an exception is the 8 km long coast close to Sulina, strongly influenced by the jetties, where the longshore current is oriented northward due to wave diffraction processes, and the present-day status of the coastal zone is accretive); stability of the coast along 6 km near Sf. Gheorghe, with periods of erosion alternating with periods of accretion; strong erosion of the 20 km long section in between, with rates ranging from 5 to 20 m/year (Panin, 1989, 1998, 1999; Stănică et al., 2007; Stanica and Panin, 2009; Dan, 2013) (in some parts of this section, merging of the lakes from this area with the sea caused the retreat of the coastline by more than 500 m since 1950). Southward, down to Portiţa Inlet, over a distance of 23 km the shore is in relative dynamic equilibrium, with episodes of alternating erosion/accretion of 5 to 10 m/year (Panin, 1996).

For the coastal area between Sulina and Sf. Gheorghe, preliminary vertical movements of the shore, using long term deformation maps (derived through InSAR technology) (Oaie et al., 2010) show a constant subsidence of 0.5-1.5 cm/year for an interval of 17 years (1992-2009). North of Sulina town, the beach keeps a constant subsidence of around 2-3 cm, the maximum subsidence observed relative to Sulina town being around 5 cm/year.

Using the existing bathymetry of the Danube Delta coast and the water-sediment characteristics computationally-derived data, Dan (2013) estimated a net longshore sediment transport generally oriented southward, with steep gradients, for the Sulina-Sf. Gheorghe area and the Sahalin spit, and northward-oriented for the Sahalin-Portiţa Inlet with mild gradients. Numerical modeling by the same author, used to simulate the position of the shoreline for the next 25 and 50 years, revealed that the trends and erosion/advance rates are similar to the current ones. Examining several scenarios for the vulnerability of the Danube Delta coast to episodic, storm-induced water-level changes, the results show significant water-level increases especially for storms from a northern direction, when the storm water level may rise over 1 m. In this case, the maximum flooding of the beaches would take place in the central part of the Sulina-Sf. Gheorghe area, induced by storms from the north. This area is particularly vulnerable to extreme storms which can result in breaching of the dune system, with negative consequences for the freshwater inland ecosystems, the infrastructure, and local economic activities.

Based on historical data and state of the art numerical modeling, Dan (2013) shows that, fed by the Sf. Gheorghe distributary and the longshore current from the north, sediments transported from the sea side are deposited at the landward side of the Sahalin spit; the volume of sediment is of the same order of magnitude as the accommodation space created by relative sea-level rise, which explains the relatively constant depth of the bay created behind the spit. The position of Sahalin spit at a certain moment is the result of the constant interaction between cross-shore processes which roll the spit towards the mainland and longshore processes restoring the equilibrium, but always closer to the mainland. The author interprets the spit cycle as part of the wave-dominated deltaic lobe development, the evolution of a spit strongly depending on the sediment input and the wave energy level.

Conclusions

The Danube started flowing into the Black Sea in the Late Quaternary, as indicated by radiocarbon data. Factors controlling the delta sedimentation and shoreline dynamics include: Danube sedimentary input, prevalence of winds from the N and of S-directed marine currents, S-directed longshore sediment drift, and the influence of wave power.

Despite the shoreline erosion problems in the Danube Delta area, there are limited zones with net deposition in front of the Danube area during the last century, with an average accumulation rate of decimeters/year in some areas.

There are differences in the amplitude of longshore sediment transport, which are due to shoreline orientation and to different steepness of submerged active beach slopes. There is a relative accretion of the beach on limited section (about 5-7 km) just south of Sulina (over 5 m/year), a rapid retreat of the shoreline (over 10-15 m/year) in the central part of the Sulina-Sf. Gheorghe area of about 20 km (process enhanced by human intervention), and relative stability for a limited section close to the Sf. Gheorghe distributary mouth. In the Sahalin-Portiţa sector, the shoreline is generally slightly retreating (except for the central part at Periteaşca), mainly due to the undernourishment of the coast and secondarily, to the relative sea-level rise.

The Sf. Gheorghe lobe is still developing moderately, forming and reworking the Sahalin spit by wave action, which results in merging with the mainland in the direction of the longshore current. A very dynamic system, the Sahalin spit shows average rates of elongation between 100 and 140 m/year and landwards migration by overwashing of over 20 m/year.

From the entire Danube Delta coast, the central part of the Sulina-Sf. Gheorghe sector is the most affected by erosion, with a maximum shoreline retreat rate of over 20 m/year. Vulnerability of this area to flooding during extreme storms is due to the morphology of the active beach, with a low and relatively short subaerial part and a steep subaqueous part. The volumes of sediments eroded from this area reach 1 million m^3/year and similar erosion rates are estimated for the next 50 years. Restoring the effective nourishment of the beaches and the longshore transports along this coast will represent an effective way to reduce the erosion in this area. Prediction of coastline evolution for the Sulina-Sf. Gheorghe sedimentary cell using linear extrapolation of currently measured erosion rates (Stănică and Panin, 2009) and presuming a sea-level rise of 30 cm by 2030 (worst case scenario), implies a hypothetical shoreline retreat between 175-600 m (maximum 700 m) and advancement of the sea of about 150 m south of Sulina.

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APSHERONIAN (EOPLEISTOCENE) DEPOSITS OF WESTERN CISCAUCASIA

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Key words: facies, molluscs, Western Kuban through

Main Goal

The main goal of the research is to reconstruct paleogeographic conditions of sedimentation of the Apsheronian (Eopleistocene) deposits on the territory of Western Ciscaucasia. To reach the goal the following tasks have been assigned: 1) to trace the distribution of Apsheronian deposits over the territory; 2) to analyse the lithological composition and its variability; 3) to reconstruct facies conditions existed during the formation of Apsheronian deposits.

Results and Discussion

The most of the territory of western Ciscaucasia is covered by sedimentary rocks with Apsheronian (Eopleistocene) deposits in the roof. They have been studied in numerous bore holes (Balukhovskii and Khain, 1975.).

Apsheronian deposits are widespread across the plains, beginning from the Taman Peninsula and northern Caucasus to the valleys of the Don and Manych, and from the Sea of Azov to the Stavropol uplift. They are often overlain by Neopleistocene and Holocene sediments with thicknesses up to 20 m. Sometimes, these Apsheronian deposits are exposed in coastal cliffs of the Sea of Azov and along the valleys of the Kuban, Laba, Belaia, Pshish, Pshekha, Psekups, Kagalnik, Mokraia Chuburka, and other rivers.

Apsheronian deposits have been discovered in the Western Kuban trough at depths of 50-60 m, where they are represented by lagoon-marine and continental facies. The former are typically light-grey and yellow-brown sands comprising different particle sizes, often with pebbles and broken mollusk shells, and interlayered with light-green and dark-grey clays, loams, and limestone. Their thickness varies from 20-40 m to 80-110 m.

From the axial part of the Western Kuban trough toward its periphery, lagoon-marine facies gradually interfinger with continental (lake, alluvial, proluvial, and deluvial) facies. Of these deposits, the lake sediments form separate interlayers. The foot of the continental deposits is represented by sandy-gravel and clayey sediments. The roof of the continental deposits is composed of mottled sediments. The upper part differs from the bottom due to an increase in fine-grained material represented by fine-grained sands, clays, and aleurolites. To the north, they gradually grade into clays, forming brownish-red clay sequences often exposed in steppe river valleys. The sequence of the continental Apsheronian sediments varies in thickness from 200 m to complete disappearance in the foothills.

In bore holes of the Primorsko-Petrovskaia area, Apsheronian deposits are represented by coarse-grain sands and pebbles that are underlain by mottled non-structured clays with interlayers of sands and coquina, including freshwater mollusks *Unio sturi* M. Hoeh., *Viviparus* sp., and the ostracods *Candonella subelipsoida* Scher., *C. albicans* (Brady), and *Cyprides* cf. *litoralis* (Brady). The thickness of the Apsheronian deposits here ranges between 60 and 110 m. They are underlain with deposits whith typical Kuyalnik.

There is an opinion that deposits of mud volcanoes, which are localized close to the zone of their eruptions dedicated to diapiric fold on Taman peninsula, have Apsheronian age. These deposits are represented by non-carbonate, sandy, with slickensides, clayey pellets, fragments of marl, limestone, amd sandstone of much older (from Pliocene to Cretaceous) sediments. Often to mud volcanoes timed weak manifistaions of oil and gas.

On the southern side of the Western Kuban trough, Apsheronian deposits are represented by sands and sandstones with aleurolites interlayered with clays containing the mollusks *Viviparus duboisianus* Mouss., *Pyrgula variabilis* (Eichw.), *P. caspia* (Eichn), and *Theodoxus* ex gr. *pallasi* Lindg., suggesting that sedimentation occurred in a shallow freshwater basin of lagoon-liman type.

All this evidence permits the conclusion that Apsheronian deposits were formed during the course of transgressive-regressive cycles of basin development.

Apsheronian sediments are overlain by marine Neopleistocene sediments, which are well traced in the coastal zone of the Black Sea and Sea of Azov, as they form terraces consisting of sandy-pebbly and sandy-clayey sediments with mollusk shells, all deposited over the course of the Neopleistocene transgressions. The Holocene is represented by soil (up to 3 m thick) underlain by loams and sandy loams with alternations of mollusks characteristic of today's brackish Black Sea and Sea of Azov and those inhabiting freshwater basins. They also contain abundant reworked fauna deriving from ancient sediments related to demolition from the slopes of western Caucasus (Beluzhenko and Pinchuk, 2006). This enables to conclude that territory of western Kuban trough underwent a series of transgressive-regressive cycles in course of which continental and lagoon-marine facies where deposited (Svitoch, 2003).

Conclusions

Geological and paleontological study of numerous boreholes enable us to trace distribution and thickness of Apsheronian deposits from the foothills of the Western Caucasus to the mouth of the Don River. Change of lithological composition of Apsheronian sequence allowed to reconstruct facies conditions, which change from marine in western Kuban trough to limane-lagoon ones on the sides of trough and than to continental in platform part of the studied area. Obtained results enabled us to draw paleogeographhic map of western Ciscaucasia in Apsheronian time.

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WHITE COLOR BEADS OF THE BRONZE AGE FROM TRIALETI BARROWS

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Keywords: talc, homogeneity, enstatite, X ray, chemical composition, phase

No one knows when human beings first beautified themselves with adornments, but indisputably the first adornments were the ones that nature itself offered. From the artistic and aesthetic point of view, the only function of an adornment is to beautify a person. Thus the form and character of an adornment changed quite rapidly in accordance with the changing of aesthetic ideals and vagaries of fashion.

In Georgia, barrows of various periods have been found to contain lots of important adornments representing fine art pieces; they belong to various times and are of diverse origins. White color beads found in Eli-Baba cemetery within the territory of the Tsalka municipality are among them. Until our research, they have been studied from the historical-ethnographic point of view only, and they have been described as talc mineral or white paste beads. In our opinion, it is necessary to research archaeological finds using modern geological methods, as the obtained data not only help the archaeologists but even appear to be decisive in solving such problems as the kind of mineral, the raw material source, geography of their mining and extraction, the origins and dating of the raw materials or adornments to various historical periods, and the technological issues of their mining, processing, and fabrication.

The white bead material has been studied by X-ray powder diffraction (XRD), chemical analysis, X-ray fluorescence, and optical photometry, and the results are quite interesting. Each grain in some beads is represented by talc, in some others there is observed a phase of the mineral enstatite in various percentages, and other beads are entirely represented by an enstatite phase (Fig. 1).

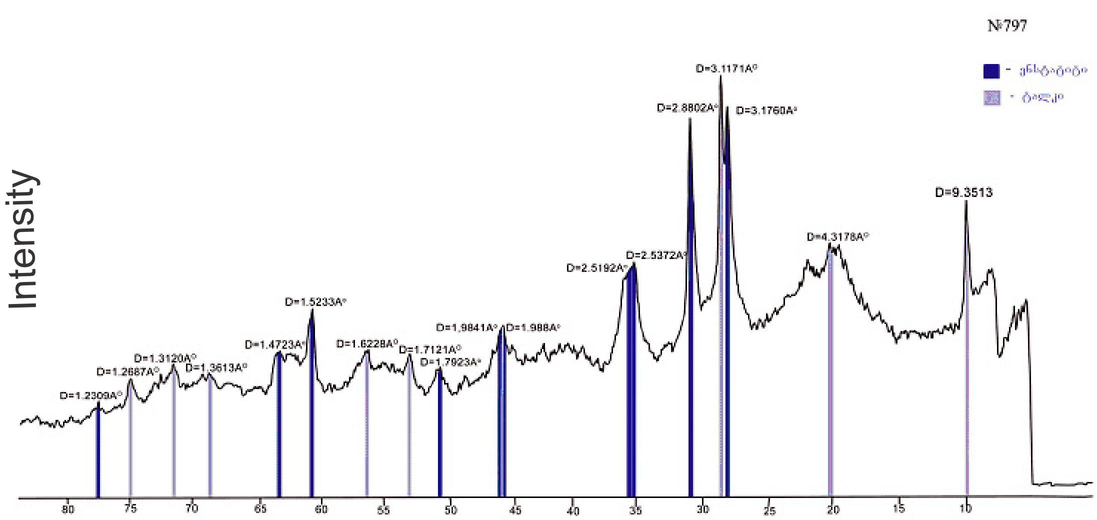

Figure 1. X-ray diffractogram (Diffraction angle 2θ).

The reality is that each bead is represented by an independent phase of talc, or enstatite, or by both phases together in varying proportions, so the chemical composition of each bead is practically uniform. The identical chemical composition of the beads, their high strength, homogeneity, and fine-granularity made us consider that the talc raw material had been subjected to thermal treatment at various temperatures in order to produce material with greater strength, density, and durability. To test this supposition, we conducted an experiment; we took a natural sample of talc, made an X-ray diffractogram of its natural condition, then we heated it to 600^0C and identified the phase structure of the solid products by XRD. The X-ray diffractogram showed, together with talc, an enstatite phase as well. Then we heated the sample to 900^0C and carried out another X-ray powder diffraction analysis. This second X-ray diffractogram showed that the talc phase was significantly decreased while that of enstatite was increased. Thus, it can be stated definitely that talc mineral was used as a raw material for making beads, and that it was heated to various temperatures to improve its properties. As talc is heated above 500^0C, it gradually turns into enstatite; the higher the temperature, the greater the proportion of enstatite that replaces the talc. When heated higher than 1000^0C, the talc turns entirely into enstatite.

As is generally known, the natural process takes place in reverse; because of exogenous weathering processes, enstatite breaks down into talc, but in our case no sign of efflorescence has been observed in any bead. Visual observation and optical microscopic research of the beads have demonstrated that they are unaffected by weathering.

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HOLOCENE PALEOENVIRONMENTAL INVESTIGATION OF THE LARIM LAGOON OF THE SOUTHERN CASPIAN SEA

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Keywords: Larim, lagoon, core, sedimentology, Caspian Sea

Introduction

Larim lagoon is located on the southern Caspian Sea coast in northern Iran (36° 43' 73″ N, 52° 56' 44″ E) (Fig. 1). This region generally has a warm humid climate, but the alpine regions of the upland areas to the south possess a semi humid climate with summer temperatures exceeding 34° C. The lagoon is separated from the Caspian Sea by a 1 km wide beach ridge. The area of the Larim lagoon is about 1,430,000 m^2. The average water depth is 4 m; while the maximum depth is less than 8 m. The pH ranges from 7.6 to 8 (Rahimi et al., 2005).

Two main Holocene aeolian units are recognized along the southern Caspian Sea coasts. Mid-Holocene dune belts were formed by beach progradation during a relative sea-level highstand. Detailed facies characterization based upon sedimentology and geochemistry allows reconstruction of the depositional history of these lagoons during the late Quaternary. The late Quaternary evolution of coastal systems in the southern Caspian Sea region has been shown to be controlled mostly by relative sea-level changes.

Figure 1. Location of the study area.

Methodology

A total of 30 sediment samples and 3 cores were taken from the lagoonal basin of the Caspian Sea coast region in April of 2012. Cores were taken from the landward and seaward sides of the lagoon; the maximum length of the cores was 465 cm, and penetration usually stopped when unmixed sand layers were reached. In the laboratory, cores were cut open with a portable saw and the sediment split in half using a metal wire or knife. Cores were logged, photographed, and, from one half of the core, 5-cm-long samples were taken for sedimentologic (texture, composition), mineralogic (XRD), and chronologic (C-

14 dating) analyses. The other half of the core was sealed and kept for reference. One part was used for XRD analysis, and the relative abundance of carbonate minerals was determined using the method of Milliman (1992: 21-29). The surface sediment samples were analyzed by sieve shaker, laser particle sizer, and calcimetry.

Results

The examined sections characterize the structure of different successive Holocene lagoons and provide information on their formation history. A total 10.50 m of core was recovered where the sediment was rich in pore water and therefore had a “soupy” texture. The lagoonal facies succession begins with roots and shells. The sediments of this lagoon are composed of poorly sorted sands and silt rich in articulated bivalve shells. The texture of sediment samples consists of muddy sand, and sediment size decreases from landward to seaward.

Conclusion

Integrated sedimentological and micropaleontological investigations of three cores from the subsurface and 30 surface sediment samples from the lagoon show a vertical cyclic pattern of facies, including lagoonal, shoreline, and a mixture of both facies. The fossil assemblage of these sediments indicates open lagoon conditions during sedimentation, while the top sections were deposited in a shallow, low-energy, closed lagoon.

The overlying sequence of mid- to late Holocene age displays two distinct phases of deposition that can be referred to the Holocene sea-level rise and highstand, enhancing the role of eustasy. This subject shows human migration in this region was related to sea-level oscillations from the mid Holocene to late Holocene.

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PALEOGLACIATIONS IN NORTHEASTERN ANATOLIA AND THEIR PALEOENVIRONMENTAL IMPLICATIONS

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Paleoglaciers are a first-order terrestrial climate proxy for cold and/or wet periods, as well as for episodes of rapid warming during the Quaternary. Rates of deglaciation will help to determine the loss of ice volume, and this information is then directly used to reconstruct rates of climate change and feed-back mechanisms at work during Quaternary climate evolution (e.g., Schlüchter, 2004). Unfortunately, the reconstruction of glacier extensions and ice volume involved during paleoglacier build-up is extremely difficult to achieve, for obvious reasons.

Paleoglacier reconstructions and chronologies in the circum Black Sea area are still incomplete yet very much needed for such a circulation-sensitive area (Ehlers & Gibbard, 2011). We are reporting here on mapping and dating results achieved in the northeastern Kaçkar Mountains of Anatolia. The chronologies are based on extensive dating efforts using terrestrial cosmogenic nuclide methodology.

Sampling in the field was done by traditional methods (with hammer, chisel, and manpower). Laboratory analysis was carried out in the ultraclean cosmogenic nuclide analysis laboratory at the University of Bern for ^{10}Be, ^{26}Al, and ^{36}Cl isotopes. State-of-the-art international standards have been used for the calculations of the resulting surface exposure ages (erosion, snow cover, production rates and scaling factors). The measurements of the actual nuclide concentrations were done at the Accelerator Mass Spectrometry Facility at the Ion Beam Physics Laboratory of ETH Zürich.

The most spectacular results of our research efforts over the past ten years are the simple field evidence for important paleoglacier expansions. The ice age was an important factor in shaping the Anatolian landscape and, most likely, it was a driving mechanism for human cultural evolution. We have focused our investigations on Uludağ (Western Anatolia), Dedegöldağ (Southern Anatolia) and the eastern Black Sea Mountains (the Verçenik, Başyayla, Kavron, and Çoruh valley systems; Akçar et al., 2007; Akçar et al., 2008; Zahno et al., 2009). For the eastern Black Sea Mountains, an interconnected paleoglacier complex could be reconstructed. As a consequence, such a reconstruction requires a careful analysis of atmospheric paleocirculation during the glaciation(s).

Apart from mapping, we have focused on the dating of the major moraine systems in the areas of study. The main results are as follows:

the major moraine systems are related to the Last (Global) Glacial Maximum (LGM) at 20 to 22 ka ago (Shakun & Carlson, 2010).

pre-LGM data are either from weathered bedrock, or from LGM-external glacial landscape elements (Başyayla and Çoruh valleys).

LGM deglaciation started in the Kaçkar Mountains at around 20 ka and as early as 18 ka at Uludağ in Western Anatolia.

Late Glacial glacier advances are recorded in all investigated areas. However, glacial records of the Younger Dryas cooling and of the Little Ice Age need more work, both in the field and in the laboratory.

Important paleoglaciers to the south of the modern weather divide in the Kaçkar Mountains suggest variable atmospheric circulation patterns (with a more easterly component?) during the LGM.

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FORAMINIFERA UNDER CONDITIONS OF HYPOXIA/ANOXIA AT THE ISTANBUL STRAIT'S (BOSPORUS) OUTLET AREA TO THE BLACK SEA

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Keywords: Protozoa, hard-shelled and soft-shelled foraminifera, vertical distribution, abundance, depth gradient

Introduction

The Black Sea contains the world's largest body of anoxic water. In the hypoxic/anoxic transition and permanent hydrogen sulfide zone of the Black Sea, the existence of eukaryotic life has often been challenged, and it has been assumed that anoxia or severe hypoxia may lead to the preservation of non-indigenous organisms. Previous experience carried more conviction of the existence of eukaryotic life in the transition zone between hypoxic, but non-sulfidic, bottom water and the anoxic/sulfidic layer below it in the Black Sea (Yanko and Troitskaya 1987; Sergeeva, 2002; Sergeeva et al., 2012, 2013).

This work continues the study of deep-water foraminifera in the Istanbul Strait's (Bosporus) outlet into the Black Sea, conducted within the framework of the EU 7th FP project HYPOX (Grant 226213). The aim of that study was to understand the response of benthic fauna to oxygen depletion. Earlier, hard-shelled benthic foraminifera in the Bosporus area (depth 80-100 m) were studied (Didkowsky, 1969; Yanko and Vorob'eva, 1991). Benthic soft-walled foraminifera in the Bosporus outlet area had not been studied previously.

Methodology

A twelve-day cruise was carried out on board RV "Arar" from Istanbul University from the 9th to the 21st of November in 2009 in the Istanbul Strait's (Bosporus) outlet to the Black Sea. Geophysical subbottom profiling and sediment coring along depth transects from 70 m to 300 m were conducted. Nine benthic stations were chosen along this transect from the oxic to the anoxic zone. A description of the hydrological characteristics of the study area, a history of studies, and the distribution of meiobenthos was presented in a first paper of a series as part of these studies (Sergeeva et al., 2013).

Samples for biological analysis were collected using a multiple corer and a gravity corer, devices that obtain virtually undisturbed sediment samples. At each station, the sediment cores were sectioned into the following horizontal layers: 0-1, 1-2, 2-3, 3-5, 5-7, and 7-9 cm. All sediment sections were preserved in 75% alcohol, which is known to preserve morphological structures without distortion. We avoided prior fixation in formalin in order not to damage calcareous taxa. The sediments were washed through sieves with a mesh size of 1 mm and 63 µm, and stained with Rose Bengal solution before being sorted in water under a microscope for "live" (= stained) organisms. We extracted only those specimens that stained intensely with Rose Bengal and showed no signs of morphological damage. All of the organisms isolated were counted and identified to higher taxa.

High resolution oxygen profiles (increments of 250 µm) were measured with Clark-type microsensors on retrieved cores from the sediment and the overlying water. The microsensors were mounted on a motor-driven micromanipulator, and data acquisition was performed with a DAQ-PAD 6015 and a computer. Measurements were performed immediately after core retrieval, however, diffusion of atmospheric oxygen cannot be completely excluded, and thus the measured oxygen concentrations might be slightly higher than the *in situ* values. Oxygen measurements were conducted only at three stations (88, 103, and 122 m water depth) as at the remaining stations pebbles and shells, densely covering the sediment surface, impeded the penetration of the fragile microsensors. In the Bosporus area, the intrusion of oxygen-rich Mediterranean water could not be detected during our sampling time, and oxygen was depleted at around 150 m water depth.

Results

In all of the sediments collected from the study area, we found hard-shelled and soft-shelled foraminiferal forms. Among the soft shelled forms, the most frequent were representatives of the genera *Tinogulmia* and *Goodaiya.* The distribution of foraminiferal abundance was irregular along the observed depths (Fig. 1) .

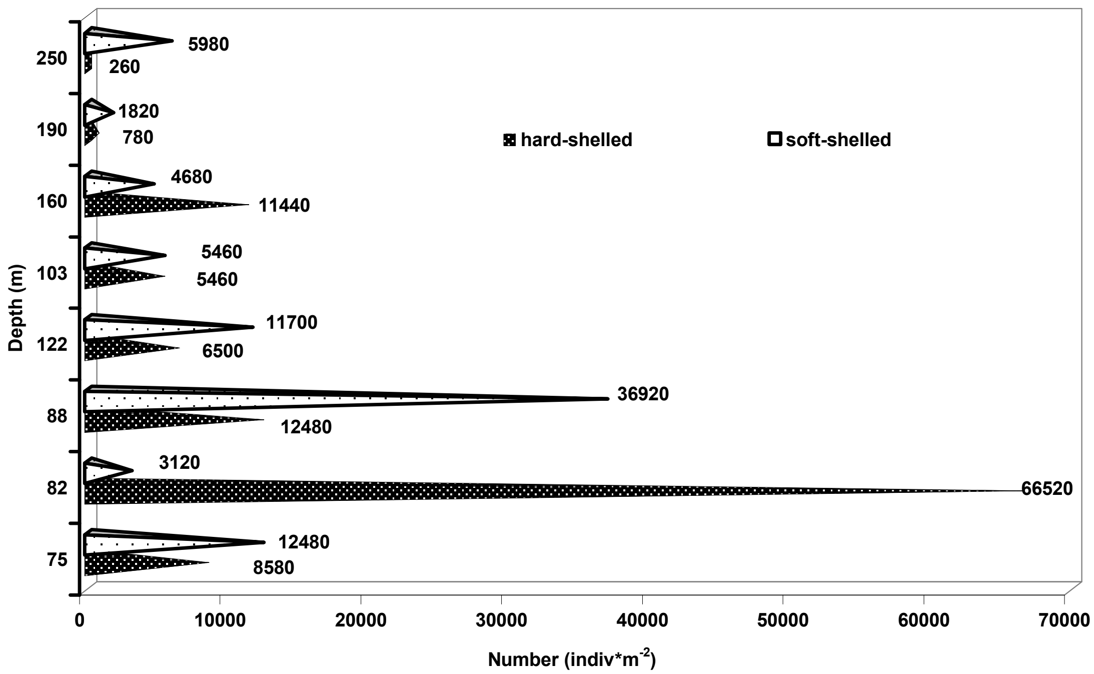

Figure 1. Abundance of foraminifera (hard-shelled and soft-shelled) along the depth gradient at the Bosporus Strait's (November 2009).

Hard-shelled foraminifera, in contrast to the soft-walled, are more numerous at lower depths (75-160 m). At a depth of 82 m, a peak in hard-shelled foraminifera was encountered due to the presence of specimens of *Hyperammina,* new for Black Sea genera. These species have a fragile sandy shell. The largest individuals can be included in the category of macrobenthos. Other quite numerous species were *Ammonia compacta* (Hofker) and *Eggerella scabra* (Williamson). At a depth of 88 m was found the peak in abundance for soft-shelled foraminifera (Fig. 1). Soft-shelled forms were found at all studied depths. At this point, we can identify representatives of the soft-shelled forms *Goodayia rostellatum* Sergeeva, Anikeeva, 2008 and *Tinogulmia* sp. (Sergeeva et al., 2005) as the most tolerant to oxygen deficiency. There exists an opinion that soft-shelled foraminifera tend to be less tolerant of hypoxic conditions than calcareous species in both natural and experimental settings (Moodley et al., 1997; Gooday et al., 2000). The ability to tolerate low-oxygen conditions may be associated with physiological and ultrastructural adaptations developed within particular phylogenetic lineages which happen to secrete a carbonate test (Gooday et al., 2000). Presumably, most soft-shelled foraminiferal species do not possess these adaptations (Gooday et al., 2001).

However, considering that the oxygen penetration depth is limited to the upper millimeters of sediment, and foraminifera inhabit deeper sediment layers as well, we suggest that foraminifera might have the ability to adapt to hypoxic/anoxic conditions within the upper sediment column. If we compare the density and peaks of foraminifera in the different sediment layers, an uneven trend can be detected. Foraminiferal density decreased in the uppermost sediment layer (0-1 cm), correlating with low oxygen concentrations and limited oxygen penetration depth. Foraminifera also inhabit deeper sediment layers. The penetration into the sediment column of soft-shelled foraminifera was limited to a 3-4 cm layer of sediment, though hard-shelled specimens occurred until the 5-7 cm layer (Figs. 2 and 3).

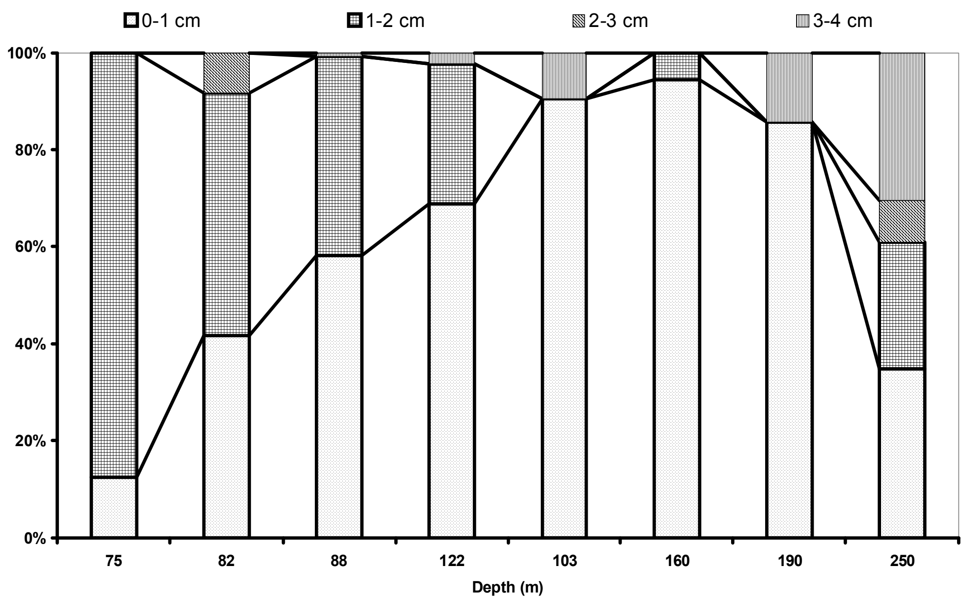

Figure 2. Relative frequencies of soft-shelled foraminifera inhabiting different sediment layers along the depth transect at the Bosporus outlet area of the Black Sea (November 2009).

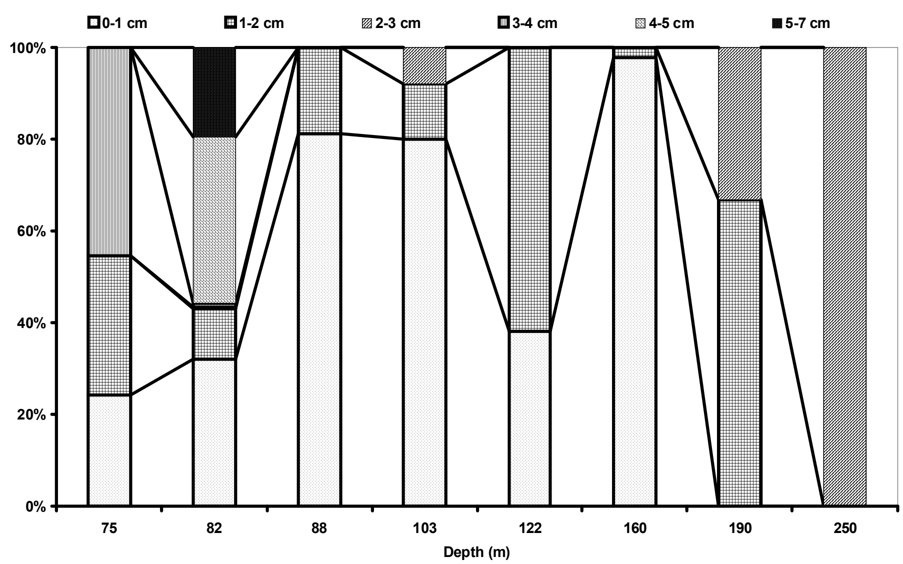

Figure 3. Relative frequences of hard-shelled foraminifera inhabiting different sediment layers along the depth transect at the Bosporus outlet area of the Black Sea (November 2009).

Many aerobic organisms have difficulties living under hypoxic conditions, and this leads to changes in the structure of benthic communities, reduced biological diversity, and in extreme conditions, it leads to the disappearance of a number of aerobic benthic forms. Although foraminifera are found in samples from deeper, anoxic/sulfidic areas, in our samples, high faunal densities were typically observed at water depths where oxygen disappears.

Our data suggest that some benthic eukaryotes can tolerate anoxic and sulfidic conditions. Future studies will yield more information about the taxonomic composition of benthos in the transitional oxic/anoxic water masses of the Black Sea. The specific physiological and biochemical processes that facilitate the survival of eukaryotes in such “extreme” environments are also important questions for study.

Previously, deep water foraminiferal assemblages were indentified for western and eastern parts of the Black Sea (Yanko and Troitskaya, 1987). Our results indicate the differing degrees to which soft-walled and hard-shelled foraminifera have adapted.

Acknowledgments

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MODERN STRUCTURE OF MEIOBENTHOS OF THE NORTHWESTERN SHELF OF THE BLACK SEA

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Keywords: meiobenthos, taxonomic richness, abundance, distribution, Zernov Phyllophora Field, Karkinitsky Bay

Introduction

As a result of eutrophication and irrational use of natural resources in the second half of the last century, the benthic ecosystems of the northwestern Black Sea registered notable changes. Regulation of river flow, hydraulic conversion of the coastal area, sand extraction, etc. led to the changing of abiotic environmental factors, and finally as a result of this, the diversity of macrobenthos decreased, and the structure of meiobenthic communities was damaged (Kaminskaya et al., 1977; Vorob'eva, 1999).

The northwestern part of the Ukrainian shelf includes the water areas of the Zernov *Phyllophora* field and Karkinitsky Bay, which are protected natural areas.

The *Phyllophora* field is a unique accumulation of red algae (water-plant) located in the center of the northwestern part of the Black Sea. Enormous supplies of *Phyllophora* in the 20th century resulted in a sharp decrease in its biomass in the mid-1970s, and in the 1980s-1990s, this figure was reduced to 300 thousand tons (Kalugina-Gutnik and Evstigneeva, 1993). Compared to the 1960s, species composition of the algae was reduced more than three times, and *Phyllophora* abundance and biomass were reduced 100-150 times. Degradation of the *Phyllophora* biocenosis may be related to the influence of river runoff from the Danube, the Dnieper, and the Dniester (Zaitsev et al., 1985). In 1991, meiobenthos of the soft bottom sediments of the Zernov *Phyllophora* field comprised 13 high hydrobiont taxa, and its density was more than 760 thousand ind./sq. m. A complex of Foraminifera-Nematoda dominated the mean density in the most persistent part of the meiobenthos of the Zernov *Phyllophora* field (Sergeeva and Mazlumyan, 2002).

Karkinitsky Bay is a very important area for Ukraine; it is a region of high biological and recreational resources. It serves as the main habitat of sturgeon in the northwestern part of the sea. In the area is situated the Reserve "Swan Island" and aquatic complexes, where there are valuable balneologic resources. Despite the existence of protected waters, the Bay is experiencing significant anthropogenic stress in connection with activities in its coastal zone, which supports large industrial and agricultural enterprises.

To date, the meiobenthos of Karkinitsky Bay (Garlitskaya, 2010; Sergeeva et al., 2012) and *Phyllophora* field (Sergeeva and Mazlumyan, 2002) and adjacent areas, is not enough studied. Now, the modern taxonomic structure and distribution of meiobenthos inhabiting the soft bottom sediments of the northwestern Black Sea are being studied, paying special attention to the meiobenthos of Zernov *Phyllophora* field and Karkinitsky Bay.

Methodology

The material for the study were bottom sediments from 27 stations during the 68th and 70th cruises of R/V "Professor Vodyanitsky" in October - November 2010 and August 2011 (Fig. 1). The meiobenthos was studied from sites between 10 to 50 m in water depth. Samples were taken by bottom grab "Ocean 50," and using meiobenthic tubes, 3 columns of 18.1 m^2 of bottom area were cut. Sampling material was analyzed in the laboratory of the Department of Ecology of Benthos in IBSS.

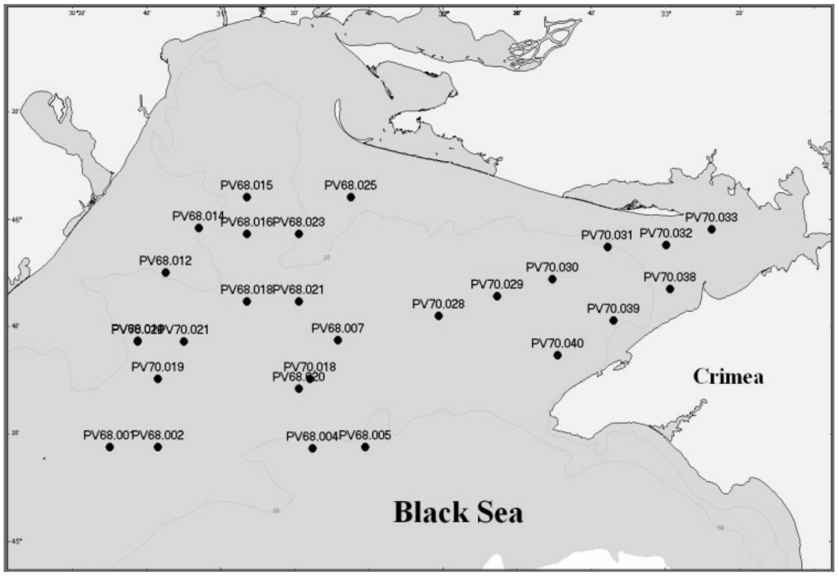


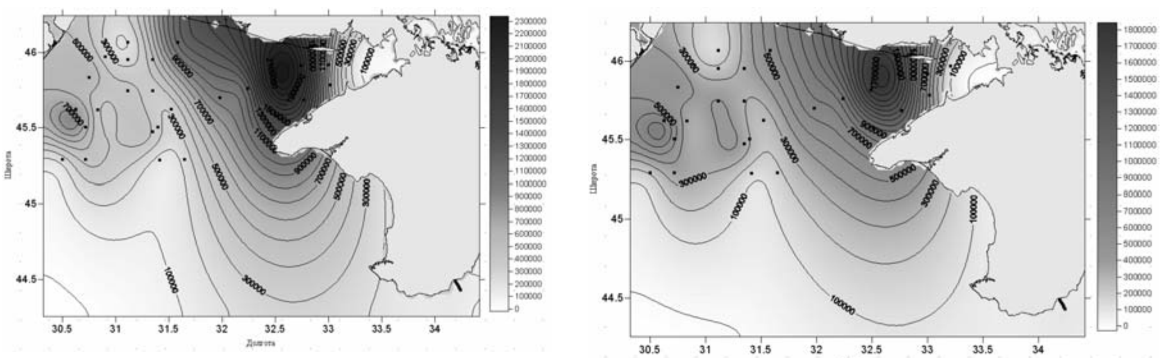
Figure 1. Benthic stations in the northwestern part of the Black Sea (2010 and 2011).

Results

Within meiobenthos, we include Protozoa and multicellular animals, as is the practice for researchers of meiobenthic communities (Galtsova, 1991; Higgins and Thiel, 1988). In total, 22 higher taxa of the representatives of meiobenthos were found (phylum, class, order). Among the eumeiobenthos were found Gromiida, Ciliophora, Foraminifera, Nematoda, Harpacticoida, Ostracoda, Acari, Kinorhyncha, and Tardigrada. Among the pseudomeiobenthos were found Polychaeta, Oligochaeta, Turbellaria, Nemertini, Bivalvia, Gastropoda, Coelenterata, Decapoda, Isopoda, Amphipoda, Cumacea, Ophiuridea, and Chironomida. In Karkinitsky Bay, 20 higher taxa were recorded, and within the *Phyllophora* field, 22 taxa.

Meiobenthos in the investigated periods included representatives of the eu- and pseudomeiobenthos. At all stations, eumeiobenthos dominated in numbers; pseudomeiobenthos (juvenile stages of macrobenthos) accounted for no less than 13%.

The distribution of meiobenthos in general and its leading groups are given in Figs. 2-5.



a b

Figure 2. Average density of all meiobenthos (indiv. m^{-2}) (a) and free-living nematodes (b) in the study area.

The distribution of meiobenthos and nematodes is not homogenous. The placement of isobentihc lines of meiobenthos and nematodes have the similarities, indicating that the primary role of nematodes is within the meiobenthos community. In Karkinitsky Bay, the core concentration is confined to the middle of the bay, where the most stable habitat is located.

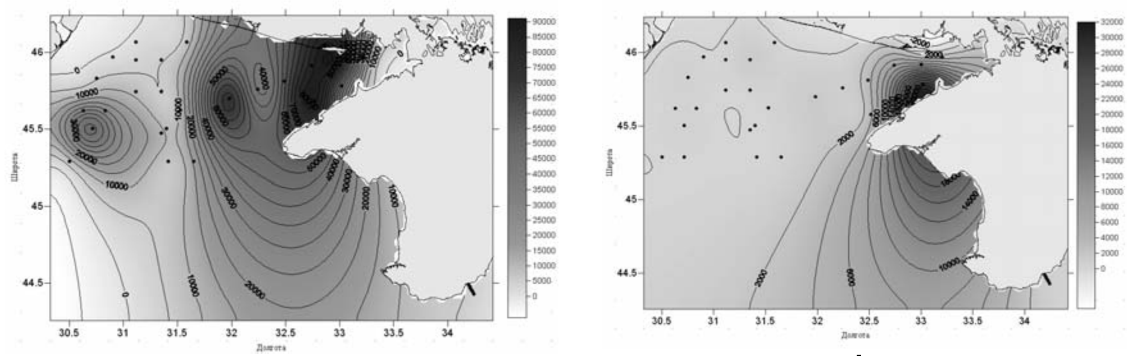


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Figure 3. Change of density (indiv. m-2) of Harpacticoida (a) and Coelenterata (b) in the study area

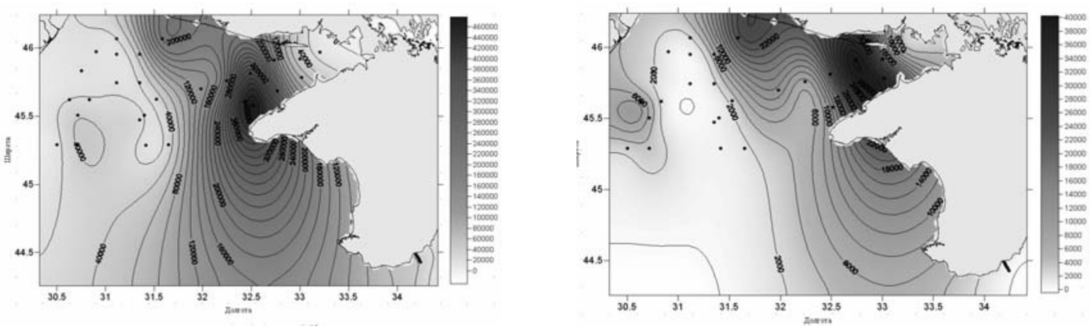

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Figure 4. Change of density (indiv. m-2) of Foraminifera (a) and Ostracoda (b) in the study area.

There are distinct differences in the distribution of the other groups of meiobenthos. The highest population density of Harpacticoida was recorded in the middle of the bay and out to sea. It is noteworthy that the bulk of the Coelenterata is formed by *Protohydra leuckarti* Greef, not previously noted in the northwestern part of the Crimean coast (Sergeeva, 2006). Its population is located in the southeastern part of Karkinitsky Bay, but also representatives were first found in the *Phyllophora* field.

The distributions of Foraminifera and Ostracoda are different. The highest population density of the first group is more to the west of the investigated area, while the concentration of the second group is confined to the middle part of the bay. The main group of the Foraminifera are the soft-shelled foraminifera (Allogromiida). Previously, these aquatic animals were not known from this area. For the first time, 5 species of Tardigrada were found in the study area (Kharkevych, 2012).

Among the eumeiobenthos, the leading group is Nematoda in all investigated areas. At different stations, a great part of the meiobenthic community is from Ciliophora, Foraminifera, and Harpacticoida. Among the pseudomeiobenthos, there is more of a mixed picture among the different groups.

During the last 20 years, there have been changes in the meiobenthic complex of Zernov *Phyllophora* Field. In the 1990s, the dominant groups in the complex by average density were Nematoda and Foraminifera. To date, our data show that the complex of Nematoda-Foraminifera has changed to a Nematoda-Harpacticoida complex. Also, we recorded an increase in the average abundance of meiobenthos from 760 thousand ind./sq. m in 1990s to 820 thousand ind./sq. m in 2010-2011. The distribution of meiobenthos in the *Phyllophora* field as in Karkinitsky Bay is determined by the following factors: the presence of oxygen deficiency, state of the *Phyllophora* population, and the composition and density of the macrobenthos.

Conclusion

Meiobenthos of soft substrate in the study area has high taxonomic richness and density. Eumeiobenthos dominates in the meiobenthos community. The ratio of the distribution of major groups of meiobenthos depend on the environmental conditions, and they change across the study area.

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THE LOWER DNIESTER – LOWER DNIEPER REGION DURING THE BOREAL PERIOD OF THE HOLOCENE: HUMAN ADAPTATION TO ENVIRONMENTAL CHANGES

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Keywords: Lower Dniester, Lower Dnieper, human adaptation, Boreal, Anetivka, Grebeniki

Introduction

The territory located between the lower valleys of the Dniester and Dnieper, the biggest rivers of the northwestern Black Sea region, is traditionally viewed as the embodiment of the most typical features of the inner Pontic steppes, their paleogeography, and landscapes. This region demonstrates the most characteristic features of the exploitation system for life in the steppes. Moreover, it occupied space where the continuity of economy and the evolution of ethnic culture was displayed in the fullest measure during the entire Mesolithic, demonstrating no clear tendencies toward the transition to a productive economy even in its most recent phases.

Paleogeography

There are certain limitations to the evidentiary sources for the reconstruction of this region's fauna and flora insofar as most of the Late Mesolithic sites are represented by surface finds with no clearly stratified cultural layers. Also, currently available spore-pollen diagrams of Early Holocene subaeral alluvial sediments as well as those of swamps and estuaries have no associated chronometric chronology. So, high-resolution modeling of the paleogeographic situation in this region has been the subject of further investigation. Analysis of available evidence for the resource base (Smyntyna 2004: 64) allows one to assume that open steppe landscape was the dominant feature within the broad space of the Dniester-Dnieper interfluve during the Late Mesolithic. The proportion of grasses in the vegetation sometimes reaches 80-90%, and among them, species adapted to arid conditions absolutely prevailed. The proportion of Chenopodiceae, Artemisiae, and Graminae taken together could be as much as 40-70% of all grasses. Most widespread (if not the only) faunal inhabitants there were horse (Equus caballus L. and Equus gmelini L.) and ass (Asinus hydruntinus L.), bones of which were found at the two largest Late Mesolithic settlements of this locale – Grebeniki and Girzheve (Stanko, 1966).

At the same time, in all spectra without exception there is a definite increase in the proportion of arboreal vegetation in comparison with the previous period. In this category of flora, the percentage of deciduous species augments considerably. So, the proportion of oak (Quercus sp.), elm (Ulmus sp.), linden (Tilia), and other deciduous species, taken together, sometimes reaches 25% of the total arboreal pollen. Nevertheless, pine (Pinus silvestris) and birch (Betula sp.) remain the leading arboreal species in the steppe zone (Artyushenko, 1970: 47-51, 60-61, 90-93; Neishtadt, 1957: 69-71). The aurochs (Bos primigenius Boj.), which gradually disperses to the west, has become the most typical inhabitant of these semi-closed locales. Most probably, afforested areas were mainly associated with the flows of large and secondary rivers as well as with springs. In the Boreal period, the activity of these waterways considerably intensifies in line with the general tendency of climate changesin the Black and Mediterranean seas

Therefore, there are serious grounds to consider that during the Boreal, total vegetative and animal biomass of the Dniester-Dnieper living space increased in comparison with the previous, dry and cold Preboreal period.

Population density, settlement pattern and subsistence strategy

An enrichment in food supply contributed to the growth of population density, which was mirrored in the sharp increase in settlements in this region. Nevertheless, the basic mode of life of the steppe inhabitants did not principally change. Just as was the case during the Early Mesolithic, briefly occupied sites represented by extremely small quantities of flint artifact surface finds still remain the leading type of archaeological site in this region (Smyntyna 2007: figure 2). Only three sites found here (Abusova Balka, Grebeniki, and Girzheve) could be conditionally interpreted as seasonal settlements regarding the character and quantity of their artifacts. Nevertheless, no diagnostic cultural layer nor interior structures or architectural remains were traced at these settlements.

Such a settlement system implies a high level of mobility for the local population, which must have preferred an extensive method of resource exploitation. This is why one can observe here the highest quantity and density of evidence relating to the movements of small groups together with the complete absence of durable settlement occupation in the Ukrainian steppe.

This pattern of occupation correlates well with the peculiarities of a local subsistence strategy fully based on hunting. The central place within the range of available game species was taken by non-gregarious animals – aurochs were the most fruitful prey for hunting by individuals or small groups using projectile devices with sighting capabilities. Horses were represented in the bone assemblages of Grebeniki and Girzheve, and this suggests that these sites were exploited as central locations for short-term population agglomeration for collective procurement of gregarious animals in the northwestern Pontic steppes.

The presently available resource base gives no reasons to assume that the inhabitants of the Lower Dniester - Lower Dnieper were transitioning to a productive economy: in contrast with the Late Mesolithic population of the Lower Danube region, no signs of domestication of animals or plants could be traced in the region under study.

Flint assemblages

Distribution of different flint-knapping traditions in the lower Dniester-Dnieper region, as it seems now, is also connected with the extensive character of the exploitation strategy. The extraordinary situation in this region during the Late Mesolithic is that groups using two different technocomplexes (Anetivka and Grebeniky cultures) settled here side by side, and in some cases, their sites were arranged in immediate proximity.

The Grebeniky technique of primary flint processing is based on flattened nuclei and characterized by a dominance of thin prismatic blades with thin cross-sections; in the tool complex, small circular end-scrapers absolutely prevail, high trapezes are practically the only type of geometrized inserts. The full absence of micropoints and non-geometric microliths is typical for the Grebeniky industry. For the Anetivka technocomplex, by contrast, diverse types of retouched micro-blades and backed blades are typical; the most characteristic forms of tools are blades with ventral processing and burins on massive debitage flakes.

The two cultures jointly exploited this living space, and did not divide it up into areas of influence. Moreover, the locale has become the birthplace of both traditions, each one of which has local ancestors. The formation of both cultures is the result of a gradual evolution of the local Early Mesolithic flint processing traditions. Now, is it beyond doubt that it was the Tsarinka-Rogalik Preboreal cultural circle that was the origin for the Grebeniki technocomplex. In the Anetivka Late Mesolithic culture, all the principal peculiarities of flint artifact morphology inherent to the Preboreal phase of this culture were preserved (Stanko, 1991).

Discussion and conclusions

During last decade, two basic questions have been discussed in relation to the ecological interpretation of the Late Mesolithic of the inner northwestern Pontic region. One of them is connected with the attempts to explain such a unique co-existence of two different flint-knapping traditions and joint exploitation of the same living space by their representatives. In this context, the attention of most researchers has been paid to the intensive interaction of these populations, which actually starts from the moment of their first appearance during the Dryas III and Preboreal periods of the Holocene (Kovalenko and Tsoy, 1999: 259). It should be stressed that traces of such interactions to some extent can be seen also in the assemblages of other regions of the Ukrainian steppe.

As it seems now, the intensive inter-penetration of different cultural traditions became possible due to two circumstances. On one hand, their ancestors' long-lasting existence side by side contributed to it greatly. On the other hand, the high mobility of the Anetivka and Grebeniki populations should not be underestimated because it was just this mode of life that caused the numerous multi-level contacts. Their peaceful nature led to a definite improvement in the food supply. As a whole, irrespective of any concrete interpretation of the course and consequences of Anetivka and Grebeniky culture interaction in the Dniester-Dnieper area, the fact that the local population developed a peculiar understanding of their living space is beyond doubt. Such an understanding was based on a joint exploitation together with their neighbors since earlier times and it brought about an improvement in their extensive means of resource procurement. The second central point of discussion about human exploitation of the Dniester-Dnieper area during the Boreal period is connected with our understanding of the mode of life, system of occupation, and procurement as a response to environmental changes in the northwestern Pontic region at the Pleistocene-Holocene boundary. Proponents of the so-called 'catastrophic flood' scenario of the northwestern Black Sea shelf suggest that a rapid rise in the level of the Black Sea practically desolated the local population that had settled there living on agriculture and cattle breeding which they brought from the west (Ryan, 2007; Zalizniak, 2005).

State-of-the-art archaeological site studies of the Late Mesolithic in the Dniester-Dnieper area give no signs of this region's desolation nor the penetration of immigrant culture groups nor the transition to a productive economy. As the number of known archaeological sites has risen, the roots of flint production techniques were easily found in the local Early Mesolithic assemblages, and the subsistence system was understood as based on the extensive exploitation of local gregarious and non-gregarious game. So, the local population apparently continued its history in the region under study, successfully and logically adapting to non-catastrophic climate changes and a non-catastrophic rise in the level of the Black Sea.

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HUMAN RESPONSE TO CLIMATE CHANGES IN THE NORTHWESTERN PONTIC REGION AT THE PLEISTOCENE-HOLOCENE BOUNDARY: AN APPLICATION OF ENVIRONMENTAL STRESS THEORY

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Keywords: Stress theory, stressors, northwestern Pontic region, Mesolithization, adaptation

Introduction

At the start of this new millennium, it is practically conventional to recognize the extreme importance of stress on the psycho-physiological processes of the contemporary human body and on cultural behavior. Recent developments in the ecological paradigm within historical studies have made it possible to use stress theory to study some issues involving the origin of *Homo sapiens sapiens* and its social organization as possible explanations for paleohistorical stadiality, in interpreting the origins of new economic forms, etc.

Peculiarities of the paleogeographic history of the Pleistocene have led us to assume that environmental stresses should be regarded as one of the basic reasons for changes in the behavior of prehistoric humans and the elaboration of new adaptive modes of life as well as the foundation for cultural transformations.

The purpose of the current contribution is to discuss the principal points of environmental stress theory as it is applied to the interpretation of human responses to global climate changes in the northwestern Pontic region at the Pleistocene-Holocene boundary.

Stress theory: basic points

Stress is regarded as a basic reason for the transformation of behavior as well as an important premise for the reshaping of cultural systems and the creation of new adaptations (Brothwell 1997: 7-8). Traditionally, stresses and stressors (factors causing stress) are characterized through their classifications. In the English-language literature, differentiation of stresses based on their spheres of influence and the potential for overcoming them is one of the most popular classifications. In such a context, three kinds are distinguished: system stresses in which physiological components dominate, psychological stresses in which behavioral and emotional components dominate, and ecological stresses that combine system and psychological components (Bell et al., 1996: 131). Soviet researchers preferred a classification of stresses and stressors as having evolutionary, social, and technogenic origins (Khlebovich et al., 1975: 155-157).

Environmental stress is highly ranked by proponents of both approaches. It is understood mostly as a series of natural, social, economic, psychological, and physiological factors that cause tension in regulatory mechanisms and disturb society or the dynamic equilibrium of a social organism. The special concept of social and ecological resilience was introduced in order to estimate the capacity of a community to overcome external stresses, and a series of factors that helps to increase resilience was outlined (Adger, 2000: 347, 349, 354).

The result of the general theory of stress development is the creation of a great diversity of models of stress and, in particular, patterns of stress display in archaeological human populations (Dincauze, 2000: 486). Unfortunately, these models, as well as the simulations of "new archaeology," are often characterized by an abuse of generalized and sometimes indefinite concepts and terms, such as "individual growth rate change," "decrease of health," "buffer role of culture strengthening," and so on. Taken on their own, these notions hardly contain the information necessary for a thorough comprehension of the ecological implications of the mode of life among prehistoric societies. Moreover, the proponents of this approach sometimes tend to stereotype and excessively generalize about processes that took place in the distant past.

On the other hand, this theory has greatly contributed to the development of an environmental mentality through its attention to stresses inherent within human society. In the framework of this theory, adaptation is regarded as only one possible result of the impact of stressors alongside other potential human responses to environmental stresses, such as regulation, adjustment, and cultural system destruction.

The northwestern Pontic region at the Pleistocene-Holocene boundary: stressors, stresses, and human responses to them

Comprehensive interdisciplinary studies of the paleogeography of the northwestern Black Sea region at the Pleistocene-Holocene boundary provide no doubt that this period was marked by a series of drastic climatic and environmental changes. Most researchers agree that the principal changes in the fundamental paleogeographic components, including overall dry land and marine landscape, took place at least three times during the Allerød, Dryas III, and Preboreal. Major discrepancies here are concerned with the interpretation of their scale and extent of their influence on the mode of life, subsistence strategies, and social adaptations of humans. Basic versions of such interpretations vary between two main controversies: the Black Sea Flood hypothesis and that of gradual human adaptation to global environmental changes. These two hypotheses imply, in their turn, principally different understandings of the Black Sea basin's shelf and adjacent dry land at the Pleistocene-Holocene boundary.

From an archaeological point of view, three basic sets of stressors influenced the human procurement system and social behavior in the northwestern Pontic region at the time. The first and most significant of them was the transformation of the faunal complex resulting from unsustainable human behavior during the LGM, i.e., bison overkills complicated by the high population density in the region during the Late Paleolithic (Bibikova, 1978). Replacement of bison and horse herds by aurochs and smaller horses at the beginning of the Holocene implies a transition from collective procurement of large gregarious game toward hunting for small non-gregarious species conducted mainly by small groups or individuals. In its turn, it stimulated a re-shaping of traditional tool kits among the inhabitants of the North Pontic steppes (initially, their hunting weapons and tool inventory for game butchering and further processing) and re-structuring of their social groups: there was no longer a need for collective agglomeration around large game kills, even for short periods of time at the beginning of the Holocene.

Reduction in the number of archaeological sites across the landscape, disappearance of large long-lasting settlements, absolute predominance of short-term sites, and preponderance of bones from small non-gregarious game in faunal assemblages implies significant reduction of population density, increase in mobility of separate groups, and formation of a dispersed occupation system based on an extensive economy during the Dryas III-Preboreal interval. These tendencies are in full conformity with modifications in the character of tool processing and functional characteristics. Such changes in social behavior and mobility were accompanied by a transformation in tool production strategy within the flint industries of local populations. Traditionally, these phenomena imply the beginning of a new stage of human history: the Mesolithic one.

The second set of stressors influencing human populations of the northwestern Pontic region at the Pleistocene-Holocene boundary should be connected with the rise in the level of the Black Sea and coastline migration. It needs to be stressed that, in the case of the dry Pontic steppes, the formation and early activity of its estuaries (lakes and limans) and watercourses (rivers, springs, etc.) are equally if not more important than Black Sea shoreline migration. Re-shaping of the hydrological network together with the new configuration of the Black Sea coast and adjacent dry lands created new forms of living space which needed to be explored by the local populations. Occupation system, choice of settlement space, possibility of contacts among groups inhabiting different niches, and other traits of human spatial behavior on the macro-level (living space exploitation system) were determined in many respects by these features.

The third basic set of environmental stressors in the northwestern Pontic region at the Pleistocene-Holocene boundary is the dynamic of floral complexes and species composition, which usually is regarded as a product of the climatic oscillations that took place during the Last Glacial retreat (Artyushenko, 1970). In spite of the major importance of plants in the diet of most prehistoric huntergatherers, this phenomenon probably had little direct impact on human diet in the study area at the time in question. There are very few archaeological records indicating plant use for food, and those that exist originate mainly from the Late Mesolithic settlement at Myrne. In this area, flora influenced human resource procurement strategies through being the basic food of the animals they hunted, that is, vegetation changes were stressors because they brought about faunal changes.

Conclusions

Complex analysis of the basic stressors influencing mode of life and social behavior of human populations in the northwestern Pontic steppes at the Pleistocene-Holocene boundary allows the detection of four stages of environmental stress development in this region.

The first indicators of ecological crisis in the region under study are associated usually with the LGM and its subsequent development through time, traditionally correlated with stages of the Last Glacial retreat. The rapidity of the deglaciation process in most cases makes it impossible to detect direct evidence of the stressors simultaneously in paleogeographic records and in the remnants of human activity.

The second basic phase of environmental stress could be correlated with the Allerød oscillation of the late glacial period, which is relatively well represented in environmental records but is characterized by very poor archaeological evidence.

The Dryas III-Preboreal is the third basic phase of ecological stress displayed in the archaeological and paleogeographical records of the northwestern Pontic region. It correlates well with Black Sea level changes and coastline migrations in the course of the final Neoeuxinian transgression of the late Pleistocene-early Holocene, phases of which correspond with the main climatic stages of this period.

The later phase of the Boreal period is the fourth and last phase of environmental stress in the northwestern Pontic region. This phase resulted in a fundamental transformation in the human mode of life and subsistence strategy in the region, opening a new stage connected with the introduction of a productive economy.

These phases in the development of environmental stresses, nevertheless, cannot be recognized as catastrophic ones for the human population: no signs of total desertion of the northwestern Black Sea steppes as well as no traces of human failure to find suitable means to overcome the stressors are observed at Late Paleolithic and Early Mesolithic sites. Negative influences of global climate changes were successfully compensated already in the short-term perspective through a broad spectrum of adaptive strategies, most important among which were transformation of living space exploitation and modification of tool kits.

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THE KERCH-TAMAN VOLCANIC PROVINCE: MICROBIOTA FROM "THE ATMOSPHERE—VOLCANIC MUD DISCHARGE" CONTACT ZONE

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Keywords: ***mud volcanoes, alkaline lakes, nitrogen cycle, anaerobic ammonia oxidation***

Introduction

The study of mud volcanoes on the Crimean and Taman peninsulas and in the Kerch Strait gives important information about geophysical changes and degassing of the Black Sea (Shnyukov et al., 1986; Shnyukov and Yanko-Hombach, 2009). On the surface of the earth, volcanic mud discharges, oil shale, clay and hydrogen sulfide emissions, various gases, and mineralized water make contact with the atmosphere. Different chemical and microbiological processes take place in the biotopes formed within these contact zones. The biological cycle of nitrogen—the main element of the Earth's biosphere—is the most interesting for study.

In the course of the evolution of the Earth's ecosystem involving the transition from an anoxic to oxic environment, the nitrogen cycle has suffered drastic changes under human impact. Changes in atmospheric composition have influenced peculiarities of (1) nitrogen fixation and (2) recycling of ammonium from anaerobic ammonium oxidation (anammox) to oxygen-dependant nitrification. Anammox involves the anaerobic oxidation of ammonium to nitrogen using nitrites (Cabello et al., 2009). In this study, the dominant groups of microorganisms of the nitrogen cycle involved in the contact zones between the atmosphere and volcanic mud discharges of different composition were studied.

Methodology

On the Kerch Peninsula, samples were taken from the mud volcano Nasyrsky (N45°17'27.0"; E35°40'54.9") and the alkaline lake (N45°17'30.0"; E35°40'57.5") located north of the volcano (Fig. 1, point 1). Petroleum fraction of clay and water from volcanic mud. Samples of semi-liquid black mass saturated with hydrogen sulfide were taken from the active Bugarsky volcano on the Taman coast of the Black Sea (Fig.1, point 2).

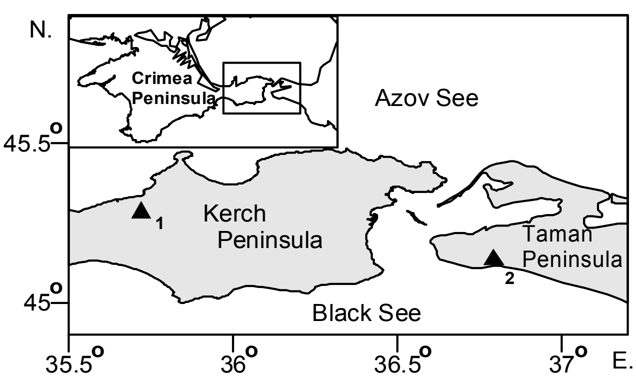

Figure 1. Map of the Kerch-Taman volcanic province and location of the study area.

Microbiological investigations were based on the culturing of samples in different physiological media and their analysis by standard light microscopy. Some chemical elements were determined using a spectrophotometric method.

Results

It can be noted that the pathways of the main processes in the biological nitrogen cycle—recycling of ammonium and nitrogen fixation—are different in the investigated biotopes. The quantitative distribution of microorganisms within the nitrogen cycle is represented in Table 1.

Table 1. Some biotic and abiotic parameters in the investigated biotopes.

Physiological groups of microorganisms	The abundance of microorganisms, cells (gram dry weight)$^{-1}$		
	Volcanic mud containing hydrogen sulfide (Taman)	Alkaline lake, bottom deposits	
		Top layer	At 0.3 m depth
Ammonificating	$>2.5 \cdot 10^6$	$4.2 \cdot 10^2$	$1.1 \cdot 10^3$
Ammonium oxidizing	0	$2.5 \cdot 10^3$	$2.5 \cdot 10^3$
Nitrite oxidizing	0	$1.4 \cdot 10$	$2.5 \cdot 10^2$
Denitrifiers	$2.5 \cdot 10^8$	$2.5 \cdot 10^8$	$2.5 \cdot 10^8$
Nitrogen fixing	$2.5 \cdot 10^5$	0	0
Chemical parameters			
pH	7.1	More than 9.5	7.3
Salinity, ‰	10.5	14.3	8.4
Corg, %	3.3-3.7	5.5-5.8	1.7-1.4

In the alkaline lake, aerobic processes are dominant. There is oxidation of ammonium (oxygen-dependant nitrification) and fixation of nitrogen by filamentous cyanobacteria (genus *Nostoc*). Nitrogen-fixing bacteria at the surface and at depth within the lake bottom deposits were absent.

In the black mass, saturated with hydrogen sulfide (Eh – 408.5mV), ammonium oxidizing and nitrite oxidizing bacteria were absent. In this biotope, anaerobic ammonium oxidation (anammox) was noted. The pathways of nitrogen fixation in the transition of reduced gases into the aerobic zone (atmosphere) were connected with the live-activity of unicellular cyanobacteria and nitrogen fixing bacteria. It is known that these bacteria have Fe, Cu-containing enzymes **(**Cabello et al., 2009**)**. Chemical analysis of samples permitted the measurement of average concentrations (microgram per kilogram): Fe = 996.0; Zn = 60.0; Cu = 26.5; Pb = 11.14; Cd = 0.80 in the Bugarsky volcano. Discharges were 1.5 to 2.0 times higher than in the alkaline lake and Nasyrsky volcano.

Thus, quantitative and species composition of the microbiota are connected with peculiarities of the chemical nature of the volcanic mud. The contact zone between the atmosphere and the volcanic mud discharges saturated with hydrogen sulfide (Bugarsky volcano on the Taman Peninsula) can be useful as a model for studies of the key processes of the nitrogen cycle and diversity of microbiota at the oxic/anoxic interface.

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CHANGING BIOGEOGRAPHIC IDENTITY: MEDITERRANEAN VS PONTOCASPIAN MOLLUSK TURNOVER IN THE RECORD OF GEMLIK BAY MARKS THE POST-GLACIAL MARINE INUNDATION OF A SECLUDED EMBAYMENT OF THE MARMARA SEA

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Keywords: Pleistocene, Holocene, Pontocaspian mollusks, biogeography, Marmara, Mediterranean

The Pontocaspian fauna, inhabiting at present the Caspian Sea and lagoonal habitats of the Black Sea, is interpreted as a post-Miocene relic of faunal radiations in anomalohaline lakes of central-eastern Europe and adjacent areas. The Late Pleistocene Pontocaspian fauna that occupied the Black Sea basin between ca. 8-16 ka is referred to as Neoeuxinian fauna. The mollusk component of such fauna appears dominated by dreissenid and lymnocardiine bivalves and hydrobioid gastropods, and it includes species nowadays endemic to the northern and western coastal lakes and estuaries of the Black Sea as well as other species that also inhabit the Caspian Sea (Fig. 1).

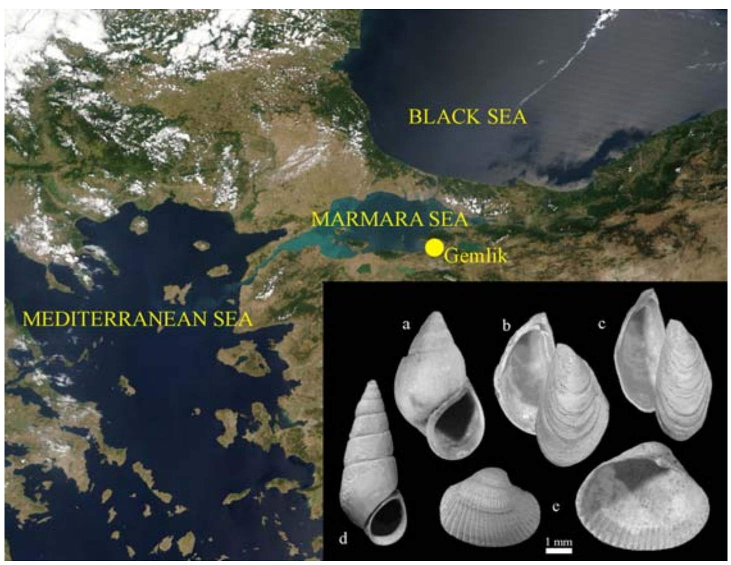

Figure 1. Map of the Mediterranean-Marmara-Black Sea region showing Gemlik Bay; inset: emblematic Pontocaspian Neoeuxinian mollusks recovered from sedimentary cores in Gemlik Bay: (a) *Lithoglyphus naticoides*, (b) *Dreissena bugensis*, (c) *D. caspia*, (d) *Micromelania lincta*, (e) *Monodacna pontica*.

A Neoeuxinian, dominantly-Pontocaspian molluscan fauna is documented from sediments cored in the shallow-silled (ca. 50 m) Gemlik Bay of the Marmara Sea in ~75 m of present water depth (cruise MARM05). The age of such fauna is Late Pleistocene as determined by AMS-^{14}C dating of Pontocaspian gastropods (15860±90 BP, uncal).

The fossil molluscan fauna is relatively diverse (10 taxa) and made up of neritid and hydrobioid gastropods, and dreissenid and lymnocardiine bivalves. The faunal stock comprises the following lacustrine-brackish taxa: *Theodoxus* sp., *Theodoxus fluviatilis* (Linné, 1758), *Theodoxus* cf. *subthermalis*

Bourguignat, 1865, *Micromelania lincta* (Milaschewitsch, 1908), *Clessiniola variabilis* s.l. (Eichwald, 1838), *Lithoglyphus jahni* Urbanski, 1975, *Monodacna pontica* Eichwald, 1838, *Dreissena polymorpha* (Pallas, 1771), *D. caspia* Eichwald, 1855, and *D. bugensis* Andrusov, 1897.

Several indications exist that the modern Pontocaspian taxa in the coastal zones of the Black Sea originate from Caspian ancestors that invaded the Black Sea basin during a number of overspills in the Late Pleistocene, the latest of which was only 13-16 ka. The presence of hitherto poorly known Pontocaspian taxa in the Marmara Sea, further documented by our record in Gemlik Bay, seems to document that the Euxinian Sea extended south of the Bosphorus. Further, they give insight into the origin of the modern Black Sea Pontocaspian taxa and whether these diverged after their arrival as Caspian taxa. Noteworthy, the Gemlik Neoeuxinian lacustrine-brackish fauna under scrutiny is the westernmost expansion of the Pontocaspian domain so far known.

This distinct biogeographic faunal affinity with all its obvious eastern implications in terms of landscape and seaway connections, came to an end with the abrupt marine inundation that accompanied the postglacial sea-level rise from the Mediterranean Sea.

In fact, the marine muds superimposed atop the Neoeuxinian lacustrine-brackish sedimentary units contain abundant Mediterranean fully-marine mollusks, dominantly infralittoral gastropods (*Turritella communis* Risso, 1826), and bivalves (*Corbula gibba* Olivi, 1792), this latter dated by AMS-^{14}C at 10810.5 ± 219.5 cal BP.

The postglacial sea-level rise therefore marked the shift of Gemlik Bay in the Marmara Sea from the Pleistocene Pontocaspian to the current Mediterranean biogeographic domain, which also extends well into the Black Sea.

THE INFLUENCE OF GLACIAL LAKE AGASSIZ ON OCEANS, CLIMATE, AND HUMANS AROUND THE WORLD

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Key words: late glacial, freshwater, glacial runoff and precipitation

The abrupt introduction of freshwaters into the North Atlantic Ocean during the late glacial is considered to have been the trigger for changes in ocean circulation and, in turn, climate. Reservoirs of water in lakes along the margin of the Kara and Barents ice sheets in Eurasia were envisioned by Grosswald (1980) as providing large influxes of water. At times, glacial runoff and precipitation from a large area of western Asia were routed into the Aral, Caspian, and Black Sea system, including through the Manych Spillway between the Caspian and Black Seas (e.g., Chepalyga, 2007; Yanko-Hombach et al., 2011), and then into the Mediterranean Sea and Atlantic Ocean. However, research by the QUEEN project concluded that the extent of the last Eurasian ice was not as expansive as postulated in Grosswald's reconstructions (e.g., Svendsen et al., 2004), and Late Weichselian meltwater could not have been responsible for most geomorphic forms along the Aral-Caspian-Black overflow pathways, and would not have played a role in altering late glacial thermohaline ocean circulation and climate. However, Chepalyga (2007) identified a "great flood" from the Caspian Sea basin just after the LGM, and that may have helped shape the Manych Spillway; given that the Black Sea was not overflowing at that time, the "flood" may have raised the level of the Black Sea, although apparently those waters were not enough to have influenced ocean circulation and climate. It is possible that meltwater from a network of ice-marginal lakes along a more expansive *Early* Weichselian ice sheet played a role in shaping the morphology of the Caspian and Black Sea pathway and could have delivered a large volume of freshwater to the North Atlantic Ocean.

Broecker et al. (1989) proposed a link between overflow from the world's largest glacial lake, Lake Agassiz, and the Younger Dryas cooling, which began ~12.9 cal ka and spanned more than 1000 years. This dramatic cooling is recorded in sedimentary records on most continents of the world. Subsequent ocean-atmosphere modeling confirmed the theoretical likelihood of the Lake Agassiz link with the Younger Dryas. Included in the Lake Agassiz hypothesis was an initial outburst from the lake of >6000 km^3 (in a few months) when its route was diverted from the Gulf of Mexico to the North Atlantic via the Great Lakes of North America and the St. Lawrence Valley; this event was considered the trigger for the Younger Dryas. The continued overflow of Lake Agassiz waters after 12.9 cal ka, plus meltwater additions from more eastern regions of North America, sustained the change in thermohaline circulation in the North Atlantic Ocean and the cooling for more than a thousand years (Clark et al., 2001). More recently, the routing of Lake Agassiz overflow during the Younger Dryas has been debated, with an alternative pathway proposed toward the northwest into the Athabasca-Mackenzie River system of northwestern Canada and into the Arctic Ocean, entering the North Atlantic through the GIN Sea (e.g., Teller et al., 2005a; Murton et al., 2010). Recent modeling has supported this route (Tarasov and Peltier, 2005; Condron and Winsor, 2012).

The largest outpouring of water from Lake Agassiz, when the lake drained for the final time ~8.4 cal ka, released >150,000 km^3 into Hudson Bay in about a year, and in turn, into the North Atlantic. This led researchers to conclude that this was responsible for the 8.2 cal ka cooling event, which is clearly recorded in Greenland ice cores and the circum-Atlantic region (Barber et al., 1999; Teller and Leverington, 2004; Clarke et al., 2004). This event resulted in sea level abruptly rising about 0.4 m. Along many coastlines, this would have had little impact on humans, but where the land had a very gentle slope, such as in the Persian Gulf (which was dry during the LGM), the rate of transgression was substantial; humans who lived around the Gulf would have been forced to move rapidly inland to avoid the encroaching "flood" from the sea. Teller et al. (2000) estimated that the final Lake Agassiz outburst at ~8.4 cal ka may have resulted in a transgression rate of >12 km/yr across the Persian Gulf for a short time, and that may have led to stories about a great flood such as that recorded in the Epic of Gilgamesh, which was recorded later (~4800 years BP) on clay tablets (in the first cuneiform script) that were discovered at the northwestern end of the modern Persian Gulf, or as Noah's Flood in the Bible. As well, migration of people from this region would have occurred during normal postglacial transgression across the floor of the Persian Gulf, forcing them to move westward up the Tigris and Euphrates Rivers into the "cradle of civilization." Rapidly transgressing shorelines probably also impacted human settlements along other gently-sloping coasts. Teller et al. (2005b) suggested that the huge 8.4 cal ka influx of water from Lake Agassiz may have generated a tsunami, and speculated that the giant Storegga submarine landslide at ~8200 years BP off the west coast of Norway, recorded by tsunami deposits along the coastal areas of Scotland, Norway, the Shetland Islands, and Greenland (Bondevik et al., 1997) may have been triggered by the last outburst from Lake Agassiz.

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PALEOLITHIC OF GEORGIA

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Keywords: Acheulian, Middle Paleolithic, Upper Paleolithic, Neanderthal, Levallois, Paleoenvironment

The geographic situation of Georgia – as a cross-road between Europe and Asia and simultaneously as a natural refuge, where the Pleistocene glacial periods had less severe influence, could provide a key information for deciphering the processes that have taken place during the Paleolithic in Eurasia: changes of its major chronologic and cultural-technological stages, driving forces of transitions from one phase to another, ways and directions of human migrations.

Understanding the paleoenvironment during the Pleistocene is important for reconstruction of routes used by Humans to expand into Eurasia. First time the hominids appeared on the territory of Georgia through the ‘‘Levantine Corridor’’. The Early Middle Paleolithic is similar to Levantine Early Middle Paleolithic. Late Middle Paleolithic and Upper Paleolithic are more similar to Zagrosian Paleolithic.

Research of Paleolithic of the region gives a unique possibility to study extremely topical and up-to-date problems not only in terms of Caucasus but generally for prehistoric sciences:

- Dynamics, technological and typological changes and helpful factors of the transition periods from low to middle Palaeolithic,
- Trends of Palaeolithic development and a complete technological cycle and sequences;
- Dynamics, technological and typological changes and helpful factors of transitional periods from Lower-Middle-Upper Palaeolithic;
- Trends of various kinds of (e.g. diffusion) cultural influences and migrations;
- Raw materials**,** its spreading and accessibility in various epochs, reasons for intensity of their usage and the issues connected with it;
- Initial art and religion (First evidence of them were found some years ago);
- Peculiarities of sedimentation**;**
- Tectonic and seismic processes (the region is located on the fault zone) and their influence on human being adaptations;
- Approximately 490 Paleolithic sites were identified on this territory which is occupied by humans since 1, 85 MA.

The oldest fossil hominid site found in western Eurasia to date.This was well proved by Dmanisi archaeological discoveries, where remains (skulls, lower jaw and other) of the african type of one the oldest human being-Homo ergaster, have been excavated.

The next most ancient Paleolithic site After Dmanisi is Akhalkalaki I. The stratigraphy of the site together with faunal correlations and reversed paleomagnetics indicates an age most likely in the late Matuyama Chron, probably between 980,000 and 780,000 years ago.

Only few Lower Paleolithic (Acheulean) sites with more or less clear stratigraphy are discovered on the territory of Georgia: Kudaro I, III, and Tsona Caves. The results of dating dates of these sites are: Kudaro I and III (360-350000; 252000; 560000) (Middle Pleistocene).

The Middle Palaeolithic sites in Georgia are distinguished by especially large number and diversity. Human trace is found in rock-shelters and caves as well as in open areas**.** In this very region, supposedly of the earliest of the Middle Palaeolithic (Djruchula cave 275000-140000), and those of the latest one

(Ortvala Klde -34000-32000) have been confirmed (we would like to note here that we possess advance data which indicate that in the Bronze cave (Tsutskhvati multi-staged cave system) even later Middle Palaeolithic may be represented**).**

All Upper Paleolithic sites are located only in Western Georgia.

According to existed opinions, during glacial episodes, when the availability of human occupations in high altitude was reduced, Transcaucasia remained a preserved zone of relatively low height. And some archaeologists fixed the limit of vertical dispersal of human populations during Upper Paleolithic was about 800 m above the sea level. Recently discovered by us some Upper Paleolithic materials in Western Georgia (Imereti and Racha regions) on the altitude 1100-1350 m at the bottom of South slopes of Great Caucasus make us think that high lands have been occupied by humans or during warm episodes. Another version is that we discovered the areas where located the paths of Northern-South migrations which took a place during the coldest periods. This could document a cultural connection between North and South parts of Caucasus, as already attested in the lithic assemblages.

Co-existence of features of different cultures is one of the characters of Upper Paleolithic of Western Georgia.

The results of study of some Middle-Upper Paleolithic sites gives us base of supposing that there were existed some traditions of hunting.

Also, seems that in parallel gorges have been existed different economical activities of different groups, or distribution of the habitat areas between the tribes lived there.

In two caves (Bondi and Dzudzuana caves) were discovered the most ancient flex and fibers dated from 35000-34000.

All the stages of Paleolithic are represented in Georgia. This gives us a good possibility to research Human being, paleoenvironment and Human adaptations. The results will be important not for understanding only the history of this region but it is one of the keys for deciphering the processes that have taken place during the Pleistocene and Paleolithic in Eurasia.

THE IMPACT OF SEISMIC AND VOLCANIC PROCESSES ON HUMANS IN THE PALEOLITHIC

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The goal of our project is research into the evolutionary history of Neanderthals in the Caucasus, their replacement by Anatomically Modern Humans, and how much natural catastrophes, namely earthquakes, might have influenced this process.

We may have found evidence of Pleistocene paleo-earthquakes in some caves of western Georgia (Upper Imereti region). The upper Imeretian plateau is located on the fault zone where one of the strongest earthquakes of recent times occurred in 1991 (magnitude 7).

Our attention is focused on a roof collapse accident, marked by large blocks that had been evidenced in some layers of Bondi Cave (Western Georgia, Upper Imereti region). These layers, in the front space of the cave, are dated to 19,360 ^{14}C BP (14,330 cal BP Hulu). The cracks on the ceiling and wall suggest that the blocks fell from the ceiling. Apparently, collapse of these large blocks was caused by a massive earthquake, which may be the first evidence of a paleo-earthquake in the region. In the view of paleo-seismology, this provides a new opportunity to detect paleo-earthquake events. The collapse itself caused disruption of the layers and the intensity of occupation in the cave.

Also, the huge blocks and rocks fell just at the entrance of the cave. The crushed remains of a young cave bear have been found under the big rocks.

Supposedly, the same evidence has been recovered at other cave sites of the same period located in neighboring gorges—Undo Klde and Ortvala Klde. The broken skeletons and remains of many cave bears have been found at the entrance of Undo Klde under the collapsed blocks.

The 47 m deep karstic well at the end of the cave is especially intriguing. During explorations, some material was collected from the well, and among the fossils several human remains were found (*H. sapiens sapiens*, 2 individuals). It would be interesting to know what the function of the well was during different periods of prehistoric time.

The depth of the pit is 47 m at the present time, but it could descend farther to the river base, the depth of which is about 90 m. The pit appears to be filled with rocks and stones collapsed from the ceiling of the cave after some earthquakes as well.

The RESET project (RESponse of humans to abrupt Environmental Transitions) conducted operations in Undo Cave and Bondi Cave. This project used microtephras (i.e., distal ash fall from past volcanic eruptions) to correlate European and circum-Mediterranean geological, environmental, and archaeological events over the last 100,000 years.

One of the most interesting aspects of our research deals with refining the chronology of late Neanderthal and early Modern Human occupations in Europe between 60-25 ka BP by identifying tephra stratigraphic markers of known age and provenience and integrating these site datasets with high-resolution climate change records.

Microtephras have been found in Bondi Cave. They appeared in the cave as a result of local eruptions.

BOTTOM SEDIMENT THICKNESS AS AN INDICATOR OF SEDIMENTATION RATE AND DEPOSITION ENVIRONMENT ON THE NORTHWESTERN SHELF OF THE BLACK SEA

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Keywords: Holocene sediment thickness, sedimentation rate, paleogeography, northwestern Black Sea shelf

Introduction

The northwestern Black Sea shelf is an outstanding area for research. On one hand, its geomorphological features and geological structure make it possible to trace the course of transgressions, and on the other hand, the place is rich in paleoanthropologic data on the adjoining land surface (Yanko-Hombach, 2011). Detailed reconstructions of its geologic history allow an understanding of the environmental influence on human development, and the results of investigation may be used to search for ancient human settlements within the shelf area now covered by sea.

In this work, we present data about the distribution of thicknesses in Holocene sediments (Drevne- and Novochernomorian time) and their connection with the bottom relief of the northwestern Black Sea shelf.

The objectives of the research were:

- to characterize the relief of the study area;
- to construct sediment thickness maps for Drevne- and Novochernomorian time;
- to estimate the sedimentation rate during the Holocene.

In the study area, during the period from 1976 to 2006, many cores were collected across the whole northwestern continental shelf of the Black Sea. The results of the investigation are based on extensive sampling of bottom sediments and the analysis of more than 3000 gravity and piston cores as well as 250 boreholes. These data are the result of previous geological surveys that were carried out by Prichernomorskoe State Regional Geological Enterprise “Prichernomor GRGP” (Odessa, Ukraine) and Odessa I.I. Mechnikov National University.

Geomorphologic characteristics of the northwestern Black Sea

The northwestern part of the Black Sea shelf includes the Dniester-Danube coastal waters in the west, the Dnieper-Dniester interfluves, the Tendra spit and Dzharilgach Island in the north, and the western part of the Crimean peninsula in the east (fig. 1). Its width is up to 170 km and its extent about 270 km. Maximum sea depths are -55 meters. The surface of the shelf before the Chernomorian transgression was represented by an alluvial plain which was formed under the influence of such large river systems as the Danube, Dniester, Yuzhniy Bug, and Dnieper (Zenkovich, 1960; Ionin et al., 1987; Fesyunov, 1996). In the course of the Chernomorian transgression, the shelf was flooded by the sea, and its surface was partly flattened by the sediments (Fedoronchuk et al., 2010). The system of paleoriver valleys, paleo-terraces, ancient shorelines, and sandbars are represented on the surface of the shelf, which was formed during the late Würm glaciation. The main subaerial relief elements despite partial wave reworking were preserved and are visible, though they are covered with a layer of marine sediments. Positive relief forms are represented by the Odessa and Dniester sandbanks, and the Budak, Western Tendra, and Dniester elevations (fig. 1). Elevations are the ancient watersheds that were characterized by the presence of mesa relief forms (Radzvil and Polovka, 2002). Uplifted areas lie at a water depth of less than 30 m, usually in the interval between -17 and -23 m.

The Odessa sandbank is the largest accumulative form on the shelf; its area is 178 km^2. It rises over the bottom surface an average of about 10-15 meters. The Odessa trench separates the Odessa sandbank from the shoreline, which is situated some 5-8 km to the north. This accumulative formation started to form in the Middle Pleistocene and consists of sediments from the first, second, and third terraces above the floodplain. The Odessa sandbank is a submarine continuation of the Kinburnskaya spit (fig. 1).

The Dniester sandbank is situated about 12-16 km from the shore; its length is 12 km, its width 6 km. It follows an E-W direction.

The Budakskoe elevation is situated some 10 km from the shore. The minimum water depth above it is -20 m.

The western Tendra elevation is situated westward of the Tendra spit; it has submeridianal extension and an asymmetric shape: its northern part is 5 km in width, and its southern is 20 km. Water depth above its surface is 20 m.

Negative topographic forms in the shelf are represented by the Odessa trench, the Paleo-Dnieper, the Paleo-Dniester, and the Paleo-Sarata valleys.

The Odessa trench has a U-shaped profile, and its bottom becomes deeper in the western direction. The width of the trench varies from 4.5 to 9 km, and the maximum depth is 22 m. The Odessa trench was formed by the Paleo-Dnieper and Paleo-Yuzhniy-Bug waters during the late Pleistocene. The Paleo-Dnieper valley occupies the central part of the inner shelf. Maximum water depths within the valley are in the southern part (-30 m).

The Paleo-Dniester valley has distinctively shaped relief, and its width is up to 10-25 km. The Paleo-Sarata valley is a narrow depression with a width between 3 and 5 km.

Results

To study the patterns of sediment accumulation, their processes, and their connection with bottom relief, maps of the thickness of Drevne- and Novochernomorian sedimentary deposits were constructed. Also, the rate of sedimentation was estimated. Determinations of sediment age were based on the results of bulk, uncalibrated radiocarbon dating by Sibirchenko et al. (1983). The results of radiocarbon dating are not corrected according to a reservoir effect due to the uncertainty in the correction. That is why the precision may vary over wide ranges (Major et al., 2006). According to available age estimations, the Drevnechernomorian sediments were formed in the time range between ca. 10.5 and 7.1 ka BP and the Novochernomorian, from ca. 7 ka BP until the present.

The distribution of Drevnechernomorian bottom sediments is shown in fig. 2. The thickness of the studied sediments varies from 0.05 to 1 meter within the outer shelf (water depths greater than 35 m), and from 1 to 10 meters in the north (within the valleys of the Paleo-Dnieper, Paleo-Dniester, and Paleo-Sarata). The outlines of the Paleo-Dnieper valley match the isopach of 1-2 meters, those of the Paleo-Dniester and Paleo-Sarata valleys, 0.5-1 m. Maximum thickness is encountered in Odessa Bay at 18.2 m. These sediments are absent in the area of the Odessa and Dniester sandbank, and the Tendra spit. According to radiocarbon dating (Sibirchenko et al., 1983), the sediment formation rate during Drevnechernomorian time was estimated. Maximum sedimentation rate is within Odessa Bay (5.35 m/1000 yrs), and for the Dnieper-Bug liman (3.5 m/1000 yrs), for the Dniester coastal waters (up to 5.3 m/1000 yrs), and for the Paleo-Sarata and Paleo-Dnieper (up to 0.8-0.6 m/1000 yrs, respectively). The outer shelf with a water depth more than 35 meters is characterized by a sedimentation rate of 0.3 m/1000 yrs. Mean sedimentation rates are in Table 1. Odessa Bay, the Dnieper-Bug liman, the Dniester coastal waters, the Paleo-Dniester, the Dnieper depression, the Paleo-Sarata, and the western Tendra elevation are characterized by high sedimentation rates. At the end of Drevnechernomorian time, favorable paleogeographical and geomorphological conditions arose and deep sediment thicknesses were formed within the western Tendra elevation area.

Novochernomorian bottom sediment thicknesses (fig. 3) vary from 0.1 to 0.4 meters on the outer shelf and from 10 to 18 meters within the river mouth areas in the north. Maximum thickness can be encountered in the Dnieper-Bug liman (18 m). Bottom sediments of Novochernomorian age are widespread in the study area. The Odessa sandbank, and the Dniester and Tendra elevations are outlined by isopach 0.5, 0.2-0.5 and 0.3-0.5 meters, respectively.

In the Dnieper-Bug liman, average sediment thicknesses are from 1.5 to 12 m, in Odessa Bay; in the Paleo-Dniester, from 0.5 to 5 m; in the Paleo-Dnieper, from 0.3 to 5 m; and for the Paleo-Sarata, up to 0.15 m. The areas with high sediment thicknesses concur with depressions, though during Novochernomorian time, these areas had smaller sizes and were displaced toward the northern direction.

The duration of the Novochernomorian time is about 7100 years (Sibirchenko et al., 1983). The maximum sedimentation rate for the Dnieper-Bug liman is 2.9 m/1000 yrs; for Odessa Bay it is up to 0.35 m/1000 yrs; for the Dniester coastal waters, up to 1.4 m/1000 yrs; for the Paleo-Sarata up to 0.3 m/1000 yrs; for the Dnieper depression 0.2 m/1000 yrs; and for areas of the shelf with water depths greater than 35 m, up to 0.1 m/1000 yrs. On the elevations, sedimentation rates are low and vary from 3 to 7 cm per 1000 years. Average sedimentation rates for the Drevnechernomorian and Novochernomorian time were calculated (Table 1).

Table 1. Average sediment accumulation rate (m/1000 yrs)

Areas within the NW shelf of the Black Sea	Drevnechernomorian time	Novochernomorian time
Odessa Bay	4.95	0.22
Dnieper-Bug liman	0.67	1.4
Dniester coastal waters	1.35	0.36
Dniester elevation	0.06	0.096
Paleo-Dniester	0.4	0.05
Dnieper depression	0.33	0.14
Budak elevation	0.09	0.12
Paleo-Sarata	0.2	0.07
Western Tendra elevation	0.1	0.08
Central part of the shelf	0.02	0.05

Conclusions

The distribution of thickness within the Drevne- and Novochernomorian sedimentary deposits is closely associated with bottom relief. During periods when the recent shelf surface was land, certain features of the bottom relief were formed. Subsequently, these relief features caused incremental sediment thicknesses in the depressions.

During Drevnechernomorian time, the ancient limans were situated farther to the south than recent ones, and their position determined the environments and patterns of sediment formation. The limans on the shelf correspond to paleoriver valleys, and these areas are characterized by the accumulation of deep sediment thicknesses (from 5 to 10 m). Such areas as Odessa Bay, the Dnieper-Bug liman, the Dniester coastal waters, the Paleo-Dniester, the Dnieper depression, and the Paleo-Sarata are characterized by high sedimentation rates. This is connected to a large volume of terrigenous material brought by river flow. In the Dnieper and Dniester depressions, accumulation of sedimentary material took place close to the shoreline of the early Holocene. As the result of northward movement of the coastline, the character of the distribution of sediment thicknesses changed. Such shelf accumulative forms as the Odessa and Dniester sandbanks are usually formed by terrigenous sediments from rivers, but besides this source, washout, re-sedimentation of ancient accumulative formations (Ischenko, 1971), and shore abrasion (Shnyukov et al., 1985) also make a contribution. The Holocene sediments of the Odessa sandbank are represented by dark-grey mud with shell detritus and anisomerous sand followed by shell sediments. The source of the sand in this area is Dnieper alluvial deposits. According to Pazyuk and Rychkovskaya (1972), Odessa sandbank mineralogical composition is similar to recent Dnieper alluvial deposits.

Several patterns in the distribution of bottom sediments during the Novochernomorian can be noted: deep thicknesses of sediments can be encountered in paleoriver valleys on the shelf, but these areas have smaller sizes and are displaced closer to the recent coastline in comparison with those of Drevnechernomorian time. Sediment accumulation processes led to bottom surface flattening. For example, the Paleo-Sarata valley features are smoothed in the modern relief, even though this area was characterized by high average sedimentation rates during Drevnechernomorian time (Table 1). This shows that the Paleo-Sarata valley was a negative geomorphological site during the Drevnechernomorian. On the contrary, during Novochernomorian time, this area shows low rates of sediment accumulation, which could be the result of gradual flattening and burial by sediments. River mouth areas and depressions within the northwestern Black Sea shelf are the places of avalanche sedimentation. Our results confirm data obtained from previous research (Shnyukov et al., 1985; Fesyunov, 2000).

Bottom relief flattening in the shelf was caused mostly by burial of depressions. Wave erosion of positive relief forms was not significant for several reasons: (1) high speed of the transgression, (2) active accumulation of terrigenous sediments on the shelf, and (3) shallow depth of wave influence on bottom sedimentary deposits. As a result, a lot of positive paleorelief forms on the bottom were covered by a layer of recent sediments. Thus paleorelief forms were protected and preserved from significant erosion processes.

Even so, the limited thickness of the overlapping sediment layer was sufficient to prevent washout processes of these relief forms. Nevertheless, at the present time on the shallow shelf (at water depths from 15 to 18 m), positive relief forms are under the influence of scour. Similar processes probably took place in the past, and this allows us to suggest that small forms of ancient relief could be destroyed by wave activity. Large forms of ancient relief probably did not experience strong erosion during the Holocene and can be traced because of the shallow thickness of the overlapping sediments.

As a whole, the paleogeography of the study area (position of the coastlines, relief of the bottom surface) has a strong influence on the distribution of bottom sediments. During the Holocene, the connection between sediment thickness and relief forms can be traced.

Maximum thicknesses correspond to depressions and to river mouth areas, minimal thicknesses to positive forms of ancient relief. The processes of sediment formation on the shelf of the northwestern Black Sea during the Holocene resulted in flattening of the bottom surface.

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ON THE QUESTION OF THE LEVALLOIS CONVERGENT POINT METHOD: NEAR EAST OR UKRAINE? MIGRATION OR CONVERGENCE?

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The presence of Levallois point industries of the so-called transitional Bohunician type in Moravia at a time between 50-40 thousand years ago has been considered intrusive to the "contact zone" of this part of Central Europe mainly because a similar kind of elongated bidirectional Levallois point production was known in the Near East (Boker Tachtit, Level 1, 2 (Marks, Volkman, 1983)), which related to the local Levallois sequence (Škrdla, 2003; Škrdla and Rychtarikova, 2012). It would be a logical conclusion in a case where an isolated industry appeared in a remote area without chronological or technological roots in any local industry or from neighboring regions. At the same time, in the adjacent territory of Transcarpathia prior to "Bohunician" time, there is a Middle Paleolithic Levallois industry with short convergent points (Korolevo I, Level 2-b), which, in turn, are similar to the Late Levantine Mousterian of Tabun B type. Therefore, the same question can be raised: one more wave of migration or local development?

At the Korolevo site, the sequence of Levallois industries is represented by level III (OIS 5e) with a classical "tortoise" centripetal Levallois method and Level 2-b (OIS 4) with a short convergent Levallois point method. If the recognition of classical Levallois "tortoise" method is correct, then there are different views on the interpretation of method and variable technological models of production for short convergent Levallois points (Bordes, 1961, 1980; Crew, 1976; Boëda, 1982, 1995; Meignen, 1995). These models suggest a "recurrent" mode of Levallois point production.

Apart from problems of practical usage in Levallois "recurrent" definitions (Van Peer, 1992), one of the main difficulties is that the interpretation of the "classical Levallois method" does not correspond to the "Levallois concept" (Boëda, 1994, 1995; Boëda et al., 1990) and division of the cycles of preparation. The "Levallois volumetric concept" covers all cores with flat working surfaces (Levallois and non-Levallois) and does not include the main technological rules for the classical Levallois.

Technological data obtained from refitting material from Level 2-b of the Korolevo site (Fig. 1) (Ukraine) and Tor Faraj (Fig. 2) (Jordan) allow one to investigate the technological sequence of short convergent Levallois points, examine similarities and differences in the reduction processes, and the nature of this method.

In Level 2-b of the Korolevo I site, the organization of triangular relief consists first in the removal of a flake or blade along the middle part of the core's working surface. The next two convergent removals from the two sides of this initial central flat concavity came from supplementary (as a rule) facetted platforms that created the final Y-shaped relief. Finally, the Levallois point was produced from a facetted convex, "chapeau de gendarme," or rare dihedral platform and left a triangular concavity on the upper core surface (Usik, 1989; Demidenko and Usik, 1995). To create the shape/relief of the next LP after the first, or previous one (in contrast to the widespread opinion about the wasteful character of Levallois technology), it is enough to remove two or even only one supplementary flake/blade from one or two sides along the triangular concavity. The method of LP production in Level 2-b clearly belongs to the classical kind: one cycle of preparation finished with the production of one, rarely two (Gladilin, 1977) end products. There are no traces of multiple production by the so-called "recurrent" method or high variability in sequences of preparational scars.

The balance between the shorter length of the proximal V-shaped part and the equal or longer distal medial ridge allow one to repeat LP production several times accordingly as the common length of the core surface and its thickness decrease. In the technological process, blades are important, especially lateral ones (*débordants*, or core edge flakes), which are a waste product of "Levallois surface" preparation.

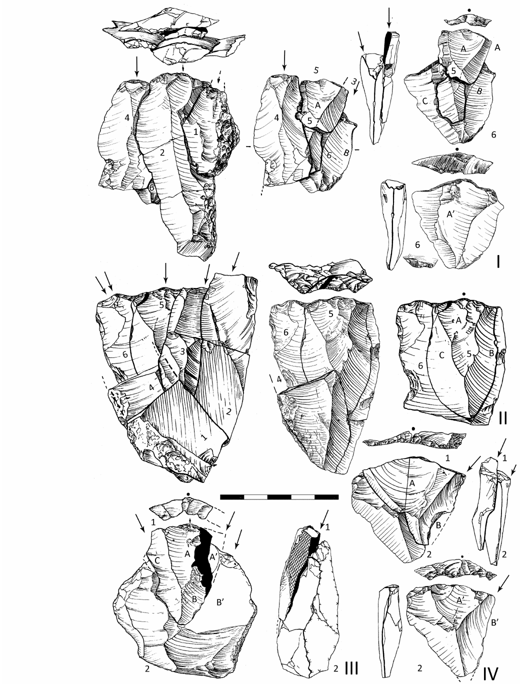

Figure 1. Korolevo I, Level 2-b (Transcarpathia, Ukraine). I-IV: Classical Levallois convergent points production. Refitting data.

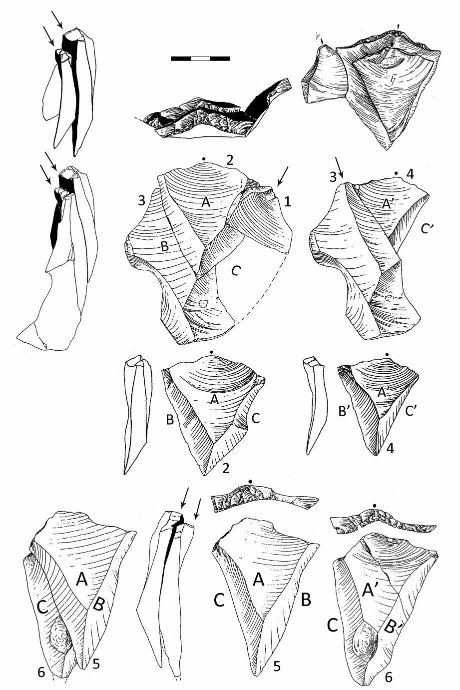

Figure 2. Tor Faraj (Jordan). 1-6: Classical Levallois convergent points production. Refitting data (from: Demidenko and Usik, 2003).

Investigation of the refitting data for Tor Faraj (Tabun B type) revealed the use of the same technological sequence of production for short LP points by the classical method (Demidenko and Usik, 2003). Based on these data, it seems that in other Near Eastern Levallois Tabun B type industries (for instance, Kebara, levels IX/X), the same classical method was used as well.

The "recurrent" method does not look appropriate for Levallois point production because it does not have a fixed preparation sequence that can be repeated the same way (Van Peer, 1992). Additionally, refitting data do not demonstrate evidence of multiple means of production, which is proposed by the "recurrent" models.

From the perspective of similarity in the classical mode of Levallois production, the same convergent technique (direction of preparation), reduction sequence, and type of Levallois end product in Transcarpathia and Near East, it is theoretically possible to suppose that the relationship was due to migration. At the same time, there are definite differences in technological details as well as tool types between Level 2-b Korolevo and Tabun B type industries. For example, for Tabun B, the prominent "chapeau de gendarme" platforms and specific "concordian profile" of Levallos points are common. There are small Levallois points and, related to them, the so-called "truncated-facetted pieces" (cores mainly), which are practically absent in the Level 2-b Korolevo collection. The same situation can be mentioned for the inverse retouched points characteristic of Tabun B tool-kits. Chronologically, these industries are quite close in time (OIS 4). The influence of raw matherial on the technology does not look to be sufficiently influential to modify the main inherent cultural features between the Near East and Central Europe.

The migration model for the appearence of the Levallois point industry in Transcarpathian territory seems less likely than its emergence from local development. At least for the Transcarpathian region, the sequence of Levallois industries shows that one follows after another: classical "tortoise" centripetal flake Levallois (Korolevo I, Level III; OIS 5a), then classical convergent point Levallois (Korolevo I, Level 2-b; OIS 4). It should be stressed that in western Ukraine, from the other side of the Carpathian Mountains, the Levallois industries are represented by the Molodovo type (OIS 5-3) of the original variant of classical Levallois method based on a combined technique of core preparation. The end product of this type of Levallois is characterized by the production of elongated blanks with a crossed scar pattern. The later appearance of parallel bidirectional Levallois points from the site of Koulichivka (that is technologically similar to the Bohunician) may have local roots.

Therefore, it is possible to conclude that in the "contact zone" of Central Europe (Moravia and Transcarpathia) and in adjacent territories of Eastern Europe on the other side of the Carpathian Mountains (Western Ukraine: Ezypil, Pronyatin, Ketrosy, Molodovo I and V, Koulichivka (Anisytkin, 1981; Chernysh, 1987; Sytnik, 2000), Crimea (Kabazi II/8 (Chabay, Sitlivy, 1993), and Russia (Desna region: Khotylyevo (Zavernayaev, 1978), and between OIS 5e?/5a and OIS 3, there were present different variants of Levallois industries which demonstrate local convergent development (or replacement?) of the classical Levallois techno-complex.

The next important question is the investigation and determination of the mechanism of technological transformation and/or replacement of the methods used in the Levallois industries (Demidenko and Usik, 1993, 1995; Usik, 2009).

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PALEOGEOGRAPHY OF THE CASPIAN LATE PLEISTOCENE: NEW DATA

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Keywords: Caspian Sea, late Pleistocene, cores, transgressive deposits, regressive sediments, radiocarbon dating, paleogeography

The event scheme of the Caspian late Pleistocene includes two transgressive intervals: the Late Khazar (early Late Khazarian and late Late Khazar (Girkan) transgressive stages) and the Khvalynian (Early Khvalynian and Late Khvalynian transgressive stages), separated by the Atel regression. Many questions surrounding the paleogeography of these transgressive and regressive events (number of stages, age, environmental conditions, correlation with events in neighboring territories and with climatic events) are debated. Much of the material related to these problems has been obtained as a result of research on the coasts of the Caspian Sea. Therefore, substantial interest has been shown by researchers in drilling to sample layers from the bottom of the Caspian Sea. We studied the sequences of these boreholes up to 100 m in depth that were extracted during engineering-geological research in the northern Caspian Sea. They revealed thicknesses of the late Pleistocene deposits. Studying of the structure of the sections and spatial correlation of lithological-stratigraphical thicknesses were conducted by means of seismoacoustic profiling and static sounding. The sediments of the cores were studied by lithological, malacofaunal, and geochronological methods. Among the mollusks, we mainly focused on the brackish water species of the genus *Didacna* Eichw. Members of this genus are endemic and are index species for the Caspian Sea. This genus is known for its high evolutionary rates at the species and subspecies levels, which highlights its significance for establishing the stratification of the Caspian marine Pleistocene as well as for paleogeographic reconstructions of the basins.

The Late Khazar transgression developed in two independent stages, separated by a regression. Sea level during the earlier Late Khazar basin, according to the spatial distribution of sediments, did not exceed -10 m, and its areal extent was much bigger than the modern Caspian. Malacologic fauna represent an assemblage with crassoidal *Didacna* and characteristic species *D. nalivkini* and *D. surachanica*. Its distinguishing feature is the large dimensions and massiveness of the shells, especially common in the southern parts of the Caspian. Common gigantism of shells, high carbonate content in the sediment, and the presence of oolites indicated the warm climate of the Late Khazar. Warm waters of the basin obviously had higher salinity than in the modern Caspian: between 10-12‰ for the northern and up to 14-15‰ for the southern Caspian Sea (Yanina, 2012). The early part of the Late Khazar transgression was followed by a regression. It was evidenced by hiatuses in marine sedimentation (Dagestan), and wash-outs and soil formation (Volga River valley) (Svitoch and Yanina, 1997).

Traces of the second transgressive Late Khazar stage are not preserved along the Caspian coasts. Based on drill sites and materials from the northwestern part of the Caspian region, G.I. Popov (1983) reconstructed a freshened brackish water basin. He defined it as an independent Girkan transgression of the Caspian that took place after the Late Khazar transgression and was separated from the Khvalynian transgression by the Atel regression. The basin was inhabited by “Khvalynian-like” fauna, traces of which have not been recorded elsewhere. A number of researchers strongly objected to this concept.

The structure of the cores studied by us showed that between two regressive thicknesses (Chernoyarsk and Atel) lie two thicknesses of marine deposits. The lower part of the Late Khazar deposits is most fully represented in the north. Sandy sediments at the base of the studied sequences are characterized by the predominance of freshwater species (*Corbicula fluminalis*, *Lymnaea stagnalis*, and *Valvata* sp.) and slightly brackish water species. They characterize the shallow, warm, and almost freshwater basin existing in the area of the modern central part of the northern Caspian Sea. Sediments at higher levels contain a malacofaunal complex that features a combination of two thermophilic species belonging to different types of fauna: *Didacna nalivkini* and *Corbicula fluminalis*, and also rare *D. surachanica*, *D. vulgaris*, and *D. pallasi*, obviously testifying to the Late Khazar age of the complex. The complex represents a shallow, brackish, warm-water basin with inflow of freshwater. The described layers reflect different phases in the development of the Late Khazar transgression.

The subsequent stage of development in the Caspian Sea is represented by sandy-clay deposits. The faunal complex is characterized by an abundance of *D. subcatillus*, the occurrence of *D. cristata* and species of Khazar type, *D. pallasi*, *D. shuraosenica*, and *D. subcrassa*. According to G.I. Popov (1983), *D. subcatillus* in combination with *D. cristata* are the "face" of the Girkan fauna. Probably, the layers described by us belong to the Girkan transgression. ^{14}C dates obtained by the scintillation method yielded a date of >42 ka (calibrated age, >45 ka); those dates obtained by AMS, >54 ka. Conclusions about the taxonomic status of this transgression and its age can be made only after these layers are dated by methods that will be applicable from the end of the middle Pleistocene to the beginning of the late Pleistocene.

The beginning of the late Pleistocene was characterized by the warm interglacial epoch of MIS 5, the Mikulino interglaciation, on the Russian Plain. The Late Khazar and Girkan transgressions corresponded to this warm epoch.

The end of the Khazar stage of Caspian development was marked by the deep Atel regression. During this time, vast areas of the Caspian shelf were exposed. Of all the continental formations due to Caspian regressions, sediments of this age are the most widespread and are found on all Caspian coasts (Svitoch and Yanina, 1997). Atel regressive sediments are well exposed in the cores. They were transformed by the subaerial environment, and their deposits include freshwater mollusks and plant remains. In the Lower Volga region, at the base of the regressive layer, there are Akhtuba deposits, first distinguished by G.I. Goretskiy (1958) and referred to as a periglacial formation. They represent a perfect horizon marker in the Lower Volga sections, often with sharp wedges penetrating the underlying sediments. These wedges and winterkill fractures at the base of the Akhtuba sands are syngenetic to them, and represent convincing proof of the severe climatic conditions and permafrost development at the time of deposition. It is obvious that upon approaching the cooling maximum (MIS 4, early Valdai glaciations on the Russian plain), the transgressive development of the Caspian was disrupted by the Atel regression under a cold and dry climate.

The Atel regression was followed by the Khvalynian transgression with the most significant sea-level rise in the late Pleistocene history of the Caspian. Unlike earlier transgressions, traces of Khvalynian Sea development are found on all Caspian coasts. The maximum sea level can be easily traced by the distinct relief found with rare exceptions at levels of 46-50 m absolute scale throughout the entire perimeter of the paleobasin. Almost all researchers who have studied Caspian history agree that there were two Khvalynian transgressions: an early and late Khvalynian, separated by the Enotaevka regression.

Drilling material and dates, obtained from shells and organic matter from sediment cores, are of great interest. The Khvalynian section on the bigger area of the northern Caspian Sea begins with a layer of coarse-grained marine sediments with faunal material, among which the community of *Didacna subcatillus* predominates. The ^{14}C age is from 28.5 to 31.5 ka; the calibrated dates are from 33.5 to 36.5 ka. AMS dating showed an older result: 44.5 ka.

The thickness of deep-water clay deposits with inclusion of typical Khvalynian fauna of *Didacna protracta*, and *D. parallella* lies above it. According to the structure of the cores and properties of the malacofauna (*Didacna protracta submedia*, *Dreissena rostriformis compressa*), this deposit reflects the deepest water of the Khvalynian basin. Dating of this interval by ^{14}C gave an age of about 27 ka (the calibrated date is about 32 ka) (Bezrodnykh et al., 2004, 2013). Evidently, the first transgressive stage of the Khvalynian transgression took place during the warming of MIS 3, in the Valdai interstadial.

Above it in a number of boreholes (mainly in the southern part of the northern Caspian Sea), an accumulation of sandy and fine silt sediments was noted. Obviously, they correspond to a drop in the level of the Khvalynian Sea. The age interval of this event was from 22 to 19 ka. Apparently, this decline in sea level represents the last glacial maximum (MIS 2, late Valdai glaciation). In northern areas of the Caspian Sea, this stage is fixed in the structure of the cores by wash-outs.

This sequence of deposits is covered in the southern part by sandy-clay sediments with a thickness of up to 2 m; brown clay deposits with a thickness up to 5 m lie above them with unconformity. This clay thickness is present in the all cores. It is characterized *by Didacna parallella*, *D. protracta*, *D. ebersini*, and *D. praetrigonoides.* According to the ^{14}C dates, its age interval is 17,645-16,075. The authors have found no consensus about paleogeographic treatment (Early or Late Khvalynian transgression) for this deposit. The transgression developed during the degradation of the late Valdai glaciation.

The Khvalynian cycle of deposits comes to an end with marine-deltaic sediments in the northern part of the northern Caspian Sea, and sandy sediments in its southern part. The deposits, representing the Mangyshlak regression (sapropel and peat), the ^{14}C dates yielded ages between 8.8-9.6 ka (calibrated dates are 9.9-10.9 ka). It corresponded to the continentalization of climate in the early Holocene.

Materials obtained by drilling into the bottom of the Caspian Sea show that not all events of the late Pleistocene history of the Caspian Sea are reflected in deposits of the coasts. The present problem is correlating the Caspian seafloor layers opened by boreholes with the deposits exposed in coastal sections. Only in this way will a full interpretation of the Pleistocene history of the Caspian Sea be achieved.

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FORAMINIFERA AS INDICATORS OF ENVIRONMENTAL STRESS: NEW EVIDENCE FROM THE ROMANIAN SHELF

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Key words: Black Sea, Danube, riverine discharge, superficial sediments, seasonal changes

Introduction

The river-dominated shelves of the Black Sea, e.g., the northwestern shelf adjacent to the Danube delta, are characterized by highly dynamic conditions. Their ecosystems are constantly under environmental stress caused by uneven riverine discharge of freshwater enriched with organic and inorganic compounds that provide a local increase in primary productivity and contribute to eutrophication of the water column and export of organic matter to the sea floor. This in turn affects the geochemical processes in bottom sediments and benthic life on both short- (i.e., seasonal) and long-term scales.

The main goal of our study is to discover whether there is any correlation between distributional patterns of river input and response to it by the benthic ecosystem (exemplified by foraminifera); the study area is the NW Black Sea shelf adjacent to the Romanian part of the Danube delta. The study consists of two parts: (1) investigation of seasonal (early spring and fall) foraminiferal distribution with regard to environmental parameters, and (2) application of obtained knowledge to the study of sediment cores on both short and long time scales, respectively.

In this paper, we present our results on the study of benthic foraminifera in superficial sediments recovered in early spring 2012. Our intent is to demonstrate the interrelation between foraminiferal (e.g., abundance, taxonomic content, and diversity) and environmental parameters that we measured in bottom water (e.g., depth, salinity, transparency, conductivity, T°C, DO, O2, pH, ORP, ō15N, C/N) and superficial sediments (Corg, grain size). The aim of this study is to gain insight into whether the benthic ecosystem experiences environmental stress caused by river discharge into the sea.

Study area

The Danube is the second largest river in Europe (after the Volga River) with a width up to 1.2 km, an average depth of 5-7 m, and a velocity of 0.5-1.0 ms-1. Its catchment basin embraces 15 highly industrialized European countries with a population of 76 million people that together produce enormous anthropogenic pressure on the river ecosystems and, via them, on the marine environment. The Danube is a delta-type river with four main branches: the St. George I, the Sulina, the St. George II, and the Chilia (or Kilia). The delta area is about 5640 km2 and is located in two countries (Ukraine and Romania). The Romanian part of the delta is 4400 km2 in area and is bordered by the Burgas Plateau on the north and the Dobrogea orogenic area on the south (Panin and Jipa, 2002).

The NW Black Sea littoral zone consists of Ukrainian and Romanian sections. The former is north of the Danube Delta (from Jibriany to Odessa) and is characterized by a sediment starving regime. The latter consists of two units: the Danube Delta coastal zone, and the so-called Southern Unit (from Cape Midia to the Romanian-Bulgarian border). The former is characterized by longshore sediment drift along the delta generated by winds, waves, and longshore currents with potential values varying in different places from 0 to 1230 million m3/yr (Giosan et al., 1997), while the latter is strongly influenced by the Midia harbor jetties. The sandy supply of the longshore drift is trapped upstream of the Midia harbor protection dikes, causing sediment starvation of the entire Southern Unit, where most of the public beaches and tourism centers are located. In addition, this zone is surrounded by an almost continuous loess cliff up to 12-29 m high, which is more stable to erosion than the northern deltaic unit.

The dispersal patterns of the Danube sediment supply to the NW shelf indicate two main areas with different depositional processes: the Danube-fed inner shelf (before isobath 50 m) and the sediment starving outer shelf (behind isobath 50 m). The area under study includes the littoral zone, inner and partially outer shelf (up to isobath 80 m) within the Romanian part of the NW Black Sea shelf (Fig. 1).

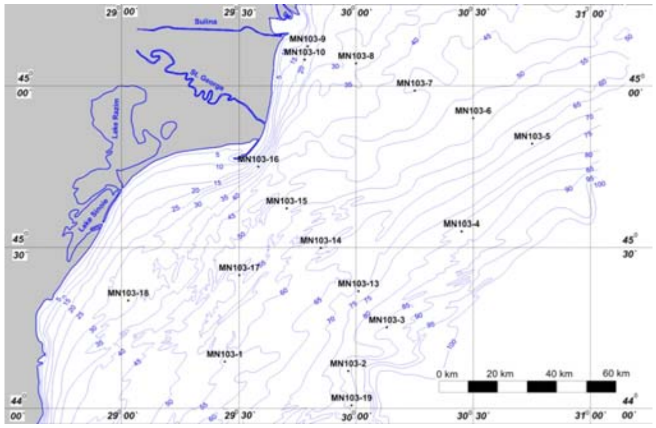

Figure 1. Study area and location of sampled stations.

Material and methods

Material was collected in the Romanian part of the NW Black Sea shelf on May 3-9, 2012 using Romanian R/V "Mare Nigrum." Seventeen stations (Fig. 1) were sampled by 0.1 m2 van Veen grab and by Multicorer Mark II-400 with four tubes, each 60 cm long and 10 cm in diameter. In this report, we present results of the study of the grab samples. Hydrological parameters of the water column were measured using the Neil Brown Instrument Systems (CTD) with a General Oceanic rosette and Niskin bottles. The transparency of the water column was measured by Secchi disk. Corg in the sediments was measured by Method of Ignition .

For the foraminiferal analysis, sediment samples were collected from the uppermost 2 cm of the sediment column with the help of two rings, each 10 cm in diameter and 2 cm in height, using a wooden spatula, and fixed in a 4% formalin solution buffered with sea water and Rose Bengal in order to identify live (stained) specimens. After 48 hours, the samples were washed in a sea water trough sieve with a mesh size of 63 μm, dried at air temperature, placed in small plastic containers, and studied in the micropaleontological laboratory of Odessa I.I. Mechnikov National University. Foraminifera were picked by hand under the binocular microscope. Large samples were randomly split with a splitter into sub-samples containing at least 300 specimens. The total assemblage, including live (stained) and dead foraminifera, was calculated together and expressed as the number of tests (abundance) per 50 g dry sediment. All the shells present in the samples were identified and counted, and the data were expressed as percentages (relative frequencies) of the total number of foraminifera. Species diversity is defined by simple species richness (number of species) and the Shannon-Wiener index (H'). All identified species were imaged with an SEM at the University of Manitoba, Winnipeg, Canada.

According to their ecological preferences, foraminifera are divided into oligohaline (1-5 psu), strictoeuryhaline (11-26 psu), polyhaline (18-26 psu), holoeuryhaline (1-26 psu), shallow (0-30 m), relatively deep (31-70 m), and deep (71-220 m) species (Yanko and Troitskaya, 1987; Yanko, 1990a; Yanko-Hombach, 2007).

Statistical treatment

All obtained parameters were treated statistically using the Statistics-7 package in order to find out whether there is any correlation between the abundance, diversity and taxonomic distribution of foraminifera and environmental parameters. The Q-mode cluster, factor and dispersion analyses, as well as multidimensional scaling were applied.

Results

Foraminifera

The limited number of live foraminifera did not allow a reliable study of their distributional patterns. Therefore, we studied the total assemblages, including live (stained) and dead individuals. The presence of live specimens shows that these species most likely live in the study area and that their empty tests are most probably autochthonous. No planktonic species were discovered. Benthic foraminifera are represented by 15 species (14 calcareous and one agglutinated) from 3 orders, 7 families, and 14 genera (Fig. 2).

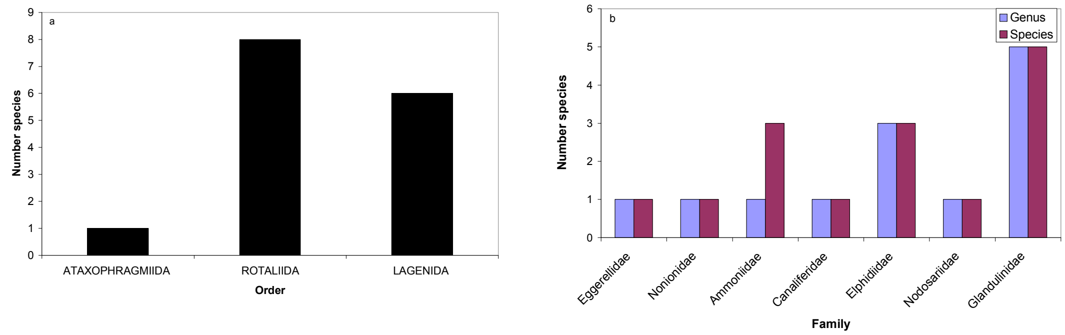

Figure 2. Taxonomic content of benthic foraminifera showing the number of orders (a), families, and species (b).

The orders Rotaliida, Lagenida, and Ataxophragmiida are represented by 8, 5, and 1 species, respectively. Among the Rotaliida, the most abundant are three species of Ammonia (A. tepida, A. compacta, A. ammoniformis), and among the Lagenida, Fissurina lucida.

Q-mode cluster analysis of the matrix consisted of 17 cases (stations) and 15 variables (relative frequencies of foraminiferal species) and produced a dendrogram (Fig. 3a) in which two, three, or four clusters corresponding to Linkage Distance 3, 1, and 0.6, respectively, can be recognized. The question appeared where to "trim" the tree in order to get the optimal number of clusters. Because "…this problem is still among unsolved problems of cluster analysis" Kim et al. (1989: 184), multidimensional scaling of stations was performed. This analysis distinguished three groups of stations, suggesting that the tree can be trimmed at Linkage Distance 1 (dotted line in Fig. 3a).

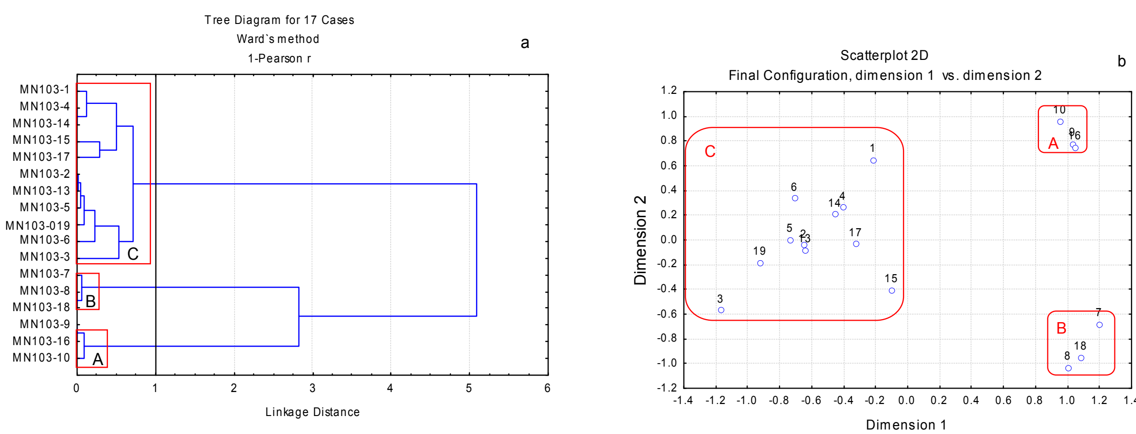

Figure 3. Grouping of stations with similar foraminiferal species composition: a. Dendrogram from a Q-mode cluster analysis based on species population in which separation of the three clusters A, B, and C can be recognized; b. MDS plot of stations showing groups distributed on a metric scale suggesting that the dendrogram of Fig. 3a should be "trimmed” at Linkage Distance 1 (dotted vertical line). For clarity, the cruise number “MN103” has been omitted from the station numbers.

The spatial distribution of clusters A, B, and C is shown in Fig. 4.

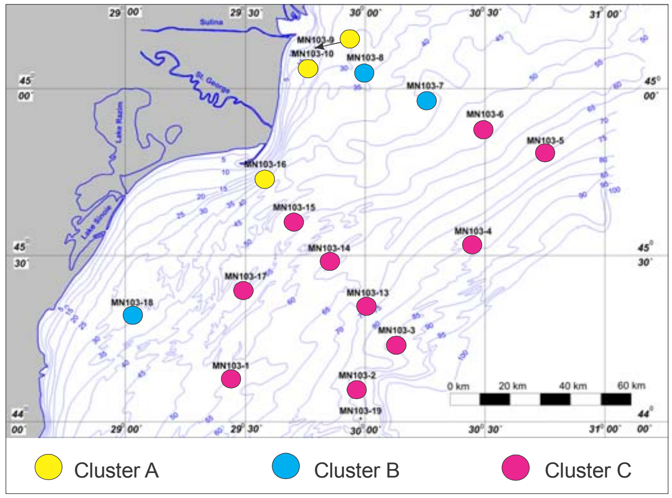

Figure 4. Map showing the spatial distribution of sample localities falling within the three clusters obtained by cluster analysis (Fig. 3a) and multidimensional scaling (Fig. 3b).

Cluster A includes the shallowest stations MN103-9, MN103-10, and MN103-16, with depths ranging between 17.5 m and 24.6 m. These stations are located within the littoral zone and as such are under the strong influence of freshwater discharge from the Sulina (Stations MN103-9 and MN103-10) and St. George (St. MN103-16) arms of the Danube River (Fig. 1). Therefore, the salinity here is the lowest of all other stations, ranging between 17.8 and 18 psu. The foraminiferal abundance varies from **11,123** to **15,616 specimens**/50 g dry sediment. The Shannon-Wiener Index varies from **0.38 to 1.47.** The number of species per station varies between **3** and **4**; the total number of species per cluster is **6**; the number of common species that present at all stations is **2**. They are *Ammonia tepida* and *Porosononion subgranosus mediterranicus* with relative frequencies up to 60% and 35%, respectively (Fig. 5). Both species are holoeuryhaline shallow-water species, well adapted to salinity variations, being distributed mostly on the inner shelf of the Black Sea (Yanko, 1990 a,b).

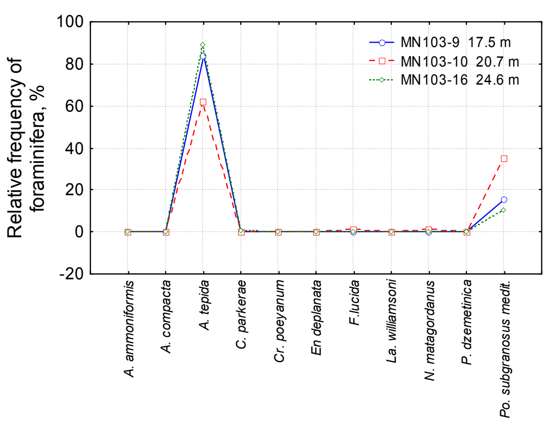

Figure 5. Species composition of foraminifera in cluster A, showing the dominant role of *Ammonia tepida,* and to a lesser degree, *Porosononion subgranosus mediterranicus* .

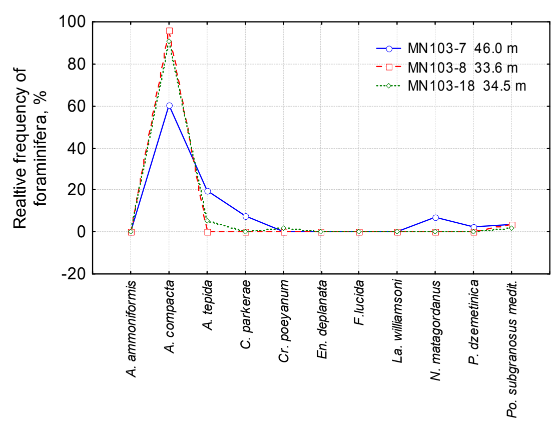

Figure 6. Species composition of foraminifera in cluster B showing the dominant role of relatively deep- water polyhaline *Ammonia compacta*.

Cluster B includes stations MN103-7, MN103-8, and MN103-18, located on the inner shelf, with water depths ranging between 33.6 m and 46 m, and salinity 18.2-18.3 psu. The foraminiferal abundance is lower compared to littoral assemblages, varying between **5540** and **10,368** specimens/50 g dry sediment, but the total number of species per cluster is higher at **8** species. The Shannon-Wiener Index varies between **0.19 and 1.21**. The number of species per station varies between **3 and 6**; the number of common species that present at all stations is **2**. They are *Ammonia compacta* and *Porosononion* *subgranosus mediterranicus*, with relative frequencies up to **95.8** and **3.2%,** respectively (Fig. 6). Compared to cluster A, the relative frequency of *Ammonia tepida* and *Porosononion subgranosus mediterranicus* sharply decreases. The most significant among the newly appearing species are *Canalifera parkerae* and *Nonion matagordanus* (each up to 7%), both strictoeuryhaline and relatively deep-water species that, together with the dominant polyhaline *Ammonia compacta*, are widely distributed on the inner shelf of the Black Sea (Yanko, 1990 a,b).

Cluster C includes stations MN103-1, MN103-2, MN103-3, MN103-4, MN103-5, MN103-6, MN103-13, MN103-14, MN103-15, MN103-17, and MN103-19, located on the outer shelf with depths ranging between 50.4 m and 80.0 m (Fig. 7).

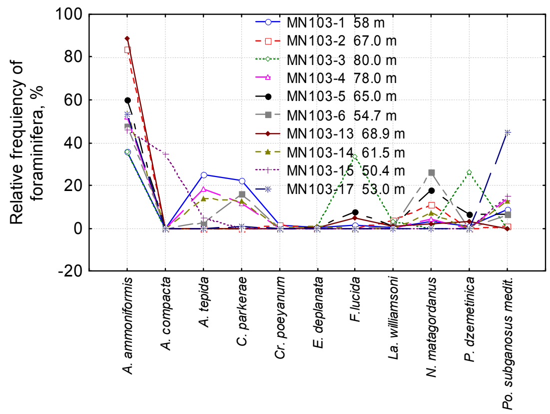

Figure 7. Species composition of foraminifera in cluster C showing that this group of stations is dominated by relatively deep-water strictoeuryhaline *Ammonia ammoniformis* with numerous lagenids.

Being the farthest from the shore, this cluster of stations is much less affected by freshwater input compared to stations of clusters A and B. Therefore, the salinity here is the highest, ranging between 18.2 psu and 18.9 psu. Foraminiferal abundance ranges from **2519** to **13,348** specimens/50 g dry sediment, but the total number of species per cluster is much higher, 14 species, compared to clusters A and B. However, the Shannon-Wiener Index is almost the same, varying from **0.6** to **1.34**. Both the lowest and highest values were calculated at stations located at the same water depth, 67 m. The number of species per station varies between **4** and **11**; the number of common species that present at all stations is **one**, the strictoeuryhaline and relatively deep-water *Ammonia ammoniformis*; it is mostly distributed on the outer shelf (Yanko, 1990 a,b; Yanko-Hombach, 2007). This cluster is characterized by the presence of six Lagenida species (*Entolingulina deplanata*, *Esosyrinx jatzkoi*, *Fissurina lucida*, *Lagena vulgaris*, *Laryngosigma williamsoni*, and *Parafissurina dzemetinica*) with total frequencies up to 69% at the deepest station MN103-3, located at a water depth of 80.0 m. In the Black Sea, Lagenida species are polyhaline and are mostly distributed on the outer shelf below isobath 70.0 m under salinities above 18 psu (Yanko, 1990 a,b; Yanko-Hombach, 2007).

Environmental parameters

Factor analysis of environmental parameters revealed three factor units called here Groups of Environmental Parameters (GEP) with eigenvalues listed in Table 1.

Table 1. Eigenvalues of environmental parameters of bottom water extracted by factor analysis.

Value	Eigenvalues Extraction: Principal components			
	Eigenvalue	% Total variance	Cumulative Eigenvalue	Cumulative %
1	5.650478	47.08732	5.650478	47.08732
2	2.325936	19.38280	7.976414	66.47012
3	1.861694	15.51412	9.838108	81.98424

All together, they explain 82% of the information from the original variables and are therefore statistically satisfactory. GEP 1, accounting for 47.08% of the variance of the revised raw data, includes transparency, salinity, conductivity, T°C, and C_{org}, where the highest factor loading is conductivity. GEP 2, accounting for 19.38% of the variance of the revised raw data, consists of O_2 and DO, with equally important factor loadings. GEP 3, accounting for 15.5% of the variance of the revised raw data, consists of ORP and pH, with equally important factor loadings (Table 2).

Table 2. Rotated component matrix of environmental parameters: the first column lists the names of the variables originally entered into the analysis; the second, third, and fourth columns contain factor loadings to match the components from Table 1 that have corresponding eigenvalues. In bold are the most significant factor loadings. Note that neither δ15N nor C/N show significant loading to any of the factors. However, C/N obviously trends with water depth as can be seen in Table 3.

	Factor Loadings (Varimax normalized) Extraction: Principal components (Marked loadings are >.700000)		
Variable	Factor 1	Factor 2	Factor 3
Water depth	**0.905389**	-0.034129	0.317102
Transparency	**0.807886**	0.022799	0.193598
O_2	-0.164564	**-0.974761**	-0.022073
DO	-0.142755	**-0.973969**	0.055470
Salinity	**0.860709**	0.362823	0.166104
Conductivity	**0.954194**	0.149351	0.098880
T°C	**0.802046**	0.253112	-0.032223
pH	0.163148	-0.184154	**0.893834**
ORP	0.198201	0.038048	**0.841562**
Corg, %	**0.835773**	-0.255905	0.026209
C/N	0.560049	0.318123	0.623442
d15N	0.253105	-0.476924	-0.506961
Expl.Var	4.956587	2.547975	2.333546
Prp.Totl	0.413049	0.212331	0.194462

The 2D diagram of Factor Analysis (Fig. 8) shows that GEP 1 and GEP 3 are located in opposite corners of the graph, while GEP 2 takes an intermediate position. C/N and $\delta^{15}N$ are located outside of all three groups.

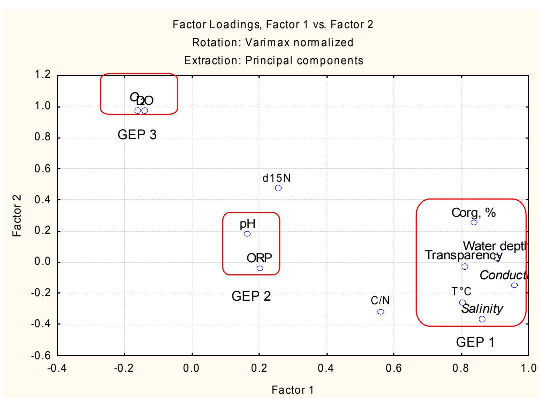

Figure 8. 2D diagram of the factor analysis shows three main Groups of Environmental Parameters (GEP): GEP 1 unites conductivity, Corg, salinity, temperature, and transparency; GEP 2 unites pH and ORP; and GEP 3 includes O_2 and DO. Note: GEP 1 and GEP 3 are located in an opposite corners of the graph, while GEP 2 takes an intermediate position between them.

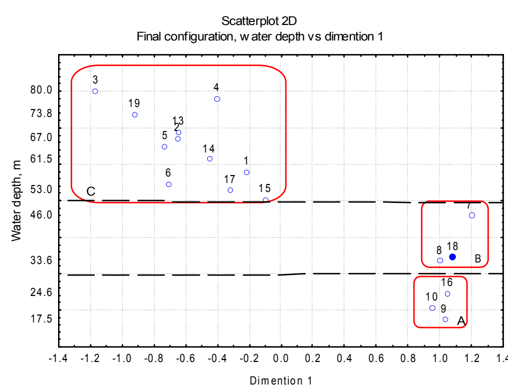

Figure 9. 2D scatterplot of clusters A, B, and C, graphing water depth against Dimension 1. The plot shows a clear trend of increasing water depth from cluster C to B, and then to A without overlap.

The position of clusters A, B, C in the two-dimensional coordinate system shows that they are clearly separated from each other along Factor 1 (Fig. 9). Factor 1 is associated with water depth and related to GEP 1 and C/N (Table 3),

Table 3. Correlations between Dimension 1 and GEP 1, GEP 2, and GEP 3, $\delta^{15}N$ and C/N. In bold correlations significant at p < .05000.

	GEP 1						GEP 2		GEP 3		$\delta^{15}N$	C/N
Parameter	Water depth	Trans-parency	Salin-ity	Conduc-tivity	T°C	C_{org}	pH	ORP	O_2	DO		
Dimen-sion 1	-0.88	-0.70	-0.64	-0.77	-0.47	-0.79	-0.31	-0.34	0.08	0.04	-0.01	-0.67

No correlation between Dimension 1 and sedimentological parameters has been discovered (Table 4).

Table 4. Correlations between Dimension 1 and lithological parameters. In bold are correlations significant at p < .05000. No significant correlation has been discovered.

Granulometry	Pebble	Granule	Very coarse sand	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay	Md	So
Dimen-sion 1	-0.19	0.17	-0.29	0.17	0.13	0.31	0.06	-0.19	0.17	-0.30	0.14

Discussion

The results obtained show the influence of three main factors that predefine the distributional patterns of environmental parameters and foraminiferal assemblages. Factor 1, which is the strongest among all the factors, represents distance from the shore and amount of Danube freshwater enriched with organic compounds discharged into the Black Sea. It affects all measured hydrological parameters as well as C/N of bottom water and Corg in the sediments.

Factor 2 has a negative relationship to Factor 1 according to the factor loadings (Table 2) and as such, it has a different meaning compared to Factor 1. It affects GEP 3, which is supposed to be a function of water depth, T°C, water circulation, and photosynthesis (REF). Logically speaking, it should be grouped together with water depth, but in fact it is located in an opposite corner of the factor diagram (Fig. 8). Therefore, the influence of temperature and water depth on concentration of oxygen in the bottom water of the study area should be excluded. We think that Factor 2 can be related to eutrophication and contamination of the surface and bottom seawater, respectively, which in turn, depend upon photosynthetic processes and the circulation of water masses. The intermediate position of GEP 2 between the two axes of the other factors (Fig. 8) suggests that Factor 3, which is the least powerful among all the factors, is influenced by both Factor 1 and 2. At the same time, its location in the same plane with GEP 1 to the left of the vertical axis (Fig. 8) speaks in favor of water depth acting upon GEP 2. We hypothesize that GEP 2 depends equally upon the distance from the shore, freshwater input, eutrophication, and hydrogen sulphide contamination of surface and bottom water, respectively. The pH parameter evaluates the hydrogen content in the sea water, being a measure of acidity. The ORP parameter indicates the activity or strength of oxidizers and reducers in relation to their concentration, and is associated only with the partial pressure of oxygen and the pH of the water (Cooper, 1937). This explains why pH and ORP are grouped together on the factor diagram. ORP serves as a measure of the ability of the aquatic environment to cleanse itself or break down waste products, such as contaminants and dead plants and animals. When the ORP value is high, there is lots of oxygen present in the water. This means that bacteria that decompose dead tissue and contaminants can work more efficiently. The higher the ORP value, the healthier is the aquatic environment. Thus, together with DO, the ORP provides additional information on water quality and the degree of pollution. In this way, we suggest that Factor 3 is related to contamination of the bottom water.

Foraminiferal distributional parameters are clearly correlated with GEP 1 and probably C/N, definitely not with grain size distribution. The closer to the shore, the less foraminiferal species can resist the freshening of the bottom water caused by Danube inflow. Farther from the shore, the influence of the Danube inflow decreases and foraminifera flourish.

Conclusions

With the help of benthic foraminifera, the distributional patterns of the Danube River inflow into the Romanian part of NW Black Sea can be traced. The study is in good agreement with our previous data obtained in other parts of the NW Black Sea adjacent to the Dniester and Dnieper Rivers, and it confirms once again that foraminifera can be used as reliable *in situ* instruments to monitor environmental stress caused by river input (Yanko and Troitskaia, 1987; Yanko, 1990 a,b; Yanko et al., 1999; Yanko-Hombach, 2007). The study is in progress. More results will be published elsewhere.

Acknowledgements

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NEW EVIDENCE FROM THE NORTHWESTERN SHELF FOR HOLOCENE MARINE TRANSGRESSION OF NORTHWESTERN BLACK SEA

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Key-words: sea level, peat, radiocarbon age, delta, foraminifera, palynology, ostracoda

Objective

For two decades, the timing and rate of Holocene marine transgression and the level of the Black Sea prior to the transgression has been the focus of many geological, paleoecological, and archaeological studies. The potential importance of confirming or rejecting the catastrophic flood hypothesis by refining the chronology of the marine transgression and determining the water level of the early Holocene Black Sea (Neoeuxinian) lake is the aim of many ongoing Black Sea paleoecological studies. In a new study, we undertook to review a vast array of previous geological and paleoecological studies, including the original sites of Ryan et al. (1997) which were used to hypothesize a catastrophic Holocene flood, and we have obtained new data on the onset and rate of the early Holocene marine transgression using multidisciplinary studies of 19 cores from different parts of the Black Sea.

Methods

We have applied, as much as possible, uniform methods of seismostratigraphic correlation, micropaleoecological, and palynological methods for re-examining selected reference cores used by Nicholas et al. (2011) to hypothesize a “prompt” Holocene flooding of the Black Sea shelves and to correlate our sites with the Ryan et al. cores. In addition, we focused on obtaining new palynological and microfossil data at three sites on the inner Ukrainian shelf (Fig. 1, 2). Core 342, located on the edge of the Dniester paleovalley on the NW shelf landward of the Ryan et al. sites, is particularly important because sieving methods and paleobotanical methods of inspection provided wood and leaf material from several peat and muddy peat beds, each up to ~10 cm thick, inter-layered in a coastal succession with mud, clay, and shell coquina. AMS ages for wood fragments and sedge leaves in the peat layers provide critical new data that are free from marine reservoir effects and can be used for calibrating and “re-tuning” of the previously published shell and bulk detrital peat ages reported by Nicholas et al. (2011). The accuracy of the peat ages is further validated by palynostratigraphic data which is also independent of the marine reservoir and “old carbon” problems known for Black Sea carbonate samples. Furthermore, we use $\delta^{13}C$ values of the separated plant materials to confirm freshwater and brackish water origins of the dated plant materials and associated ostracode microfossils. All our results are reported as conventional (uncalibrated) radiocarbon ages in order to make the best use of the vast database for Ukrainian and Russian samples assembled for the Black Sea since 1963.

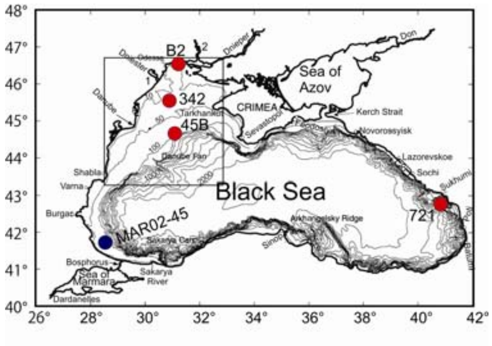

Figure 1. Map of the Black Sea and adjacent regions, showing the extent of the shelf areas, the connection to Marmara and Aegean seas via Bosphorus and Dardanelles Straits, and locations of key reference cores with 14C ages. Red circles mark location of cores described in this paper; blue circle is core of Hiscott et al. (2007, 2010). 1- Dniestrovian liman, 2-Berezan liman..

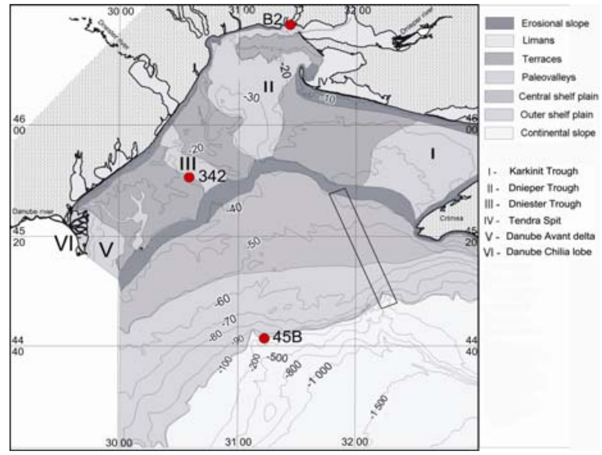

Figure 2. Northwest Black Sea study area showing present bathymetry (in m bsl), paleovalleys I – III, locations of cores in present study, shelf section (in rectangle) studied by Ryan et al. (1997), and other important geomorphological features I-VI, listed below.

Results

Our multidisciplinary study of geological material recovered from eastern, northern, and western shelf areas of the Black Sea further refines the chronology of the marine transgression established from a wood sample by Soulet et al. (2011) and shows that many early Holocene shell ages are up to several hundred years too old. We also show that “bulk” peat including detrital sediment of unknown source is decades too old. Our microfossil and palynological data clarifies conflicting interpretations of the water level and salinity of the Neoeuxinian lake prior to the initial Mediterranean inflow (IMI) and the transgression of Mediterranean water in the Holocene, and our refined chronology allows more accurate calculation of the rate of the transgression. We find the following. (1) The level of the Late Neoeuxinan lake prior to the early Holocene Mediterranean transgression stood around -40 m bsl but not -100 m or more as suggested by advocates of catastrophic/rapid/prominent flooding of the Black Sea by Mediterranean water. (2) At all times, the Neoeuxinan lake was brackish with a salinity not less than 7 psu. (3) By 8.9 ka BP, the Black Sea shelf was already submerged by the Mediterranean transgression, as was previously established by Bradley et al. (2012). The increase in salinity took place over 3600 years, with the rate of marine water incursion being estimated in the order of 0.05 cm to 1.7 cm.a^{-1}. (4) The combined data set of sedimentological characteristics and microfossil data establish that the Holocene marine transgression was of a gradual, progressive nature in the early Holocene.

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NEOPLEISTOCENE STRATIGRAPHY OF THE PONTO-CASPIAN CORRIDORS

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Keywords: sttratotypes, stratigraphy, paleogeography, sea level, water exchange

There are many past/present geological projects in the "Ponto-Caspian Corridors." The most recent geological projects have been carried out by Odessa I.I. Mechnikov National University, Ukraine; Prichernomorskoe State Regional Geological Enterprise "Prichernomor GRGP," Odessa; Moscow M.V. Lomonosov State University, Russia; the Institute of Geography, Russian Academy of Sciences; the Department of Marine Geology and Mineral Resources of the National Academy of Sciences of Ukraine; P.P. Shirshov Institute of Oceanology, Russian Academy of Sciences; Avalon Institute of Applied Science, Canada; the National Institute of Marine Geology and Geoecology, Romania; the Geology Institute of the Azerbaijan National Academy of Sciences; the Museum of Natural History, Bulgaria; the Institute of Oceanology, Bulgaria; IFREMER, France; Memorial University, Canada; Lamont-Doherty Earth Observatory of Columbia University, USA; Temple University, USA; Delaware University, USA; Istanbul University and Istanbul Technical University, Turkey; and many others. These efforts have produced a variety of geochronological scales for the Ponto-Caspian Corridors.

Geological data obtained by past and present projects were analyzed by many scientists, such as N.I. Andrusov, A.D. Arkhangelsky, N.M. Strakhov, M.M. Zhukov, V.M. Muratov, L.A. Nevesskaya, P.V. Fedorov, G.I. Popov, A.A. Svitoch, V.A. Zubakov, E.F. Shnyukov, A.L. Chepalyga, F.A. Shcherbakov, A.B. Ostrovsky, N. Panin, V. Yanko-Hombach, T.A. Yanina, A. Mamedov, P.N. Kuprin, V.M. Sorokin, E. Aliyeva, G. Oaie, M. Melinte, I. Motnenko, G. Karaivan, Ya.A. Izmailov, S.A. Nesmeyanov, I.P. Balabanov, N.V. Esin, M. Filipova-Marinova, D. Petko, G. Lericolais, R. Hiscott, A. Aksu, P. Mudie, W.B.F. Ryan, I. Buynevich, E.P. Larchenkov, R. Martin, M.N. Çağatay, H. Koral, Y. Yılmaz, O. Algan, and many others.

A stratigraphic scale for the Ponto-Caspian region was developed based on mollusks (e.g., Nevesskaya, 1965; Fedorov, 1978; Yanina, 2013) and foraminifera (Yanko, 1989; Yanko-Hombach, 2007). This, in turn, enabled reconstruction of the hydrological regime of the basins as well as an approximate correlation of major events in this region with those in the Mediterranean Sea and the World Ocean. Scientists more or less agree to the following correlation between stratigraphic units and MISs in the Black Sea, Caspian, and Mediterranean regions, respectively: Bakinian-Chaudian-Sicilian (MIS 19-13), Early Khazarian-Old Euxinian+Uzunlarian-Paleotyr-renian (MIS 11-7), Late Khazarian-Karangatian-Tyrrenian (MIS 5), Khvalynian-Neoeuxinian- Grimaldian (MIS 4-2), and Novocaspian-Chernomorian-Verzilian (MIS 1). However, many questions remain unsolved. For example, there is no unanimous opinion on the correlation of local horizons not only with each other but with MISs as well. This is because the absolute age of the sediments in the holo-, lecto-, neo-, hypo-, para-, and boundary stratotypes (defined here as QPCR STRATOTYPES) varies depending on the method used, e.g., ^{230}U/Th, thermolumi-nescence, etc. (Zubakov, 1986) and requires revision. There is no unanimous opinion on the number of transgressive and regressive stages and their amplitude in certain geological epochs.

Because of this lack of agreement, some researchers are trying to use alternative methods to clarify the order of events, thereby introducing even more confusion. For example, Badertscher et al. (2011) used oxygen isotope ($\delta^{18}O$) signatures in stacked speleothems from Sofular Cave in northern Turkey to propose that the Black Sea and Mediterranean connection as well as that between the Black Sea and Caspian have been open for a greater number of periods than previously thought. In particular, Caspian-Black Sea connections opened at least seven times, while Mediterranean-Black Sea connections occurred at least twelve times since 670 ka BP. However, Yanko-Hombach and Motnenko (2011) respond that if the data of Badertscher et al. (2011) are correct, we would see corresponding alternations of faunal assemblages in coeval age sequences exposed in stratotypes of the Kerch and Taman peninsulas, and the Caucasian coast. However, foraminifera show that the Caspian-Black Sea and Mediterranean-Black Sea connections existed four and six times, respectively, since the Matuyama-Brunhes reversal (i.e., the last 780 ka), and in most cases, these connections did not occur synchronously with those of Badertscher et al. In summary, despite over 150 years of intensive field studies and interpretative research, there is no up-to-date high-resolution stratigraphic scale for the Corridor as well as exact timing of the water exchange between adjacent basins.

This paper intends to provide an outlook on the existing geochronological scales and demonstrate the number, time, and direction of MS and CS water intrusions into the BS during the Pleistocene. In our work, we follow the Russian divisions of the Quaternary System, which separates the Quaternary into the Eopleistocene [1.8-0.78 Ma], the Neopleistocene [0.78-0.01 Ma], and the Holocene [0.01-0.0 Ma]. The boundary between the Eopleistocene and Neopleistocene coincides with the Matuyama-Bruhnes reversal [MBR], which is readily traced in both the BS and CS regions at the bottom of the Lower Chaudian and Tyurkanina horizons, respectively.

The Caspian region

Stratigraphy of the Caspian Neopleistocene is based on changes in the evolutionary patterns and ecological assemblages of the mollusk genus *Didacna* Eichwald (Andrusov, 1915; Pravoslavlev, 1939; Zhukov, 1945; Fedorov, 1957, 1978; Vekilov, 1969; Popov, 1983; Svitoch, 1991; Svitoch and Yanina, 1997; Nevesskaya, 2007; Yanina, 2005, 2013; and others). The researchers subdivided the Neopleistocene Caspian deposits with high resolution and detail; however a number of unresolved questions remain.

The Bakinian horizon (lower Neopleistocene) in all schemes is divided into two divisions – lower and upper. But some researchers (Fedorov, 1957, 1978; Vekilov, 1969; Popov, 1983; Nevesskaya, 2007) allocate them at the rank of subhorizon with a stratigraphic break between them, while others (Zhukov, 1945; Svitoch, 1991; Yanina, 2013) consider them as layers with a gradual transition between them. Fedorov (1978) and Nevesskaya (2007) labeled Urundjikian layers as part of the Bakinian horizon; and Yanina (2012) considers it a horizon at the beginning of the middle Neopleistocene.

In the middle Neopleistocene, the lower Khazarian horizon is present in all stratigraphic schemes. However, some researchers dismember it into three subhorizons (Yanina, 2013) or three layers (Fedorov, 1978; Svitoch, 1991). Others (Vasilyev, 1961; Vekilov, 1969; Nevesskaya, 2007) consider it as a uniform stratigraphical unit. In some schemes, the upper Khazarian horizon is included in the middle Neopleistocene (Vekilov, 1969; Popov, 1983; Rychagov, 1997).

A debated question of the upper Neopleistocene stratigraphy is the existence of the Girkanian horizon (Popov, 1983) or subhorizon (Yanina, 2013). It is denied by Fedorov (1978), Shkatova (2006), and Svitoch (1991). Researchers placed the Khvalynian horizon in the second half of the upper Neopleistocene, having divided it into two subhorizons (Fedorov, 1957, 1978; Vekilov, 1969; Popov, 1983; Rychagov, 1997, etc.) or two layers (Svitoch and Yanina, 1997). Vasilyev (1961) distinguishes two marine units of the lower Khvalynian horizon divided by the regressive Elton layers. Chepalyga (2006) also separates the Khvalynian horizon into three layers.

The majority of researchers allocated only one marine horizon to the Holocene – Novocaspian. Fedorov (1978) and Svitoch and Yanina (1997) break it into three layers. In Svitoch's latest work (2011), Dagestan layers indicating an independent Holocene transgression are identified. Moreover, Svitoch transfers the late Khvalynian subhorizon to the Holocene.

As we see, the stratigraphic scheme of the Caspian Neopleistocene has no uniform systematics, as well as reconstructed paleogeographical events. So, on the basis of so many different stratigraphic schemes, the number of functioning epochs within the Manych Passage has been variously reconstructed by researchers: eight (Goretsky, 1966; Popov, 1983), seven (Fedorov, 1978), six (Yanina, 2012), and four (Svitoch et al., 2010).

The biostratigraphic scheme of the author (Yanina, 2013) is one of the latest schemes. It is an ecostratigraphic and paleoevent scheme as well, because all recognized stratigraphic units are related to the paleogeographical events at varied hierarchical levels (transgression, stage, phase) in the development of the Caspian Sea.

The Pontian region

The stratigraphic subdivision and interpretation of the Neopleistocene events of the Pontian region have no uniform agreements also. All researchers are agreeable about placing the Chaudian horizon in the lower Neopleistocene. The Pre-Chaudian regression is recognized by many scientists (Fedorov, 1978; Dimitrov et al., 1979; Krystev et al., 1990, etc.). At the same time, according to Kitovani (1976), deposits of the Gurian basin were gradually replaced by Chaudian sediments. Numerous disputes have arisen around a question about the "Bulgarian Chauda." This basin was assigned to the regressive early Chaudian (Chepalyga, 1997; Fedorov, 1982; and others) and to the late Chaudian (Dimitrov and Govberg, 1978). The distribution of Caspian fauna in the Chaudian basin was noted as occurring twice (Fedorov, 1978; Popov, 1983; Nevesskaya, 2007), or once (Yanina, 2005). According to the majority of researchers (Arkhangelsky and Strakhov, 1938; Fedorov, 1978; Dimitrov, 1978; Khrischev and Shopov, 1979; and others), the Chaudian basin level was negative. Water from the Chaudian basin exited through the Bosphorus into the Sea of Marmara and Dardanelles. It is obvious that sea level changed repeatedly. Seismoacoustic profiles testify to it (Limonov and Krystev, 1990). The first intake of Mediterranean water and euryhaline fauna into the Chaudian basin is recognized in the Neopleistocene (Fedorov, 1978; Yanko et al., 1984; Chepalyga, 1997). The stage with marine fauna was named the Epichaudian basin by P. Fedorov (1978), the Karadeniz basin by A. Chepalyga (1997), and the Patray basin by V. Zubakov (1986). Its deposits terminated the lower Neopleistocene sedimentation stage.

The Euxinian-Uzunlarian epoch of the middle Neopleistocene has been differently reconstructed in the stratigraphical schemes also. One alternation of Caspian and marine type deposits (Old Euxinian and Uzunlarian) has been recognized by Arkhangelsky and Strakhov (1938) and Nevesskaya (2007); two alternations were identified by Fedorov (1978) and Chepalyga (1997); three were proposed by Ostrovsky et al. (1977), Nesmeyanov and Izmailov (1995), and Yanina (2012). Thus, from one to three invasions of Mediterranean water and fauna have been identified respectively. The subsequent regression was noted by Fedorov (1978), Popov (1983), and others; the absence of a break between the Uzunlarian and Karangatian deposits was noted by Khrischev and Shopov (1979) and Grigoriev et al. (1985).

The beginning of the late Neopleistocene was marked by the Karangatian transgression. Its deposits are widespread and have been well studied (Arkhangelsky and Strakhov, 1938; Nevesskaya, 1965; Fedorov, 1978; Yanko et al., 1984, 1990; Grigoriev et al., 1985; Kuprin, 1988; Chepalyga et al., 1989; Nesmeyanov and Izmailov, 1995; Chepalyga, 1997, 2002; and many others). In the fullest stratigraphic schemes (Yanko et al., 1984, 1990; Chepalyga, 2002), deposits from three or four stages are identified; they differ on the basis of the presence of various stenohaline and euryhaline groups of organisms. The gulf of the maximum phase of the Karangat Sea extended to the watershed of the Eastern and Western Manych.

G. Goretsky (1966) and G. Popov (1983) recognized deposits from the Surozhian transgression, the existence of which has not been agreed upon by many researchers (Fedorov, 1978; Nevesskaya, 1965; etc.). The upper Neopleistocene ended with deposits of the Neoeuxinian basin, with a minimum level of -110 m (Ostrovsky et al., 1977; Balabanov and Izmailov, 1988) to -150 m (Ryan et al., 1997).

On the Holocene stratigraphy of the Black Sea, consensus is also absent. The structure of the deposits and the development of macro- and microfauna testify to stages in the basin's evolution, concerning which there is no agreement among researchers. According to Nevesskaya (1965), salinity increase in the sea and colonization by Mediterranean fauna proceeded gradually; she established four stages for such a development (Bugazian, Vityazevian, Kalamitian, and Dzhemetian). Fedorov (1978) assigned two phases of transgression: Old Chernomorian and Neochernomorian; in the late Holocene, he identified the Phanagorian regression and the Nymphaean transgressive phase. Other researchers (Balabanov and Izmailov, 1988; Yanko-Hombach et al., 2007) consider that the sea level rose gradually with an oscillating mode. In the Holocene, they noted not less than 5 transgressive and regressive phases in turn, complicated by smaller rhythmics. According to the opinion of Ryan et al. (1997, 2003) and others, the Holocene transgression had a catastrophic character (Flood). This hypothesis divided scientists even more from a uniform point of view on the geological and geographical events in the region.

The basic goal of the IGCP-610 Project is to obtain new data on the environmental evolution of the Caspian-Black Sea Corridor using a multidisciplinary research strategy that comes with the advantage of mutual cross checking of results received independently from varied specialists. The results may lead to many consensus conclusions regarding the development of the region during the Quaternary as well as correlations of local events with adjacent areas.

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NEOLITHIC AND BRONZE AGE CULTURES IN THE WESTERN CAUCASUS AND CHANGES IN BLACK SEA LEVEL

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Key words: Western Caucasus, Neolithic, Bronze Age, Dolmenian culture, Black Sea level, environment

Introduction

In this presentation, questions concerning the spread of Neolithic-to-Bronze Age cultures and their connection with levels of the Black Sea are considered.

The Neolithic of the western Caucasus is poorly understood in comparison with other cultures of the area, including those of the Paleolithic and the Bronze Age. The rarity of Neolithic sites is most probably connected with Black Sea transgression (Trifonov, 2009). One can say that sea level in the Pontic basin had periods of sharp rises and falls. During the Neolithic, the Black Sea level was very low, and as a consequence, it is now rather difficult to find the remains of Neolithic sites (Fig. 1).

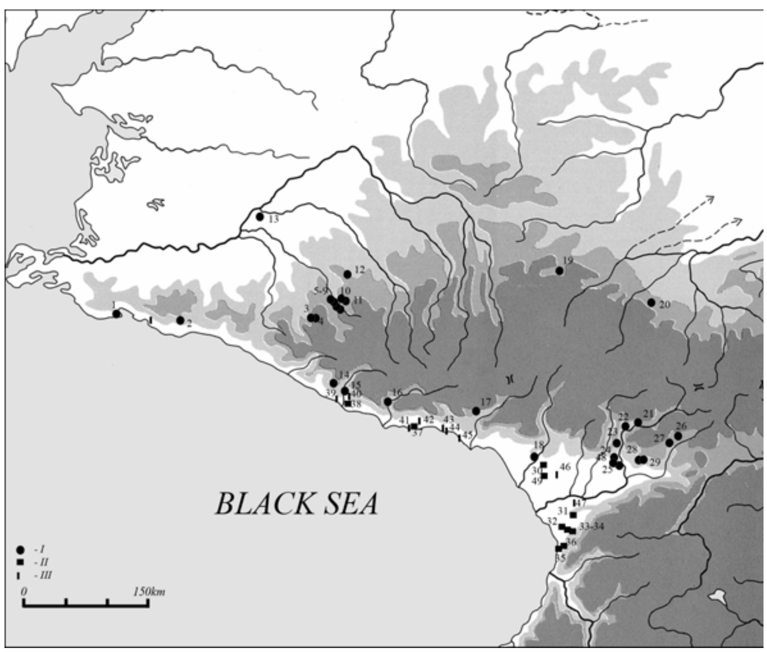

Figure 1. Neolithic sites of the Western Caucasus.

The most representative cultures in the western Caucasus are the different Bronze Age cultures, among which are the dolmen (megalithic) cultures. The Caucasian dolmens represent a unique type of prehistoric architecture, built using precisely dressed stone blocks. The monuments date between the end of the 4th millennium and the beginning of the 2nd millennium BC. While generally unknown to the rest of the world, these Russian megaliths are equal to the great megaliths of Europe and Asia in terms of age and quality of architecture. Yet their origins remain unknown. The question is whether the origin of ashlar masonry in the region is due to an influence from Anatolia or the Mediterranean, or whether it is completely independent. What lies behind the significant similarities between dolmens in the Circumpontic area (Russia, Abkhasia, Turkey, and Bulgaria) and Western Europe?

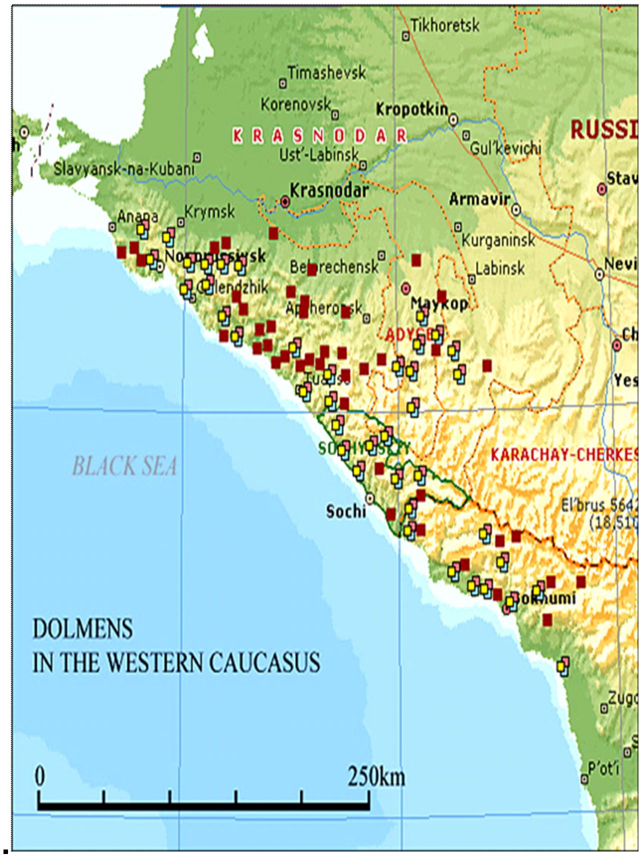

Figure 2. Dolmens of the Western Caucasus

Results

This article is focused mainly on the study of the dolmen cultures of western Caucasus, their chronology, funerary tradition, and the migration of the people using different scientific methods, including radiocarbon dating, stable isotopic analyses, and other archaeological evidence.

From the end of the 4th/beginning of the 3rd millennium BC to the last quarter of the 2nd millennium BC, the western slopes of the Caucasus Mountains were occupied by an archaeological culture named for its massive mortuary constructions and megalithic burials – dolmens. Such megaliths are distributed on both slopes of the Great Caucasus range from Anapa to Kolkhida. The hypothesis of a West European origin for the Caucasian megalithic structures dates back to the beginning of the 20th century. This concept was worked out further by Nikolaeva and Safronov (1974), who argued that the practice of burials in the “novosvobodnaya” type tombs was introduced into the Caucasus together with other features, like globular amphora, funnel beakers, corded ware, and even the Baden-Boleráz cultural complex. This then spawned the local development of “two-chambered” tombs into “true” dolmens. Lavrov (1960) was the first to propose the possibility of Caucasian people copying megalithic structures from somewhere in the Mediterranean as a result of their own marine expeditions.

Currently, about 3000 dolmens have been documented, usually clustered in groups of 2-3 to several dozen burials. The largest cluster consists of about 500 dolmens. For the last few years, we studied two dolmens: Kolikho and Shepsi, which are situated now under water (Trifonov et al., 2012; Rezepkin, 2010). Due to this factor, the archaeological artifacts are well preserved.

It is very interesting that in these dolmens, the remains of the ancient people were found: 70 and 20 bodies, respectively. According to our study, the Kolicho dolmen was in use more than 500 years without interruption. To estimate the origin of the people buried, we used the content of isotopic strontium in the bones and teeth. To characterize the local background of strontium, we used snails. Most of the buried people originated from this region; some were from elsewhere, As one can see from the figures, the Neolithic and the Dolmen sites are located close to the coastline of the Black Sea (Fig. 2), where sea level fluctuations (Fig. 3) could have a significant influence.

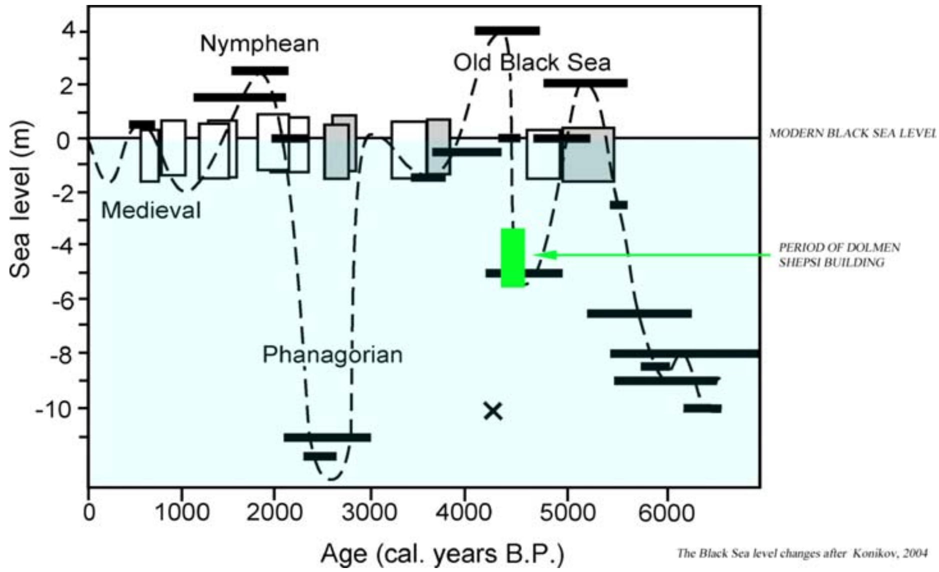

Figure 3. Black Sea levels during the Holocene (Konikov et al., 2009).

Conclusions

The evidence concerning the Black Sea level changes is correlated with the solar and cosmic ray activity (Raspopov et al., 2012). These changes had an influence on the ancient cultures that existed in this region.

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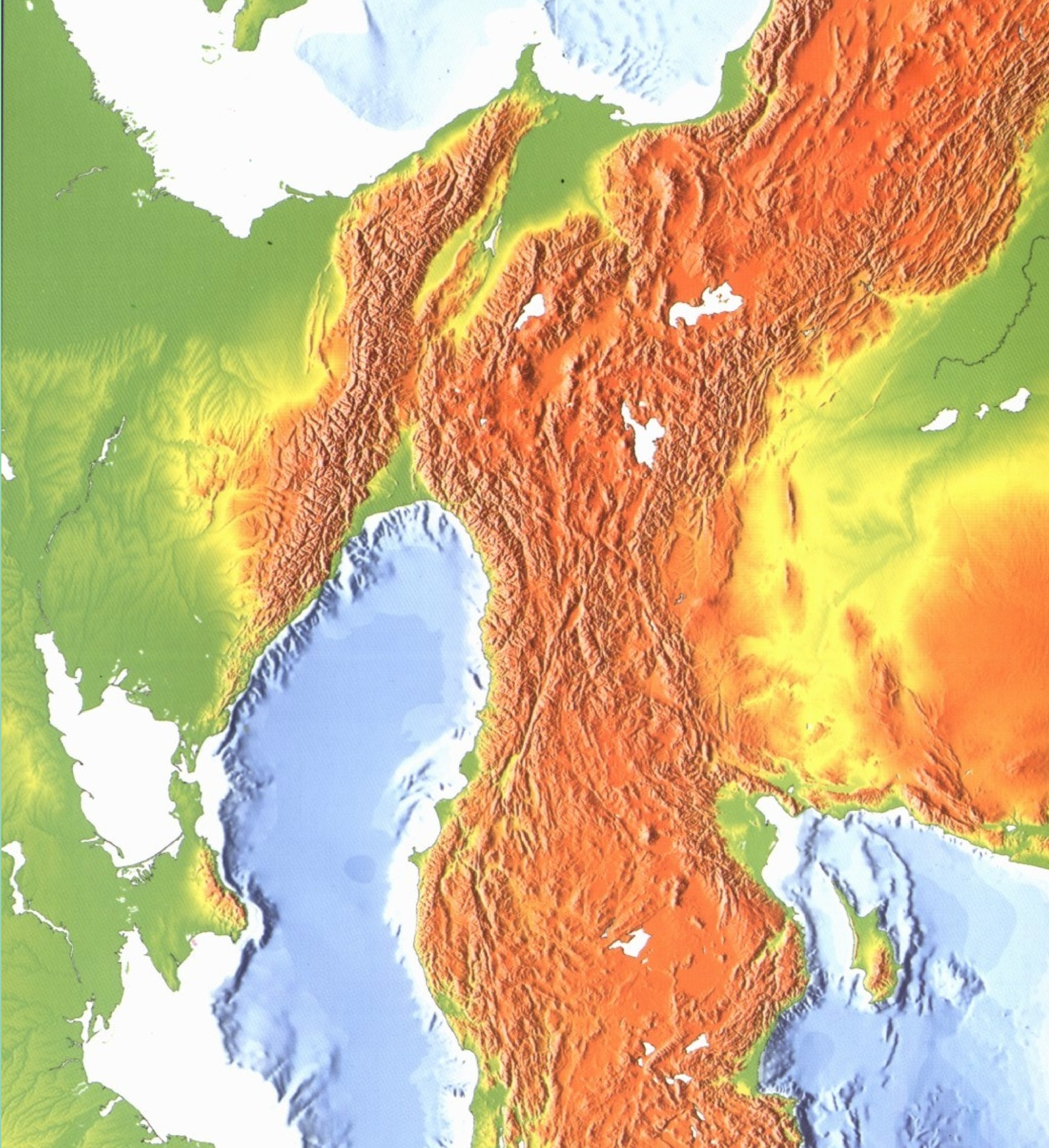

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