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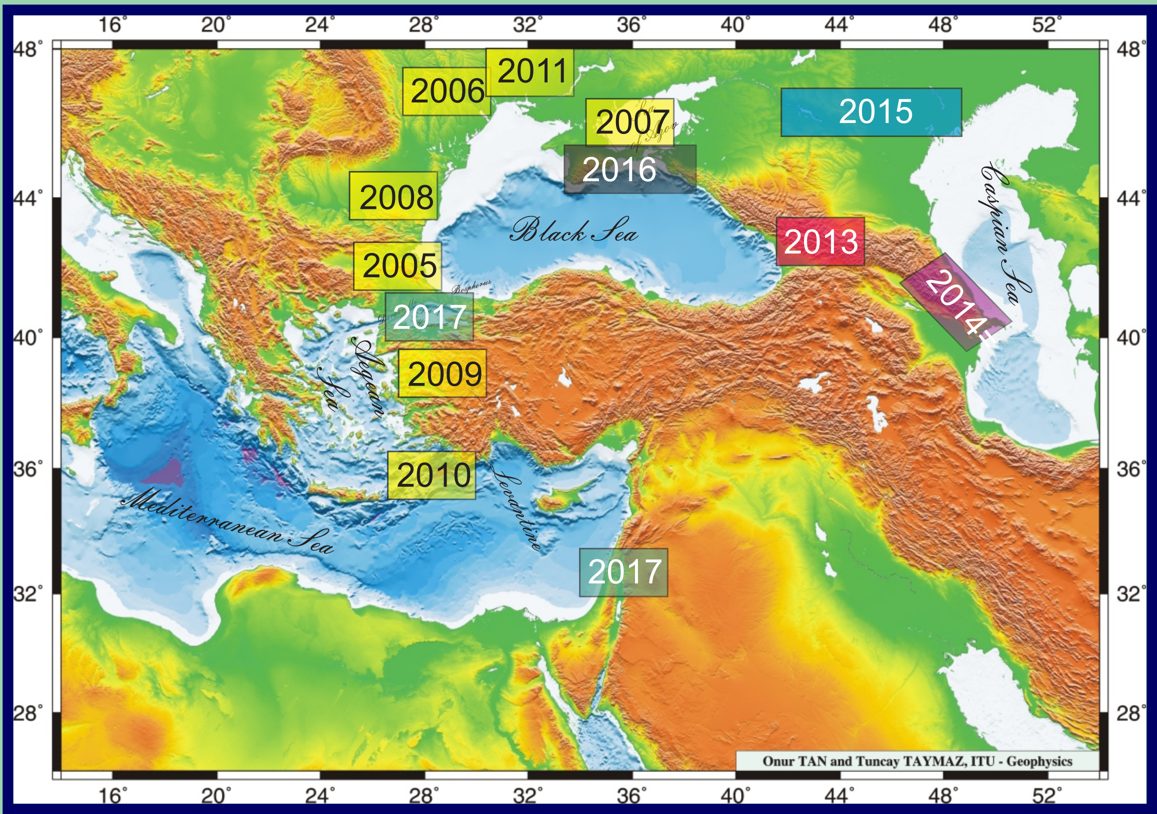
Georgian National Academy of Sciences, Department of Earth Sciences, Tbilisi, Georgia

2-9 October 2016

INTERNATIONAL GEOSCIENCE PROGRAMME



Proceedings of the Fourth Plenary Conference

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

http://www.avalon-institute.org/IGCP610

IGCP 610 Fourth Plenary Conference and Field Trip, Tbilisi, Georgia, 2-9 October 2016

PROCEEDINGS

Organizers:

Georgian National Academy of Sciences, Department of Earth Sciences

Ilia State University, Faculty of Natural Sciences and Engineering

Sponsors

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Avalon Institute of Applied Science, Winnipeg, Canada

PROCEEDINGS

IGCP 610 Fourth Plenary Conference and Field Trip

"From the Caspian to Mediterranean: Environmental Change and Human Response during the Quaternary"
(2013 - 2017)

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Tbilisi ◆ Georgian National Academy of Sciences ◆ 2016

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AIMS AND SCOPE

The main goal of the IGCP 610 Project 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 Caspian-Black Sea-Mediterranean Corridor [“CORRIDOR”] for a deeper understanding of Eurasian history, environmental changes and their relevance, as well as past and future impacts on humans.

The “CORRIDOR” is perfectly suited for these purposes. (1) It encompasses the large chain of intercontinental basins—the Caspian, Black (together called Ponto-Caspian), Marmara, Aegean, and Eastern Mediterranean (Levantine) seas—with their connecting straits and coasts. Here, sea-level changes are clearly expressed due to geographical location and semi-isolation from the World Ocean, which makes the “CORRIDOR” a paleoenvironmental amplifier and a sensitive recorder of climatic events. Periodic connection/isolation of the basins during the Quaternary predetermined their specific environmental conditions and particular hydrologic regimes, and thus, the area, and especially the Ponto-Caspian, represents a “natural laboratory” to study the responses of semi-isolated and isolated basins to GCC. (2) It has rich sedimentary and geomorphologic archives that document past environmental changes. (3) It has a substantial archaeological, anthropological, and historical record. (4) It is easily accessible for study.

To achieve the main goal and objectives, the Project incorporates six dimensions, each addressed by integrating existing data and testing of hypotheses: 1. The geological dimension examines the sedimentary record of vertical sea-level fluctuations and lateral coastline change. 2. The paleoenvironmental dimension integrates paleontological, palynological, and sedimentological records to reconstruct paleolandscapes. 3. The archaeological dimension investigates cultural remains. 4. The paleoanthropological dimension studies responses of different *Homo* species to environmental change. 5. The mathematical dimension provides

GIS-aided mathematical modeling of climate and sea-level changes, and human dispersal linked to paleoenvironmental variation that can be meaningfully compared with current global changes. 6. The geo-information dimension grasps the "big picture" of geoarchaeological events over the duration of the Quaternary. Particular attention will be given to synthesizing the wealth of literature published in local languages, stored in archives, and largely unknown or ignored in the West.

Study sites include the Caspian, Azov-Black Sea, Marmara, and Eastern Mediterranean. These sites are characterized by rich sedimentary, geomorphological, archaeological, paleoanthropological, and historical records providing a superb opportunity to assess the influence of climate and sea-level change on human development.

Six Plenary Conferences and Field Trips are planned in the following regions: 2013 – Western Georgia; 2014 – Azerbaijan and Russia (Dagestan); 2015 – Russia (Northern Caspian and Manych Outlet); 2016 – Eastern Georgia (Inner Kartli and Kakheti regions); 2017 – Israel (Eastern Mediterranean), Turkey (around the Sea of Marmara), and/or possibly Turkmenistan (under consideration). They are scheduled for the third quarter of each year. Prior to each Conference and Field Trip, the Conference Proceedings and Field Trip Guide are prepared. Each Plenary Conference provides a forum for dialogue between multidisciplinary specialists in the Quaternary history of the “CORRIDOR” and other workers in related areas. The Field Trips follow the Plenary Meetings (Fig. 1).

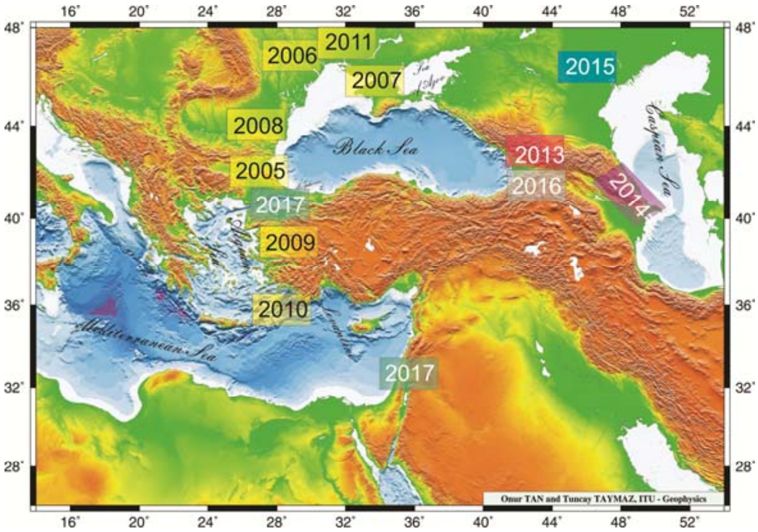

Figure 1. The Caspian-Black Sea-Mediterranean “CORRIDOR”: in yellow are the locations of IGCP 521-INQUA 501 meeting and field trip sites (2005-2011); in other colors are sites to be studied by the present IGCP 601 Project: 2013 – Tbilisi, Western Georgia; 2014 – Baku, Azerbaijan; 2015 - Astrakhan’ (Volga Delta), Russia; 2016 – Tbilisi, Eastern Georgia; 2017 – Haifa, Israel, and Istanbul, Turkey.

They are focused on observation of geological characteristics of Quaternary stratotypes as well as key archaeological and paleontological sites. All of them are easily accessible for study and can be sampled during the Field Trips for further investigation in various laboratories around the world.

The Fourth Plenary Meeting and Field Trip will focus on the pre-Pleistocene and Pleistocene geological history of the Eastern Paratethys remnants within Eastern Georgia. This subject is very important in shedding light and achieving a better understanding of a possible mechanism of separation of the Eastern Paratethys into the individual seas leading to formation of the Black and Caspian Seas.

It is expected that the meeting will bring together multidisciplinary scientists from all over the world to enhance the West-East scientific dialogue and provide a foundation for collaboration on correlation and integration on the subject of the conference as previous IGCP 610 meetings have done.

The meeting will cover eight days. Two days (3-4 October) will be spent in Technical Sessions, and four days (5-8 October) will be dedicated to the Field Trips.

WELCOME

On behalf of the Organizing and Executive Committees as well as the Georgian National Academy of Sciences (GNAS), Ilia State University, Georgia, and Avalon Institute of Applied Science, Canada, we are delighted to welcome you to the IGCP 610 Forth Plenary Conference and Field Trip being held on 2-9 October 2016 in Georgia.

This conference is the fourth 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 Fourth Plenary Conference and Field Trip has been organized and sponsored by the Georgian National Academy of Sciences (GNAS), the Ilia State University, Georgia, and 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 Fourth Plenary Meeting and Field Trip

VENUE

Tbilisi is the capital and the largest city of Georgia, lying on the banks of the Kura River. The city was 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.

The Georgian National Academy of Sciences (GNAS), established in 1941, is an autonomous body financed by the Georgian government (Figs. 2, 3). GNAS is the highest scientific institution conducting and coordinating fundamental research in the natural sciences and the humanities in Georgia. It oversees 9 scientific departments of the Academy (www.science.org.ge). GNAS has 61 members and 40 corresponding members. The Georgian National Academy of Sciences coordinates scientific researchers in Georgia and develops relationships with up to 20 Academies of foreign countries and other scientific countries. It is a scientific Adviser to the Georgian Government. GNAS oversees the richest depository of manuscripts and rare book collections in the country.

Figure 2. The main building of the Georgian National Academy of Sciences.

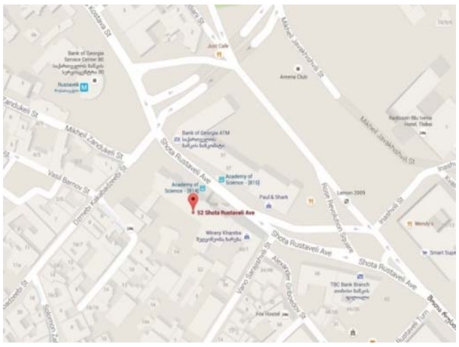

Figure 3. Location of the Georgian National Academy of Sciences.

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We gratefully acknowledge the support and hospitality of the Georgian organizers, the Georgian National Academy of Sciences (GNAS), and the Ilia State University for hosting the IGCP 610 Fourth 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 Academician Irakliy GAMKRELIDZE, Georgia, President of the Conference, Prof. Dr. Avtandil OKROSTSVERIDZE, Chairman of the Organizing Committee, Dr. Eteri KILASONIA, Executive Secretary for their extraordinary efforts in organizing the conference and field trips. Particular appreciation is extended to Acad.-member Michael Kakabadze, Dr. Nonna Gagnidze, Prof. Vakhtang Licheli, Doctorant Dr. David Bluashvili, Dr. Zurab Janelidze, Prof. Nikoloz Tushabramishvili, and Doctoral Student Lasha Sukhishvili, for arranging the Field Trips and preparing the Field Trip Guide.

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 Project and website administrator Dr. Irena MOTNENKO.

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

PART I.
IGCP 610 PROGRESS REPORT (2013-2015)

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http://www.geogr.msu.ru/science/projects/unesco/
http://www.geoecomar.ro/website/proiecte.html
http://archaeology-ethnology.onu.edu.ua/?p=1096
https://www.facebook.com/groups/180481035443572/
http://vk.com/album115218532_181815723

1. List of countries involved in the project

IGCP 610 community includes about 250 scientists from 22 countries: Azerbaijan, Belgium, Bulgaria, Canada, Georgia, Germany, Greece, France, Israel, Italy, Kazakhstan, Latvia, Romania, Russia, The Netherlands, Switzerland, Turkey, Turkmenistan, UK, Ukraine, and USA.

IGCP 610 Project investigates 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 commenced on 1 April 2013. Since that time, it has served as a focal point for correlation of scientific data obtained by research projects dealing with environmental change and human response in a variety of settings within the Caspian-Black Sea-Mediterranean Corridors [CORRIDORS] during the Quaternary. In general, two years of IGCP 610 activity have been carried out in a strict agreement with the Working Plan [http://www.avalon-institute.org/IGCP610/work_plan.php]. The one exception was the creation of the GIS-aided Interactive Data Base that was postponed until the end of the project.

Its main 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 has a triple focus: (1) geological history, (2) paleoenvironmental change (climate, sea level, coastline migration), and (3) human response (migration, subsistence strategy, physical and cultural adaptation, etc.) to environmental changes. Six dimensions of evidence are explored by integrating existing data and hypothesis testing: 1. The geological dimension examines the sedimentary record of vertical sea-level fluctuations and lateral coastline change. 2. The paleoenvironmental dimension integrates paleontological, palynological, and sedimentological records to reconstruct paleolandscapes. 3. The archaeological dimension investigates cultural remains. 4. The paleoanthropological dimension studies responses of different *Homo* species to environmental change. 5. The mathematical dimension provides GIS-aided mathematical modeling of climate, sea-level change, and human dispersal linked to environmental change. 6. The geo-information dimension will try to grasp the "big picture" of geoarchaeological events throughout the Quaternary. Attention is constantly given to synthesizing the wealth of literature published in local languages, stored in archives, and largely unknown in the West.

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. That Project examined the "CORRIDOR" for the last 30 ky only. The new IGCP Project begins in the early Quaternary, examining responses of pre-modern humans to environmental change, and includes the Central Asian basins thereby covering the Eurasian cascade more completely and involving scientists from countries farther east. It links Europe and Asia more closely in the successive conferences and field trips, and like its predecessor, the new Project improves our understanding of the geoscientific factors affecting global environment in order to improve human living conditions; increases understanding of geological processes and concepts of global climate change [GCC], including socially relevant issues; and improves standards, methods, and techniques of carrying out geological and archaeological research, including the transfer of geological and geotechnological knowledge between industrialized and developing countries.

The Project's wide scope provides a superb opportunity to collaborate with other ongoing/past projects, as well as the MAB Programme of the UNESCO Strategy for Action on Climate Change, LOICZ, IGBP, and especially with SPLASHCOS, in which two co-leaders of this Project (V. Yanko-Hombach and O. Smyntyna) were members of the Management Committee. The Project complements the IGU Commission on Coastal Systems, INQUA CMP, and TERPRO Commissions, with which IGCP 521 cooperated previously through the INQUA 501 project, as well as the HaBCom, SACCOM, and PALCOMM Commissions. The Project also collaborates with geological surveys, archaeological expeditions, and corresponding museums in all countries bordering the "CORRIDOR."

The Project is linked to the EU-ITN programme "Drivers of Pontocaspian biodiversity rise and demise"; EU-WAPCOAST BS-ERA.NET 076 "Water Pollution Prevention Options for Coastal Zones and Tourist Areas: Application to the Danube Delta Front Area"; ICOMOS - The International Council on Monuments and Sites; COCONET "Towards COast to COast NETworks of marine protected areas (from the shore to the high and deep sea), coupled with sea-based wind energy potential"; SPLASHCOS "Submerged Prehistoric Archaeology and Landscapes of the Continental Shelf"; "Study of the formation processes and spatial distribution of methane in the Black Sea and theoretical considerations of their influence on basin eco- and geosystems," supported by the Ministry of Education and Science of Ukraine; and "Paleogeographical evolution of the Gulf of Taman with special regard to the underwater excavations in Phanagoria" funded by the University of Cologne and Russian Foundation for Basic Research (RFBR); and the series of projects supported by RFBR: № 14-05-00227 "Environmental evolution of the Caspian and Black Sea under the multiscale changes of climate", № 13-05-00086 "Pont-Manych-Caspian oceanographic system in the late Pleistocene: Systematics and correlation of events, evaluation of character and degree of interaction, paleogeographic consequences in the region", № 13-05-00242 "Radioisotope stratification of age and synchronization of the Quaternary deposits of the Ponto-Caspian", №

13-05-00625 "Peculiarities of the evolution of relief in the Northern Caspian region in the late Pleistocene: Main stages of the development, chronology, and correlation with climatic rhythms in the Black Sea-Caspian region", № 14-05-00227 "Regularities of evolution of environment of the Caspian Sea and the Black Sea in the conditions of multi-scale climate changes"?; and several others. Disseminating the project events and activities via regular updating of Project websites and mailing list of the project contributors, which increased from 957 in 2013 to 1054 in 2014, as well as social networks (Facebook for English and non-English-speakers, and Вконтакте for mostly Russian speakers) https://www.facebook.com/groups/180481035443572/, http://vk.com/album115218532_181815723.

2. Plenary Conferences and Field Trips

The First Plenary Conference and Field Trip of IGCP 610 was organized by the Institute of Earth Sciences, Ilia State University and the Avalon Institute of Applied Science, Winnipeg, Canada, and hosted by Ilia State University, on 12-19 October 2013, in Tbilisi, Georgia (Yanko-Hombach, 2016). President of the conference was Prof. Zurab Javakhishvili. Executive Director was Prof. Valentina Yanko-Hombach. One hundred and fifty one scientists from 19 countries contributed to the conference; 66% of them were from developing countries (Fig. 1). Their peer-reviewed contributions are assembled in a 182-page Conference Proceedings volume (Gilbert and Yanko-Hombach, 2013).

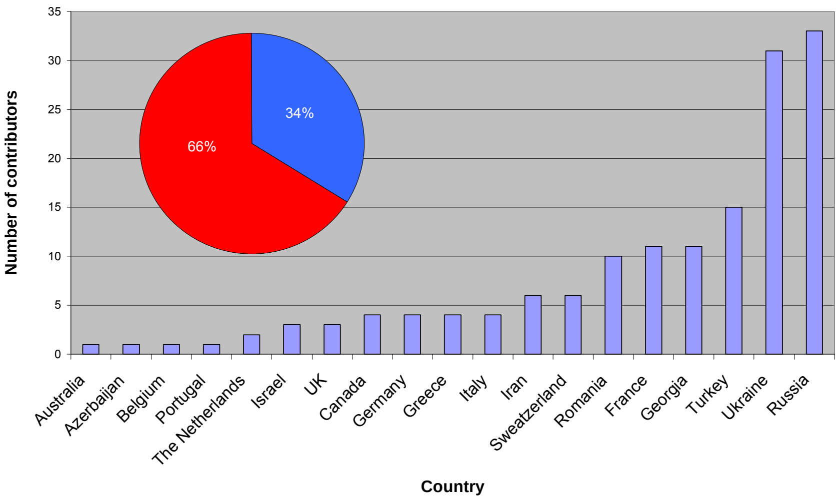

Figure 1. Number of countries and contributors to IGCP 610 First Plenary Conference and Field Trips. The circle shows the percentage of scientists from developing (red) and developed (blue) countries, respectively.

The two days of Technical Sessions were organized into four panels and five Oral/Poster sessions. Panel 1 was titled "STRATIGRAPHY AND PALEOENVIRONMENTAL RECONSTRUCTIONS" (Moderators: Nikolay Panin, Romania, and Andrei Chepalyga, Russia) and included 24 presentations with two key-note talks by Prof. Teller (Canada) and Prof. Okrostsvaridze with co-authors (Georgia). The presentations covered a wide range of topics including Quaternary geomorphology, geology, stratigraphy, paleogeography, volcanism, seismicity, and mineral resources of the Ponto-Caspian and Marmara region. Panel 2 was titled "RECENT ECOSYSYTEMS" (Moderators: Nelly Sergeeva, Ukraine, and Valentina Yanko-Hombach, Ukraine, Canada) and included four presentations on recent fauna of the Black Sea. Panel 3 was titled "ARCHAEOLOGY, HISTORY, AND ETHNOLOGY" (Moderators: Nikoloz Tushabramishvili, Georgia, and Olena Smyntyna, Ukraine) and included ten presentations. The presentations covered a wide range of topics, such as Paleolithic of Georgia, 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, the Aegean route: an alternative route for Neanderthals and Anatomically Modern Humans (AMHs) traveling from Asia to Europe and vice-versa. Panel 4 was entitled "MODELING" (Moderators: Nikolay Esin and Alexander Kislov, Russia) and included four presentations, such as a mathematical model of Black Sea coast and shelf evolution during the Quaternary period, etc.

The POSTER session included 17 posters that were organized into five topics: GEODYNAMICS AND ACTIVE TECTONICS (Moderator: Hayrettin Koral, Turkey), RECENT ECOSYSTEMS (Moderators: Nelly Sergeeva, Ukraine, and Valentina Yanko-Hombach, Ukraine, Canada), SEA LEVEL CHANGES AND PALEOENVIRONMENTAL RECONSTRUCTIONS (Moderators: Nikolay Panin, Romania, and Andrei Chepalyga, Russia), and PALYNOLOGY AND PALEONTOLOGY (Moderators: Petra Mudie, Canada, and Valentina Yanko-Hombach, Ukraine, Canada), ARCHAEOLOGY, HISTORY, and ETHNOLOGY (Moderators: Nikoloz Tushabramishvili, Georgia, and Olena Smyntyna, Ukraine). The Technical Sessions were followed by the Round Table that enabled the formation of 12 Working Groups for the Project and the selection of their coordinators. It also led to decisions about the future strategy in running the project. For more details see the Conference Programme.

The four days of field trips (by bus) were led by prominent Georgian geologists and archaeologists (Okrostsvaridze et al., 2013) and were focused 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 (Fig. 2).

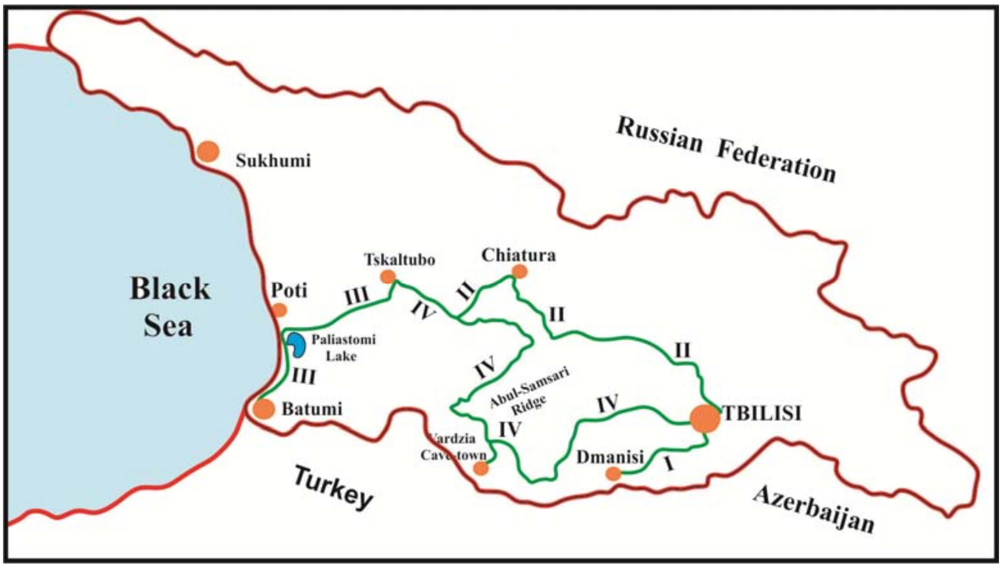

Figure 3. Map of Georgia with geological and archaeological sites visited during the Field Trips of IGCP 610 in 2013. Field Trip I (15 October 2013): Mtskheta, Chiatura Paleolithic sites, Sataplia dinosaur footprints, and cave state reserve. Field Trip II (16 October 2013): Mtskheta, Chiatura Paleolithic sites, Sataplia dinosaur footprints, and cave state reserve. Field Trip III (17 October 2013): Paliastomi Lake, Tsvermagala Chaudian Black Sea Terrace, Batumi seashore. Field Trip IV (18 October 2013): Dzirula massif, Borjomi, Vardzia Cave Town and Quaternary Abul-Samsari volcanic ridge.

The Second Plenary Conference and Field Trip of IGCP 610 was organized by the Institute of Geology and Geophysics of the Azerbaijan National Academy of Sciences (www.gia.az) and the Avalon Institute of Applied Science, Winnipeg, Canada, and hosted by the Institute of Geology and Geophysics, on 12-20 October 2014, Baku, Azerbaijan (Yanko-Hombach, 2016). President of the conference was Corresponding Member of the Azerbaijan Academy of Sciences Prof. Elmira Aliyeva. Executive Director was Prof. Valentina Yanko-Hombach. One hundred and twenty four scientists from two continents and 18 countries contributed to the conference; 71% of them were from developing countries (Fig. 3). Their peer-reviewed contributions are assembled in a 186-page Conference Proceedings volume (Gilbert and Yanko-Hombach, 2014).

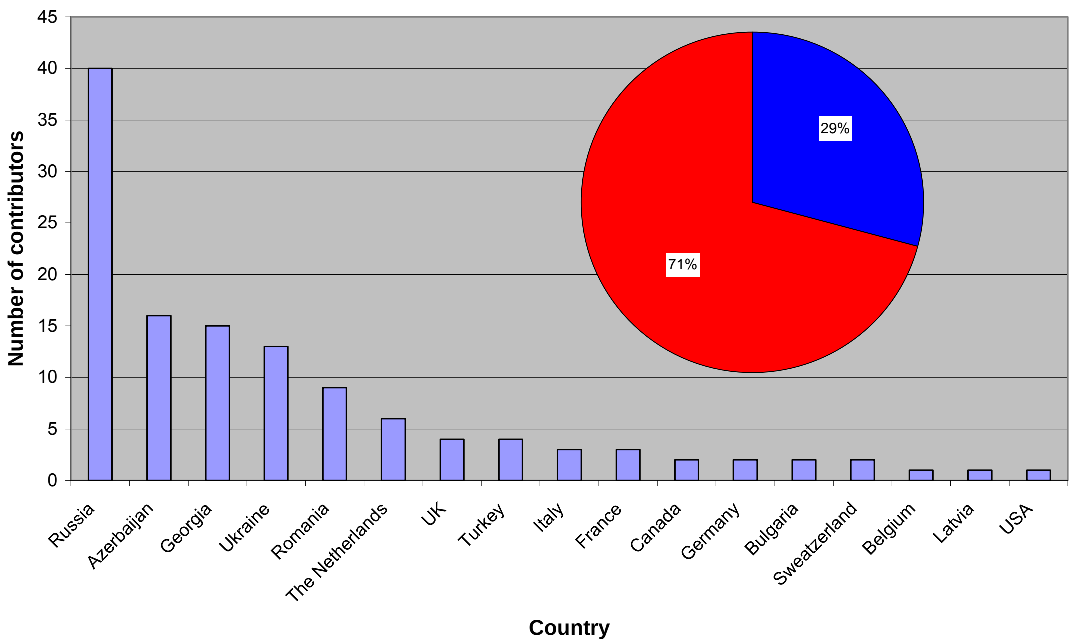

Figure 3. Number of countries and contributors to the IGCP 610 Second Plenary Conference and Field Trips in Baku, Azerbaijan. The circle shows the percentage of scientists from developing (red) and developed (blue) countries, respectively.

The meeting was focused on the whole spectrum of Quaternary geological sequences exposed in the terraces and ridges of the Caspian region. This includes the stratotype of the Mountain of Bakinian stage (ca. 600–450 ka BP) located in the suburbs of Baku on the Absheronian Peninsula; major exposures in the southwestern part of the peninsula of Garagush mountain, Bakinskie Ushi. This includes outcrops of Quaternary deposits at Garamaryam and Turianchay in the Ajinour region, and Bozdag located in the Middle Kura region, which is a reference section of the marine sediments of the Bakinian stage in western Azerbaijan. The Neogene-Quaternary boundary as well as the Matuyama-Brunhes Reversal with Olduvai and Jaramillo episodes were traced. The archaeological sites in Gobustan with its famous petroglyphs of Mesolithic age were observed. Plans included visits to some archaeological and historical places in Baku: the Shirvanshakh Palace constructed during the period from the XIIIth to the XVIth century; the Maiden Tower (the most mysterious monument of Baku) of which the unique construction has no analogs in the East. The Palace complex and Maiden Tower are included in the UNESCO list of World heritage sites. The participants also visited the historical-cultural reserve of Lagich that dates from the XV-XIX centuries, the first Christian Church in the Caucasus dated to the Ist century, excavations of an ancient town located in the suburbs of Gabala city, which for six centuries (until the VIth century) was the capital of Caucasian Albania, and famous for the beautiful wall paintings of Khan Palace in the old Sheki town.

The two days of Technical Sessions were organized into five panels and five Oral/Poster sessions. Panel 1 was titled "RECENT ECOSYSYTEMS AND PROCESSES"—moderators: Nelly Sergeeva (Russia) and Valentina Yanko-Hombach (Ukraine, Canada)—and included five ORAL presentations. The presentations covered a range of topics on recent environments and ecosystems of the Caspian-Black Sea-Mediterranean Corridors. Panel 2 was titled "STRATIGRAPHY, PALEONTOLOGY, AND PALEOENVIRONMENTAL RECONSTRUCTIONS"—moderators: Nikolay Panin (Romania) and Andrey Chepalyga (Russia) —and included 19 ORAL presentations with a key-note talk by Profs. Yanina and Svitoch (Russia). The presentations covered a range of topics on Quaternary ecostratigraphy and paleogeographic reconstructions of the Ponto-Caspian and Marmara region. Panel 3 was titled "TECTONICS"—moderator: Hayrettin Koral (Turkey)—and included three presentations on the earthquakes of Eastern Turkey, interrelationships between sea-level changes and tectonics along the southern Black Sea coasts of Turkey, and modern active tectonics in Azerbaijan. Panel 4 was titled "MODELING"—moderators: Nikolay Esin and Alexander Kislov (Russia)—and included five presentations devoted to modeling of coastline migration, climate change and infilling of the Black Sea by Mediterranean salt water over the course of the Holocene transgression. Panel 5 was titled "ARCHAEOLOGY, HISTORY, AND ETHNOLOGY" —moderators: Andrey Chepalyga (Russia) and Olena Smyntyna (Ukraine)—and included five presentations with a key-note talk by I. Babaev (Azerbaijan). The presentations were devoted to the North Black Sea passageway for the first peopling of Europe, ties between Southeast Caucasus and Mediterranean countries in antiquity, influence of paleoecological changes on migration and economic activities of the Neolithic people of Azerbaijan, and archaeological landscape of Gobustan at the end of the upper Pleistocene and early Holocene.

The POSTER session included 23 poster presentations that were organized into five topics: GEOMORPHOLOGY—moderator: Ekaterina Badyukova (Russia); RECENT ECOSYSTEMS AND ENVIRONMENTAL MONITORING—moderators: Nelly Sergeeva (Russia) and Valentina Yanko-Hombach (Ukraine, Canada); SEA LEVEL CHANGES AND PALEOENVIRONMENTAL RECONSTRUCTIONS—moderators: Nikolay Panin (Romania) and Andrey Chepalyga (Russia); PALYNOLOGY AND PALEONTOLOGY—moderators: Petra Mudie (Canada) and Valentina Yanko-Hombach (Ukraine, Canada); ARCHAEOLOGY, HISTORY, AND ETHNOLOGY—moderators: Mehmet Özdoğan (Turkey) and Olena Smyntyna (Ukraine). The Technical Sessions were followed by the Round Table that enabled participants to discuss the progress of IGCP 610 and to plan future strategy in running the project. For more details see the Conference Programme.

The five days of field trips (by bus) were led by prominent Azerbaijani geologists and archaeologists and were focused on the Apsheronian stage sediments, the classic stratotype of the Mountain of Bakinian stage, examples of the rapid Caspian Sea level changes in the Pleistocene successions, Azerbaijan mud volcanoes, Western Azerbaijan and the Greater Caucasus continuous outcrop of Quaternary continental sediments of the Ajinour, reference outcrop of the marine Bakinian sediments at Bozdag, as well as archaeological sites of Gobustan, Gabala, and historical sites of Baku and Lagich (Fig. 4; Aliyeva and Kengerli, 2014).

Figure 4. Map of Azerbaijan with geological and archaeological sites visited during the Field Trips of IGCP 610 in 2014. Field Trip 1 (15 October 2014): Stop 1.1. The Maiden Tower and Shirvan Shakh Palace; Stop 1.2. The Bakinskie Ushi; Stop 1.3. The Garagush mountain. Field Trip 2 (16 October 2014): Stop 2.1. Classic stratotype of the Mountain of Bakinian stage, examples of the rapid Caspian Sea level changes in the Pleistocene successions; Stop 2.2. Mud volcano Dashgil; Stop 2.3. Gobustan National Park. Field Trip 3 (17 October 2014): Stop 3.1. Outcrop Padar "windows." Continental sedimentation. Stop 3.2. Historical village Lagich. (18 October 2014): Stop 4. Exposure of the Quaternary continental and marine sediments of Ajinour (outcrop Turianchay). Field Trip 5 (19 October 2014): Stop 5.1. Khan palace in Sheki town and historical museum; Stop 5.2. Reference outcrop of the marine Bakinian sediments at Bozdag. Field Trip 6 (20 October 2014): Stop 6. Ancient town of Gabala and Archeological Museum.

The Third Plenary Conference and Field Trip of IGCP 610 was organized by the M.V. Lomonosov Moscow State University, Astrakhan State University, Astrakhan Museum-Reserve, Russia, and the Avalon Institute of Applied Science, Winnipeg, Canada, and hosted by the Astrakhan Museum-Reserve. President of the conference was Prof. Tamara Yanina. Executive Director was Prof. Valentina Yanko-Hombach. The Meeting and Field Trip were held in the Northern Caspian region in the city of Astrakhan and the Astrakhan region. One hundred seven scientists from 14 countries contributed to the conference; 77% of them were from developing countries (Fig. 5). Their peer-reviewed contributions are assembled in a 220-page Conference Proceedings volume (Gilbert et al., 2015).

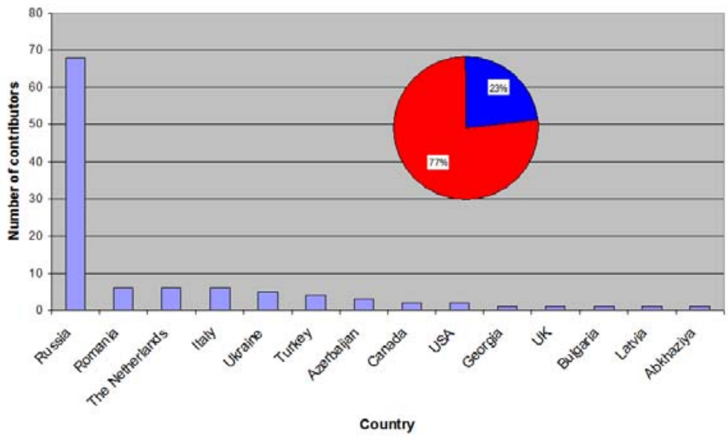

Figure 5. Number of countries and contributors to IGCP 610 Third Plenary Meeting and Field Trips. The circle shows the percentage of scientists from developing (red) and developed (blue) countries, respectively.

The two days of Technical Sessions were organized into five panels and five Oral/Poster sessions. Panel 1 was titled "PANEL 1: RECENT ECOSYSYTEMS AND PROCESSES"—moderators: Nelly Sergeeva (Russia) and Valentina Yanko-Hombach (Ukraine, Canada)—and included three ORAL presentations. The presentations covered a range of climate, precipitation, and faunal migration in the "CORRIDORS." Panel 2 was titled "STRATIGRAPHY, PALEONTOLOGY, AND PALEOENVIRONMENTAL RECONSTRUCTIONS"—moderators: Nikolay Panin (Romania) and Andrey Chepalyga (Russia)—and included 15 ORAL presentations with two key-note talks given by Tamara Yanina and others (Russia) and Nikolay V. Esin and others (Russia, Ukraine, Canada). The presentations covered a range of topics on the processes of formation within the "CORRIDORS" and the Paratethys Sea-Lake degradation, origin and taxonomy of the Quaternary Ponto-Caspian foraminifera and mollusks, morphodynamics of loess watersheds, changes of landscape and migration of humans, correlation of marine and continental deposits, ecostratigraphy, etc. Panel 3 was titled "TECTONICS"—moderator: Nikolai Esin (Russia) and Hayrettin Koral (Turkey)—and included three presentations on the neotectonics of Anatolia in the crossroads of an evolving orogen (key-note), vertical movements of the coast and shelf of the Black and Mediterranean seas and their impact on coastal processes, and seismic-geotechnical hazard zonation. Panel 4 was titled "MODELING"—moderators: Nikolay Esin and Alexander Kislov (Russia)—and included two presentations devoted to modeling of climate and marine ecosystems. Panel 5 was titled "ARCHAEOLOGY, HISTORY, AND ETHNOLOGY"—moderators: Andrey Chepalyga (Russia) and Olena Smyntyna (Ukraine)—and included six presentations with a key-note talk by A. Chepalyga (Russia). The presentations were devoted to new data on the North Black Sea corridor of the first European migrations focused on the discovery of multilayered Oldowan sites in Crimea (key-note); reconstruction of the archaeological landscape of the western shore of the Caspian Sea at the end of the upper Pleistocene-Early Holocene; paleoanthropology of the Yamna-culture populations in the Kumo-Manych depression: craniological specificity of the Yamna culture people from the Lower Volga region; paleoanthropology of fossil hominins from the Levant and Iraq; and response of humans to global climate change in the NW Black Sea region at the Pleistocene-Holocene boundary.

The POSTER session included 34 poster presentations with wide range of subjects on geophysics, morphotectonics, structure and genesis of islands, remote sensing, transgressive-regressive sea-level changes and coastline migration, economy of Late Mesolithic–Early Neolithic communities with respect to climate changes, marine habitats, lithostratigraphy, paleogeography, palynology (diatoms, pollen, NPP), deepwater peloids, modern fauna of the anoxic zone as a remnant of the ancient anoxic biosphere, mud volcanoes, underground freshwater sources, micro-(foraminifera) and macrozoobenthic communities, environmental stress caused by the Danube discharge into the Black Sea, and the first evidence of Lower Paleolithic open-air sites in Eastern Georgia.

The Technical Sessions were followed by the Round Table that enabled participants to discuss the progress of IGCP 610 and to plan future strategy in running the project. One of the key problems that participants discussed was organizing the Fourth Plenary Meeting and Field Trip in 2016. According to our working plan, it should have been held in Crimea. But due to the geopolitical problems (no need to discuss it here), this was impossible to organize. The Fourth Plenary Meeting and Field Trip was ultimately organized in Eastern Georgia with the main goal of studying the pre-Pleistocene and Pleistocene geological history of the Eastern Paratethys remnants. This subject is very important in shedding light and achieving a better understanding of a possible mechanism of separation of the Eastern Paratethys into the individual seas leading to formation of the Black and Caspian Seas.

The five days of field trips (by bus) were led by prominent Russian geologists and archaeologists and were focused on the archaeological sites "Selitrennoe Gorodische," Gorodishche Samosdelka, and Pleistocene stratotypes and important outcrops Cherniy Yar, Nizhnee Zaimische, Tsagan-Aman, Lenino, Seroglazovka as well as the Baer Knolls and Volga Delta (Fig. 6; Yanina et al., 2015).

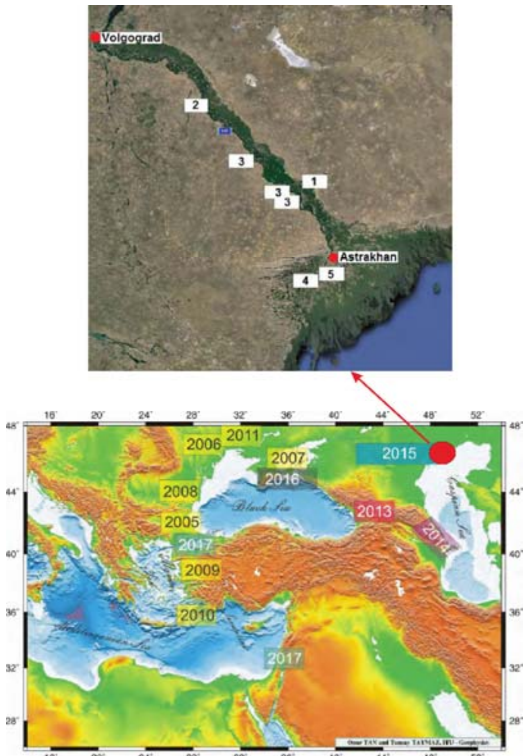

Figure 6. The Caspian-Black Sea-Mediterranean "CORRIDORS" (lower): in yellow are the locations of IGCP 521-INQUA 501 meeting and field trip sites (2005-2011); in other colors are sites to be studied by the present IGCP 601 Project: 2013 – Tbilisi, Georgia; 2014 – Baku, Azerbaijan; 2015 – Astrakhan (Lower Volga), Russia (marked in red circle); 2016 – Sevastopol (Crimea) and the Taman Peninsula, Russia; 2017 – Haifa, Israel, and Istanbul, Turkey. (upper): Map of the Lower Volga region with geological and archaeological sites visited during the Field Trips on September 25 (1), 26 (2), 27 (3), 28 (4), 29 (5) 2015.

Field trips were focused on the spectrum of Quaternary geological sequences exposed within sections of the Lower Volga area. This includes major exposures in the Volga valley between Astrakhan and Volgograd: Cherniy Yar – Nizhnee Zaimische, Kopanovka, Lenino, and Seroglazka. The conference participants were able to see deposits of the Baku, Early Khazarian, Late Khazarian, Khvalynian, and Novocaspian transgressions, and the continental sediments separating them: Singilsky, Chernoiarsky, and Atel. Participants were able to select samples for faunal, palynological, and other tests. They also observed the Baer knolls (named for Karl Baer, who described them for the first time in the 19th century), which are east-west elongated ridges in the Caspian Lowland, a unique natural formation that has no analogues in the world.

Archaeological tours were held at the main ancient sites of the region. The first is the archaeological complex "Selitrennoe gorodishche" (Saltpeter Settlement), which is located 130 km north of Astrakhan. In the XIII to XIV centuries, it was the capital of the richest nomadic state in the Middle Ages, Sarai-Batu, seat of the Golden Horde founded by Genghis Khan's grandson, Batu Khan. A natural outcrop of the Caspian Pleistocene sediments is situated on the Akhtuba coastal cliff near the archaeological complex, so it was also available for a visit. Another archaeological site of the region—Gorodishche Samosdelka (the Ancient Itil Settlement)—is located 45 km below Astrakhan on the right bank of the Old Volga River. The main part of the settlement is situated on an island, surrounded by dried up canals. Cultural layers of this medieval city, with a total depth of about 3–3.5 m, contain the artifacts of the Khazar Khaganate Culture, the golden age of the city Saksin (XI to XIII centuries) which predated Sarai Batu. There also is located the famous Museum of Russian Watermelon. September is the best time for this delicious fruit. Plans were made to visit other archaeological and historical places in Astrakhan: the Astrakhan Kremlin, which was built between 580 and 1620, and the Regional Natural History Museum, which covers the history of the natural environment of the region and displays many of the paleontological finds from the Pleistocene deposits of the Volga valley, together with historical and archaeological objects.

3. Workshops and Summer Schools

- Workshop in Sozopol (Bulgaria, September 2013)
- Workshop in Kirklareli (Turkey, September 2014)
- Workshop in Ahtopol (Bulgaria, December 2014)
- Workshop "Late Pleistocene of the Caspian Sea: Paleogeography, Correlation with Events in the Black Sea Region and Russian Plain" (Moscow, Russia, April 2015)
- Workshop "Caspian Sea Level Change from the from the Point of View of Geomorphology" (Moscow, Russia, November 2015)
- Summer School in Kalmykia (May 2014)
- Summer School in the Danube Delta on-board the floating laboratory boat "Halmyris" (Romania, summer 2013, 2014, 2015)

4. Field studies (2013-2015)

The field studies were performed in the:

- Kalmykia region, where transgressive geological sections of Khazarian and Khvalynian age were studied.

- Lower Volga region, where the Srednyaya Akhtuba (Middle Akhtuba) geological section was investigated. This section is located within Volgograd county and includes Khvalynian and Atelian sediments as well as three horizons of buried soils of Khazarian age.
- Eastern part of Manych, where relics of different stages of the Early Khvalynian transgression were investigated.
- Turkmenistan, where Cheleken geological sections have been studied and samples from the Bakinian, Urundzhikian, Khazarian, and Khvalynian strata were collected.
- Kerch Strait coast, where Holocene geological sequences were investigated.
- Iznik Lake (Turkey), where Middle Pleistocene geological sequences were studied.
- Moldova, Crimea, Taman peninsula, Eastern Thrace, Bosporus coast and Aşaği Pinar, and the Danube delta, where particular attention was paid to geoarchaeological evidence.
- The fieldwork projects permitted collection of several hundred samples that were treated in different laboratories by various techniques. In particular, the first optical-luminescent dates of all strata in geological sections were obtained.

5. IGCP 610 special sessions at the international fora:

- 2013: “Under the Sea: Archaeology and Palaeolandscapes” (Szczecin, Poland, September 2013)
- 2014: “Recent Problems on Lithology of Sedimentary Basins of Ukraine and Adjacent Territories” (Kiev, Ukraine, October 2014)
- 2014: “Geography and Geology in Secondary Education: the Modern State and Problems" (Odessa, Ukraine, October 2014)
- 2015: XXI International School on Marine Geology (Moscow, November 2015)
- 2015: All-Russian Conference "VII Shchukin readings" (Moscow, May 2015)
- 2015: All-Russian Conference “Actual Problems of Paleogeography and Stratigraphy of the Pleistocene” with international participation (Moscow, Russia, June 2015)
- 2015: “IGCP 610 Quaternary stratigraphy of the Ponto-Caspian region” at the 2nd International Congress on Stratigraphy - STRATI 2015 (Graz, Austria, July 2015)
- 2015: IGU Regional Conference 2015 "Geography, Culture and Society for Our Future Earth" (Moscow, Russia, August 2015)
- 2015: IGCP 610 Session #37125 “From the Caspian to Mediterranean: Environmental Change and Human Response during the Quaternary (IGCP 610)” at the GSA Annual Assembly (Baltimore, USA, November 2015)

6. IGCP 610 Special Volumes:

- 2013: Peer-Reviewed Conference Proceedings of IGCP 610 First Plenary Conference.
- 2013: Field Trip Guide of IGCP 610 First Plenary Conference
- 2014: Peer-Reviewed Special Volume of the international scientific journal *Stratigraphy and Sedimentology of Oil-Gas Basins*
- Conference Proceedings of IGCP 610 Second Plenary Conference.

- 2014: Field Trip Guide of IGCP 610 Second Plenary Conference.
- 2015: Peer-Reviewed Special Volume of the journal *Quaternary International* devoted to IGCP 510 studies
- 2015: Peer-Reviewed Conference Proceedings of IGCP 610 Third Plenary Conference
- 2015: Field Trip Guide of IGCP 610 Third Plenary Conference

7. Linkage with other projects and organizations

- EU-ITN programme "Drivers of Pontocaspian biodiversity rise and demise" (2015-2019)
- EU-WAPCOAST BS-ERA.NET 076 "Water Pollution Prevention Options for Coastal Zones and Tourist Areas: Application to the Danube Delta Front Area"
- ICOMOS The International Council on Monuments and Sites
- COCONET "Towards COast to COast NETworks of marine protected areas (from the shore to the high and deep sea), coupled with sea-based wind energy potential," supported by EU
- ECOST-MEETING-TD0902-090310-001280 SPLASHCOS "Submerged Prehistoric Archaeology and Landscapes of the Continental Shelf"
- Project № 539 "Study of the formation processes and spatial distribution of methane in the Black Sea and theoretical considerations of their influence on basin eco- and geosystems," supported by the Ministry of Education and Science of Ukraine (2015-2017)
- Project № 557 "Theoretically justify interaction between nature and human society in the northwestern Black Sea during the late Pleistocene and Holocene" supported by the Ministry of Education and Science of Ukraine (2016-2018)
- Project № 11-05-00093 "Caspian region: Peculiarities of development of the environment under climate and sea level change," supported by the Russian Foundation for Fundamental Research (2011-2013)
- Project № 12-05-01052 "Evolution of the relief of the Azov and Black Sea coast, climate, and sea level change: Comparative analysis and chronology of environmental processes for the last 20 ka," supported by the Russian Foundation for Fundamental Research (2012-2014)
- Project № 13-05-00086 "Pont-Manych-Caspian oceanographic system in the late Pleistocene: Systematics and correlation of events, evaluation of character and degree of interaction, paleogeographic consequences in the region," supported by the Russian Foundation for Fundamental Research (2013-2015)
- Project № 13-05-00242 "Radioisotope stratification of age and synchronization of the Quaternary deposits of the Ponto-Caspian," supported by the Russian Foundation for Fundamental Research (2013-2015)
- Project № 13-05-00625 "Peculiarities of the evolution of relief in the Northern Caspian region in the late Pleistocene: Main stages of the development, chronology, and correlation with climatic rhythms in the Black Sea-Caspian region," supported by the Russian Foundation for Fundamental Research (2013-2015)

- Project № 12-05-31281 "Khvalynian epoch in the history of the Caspian region: Paleoclimates and environmental evolution," supported by the Russian Foundation for Fundamental Research (2012-2014)
- Project № 14-04-00227 "Environmental evolution of the Caspian and Black Sea under the climate changes," supported by the Russian Foundation for Fundamental Research (2014-2016)

8. Scientific results

- Establishing the Reference List of main publications on Project subjects; a majority of which are published in Russian and their titles required transliteration and translation into English
- Collecting the data set on chronometric data
- Correlating the Regional Stratigraphic Scales
- Establishing a reference collection on Ponto-Caspian foraminifera (supplemented by SEM images) and mollusks
- Collecting a series of regional paleogeographic and geological maps
- Continuing the development of a common geochronological frame necessary for correlating major events in human prehistory and history with global environmental changes
- Collaborative Danube Delta studies of samples from delta front to the outer shelf enabling the quantification of differences among palynology processing methods and revealing a new paradigm for palynomorph distribution models in microtidal semi-enclosed basins
- Collaborative Danube Delta studies from delta front to the outer shelf on soft and hard-shelled meiobenthos (nematodes, polychaetes, foraminifera, ostracoda, etc.) and mollusks
- Developing a model for the filling of the Black Sea basin by Mediterranean salt water during the Holocene
- Developing a model for the processes of Caspian-Mediterranean corridor formation and Paratethys Sea-Lake degradation
- Observations of geological characteristics of Quaternary stratotypes as well as key archaeological and paleontological sites in Georgia, Azerbaijan, and Russia with further investigations of samples in various laboratories around the world
- The study of archaeological sites including Gobustan with its famous petroglyphs of the Mesolithic age. Plans included visits to some archaeological and historical places in Baku: the Shirvanshakh Palace constructed during the period from the XIIIth to the XVIth century; the Maiden Tower (the most mysterious monument of Baku) of which the unique construction has no analogues in the East
- Detailed study of chocolate clays in the Middle and Lower Volga region that have enabled the discovery of a direct correlation between their occurrence and morphology of relief. Material collected by the expedition is currently being studied using palynologic, lithologic, geochronologic, malacofaunal, and micropaleontologic methods

- Developing of a Holocene stratigraphic scale for the Iranian coast of the Caspian Sea
- Obtaining new material for paleogeographic reconstructions of the Caspian basin from biostratigraphic analysis of five boreholes recovered in the North Caspian. Two marine strata that are absent on the coasts were discovered. Also, obtained a series of new radiocarbon dates for sediments and events of the late Pleistocene in the Caspian.

9. Disseminating the project events and activities

Via regular updating of Project websites and mailing list of the project contributors, which increased from 957 in 2013 to 1039 in 2014 and 1310 in 2015, as well as social networks (Facebook for English and non-English-speakers, and Вконтакте for mostly Russian speakers):

https://www.facebook.com/groups/180481035443572/,
http://vk.com/album115218532_181815723

10. Social benefits

Implementing cultural heritage projects, open-air site museums, training centers in schools with the possibility of conducting experimental research, working together with local Governmental and Non-Governmental Organizations across the Caspian-Black Sea-Mediterranean Corridors that we study as a single geographic unit, bypassing linguistic and political boundaries, and thus encouraging East-West dialogue, cooperation, and integration of researchers from different countries into the international R&D community; enhancing our understanding of the links between environmental change and human adaptation, contributing to an improvement in human living conditions (especially for those at risk from coastal flooding), and promoting the wise use of the Earth as a human habitat; and preserving human heritage by addressing and clarifying existing archaeological, ethnological, and paleoanthropological questions concerning the evolution of human subsistence strategies, social and ideological spheres in the light of environmental change, and human physical and cultural adaptation theory.

11. Educational, training or capacity building activities

Enabled participants to visit relevant sites in the Caspian region of the CORRIDORS under the guidance of local experts with on-site discussion of scientific issues; formed a platform for young undergraduate and postgraduate students to benefit from international exposure and interaction with scientists from different parts of the world and varied specialties in order to cultivate traditions of "European style" scientific fora as well as scientific discussion and informal meetings. This also promoted their interest in particular specialties and motivated them to learn foreign languages in order to improve communication skills with western colleagues.

Promoted a multidisciplinary approach in paleoenvironmental studies, which has encouraged students in geology to take archaeological courses and *vice versa*. This has stimulated teachers to modify their curricula for undergraduate and graduate students; promoted the preparation of several MA and PhD theses on subjects within the IGCP 610 project.

Encouraged the establishment of direct contacts between western and eastern youth, creating the background for better understanding of modern priorities in the developing world of science and humanities.

Exposed the younger generation in developing countries to new analytical techniques and state-of-the-art data interpretation in the field of sustainable development and environmental risk protection, as well as human cultural development; informed the wider public about the evolution of the environment during the Quaternary.

12. Activities planned

Efforts are ongoing:

- To maximize IGCP 610 exposure via diffusion of results in key international journals and updates of our web pages to ensure wide accessibility and increased interactive potential for project participants, the scientific community at large, relevant agencies, and the public
- To consolidate scientific achievements as a basis for developing future strategies
- To continue to augment the funding base with upcoming and submitted research proposals through various funding agencies
- To publish the next special volume of *Quaternary International* devoted to the achievements of IGCP 610

Meetings and field trips planned (and completed) include:

- The Fourth Plenary Meeting and Field Trip, Tbilisi, Georgia, (2-9 October 2016)
- Special Session SSP4.5 “From the Caspian to Mediterranean: Environmental Change and Human Response during the Quaternary (IGCP 610)" and "ERE1.5 Methane in marine ecosystems: Significance for geological exploration, ecology and navigation" to be held in the framework of the European Geosciences Union General Assembly in Vienna, Austria, 17–22 April 2016
- Symposium “From the Caspian to Mediterranean: Environmental Change and Human Response during the Quaternary (IGCP 610)” to be held at the 35 International Congress, 27.08-4.09.2016, Cape Town, South Africa
- Winter-2016 youth School-Expedition to the Manych valley

Field and sea work

- Middle Volga
- Coastal zone of the Sea of Azov
- Drilling of the borehole with 30 m deep in the delta of the Don River
- Complex investigation of Middle Akhtuba geological section
- Complex investigation of geological sequences on the Taman peninsula
- Large-scale complex expedition – Youth School in the Lower Volga area
- Expedition to the northwestern Black Sea

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PART II. PROCEEDINGS

PRELIMINARY MAGNETOMETRIC INVESTIGATION AT CALATIS ARCHAEOLOGICAL SITE

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Keywords: megnetometry, archaeology, grophysics

Introduction

Calatis citadel, today the Mangalia resort on the Black Sea, is located 49 km from Constanta. According to the versified chronicle Pseudo Skymnos and the information provided by Demetrios from Calatis, the citadel was founded by colonists from Heraclea Pontica (Fig.1) during the time that Amyntas was taking command over the Macedonians.

Figure 1. Map with antique citadels.

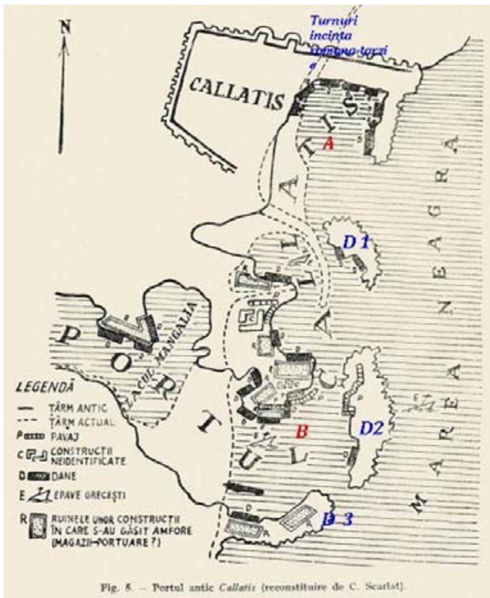
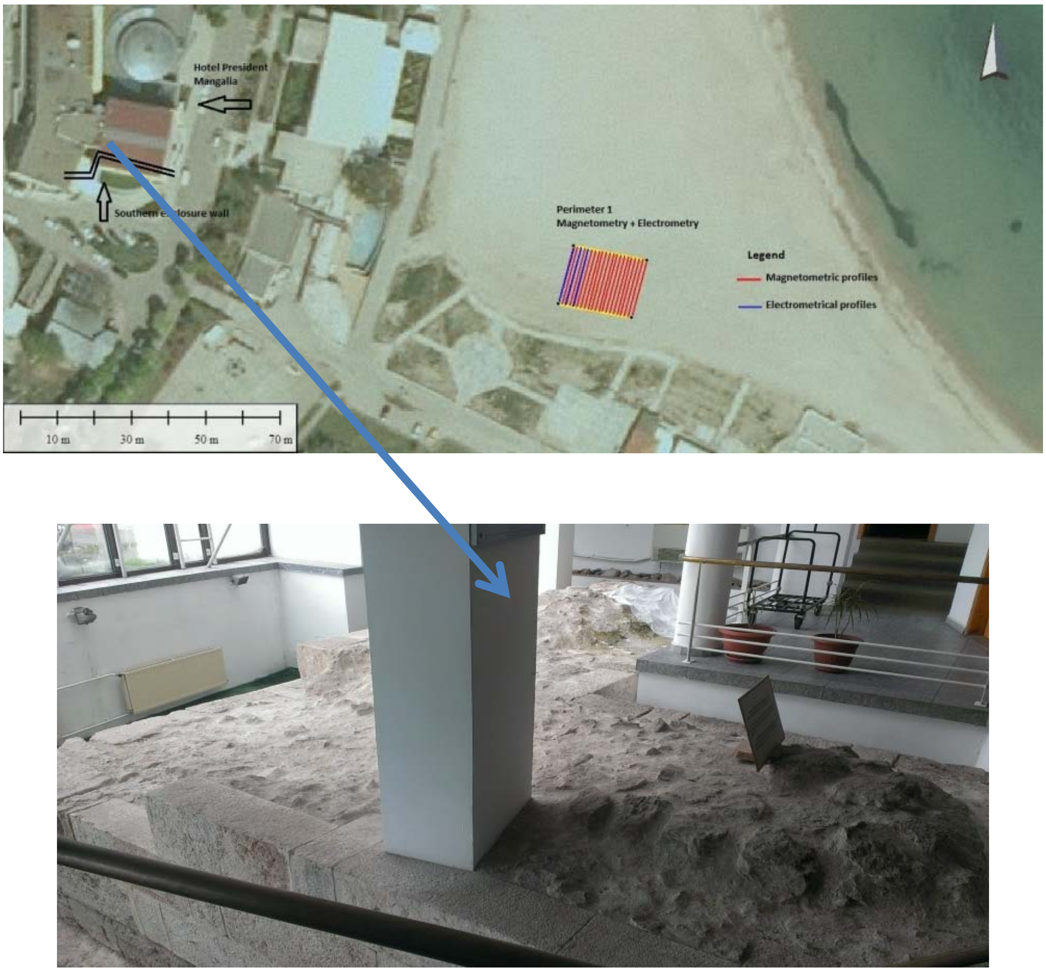


Figure 2. Calatis citadel – Reconstitution (after C. Scarlat).

Researcher's opinions over the exact time of its foundations differ greatly, some opting for the end of the sixth century BC and others for the beginning of fourth century BC. Large scale research on the Calatis citadel started in 1962 and was conducted for ten years by Captain-Commander Constantin Scarlat. Due to his research, we have today a detailed map of the citadel, including the submerged part. According to Constantin Scarlat, until 1973, only 20% of the submerged artifacts pertaining to Calatis were discovered (Fig. 2).

Main objectives of the magnetometric investigation

The targets of our investigation were the southern (Fig. 3a) and the northern precinct walls of the citadel. In order to achieve our objectives/targets, we measured two perimeters, a southern (Figs. 3 a,b) one (Perimeter 1) and a northern one (Fig. 4; Perimeter 2).



A

B

Figure 3a. Perimeter 1-20/16 m (southern enclosure wall zone), b. Ancient wall in the President hotel.

The northern (Perimeter 2) is shown in Fig. 4.

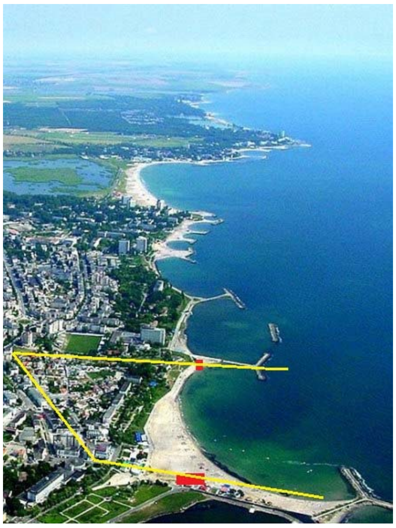


Figure 4. Investigation area. Red square - magnetometric investigation area; yellow line - enclosure wall - Calatis archaeological site.

This investigation will provide new information for the GeoEcoMar database of archaeological buried structures.

Key features for geometrics G 856AX portable proton-precession magnetometer

- Resolution – 0.1 gamma in average conditions
- Displays – six digit display of magnetic field to resolution of 0.1 gamma
- Gradient – tolerates gradients to 1800 gamma/meter
- Memory – store 12500 readings in survey mode

Methodology-magnetic surveying

The typical survey geometry (Fig. 5) in gradiometer configuration (Fig. 6) consists of a series of measurements equally spaced along a series of parallel lines (Boyce et al., 2004).

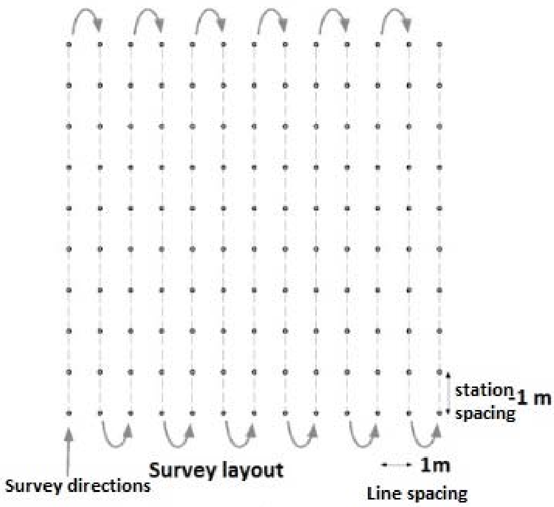


Figure 5. Survey geometry.

Usually the lines are positioned so as to form a rectangular area. This survey design insures that the measurement points (stations) will define a grid that samples the magnetic field strength at a uniform spatial density (Anghel and Ion, 2005). For greatest measurement accuracy, it is best to orient the sensor in the same direction at each station when acquiring the measurements (Hall, 1966; Anghel, 2008a,b).

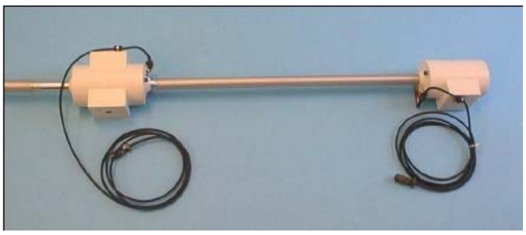


Figure 6. Gradiometer configuration.

This survey design insures that the measurement points (stations) will define a grid that samples the magnetic field strength at a uniform spatial density. Results

The magnetic data recorded along the two perimeters were processed using Oasis Montaj and Magmap2000 software. The figures above illustrate the magnetic vertical gradient variation (2D and 3D) over the two perimeters (Figs. 8,9,12).

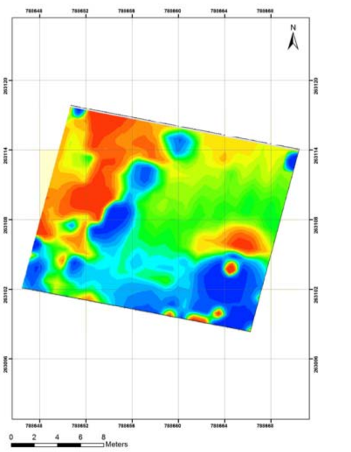


Figure 8. Magnetic gradient map on a 2D surface – Perimeter 1.

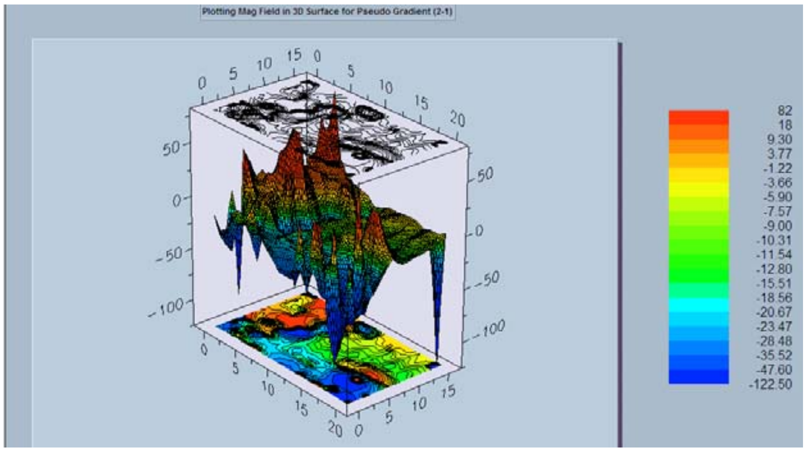


Figure 9. Magnetic gradient map on a 3D surface – Perimeter 1.

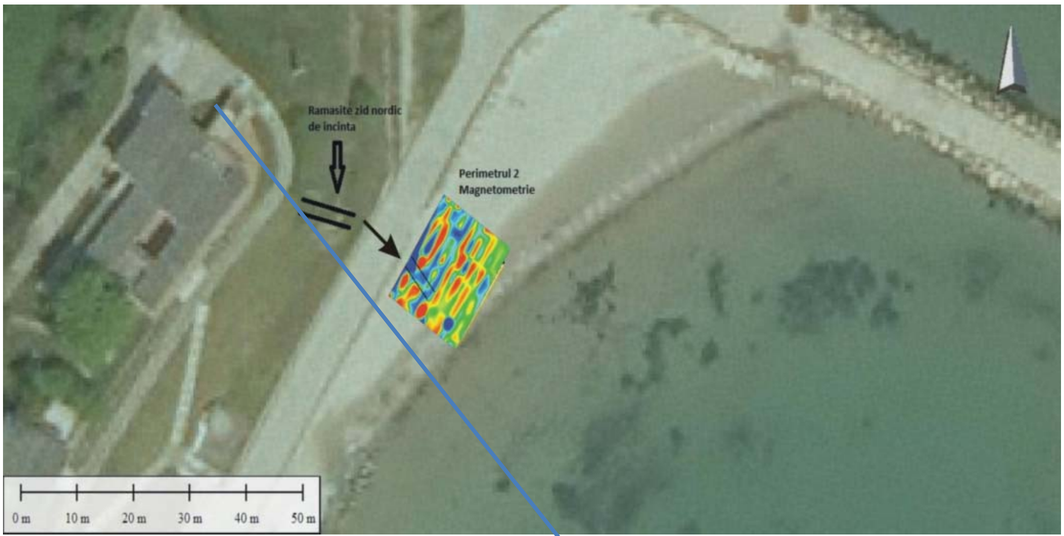


Figure 10. Perimeter 2- 15/16 m (northern enclosure wall zone).

Figure 11. Northern ancient wall.

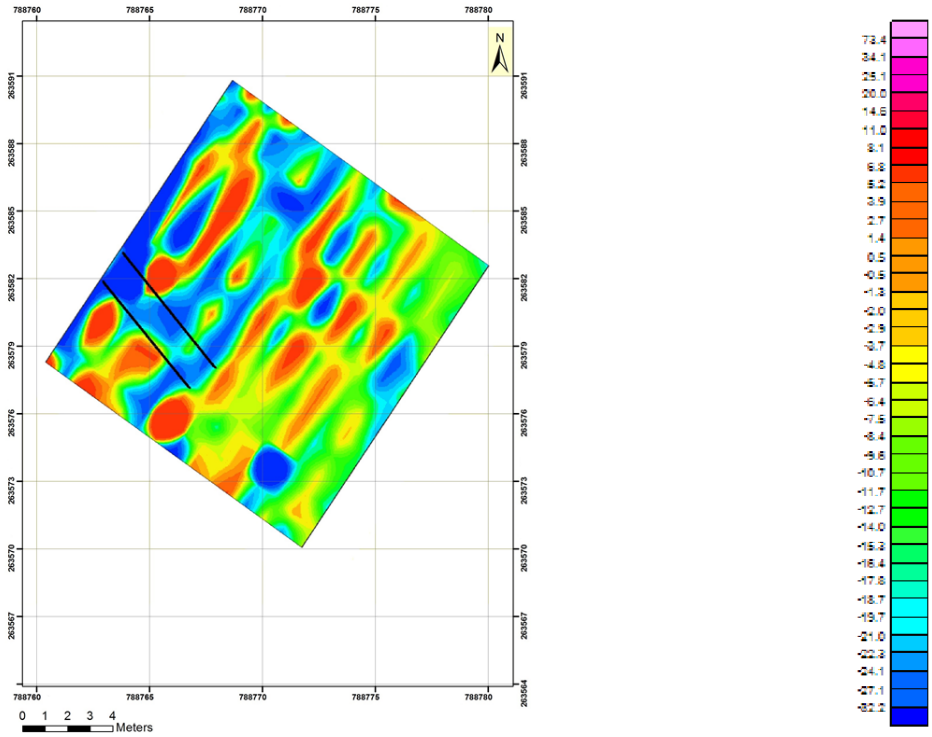


Figure 12. Magnetic gradient map on a 2D surface – Perimeter 2.

On the resulting maps presented above, one can observe minimum magnetic anomalies (wall is built of limestone sometimes associated with burnt bricks) (Anghel, 2004) longitudinally arranged that seem to correspond to the prolongation into the marine environment of the precinct walls exposed in the basement of the hotel Premier of Mangalia (Fig. 3b).

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HISTORY OF CASPIAN SEA LEVEL OSCILLATIONS IN THE LATE PLEISTOCENE (IF THERE WAS A GREAT KHVALYNIAN TRANSGRESSION AND A DEEP ATELIAN REGRESSION?)

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Keywords: coastal zone, sea level oscillations, lagoon-transgressive terraces

The basis of the modern stratigraphic units of the Caspian Sea coasts was initiated by P. A. Pravoslavlev, who expounded on this subject in his articles more than 100 years ago. Later, well-known researchers made additions, clarifying and detailing the layers and the boundaries between them in the most complete outcrops. Now, a large amount of data has been accumulated, mainly from sections in the Lower Volga region and in Dagestan. However, despite this, the substantial new material has not led to a common vision of the history of transgressive-regressive cycles of the Caspian Sea in the Pleistocene-Holocene.

A relatively large effort at dating has also not produced much clarification in this problem. For example, there is still much disagreement about the time and depth of the Atelian regression, the existence of the Girkanian transgression, and the age of the early Khvalynian transgression. There are debates about the Enotaevsky regression and the presence of its sediments on the bottom of the North Caspian Sea and on the Mangyshlak threshold. There are examples where the same strata have been assigned by different researchers to different stratigraphic formations. Facies and lithological variability of the sediments in the outcrops and boreholes has led to even greater discrepancies, which have increased with the correlation of formations and layers in the outcrops of the Lower Volga region.

According to researchers in the Pleistocene history of the Caspian Sea, the reliably identified major transgressions include the Bakunian, Early and Late Khazarian, and Early and Late Khvalynian. They are separated by deep and prolonged regressions, when accumulation of continental, alluvial, and proluvial sediments occurred. These lie, as a rule, with sharp contacts on their underlying deposits and are overlain (also with a sharp contact) by marine sand with malacofauna or lacustrine silt and clay with sand interbeds. In the latter, there are often malacofauna.

Study of the history of the Caspian basin and, in particular, the Northern Caspian Lowland is impossible without referring to the question of the genesis and age of chocolate clays (CC), which are distributed across a significant area. CC lie almost from the surface and are a distinctive and characteristic facies of the Khvalynian sediments. Until recently, most researchers of CC have considered them to be deep-sea sediments, and their age was understood as Early Khvalynian, so finding shells in the sand layers among the chocolate clays allowed the authors *a priori* to consider CC only as sediments of Early Khvalynian age.

In our previously published articles, a conclusion was proposed about the lagoonal origin of CC, typical deposits of which can be dated to a wide time range (Badyukova, 2010a, 2010b); and so we give here only briefly the main data of the genesis of CC. They are lens-shaped and sharply pinched out. They have many sandy layers, within which are often found the shells of mollusks that prefer to live in shallow brackish or fresh water. CC are deposited almost on the surface under the soil, directly on subaerial**,** lacustrine, alluvial, deltaic, or marine nearshore and coastal deposits.

Sometimes at the base of CC there is a clear facies unconformity with the underlying sediments, and the roots of reeds are found. According to verbal communication from Professor D. Huseynov (Institute of Geology of the Azerbaijan National Academy of Sciences), the following test results of CC were obtained. First, low values of hydrogen and high oxygen index values clearly indicate a continental type for the original organic matter (OM). Second, very little OM is found in CC, which indicates oxidizing shallow-water conditions and a highly hydrodynamic environment. The large numbers of iron hydroxides, which give the characteristic color of the sediments, also indicate such an environment.

Taking CC for lagoon sediments, it is necessary to explain their distribution across the surface (for hundreds of kilometers in almost all outcrops in the Lower Volga region). It is known that in the background of the general Caspian Sea regression, there were positive oscillations that left coastlines in relief. Investigations have shown that the development of the coast during the transgressions depends on the associations of slopes, flooded coastal plains, and the nearshore (Badyukova and Solovieva, 2003). The formation of a lagoon is possible only in those areas where the primary slope of the coastal plain is less than the nearshore slope. This situation occurred in the Northern Caspian region, where numerous prior transgressive-regressive phases had led to a leveling of the coastal plain relief.

Lagoons formed on the surface of former regressive terraces, i.e., in the transgressive series, reveal lagoon deposits lying with sharp contact upon the more ancient deposits. A series of large lagoons separated by barriers was formed as a result of the Caspian Sea's positive oscillations**.** During the inherited development of the coastal processes, multiple sea-level oscillations can lead to a situation where the North Caspian Lowland will represent the coastal plain, composed of a series of successive lagoon-transgressive terraces (Fig. 1). In the lagoons, lying on the lower hypsometric levels, chocolate clays were accumulated, and marine sands recorded the former coastline (coastal bar or barrier).

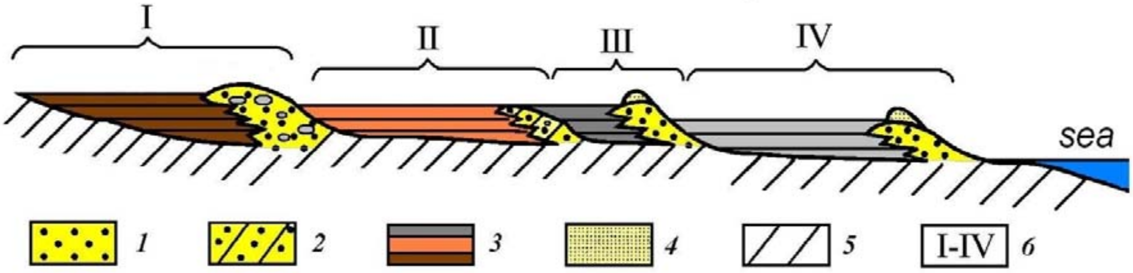

Figure 1. Diagrammatic scheme of successive lagoon-transgressive terraces. Key: 1 = deposits of the coastal bar; 2 = buried bar; 3 = lagoon deposits; 4 = eolian sands; 5 = underlying sediments; 6 = series of lagoon-transgressive terraces.

It is important to note that the deposits formed in the lagoons and were overlain by stratigraphically unconformable sediments of different genesis and age. There is a clear boundary between the lagoon and underlying sediments, but this unconformity does not always mean erosion. Thus, in the coastal zone of the Caspian Sea, which experienced repeated level changes, it is impossible to correlate deposits exposed in outcrops and boreholes located across the stretch of ancient coastlines. In this case, deposits of the same genesis have different ages, as they belong to different lagoon-transgressive terraces formed during the next minor sea-level rise in the background of its regression.

However, this conclusion has not been heeded in studies of the outcrops on the coast of the Caspian Sea and in the Lower Volga region. As a result, correlation of layers in the outcrops has been carried out as is usual in geologic research. Thus, loess loam on the top of many outcrops has been understood as a subaerial Atelian deposit that formed, as is commonly believed, during the deep Atelian regression between the Khazarian and Early Khvalynian transgressions.

A detailed study of the literature and field investigations has shown that none of the outcrops in the North Caspian Lowland display typical Khvalynian marine deposits, only lagoonal ones. Lagoon deposits (CC) of the Khvalynian age are only in the roof of the outcrops, fixing the gradual sea-level fall. Moreover, they occur consistently in alluvial-deltaic sand deposits—Akhtuba, Chernoyarsky sands, sands in a quarry near the settlement Tsagan-Aman, and so on. All the above leads to the following conclusions, which are closely related to each other and are supported by literature and field materials. There was one large, temporally-extended Khazarian transgression with oscillations. The transgression level was high, in some areas; Khazarian terraces are located above the early Khvalynian coastlines and form a sloping coastal plain.

All researchers have noted that on the shores of the Caspian Sea at this time a very active wave regime existed, and the waters were substantially desalinated. According to the author, it was the Great Khazarian transgression which happened, due in particular to the flow of water from Western Siberia (Mangerud at al., 2004). Fedorov (1957), describing the eastern Caspian coast, emphasized that there are entire blocks (up to 1 m) of sandy clays with undisturbed stratification that occur from the Cheleken peninsula and further up the Uzboy. The nature of the fragments and boulders of undisturbed clay indicates, in his opinion, the short duration of the catastrophic flow, and the presence of *Corbicula fluminaris* suggests that it was a freshwater stream.

Between the Khazarian and Khvalynian deposits in the Lower Volga region, alluvial and lacustrine-marsh deposits are present; on the Caucasus coast, the alluvial fan deposits reveal a thickness up to 20 m. On the eastern coasts, Khvalynian deposits lie on loess loam or directly on the Khazarian deposits. According to our views on the Lower Volga, after the Khazarian transgression sea levels had fallen (by 10-15 m), the formation of the first alluvial series happened, i.e., the Akhtuba sands. The subaerial period was lengthy, and a series of soils and loess loams were formed (the so-called Atelian in the outcrop at Srednyaya Akhtuba).

Then, sea-level rise followed with the formation of a lagoon on the previous regressive terrace overlain by subaerial deposits (but younger than Atelian). CC were formed in this lagoon. The next sea-level rise once again gave way to a sea-level fall and the formation of a second alluvial member, the Chernoyarsky sands, which were covered by a younger loess loam. And again, the sea-level drop was not deep. The Chernoyarsky sands with loess loam were in turn overlain by lagoon deposits (CC) during the subsequent oscillation. This course of events continued up to the settlement of Nikol'skoe. The clearly defined Late Khvalynian coastline can be traced here at about 2-0 m amsl. There is an erosional slope in this region, which proves that there was a deep regression of the sea. The latter occurs when the coastal plain and underwater slope angles change, as deep regression reveals a steeper underwater slope.

It is necessary to note that during the Khvalynian transgression, the estuary was in the Lower Volga. Analysis of the hypsometric positions of the outcrop roofs has shown that during the Late Khvalynian transgression, the estuary stretched far up to the settlement Srednyaya Akhtuba. At the present time, there are numerous Akhtuba channels and lakes that were generated by this estuary. Consequently, the large arrays of sediment data (^{14}C and OSL) from samples representing the outcrops along the Lower Volga are not only of the Early Khvalynian but Late Khvalynian age.

Thus, there was no deep Atelian regression and, subsequently, the Great Khvalynian transgression was not exited. The latter is, in fact, gradual regression after the Khazarian transgression, accompanied by positive oscillations of the Caspian Sea level; during these periods, lagoon-transgressive terraces containing Khvalynian chocolate clays were formed.

Acknowledgments

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METHODS OF OBTAINING DATA ON THE CHARACTERISTICS OF SUPERFICIAL AND SUBSURFACE STRUCTURES OF THE EARTH BY REMOTE SENSING IN THE SHORT-WAVE RANGE OF RADIO WAVES

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Keywords: measurement technique, the scattering parameter signal/noise ratio

Introduction

In this paper, we propose a new method for estimating the parameters of the noncoherent signal/noise ratio β_K (Belov, 2015). A comparative analysis shows that the analytical (relative) accuracy of the determination of the parameter β_K using the new method exceeds the widely-used standard (Belov, 2016a).

This range allows us to diagnose subsurface layers of the earth because the scattering parameter is formed by inhomogeneities in the dielectric permittivity of the subsurface structures.

The problem of measuring and accounting for the scattering power of the earth's surface in the short-wave range of radio waves is important for solving such challenges as diagnosing properties of the environment using methods that apply this radio band; an intermediate reflection (scattering) of the waves by layers below the earth's surface can be of interest for exploration and environmental studies (Belov and Belova, 2015a).

Calculation methods

Narrowband random process $\mathcal{E}(t)$ in fixed point of reception in the ground in scalar approximation is the superposition of mirror $\mathcal{E}_0(t)$ and scattered $\mathcal{E}_P(t)$ components distributed by the normal law:

$$\begin{aligned} \mathcal{E}(t) = \mathcal{E}_0(t) + \mathcal{E}_P(t) &= E_{00} \cdot e^{i\cdot(\omega_0 \cdot t - \varphi(t))} + \mathcal{E}_P(t) = \\ &= R(t) \cdot e^{i\cdot(\omega_0 \cdot t - \Phi(t))} = \left[E_C(t) + i \cdot E_S(t)\right] \cdot e^{i\cdot\omega_0 \cdot t}, \end{aligned} \quad (1)$$

where $\varphi(t)$, $\Phi(t)$, $R(t)$, $E_m(t)$, m=c,s – shown to slow random processes on the period $T = \frac{2 \cdot \pi}{\omega_0}$; E_{00} = Const. Scattering parameter is the ratio:

$$\beta_k^2 = \frac{\textit{power of mirror components}}{\textit{power of scattered components}} = \frac{E_{00}^2}{2 \cdot \overline{E_P^2}} \ . \quad (2)$$

Here and below, "$\overline{}$" means statistical averaging. $E_C(t) = R(t) \cdot \cos \Phi(t)$ and $E_S(t) = R(t) \cdot \sin \Phi(t)$ are the low-frequency quadrature of the ionospheric signal, $R(t)$ is the envelope, $\Phi(t)$ is the total phase.

The subscript k = E4, R2, R4 means experimentally recorded primary random processes, and the appropriate method of their registration: E4 – coherent; R2, R4 – noncoherent amplitude. Index k indicates the primary parameter recorded: E – quadrature, R – envelope of the ionospheric signal.

Standard noncoherent R2-method based on the relationship (3) is widely used for estimating β_K (2) (Belov and Belova, 2015b):

$$\frac{\overline{R^2}}{\left(\overline{R}\right)^2} = f\left(\beta_{R2}\right) = \frac{4}{\pi}\cdot\frac{\left(1+\beta_{R2}^2\right)\cdot\exp\left(\beta_{R2}^2\right)}{\left[\left(1+\beta_{R2}^2\right)\cdot I_0\left(\beta_{R2}^2/2\right)+\beta_{R2}^2\cdot I_1\left(\beta_{R2}^2/2\right)\right]^2}\,. \quad (3)$$

$I_n(x)$ is the Bessel function of the n^th order of a purely imaginary argument.

Using the coherent E4-method and estimating β_{E4} by the γ_{E4} kurtosis of quadrature:

$$\gamma_{E4}\left(\beta_{E4}\right) = \frac{\overline{E_m^4}}{\left(\overline{E_m^2}\right)^2} - 3 = -\frac{3}{2}\cdot\frac{\beta_{E4}^4}{\left(1+\beta_{E4}^2\right)^2}; \quad m=c,s. \quad (4)$$

It should be noted that the measured primary parameters are the ratio of moments $\overline{R^2}/\left(\overline{R}\right)^2$, $\overline{E_m^4}/\left(\overline{E_m^2}\right)^2$, respectively.

Probabilistic properties of the signal (1) of the first multiplicity response are well described by the Rice model with a displaced spectrum (RS-model). Expressions (3) and (4) are obtained based on the Rice model with a displaced spectrum (Belov and Belova, 2016).

In this paper, we propose a new noncoherent R4-method of determination of β_{R4} by γ_{R4} kurtosis of the envelope for the RS-model:

$$\gamma_{R4}\left(\beta_{R4}\right) = \frac{\overline{R^4}}{\left(\overline{R^2}\right)^2} - 3 = \gamma_{R4}\left(\beta_{R4}\right) = -1 - \frac{\beta_{R4}^4}{\left(1+\beta_{R4}^2\right)^2}\,. \quad (5)$$

For comparison of the given methods in the sense of relative errors permitted in calculating β_K, due to their functional dependencies $f(\beta)$, $\gamma_{E4}(\beta)$ and $\gamma_{R4}(\beta)$, we obtain the following expressions (6):

$$\varepsilon_k = \left|\frac{\Delta\beta_K}{\beta_K}\right| = \left|\frac{1}{\beta_K}\cdot\frac{dG_K}{dZ_K}\cdot\Delta\left(Z_K\right)\right|, \qquad Z_K = \frac{\overline{R^2}}{\left(\overline{R}\right)^2}, \frac{\overline{E_m^4}}{\left(\overline{E_m^2}\right)^2}, \frac{\overline{R^4}}{\left(\overline{R^2}\right)^2}. \quad (6)$$

where $K = R2, E4, R4$; $G_K = f, \gamma_{E4}, \gamma_{R4}$; and $\Delta(Z_K)$ – absolute statistical errors of measured values. Measures of inaccuracy, including statistics for the different techniques of determination of β_K, are:

$$\varepsilon_{R2}(\beta) = \frac{\pi}{8}\cdot\frac{\left[\left(1+\beta^2\right)\cdot I_0\left(\beta^2/2\right)+\beta^2\cdot I_1\left(\beta^2/2\right)\right]^3}{\beta^2\cdot\exp\left(\beta^2\right)\cdot I_1\left(\beta^2/2\right)}\cdot\Delta\left(Z_{R2}\right);$$

$$\varepsilon_{E4}(\beta) = \frac{\left(1+\beta^2\right)^3}{6\cdot\beta^4}\cdot\Delta\left(Z_{E4}\right); \quad (7)$$

$$\varepsilon_{R4}(\beta) = \frac{\left(1+\beta^2\right)^3}{4\cdot\beta^4}\cdot\Delta\left(Z_{R4}\right).$$

Statistical error $\Delta(Z_K)$ depends on the sample volume N. It may be different for identical sample volumes for each of the methods. We normalize (7) on $\Delta(Z_K)$ for focusing on the errors due to differences in functional dependencies (3) – (5).

Dependency Graphs $\varepsilon_K^* = \frac{\varepsilon_K}{\Delta(Z_K)}$ for β_{R2}, β_{E4} and β_{R4} are shown in figure 1. ε_K^* will be called analytic (relative) error method.

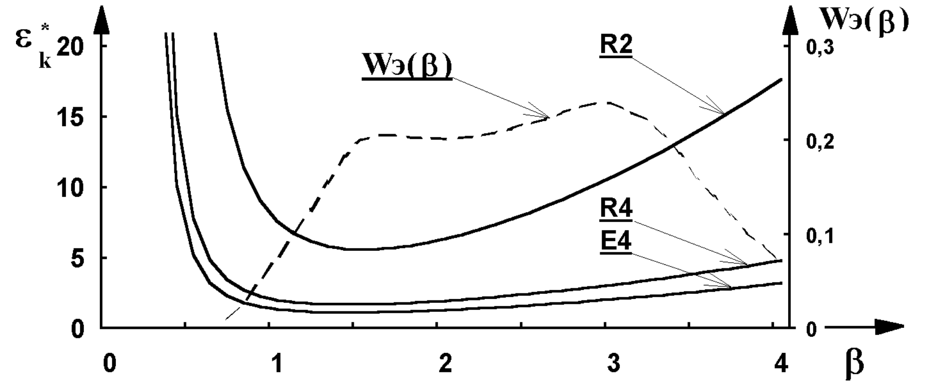

Figure 1. Dependency Graphs ε_K^*, K = R2, R4, E4 (solid curves) and the experimental distribution $W_Э(\beta)$ (dashed curve) (F2-layer, 4,5 – 9,5 MHz, single signal).

Experimental distribution $W_Э(\beta)$ determines the range of variation of β.

From equation (4) and (5), we conclude that $\varepsilon_{E4}^* = \frac{2}{3}\cdot\varepsilon_{R4}^*$ have the same order and significantly (by order) exceed the measurement accuracy of the standard R2-method.

Analysis of analytical error of estimation of the parameter β_K allows us to recommend the R4-method instead of the standard R2-method. A sufficiently high analytical (relative) accuracy of parameter estimation for β_K can be achieved using a noncoherent apparatus applying (5) the R4-method. Naturally, the ability to optimize the statistical error by the relevant special digital processing of ionospheric signal is keep on coherent methodology E4 (Belov, 2016b).

Conclusion

The comparative analysis of the normalized relative analytical errors ε_K^* of the known methods and the new one was performed. It was shown that errors ε^*_E and ε^*_{R4} have the same order, and both errors significantly exceed the error ε^*_{R2} in comparison with the standard R2-method by a measurement accuracy of β_K.

This band range allows one to diagnose subsurface aspects of the earth, as the scattering parameter is affected by irregularities in the dielectric permittivity of subsurface structures. This method based on the organization of the monitoring probe may detect changes in these environments, for example, to assess seismic hazard and seismic risk. The problem of measuring and accounting for the scattering power of the earth's surface in the short range of radio waves is important for a number of purposes, such as diagnosing properties of the medium using this radio band when going on the road to interpret the intermediate reflection (scattering) from the earth's surface, which is of interest for geological and environmental studies.

As a result, it was found that sufficient β_K analytical measurement accuracy can be achieved when using a noncoherent apparatus applying a new R4-method (Belov, 2016b).

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PIONEER DENDROCLIMATOLOGICAL RESEARCH IN WESTERN AND SOUTHWESTERN TURKMENISTAN USING *JUNIPERUS TURCOMANICA* B. FEDTSCH

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Keywords: dendroclimatology, dendrochronology, climate changes, paleoenvironmental reconstructions, Late Holocene

Introduction

Annual tree rings are a natural archive that stores a lot of information about environmental conditions of the past. Studying such proxy dendrochronology can become a very useful instrument for hydrometeorological reconstructions. Previously, tree rings have been successfully used for hydroclimate reconstructions covering the last millennium. Such reconstructions have uncovered possible climatic causes of many social cataclysms in human history. In arid regions, tree rings are especially useful for hydroclimatic reconstructions, explaining around 60-80% of the variability of instrumental records. Paleogeographic reconstructions for the Late Holocene based on dendroclimatological data can reveal the climatic characteristics of periods when the Aral Sea basin was connected with the Caspian Sea. The other possible prospect of our research is revealing the paleoclimatic characteristics for western Turkmenistan describing evaporation and precipitation— the basic indicators for understanding Caspian sea-level change.

Moreover, dendrochronology is one of the most effective methods for climate reconstructions in the arid zone during the Holocene. Unfortunately, it has been applied only in several geographical regions. Turkmenistan is a very special place in Central Asia where the desert covers 80% of the territory. There have been no previous dendrochronological or dendroclimatological studies. That’s why this country, as the northernmost part of Central Asia, represents a blank space on the map of dendrochronological research. Water supply is a subject of national importance in Turkmenistan. To understand the mechanisms that affect the amount of precipitation in the region on decadal and centennial time scales, long records of atmospheric precipitation are necessary. Unfortunately, such records are sparse and short in the region. Dendrochronology is an effective method for paleoenvironmental reconstruction in many geographical areas because it provides very specific data due to its ability to provide annual resolution.

The main aim of this study was to assess the potential of applying the dendroclimatological method in Turkmenistan for the purpose of hydroclimatological reconstructions and to determine the main limiting factor of tree-ring growth. Such reconstructions may extend the existing instrumental record of atmospheric precipitation in the region significantly.

Study region and methodology

The study region is situated along the southwestern border of Turkmenistan (Fig. 1), in the northern piedmont of the Kopetdag range.

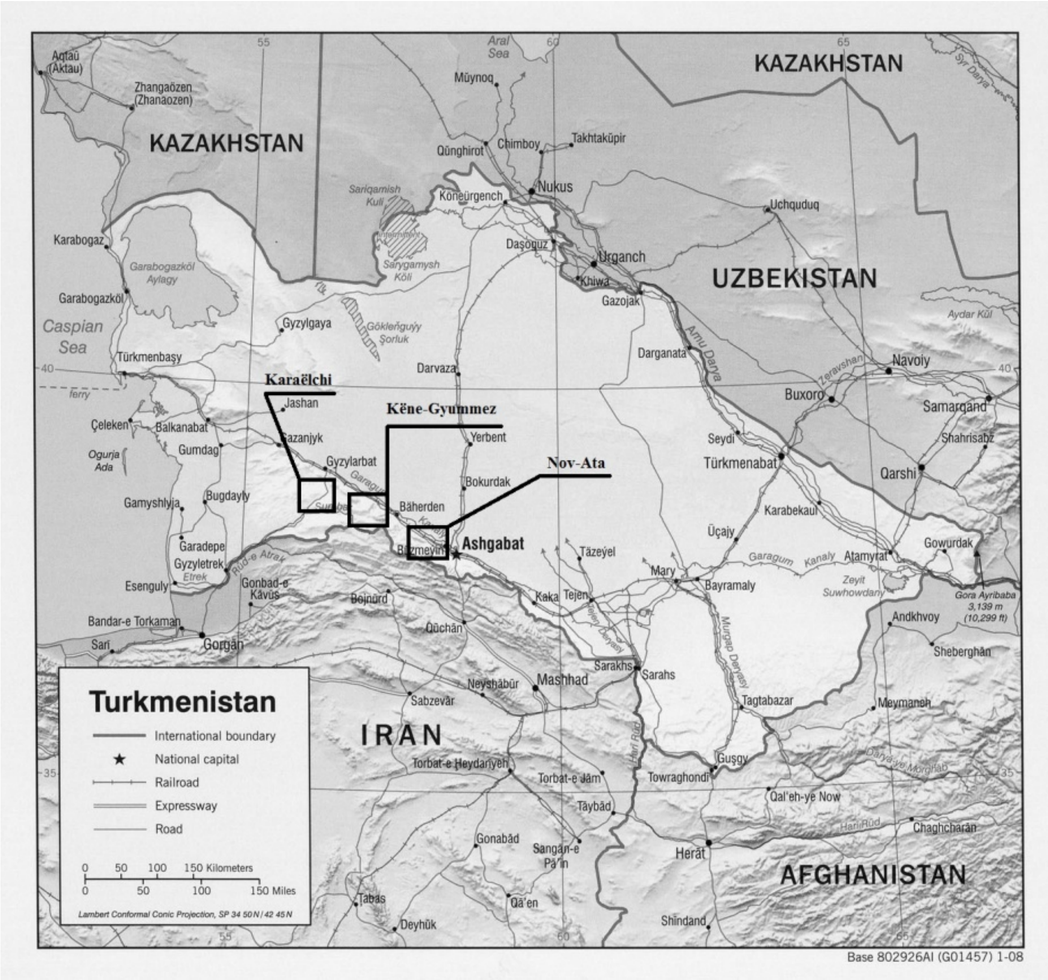

Figure 1. Map of Turkmenistan map showing thewith key areas of study (http://www.lib.utexas.edu/maps/middle_east_and_asia/txu-oclc-212818165-turkmenistan_rel_2008.jpg).

Major features of the modern Kopetdag mountain morphology have been formed through intensive neotectonic uplifts during the Pliocene-Quaternary. This region is extremely interesting for paleogeographic reconstructions because of various reasons:

1. Research into the climatic dynamics and aridity patterns of the region. Currently there are no data on the Holocene history of the Kopetdag mountains and Karakum desert due to lack of paleogeographical proxies (no lakes, no glaciers, etc.). Dendroclimatological research can shed light on this problem.

2. Dendrochronological studies can help to uncover possible climatic causes of many social cataclysms in human history. The region experienced active social dynamics: many archaeological objects of the Early Bronze Age have been discovered in the zone between the desert and mountains (e.g., the cultures of Gonur-Depe, Margush, Altyn-Depe, etc.). Archaeological sites characterized by cultural layers and desert sand describe the dependence of ancient societies on climate. Apparently in arid stages, people left the settlements.

3. In the westernmost part there is a mountain system (Uly Balkan) surrounded by desert while being limited on the west by the Caspian Sea. Reconstructions can reveal the climatic characteristics of periods when the Aral Sea basin was connected with the Caspian Sea (Uzboi River system). The other possible prospect of research is revealing the paleoclimate characteristics for Turkmenistan that describe rates of evaporation and precipitation—the

basic indicators for understanding Caspian sea-level change. Unfortunately, decadal and centennial time scales, i.e., long records, are sparse in the region.

Physical and geographical features in the piedmont of the Kopetdag range are caused by a sharp continental climate with a large deficit of moisture and high summer temperatures. Competent sampling is very important for dendrochronological analysis, so the conditions of relief and manifestation of adverse climatic effects were the main factors determining the choice of key areas. So sampling was focused on the northern slopes of the central and western Kopetdag, as well as in the area of Ashgabat. Selection of samples was carried out on slopes of 15-20˚, in areas where the soil and groundwater characteristics were extremely unfavorable for growth of wood and vegetation under such climatic conditions. Three key areas were selected (Fig. 1): the territory of the village of Nov-Ata (district of Geoktepe), the Karaëlchi tract near the village of Kara-Kala, and the ridge near the village of Këne-Gyummez.

We tried to date several species of wood: black pine (*Pinus nigra*), oriental plane (*Platanus orientalis*), paper mulberry (*Broussonetia papyrifera*), and osage orange (*Maclura pomifera*). Age, however, was not enough to build a long tree-ring chronology. That's why the main object of our study involved the selection of a unique kind of juniper—turkman juniper (*Juniperus turcomanica*). It grows only in the Kopetdag range and in the Big Balhan Mountains, and it is the only "long-lived" species in the territory of Turkmenistan. Although old trees are rare in Turkmenistan, we have found a site with junipers that are old enough to extend the existing climatic records. In total, 89 samples of turkman juniper were taken. Individual trees with the largest diameters and cylindrical stems without obvious sign of injury, disease, or human disturbance were selected for sampling. It has to be noted that the selected samples were minimally affected by different human activities. Two increment cores were extracted with an increment borer at breast height on different sides of each tree.

The ring widths were measured using a LINTAB 5 measuring system with a resolution of 0.01 mm, and all cores were cross-dated by visual (Stokes and Smiley, 1968) and statistical tests (sign test and t-test) using the software package TSAP-Win (Time Series Analysis and Presentation for Windows) (Rinn, 2003). The raw ring-width series were standardized using the program ARSTAN (Cook, 1985) to remove non-climatic trends related to tree age. The ARSTAN program produces four chronologies: RAW, RES, STD, and ARS (Cook, 1985). We used the STD and the autocorrelationfree RES chronologies for correlating with the meteorological data. The RES chronology comprises residual indices after pre-whitening the STD chronology by autoregressive pre-whitening that removes autocorrelation from the original tree-ring series (Cook and Holmes, 1986). The standard (STD) and ARSTAN (ARS) chronologies are usually used to reduce the possible effects of competition in closed canopy forests (Cook and Holmes, 1986). For our study area, all these chronologies were close, so we use the standard one.

First, a linear regression line of any slope was fitted to each tree ring-width series. Second, the tree-ring sequences were detrended using a cubic spline with a 50% frequency-response cutoff equal to 67% of the series length. All detrended series were averaged to chronologies by computing the biweight robust mean (Cook, 1985; Cook and Kairiukstis, 1990). The reliability of the chronologies was evaluated by the expressed population signal EPS (Wigley et al., 1984; Briffa and Jones, 1990). Since a high correlation was found between the three site chronologies, we combined them into a master-chronology (Fig. 2) covering 100 years.

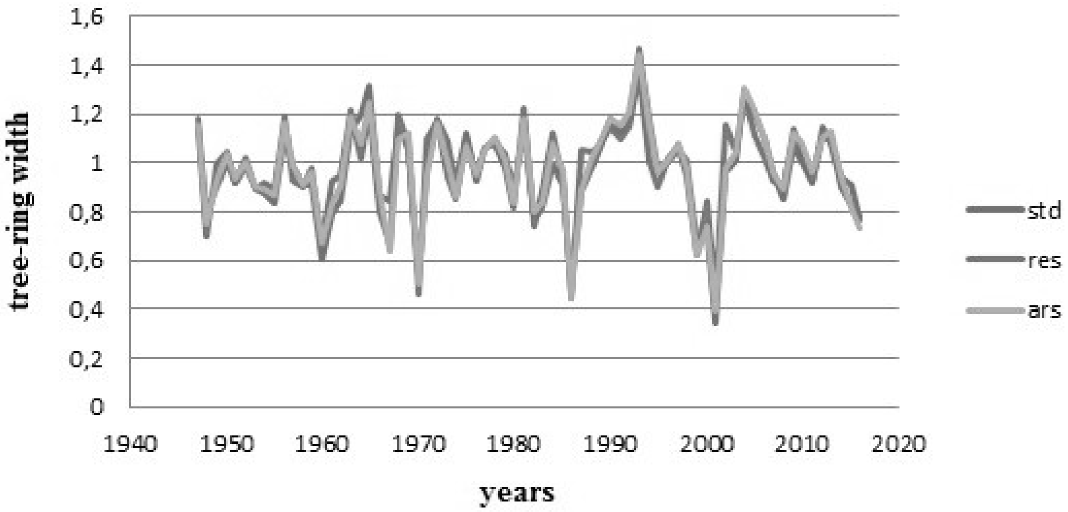

Figure. 2. Tree-ring chronology using turkman juniper.

Results

When the tree-ring chronology was completed, meteorological data on temperature and precipitation were taken for correlation with the master-chronology. For the sampling point with the coordinates N 38.25º, E 57.25º, the master-chronology was compared with temperature and precipitation data to calculate the spatial correlations between climate data and the tree-ring series. As a result, a climatic response was obtained (Fig. 3).

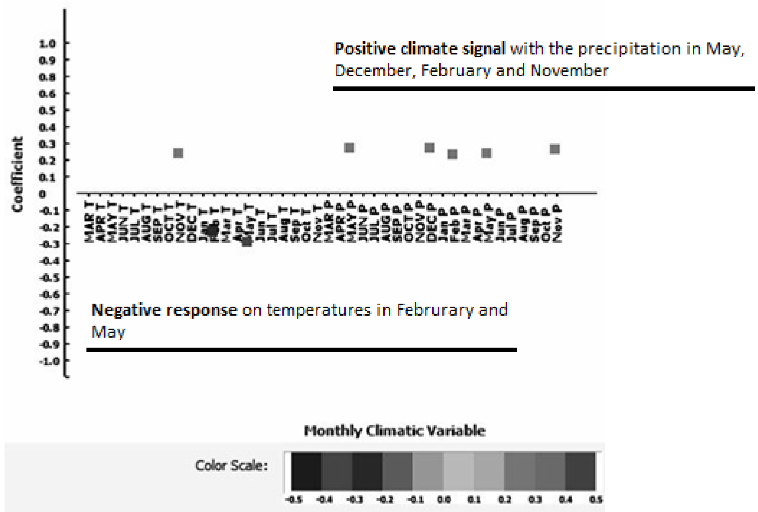

Figure 3. Climate response

High correlation (0.54) of the general chronology and weather data grid was obtained. The result was the graph of Fig. 3 that clearly reflects a significant positive climate signal with precipitation in the months of May, December, February, and November, revealing the response of tree growth to the precipitation and soil moisture in these periods. In addition, a negative response to temperature has been detected, indicating that the limiting factor in this area is truly precipitation. That means that biological productivity of trees is poor, and trees grow slowly even during periods of comfortable temperature because of low humidity. So we can distinguish the main results. First, the tree-ring chronology shows a significant climate response; therefore, it is potentially suitable for creating paleogeographical reconstructions.

Moreover, the main limiting factor for the piedmont of the Kopetdag range is the amount of precipitation.

Conclusions

In this research, it was found that there is high potential for the use of dendroclimatological methods in Turkmenistan for the purpose of hydroclimatological reconstructions. We found trees more than 100 years old. According to Turkmenistan forestry reports (Obzor sostoyania…, 2002), there are a lot of old trees (750 years and more) in the Kopetdag mountains. The wood samples of turkman juniper have good sensitivity and are suitable for building tree-ring chronologies and making further comparisons with climatic parameters.

We found a high correlation between the amount of precipitation and tree-growth in the study region. In this way, we understand that trees reflect the level of precipitation and soil moisture in the months of May, December, February, and November. In addition, we found a negative temperature response in the months of February and May. So we can say with confidence that the limiting factor for Turkmenistan is the amount of precipitation.

We plan to continue this research and construct new long chronologies, create regional reconstructions, and correlate them with archaeological research.

Acknowledgments

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PRELIMINARY RESULTS OF PALYNOLOGICAL ANALYSIS OF THE ATELIAN DEPOSITS FROM A BOREHOLE CORE IN THE NORTHERN CASPIAN SEA

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Keywords: ***Northern Caspian Sea, borehole core, Atelian deposits, palynological record, climatic reconstructions, correlations***

Introduction

The Atelian regression plays an important role in the late Pleistocene history of the Caspian region, being a critical boundary in the development of the basin. The Atelian suite of deposits was described for the first time by P. Pravoslavlev (1926) in the Lower Volga area. It is represented mainly by continental formations of different genesis: sandy loams and loams with traces of automorphic and hydromorphic soils, with inclusions of terrestrial and freshwater mollusk shells, and bones of mammals of the Upper Paleolithic complex ("mammoth fauna"). In the suite, G. Goretski (1958) described the Akhtubian deposits—periglacial sands. The thickness of the Atelian-Akhtubian deposits reaches 20 m. Traces of frost deformations and wedges penetrating into underlying beds are observed. According to results of seismic-acoustic profiling, the basin level was about -100 m.

The analysis of published data (Grichuk, 1954; Moskvitin, 1962; Vronsky, 1976, Yakhimovich et al., 1986) indicates that deposits of the Atelian regressive stage still have no reasonable and representative palynological record. Spore and pollen data on the Atelian deposits, such as from the coastal sections of the northern Pre-Caspian lowland and from boreholes drilled in the northern water area of the Caspian Sea, are extremely poor. For the Lower Volga area, the only single full-fledged spore and pollen range (the total sum of pollen and spores: 781) was executed by V.P. Grichuk (1954) on the basis of the Atelian deposits from the Cherniy Yar section. The structure and percentage of pollen and spores in this range, attributed by Grichuk to ranges of transitional (forest-steppe) type, reflects (according to N.S. Bolikhovskaya) vegetation of the periglacial steppes or forest-steppes: pollen of trees and shrubs (AP)—16%, pollen of grasses and subshrubs (NAP)—66%, spores—18%. Pollen and spores of thermophilic plants are absent. Within the dominating NAP group, pollen of undetermined dicotyledonous plants (67%) and Chenopodiaceae (16%) prevails, the significant part comprising *Artemisia* grains (6%) and other Asteraceae (6%). In the AP group, the pollen of coniferous trees—*Pinus* (48%) and *Picea* sect. *Eupicea* (20%)—prevails. The pollen of birch (23%) and alder (9%) is present also. Spores belong to bryophytes (Bryales – 71%, Sphagnales – 10%) and to ferns (Polypodiaceae – 19%).

A.I. Moskvitin (1962) wrote about the forest character of vegetation during Atelian time. He gave his own stratigraphical and paleogeographical interpretation of the single spore and pollen ranges obtained by V.P. Grichuk (1954) for the Atelian and Akhtubian sediments from the Raygorod and Cherniy Yar sections in the Lower Volga valley, and for the Atelian and lower Khvalynian deposits from the second terrace of the Volga River near Mordovskoe village (near Verkhniy Balykley village, 50 km below Kamyshin). Moskvitin considered that the accumulation of Akhtubian sands happened under "tundra and steppe conditions," and the

Atelian sediments were formed in taiga landscapes. The conclusion about the taiga phase in the development of vegetation in Atelian time is based on the fact that Moskvitin considered the lower Khvalynian sandy loam (at depths of 7.75-10.8 m in the Mordovskoe section) by Grichuk (1954) as sediments from the Atelian regression. Grichuk received from these deposits spore and pollen ranges showing dominant pollen from trees (to 85%), of which most belonged to fir (29-56%) and pine (40-60%).

We studied the Atelian deposits obtained from a core in the central part of the northern Caspian Sea using spore-pollen analysis. The results of these investigations make a contribution to this inade-quately studied question in Caspian history.

Results

The Atelian regression is clearly expressed in the structure of the Pleistocene deposits of the northern basin that was studied by seismic-acoustic profiling, static sounding, and explored with engineering-geological cores. It is reflected by the cuttings in the seismoacoustic profiles under the base of the Khvalynian deposits. The regressive thickness has a non-uniform lithologic structure and occupies a stratigraphic niche between Girkanian and Khvalynian transgressive deposits. Atelian sediments are encountered in the range of 26.6-21.8 m. They are represented by an alternation of thin sands and clays with vegetal detritus and rare shells of freshwater and terrestrial gastropods. These sediments, according to the analysis of the malacofauna and the macroremains of plants, were deposited within small freshwater or brackish-water basins (Bezrodnykh et al., 2015). Palynological data confirmed the conclusion about the formation of this facies in the Atelian deposits. The studied sediments contain the pollen of water and coastal-water plants (*Potamogeton*, *Sparganium*, *Lemna*, *Myriophyllum*), the remains of freshwater and brackish-water seaweed, and dinocysts (*Pediastrum*, *Botryococcus*, *Spiniferite scruciformis*, etc).

Preliminary results of the palynological analysis of 10 samples from the 4.8-meter thickness of the Atelian deposits testify to the considerable changes occurring within the environment during their accumulation. In the course of the palynological analysis, it was revealed that within the studied samples, along with pollen and spores of rather good preservation, strongly damaged and/or mineralized grains of pollen and spores from Pleistocene deposits, and pollen and spores from Pre-Quaternary deposits (from Carboniferous to Neogene) were redeposited. Among them: *Gorgonispora appendica* (Hacquebard et Barss) Oshurkova (from sample no. 37), *Vallatisporites variabilis* (Waltz) Oshurkova (no. 37), *Psilohymena* cf. *mirabilis* (Luber) Hart et Harrison (no. 37), *Murospora aurita* (Waltz) Playford (no. 39), *Gleicheniidites* sp. (no. 39), *Toroisporis* sp. (no. 39), *Tripartites* cf. *vetustus* Schemel (no. 42), *Toroisporis vulgaris* (Maljavkina) Barchatnaja (nos. 42, 44), *Triquitrites trivialis* Byvscheva (no. 44), *Labiadensites macroduplicatus* (Kedo) Oshurkova (no. 44), *Ruffordiaspora australiensis* (Cookson) Dettmann & Clifford (no. 44), and *Sciadopityspollenites macroverrucosus* (Thierg.) Iljina (no. 44).

The picture of the dynamics in climate and vegetation is clearly reflected by the representative spores and pollen ranges of samples no. 37 (from a depth of 26.20-26.25 m), 39 (25.2-25.4 m), 42 (24.72-24.75 m), and 44 (23.25-23.30 m). They are represented by well preserved pollen and spores, full size grains with quite fresh sporodermy. Deposits from the base of the Atelian thickness probably were formed in a rather humid and cool climate, in a phase dominated by pine and fir woods and alder thickets (with lesser amounts of fir and larch). The spores and pollen range of forest type in sample no. 37 testify to this. The pollen of coniferous species (*Picea* sect. *Picea*, *Pinus sylvestris*, *P.* subgen. *Haploxylon*, *Abies*, *Larix*, ~60% of the total AP pollen) and an alder (*Alnus incana*, *A. glutinosa* – 37%) also testify to it. Pollen of cereals (Poaceae), sedge (Cyperaceae), different grasses (Liliaceae, Asteraceae, Polygonaceae, Fabaceae, etc.) and the spores of ferns (Polypodiaceae, *Botrychium*) dominate among grassy and low shrubby plants.

The spores and pollen range of sample no. 39, perhaps fixes an interval of climate aridization in the development of desert-steppe or dry steppe landscapes, with primary development of wormwood associations in the open spaces and alder trees in the valleys and hollows on the most humidified sites. In this range, there are no spores of the higher spore-bearing plants, the pollen of herbs and low shrubs represented in the main by Chenopodiaceae, *Artemisia* subgen. *Seriphidium*, *A.* s.g. *Euartemisia* (about 75%) prevails, and within the group of trees and bushes, alder pollen (*Alnus incana*, *A. glutinosa*, about 70%) dominates. The share of pollen from coniferous trees was considerably reduced, and juniper pollen (*Juniperus*, about 10%) reaches a noticeable quantity.

It is possible to draw a conclusion about the growth of climatic humidity, expansion of the area of woody vegetation, and development of periglacial forest-steppe landscapes on the basis of the spore and pollen range in sample no. 42 from the middle part of the Atelian deposits. In the vegetation cover, the biotopes of alder and pine-birch trees with *Betula* sect. *Nanae* in the shrubby circle prevailed together with different cereal grasses and Chenopodiaceae associations. In this sample, the tree pollen (60%) of alder (*Alnus incana*, *A. glutinosa*), birch (*Betula pubescens*, *B.* sect. *Al-bae*), and pines (*Pinus sylvestris*) prevails, the amount of wormwood pollen is considerably reduced (to 4%), the role of cereals and different grasses (Liliaceae, Asteraceae, Polygonaceae, etc.) increases, and the pollen of shrubby birch, the spores of Bryophyta (*Bryales*, *Sphagnum*), and ferns (Polypodiaceae) appear.

The spore and pollen range from sample no. 44 from the top of the Atelian deposits reflects considerable strengthening of cold temperatures and, perhaps, a climate continentalization. It pushed the tundra-forest-steppe environment to the final stage of its formation. The content of pollen from trees and bushes decreased to 40%, and the role of spores increased (to 25%). In the AP group, the pollen grains of coniferous species (a fir-tree, a cedar-pine, and an ordinary pine) dominate with more than 55% of the total; at noticeable quantity is pollen of a shrubby birch (*Betula* sect. *Nanae* – about 20%), and an alder forest (*Alnaster* – 5%) that all indicate a cold climate. Among the spores of the higher spore-bearing plants, the remains of bryophytes (*Bryales*, *Sphagnum* – making up 60% of the total) and ferns (Polypodiaceae) prevail. The finding of spores from the frost-resistant fern *Cryptogramma crispa* growing nowadays in mountain-tundra, alpine, and subalpine belts of Eurasian highlands is of interest. Pollen of grassy-bushy plants includes ephedra (*Ephedra* – 5%), cereals (16%), a wormwood (*Artemisia* subgen. *Seriphidium*, *A.* s.g. *Euartemisia* – 18%), Chenopodiaceae (13%), Liliaceae and Asteraceae (25% of the sum), and the remains of water plants of pondweed and milfoil (*Potamogeton*, *Myriophyllum*) (12% of the sum).

Results of the spore and pollen analysis testify to the heterogeneity of climatic conditions and landscapes of the Lower Volga region during the Atelian epoch. Radiocarbon dating determined using humic acids, which are emitted from the Atelian deposits, lie in the age interval of 36,680 ± 850 to 40,830 ± 100, the calibrated age being 41,191 ± 750 to 44,390 ± 180 years (Bezrodnykh et al., 2015). They indicate that the closing stages of the Atelian epoch in the Caspian Sea (filling of regressive cuttings with sediments of freshwater basins) occurred in the initial stages of the Valdai interstadial epoch on the East European Plain. OSL dating of Atelian deposits from the section at Srednyaya Akhtuba (the basal section of the Lower Volga area) confirm this conclusion (see paper of Yanina et al. in these Proceedings). But the lowest level of the Atelian regression and formation of erosive cuttings in the territory of the northern Caspian Sea were timed to the global cold snap in the Early Valdai glacial epoch (MIS 4).

Climatic conditions of MIS 4 differed according to heterogeneity (Bolikhovskaya, 2007) and numerous alternations of cold and warmer intervals. Results of the spore and pollen analysis of the Atelian deposits in the core from the Caspian borehole contained evidence to confirm it. It is necessary to note (as is specified in the title of this paper) that preliminary data are presented; however, the authors consider it necessary to present them to the scientific community because of the acute shortage of palynological data on this very important paleogeographical epoch in the history of the Caspian Sea: the Atelian regressive epoch. The results will be supplemented and specified by further research into the Atelian sediments, especially in their comparison with the spreading and covering deposits sampled from the core and from coastal sections.

Acknowledgments

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THE PALYNOCLIMATOSTRATIGRAPHY OF THE PLEISTOCENE DEPOSITS IN TRLICA CAVE AND ENVIRONMENTAL RECONSTRUCTIONS (THE NORTHERN MEDITERRANEAN, MONTENEGRO)

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Keywords: Early-Middle Pleistocene, palynology, environments, Mediterranean Sea Region

Introduction

In Montenegro, Paleolithic cave sites have been studied by specialists from Russia (the Institute of Archaeology and Ethnography of the Siberian Branch of the Russian Academy of Sciences, Lomonosov Moscow State University, and Borisyak Paleontological Institute of the RAS), and those from the Centre of Archaeological Studies of the Montenegrin Academy of Sciences and Arts since 2010. A significant part of the multidisciplinary investigations performed on the Trlica Cave site (43°20′38″ N., 19°23′00.2″ E., 2.5 km southeast of the town of Pljevlja) consisted of the palynological analysis of the cave site sequence. Paleobotanical data available for Pleistocene sediments of Montenegro are extremely scarce, so the data obtained from the pollen and spore assemblages make a noticeable contribution to our understanding of the Pleistocene environments in that region of the northern Mediterranean.

Material, methods, and previous studies

Trlica Cave is a karst cavity formed in Triassic limestones on the side of an intermontane depression at 925 m a.s.l. Studies of the loose sediments infilling the cave enabled us to identify 12 lithological layers grouped into three facies-genetic members dated to the Early and Middle Pleistocene, up to 5.5 m thick altogether (Derevyanko et al., 2011). The lithological characteristics and paleontological data suggest that the depositional process was repeatedly interrupted. The lower member up to 1.5 m thick (layers 11 and 12) accumulated in subaqueous environments, which is confirmed by the presence of freshwater green algae of the genera *Botryococcus* and *Pediastrum* in palynological slides. The middle member (layers 5 to 10) bears traces of mostly deluvial and proluvial processes. The uppermost member (layers 1 to 4) presents a red-colored pedo-sedimentological complex. The conclusion of the genesis of layers 1-4 is based on the field study results, taphonomic characteristics of the palynoforms recovered from the described layers, as well as on the ecological and phytocoenotic characteristics of the plants-producers.

A representative collection of mammal bones, both large and small, collected from layers 5-6 and 10-11 has been thoroughly studied by I.A. Vislobokova and A.K. Agadjanyan (2016). The specialists identified two faunistic assemblages corresponding to two large paleogeographic stages, which permitted us to determine the age of the enclosing deposits. The small mammal fauna recovered from layers 5 and 6 correspond, judging from its evolutionary level, to the beginning of the Middle Pleistocene (i.e., its age is approximately 0.780 Ma). The faunal assemblage from layers 10 and 11 is dated to the second half of the Early Pleistocene – from the Olduvai Subchron to the mid-Late Villafranchian (that is, from ~1.8 to ~1.4 Ma).

A comprehensive palynological analysis of the Pleistocene sequences hasn't been performed yet in Montenegro. Some important data, however, were obtained by J. Argant (Argant and Dimitrijević, 2007), who studied pollen retrieved from coprolites of hyaena (*Pachycrocuta brevirostris*) found in Trlica Cave together with bones of Early Pleistocene mammals. Two of the studied samples contained neither pollen, nor spores; the other three samples yielded 1-3 pollen grains. The only pollen-bearing sample produced an assemblage indicative of forest biotopes existing under conditions of a relatively cool and humid climate. The upper levels were presented by coniferous tree stands (*Pinus*, *Abies*) and those of beech (*Fagus*); widely spread were also open biotopes with *Juniperus*, heather (*Calluna*), ground box (*Buxus*), and various herbs (Poaceae and others). The slopes were overgrown with oak and hornbeam, and the valley floor was mostly occupied by wetlands with alder (*Alnus*) forest and *Sphagnum* in the moss cover.

To get accurate and better substantiated paleoenvironmental reconstructions, about 40 samples were taken from the Pleistocene series of Trlica Cave; besides, a series of subfossil samples from various facies of the recent deposits were collected in test plots occupied by various plant communities. The pollen analysis of 39 samples taken from all the layers of the Trlica Cave sequence showed a low concentration of pollen and spores. Consequently, to obtain statistically valid data, we had to repeat the procedure of separating the plant remains (pollen, spores, and other microremains) from the each sample (150-200 g) of loose deposits many times, each time taking a new portion of the material weighing 50 g. The representative pollen assemblages thus obtained provided the data necessary for reconstructing the climate and environments during the deposition of all the horizons of the series under study and enabled us to subdivide it into several climato-stratigraphic units.

Results and discussion

The list of the taxonomic composition of the palynoflora recovered from layers 1 to 12 includes about 100 species, genera, and families of arboreal plants, shrubs, dwarf shrubs, herbs, and grasses, as well as spore-bearing plants. Also found is pollen of relict plants typical of subtropical and temperate environments of the Neogene, such as *Cathaya* sp., *Podocarpus* sp., *Keteleeria* sp., *Tsuga* spp., *Cedrus* sp., *Parrotia persica*, *Celtis* sp., and some genera of Taxodiaceae (cf. *Taxodium*, cf. *Sciadopitys*, *Cryptomeria japonica*), Cupressaceae, and other families. The listed taxa are constituents indicative of the interglacial floras attributable to the Early and the first half of the Middle Pleistocene in the Mediterranean historical-floristic region, and their presence confirmed the conclusion of an Early-Middle Pleistocene age for the Trlica Cave deposits. Considering the chronology of the appearance, peak development, and disappearance of exotic taxa identified in the Pleistocene floras of the Mediterranean, palynologists noted a diversity of regional and local characteristics of those processes (Suc and Popescu, 2005; Popescu et al., 2010; Bolikhovskaya, 2011; Manzi et al., 2011; and many others). On the whole, the Early-Middle Pleistocene interglacial intervals in the central Mediterranean region were distinct for dominance of broadleaf and coniferous-broadleaf forests with some subtropical elements, while phases of dark coniferous trees (with hemlock, cedar, and other exotic plants) were typical of the transitional periods. Climatic rhythms of the glaciation rank corresponded to phases revealing an increasing importance of non-arboreal steppe elements, such as sagebrush (*Artemisia*), Amaranthaceae, Chenopodiaceae, etc.; these species indicate rather cold and dry environments. Coniferous forests of middle and high mountain type were widespread during cooler and more humid intervals (Joannin et al., 2007).

As follows from the newly obtained palynological data, forests were the dominant landscapes in the vicinity of Trlica Cave during the entire period represented by the cave series deposition. The species composition of the forests, however, changed depending on the climate fluctuations: coniferous-broadleaf forests prevailed at the time of warmings, while coolings featured purely coniferous forests or those with an insignificant admixture of broadleaf species.

At the present stage of our studies, three periods of relative cooling may be correlated with deposition of layer 12, the upper part of layer 9-lower part of layer 8, and the uppermost portion of layer 5.1 (sub-layer 5.1A), the latter abounding in rock fragments resulting from the desquamation process. Layer 12 began to form during the phase of predominant fir-spruce-cedar pine forests (*Abies* sp., *Picea* sect. *Picea*, *Pinus* subgen. *Haploxylon*) and pine (*Pinus sylvestris*) forests with a dense shrub layer of juniper (*Juniperus* spp.). Then, under conditions of relatively warmer climate, some warm-requiring species appeared in the tree stands, including Serbian spruce (*Picea* sect. *Omorica*), hemlock (*Tsuga* of *piccolo* type), beech, oak, and hazel. During the first warmer stage, at the time of the deposition of layer 9 (lower part) to layer 11, the region was mostly covered with coniferous-broadleaf forests predominantly of spruce, European cedar pines, European hornbeam (*Carpinus betulus*), oriental hornbeam (*Carpinus orientalis*), and lime trees (*Tilia* cf. *cordata*, *Tilia* cf. *platyphyllos*), with an admixture of beech (*Fagus sylvatica*), oak, hop hornbeam (*Ostrya* sp.), alder, hazel, mulberry, etc. An old age of the deposits is suggested by the presence of some relicts of the Cretaceous and Neogene periods in the pollen assemblages; among them, there are evergreen coniferous *Cathaya* sp. and *Keteleeria* sp., now extinct from the region and growing in SE Asia. The climate-controlled phytocoenoses dated to the second cooling (the upper part of layer 9 and the lower part of layer 8) were dominated by forests of fir, cedar, and spruce. At the time of deposition of layer 7, a temperate warm climate was favorable for mixed forests of spruce, pine, and broadleaf trees (lime *Tilia* cf. *cordata*, oak *Quercus* sp., *Quercus* cf. *ilex*, and hornbeam *Carpinus betulus*,) with hazel (*Corylus avellana*) and mulberry (*Morus* sp.) in the underwood, and with isolated tree stands of oriental hornbeam, birch, and alder. The coniferous group is diversified in composition and includes *Picea* sect. *Picea*, *Pinus* sect. *Cembra*, *P.* sect. *Strobus*, *P.* s.g. *Diploxylon*, *Pinus sylvestris*, and *Juniperus* sp.

Layers 5 and 6 (?) composed of ochreous loam ~130 cm thick were deposited at a warm stage correlatable with the first interglacial of the Brunhes epoch (MIS 19), when open broadleaf and coniferous-broadleaf forests grew in the greater part of the region under conditions of a warm and relatively dry climate. The broadleaf communities consisted mostly of taxa typical of montane xerophytic flora, such as *Ostrya* sp., *Carpinus orientalis*, *Celtis* sp., *Tilia argentea*, and others), as well as *Quercus* sp., *Carpinus betulus*, *Corylus avellana*, *Corylus* sp., *Ulmus* sp., *Alnus* sp., and *Alnus glutinosa*. The coniferous tree stands were dominated by pines (*Pinus* s.g. *Haploxylon*, *Pinus* sect. *Cembra*, *Pinus* s.g. *Diploxylon*, *P. sylvestris*), with a constant presence of Cupressaceae, *Picea* sect. *Omorica*, *Picea* sect. *Picea*, and *Abies* sp. The presence of subtropical coniferous exotics – *Cathaya* and *Podocarpus* – is quite possible. Pollen of Persian ironwood (*Parrotia persica*) suggests some ecotopes with wet soils; at present, this tree occurs in warm and wet climate, on the coasts of water bodies, or on wetlands in mountain valleys. The petrophyte-steppe biotopes were dominated by Chenopodiaceae, wormwoods (including *Artemisia* s.g. *Seriphidium*), and plants of the Liliaceae and Asteraceae families.

The third cooling (sub-layer 5.1A) was marked by the disappearance of subtropical coniferous and broadleaf species from the forests.

At the present stage of palynostratigraphic studies, one may state more or less confidently that the major part of the deposits (layers 1 to 4) was accumulated during the warm interval of the Middle Pleistocene, correlatable with the Noordbergum (Interglacial IV, Voigtstedt, Ferdynandowian) Interglacial of the West European scale and with the Muchkap Interglacial of the European Russia stratigraphic scale, the latter dated by the EPR technique to ~610-536 ka BP (Molodkov and Bolikhovskaya, 2010). The upper red-colored soil and deposit complex yielded a flora most diversified and rich in Neogene relicts. The warm and wet climate was favorable for the subtropical broadleaf-coniferous forests dominated by pines (including cedar pines *Pinus* sect. *Cembra*, *Pinus* sect. *Strobus*, and light coniferous pines), with a notable participation of Neogene relicts (*Cathaya* sp., *Podocarpus* sp., *Keteleeria* sp., *Cedrus* sp., *Cupressus* spp., etc.). Broadleaf dendroflora was abundant (*Parrotia persica*, *Fagus* sp., *Quercus* sp., *Quercus ilex*, *Quercus pubescens*, *Carpinus betulus*, *Carpinus orientalis*, *Carpinus* sp., *Ostrya* cf. *carpinifolia*, *Corylus avellana*, *Corylus* sp., *Tilia* sp., *T. cordata*, *T. argentea*, *Celtis* sp., *Ulmus* sp., cf. *Pistacia*, etc.).

Conclusion

The studies we conducted proved that the Trlica Cave deposits are a promising source of palynological information that may be used in climatic stratigraphy and reconstructions of the Early and Middle Pleistocene environments on the Balkan Peninsula.

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MIDDLE MIOCENE MARINE MOLLUSKS IN NORTHERNMOST ANATOLIA: BIOSTRATIGRAPHIC RESPONSES TO CHANGING PALEOGEOGRAPHY

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Keywords: Sinop Basin, Eastern Paratethys, Tarkhanian, Tchokrakian, Konkian

Middle Miocene mollusks of the Sinop basin are well-known as having different Eastern Paratethyan type molluscan assemblages (Özsayar, 1971; Schütt, 1992; Ilgar and İslamoğlu, 2013; Goncharova et al., 2014). In general, the Sinop formation comprises neritic to littoral facies of Tarkhanian-Tchokrakian deposits with a forced regressive tendency. The overlying Konkian-Bessarabian Gelincik formation represents the infill of fluvial valleys incised during Karaganian time and comprises deltaic and non-deltaic bayhead shoreline deposits (Ilgar, 2015).

In this study, Tarkhanian, Tchokrakian, and Konkian deposits in the Akliman, Carta Cape, Kurtkuyusu, Keçideresi, and Gelincik localities bearing a high resolution record of relative sea level changes are revisited and logged.

Sixty (60) molluscan species were recorded from the deposits of the Tarkhanian and Tchokrakian. In the Akliman locality, *Ostrea edulis caucasica* Zhizhcenko, *Ostrea (Ostrea) frondosa* De Serres, *Ostrea (Ostrea) digitalina* Dubois, *Neopchynodonte cochlear navicularis* (Brocchi, 1814), *Crassostrea gryphoides* (Schlotheim), and *Chlamys (Aequipecten) domgeri derbentica* (Grig.) are found in the transgressive deposits, overlying the Eocene basement. The molluscan species collected from the deposits of the Carta Cape and Kurtkuyusu (Sinop formation) are dated to Tarkhanian-Early Tchokrakian by the presence of gastropods *Gibbula (Colliculus) retowskii* (Kolesnikov, 1931), *Bittium digitatum* (Zhizhchenko, 1934), *Obtortio tschokrakensis* (Özsayar, 1979), *Bittium multiliratum tulskajense* Iljina, 1993, *Acteocina fusiformis* (Boettger, 1905), *Obtortio andrussovi* (Bajarunas, 1910), *Cerithium cattleyae* Baily, and bivalves *Aequipecten domgeri derbentica* (Grig.), *Acanthocardia centumpania* (Andrussov), *Ervilia praepodolica* Andrussow, 1899, and *Lembulus pella elongata* (Zhizhchenko, 1936). Among the assemblages, *Gibbula*, *Turritella*, *Rissoina*, *Obtortio*, *Potamides*, *Cerithiopsis*, *Aclis*, and *Bittium* are known as thermophilic taxa. *Obtortio praeroxolanica* (Zhizhchenko, 1936), *Cerithidium agibelicum* (Zhizhchenko, 1936), *Cerithium cattleyae* Baily, *Bittium digitatum* (Zhizhchenko, 1934), *Potamides cicur*, and *Bittium digitatum* are species of Indo-Pacific origin, migrated to the Early Tchokrakian Sea. These findings contribute the idea of an open marine connection between the Eastern Paratethys, Eastern Mediterranean, and Mesopotamia, through a system of straits. The sea-level fall at the Tchokrakian/Karaganian transition (de Leeuw et al., 2010) disconnected the Mediterranean and Paratethys from the Indo-Pacific domain (Rögl, 1998), resulting in subaerial exposure and fluvial incision in large parts of the Paratethys (Popov et al., 2010).

Fourteen (14) polyhaline molluscan species were determined from the Gelincik and Sarikum localities (Gelincik formation). *Thericium turonicum* (Mayer, 1878), *Cerastoderma arcella bogatchevi* (Zhizhchenko, 1936), *Thericium rubiginosum* (Eichwald, 1853), and *Cardium praeplicatum* Hilber are endemic species for the Konkian. The presence of Mediterranean taxa such as *Thericium vulgatum miocenicum* (Vignal, 1910), *Nassarius edlaueri* (Beer-Bistrický, 1958), *Nassarius (Phrontis) serraticosta*, *Arca turonica bosphorana* (David), *Arcopsis lactea* (Linnaeus), and *Corbula (Varicorbula) gibba* (Olivi) supports the migration from the Mediterranan and a wide connection between two different paleogeographical realms. The abundance of Konkian mollusks in the region is much lower than that of the assemblages from the eastern and sourteastern part of the Eastern Paratethys.

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QUATERNARY MOLLUSCAN FAUNAS OF THE SINOP PENINSULA (N. TURKEY) ELUCIDATE BIOGEOGRAPHIC CONNECTIONS

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The Sinop peninsula is located in the northernmost part of the Anatolian Peninsula, Turkey. It is one of the best preserved localities at which Neogene to Quaternary marine stratigraphy is exposed along the whole southern Black Sea coast. In the Late Quaternary, the Black Sea had a complicated connection pattern with the global ocean as well as intracontinental water bodies (i.e., the Caspian Sea). During interglacials, Mediterranean water reached the Black Sea basin via the Marmara gateway (Büyükmeriç, 2016; Büyükmeriç et al., 2016 and references therein), whereas the Black Sea has been repeatedly subject to Caspian overspills (isotopically depleted freshwater from the Caspian Sea) through the narrow straits of the Manych and Kerch (Fedorov, 1977, 1978; Popov, 1983; Tchepalyga, 1995; Yanina, 2014), at least twelve and seven times, respectively, over the last 670,000 years (Badertscher et al., 2011).

The presence of Sinop Quaternary molluscan faunas has already been known in the region (Erinç and İnandik, 1955; Tchepalyga et al., 1997), however, their descriptions and age determinations have not been completed yet. This situation complicates any answers to major questions about faunal compositions and their paleobiogeographic features. In this study, 29 samples from eight localities spanning the middle to late Pleistocene interglacial intervals are reviewed. We fully defined 37 mollusk species (12 gastropod and 25 bivalve species), some of which have not previously been reported in the region. Sinop assemblages include fauna of Mediterranean origin as well as endemics, so-called Ponto-Caspian faunas. The middle Pleistocene fauna is dominated by species that typify the Chaudian while the middle-late Pleistocene molluscan fauna are identical to Uzunlarian and Karangatian faunas of the stratotypes on the northern coast of the Black Sea representing two different interglacial periods. Chaudian fauna consist of brackish water, coastal (above the storm wave base) endemic Ponto-Caspian species: *Didacna crassa pontocaspia* (Pavlov), *Didacna crassa baericrassa* (Pavlov), *Dreissena rostriformis*, and *Dreissena polymorpha*, indicating the absence of a Mediterranean effect. The fauna document outflow from the Caspian Sea and endemic shallow water habitats, similar to that of the Caspian and the northern coasts of the Black Sea (Andrussov, 1904-1905; Arkhangel'sky and Strakhov, 1938; Nevesskaya, 1963, 1965; Yanina, 2005).

On the other hand, the Uzunlarian assemblage includes mesohaline faunas such as *Polititapes discrepans* (Milaschevitch), *Cerastoderma glaucum* (Bruguiére), as well as reworked fragments of pontocaspian elements *Didacna* and *Dreissena*. Sinop Karangatian fauna consist of typical Mediterranean species: *Acanthocardia tuberculatum* (Linné), *Polititapes senescens* (Cocconi), *Chamalea gallina* (Linné), *Ostrea edulis* Linneaus, *Parvicardium exiguum* (Gmelin), *Spisula subtruncata triangula* (Rénier), *Bittium (Bittium) reticulatum* (Costa), *Patella (Patella) caerula caerula* (Linné), *Arcularia (Arcularia) gibbosula* (Linné), and *Tricolia pulla* (Linné), representing polyhaline salinity, typically above 20 psu. Compared to the Uzunlarian asemblage, the Sinop Karangatian fauna include a higher number of Mediterranean species, some of which are thermophilic taxa.

In our work, Chaudian mollusk-bearing units are found in the Denizci Amca and Bedre localities, 30-32 m asl (above sea level), whereas Uzunlarian units are recorded at 40 m asl in the Ustaburnu and Ayancik localities, situated in different morphotectonic units. Karangatian assemblages are recorded between 9-23 m asl in the Sinop liman, Gerze, Gerze liman, and Bedrekayasi localities. However, Arkhangel'sky and Strakhov (1938) proposed the term "Karangatian" for the deposits of Cape Karangat, Crimea/Kerch peninsula, at a level 6-8 m higher than the present sea level (Fedorov, 1988). The Karangatian marine terraces and coastal sediments are also exposed along the coasts of Crimea, Azak, the Caucasus, and Bulgaria (Fedorov, 1978; Nevesskaya, 1963, 1965; Popov, 1983). Recently, it is known that Pleistocene deposits are found in the tectonically uplifted Kerch-Tamanian block along the Caucasian and northern Turkish coastline (Sinop, Gerze, Ünye, and Trabzon) (Tchepalyga et al., 1997; Dodonov et al., 2000), whereas some coastlines in the northwestern Black Sea coast and in the Azov Sea region are below the present sea level (Dodonov et al., 2000). The stratigraphic discrepancies of the uplifted marine terraces in the Sinop peninsula support the differential uplift modal for the region, as proposed by Yıldırım et al. (2013).

Sinop molluscan faunas may allow the interpretation of various paleoenvironmental/ paleobiogeographical situations and sedimentary cycles related to sea-level changes. In the Uzunlarian and Karangatian oceanic sea levels (Mediterranean effects), it is considered likely that there were two high-stand intervals corresponding to relative sea-level high stands of interglacials MIS7 and MIS5. But it is difficult to estimate the MIS periods corresponding to the Chaudian deposits. Episodic Caspian overflows occurred at glacial terminations during that time, possibly MIS13/15, but further dating information and precise ages are necessary.

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RE-ASSESSING EAST MEDITERRANEAN SEA-LEVEL TRENDS: 3000 YEARS OF ARCHAEOLOGICAL INDICATORS IN GREECE AND ISRAEL

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Introduction

Coastal and submerged archaeological remains have long been used to reconstruct Holocene relative sea level (RSL) in Israel (Flemming et al., 1978; Toker et al., 2012) and Greece (Flemming, 1969; Baika, 2008). The area is believed to be tectonically stable (Sivan et al., 2010) with small glacio isostatic adjustment (GIA) over the last two millennia (Sivan et al., 2004), so local observed RSL can reveal eustatic fluctuations. To substantiate these observed fluctuations as regional trends, new and existing Israeli data were reassessed, analyzed, and compared to RSL observations from Greece and GIA model predictions (Peltier, 2004; Lambeck and Purcell, 2005; Spada and Stocchi, 2007).

The study has three objectives: (1) identification of archaeological sea-level indicators from the last 3000 years in Israel and Greece, including published and new measurements; (2) consistent assessment of indicators; and (3) creation of a more complete sea-level reconstruction for the East Mediterranean. These objectives can answer several questions: Which types of sea-level indicators are most reliable and precise? What are the sea-level trends in both areas for the past 2-3 millennia? Are regional eustatic fluctuations apparent, and do observations align with a particular GIA model?

Methods

Data were collected by review of published sources on archaeological sea-level indicators in both areas. Indicator interpretations were reassessed, as were metadata and assumptions used to estimate uncertainties. Indicators were compiled into a dataset with extensive metadata, then sorted by typological category and quality.

New measurements were taken in Israel at imperfectly understood sites such as the pool at Caesarea and a Roman fishpond at Achziv (Anzidei et al., 2011), and unidentified carved structures at Dor (Raban and Galili, 1985). New research (Bechor, forthcoming) using indicators from Crete, Methoni, and the Island of Paros in Greece was also incorporated.

In Greece, significant local tectonic activity is a challenge to RSL trend analysis. This study consulted work by Pavlopoulos et al. (2012) that calculates vertical motion rates from the difference between observed and GIA model-predicted sea level. Sites with lower vertical displacement rates were targeted, and data were subject to statistical analysis (Cahill et al., 2015).

Results

The survey analyzed ~150 indicators from Israel, including a number of bio-construction cores (*Vermitidae*) and ~140 from Greece. In Israel, ~120 were deemed reliable enough for reconstructions, and in Greece, ~40. Indicator typological analysis suggested no clearly superior choice, but favored large sets of the same indicator type for reliable trend analysis.

Disparities between the two regional datasets are apparent. Israel (Fig. 1) has a strong set of many indicators from ~2000 BP to the present, but few from the period 3000-2000 BP.

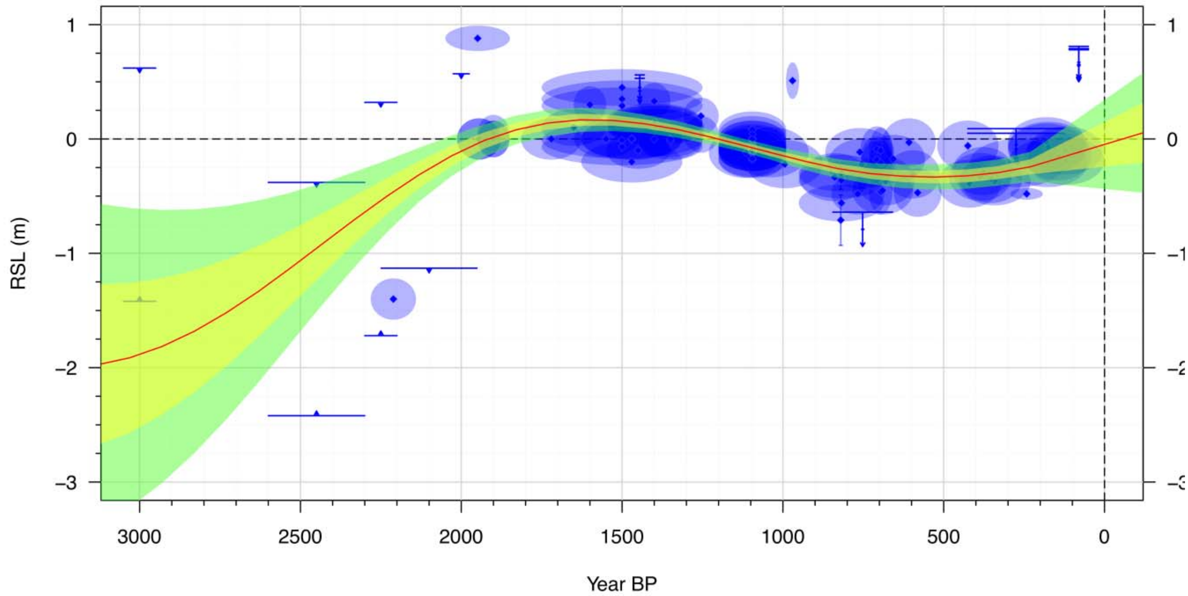

Figure 1: Archaeological and biological sea-level indicators from Israel (blue), with statistical analysis in yellow (68% confidence) and green (95% confidence).

Greek indicators are biased to 2500-2000 BP, reflecting the focus of archaeological scholarship. This makes it difficult to compare trends between areas, but the results imply lower sea levels during the last 2 ka, and solidify observed Israeli fluctuations not exceeding 0.5 m peak amplitude at ~1500 BP and ~750 BP. Both areas tentatively indicate sea-level rise between 2500-2000 BP. The dataset in its current condition does not decisively support GIA models with late-Holocene melting (Lambeck and Purcell, 2005) versus those without (Peltier, 2004), since more datapoints are needed for a final determination.

The current study also identifies targets for on-going research: in Israel from 3000-2000 BP; in Greece from periods besides 2500-2000 BP—particularly in subregions of reported tectonic stability (Baika, 2008: 35) like the Cyclades.

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THE VALUE OF THE HYDROLOGICAL AND LANDSCAPE CHARACTERISTICS OF THE REGION FOR THE LIFE OF THE PRIMITIVE POPULATION (AN EXAMPLE OF LATE-MESOLITHIC AND NEOLITHIC SITES OF DNIEPER RAPIDS REGION)

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Introduction

As an integral part of the Black Sea basin, the Dnieper River valley (Fig. 1) is largely dependent, and, to a certain extent, influenced by the changes that took place in the Black Sea and Azov region in connection with global climate fluctuations.

Figure 1. The Dnieper Rapids Region.

Humans were an unwitting witness to these processes and could not fail to respond to environmental changes. The fate of each group depended on successful adaptation to new conditions.

The Dnieper River has always been one of the major water basins of Ukraine, for which a significant cultural focus involved the peoples who inhabited the valley from the most ancient times. However, the valley of the Dnieper was not static and unchanging throughout the period of its existence. The modern landscape and hydrological regime of the river are the result of numerous disturbances by natural and anthropogenic influences. According to its geomorphologic and hypsometric situation, the territory of the Dnieper Rapids Region provides the best conditions of all other areas of the Dnieper.

This is primarily due to the fact that this region is a breakout section of the river through the crystalline shield. The breakthrough occurred during the Pliocene and has largely determined the specificity of paleo-landscapes in this area.

Hydrological and landscape conditions that developed here in the Late Boreal period of the Holocene became important factors influencing the particular settlement strategy of Meso-Neolithic populations; they produced the preconditions for a successful economic strategy.

Hydrological and landscape characteristics of the region

The Dnieper Rapids Region geographically covers the space between the middle and lower streams of the Dnieper, from the modern city of Dnieper to Hortitsa Island in Zaporozhe. The total length of the region is about 80 km. After its confluence with the Samara River, the Dnieper takes a meridional direction, which is maintained throughout the segment of the river that passes through the crystalline array. Specificity and originality of the hydrological landscape is manifested by the concentration here of a large number of islands, large rocks, rapids, and an enclosure. In addition to the 9 main rapids—Kodatsky, Surskoy, Lohansky, Dzvonetsky, Nenasytetsky (Revushiy), Vovnigsky, Budylo, Lyshniy, and Volniy (Gadyuchy)—a few tens of rocks (the enclosure) rise above the surface of the Dnieper; there were more than 60 islands (Vermenich, 2004). The hydrological regime was characterized by a fairly rapid flow (up to 6 m/s) at the location of the rapids and the enclosure. In places where the gneiss-granite massif diverged from the shoreline, the Dnieper spread widely.

The islands of the Dnieper Rapids Region can be divided into several groups according to their hypsometric characteristics. The largest islands are large granite massifs (Kuharev, Tavolzhany, Kamenolomnya, etc.). Another group is the small island-cliffs (Strilcha Skelja, Sredniy Stog, Durna Skelja, Perun, and others). Some islands are remnants of alluvial terraces (Kodachek, Volchok, and others). A separate group includes sandy islands that cap a granite rock, which has contributed to the sand wash and alluvium of first, a barrier beach, then the islands (Surskoy, Shulaev, Vynogradniy, and others).

The plateau divide of the Dnieper Rapids Region is characterized by a general slope to the south. The left-bank watershed lies above that of the right-bank. The right-bank of the Dnieper is steeper than the left, and this phenomenon was explained by L.A. Lepikash by the different levels of occurrence of crystalline rocks at the base of the Quaternary sediments (Lepikash, 1934). The different depth of the shoreline slopes is largely influenced by the nature of the many gullies and ravines, as well as the intensity of their buildup. In general, in the area of the Rapids, there are not deep gullies. Their bottoms do not go deep into the rock, which prevents them from deepening intensively. Since the surface of crystalline rocks is cool and rapidly decreases toward the river, the bottom gullies are tilted in the same direction. Depending on the nature of rock fall longitudinal sectional gullies may be flat or convex, or a step (Smirnov, 1973: 8). A substantial number of rivers flow into the Dnieper in the area of the Rapids. The largest of them are the Mokraya Sura (left inflow), Samara, Vorona, Ploskaya Osokorovka, Vilnyanka (right inflows), and others. The total landscape has a canyon-like appearance.

Human adaptation to the Early-Middle Holocene global climate changes in the Black and Azov Sea region

The natural changes that occurred during the Neoeuxinian also modified the Dnieper channel in the area of the Rapids. These modifications concerned not only hydrological and landscape characteristics of the region, but they also affected the humans in a way that was manifested in new ways of organizing life. In this perspective, a comprehensive analysis of the geographical and archaeological components is important, as it will provide an opportunity to understand how natural changes were manifested in human life and how successful the adaptation of primitive groups was.

Changes in the hydrological and landscape characteristics are clearly seen in archaeological data through the patterns of site location. For example, early Mesolithic sites were situated at an elevation of about 11-14 m above the level of the Dnieper in the period prior to its regulation (Osokorovka, Yamburg). It is difficult to relate these sites with a particular floodplain terrace at the moment. The problem of allocation of river terraces in the Dnieper Rapids Region is still debated. Due to the uneven erosion of the crystalline rocks and the uneven occurrence of Quaternary sediments, terraces in the region are not manifested everywhere. Nevertheless, given the principles of their formation, the stages of deepening of the riverbed can indirectly fix the placement of multi-temporal archaeological localities.

It is in the overdeepening process of the Dnieper river bed that we associate the landscape upheavals that caused a complete change in the principles of settlement placement during the Late Mesolithic and Neolithic. The settlements of the late Mesolithic and Neolithic are always located much lower in elevation than those of the Paleolithic and early Mesolithic. In the Rapids Region, they are located mainly on the low sandy islands. Thus, a settlement on Surskoy island is only 5-6 m above the summer level of the Dnieper prior to its regulation (Danilenko, 1950), and a settlement on the island of Shulaev is at 6 m (Bodyansky, 1949). All this testifies to the fact that in Neolithic times, a low water level in the Dnieper, as well as the height of the spill during flood stage differed little from the contemporary values of these parameters. New in our time as compared with the Neolithic era, obviously, is that the high water level is much higher in some years than in the Neolithic. The explanation for this fact is to be found in the changing flow of the river, which, after the destruction of the forests in historical time, was the steppe with its inherent high floods (Vil'yams, 1948). In the Neolithic, the rivers, including the Dnieper, were full-flowing all summer but didn't have today's stormy spring floods (Telegin, 1962).

We should also stop at the island areas of the Dnieper, which are especially important for our research, because from the late Mesolithic period, they became a place of numerous settlements and sites. The presence of these elements led to the appearance of the landscape in the region, a specific settlement strategy that to some extent stimulated the development of economic strategies based on river fishing (Demchenko, 2015).

If we talk about the early settlement of the islands of the Dnieper Rapids Region, we should still talk about the early Mesolithic, as evidenced by the findings in the northern part of Surskoy Island (site 5). However, the absence of findings from early Mesolithic time on the other parts of Surskoy Island and on numerous nearby islands says that the formation processes of the island's portions are not completely finished. We agree, to some extent, with the concept of the breakthrough of the Polessky glacial lake considered in the works of V.G. Pazinich, L.L. Zalizniak, and others and its role in shaping the landscape and hydrological picture of the Dnieper Rapids Region. It is possible that this event, which occurred in the late Pleistocene to early Holocene, partly shaped the island portions of the Rapids Region (Igrensky peninsula, Surskoy, Shulaev, Kizleviy islands, and others) (Pazinich, 2007; Zaliznyak, 2008). However, the Dnieper river bed landscape in the Rapids Region acquires its final form in late Mesolithic time. According to many researchers, in the late Neoeuxinian (about 9.5-9 ka BP), there are certain changes in the morphogenesis of the channel of the Dnieper involving the overdeepening process of Black Sea rivers, which is fixed on the so-called "shut-in stages" in the channel facies of alluvium (Izmailov, 1982; Stanko, 1992; Konikov et al., 2006). Uplift of the area and maximum reduction of the regional base level of erosion during regressions of the Novoeuxinian basin caused a plunge in the rivers, narrowing their beds, deepening their valleys and leading to further growth related to their gullies and ravines. Most likely, this event completed the formation of the island areas, and they became available for active settlement by the human population in the late Mesolithic, as we can see by the archaeological evidence. Given the relatively high location of the archeological localities of the previous Meso-Neolithic period, it is clear that the relatively low islands of the region were not yet available for the primitive people.

To some extent, due to the specifics of its paleo-landscapes, hydromorphology, and to some degree its location, the Dnieper Rapids Region was something like "steppe oasis" or a refugium combining the features of both steppe and forest vegetation, which under favorable paleoclimatic conditions spread from here to the neighboring territory. And in the warmest and most humid period of the Holocene, the Atlanticum, the development of wet and mesophilic forests took place here, both within the river valleys, and on the watershed (Demchenko, 2016).

Conclusions

In recent years, the question of eustatic behavior of the Black Sea has gained more and more importance in the context of large-scale changes in natural and geographical conditions, which affected the adaptive strategies of human groups. Changes in the river channel of the Dnieper River in the rapids area, which occurred as a result of regressions and transgressions of the Neoeuxinian basin influenced the formation of specific adaptive systems among the primitive populations of the region during the Late Mesolithic and Neolithic.

The general climate moisture and flooding of the territory of modern Ukraine within the Boreal period of the Holocene reflected on the southern border of the steppe zone. Under the influence of post-glacial glacio-eustatics, the Flanders transgression of Mediterranean began a gradual increase in the level of the Black Sea, which reached its maximum level at 5-6 ka (Yanko-Hombach et al., 2011). Fluctuations in sea level are accompanied by certain shifts in the morphogenesis of the Dnieper and other rivers. According to many researchers, at this time there is overdeepening of Black Sea rivers, which are locked in, the so-called "incision stages" in the fluvial facies of the alluvium. The rise of the territory and the maximum reduction of regional erosion base at the pool regression of the Neoeuxinian basin caused plunging rivers, narrowing of their beds, deepening of their valleys, leading to further growth related to their gullies and ravines. Most likely, these events should be linked to the surface elevation of the rock masses in the Dnieper Rapids Region and completion of the islands' formation, which occurred just at the time of the late Mesolithic period, when they became available for encampment and settlements built by ancient fishermen and hunter-gatherers.

General hydrological, landscape, and climatic conditions that prevailed at that time in the Dnieper Rapids Region differed not only from previous periods, but also from conditions in neighboring areas. This, in turn, played a crucial role in the composition of the complex "bush" settlement system, long settled habitation of the population within the region, preserving the forms of an extractive economy based on intensive use of river resources.

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THE SEA OF AZOV UNDER ANTICIPATED SEA-LEVEL RISE

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Keywords: coastal morphology, human impact, greenhouse effect, risk assessment, flooding

Introduction

Sea-level changes are seriously affecting coastal zone dynamics, and therefore the environment of surrounding territories. Studying these processes is very important because of potential future greenhouse-induced global sea-level rise. A strong possibility exists for an accelerated sea-level rise during the next century. According to scenarios for greenhouse gas emissions by the Intergovernmental Panel on Climate Change (IPCC), the global mean sea level will rise by 0.14-0.88 m until 2100 (Houghton et al., 1990). However, even a sea-level rise of a few decimeters would have substantial negative consequences for coastal morphology and environmental conditions.

Passive inundation of low-lying land edges will occur only in a few coastal segments: in small semi-enclosed bays and on very gently sloping coasts, i.e., where wave and tidal energy dissipates long before the coastline. In most cases, active reformation and general destruction of depositional bodies and intensified retreat of erosion scarps is inevitable. Loss of unique coastal habitats and increased risk of natural hazards are also inevitable.

Coastal zones will suffer substantial economic and environmental damage due to shoreline retreat and changes in environmental conditions at preserved land areas due to underground flooding and other related processes. In addition to direct loss of property, many agricultural areas and industrial facilities will need reconstruction or reorientation of their specialization. It is reasonable to consider the problem of assessing possible losses in terms of changes in stability and vulnerability of coastal systems.

Risk factors

According to the A.O. Selivanov (1993), we can enumerate four groups of ecological factors.

1. Possibility of increased industrial hazards due to more complicated technology and less supervision.
2. Rapid increase in anthropogenic, and mostly technogenic, load on nature, leading to ecosystem structure malfunction.
3. Accumulation of negative changes in nature, leading in the end to ecosystem processes that are difficult to reverse or are irreversible.
4. Degree to which ecosystems possess a self-predisposition to changes, degradation, or destruction.

One of the most significant ecological risk factors is the extraction of unconsolidated sediments (especially sand and detritus) from the seacoast and submerged slope for construction or other purposes. For example, at the “Dolgaya” Spit in the eastern part of the Sea of Azov, about 1 million tons of sand and detritus were excavated during 1966-1975. It led to the destruction of the whole “Dolgaya” Spit and its transformation into a chain of separated islands.

The rate of risk is not equal for various natural systems but depends on system characteristics and external impact. In general, the less mass and energy exchange inside the system, the greater the risk that rates will be high.

However, we must take into account that the resistance of ecological systems is not equal with respect to different impacts. So, an abrasion-accumulation system is relatively resistant to sand excavations from the beach, but it can rapidly be destroyed after coastal defense constructions are built. Generally, when a load of one type exceeds the resistance level, natural system evolution is transformed into a rapid degradation.

Methodology of coastal risk assessment

The anticipated damage along specific coastal segments depends not only upon the value of property, both economic and cultural, in the zones subject to erosion, shoreline retreat, or underground flooding, but also upon the natural peculiarities of the environment. Other conditions being equal, the more sensitive landscapes will incur greater damage. All these facts make vulnerability assessments from sea-level rise at any particular coastal segment extremely complicated but important objectives. The research group at the Geography Faculty, Laboratory for Recent Sediments and Pleistocene Paleogeography, under the leadership of Professor Pavel Kaplin and Andrei Selivanov, put forward an integrated methodology for assessment of coastal vulnerability to potential future sea-level rise (Kaplin et al., 1993). They have concentrated on the assessment of environmental vulnerability to sea-level rise, as well as on the estimation of indirect economic losses. The concept of various types of resources (environmental, economic, and cultural) has been applied for these studies.

Direct consequences of shoreline retreat owing to sea-level rise include the loss of existing property and damage to natural and cultural resources. Under these assumptions, an economic loss estimate for any coastal segment can be expressed as a sum of property value, and the value of natural and cultural resources in the endangered zone subject to shoreline retreat, temporary inundation, or underground flooding. Total risk values can be expressed as the product of the specific value in a certain risk zone and the probability of a flooding event, the risk values being summed up over the risk zone.

However, this approach requires data on various parameters of property and natural and cultural resources. When carrying out preliminary small- and middle-scale studies, especially in developing or undeveloped coastal areas, one commonly realizes the dramatic lack of knowledge of these parameters. Moreover, even if these parameters are available, a routine summing up of property values and resource cost estimates becomes necessary. Therefore, another approach based on existing and easily obtained integrated characteristics of economy and the environment is urgently needed.

A rational methodology should allow for resource values and for natural vulnerability of coastal segments. Therefore, the general integrated expression for vulnerability, A, in a specific coastal segment under the possibility of accelerated sea-level rise takes the following form:

$$A = V \Sigma Rn, \qquad (1)$$

where V = the natural vulnerability index, and ΣRn = the sum of all resource values Rn, including various kinds of natural, economic, and cultural resources.

Practical use

The coastline of the Sea of Azov within the borders of Russia is 560 km in length and represents one of the most vulnerable areas to the possible rise in global mean sea level. Major impact threats from a dramatic sea-level rise on these coasts include: (1) the prevalence of land subsidence and, therefore, higher regional estimates for relative sea-level rise compared to the globally averaged values; (2) an intensive retreat of the prevailingly loessic coastal scarps, substantially aggravated by landslide processes, and degradation of depositional coastal bodies composed presumably of detrital sands; (3) high economic development of coastal zones with intensive crop- and fruit-growing on rich black earth soils, as well as cultivation of white beet, corn, and sunflower, and food industries, including fish processing, and light industry as principal economic strategies; and (4) relatively high sensitivity of natural steppe and meadow ecosystems and even higher sensitivity of anthropogenic ecosystems to soil moisture content and, therefore, to possible underground flooding. Sand extraction from beaches and other depositional coastal bodies contributes substantially to increasing coastal vulnerability. An assessment of environmental and economic losses for the Russian coasts of the Sea of Azov has been implemented for a scenario in which the rise in global mean sea level reaches 1.0 m by 2100 (Fig. 1).

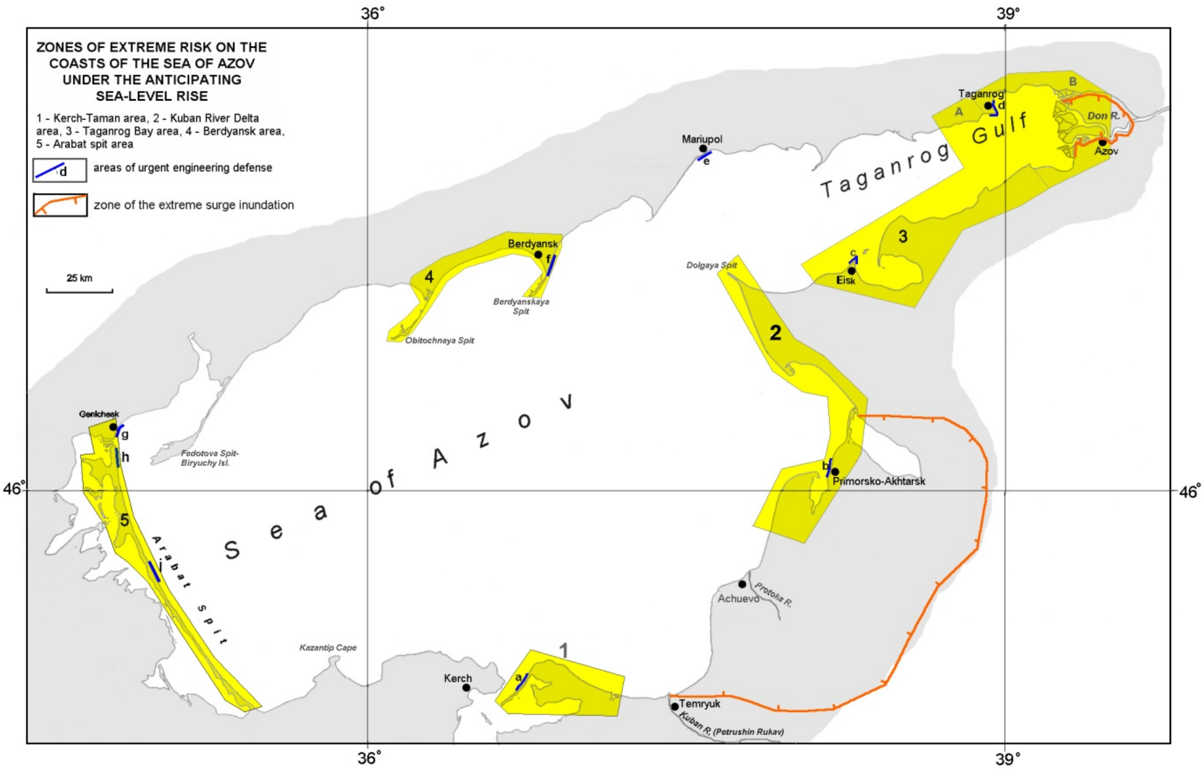

Figure 1. Anticipated morphological changes to the coasts of the northern Black Sea and the Sea of Azov under a possible 1-meter rise in global mean sea level by 2100.

The map of morphological vulnerability for the whole Sea of Azov compiled by Kaplin and Selivanov formed the basis for this analysis. Erosion and destruction of coastal depositional bodies—namely liman barriers on the northwestern Black Sea coast, tombolos and spits in the Sea of Azov—should be anticipated as major processes under conditions of future sea-level rise. One can expect partial destruction of most of these depositional bodies, whereas the "Dolgaya" Spit and some other features in the Sea of Azov may totally disappear during the next decades. The Kuban River delta, Perekop Isthmus, and some other regions would represent a catastrophic inundation potential given intensive tectonic subsidence.

Coastal evolution under possible sea-level rise would have unfavorable impacts on the economy of coastal communities. The effects would be most severe for urban, recreational, and infrastructure development on erosional and landsliding coasts, as well as depositional barriers and spits. Railways, highways, seaports, and fish-processing facilities on liman barriers, fish breeding and freshwater storage in limans, and rice cultivation in deltas would be the primary victims of sea-level rise. Existing coastal protective structures, represented primarily by sea walls, revetments, groins, rarely by boulder levees, would become ineffective.

Conclusions

Possible global greenhouse-induced sea-level rise would inevitably bring substantial losses from shoreline retreat, underground flooding, and other concomitant processes. Indirect consequences of sea-level rise may bring greater damage than direct ones. Vulnerability of the specific coastal segments depends not only upon the value of property, both economic and cultural, in the zones subject to shoreline retreat or underground flooding, but also upon the natural peculiarities of the environment. Other conditions being equal, the more sensitive landscapes will suffer the greater damage. All these facts make the assessment of environmental and economic losses from sea-level rise at a specific coastal segment an extremely complicated but important objective. Our integrated methodology for such an assessment is based on the concept of various types of resources (environmental, economic, and cultural) and probabilistic predictions of shoreline retreat for different morphological types of seacoasts.

This methodology allows for per unit area resource values and for natural vulnerability of coastal segments. The value of economic resources at risk consists of national wealth, national income, and compensation costs. A graded scale is usually constructed for each type of resource and for natural vulnerability. In small-scale surveys, a per unit area population number and value of economic production may be used as integrated indices of economic resources.

The proposed approach to the assessment of environmental and economic losses in coastal zones under possible future sea-level rise is promising in the site-specific economic comparison of various response strategies, i.e., retreat, accommodation, and protection.

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GENERAL TECTONIC/GEOLOGIC FRAMEWORK OF THE CASPIAN SEA AND ITS WATER CONNECTION WITH THE BLACK SEA AND MEDITERRANEAN

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Keywords: Endorheic basin, Manych-Kerch spillway, Paratethys, glacial-deglacial cycles

The Eastern Mediterranean and the Middle East presently make up the southern boundary of the Tethys Ocean for the last 200 Ma with the disintegration of the Pangaea and closure of the Tethys Ocean. Included in this area the following structures: the Hellenic and Cyprus arcs, the Eastern Anatolian Fault Zone, the Bitlis Suture Zone and the Zagros Mountains. The northern boundary of the Tethys Ocean is made up of the Black Sea and the Caspian Sea (Pontides, Caucasus, and Alburz), and it extends up the Po valley to the west. Between these two zones, the Alp-Himalayan orogenic belt is situated, where the Balkan, Anatolian, and the Iranian plateaus represent the remnants of the lost Ocean of the Tethys.

The Caspian Sea and the Black Sea were part of the Mesozoic chain of back-arc basins stretching over a distance of 3,000 km, and this area also included the Carpathian basin in central Europe and the Vallesian trough in Switzerland. This chain was located between the continental margins of Eurasia to the north, and Mesozoic-Paleocene basin was the south of the island-arc system. These basins were formed during three separate tectonic episodes occurring during Middle Jurassic, Late Jurassic, and Late Cretaceous times.

From the Middle Jurassic to the Early Cretaceous, extension occurred along the Pontic-Trans-Caucasus arc, resulting in rifting and the formation of the early Black Sea and South Caspian basins. To the east, the rate of spreading was more rapid and resulted in the development of the oceanic basin, the remnants of which now form the south Caspian Sea basin. The combined Caspian Sea-Black Sea paleobasin reached its maximum extent during the Paleocene, occupying an area 900 km wide and 3,000 km long.

The Caspian Sea is the largest enclosed inland body of water on Earth by area, variously classed as the world's largest lake or a full-fledged sea. The sea has a surface area of 371,000 km^2 (not including the Karabogazgцl Embayment) and a volume of 78,200 km^3. It is in an endorheic basin (lacking outflow) located between Europe and Asia. It is bounded to the northeast by Kazakhstan, to the northwest by Russia, to the west by Azerbaijan, to the south by Iran, and to the southeast by Turkmenistan. The Caspian Sea lies to the east of the Caucasus Mountains and to the west of the vast steppe of Central Asia. Its northern part, the Caspian Depression, is one of the lowest points on earth.

The Caspian Sea, like the Aral Sea, Black Sea, and Lake Urmia, is a remnant of the ancient Paratethys Sea. It became landlocked about 5.5 million years ago due to tectonic uplift and a fall in sea level. During warm and dry climatic periods, the landlocked sea almost dried up, depositing evaporitic sediments like halite that were covered by wind-blown deposits and were sealed off as an evaporite sink when cool, wet climates refilled the basin. Due to the current inflow of fresh water, the Caspian Sea is a freshwater lake in its northern portions. It is more saline on the Iranian shore, where the catchment basin contributes little flow. Currently, the mean salinity of the Caspian is one third that of the Earth's oceans. The Karabogazgцl embayment, which dried up when water flow from the main body of the

Caspian was blocked in the 1980s but has since been restored, routinely exceeds oceanic salinity by a factor of 10.

The Manych-Kerch Spillway is a large trough, deeply eroded into solid rock, which connected the Caspian and Black seas. It was inherited from an older strait between the two seas, which existed (with interruptions) since the Late Pliocene Akchagylian (White Waterfall) basin. The total length of the spillway amounted to 950-1000 km (depending on the location of sea level), with maximum and minimum widths of 50-55 and 10 km, respectively. Its depth attained 30-50 m.

Although the rise of the sea after the last glaciation took about 15,000 years, the change would nevertheless have been perceived as a continuous retreat of the shoreline and loss of land which was quite noticeable even within one generation. These matters were more devestating for the marginal seas such as the Black Sea and the Caspian Sea as well as the Sea of Marmara because the fall of sea level was much more than in the open ocean waters. Given the fertility of coastal plains, both for the terrestrial fauna on grasslands and resources in marshes, deltas, and wetlands, the continuous loss of such land must have been an unfortunate aspect of life in the Late Paleolithic and Mesolithic periods. However, it should be noted that a rising sea level would occasionally inundate an area of low gradient such as the North Caspian seafloor, creating massively extensive new marshlands and new environments which could support adapting coastal and aquatic life styles. Populations certainly moved and adapted in response to such changes of climate and sea level, and there is a need for significant further research to track these movements. In order to understand where people could live and hunt or forage in the Caspian area at different dates and different stages of the glacial-deglacial cycles, we need to analyze the details of sea-level change and ice cap limits through time.

We cannot understand the whole story by studying only the present dry land record and ignoring the submerged seabed of the continental shelf and vice-versa. Did the fluctuating climate zones and migrating coatlines and river valleys influence where people lived? Did the falling and rising sea level create cultural experiences and responses that are still felt and had an impact in the historic world of writing and oral history.

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THE EVOLUTION OF THE AKCHAGYLIAN SEA AREA AND COASTLINE BASED UPON MATHEMATICAL MODELING

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Keywords: Caspian Sea transgressions, paleoreconstruction

One of the mysterious phenomena of the Pliocene was the formation of the Akchagylian Sea-Lake in the time interval from 3.3 to 1.8 million years ago. The formation of this widespread sea-lake had the nature of a Caspian Sea transgression. The maximum Akchagylian Sea-Lake area was 969,900 km^2, which was established through geologic studies (Svitoch, 2014).

The mystery of the Akchagylian transgression of the Caspian Sea is the fact that different groups of scientists, based on the results of geologic studies, have concluded differently concerning its level, climatic conditions determining the values of the level fluctuations, and other characteristics. As for the question of the source of the water needed for the transgression of the sea-lake, as well as to compensate for evaporation, there is no clear answer to this question. Generalizations of the results of geologic research are presented in several monographs (Svitoch and Yanina, 1997; Yanina, 2012; Svitoch, 2014).

We think that the mechanism of formation for the Akchagylian Sea-Lake was the same as the mechanism that created the vast seas of the Paratethys (Esin et al., 2016), such as the Sarmatian Sea-Lake. Such seas that existed for a geologically short time were created by water flowing into the Black Sea-Caspian depression from melting glaciers. In a period when there was a bridge between the Black and the Mediterranean seas in the form of a mountain range, the inflow of glacier water significantly increased the levels of the Black and Caspian seas, upon which the water space closed up and formed the vast Paratethys seas. Periodically, excess water left to join the Mediterranean Sea, forming and eroding a drainage channel. Between the glacier malting periods, the level of the Paratethys seas dropped as a result of evaporation. In Akchagylian time, the channels of the Bosporus and Dardanelles were already formed, and they conveyed excess water from the Black Sea into the Mediterranean Sea. Thus, the Black Sea was connected with the Mediterranean Sea at that time, and the Black Sea level depended on the level of the World Ocean. The Caspian Sea, at its highest level above the Manych depression, also had an outflow into the Black Sea, but when its height was lower than the Manych depression, it was a closed lake. Thus, in the late Pliocene–Pleistocene, the changing levels of these seas operated according to different systems, as if they were not related to each other. Apparently, for this reason, the Caspian transgressions are grouped within a separate type (Svitoch, 2014). The transgressions of the Caspian Sea were caused by the flow of glacial waters, and regressions were caused by drying after the melting of the glacier.

We have estimated the volume of water necessary to compensate for evaporation volume in the Akchagylian Sea-Lake. Under current conditions, the intensity of evaporation from the Caspian Sea surface is about $10.8 \cdot 10^{-4}$ km/year (Zaikov, 1946), i.e., 371,000 $km^2 \cdot 10.8 \cdot 10^{-4}$ km/year = 400 km^3/year of water evaporates from the surface of Caspian Sea. According to mathematical modeling (Kislov and Toropov, 2006; Toropov, 2006), in the period of glacial maximum, the amount of evaporation from the sea surface was 20-30% less than at present. We assume that during the melting of glaciers, the intensity of evaporation from the surface of the Caspian Sea was 15% below the current rate, and amounted to $9.2 \cdot 10^{-4}$ km/year. Calculations show that the amount of evaporation from the Akchagylian Sea-Lake area was 892 km^3/year. This amount is approximately equal to the volume flow of four rivers the size of the Volga. Based on calculations, and with current relief conditions, the maximum level of Akchagylian Sea-Lake would be equal to +65 m above the present ocean level. Results of studies (Taner, 1982) show that Akchagylian fauna were found in the Dardanelles and the Eastern Mediterranean; the fauna do not fit into the schema of transgressions accepted by various scientists, but our proposed hydrological processes in the Caspian-Black Sea region are confirmed. At its maximum sea-lake level of about +65 meters, there was flow of water into the Black Sea, and fauna went together with the water into the Black Sea. From the Black Sea, the fauna followed into the Mediterranean Sea through the Bosporus and Dardanelles which already existed.

Thus, the source of water for the Akchagylian Sea-Lake was the melting glacier. During the period of the most intensive glacial melting, the sea-lake level reached about +65 m, the area of the sea-lake was approximately 970,000 km^2, and in this case, the volume of incoming water balanced the loss from evaporation and outflow into the Black Sea. When the glacier melted, the sea-lake area began to decrease as a result of evaporation.

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LATE NEOGENE SEDIMENTS, PETROGRAPHY, FACIES, AND DEPOSITIONAL ENVIRONMENTS, SOUTH KAKHETI, GEORGIA

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Keywords: South Kakheti, sandstone, conglomerate, facies, bedding

Introduction

The research area is located within the Kura basin, precisely at the southeastern part of a foreland basin, running along a NW-SE line from the Black Sea to the Caspian Sea; it has developed between two orogenic systems: the Greater Caucasus and the Lesser Caucasus, advancing towards each other (Adamia et al., 2010; Nemčok et al., 2013). Our main goal was to study the sedimentary rocks developed within the limits of the research area and carry out sedimentological research.

Materials and methods

During the geological fieldwork, around 150 outcrops were targeted and sedimentological measurements were made; 100 samples of sedimentary rock were taken. Sediment transport measurements were made based on pebble imbrications, cross beddings, and flute casts. The sedimentological measurement data were visualized graphically and completed with dip direction and bedding dip, and also stratigraphic position of strata.

Geological study of the region based on existing literature

Geological work within the region started at the beginning of the XXth century; it became particularly active in the early 1940s and was linked to oil exploration activities, because oil-bearing areas and sequences were located within the region.

Paleogene-Neogene sedimentary rock complexes are developed within the limits of the region, particularly within the XII block. From this entire complex, there are widespread Late Miocene-Pliocene freshwater continental sediments, which are commonly developed within all major synclinal depressions of Kartli and Gare-Kakheti (Buleishvili, 1960).

Miocene-Pliocene continental sediments are mainly represented by a series of conglomerates (Djanelidze, 1949), which originated from the Sarmatian to Akchagylian by continuous sedimentation processes. The above noted conglomerate to the southeast of the Sagarejo-Kakabeti area is gradually changing due to the continental freshwater sediments of the Shiraki suite. These sediments are widespread in the South Kakheti region. Especially good outcrops are in the south along the Iori River banks and in the north near Mirzaani. In the north zone, numerous oil seeps are linked to these sediments, which is of great interest to researchers.

Research data

Within the region, sedimentological research was conducted in the Taribani, Mirzaani, Patra Shiraki, and Dedoplistskaro districts of the XII block. Here, we'll provide our research data on the Taribani and M. Kvabebi areas, which are mainly built by Miocene-Pliocene Shiraki suite and Akchagylian sediments. The Shiraki suite, which is conformably continued with the Upper Sarmatian, is divided into three lithological facies (Buleishvili, 1960; Chubinishvili, 1982):

1. Silty shale facies—lower part of the Shiraqi suite;
2. Conglomerate facies—upper part of the Shiraqi suite in the northern zone;

3. Sandy-shale facies, which characterizes the Shiraqi suite in the southern part of the region.

According to the regularity in distribution of the lithological facies here, three zones are marked out: the northern, the central, and the southern zones. In the Taribani area, the northern and central zones occur, that is, the lower part of the Shiraqi suite represented by shaly-sandy lithofacies, and the upper part is represented by conglomerate and sandy-shaly lithofacies.

The Shiraki suite in the South Kakheti region comformably continues late Sarmatian sediments and is covered transgressively by Akchagylian sediments.

Akchagilian sediments are met only in the Gare Kakheti trough of the Alazani depression and within the Tsiv-Gombori mountain range. They transgressively cover older rocks, ranging from the Cretaceous and including Shiraki suite sediments (Mrevlishvili, 1997). These sediments in the study area are represented by two continental and marine facies. Continental sediments are widespread to the south of the northern zone of the South Kakheti, to the north of the Mlashis-khevi-Mirzaani fault, and also at Kakheti ridge. To the south of the above fault, continental sediments are gradually changed by marine formations (left bank of the Iori River) and are characterized by Akchagylian-rich fauna.

Akchagylian marine sediments are represented by loose, gray sandstones, which are mainly coarse grained. The thickness of separate layers amounts to 0.5-5 m, and sand packs—10-20 m. Dividing shaly layers are generally bluish and bluish-grey, sometimes light grey. Shales are enriched by shells of poorly preserved Akchagylian marine fauna and also numerous plant remains.

There is a good cross-section of marine Akchagylian sediments in outcrops on the left bank of the Iori River, at the foot of Kvabebi mount, where the succession is represented by the following sediments: Sandy-shaly sediments with rich mollusk fauna—15 m; bluish-grey carbonate marl shales and silts, sometimes with gypsum veins and thin siderite lenses/layers. In the upper part of the pack, two thin layers of volcanic ash are defined. The sediments contain mollusk and ostracod fauna. Here, in the upper part of the pack, remains of mammals and birds are found—190 m.

In the upper part of the cross-section, sandstones increase. Gravelite and fine-pebbled conglomerate appear. Mollusk fauna are defined—80 m.

The cross-section of Akchagylian sediments is finished by poorly sorted thick conglomerate with sandstone interlayers and lenses. This pack doesn't contain any fauna and is conventionally dated as Akchagylian. Some researchers believe (Mrevlishvili, 1997) it might contain the lower part of the Apsheronian sediments.

Towards the west, the lithology of Akchagylian sediments changes, material becomes coarse, and marine fauna disappear. The marine facies of the above sediments to the north, northwest, and south changes laterally by continental conglomerates of the Alazani suite.

Results

Based on our sedimentological research within the Taribani area, and precisely at the Kvabebi mount, sediment transport vectors derived from pebble imbrication, cross bedding, and partly from flute casts were large for the Akchagylian-Apsheronian. Meotian-Pontian and Akchagylian-Apsheronian vector patterns have an almost similar character.

According to statistical calculations, in the Taribani area, pebble imbrication based transport vectors show directions to the south, and NNE to SSW; in the Kvabebi area, NNW to SSE and NNE to SSW. And, according to bedding structures in the Taribani region, cross-, diagonal-, and wavy bedding occur. The occurrence of cross bedding indicates sediment formation in a depositional environment of progressive currents. And the capacity of the series depends on current velocity. Depending on depositional environment, signs of cross beds and cross bedded series differ in details that are conditioned by individual (local) pecularities of the depositional environment. The trend of laminas in adjacent series shows the extent of the persistence of current direction. More persistent currents form unidirectional cross bedding, characteristic of continental and also some marine currents. Variance in series and different directions of laminas in the upper and lower series shows the current direction variation time.

To the northwestern direction, Akchagylian sediments are spread until the Tbilisi area, where they lie transgressively over various horizons of Miocene and Paleogene sediments. Within the Kartli depression, Akchagylian sediments do not occur.

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GEOLOGICAL STRUCTURE OF GEORGIA AND GEODYNAMIC EVOLUTION OF THE CAUCASUS

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Key words: stratigraphy, tectonic structure, paleotectonic reconstruction

Introduction

The territory of Georgia is a component of the Caucasian segment of the Mediterranean (Alpine-Himalayan) collisional orogenic belt (Fig. 1).

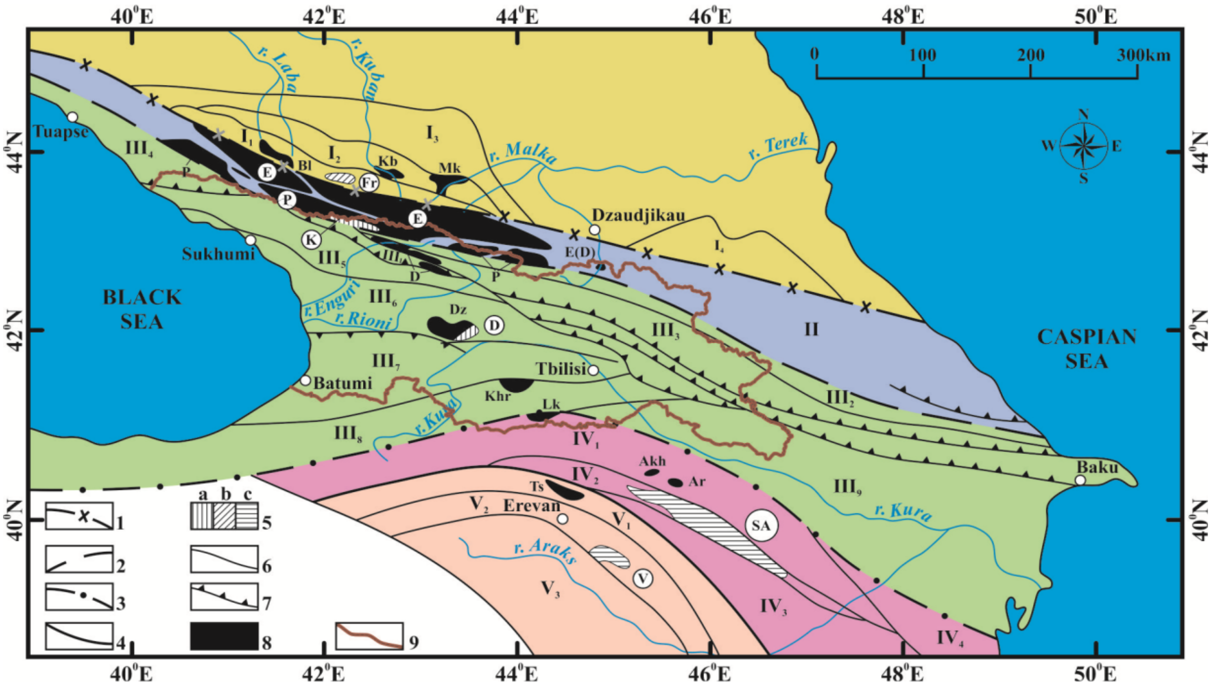

Figure 1. Tectonic subdivision of the Caucasus on the basis of terrane analysis and exposures of the pre-Alpine crystalline basement (Gamkrelidze, 1997a; Gamkrelidze and Shengelia, 2005). Key: I = Part of Scythian platform involved in Neogene time into rising of the Greater Caucasus); I_1 = Forerange zone, I_2 = Laba-Malka (Bechasin) zone, I_3 = zone of North Cauasian monocline, I_4 = Daghestan Limestone zone. Accretionary terranes and subterranes: II = Greater Caucasian terrane; III = Black Sea-Central Transcaucasian terrane. Subterranes: III_1 = Chkalta-Laila, III_2 = Kazbegi-Tphan, III_3 = Mestia-Dibrar, III_4 = Novorosiisk-Lasarevskoe, III_5 = Gagra-Java, III_6 = Dzirula (Georgian Block), III_7 = Adjara-Trialeti, III_8 = Artvin-Bolnisi, III_9 = Middle and Lower Kura; IV = Baiburt-Sevanian terrane. Subterranes: IV_1 = Somkhito- Karabakh, IV_2 = Sevan-Akera, IV_3 = Kafan, IV_4 = Talysh; V = Iran-Afghanian terrane. Subterranes: V_1 = Miskhan-Zangezur, V_2 = Erevan-Ordubad, V_3 = Araks. 1 = borders of terranes-ophiolite sutures (here and there presumable) marking the location of small and large oceanic basins: 1 = of Early?-Middle Paleozoic age, 2 = of Neoproterozoic-Paleozoic age, 3 = of Neoproterozoic-Early Mesozoic age, 4 = of Mesozoic age; 5 = ophiolite terranes (obducted plates): 5_a = of Neoproterozoic-Paleozoic age 5_b = of Paleozoic age, 5_c = of Mesozoic age; 6 = borders of subterranes (deep faults or regional thrusts); 7 = detached cover nappes of Alpine age; 8 = exposures of pre-Alpine crystalline basement: GC = Greater Caucasian, D = Dizi series of the southern slope of the Greater Caucasus, Dz = Dzirula, Khr = Khrami, Lk = Loki, Akh = Akhum, Ar = Asrikchai, Ts = Tsakhkunyats; 9 = boundary of the territory of Georgia.

Stratigraphy and rock types of the different tectonic units of Georgia

So long as the degree of metamorphism, lithological character of the sedimentary rocks, and composition of submarine volcanites are quite different within the different tectonic zones of Georgia, the stratigraphic units are considered to be within separate tectonic zones (Gamkrelidze, 1997b; Gudjabidze, 2003).

The pre-Alpine metamorphic complexes outcrop within the Greater Caucasus (Main Range and southern slope zones), in the Black Sea Central Transcaucasian terrane (Dzirula and Khrami massifs), and within the Baiburt-Sevanian terrane (Loki massif) (see Fig. 1).

The oldest (Precambrian and Lower-Middle Paleozoic) rocks are exposed in all the tectonic units (Fig. 1). They are represented by gneisses, migmatites, crystalline schists, and amphibolites within the Main Range zone of the fold system of the Greater Caucasus, the Georgian Block (in the so-called Dzirula Massif), and the fold system of the Lesser Caucasus (in the so-called Khrami and Loki massifs) (Gamkrelidze and Shengelia, 2005). Paleozoic rocks are exposed in the central part of the southern slope of the Greater Caucasus as well. They are represented mainly by black shales, phthanites (cherts), sandstones, turbidites, olistostromes, lenses of marbles and calc-alkaline andesite-dacitic volcanoclastics. Their visible thickness reaches 2000 m. This is the so-called Dizi Series, in which faunally (by corals, foraminifera, and conodonts) the Devonian, Carboniferous, and Permian are established. Comparatively weakly metamorphosed Paleozoic sediments are exposed in the Dzirula Massif as well. These are the allochthonous plates of the so-called 'phyllitic suite', which are in contact with Upper-Paleozoic granitoids and Paleozoic and Precambrian gabbro-amphibolites and serpentinites. The latter are meta-ophiolites (Gamkrelidze et al., 1981). Precambrian and Paleozoic meta-ophiolites within the crystalline core of the Greater Caucasus and in Somkhito-Karabakh zone (in the Loki massif) are present as well.

The Upper Paleozoic rocks are also developed in all tectonic units. In the Main Range zone, crystalline rocks are overlain by weakly metamorphosed sandstones, conglomerates, and argillites, which contain Upper Carboniferous-Lower Permian marine fauna (marine molasse).

Continental and coastal calc-alkaline rhyolitic volcanic rocks and coal-bearing argillites with lenses of reef limestone are known in the Dzirula and Khrami massifs. Lower-Middle Carboniferous corals, brachiopods, foraminifers, and terrestrial flora have been found in this formation in the Khrami massif.

Mesozoic and Cenozoic formations are developed in all tectonic units of Georgia (Gamkrelidze, 1997b; Gudjabidze, 2003).

Triassic sediments are observed in the Dizi Series apart from the above-mentioned Upper Paleozoic deposits. To the Triassic also belong dacitic-rhyolitic volcanics, quartz sandstones, and siltstones with variable thickness (80-500 m), which crop out in the Dzirula massif and contain flora of Triassic age.

Lower Jurassic-Aalenian sediments that everywhere rest transgressively are spread throughout all tectonic units of Georgia.

In the fold system of the Greater Caucasus, these deposits are more than 5000 m in thickness and are represented by black shales, sandstone turbidites, rhyolitic (in the lower part) and tholeiite-basaltic (in the upper part) lavas, and their pyroclastics.

In the Georgian Block, Lower Jurassic sediments (80-90 m thick) crop out only along the edges of the Dzirula massif and are represented by arkosic sandstones, gravelstones, conglomerates, clays, and red zoogenic limestones containing rich marine fauna (Ammonitico Rosso facies).

In the southern parts of the Khrami and Loki massifs, the Lower Jurassic consists mainly of terrigenous deposits (120-600 m thick).

In the central part of the fold system of the Greater Caucasus, the Bajocian stage is represented by sandstone-siltstone flysch, shales and marls, and elsewhere by a thick (3500 m) volcanogenic series, which contains marine fauna and consists mainly of calc-alkaline basaltic, andesite-basaltic, and andesite-dacitic lavas and pyroclastics. Tephroturbidites, sandstones, and conglomerates are rather scarce.

The Bathonian Stage in the fold system of the Greater Caucasus is represented by sandstone-siltstone flysch, and by regressive coal-bearing terrigenous deposits (65-200 m) on its southern slope (in the Gagra-Java zone).

In the central and eastern parts of the southern slope of the Greater Caucasus (Mestia-Tianeti zone), the Upper Jurassic sediments which follow conformably the Middle Jurassic slates consist mainly of clastic limestone flysch (1100-1500 m). On the rest of the territory, they lie transgressively and discordantly.

In the western and eastern parts of the Gagra-Java zone, an upper Jurassic marine facies is present. In the lower part, it is represented by sandstones and clays (120-200 m), and in its upper part by reef limestones (400-900 m). A rich marine fauna (ammonites, corals, etc.) is found in these sediments. To the south and within the Georgian Block, gypsum-bearing lagoonal-continental terrigenous (Kimmeridgian-Tithonian) deposits and to a lesser extent alkaline basalts, trachytes, and pyroclastics are present.

Upper Jurassic shallow-water limestones and marls, alternating with calc-alkaline basalt-andesite-dacite volcanics, are exposed at the western edge of the Khrami massif and in the Somkito-Karabakh zone also.

There is a variety of Cretaceous deposits in Georgia. Within the Greater Caucasus fold system (in the Mestia-Tianeti flysch zone), the Lower Cretaceous is developed in the form of clastic limestone and sandstone siltstone flysch (750-1600 m), which conformably follows the Upper Jurassic flysch. In the south and within the Georgian Block, the old formation, including crystalline rocks of the Dzirula massif, is overlain transgressively by Lower Cretaceous rocks (300-550 m). In the main, limestones are developed within this area. Only in the middle of the section appear marls and clays (Albian Stage) and glauconitic sandstones (Cenomanian Stage). Reef limestones of Urgonian facies (Barrenian Stage) and ammonitic limestones (Aptian Stage) are distinguished in the Lower Cretaceous.

In the Upper Cretaceous sediments of the Mestia-Trileti Flysch zone, sandstone-siltstone (in the lower part) and clastic limestone (in the upper part) flysch (500-900 m) prevail. Within the Gagra-Djava zone and Georgian Block, they are spread mainly as shallow-water limestones, marls, and glauconitic sandstones (250-1200 m), whereas to the west in the Dzirula massif, an alkali basalt-phonolitic series (70-300 m) occurs locally.

In the Adjara-Trialeti zone, the Upper Cretaceous is represented by a volcanogenic suite with calc-alkaline basaltic composition, which in the lower part also contains the Albian Stage. Stratigraphically higher, upper Turonian-Senonian limestones and marls (300-1200 m) follow.

In the Arthvin-Bolsini Block and Lock-Karabach zone, transgressive upper Cretaceous sediments are present, which subdivide into three parts. A Cenomanian volcanogenic-carbonate series (900-1200 m) overlaps directly the Khrami and Loki massifs and Jurassic rocks. Ascending the section, there follows a basalt-andesite-dacite-rhyolite series (1100-3300 m) of Turonian-Santonian age. The uppermost part (Campanian-Maastrichtian) is represented by shallow-water limestones and marls with interlayers of acidic tuffs (300-350 m).

Paleogene deposits are found in all tectonic units. In the southern slope of the Greater Caucasus, the Paleocene-Eocene is represented by sandstone-siltstone flysch (600-850 m). In the southern part, the Upper Eocene is built up of olistostromes (10-400 m).

In the Georgian Block, the Paleocene and Eocene consist of an alternation of limestones and marls (30-400 m). In the middle part of the Lirolepis horizon, a horizon of marls is distinguished, which begins the Upper Eocene.

In the Adjara-Trialeti zone, the Danian is built up of limestones and marls, whereas the transgressive Paleocene-Lower Eocene consists of sandstone-siltstone and clastic limestone flysch (Borjomi flysch), the thickness of which increases from west to east (1500-3000 m). These are followed by a very thick Middle Eocene volcanogenic suite, which in the western part of the zone is represented by tholeiitic and shoshonitic, mainly basaltic, submarine volcanics and tephro-turbidites, whereas in the eastern part there are calc-alkaline and tholeiitic, mainly andesitic rocks, olistostromes, and tephro- and sandstone-siltstone turbidites. Its thickness increases from east to west (1000-5000 m). In the Artvin-Bolnisi zone and the Somkhito-Karabakh zone, a Middle Eocene volcanogenic suite is built up of calc-alkaline basalt-andesite-dacite-rhyolite volcanics (1200-2700 m) and transgressively overlaps Cretaceous and Jurassic rocks and the Loki Crystalline Massif.

In the Adjara-Trialeti zone, the Upper Eocene is distinctly transgressive and consists of marls, clays, sandstones, and gravelstones (500-1500 m), whereas in the western part of the zone, it consists of andesitic-basaltic volcanoclastics (1000 m).

Oligocene deposits (mainly the Maikop Series) are generally represented by thin-bedded gypsiferous clays, which contain fish scales and sandstones. This series continues in the lower part of the Miocene, too. It outcrops in the Gagra-Djava zone, in the Georgian and Artwin-Bolnisi blocks, and in part of the Adjara-Trialeti zone. Its thickness is rather variable (250-3000 m).

Neogene formations are present only in molasse depressions. The Lower Miocene, as was mentioned, belongs to the Maikop Series. Further up the section, the Miocene is represented in the lower part (Middle Miocene-Middle Sarmatian) by marine molasse (clays, sandstones, conglomerates, limestones, and marls), and in the upper part (upper Sarmatian-Pliocene) by marine and continental molasse (conglomerates, sandstones, sands, and clays). There are very distinct unconformities at the bases of the Miocene, Meotian Stage, and Upper Pliocene.

In the Artvin-Bolnisi zone and Somkhito-Karabakh zone, and partially in the southern part of the Adjara-Trialeti zone, the Neogene is represented by subaerial calc-alkaline andesites, andesite-dacites and dolerites. Their upper part includes the Pleistocene and Quaternary, too. In the lower part (Upper Miocene-Lower Pliocene) subaerial volcanics contain a rich terrestrial flora, and in the Upper Pleistocene there are mammalian fauna.

Quaternary deposits are distributed very irregularly. These consist of river terraces, moraines of three glaciation periods, and a volcanic formation in the form of volcanic cones and lava flows (in the Greater Caucasus, to the south of Kazbegi, and on the Trialeti Range in the Borjomi region). There are also vast accumulation plains in intermontane areas.

Tectonic structure

The territory of Georgia, as a part of the Caucasus, underwent a long and complicated tectonic evolution and contains structures of various types, scales and genesis (Gamkrelidze et al., 2013)

Tectonic structures of the pre-Alpine basement are characterized by the existence of several deep-seated nappes including obducted ophiolites (Gamkrelidze and Shengelia, 2005).

Alpine structures have a different character in the various tectonic zones. The northeastern tectonic unit of Georgia, the fold system of the Greater Caucasus, is characterized by a distinctly expressed asymmetry in its structure: southward verging, often isoclinal folding on the southern slope and quiet, poorly folded, or monoclinal structures on the northern slope. Large, southward-directed nappes are developed also on its southern slope (Gamkrelidze, 1991). The above-mentioned structures provide evidence of the leading role of late Alpine underthrusting of the comparatively rigid Georgian Block under the Greater Caucasus during its deformation (intraplate subduction).

The northern boundary of the Georgian Block, in its western part, is formed by a deep fault, which in the sedimentary cover manifests itself as a regional flexure. Study of the structural peculiarities of the Georgian Block has shown that its central and western parts are characterized by a mosaic-block structure of the basement and occurrence of typical above-fault folds in the sedimentary cover. In the eastern area of subsidence of the Georgian Block, its cover is detached and shifted towards the south together with the nappes of the southern slope of the Greater Caucasus (Gamkrelidze, 1991).

The Adjara-Trialeti zone of the Lesser Caucasus, which is situated to the south of the Georgian Block is, on the whole, an anticlinorium and is characterized by block-fold structures. To the west from the Dzirula Massif along the northern margin of this zone, an overthrust nappe is developed.

The Artvini-Bolnisi zone consists of two different tectonic units: the Javakheti zone (in the west) and the Bolnisi zone (in the east). In the young (Neogene-Pleistocene) volcanic cover of the Javakheti zone, sublatitudinal gentle folds are observed. Two deep submeridional seismogenic faults are established which served as conduit channels for young volcanics. The Bolnisi zone includes the horst-like Khrami salient of pre-Alpine basement and the territory covered with Cretaceous and Paleogene volcanic rocks. Brachyanticlines and steep faults of various orientations are developed to the south in a sedimentary cover, which generally forms a gentle syncline.

The northeastern wedge of the Somkhito-Karabakh zone forms part of Georgia and is characterized by echelon-like disposition of internal anticlinoria. In the core of a sub-latitudinal Loki anticlinorium, the pre-Jurassic crystalline basement is exposed. The axis of this structure plunges in both western and eastern directions and causes periclinal closure of the sedimentary cover.

The fold and fault systems of the Adjara-Trialeti, Somkhito-Karabach, and the Artvini-Bolnisi zones were formed as a result of the manifestation of late Alpine (Neogene) tectonic movements with the displacement of masses from south to north (Gamkrelidze, 1991).

Geodynamic evolution of the Caucasus and paleotectonic reconstructions

The aforesaid data about geological structure, character of sedimentation and magmatism, geology, and the age of ophiolites, side by side with paleomagnetic data and global plate tectonic reconstructions (Stamfli and Borel, 2002) allow us to consider the main features of the geodymanic evolution of the Caucasus and adjacent areas (Gamkrelidze, 1986; Gamkrelidze and Shengelia, 2005).

As a result of horizontal displacements of the ancient East European and African platforms, as well as of certain lithospheric plates within the Mediterranean belt during the Precambrian-early Mesozoic, the generation and development of oceanic basins took place. In the present structure of the Earth's crust, these basins are marked by rocks of ophiolitic association.

The most ancient of these oceans, the Proto-Paleotethys, developed in the course of time from the Precambrian up to the Middle Jurassic. At this time, the Caucasian province was an active continental margin of Europe. The southern, Lesser Caucasus part of the Transcaucasus massif was located at the margin of the Paleotethys and belonged to the northern margin of the Iran-Afghanian plate (Gamkrelidze, 1986).

Side by side with the Proto-Paleotethys Ocean during the Neoproterozoic and Paleozoic, relatively small oceanic basins of the southern slope of the Greater Caucasus and the so-called Arkhis basin (between the Main and Fore Range zones of the Greater Caucasus) are developed.

In the rear of the gradually closing Paleotethys, the joining together of Iran and Arabia and the generation of Neotethys had been taking place already since the Triassic.

The next extension occurred during the early Jurassic and beginning of the Middle Jurassic. At the northern active margin of the Paleotethys, the Transcaucasus island arc and marginal sea of the Greater Caucasus can be discerned.

One can suppose that the Lesser Caucasus branch or bay of the Tethys was formed in the rear of the closure of the Paleotethys since the end of the Middle Jurassic.

The closure of the Neotethys Ocean, as well as of the Paleotethys relic basin, occurred as a result of movements which spread from north to south. In particular, only the northern part of the Caucasian segment of the Mediterranean belt was affected by the Bathonian (Adygean), Late Cimmerian (pre-Cretaceous), and Austrian (pre-late Cretaceous) movements. These epochs of tectonic activity are associated with the intense manifestation of andesitic volcanism and granitoid plutonism due to the processes of subduction on the continental margin of the oceanic basins (Gamkrelidze and Shengelia, 2005).

The movement of the Austrian phase closed the Lesser Caucasian branch of the Mesotethys. At that time, ophiolite nappes were formed in the Lesser Caucasus.

The subsidence that began in the Paleocene reached a maximum in the Eocene, especially in the Middle Eocene, and it was accompanied by calc-alkaline volcanic activity throughout the Lesser Caucasus. Northwards, this was substituted mostly by the basaltic sub-alkaline series of the Adjara-Trialeti rift.

The subsequent phases of Alpine tectogenesis caused the accumulation of molasse deposits, total compression, and final formation of the present-day structure of the Caucasus (Caputo et al., 2000).

The abundance of andesitic and andesite-dacitic volcanism, and granitoid plutonism in the orogenic stage can be related to the continuing activity of subduction zones (intraplate subduction).

At the same time, at the location of maximum compression of the Mediterranean belt caused by an active northward sub-meridional advance of the Arabian Plate, a vast transecting transverse set of extensional fissures developed which was responsible for the penetration of orogenic volcanism far into the continent, in a zone of Transcaucasian transverse uplift.

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THE LAST INTERGLACIAL VEGETATION PATTERNS ON THE NORTHERN MARGINS OF THE BLACK SEA

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Changes in vegetation composition of coeval phases of the Last Interglacial from west to east along the northern margins of the Black Sea are revealed on the basis of pollen study at sites located in the river basins of the Dniester (Neporotovo and Tovtry), Dnieper (Sazhavka and Dachne), and Siversky Donets (Kryva Luka and Novorayske), as well as in the Crimean Mountains (Kabazi II and Emine-Bair-Khosar). The correlation of phases in the vegetational evolution is supported by correlation of paleosol successions in the described sites. Pollen data from the Paleolithic site of Molodova I on the Dniester (Bolikhovskaya, 1982, 1995) was important for this study. The changes in vegetation of the higher and lower landforms are demonstrated for each area.

In Eastern Europe, the pre-temperate stage of the Last Interglacial is characterized by the vegetational succession *Picea-Betula-Pinus* (pollen zones M1-3: Grichuk, 1989). In the Middle Dniester area (the Chernivthsi region), *Picea* formed a significant admixture in the birch-pine forests of this stage, with a large increase in the spruce population in the lower landforms. The presence of *Pinus cembra* in the forests was characteristic, and plants of the Ericaceae family were most abundant on the plateaus. In the Middle Dnieper area, forests were replaced by a forest-steppe. *Betula pubescens* was rather abundant in wooded areas, and at the first phase of the interglacial, *Picea* grew sporadically in gullies. In the Siversky Donetsk area, plateaus were occupied by mesophytic steppe, *Pinus sylvestris* dominated in the vegetation of lower landforms, and *Picea* did not occur (Gerasimenko, 2000). The vegetation patterns demonstrate a decrease in humidity from west to east.

During the early-temperate stage of the Last Interglacial (pollen zones M3-4), a forest zone existed only in the Crimean Mountains and in the Middle Dniester area; this vegetation cover was replaced to the east by a forest-steppe. In the Dnieper and Donets river basins, forests consisted of *Quercus* and *Ulmus*, but near the Dniester and in Crimea, they had a notable admixture of *Carpinus*. In the high forest belt of the Crimean Mountains and on plateaus of the right bank of the Dniester, *Fagus* also appeared, and − what is of a particular interest − *Juglans* occurred sporadically in Crimea, the Dniester, and Donets areas during the thermoxeric optimum of the interglacial (pollen zone 4). The presence of *Juglans* might indicate that this warm-loving tree spread rather quickly from its southwestern and southeastern (the Caucasus) refugia and probably was preserved even in the southern coast of Crimea (Gerasimenko, 2005). This confirms the suggestion of a less harsh climate during the penultimate glaciation as compared with the last one, and of a warmer climate of the Last Interglacial than during the Holocene.

The *Corylus* spread (pollen zone M5) was most abundant on plateaus and high terraces of the right banks of the Dniester and Dnieper valleys, where oak forests were practically replaced by stands of hazelnut. In the west, plants of the Ericaceae family at this time occurred much less frequently. In the Donetsk area, other bushes (*Euonymus* and *Sambucus)* spread more extensively than *Corylus*. In the Crimean Mountains, hazelnut obviously grew on the lower elevations as it does at the present. After the phase of *Corylus* spread, the population of broad-leaved trees noticeably decreased, which can be attributed to the endothermal cooling within the interglacial. This phase was first established by Bolikhovskaya (1982, 1995) in the Dniester area, where arcto-boreal plants (including shrub birches) occurred in pine forests on the left bank of the river. On the right banks of the Dniester and Dnieper, the reduction in broad-leaved trees coincided with a spread of *Alnus* (in the west also a spread of *Picea*, *Tilia cordata*, and in the ground cover, Ericaceae and Bryales). In the Middle Dnieper area, only a few *Picea* appeared. In the Donetsk area and in the lower ridges of the Crimean Mountains, the reduction in broad-leaved species occurred at the expense of an extensive spread of *Pinus sylvestris*. Only a few oaks grew in the woods, and *Fagus* appeared in the lower forest belt of the mountains. These vegetation patterns indicate a cool and relatively wet climate. No spread of herbal xerophytes occurred at this time.

During the late-temperate stage of the interglacial (pollen zone M6), hornbeam strongly predominated in plateau forests of the Middle Dniester area, on low landforms of the Middle Dnieper area, and on the high mountain ridges of Crimea. In the Dniester valley and the lower ridges of the Crimean Mountains, the forest composition was much richer in diversity and, besides the prevailing hornbeam, it included oak, elm, lime, beech, and (sporadically) *Juglans*. Evidently, pollen productivity of the latter was re-established after the endothermal cooling. In the Donetsk area, hornbeam formed an admixture in oak forests on low landforms, but it was absent on plateaus where a pine-oak forest-steppe existed.

A gradual transition to the post-temperate stage of the interglacial was well expressed in the forests on plateaus of the right bank of the Dniester and in the lower mountain ridges of Crimea, whereas in the other areas, this climatic change occurred rather rapidly. On the right bank of the Dniester, an admixture of boreal trees (*Abies*, *Picea*, *Pinus cembra*, and arboreal birches) appeared in the *Carpinus* forest. In the foothills of the Crimean Mountains, diversity of the forest composition decreased, and the reduction of forested area occurred at the expense of a spread of meadow-steppe. Here, the trend toward aridification was stronger than that of cooling.

In the majority of the studied areas, the cool post-temperate stage of the interglacial (pollen zones M7-8) was marked by a complete disappearance of broad-leaved trees. Few of them (including *Fagus* and *Carpinus*) persisted only in the lower forest belt of the Crimean Mountains, and oak occurred in deep gullies of the Donets River basin. Boreal forests (arboreal *Betula*, *Pinus sylvestris*, and a few *P. cembra* and *Picea*) occupied the right bank of the Dniester, whereas on its left bank, steppe associations began to spread. In the Middle Dnieper area, birch forests (with a few spruce) were replaced by a pine forest-steppe and, finally, by a meadow-steppe. In the Donets area, steppe vegetation spread from the very beginning of the stage (birch-pine groves occurred only in gullies).

Thus, the climatic continentality increased from west to east during all stages of the interglacial. Reduction in forested areas occurred in this direction, as well as a decrease in the proportion (if any) of wet-loving trees. The least contrast in vegetation patterns existed during the thermoxeric optimum of the interglacial. Quercetum mixtum forest existed in all areas studied, and warm-loving *Juglans* was absent only in the Middle Dnieper. On the contrary, during the very beginning of both pre-temperate and post-temperate stages, wet-loving *Picea* grew only in the Middle Dniester area (sporadically in the Middle Dnieper basin), whereas *Abies* occurred only on the right bank of the Dniester. During the late-temperate stage, a spread of mesophyllous *Carpinus* in the Donetsk area was limited, and *Fagus* grew only in the Middle Dniester area and the Crimean Mountains. The low ridges of the Crimean Mountains had a much more diverse forest composition than their high ridges. During all stages of the interglacial, the proportion of broad-leaved trees was highest in the Crimean Mountains, where the existence of refugia during the penultimate glaciation is suggested.

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THE STRUCTURE AND GEOCHEMISTRY OF THE KILA-KUPRA MUD VOLCANO (GEORGIA)

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Keywords: Caucasus, Kura Depression, Eastern Georgia, Kakheti Region, Iori Plateau

Introduction

Georgia is the one of the countries where mud volcanoes are widespread. Within Georgia, their core distribution area encompasses the Iori plateau and the Gombori range (Kakheti region). Minor occurrences are observed in the northern flank foothills of the Trialeti range near the village of Kavtiskhevi (Ebralidze et al., 1975).

Methodology

The Kila-Kupra fold is complicated by exposures of three mud volcanoes (Kila-Kupra East, Central, and West, Fig. 1) and is located in the central part of the Iori plateau. Investigation of the genesis of the above-mentioned mud volcanoes included water and oil sampling of the gryphon for geochemistry studies. The samples were shipped to the Engrgy and Geoscience Institute at the University of Utah and are currently being processing. Aside from geochemical studies provided by the "Frontera Eastern Georgia" company designed to gain a better understanding of the structure of the Kila-Kupra mud volcanoes, 2D seismic data have been analyzed using IHS Kingdom software (Fig. 1).

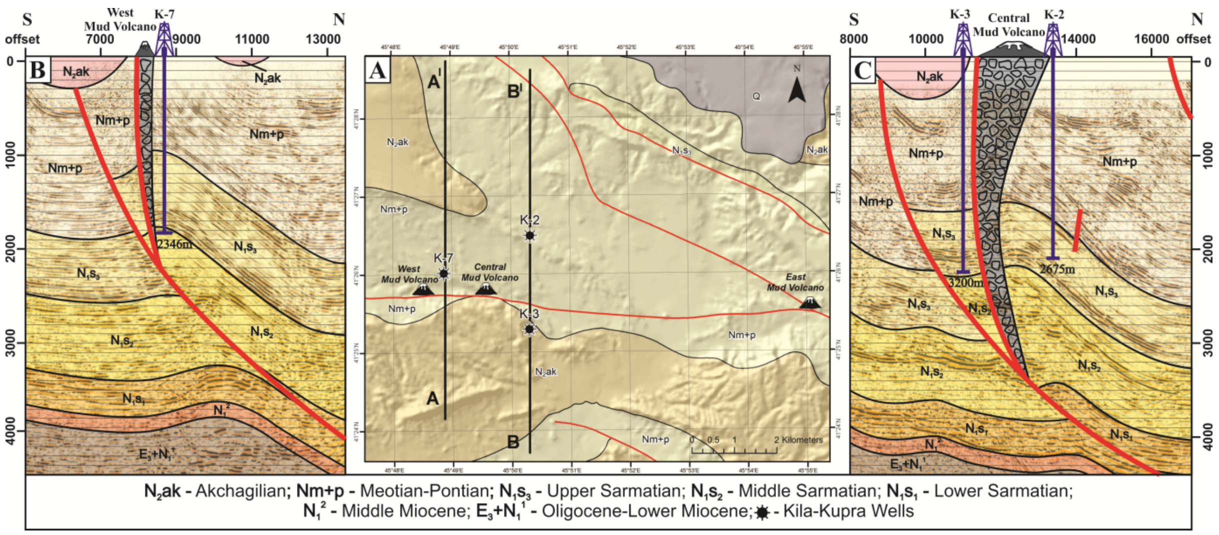

Figure 1. A: Geological map of the Kila-Kupra area with the location of mud volcanoes and seismic lines; B: Interpretation of Seismic line A-A^{I}; C: Interpretation of Seismic line B-B^{I}.

Results

As a result of the seismic data processing (Fig. 1), it is now known that the Kila-Kupra mud volcanoes are related to the asymmetric anticline structure that is complicated by the fault dome of the same name. Apparently, the Middle Sarmatian sediments are the source of these volcanoes. To date, based on paleontological and petrographic studies of mud volcano breccia samples, Upper Sarmatian sediments have been regarded as the source of the Kila-Kupra volcanoes (Ebralidze et al., 1975; Buleishvili, 1960). However, the presence of *Porosononion subgranosum* (Egger) and *Nonion bogdanowiczi* Voloshinova in the foraminifera complexes introduced in the cited publications indicates the existence of older than Upper Sarmatian sediment material (apparently Middle Sarmatian) in the mud volcano breccias as well (Gruzinskaya et al., 1986; Koiava et al., 2008).

Conclusions

On the basis of the studies conducted and available data, that Kila-Kupra mud volcanoes are related to the asymmetric anticline structure complicated by the fault dome of the same name. A possible link between the source of these mud volcanoes and Middle Sarmatian sediments has been proposed.

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CLIMATE CHANGE AND PALEOENVIRONMENTAL EVENTS IN THE BULGARIAN BLACK SEA ZONE DURING THE LATE PLEISTOCENE

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Keywords:* *climatic and sea level changes, shelf, coastal terrace complex, paleogeographical events

Introduction

From a geological point of view, the climate changes and sea-level fluctuations during the Late Pleistocene geological history of Black Sea are among the most interesting paleoenvironmental events for the scientific community (Yanina, 2014). Climate fluctuations controlled the glacial-interglacial phases in the Ponto-Caspian region, which in turn determined transgressive-regressive cycles in the Quaternary evolution of the Black Sea. The sediments of the Black Sea basin deposited during the Late Pleistocene contain Caspian type molluscan fauna marking a connection with the Caspian Sea (Lower Karangatian stage and Upper Neoeuxinian stage) as well as Mediterranean mollusk species, demonstrating also a Mediterranean invasion (Middle and Upper Karangatian stage).

Methodology

The climatic and sea-level changes within the Bulgarian Black Sea zone during the Late Pleistocene have been traced on the basis of an analysis of the transgressive-regressive cycles and the correlation between the terrace complexes along the coastline and shelf area. This paper presents complex lithological and biostratigraphical research of the Late Pleistocene (Karangatian) sediments recovered in a 30 m deep borehole in the Yurij Godin structure (YG on Fig. 1) on the Bulgarian Black sea shelf. The borehole is located in the peripheral area of the shelf and within the area of the Low Kamchia depression at a sea depth of 85 m. A correlation has been done between the Karangatian sediments from the shelf and terrace complex, like the Karangatian terrace of Varna and the firth of Fandakliiska River. The existence of Neoeuxinian sediments on the North Bulgarian shelf in the structures Samotino Sea and Samotino East categorically prove deep Postkarangatian regression by lithological and biostratigraphical research.

Results

The Karangatian transgressive stage was the most important paleogeographical event during the Pleistocene, which resulted in an increase in sea level higher than the contemporary one. According to Svitoch et al. (1998), the Karangatian sea level reached +6 to +8 m during the maximal phase of the transgression. The sediments of the Karangatian regional stage demonstrate a change in the paleogeographical environmental. The soft warm spell and the increase in saltiness which began during the Uzunlarian age reached their maximum in the culmination of the Karangatian transgresstion. The established molluscan fauna is the most thermophilic and the most halophilic in the geological evolution of Black sea during the Quaternary. The influx of Mediterranean waters also reached its maximum. The Mediterranean influence is proved by the one-sided migration of a euryhaline and stenohaline fauna. The Karangatian waters were warm and high in salt content: up to 30‰ (Nevesskaya, 1965) which is revealed by the rich diversity of species. The studied sections of the shelf and of the fluvial firth on the Bulgarian coast have established different climatic conditions. The known Karangatian sediments on the Yurij Godin structure and their geostructural position reveal that the Karangatian basin was located on the entire contemporary shelf. The biostratigraphical analysis proves their Early Karangatian age: *Corbula gibba* (Ol.), *Eulimella pointeli* (M.), *Cardium paucicostatum* Sow., *Nucula nucleus* (Linné), and *Retusa* sp. They correlate by age to the studied Early Karangatian terraces on the coast, like the Karangatian terrace of Varna, the valley of the Fundukliiska River (Krastev et al., 1990), which mark the early phase of the Karangatian transgression. These terraces are genetically related to the early Karangatian sediments of the shelf because they are the result of the same paleogeographical event—the transressive phase with the highest amplitude in Early Karangatian time. In the coastal sections, the monodominant presence of the euryhaline taxon *Corbula gibba* (Ol.) has also been established. The frigophilic glacial advance Celtic species indicate relatively fresh and cold waters during the Early Karangatian basin. The analysis of pollen spectra from the terraces of Varna and the firth of the Fundukliiska River establishes mostly a pollen spectrum of grassy vegetation typical of dry and colder climates. The radiocarbon data of shells from *Corbula gibba* (Ol.) yielded an age of $23{,}880\pm BP$ (Krastev et al., 1990). The paleomagnetic analysis revealed a positive magnetic polarity with low values of magnetic declination ($j\approx 31$) (Krastev et al., 1990). It is important to mention that the comparison in age between the Karangatian sediments of the shelf and coast and Early Karangatian (Tobetchikski) sediments from the Russian Black sea coast marks an inversion comparable to the Blake magnetic polarity episode (Chepalyga et al., 1989).

The beginning of the Neoeuxinian epoch was marked by a deep regressive phase of the basin's development. The Neoeuxinian regression in the Late Pleistocene coincides with the Würm glacial advance. The relict Postkarangatian refreshed basin existed as an isolated lake-sea, and the sea level declined to -90 to -100 m, therefore breaking the connection with the Mediterranean and Caspian seas. The Neoeuxinian sediments on the Bulgarian shelf differ lithofacially from the sea coastal type of terrigenous shell sediments from the peripheral area of the shelf. They are represented by aleurite-pellite and silt sediments, marking a deeper facies in the sections of the North Bulgarian shelf: the Aprilska and North structures. In the sea, continuation of the Low Kamchia depression, the Neoeuxinian aleurite-pellite muds lie directly upon Pliocene clays (Samotino Sea structure - SS-C-3) or directly upon Tschaudinian sediments (Samotino East structure - SE-C-6). The high amplitude of the Postkarangatian outwash is demonstrated by the significant stratigraphic hiatus of the washed away Oldeuxinian, Uzunlarian, and Karangatian sediments. The Batova and Kamchia firths were morphologically well expressed on the shelf and formed on Postkarangatian incisions during the first half of the Neoeuxinian epoch. As a result, the fluvial firths filled initially with alluvial type sediments and later with sea sediments. During the Neoeuxinian transgressive phase, a Caspian type molluscan fauna dominated: *Dreissena rostriformis distincta* (Andrus.) and *Dreissena polymorpha regularis* (Andrus.). Poor in species diversity, but rich in quantity, it marks a freshwater influx of Caspian waters.

Conclusions

A complete paleogeographical reconstruction of the Late Pleistocene evolution of the Bulgarian Black sea zone is presented. The correlation of Karangatian sediments from the shelf and terrace complex provides a reconstruction of the different paleogeographical conditions. We can reach the conclusion that the examined Karangatian sediments do not mark the height of the Karangatian transgression. In the Bulgarian part of the Black Sea basin, the Karangatian transgression developed in two phases: Early Karangatian and Late Karangatian (Fedorov, 2000). The biostratigraphical analysis of the sediments allows them to be related to the Early Karangatian epoch, i.e., this is not the apogee of the Karangatian transgression but its early phase. The paleomagnetic analysis shows a positive magnetic polarity of the sediments.

On the Bulgarian Black Sea shelf, the beginning of the Neoeuxinian transgressive epoch is marked by a deep regressive phase in the basin`s development. The high amplitude of the Postkarangatian regression is shown by the significant stratigraphic hiatus – Oldeuxinian, Uzunlarian, and Karangatian sediments are missing totally due to erosion. The Batova and Kamchia firths are morphologically well expressed on the shelf and were formed along an inherited Postkarangatian relief in the first half of the Neoeuxinian epoch. As a result, the fluvial firths were first filled with alluvial type sediments and later on with sea sediments.

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DIATOM ANALYSIS OF MAIKOPIAN DEPOSITS OF THE WEST BORDER OF THE SOUTH CASPIAN DEPRESSION (ALONG THE SECTION OF SHIKHZAGIRLI SHAMAKHI-GOBUSTANZONE) AND SOME PALEOECOLOGICAL CONCLUSIONS

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Keywords: deposits, marine littoral, brackish plankton, freshwater, diatoms, series, upper, lower, lithofacies, sandy-clay

Introduction

The deposition of diatom valves has been occurring in all geological periods up to the present time. Diatoms are widely used in the reconstruction of paleoclimate and paleo-ecological settings, in the stratification of sedimentary strata, and in the definitions of the physical and chemical state of an impounded body. The quantitative distribution of diatoms allows us to determine the temperature conditions that existed during sedimentation and reconstruct the climate zonation of past epochs.

The deposits characteristics

Maikopian deposits are distributed from the Black Sea region to Central Asia covering the entire area of the Eastern Paratethys. Taking into account the possibilities of other methods, the Maikopian series was divided into two parts: upper and lower.

At the same time, it has been revealed that the entire section of Maikopian deposits has been faunistically characterized in some regions, but in others, only its separate parts (Khalilov and Kuznetsov, 1964; Alizadeh et al., 1986). Subsidence of the Middle Transcaucasian massif created an area of rapid erosion and one of the main sources of Maikopian deposit accumulation in Gobustan. Our research subject was Maikopian deposits in the southern part of Gobustan-Shamakha province. The upper part of the Maikopian suite is distinguished by the presence of thick layers of sands and sandstones that indicate the proximity of land (Fig. 1).

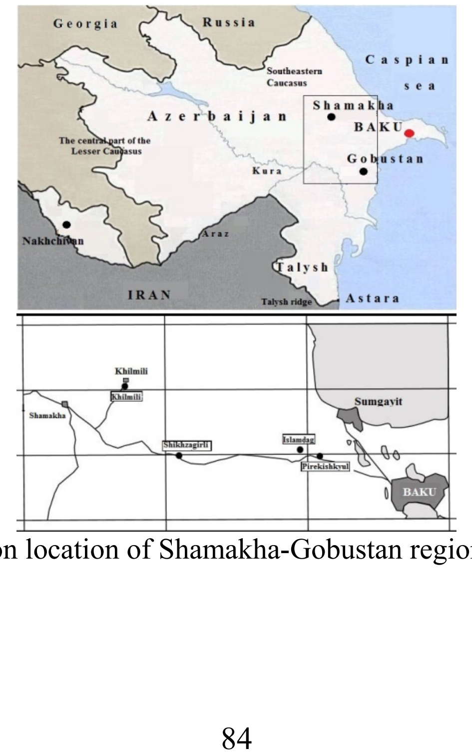

Fig. 1. Schematic map of section location of Shamakha-Gobustan region.

Materials and methods

The total thickness of the exposed part of the Maikopian deposits within the Shikhzagirli fold is 342 m. The Shikhzagirli section is geographically located on the border of the Upper Maikopian lithofacies of the Shamakha-Gobustan region: north clay and south sandy clay. The Maikopian series is lithologically represented by a complex of sandy clay deposits. The clays are gray (from light to dark) and brown, layered, massive, and schistose in places. Sandstones are small-to-medium-grained and thick, but uncemented sand has been noted in the 12th bench. The upper part of the section starting from the 8th bench is distinguished by the presence of carbonate material, but dolomite and limestone form separate layers in the 10th and 13th benches. Concretions and inclusions of gypsum have been found in the lower part of the section. The presence of jarosite is noted throughout the section. Shikhzagirli section has been characterized faunistically by foraminifera (Babazade, 2001) and also by spores of fossil flora (Sh. Sh. Bayramova, 2009). Shikhzagirli section includes deposits of the Upper Maikopian: Caucasus, Sakaraul, and Kotsahur. The section has been studied from the bottom up.

Deposits from the Shikzagirli section in the Shamakha-Gobustan zone were studied. 15 samples were subjected to laboratory treatment. Single, rarely double, samples (13 benches in total) were taken from each bench. About 70 photos containing images of the diatom valves were taken with an SEM (scanning electron microscope). The analysis of the composition of the diatom valves was made as well using the SEM. The sample processing technique used by us has been taken from Makarova (1974). Species determination and quantitative estimation, and also microphotography, were carried out on permanent preparations under immersion on a NIKON microscope under general magnification of x1000.

Results

Only 8 samples from the 15 studied samples were found to contain diatoms. Many taxa were determined to the level of genus, but only some of them to the level of species. According to some genera, the diatoms are singly and rarely in preparations, but there are also dominant forms. In almost all 8 samples from this section, there are the following diatoms: *Actinophychus undulates* Ralfs. var. *undulates*, *Actinophychus undulates* var. *minor*, *Pseudopodosira hualiana* Jouse, *Coscinodiscus obscures*, *Amphora copulate*, *Fragilaria bicapitata*, *Melosira sulcata* var. *sibericab*, *Melosira fausta*, *Triceratium* sp., *Triceratium crovei* Pont, *Biddulphi* sp., *Hemiauluss poralis* Stalnikova, *Delphineis lineate* Andreus, *Coscinodiscus argus*, *Craspedodiscus moelleri*, *Eunotogramma*, *Epithemia turgid*, *Nitzchia* sp., *Cyclotella* sp., *Actinocuclus podolicus*, *Navicula* sp., *Pseudosira hualina Grun., vardescrescens, Cladogramma elipticum, Xanthiopyxis umbonata Grev, İsthmia* sp., *Melosira* sp., *Stephanopyxis punctata*, *Cyclotella meneghiniana* Kützing, *Chaetoseris* sp., *Meridion circulare*, *Cymatosira* sp., *Cymatosira savchenkoi* Pr.-Lavr., *Stephanodiscus astrae*, *Stephanocyclus* sp., *Thalassiosira* sp., *Mastogloia* sp., *Sinedra ulna*, *Rhaphoeneis maeotica* (Milov) Sheshuk, *Etcles*, *Paralia sulcata*, *Cyclotella fotii*, *Pinularia borrealis*, *Melosira* sp., *Opephora* sp., and *Uncertain* (Fig. 2) (Diatoms, 1890-1907).

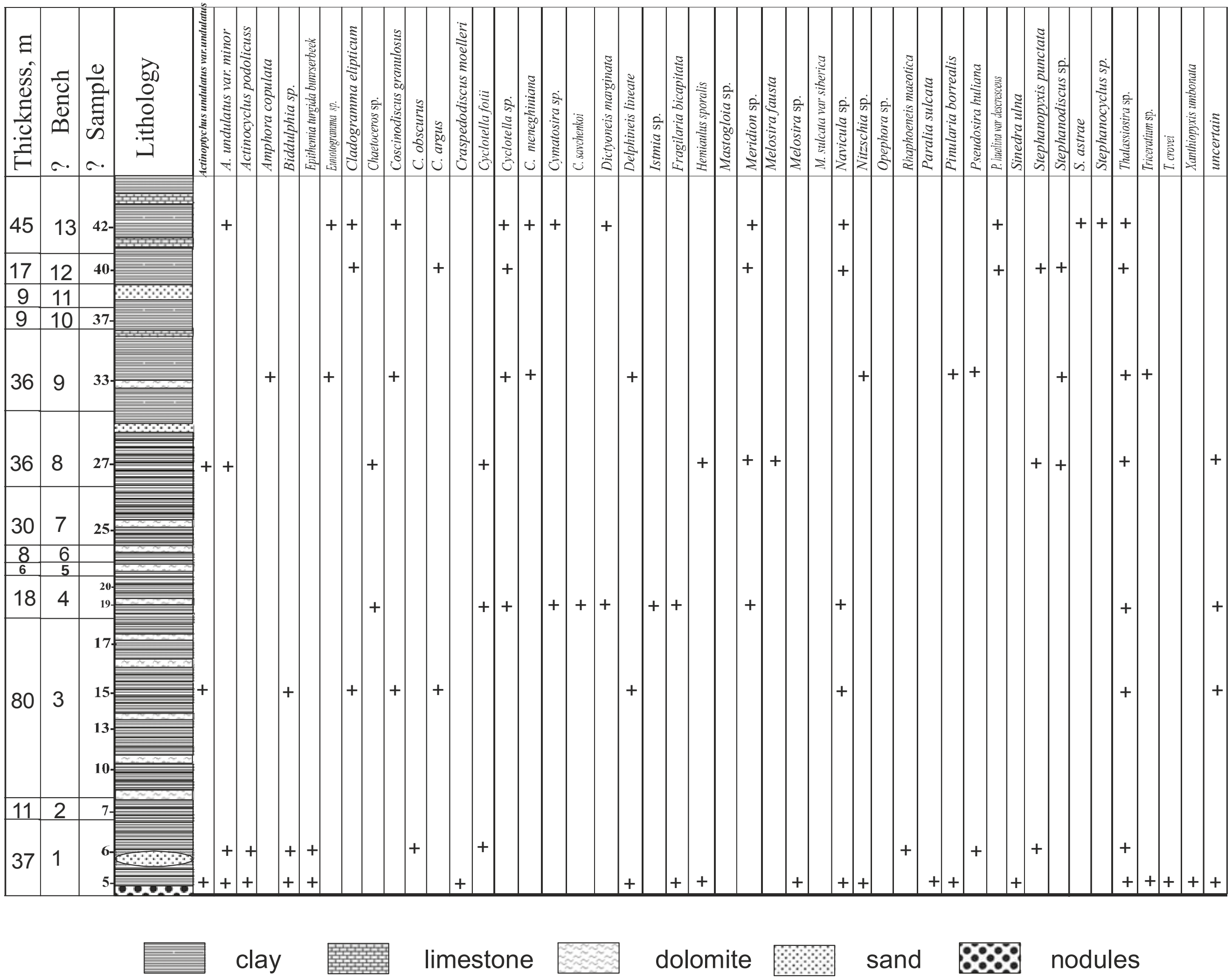

Figure 2. Composition of diatom flora (Shikhzagirli section).

The quantity of the abovementioned forms is 5-15 (very seldom) in each preparation. 42 taxa in total have been found for this section (Fig. 1). Some of them are brackish, some marine, and there are also freshwater forms (4%). But the large percentage of recovered diatoms is mainly marine forms.

The dominant ones are the genera: *Cyclotella*, *Stephanodiscus*, *Coscinodiscus*, *Melosira*, *Triceratium*, *Biddulphia*, *Actinocuclus*, *Thalassiosira* sp., and also some pennate forms which are not determined unfortunately to species due to the poor preservation of the silicon shell: *Fragilaria* and *Sinedra* (Fig. 3).

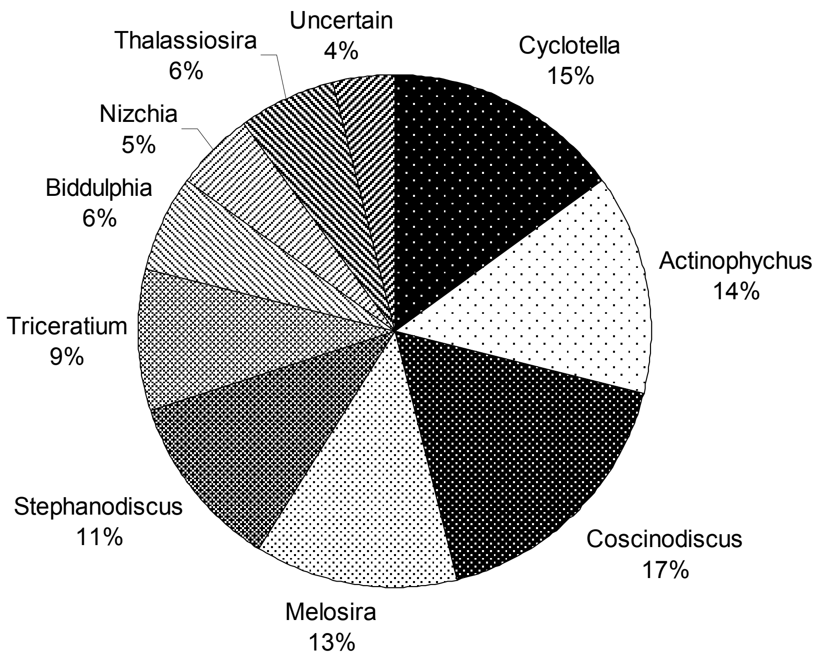

Figure 3. Pie chart of diatom flora (Shikhzagirli section).

Marine littoral (73%), brackish plankton forms (23%) prevail throughout the section, but freshwater forms amount to only 4%. There are many fragments of centric and pennate forms of diatoms as well as a completely new forms, the ecology of which is not clear (16%), and sponge spicules in the preparations. The diatoms of this section can be shown by the diagram according to genera in percentage ratio (Fig. 1). A diagram shows that mainly marine, neretic, littoral, and planktonic forms of diatoms were incorporated into the sedimentation of the lower part of the Upper Maikopian. There are also benthonic forms, but they play the smallest role in sedimentation of this complex. The pinnate freshwater diatoms are found very rarely in the lower stages of the section.

Conclusions

Laboratory investigations have shown that the investigated complex of fossil species of diatoms was composed of forms that were the most resistant to the environmental impact and resisted dissolution.

In our case, according to the investigations, the species relating to the genera: *Coscinodiscus*, *Actinocuclus*, *Cyclotella*, *Nizchia*, *Melosira*, *Stephanodiscus*, *Triceratium*, and *Biddulphia* became more resistant to all negative environmental impacts throughout the section (Fig. 3).

As previously mentioned, from 15 investigated samples removed from the section, only 8 revealed the presence of diatoms; the remaining 7 were barren. Absence and insufficient number of diatoms in some samples can be explained by the following reasons:

1. A sufficient quantity of the critical elements were not present within the basin for siliceous shell construction (silicon, phosphorus, etc. dissolved in the water).
2. Hydrogen sulfide contamination of the basin (diatoms can live in such an environment, but they are very poorly developed).
3. Weak resistance to dissolution.

The Maikopian basin of the investigated zone was different from the Eocene according to the diatom complex that has been extremely poorly represented here, both in terms of species and quantitative relationships. A number of studies based on the investigation of macro and microfauna of the Oligocene-Miocene of the Caspian Sea have been devoted to the problems of the change in faunal and floral complexes. However, the question of diatom development in connection with changes in the conditions of their habitat in the Oligocene-Miocene remains open. Further investigations will be carried out in this direction.

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THE ORIGIN OF ARTIFACTS OF BONE AND SHELL FROM THE KHVALYNSK ENEOLITHIC CEMETERIES (NORTHERN CASPIAN REGION)

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The Khvalynsk Eneolithic I and II cemeteries (KEC) were discovered and excavated in 1977-1979 (I) and in 1987-1988 (II) (Agapov et al., 1990) in the vicinity of the town of Khvalynsk, Saratov region (European Russia) on the right bank of Volga River. Geographically, they are included within the Project IGCP 610 area. Substantial Eneolithic artifactual material previously unknown for the region was collected. ^{14}C dating of bones obtained from the graves helped establish the chronology of the burials: 4500-4200 cal BC (Shishlina, 2008; Chernykh and Orlovskaya, 2010).

Grave goods in the KEC included ceramics, stone tools, and metal objects. Combined investigation of the recovered materials together with anthropological and zooarchaeological studies of the KEC enabled defining the specific *Khvalynsk* pastoralist culture of the Volga basin area. Cattle-rearing as well as hunting and fishing were the main occupations.

Many items and adornments fashioned from animal bones of different taxa were excavated. Vertebrates (birds and mammals) are represented by species still living in the area: swan (*Cygnus* sp.), a large predatory bird from the Accipitridae family, white-tailed eagle (*Haliaeetus albicilla*), great bustard (*Otis tarda*), also beaver (*Castor fiber*), elk (*Alces alces*), red deer (*Cervus elaphus*), and wild boar (*Sus scrofa ferus*). Some correlation was noted between the gender of the buried person and the type of adornment from animal skeletal parts. For instance, wild boar tusks were found mainly in male graves, pendants from red deer canines and imitations were mainly in children's burials, and slivers made of beaver incisors were noted mainly in male and children's graves. An axe made from elk antler and a unique "Elder's staff" made from red deer antler were found in a male grave, too. Besides the species mentioned above, cattle skeletal elements and "rings" from the tubular shaft bones of middle sized ungulates (Kirillova, 2010) were also present.

Finds are dominated by items of invertebrate origin, however. Especially numerous were rows of disk shaped beads made from the shells of freshwater Unionidae, most probably *Unio pictorum*. Freshwater *Corbicula* and *Viviparus* shells were also found. Decorative elements made from marine biota were rare and represented by rows of Scaphopoda shells and calcareous tubes of polychaete worms of the family Serpulidae (*Mucroserpula tricarinata* from the Jurrasic, also an unidentified sub-recent species). The use of the latter for adornments was noted for the first time (Ippolitov, 2010). An attempt to establish the allochthonic or autochthonic character of the invertebrate material in the KEC, as well as to correlate its geological age with the period of necropoleis formation was done by Kirillova (2010). We obtained new age determinations and are trying to reconsider this question focusing on *Glycimeris* shells also present in burials.

Six samples of shell material were selected for radiocarbon AMS analysis (Table 1). Five were from grave goods in the KEC, one was a modern shell from the Eastern Mediterranean for control.

Table 1. Results of AMS ^{14}C analyses.

Shell sample	ANSTO code	d(^{13}C) per mil			percent Modern Carbon			Conventional ^{14}C Age			Cal years, BC*	
		d(^{13}C)		1s error	pMC		1s error	yrs BP		1s error	Median	2s range
Glycymeris 2087/252, 15 k	OZT370	1.7	+/-	0.1	0.51	+/-	0.02	42380	+/-	380	43260	43960 - 42550
Scaphopoda 2087/265	OZT371	0.3	+/-	0.1	0.45	+/-	0.02	43390	+/-	450	44100	45060 - 43240
Serpulidae 2037/66	OZT372	-0.6	+/-	0.1	0.58	+/-	0.03	41410	+/-	430	42430	43240 - 41550
Serpulidae 2087/70	OZT373	-5.3	+/-	0.1	0.15	+/-	0.02	52200	+/-	1200	54300*	49900 - 55500*
Unio 2087/192, 107009	OZT374	-12.2	+/-	0.1	40.45	+/-	0.2	7270	+/-	40	4790	5240 - 4340
Glycymeris - modern	OZT375	1.8	+/-	0.1	93.32	+/-	0.36	555	+/-	35	Post-bomb modern sample	

* Calendar date for OZT373 was obtained by extrapolation beyond the IntCal13 calibration curve range.

Samples went through a rigorous cleaning, namely the surfaces were first physically cleaned of the top layer with a dental drill followed by chemical etch with 0.5M HCl for 1-5 minutes under sonication at room temperature. Hydrolysis was performed with concentrated H_3PO_4 acid in acid pre-cleaned glassware. The first ~25% of evolving CO_2 was also discarded to eliminate any possible surface diagenesis contamination. The remaining evolving CO_2 was collected, converted to graphite, and measured for ^{14}C on a STAR AMS at ANSTO (Fink et al., 2004 and references therein). Results, corrected for laboratory blanks and isotopic fractionation, are presented in Table 1, as well as calibrated calendar age ranges. *Unio* shell material of local freshwater pearl shells were determined to be coeval with the necropoleis period, and the modern *Glycymeris* test shell also returned the expected age, agreeing with the local reservoir effect data. But other samples produced ages predating by far the Khvalynsk culture and even the Holocene.

What could be the possible pathway for *Glycymeris* shells to "Khvalynsk"? In Europe during the period of the Khvalynsk Eneolithic (5000-4500 BC), the bivalve clams of this genus were common along the Atlantic shelf zone from Gibraltar to the North Sea, and in the Western and Eastern Mediterranean to the Aegean Sea. It is reasonable to accept these areas as a source of shell material for the KEC. But radiocarbon dates of the shells point to marine deposits of the MIS 3 interstadial.

The nearby Caspian could not serve as a source of shells of this genus, since in MIS 3, it was a brackish water body (the end of the Atelian regression and the early phase of the Khvalynian transgression) with mollusk fauna consisting mainly of Cardiidae of *Didacna*, *Monodacna*, and *Hypanis* genera as well as *Dreissena*. The Black Sea of the time was going through the Surozh transgression, less saline then its modern state. But even in the Karangatian transgression of the Black Sea with the highest known salinity for the basin, its well-studied malacofauna had no *Glycymeris*. Hence, one should not expect it in the Surozh basin either.

The only possible source of these clams from the Mediterranean direction is the Mediterranean itself. In MIS 3, it was a warm basin with sea level below that of modern times but not less than -30 m. We are not aware of publications covering the malacofauna of the period. However, since in the previous Tyrrhenian transgression (MIS 5) *Glycymeris* clams were widespread, it is reasonable to expect it in MIS 3 Mediterranean basin. The problem is that those deposits were submerged by Holocene sea rise in Khvalynsk times. The only possibility then was to collect shells, which were dislodged and redeposited in Holocene sediments.

Glycymeris shells are widespread in the Eneolithic cultures of the Balkan-Carpathian region. It appears logical that they reached the Volga region by barter and trade with neighbors. Clams could be picked up on Mediterranean shores by groups migrating north from the fairly rapid postglacial sea-level rise, which started in the Mediterranean around 17-15 ka BP. Current consensus is that the level of -30 m was reached 10-9 ka ago. Transgression reached its maximum at about 4-6 ka BP, with its level exceeding that of today by a few meters. That produced low (3-5 m) terraces on the shorelines. The modern level was established not earlier than 3-4 ka BP (Kaplin and Selivanov, 1999). A Balkan origin of *Glycymeris* shells from the KEC is also supported by the items made of Balkan ores, discovered in the necropoleis as well. Adornments made of *Glycymeris* shells are found in burials extending from the Balkans to Kvalynsk and even farther east.

The rarest bivalve clams used for Khvalynsk adornments were *Corbicula fluminalis*. In the Khvalynsk period, its habitat didn't include the Lower and Middle Volga regions, but they were very common in Late Pleistocene sediments in the Lower Volga area (the Astrakhan region) and Caspian shores, with excellent preservation. Those layers were deposited along the late Khazarian (MIS 5) transgression of the Caspian Sea, which was warmer and saltier than the present sea (Yanina, 2012). This species is also present in interglacial (Eemian and Middle Pleistocene) deposits along the Black Sea coast. In the Holocene, they are found in freshwater bodies of the Middle East, Transcaucasia, and Central and East Asia. This provided the Khvalynsk people with ample sources of *Corbicula*, local and distant.

Some shells among the KEC finds were described by Popov (2010) as *Didacnoides caucasicus*, which are known from the Lower Pleistocene deposits on Caucasian and (seldom) on Mangyshlak shores of the Caspian. This prompts consideration of a Caucasian pathway for shell items to get to Khvalynsk. There are arguments in favor of this, namely: (a) *Didacnoides* clams and (b) *Corbicula fluminalis* clams were and still are present in Azerbaijan water bodies; *Glycymeris* shells are found among Eneolithic adornments in the North Caucasus (Grozny, etc.), i.e., on the route from the West Caspian shore to Khvalynsk. *Glycymeris* shells in this case could be sourced from Persia – from the Gulf across modern Iran and farther north along the Caspian shore to the Volga River.

Here, we are suggesting two possible routes and sources for *Glycymeris* shells, which are exotic to Kvalynian territory: Balkan and Persian. It is possible that both of them were used in prehistory.

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MORPHOLOGICAL ANALYSIS OF FLAT-BOTTOMED DEPRESSIONS, THE EASTERN AZOV SEA REGION

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Introduction

A characteristic feature of the east coast of the Azov Sea is a specific watershed area with flat-bottomed depressions characterizing its relief. Oval shaped with sizes from 0.5x1 km to 5x13 km and depths from 2 to 21 m are typical for this type of closed depression. The highest concentration of depressions is observed in the territory of the Yeisk peninsula. Less commonly, these forms are found to the northeast of Yeisk estuary—the coastal strip from the village of Nikolaevka to the city of Azov. Local names for these forms are: pad', pods, and estuaries. Analysis of the published literature (Safronov, 1973; Kanonnikov, 1977; Kleschenkov, 2010) shows that the problem of the origin of flat-bottomed topography of the eastern Azov is still controversial. None of the hypotheses advanced through the years (paleokarst, karst-suffosion, subsiding loess; lacustrine, eolian, heterogeneous) can find a full confirmation or a final rebuttal. This uncertainty is associated with a lack of geological and geomorphological study of flat-bottomed depressions, and poor factual data on the structure of the depressions. In addition to their origin, it remains unresolved how such depressions will develop in the future: do forms tend to increase or remain stable? The importance of forecasting the development of flat-bottomed depressions is due to the fact that the plots of land belonging to the bottoms of the depressions are usually unsuitable for practical use: on satellite images it is clear that the bottoms of the depressions are not built up and rarely used in agriculture.

Study region and methodology

The present study is an attempt to approach the problem of the depressions from the perspective of morphological analysis. We analyzed numerical data describing the size and shape of the depressions, marked morphological types, analyzed the connection of depressions with the erosion structure network, alluvial and marine terrace levels. The study is based on the use of a digital elevation model (DEM) SRTM-3, which is made up of radar data surveys. DEM was selected due to its greater convenience during morphometric analysis of relief. For the model SRTM-3, the following parameters are given (Farr et al., 2007): Spatial resolution—3 arcseconds (90 meters), the absolute error in the plan—8.8 m, the absolute error in height—6.2 m, the relative error height—8.7 m. Geodetic measurements of the terrain made for individual depressions allowed us to carry out an additional verification of the model used, which showed that the accuracy of the study was slightly above that stated. With the mapping "Global Mapper 11" package, based on the above DEM, we measured 118 identified depressions. The results of the measurements were used to create a depression database, including a set of morphometric parameters for each shape: area, depth, length, width, and azimuth orientation of the long axis. The obtained numerical data were statistically analyzed using the MS Excel program.

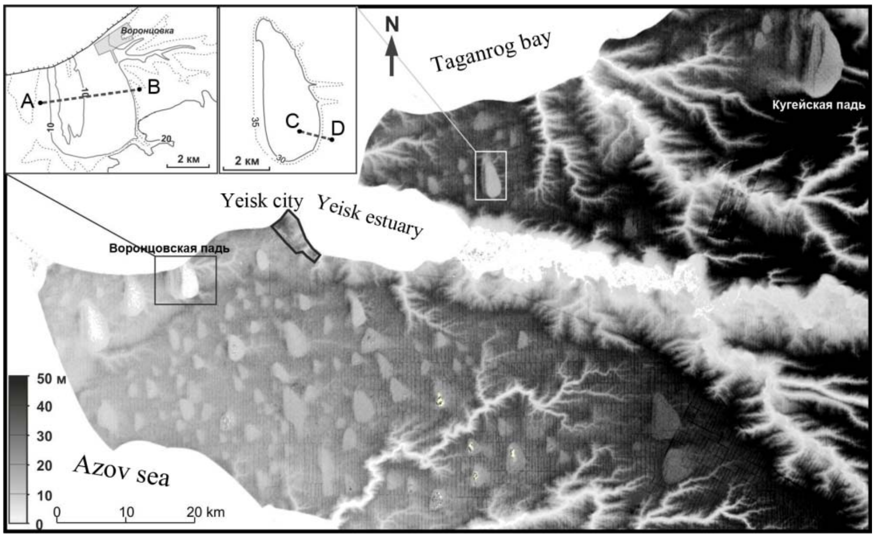

Figure 1. Study area.

Results

One of the main features of the flat-bottomed topography of the eastern Azov that attracts attention even at first glance on the DTM (Fig. 1) is a high degree of consistency in the orientation of the long axes of the depressions. 95% of all forms are aligned NNW-SSE (67%) and NS (28%). The remaining 5% were characterized by a NW-SE and NE-SW orientation. Notable is the interposition of depressions: a significant portion of the shapes are built in linear chains of (2-5 depressions), the orientation of which coincides with the orientation of individual depressions. Linear focus (elongation in one direction) of a vast number of shapes may indicate the formation of depressions under conditions of directional flow influence – most likely an aeolian or fluvial agent. Morphology of the depressions is characterized by smooth contours, regular shape (without festooned sides), and elongated ovoid shape with the presence of acute and obtuse rounded ends; the sharp end is always north, and the obtuse end south. In some cases, the depression form tends to be triangular. There are also almost exactly oval depressions with morphologically similar ends. Ideal round shapes do not occur at all. The degree of elongation of the depressions is characterized by the so-called "Elongation ratio": the ratio of length to width. The most common are depressions with values of this coefficient: 1.6-2.2 (55% of all forms), with most of the depressions showing approximately equal proportions, slightly varying in form depending on the size.

The most typical area of eastern Azov depressions is in the range 1-4 km^2; such relatively small forms are in the majority (54%). Most small depressions (<1 km^2) make up 17% of the total number of forms. Mid-sized depressions (5-10 km^2) make up just over 20%. The largest forms, with an area over 10 km^2, amount to a total of ten (8.5%). Of special note is a ‘giant’ depression, "Kugeyskaya Pad," with an area of 53.9 km^2. Also interesting is the ratio of the area of the depression to its depth. It traces a trend describing the dependence of depth to area: the depth of the depressions ranges from 2 to 21 meters, and the area increases hundreds of times with increasing depth from minimum to maximum. This suggests that the subject forms are only flattened and shallow relative to their size. Ridges within the bottom of the depressions are rarely more than 1-2 meters. The western side of some very large forms ("Kugeyskaya Pad’" and "Vorontsovskaya Pad’") is complicated with trough-ridge relief (amplitude of 3-5 m). It is noteworthy that sub-parallel ridges are oriented along the long axis of the depressions.

Another interesting problem is the relationship between the the distribution of depressions and the alluvial levels and marine terraces developed within the territory. Hypsometrically, there are two terraced levels traced in the Yeisk peninsula (Fig. 1): the lower one occupies the northwestern tip of the peninsula, and the higher terrace takes up the rest of it. However, according to geological data (Lebedeva, 1972; Velichko et al., 2010) in the study area, there are no fewer than three terraces (the Nogay terrace with Taman fauna; the Platovskaya with Early Tiraspol fauna, and the Voznesenskaya with Late Tiraspol fauna), which suggests a poor expression of terraced ledges. Depressions of various sizes and shapes are not tied to a particular terrace; they are distributed at various levels. This suggests an independent origin for depressions from the processes associated with the formation of terrace deposits (fluvial and coastal processes).

Conclusions

Flat-bottomed depressions act as indoor pools, intercepting part of the surface runoff. This is clearly illustrated by the radial centripetal pattern network of small erosion forms (SEF), i.e., depressions framed by ridges and ravines. These SEFs flowing into the depression to the east and northeast are generally 5-10 times more extended, due to the overall gentle slope in the SW direction. Depressions intercepting the runoff are probably related to the glaring lack of a valley network development on the Yeisk peninsula. Here, there are only two rivers (the Yasen and Albashi), and morphometric parameters of the river valleys do not correspond to the small size of the modern streams. Obviously, the valley of the small rivers, as well as the SEF-shaped relic, in fact formed in the non-modern landscape and climatic conditions. Emphasis is placed on the forced steep turns (up to 90°) of the river and SEF valleys, which, in our opinion, are due to the large rivers crossing the depressions. The totality of these facts gives one reason to believe that the flat-bottomed depressions are more ancient than the erosional network.

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RESEARCH INTO GLACIER VARIATION DYNAMICS IN EAST GEORGIA UNDER THE IMPACT OF MODERN CLIMATE CHANGE

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Keywords: melting, retreat, satellite, Earth observations

Introduction

Glaciers play an important role in the formation of climate at regional and global scales. Under conditions of global warming, glaciers recede and degrade, which is reflected in the related changes of glacier runoff and water balance. These processes result in an increasing number of glacial and hydrological disasters such as glacier falls, river bed blocking, and natural dam formation with consequent breaking, leading to catastrophic flash floods and/or mudflows.

The investigation of glacial melting is important for the study of sea/ocean level changes that also may carry a significant risk for the residents of coastal areas. That is one of the most negative impacts of modern climate change on humankind.

Glaciers variations are clear indicators of the anticipated climate change. It should be noted that in the 18th and 19th centuries, glacier parameters (area, length, volume) increased (Abikh, 1877; Zaporojchenko and Chernomorets, 2004). It was determined that during the second half of the last century, the characteristics of Georgian glaciers were steadily diminishing due to the impact of modern climate change. As a consequence, the glaciers' total area in Georgia decreased by 36% and their volume - by 48%. Some glaciers melted away completely. The length of glaciers was reduced by 600 m on average. In the lower part of the glaciers, ice thickness decreased by 50-150 m. At the upper part, ice thickness was reduced by 20-30 m (Sylvén et al., 2008; Keggenhoff et al., 2011). This process is still underway and most likely will continue into the future.

In the past, glacier research was carried out mainly based on terrestrial observations. Corresponding fieldwork was difficult to organize. These investigations were characterized by the following significant shortcomings: (1) high expenses, (2) data irregularity both in terms of space and time resolution, and (3) data uncertainties. Satellite Earth observations (EO) are more or less free of these limitations. Satellite EO provide the possibility to study the characteristics of the glaciers (Pellikka et al., 2010; Shengelia et al., 2015), as well as to determine glacier retreat rate.

Study area and methods

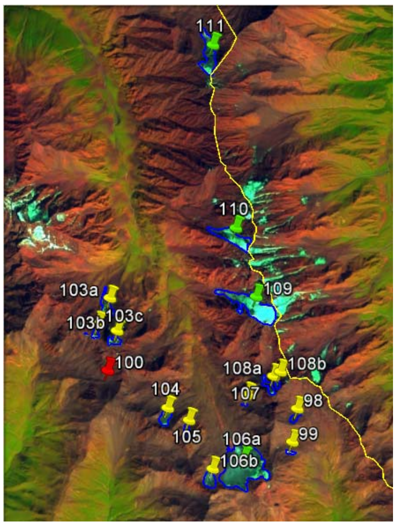
The study area is located in the eastern part of the Great Caucasus in the territory of Georgia. Georgian glaciers are widely represented here on the southern sides and ridges. In the present article, the high resolution satellite EO are applied to determine glacial contours and other characteristics. Quality assurance and quality control (QA/QC) procedures based on the complex use of high-resolution satellite EO together with historic data and expert knowledge are used to validate the results (Kordzakhia et al., 2015).

Application of several GIS systems is very important as well. The determination of a glacier's contours with high accuracy is fundamental to the research on the melting of small glaciers and the retreat of large glaciers.

In the present study, the impact of modern regional climate change on variation in the Georgian glaciers is researched.

In general, global warming has substantial negative impact on glaciers, which is particularly evident in the case of small and large glaciers. This often leads to small glaciers fragmenting, turning them into the snowfields or their full melting.

For example, consider the satellite Landsat image of some small glaciers from the Terek River basin (Fig. 1).



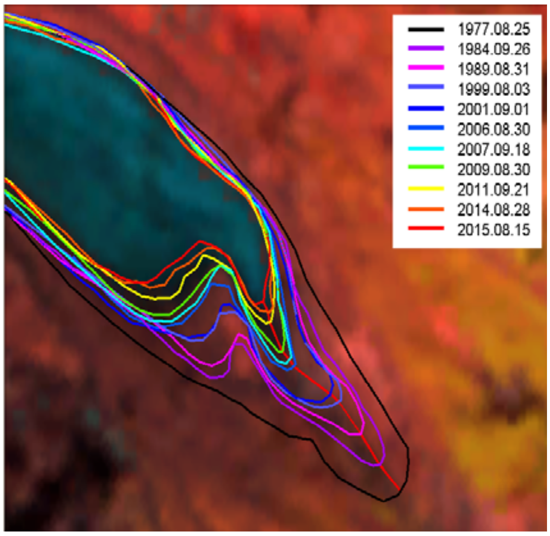


Figure 1*. Landsat satellite image for some small glaciers (№ 98 – №111) and their contours from the Tereki River basin (East Georgia).

Figure 2. Schematic picture of Gergeti glacier retreat as determined from Landsat satellite images.

* It should be remembered that the area of small glaciers changes in the range of 0.1 to 0.5 km^2. Snowfields can be formed by the degradation of small glaciers leading to residual areas less than 0.1 km^2.

Fig. 1 shows small glaciers and their contours, created using the aforementioned innovative technologies. Glacier identification revealed that they represent glaciers №98 - №111 according to the glacier catalog of the former Soviet Union (Tsomaia and Drobishev, 1977). The time period between the terrestrial observations included in the former USSR catalog and the data of the satellite EO is equal to at least 40 years. In Fig. 1, the remaining small glaciers are shown by green pins; the red pins mark the vanished glaciers and yellow pins represent the snowfields. A similar study was performed for all the glaciers of East Georgia. The results are shown in Table 1 (see section 3).

In the present study, the impact of modern regional climate change on the Gergeti glacier retreat is researched. Satellite EO data for the Gergeti glacier was selected in order to determine the speed of the glacier's retreat.

Table 1. The number of small glaciers (East Georgia) according to the catalogue and satellite EO.

Scheme	Number of small glaciers according to the catalogue	Number of small glaciers based on satellite EO			
		Small glaciers	Snowfields	Vanished glaciers	Total
1	13	10	5	0	15
2	2	2	0	0	2
3	12	3	6	3	12
4	24	2	9	13	24
5	48	13	30	11	54
6	6	1	10	0	11
Total	105	31	60	27	118

The end of this glacier is free of debris, which provides easy processing and analysis of multispectral sensor observations. To determine the speed of glacial retreat, 11 different files of Landsat satellite data were analyzed spanning the period of 1977-2015. The satellite images were all chosen from the end of the ablation period (August-September for Georgia) and with less than 20% of cloud cover.

On Fig. 2 eleven locations of the Gergeti glacier terminus with dates to indicate its retreat are shown. Every location is represented by a contour of a different color. Glacier retreat distances were determined along the mid-valley based on the red color line crossing the successive terminus outlines.

Results and conclusions

In Table 1 are presented the number of small glaciers registered from the former USSR catalog and the number of these small glaciers counted from the processing of satellite EO. Analysis of this table shows that of the 105 small glaciers registered in the former USSR catalog, only 31 remain after 40 years; 60 snowfields have resulted from glacier degradation, and 27 small glaciers fully vanished. It can be concluded that 70% of the small glaciers fully or partially melted due to the impact of regional climate change.

The numerical values representing the retreat of the Gergeti glacier were determined using the data of Landsat satellite of Fig. 2. These data indicate the dynamics of the Gergeti glacier retreat as shown on Fig. 3a.

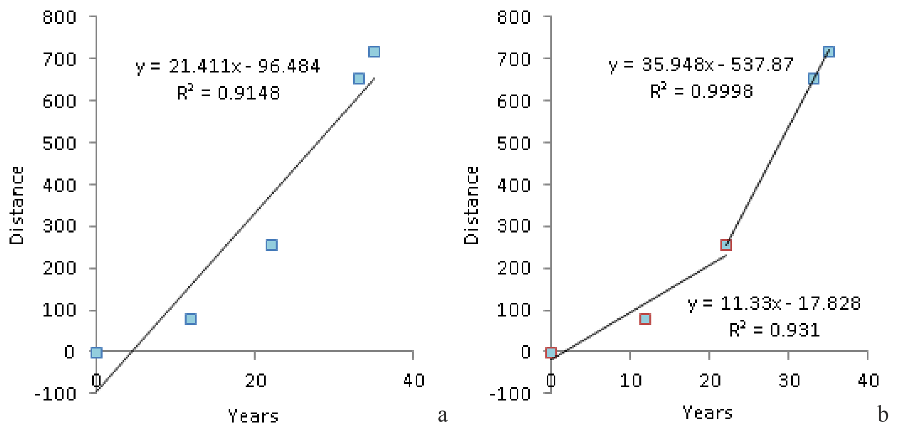


Fig. 3a. Gergeti glacier retreat dynamic (1977-2015) and corresponding linear trend; 3b. Trends of Gergeti glacier retreat for the periods 1977-2001 (5 locations) and 2001-2015 (7 locations). All data are based on satellite EO. On the horizontal axis the years of satellite images are given. Starting position refers to 1977. On the vertical axis the retreat distances are given.

For a better understanding of the impact of climate change on glacier retreat, the research period of 40 years was divided into two periods: 1977-2001 and 2001-2015. Corresponding linear trends for these periods are created (see Fig. 3b). The analysis carried out for the first period shows that the Gergeti glacier retreat was equal to 15.64 m annually, and it rose to 26.68 m per year for the second period. These numbers show that for the last 15 years, the retreat tendency increased significantly, and the difference between the two periods is about 11 m annually. Based on these data and the data for other glaciers not cited here, it can be concluded that climate change accelerated during the last period showing the nonlinear character of this process.

For QA/QC of satellite EO data related to the Gergeti glacier, data from terrestrial observations for the time period of 1978-2013 were used. Based on these data (five locations), Gergeti glacier retreat dynamics are shown in Fig. 4a.

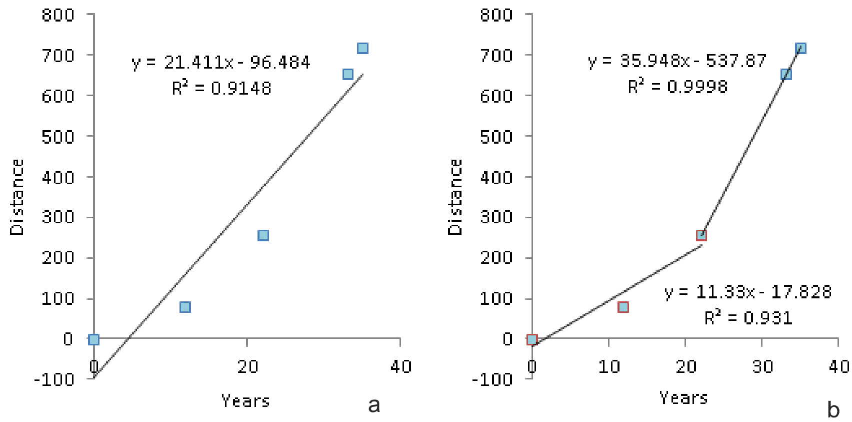


Fig.4a. The dynamic of the Gergeti glacier retreat (1978-2013) and corresponding linear trend; 4b. The trends of Gergeti glacier retreat for the periods 1978-2003 (3 locations) and 2003-2015 (3 locations). All data are based on the terrestrial observations. On the horizontal axis the years of terrestrial observations are given. Starting position refers to 1978. On the vertical axis the retreat distances are given.

The linear trend for the whole observational period (1978-2013) shows that the retreat of the Gergeti glacier according to terrestrial observations is equal to 21 m per year on average. The results reveal a similar trend: the glacier retreated as was documented in the data from the satellite monitoring. Namely, comparison of the data from terrestrial observations with those of the satellite EO shows that the retreat rate is almost the same. The difference is negligible and may be referred to the differences in observational periods.

As was done above with the satellite EO data for comparison and better understanding of the climate change impact on the retreat of Gergeti glacier, a similar approach was used for terrestrial observations. The research period of 35 years of terrestrial observations were divided into two periods: 1978-2000 and 2000-2013, and corresponding linear trends for these periods were created (see Fig. 4b). Using the data of the terrestrial observations for the first period, the Gergeti glacier retreat was determined to be equal to 11.3 m annually, and it reaches 30 m per year for the second period. There is a greater difference in these data compared with those of satellite monitoring. The difference is more than 4 m annually for the first period and more than 3 m annually for the second period. These differences are caused by the difference in the observational periods for the satellite EO (40 years) and for the terrestrial observations (35 years).

Summarizing, it can be concluded that the glaciers of East Georgia have been intensively melting under the impact of regional climate change. Medium glaciers are becoming small glaciers, small glaciers are turning into snowfields or completely vanishing, and the large glaciers are degrading and retreating. At least 70% of identified small glaciers in East Georgia are now snowfields or fully melted. Analysis of large glaciers shows that the rate of their retreat has increased. The analysis and comparison of retreat rates between the second and first periods show that the glacial retreat rate has increased significantly. We conclude that during the last 15 years, retreat has increased substantially when compared to the first period.

This research reveals the acceleration of regional climate change.

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POROSITY AND DETERIORATION OF STONE BUILDING MATERIAL IN ISTANBUL

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Keywords: porosity, deterioration, Mactra Bulgaria, limestone, Istanbul

Porosity is the ratio of pores (micro-voids) to total solid volume of stone. Pores develop as a result of compaction and the cementing process. A nearly unlimited variety of pore sizes and shapes are characteristic of sedimentary stones. Associated with stone porosity is its permeability. This is the extent to which the pores and capillary structures are interconnected throughout the stone. These networks, their size, structure, and orientation affect the degree and depth to which moisture, vapors, and liquids can be absorbed into the interior of the stone or migrate from the substrate by capillary action through the stone. Permeability may be greater in some directions than others based upon the pore size, shape, and the distribution of the interconnectedness of the system. Permeability is increased when a stone is highly fractured or the veining material is soft or grainy. The size and shapes of pores and the capillary structure differ in stones and are important factors relating to stone decay (Küçükkaya, 2004, 2014).

The processes leading to the deterioration of building stone in Istanbul have been the subject of numerous papers. Some building stones are preserved very well, even when they are very old. In some cases, deterioration is seen only on a few blocks in the same masonry structure while the others can still be in good condition even if stones showing both levels of preservation were mined in the same quarry (Erguvanlı, 1955). Considering the size of fossil remnants, some building stone can contain much more pore space than others. It also depends on issues involving selection of high quality stone in the quarry (Erguvanlı, 1967).

In general, ancient building stone in Istanbul is a limestone composed of calcium carbonate and crystalline limestone, which consists of minerals of calcite and aragonite. They are formed by inorganic chemical precipitation, sometimes with the contribution of organisms and organic processes. Pure limestone contains 56% CaO and 44% CO_2. Istanbul limestone that is named "Bakırköy kalkeri," "lumesel kalkeri," and in the Ottoman Period "kufeki" is limestone that includes fossils of the genus *Mactra*. It is mined in an area of Neogene formation lying between Haliç (Golden Horn) and Küçükçekmece Lake by the Sea of Marmara (Ariç, 1955). Mostly they are porous materials containing marine fossils in the area (Islamoğlu et al., 2008). The Bakırköy area is composed of folded Paleozoic greywacke, fine micaceous sandstone (Büyükmeriç, 1993) and shells of the Upper Devonian; over them, sand, clay, marl, and limestone beds of the upper Miocene lie uncomfortably (Aksu et al., 2000).

In recent years, restoration and conservation techniques have taken very much into account the petrology of the stone material. Complex chemical, mineralogical, and biological data have been incorporated into the consideration of weathering processes in stone, with a multi-disciplinary team working on cultural properties. Frost resistance is an important parameter for the durability of natural building stone in a cold environment. The pore structure determines, among other properties, the weathering processes of natural stones. Also, the transport and accumulation of water and dissolved gaseous pollutants in stones are highly dependent on the pore size distribution (Amoroso and Fassina, 1983). It is clear that any material that completely blocks surface porosity will lead to accelerated stone decay. Such materials should never be used (Garrod, 2001).

Shell limestone of Upper Miocene age has been used as building stone (Sayar and Sayar, 1962) in the majority of the monuments in Thrace and Istanbul because of its attractiveness, availability, and workability. The porosity and pore size distribution of a stone is related to its mollusk assemblages, which can have a major effect on durability, and a stone consolidant, which reduces the size of large pores but does not close them, may be harmful (Fig. 1).

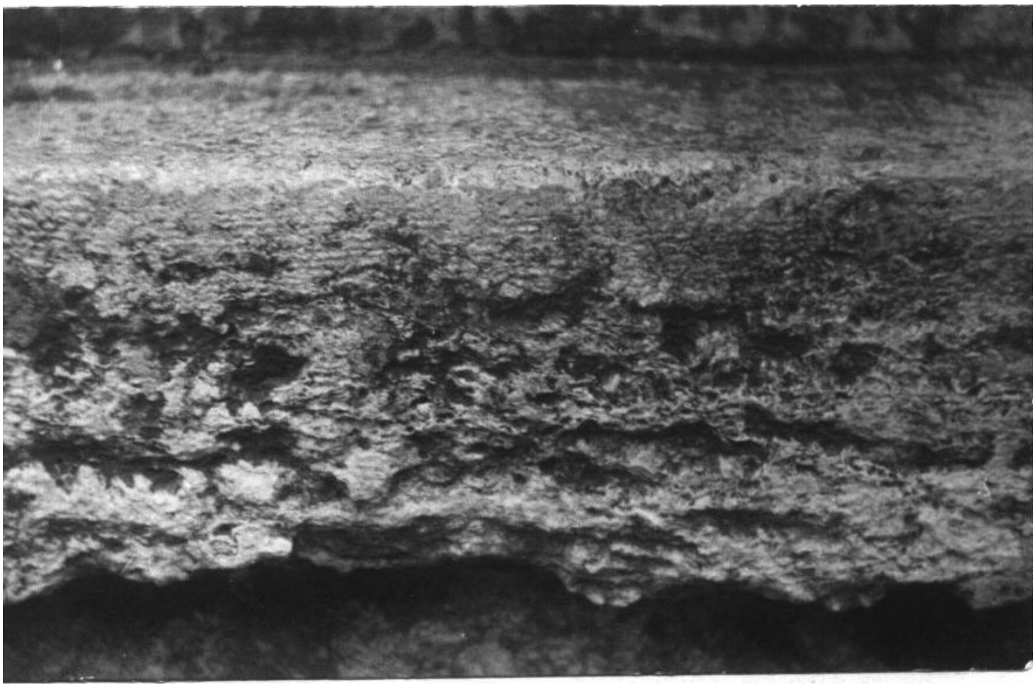

Figure 1. A border stone on the masonry structure in the courtyard of Aksaray Valide Mosque, Istanbul (1861). Deterioration of *Mactra* limestone that had been quarried from the Bakırköy quarries (Küçükkaya and Umaroğulları, 2003, 2005).

Volume and position of the pores of marine shells within the building stone are the most important issues concerning the durability of limestone in Istanbul. Microscopy gives the best information for determining porosity and mechanical properties, together with biological and chemical properties (Tuğrul and Zarif, 1999). Laboratory experiments help in the determination of the quality of suitable stones and their resistance to internal failure and external weathering.

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NEW RESULTS ON STRUCTURE OF THE SREDNYAYA AKHTUBA REFERENCE SECTION

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Keywords: Lower Volga, Caspian Sea, stratigraphy, Pleistocene, geochronology

Introduction

The Lower Volga is a unique region for understanding the history of the Caspian Sea in the Pleistocene as well as the correlation of its paleogeographic events with glacial-interglacial rhythms of the East European Plain and the global and regional climate changes. The reason is the representativeness of the Quaternary sections, their completeness, the presence of both marine and subaerial sediments, the paleontological richness of the materials, and their availability for study. The purpose of this work is to reconstruct the paleogeographic events in the Late Pleistocene of the Lower Volga region on the basis of a summary study of the Srednyaya Akhtuba reference section. This section was selected as a reference for research because it most fully reflects the events of the late Pleistocene.

Study region and methodology

Located near the city of Volgograd, at the Khvalynian plain 1 km above the bridge across the Akhtuba River (48.7005277 N, 44.89330709 E, altitude 16 m), the natural outcrop reveals a series of exposures unique to the region: a series of marine Caspian continental deposits with four levels of buried soil horizons and loess. The results were obtained during 2015 and 2016 by a complex field research program by a group of specialists from MSU, Saint-Petersburg University, and the Institute of Geography in the Lower Volga. Application of lithological, paleopedological, paleontological, paleocryological, OSL-dating, and paleomagnetic methods allowed a more fundamental approach to the chronological assessment of individual horizons.

Results

The Srednyaya Akhtuba section (Fig. 1, left chart) in its upper part is represented by modern soil, developed on subaerial post-Khvalynian (Holocene) sediments of sandy loam (layers 1-2), which received the "control" dating age of 720 ± 70 years.

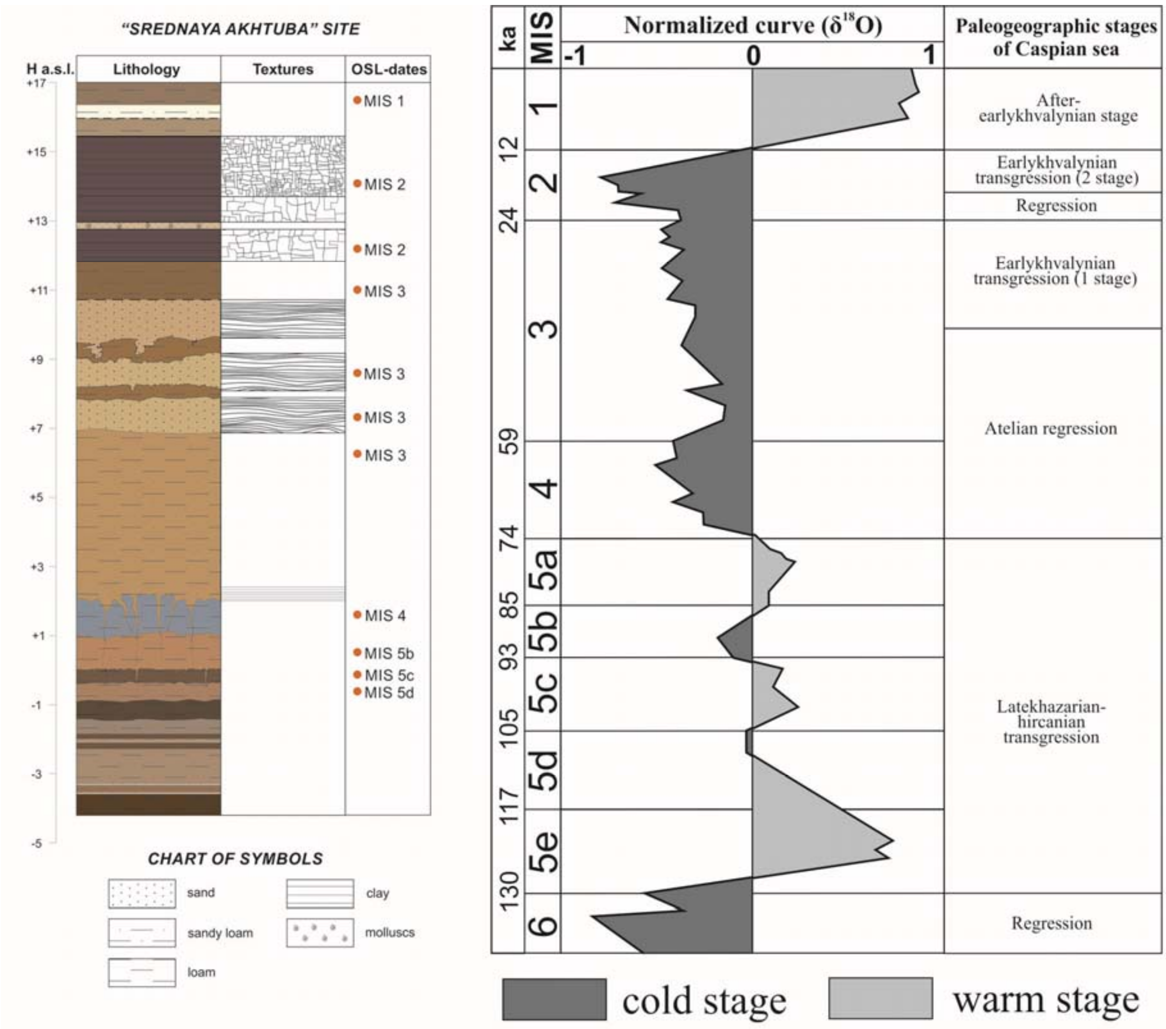

Figure 1. Srednyaya Akhtuba section and correlation of OSL-ages with MIS-stages.

Beneath them lies a thick deposit (layers 3-7) of Caspian Lower Khvalynian sediments: a layer of sandy loam, dark beige, horizontal stratification, with a smooth lithologically clear lower boundary (layer 3); two layers of chocolate clays horizontally layered on the top of each other: layer 4 of 0.75 m with small prismatic structure, thin layers (0.5 to 3 cm) of a beige-gray sand, and layer 5 of 0.95 m consisting of a solid structure in the bottom with a large prismatic texture (dating yielded 13,000 ± 500 years). Under the chocolate clays lies a layer of sand, 0.45 m in thickness, which includes numerous mollusk shells of Early Khvalynian *Didacna protracta*, *D. ebersini*, *Dreissena rostriformis*, and *Dr. polymorpha* (layer 6). The sands are underlain by another layer of chocolate clays, 0.9 m (layer 7) dated at 15,000 ± 1000 years.

Below a sharp boundary lies the formation of different facies (fluvial and subaerial genesis): sands and loams (layers 8-13) representing the Atelian stage in the stratigraphic scheme of the Caspian region (Fig. 1, right chart). Sediments of this formation represent a continental stage of development of the territory. The upper part is represented by a layer (0.5 m) of dense non-layered loam, uniformly lightly beige colored, forming a vertical wall (layer 8). Then, there is a sand layer, fine-grained, well-sorted, uniform beige color, with no clear stratification due to coarser sand layers, with calcareous inclusions and manganese smears (traces of soil formation process) showing a total thickness of 1.40 m (layer 9). Deposits of the top of the layer were dated to 27,000 ± 1580 years. Beneath this is a sand layer (0.40 m) with yellow-brown fine-grained streaks and lenses of light gray, with single manganese smears and a clear undulating lower boundary (layer 10). The sand is dated to 35,500 ± 2,800 years. Below that is a dense sand, small- and medium-grained, yellow-beige colored, with a total thickness of 1.45 m (layer 11) and dated to 36,780 ± 3000 years. The lower boundary is lithologically sharp. The stratum of sands is underlain by two layers of loess-like loam with columnar structure, forming vertical walls in the section. The top layer (12), 0.20 m, abounds in manganese smears and Calcium sulfate inclusions, dated 48,680 ± 3100 years. It passes into a thick (3.5 m) layer of sandy loam of uniform light brown color, with a few smears of manganese and gypsum inclusions (layer 13). The lower limit is irregular, with sediment penetrating into the underlying layers through deep wedges, cracks, and streaks.

Below, the section is represented by three clearly defined paleosols (see Makeev et al. in this volume). The upper soil horizon (layer 14) is represented by a dense loam gray-bluish in color, with nutty and fine comminuted structure, cryogenic cracks and wedges filled with syngenetic Atelian sandy loam (layer 13). The total thickness is from 0.7 to 1.0 m. The boundary limit is irregular with deep streaks in the underlying layer. The layers are dated to 68,280 ± 4170 years. The first paleosol is separated from the second one by a sandy loam loess layer (layer 15) with a thickness of about 0.7 m, mottled gray-brown color, with rusty spots and streaks, and dated to 87,620 ± 4100 years. The second soil horizon (layer 16) is characterized by a date of 102,500 ± 5160 years in age.

These soils are underlain by sediments (layer 17) of a shallow basin with calm (perhaps stagnant) sedimentation conditions (0.75 m); the result of dating yielded 112,630 ± 5400 years. Here lies another distinct paleosol horizon with a total thickness of 0.4 m (layer 18), represented by a dense loam with lumpy structure, dark gray and reddish-brown in color, with small calcareous concretions. The lower boundary is lithologically accurate, irregular. The underlying layer (0.3 m) is represented by a sandy loess-like loam of gray-brown color (layer 19). The lower boundary is slightly undulating and quite clear. At the base of the section, we identify estuary basin type deposits (layers 20-22) with an unstable level.

Conclusions

The structure of the Srednyaya Akhtuba reference section reflects a number of paleogeographic stages of development within the study area. The oldest phase (layers 22-19) is not characterized by OSL dating or faunal material. Based on the sequence of dated layers, we assume it is Middle Pleistocene in age (MIS 6 stage), corresponding to the Moscow stage of the Dnieper glaciation of the East European Plain and the final stage of the Early Khazarian transgressive era of Caspian Sea.

The next stage (layers 18-14), represented by three horizons of paleosols, refers to the first half of the Late Pleistocene (MIS 5). An epoch of soil formation, based on the results the OSL-dating, can be referred to the warm sub-stages (MIS 5c and 5a), and the climatically unstable transitional phase from the Mikulino (Eemian) interglacial to the the Valdai glaciation. The lower soil horizon that has no dating, logically refers to the maximum warm era of the Mikulino interglacial (MIS 5e). In the history of Caspian Sea, this era corresponded to the Late Khazarian transgressive-regressive stage (MIS 5): the Late Khazarian minor transgression (level of about -10 m), characterized by warm water (Yanina, 2014), and the Hirkanian transgression with slightly cool environmental conditions (Yanina et al., 2014). Both transgressive basins did not reach the latitude of Srednyaya Akhtuba.

The continuous stage of continental development of the territory, reflected in the structure of the section (layers 13-8), in the stratigraphic scheme of the Caspian region refers to the Atelian formation, situated between the Late Khazarian and Khvalynian transgressive epochs of the basin. Different facies complexes (layers 11-9) of alluvial deposits of the section reflect the stage of initial development of the Khvalynian transgression of the Caspian Sea—the accumulation of alluvial strata in raising erosion basis conditions. Climatically, it corresponds to the interstadial Inter-Valdai warming era (MIS 3).

The Late Pleistocene continental development stage ends with a phase of accumulation of loess sandy loam (layer 8). Obviously, it correlates with the last glacial maximum (MIS 2), a dry cold era, conditions of which were not conducive to the development of the Caspian transgression—it was a regressive (Eltonskaya regression?) stage (Yanina, 2014).

Thus, the continental Atelian era of the upper (Volgograd) area of the Lower Volga region reflects three distinct paleogeographic events in Caspian Sea history: (1) the Atelian Caspian regression under conditions of the Kalinin glaciation (MIS 4); (2) the initial stage of the Khvalynian transgression under conditions of interstadial warming (MIS 3); and (3) a regression corresponding to the Ostashkovski glaciation (MIS 2). This sedimentary complex represents the Atelian formation in the stratigraphic scheme of the Caspian region, the amount of which is beyond the scope of the same name Atelian regression (Yanina, 2012).

The "marine" stage of the area's development is expressed in the Khvalynian complex (layers 7-3), corresponding to the Early Khvalynian transgression of the Caspian Sea. The chocolate clays are interbedded with sands containing numerous shells of mollusks: *Didacna protracta*, *D. ebersini*, *Dreissena rostriformis*, and *Dr. polymorpha*. OSL dates on the chocolate clays (15,000 ± 1000 and 13,000 ± 500 years) testify to their accumulation during the era of the degradation of the Ostashkov glaciation (Chepalyga, 2009). These data are in good agreement with the results of radiocarbon dating of mollusk shells, lying in the sand interlayers within the thickness of the chocolate clays of the Lower Volga (Arslanov et al., 2016), and they are contrary to the thermoluminescence results (Shkatova, 2010).

Acknowledgments

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ANALYSIS OF SOUTH CASPIAN DEEP SEDIMENTATION FROM MARINE CORES

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Keywords: Caspian Sea, water level, deep sediment, sediment distribution

Introduction

The southern part of the south Caspian sub-basin is characterized by a narrow deep strip located between the Alborz Mountains and the Caspian deep depression. It represents a sedimentary basin with siliciclastic facies in the western and southern parts that gradually changes to carbonate in the east (Klenova et al., 1962; Lebedev et al., 1973; Kholodov and Lisitsin, 1989; Lahijani and Tavakoli, 2012). The main sources of sediments include: riverine, mudvolcano, coastal erosion, and eolian inputs, as well as biological and chemical processes. Sediments have been redistributed within a well stratified water column under rapid sea-level fluctuations and a hydrodynamically active environment (Ghaffari and Chegini, 2010). In order to understand the distribution pattern and controlling factors in the southern part of the south Caspian sub-basin, surface and subsurface sediments have been investigated.

Methodology

A total of 46 cores and 85 surface samples have been collected by gravity corer and grab sampler, respectively (Fig. 1a).

In situ physical and chemical properties of the seawater were probed by CTD. Over 1200 samples and sub-samples have been analyzed for grain size, organic matter, and carbonate content. Optical microscope, SEM, and XRD were applied to determine the mineralogy of the samples. Lead and cesium dating and CAT scans have been applied to a few cores.

Results

The analysis of sediments and measurements of the seawater have made it possible to delimit the distribution pattern. Muddy sediments are dominant in the lower shelf and slope, while in the upper shelf and nearshore, coarse-grained sediments prevail (Fig. 1b). The average content of organic materials is 3%, and calcium carbonate is 11%, and both increase in the deeper parts and eastern parts, respectively (Fig. 1c). The rate of sedimentation varies from 0.01 cm/y in the deep basin to 1cm/y in the accumulative areas of the upper shelf. The sediments are mainly composed of detrital, biogenic, and authigenic materials. The latter two materials are dependent on the overall climate and the Caspian Sea level (Pierret et al., 2012; Leroy et al., 2013). Based on the size and composition of the bottom sediments, they can be classified into three groups corresponding to the western, central, and eastern parts.

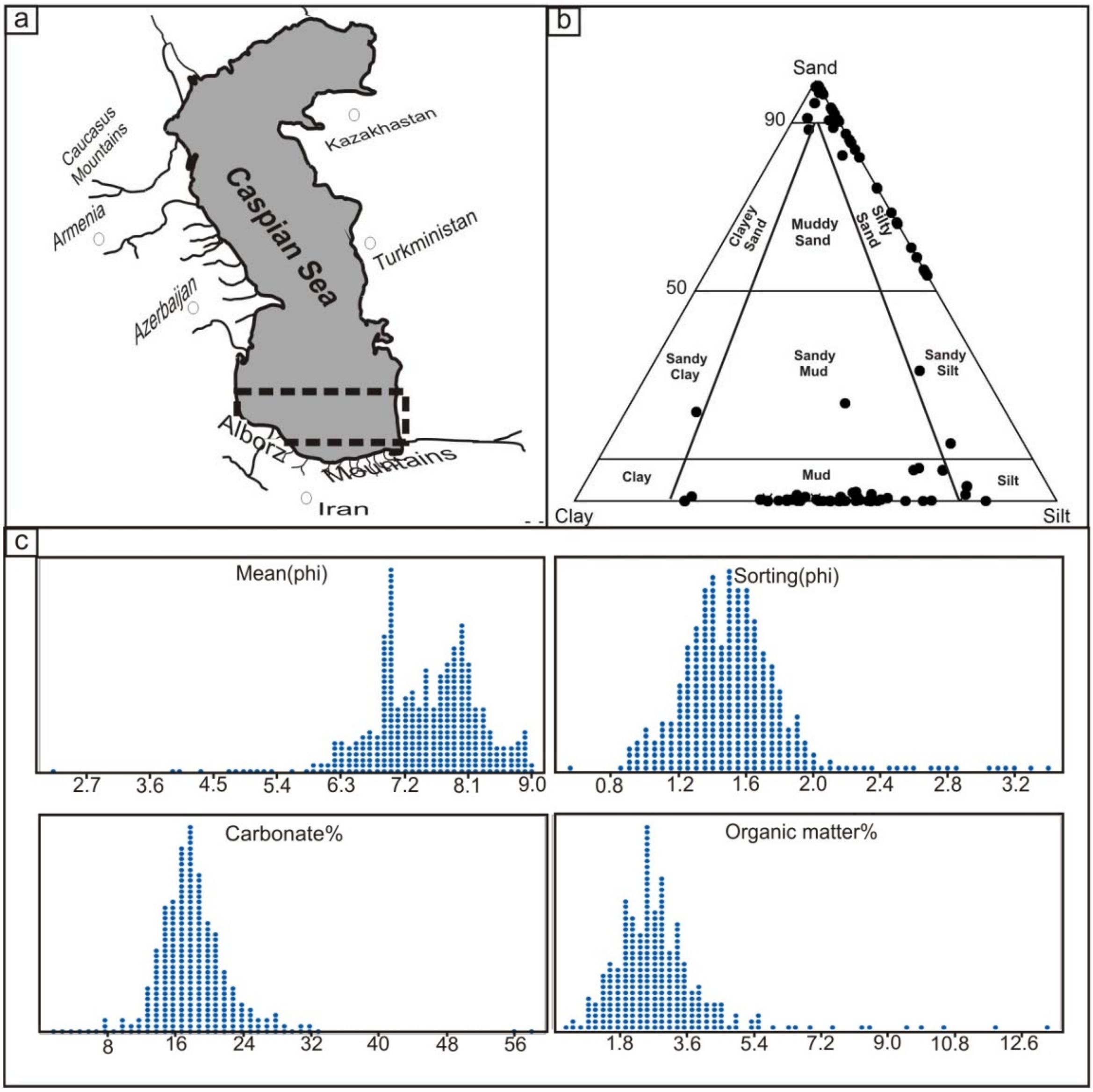

Figure 1a. Map of study area, sampling stations are within the dashed lines; 1b. Folk textural classification of sub-samples, the slope and lower shelf sediments are classified as mud texture while the upper shelf indicates a silty sand and sand texture; 1c. distribution of sedimentology parameters from the sampling stations, con-sisting of Rasht, Lahijan, Chalus, and Babolsar stations. The sedimentology data from all samples have been plotted on diagrams in the frequency graphs according to mean (φ), sorting (φ), carbonate (%) and organic matter (%).

Conclusions

Composition of the deep sediments of the south Caspian Sea represent four main sources, including detrital, biological, chemical, and biochemical. The distribution patterns of sediments are mainly controlled by riverine input in the upper shelf and sea currents (waves and bottom currents) in the slope and lower shelf. The rhythmic events and rapid changes in trace fossils occurred periodically during about a century, and their frequency coincides with sea-level change. Based on the high resolution of periodic laminations, we conclude that the depositional processes are influenced by sea-level change and its causal factor, i.e., climate change even during the course of a century.

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PEDOGENETIC RESPONSE TO CLIMATIC FLUCTUATIONS WITHIN THE LAST GLACIAL-INTERGLACIAL CYCLE IN THE LOWER VOLGA BASIN

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Keywords: paleosol, loess, marine clays, paleoenvironmental reconstruction

Introduction

Soils form under the direct influence of climatic parameters, and they retain environmental information in their features (soil memory: Targulian and Goryachkin, 2008). Thus, buried soils provide an excellent opportunity to reconstruct paleoenvironments preceding burial. The area of the lower Volga basin experienced considerable changes due to fluctuations in Caspian Sea level together with other responses to glacial-interglacial cycling in the Quaternary. Numerous horizons of buried soils have been recorded in sedimentary sequences, and they have been used for stratigraphic correlations and paleogeomorphic reconstructions in the area (Konstantinov et al., 2016). But the study of paleosols as a paleoenvironmental proxy has not been performed until now.

The study of the 20 m exposure on the terrace in the middle stream of the Akhtuba River provides a unique opportunity to reveal the complex interplay among several factors: Caspian Sea level cycling, related fluctuations in fluvial activity, continental (aeolian) sedimentation, the local environment of the Akhtuba River valley, and the pedogenetic response to environmental and geomorphic changes.

Study area and methodology

The site is situated on the terrace of the Akhtuba River with an elevation of 21 m asl and 20 km from Volzhskiy city. The exposure was thoroughly examined in the field. The stratigraphy includes a designation of loess layers separated by marine clays and fluvial deposits. Six pedogenetic levels (Fig. 1a) were examined morphologically according to the FAO Guidelines for Soil Description (IUSS, 2006: 109) and classified according to the WRB (2014). Soil samples for hierarchical morphological (mesomorphology, micromorphology, SEM) and analytical studies were taken from all horizons. OSL dating (described in the paper of Yanina et al., this volume) allows us to bracket the pedogenetic events to various stages within the last interglacial-glacial cycle.

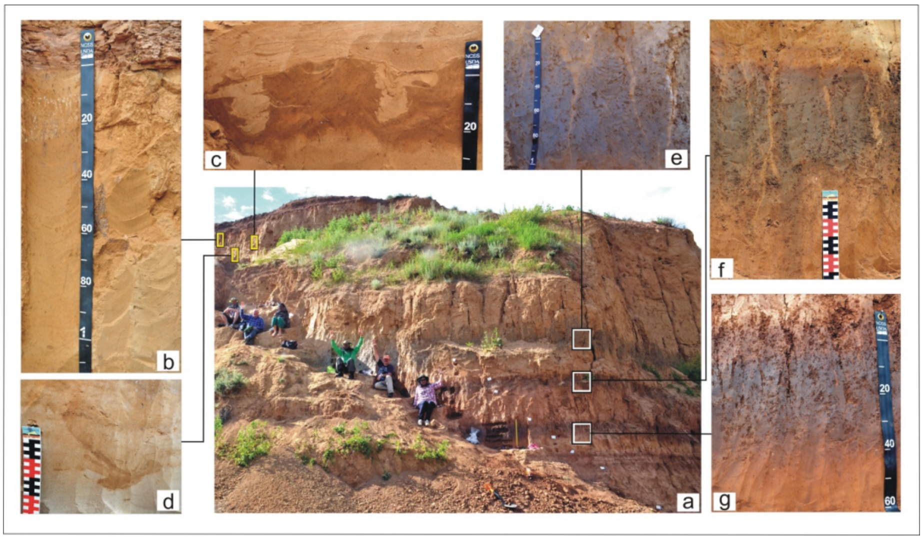

Figure 1. The Lower Akhtuba soil sedimentary sequence. a. General view; b. The upper MIS 3 paleosol in the Atel-Akhtuba strata with a truncated humus horizon; c. The middle MIS 3 paleosol of the Atel-Akhtuba strata with 30-40 cm deep sand cracks, forming a regular network; d. The lower MIS 3 paleosol of the Atel-Akhtuba strata with cryogenic deformations; e. The upper soil of the Mezin pedocomplex (MIS 5) with a network of frost wedges - Gleyic Phaeozem; f. The middle soil of the Mezin pedocomplex (MIS 5) - Gleyic Chernozem; g. The lower soil of the Mezin pedocomplex (MIS 5e) - Mollic Calcic Gleysol.

Results

The 20 m high exposure is capped by a 120 cm upper (MIS2) loess layer with modern surface soil (Kastanozem) typical for dry steppe areas. The loess is underlain by marine clays 120-520 cm. OSL dates for the middle (13,000±500) and lower parts (15,000±1000 yrs) characterizes marine clays of the Early Khvalynian transgression of the Caspian Sea (Arslanov et al., 2013). The clays consist of fine plates with a typical chocolate hue. The clay strata are slightly touched by pedogenesis down to 110±20 cm (230±20 cm from the day surface); vertical cracks and sub-angular structural units are covered by weakly developed clay cutans with overlying carbonate coatings.

Marine clays are underlain by a soil-sedimentary sequence formed during the Atel-Akhtuba regression of the Caspian Sea (MIS 3) with three pedogenetic levels developed in loess and correspond-ing to MIS 3 interstadial paleosols. The humus horizon of the upper well-developed soil (520-600 cm) is truncated to the AhB horizon (Fig. 1b). The remaining profile could be preliminarily attributed to a Relictigleyic Luvic Chernozem with Bt horizons showing well-developed clay-humus cutans covered by carbonate films. The profile is underlain by fluvial sand (600-770 cm), showing a gradual transition to silty loess loam downward. Sand merges laterally into the 10-20 cm loess layer with large gypsum crystals, confirming an arid environment at the time of loess sedimentation.

The second pedogenetic level (770-800 cm) is presented by loess strata with weakly developed soil without clear horizonation. Pedogenetic features include platy and angular structural units, clay cutans, rhizoliths, manganese mottling, carbonate concretions, and gypsum crystals. Dark spots indicate the remains of displaced humus horizons. The upper surface of the pedogenetic level is complicated by a regular network of sand cracks, indicating severe seasonal frost and possible permafrost (Fig. 1c).

The third pedogenetic level is concise with shallow loess patches (880-910 cm), merging laterally and covered by a fluvial sand interlayer (800-880 cm, Fig. 1d). Pedogenetic features are recorded in clay cutans and biopores. Remains of a carbonate horizon are visible in the upper 7 cm of loess. The third pedogenetic level is disturbed by cryogenesis (Fig. 1d). The lower part of the loess is intermixed with sandy lenses.

The study of the MIS 3 soil-sedimentary complex confirms that the soils formed in a cold, arid environment during short periods of mesomorphic pedogenesis coinciding with loess sedimentation and interrupted by an increase in fluvial activity. A cold environment and possible permafrost are indicated by frost wedges and involutions disturbing the soil horizons. Gley mottling contradicting the aridity features could be the result of waterlogging owing to long-seasonal overflooding of the terrace surface. The lower part of the Atel-Akhtuba strata (910-1530 cm) is represented by a carbonate loess without noticeable pedogenetic transformation.

The Mesin pedocomplex (MIS 5a-e, 1530-1680 cm) is attributed to the Late Khazarian transgressive epoch and includes three distinct soils formed in loess. The age of the upper soil (MIS 5a-d) is characterized by OSL as 68,000 ± yrs. The Gleyic Phaeozem has an accretionary humus horizon (about 1 m) owing to synsedimentary pedogenesis at the onset of loess sedimentation. The soil surface is disturbed by a network of frost wedges 40-50 cm apart with a broad part going down to 40 cm and narrow fissures much lower than the soil profile (Fig. 1e). The wedges start in the overlying Atel-Akhtuba loess layer, indicating the beginning of the last glacial cycle (MIS 4). Krotovinas, mostly expressed at 20-30 cm from the buried surface, show a steppe environment, and gleyic features indicate seasonal overflooding. Lower horizons (1650-1670 cm) are developed in loess and interlayered with fine sandy layers owing to contrasting sedimentation. The soil profile gradually merges into the middle soil of the Mesin pedocomplex (1670-1790 cm, Fig. 1f).

The upper 5 cm of the humus horizon of the middle soil (Gleyic Chernozem) are intermixed with the Bg horizon of the upper soil (welded paleosol). Carbonates in the upper layer are most probably diagenetic; in the Bg horizon, the complex assemblage of carbonate neoformations is a result of steppe pedogenesis. Gleyic features are due to seasonal overflooding. Narrow endings of frost fissures penetrate from the Atel-Akhtuba loess down to the middle part of the profile.

The lower soil of the Mezin pedocomplex (MIS 5e) is separated from the middle soil by a transportic layer (1790-1800 cm) and represented by a Mollic Calcic Gleysol (1790-1860 cm, Fig. 1g) formed in loess sediments accumulated during the penultimate glaciation (MIS 6).

The presence of the Mezin pedocomplex formed in loess confirms that the area was beyond the Late Khazarian transgression of the Caspian Sea. Nevertheless, the high stand of the Akhtuba River caused long-term seasonal overflooding resulting in gleyic features. Three soils of the Mezin pedocomplex have common features: well-developed humus horizons and a complex assemblage of carbonate neoformations formed in a steppe environment; gleyic features owing to long-term seasonal overflooding; welded and/or synlithogenic profiles owing to contrasting sedimentation on the river terrace.

The lower part of the sequence is represented by interlayering of loess and clay bands without clear pedogenetic influence that indicates quick sedimentation with contrasting changes in the water level of the Akhtuba River. However, carbonate pseudomicellia indicate at least primitive pedogenesis in clays on the river terrace or dried firth surface.

Conclusions

The soil sedimentary sequence is formed in loess layers intermixed with marine and fluvial sediments. The upper loess (MIS 2) is underlain by marine chocolate clays. Such a unique feature allows setting a reliable correlation for Caspian marine and lower Volga loess stratigraphic patterns. Loess sedimentation on the river terrace frequently changed to fluvial sedimentation according to fluctuations of the Caspian Sea level. Various loess units are divided by stream sands and terrace clays. Six pedogenetic levels are linked to periods of loess sedimentation between MIS 5 and MIS 1. The longer interval of geomorphic stability after loess sedimentation results in better developed loess profiles. All soils were formed in an arid environment that is indicated by a complex assemblage of carbonate neoformations and krotovinas. Nevertheless, all soils except the modern one show hydromorphic features (gley mottling, iron and manganese concretions). Such a mutually exclusive combination of soil features indicates polygenesis caused by river influence: long-term seasonal overflooding. There are three levels of interstadial paleosols (MIS 3). They formed in a cold and arid environment. This is especially obvious in the upper pedogenetic level that was influenced by deep seasonal freezing during the LGM. Interglacial soils (MIS 5a-d and especially MIS 5e) are much better developed. In contrast to the last interglacial soils of the center of the East European Plain (Mikulino) and Western Europe (Eemian), they are represented by steppe soils with gleyic features—Gleyic Chernozems and Mollic Calcic Gleysols. Soils are partly synlithogenic, their upper horizons formed simultaneously with loess sedimentation. The Mezin pedocomplex is represented by welded profiles. The upper horizons of some profiles are truncated. Interlayering and a gradual transition between loess and sand layers, contrasting pedogenetic features (humus accumulation and clay cutans, a complex assemblage of carbonate neoformations, gypsum crystals and gleyic features) indicate contrasting sedimentation and pedogenetic environments.

Pedogenetic horizons serve as good stratigraphic markers that will help correlate late Pleistocene soil-sedimentary sequences of the whole Caspian-Azov-Black Sea region of the East European Plain and link it with global stratigraphic schemes.

Detailed analytical and further field studies are required to reveal further pedogenetic responses to environmental changes in the area.

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CLAY MINERAL PROVENANCE OF LOWER KHVALYNIAN DEPOSITS IN THE MIDDLE AND LOWER VOLGA RIVER VALLEY

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Keywords: Late Pleistocene, glaciations, provenance, Northern Caspian lowland, X-ray diffraction

Introduction

During the Late Pleistocene (15-13 ka), thick masses of clays were formed in the North Caspian Sea Lowland and Middle Volga River valley. These clays are one of the dominant facies in the Lower Khvalynian sediments and are also called “chocolate clays.” One of the possible triggers for clay formation was the huge runoff through the Volga River catchment area. The Upper Volga River basin was determinative for the water balance of the entire Lower Khvalynian basin (Kalinin et al., 1966), especially its northwestern sector, which contributed to the huge runoff through the active melt regime of the Late Valdai ice sheet after the LGM (18-20 ka BP) (Svendsen et al., 2004). The aim of this research is to determine the origin of clay minerals in the Volga River basin to trace their pathways during in the Lower Khvalynian basin transgression.

Regional settings

A number of moraine complexes of the Pleistocene glaciations exist within the Volga River area, which covers 1380 thousand km^2. Each moraine complex is characterized by individual terrigenous, authigene and clay mineral compositions. These complexes form the basis for the classification of mineralogical provinces of the Russian Plain during the Pleistocene glaciations; two mineralogical macro provinces are identified: a western hornblende-garnet-illite and an eastern epidote-hornblende-smectite-illite (Sudakova and Nemtsova, 2004). The concentration of illite reaches 60-70% in the west and 40-50% in the east. In the eastern part of the Volga basin area of Permo-Triassic red clays, 60% consists primarily of smectite.

During the Early Khvalynian age, the Middle Volga River valley was an estuary where transgression and river waters were interflowing. These processes formed different sediments, which consist of a number (more than one hundred) of layers of clays, clay-loams, and sands. Only in a few semi-closed, small bay areas, especially on the right bank, clays are dominant with an average thickness of 5 m. Sediment structures of the Lower Volga River valley are different, with chocolate clays predominating in facies and filling the pre-Khvalynian depressions.

Materials and methods

In order to investigate the pathways of clay minerals, eight samples of clays and clay loams were collected during the summer field trip of 2012 from outcrops within the Middle and Lower Volga River valley (Novorpivolnoye, Torgun, Svetly Yar); these samples were separated to particles of size <2 μm and analyzed with X-ray diffraction (XRD). Also, two samples of brown moraine clay-loam and Permo-Triassic red clay were collected from the Upper and Middle Volga River basin.

First results

Clay minerals of the Middle Volga River valley are represented by illite (33%), kaolinite (16%), smectite (28%), chlorite (17%), and mixed layers (6%). See the table.

Sample	Section	Lithology	Level (cm)	Kaolinite	Illite	Chlorite	Smectite	Mixed layers
GF-1	Middle Volga	red clay	-	5	15	10	60	10
GF-2	Svetly Yar	chocolate clay	200	29	40	9	7	15
GF-3	Upper Volga	clay loam	-	33	45	-	22	-
GF-4	Svetly Yar	chocolate clay	300	33	43	8	8	8
GF-5	Svetly Yar	chocolate clay	600	26	48	17	3	6
Obr.1-13	Svetly Yar	chocolate clay	150	27	33	21	13	6
Obr.2-13	Svetly Yar	chocolate clay	530	22	34	23	9	12
Obr.3-13	Svetly Yar	chocolate clay	950	18	40	19	13	10
Obr.4-13	Novoprivolnoye	chocolate clay	670	16	33	17	28	6
Obr.5-13	Torgun	chocolate clay	150	25	38	22	11	4

In the Lower Volga River valley (Svetly Yar section), the outcrop profile demonstrates the prevalence of illite (33-48%) and kaolinite (18-33%). The concentration of chlorite decreases from 23% to 9% within intervals of 530 cm to 200 cm, respectively. Smectite demonstrates little fluctuation and does not exceed 13%. Moraine clay loam also demonstrates a prevalence of illite (45%) and kaolinite (33%), with a smaller concentration of smectite (22%), while chlorite in this sample was not detected. In the Permo-Triassic red clay, smectite reaches its maximum content (60%), and other clay minerals are represented by illite (15%), kaolinite (5%), and chlorite (10%). Enhanced concentration of smectite in the Middle Volga River valley outcrop might be a result of erosion of the Permo-Triassic formation, which is located near this area.

Illite is a major clay mineral in the Lower Khvalynian sediments of the Middle and Lower Volga River valley, and its maximum can be an indicator of intensive erosion of northern moraine complexes by a huge runoff of glacial melt water during the degradation of the Late Valdai ice sheet. According to Sudakova, material from the smectite-enriched area in the eastern mineralogical macro province also can be transported by runoff.

Acknowledgments

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PALYNOLOGY OF SARMATIAN CLAY AT ELTIGEN, KERCH PENINSULA: FIRST REPORT

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Keywords: pollen, dinoflagellate cysts, paleoclimate, paleolimnology, Paratethys

Introduction

Little is known about the pre-Pleistocene Eastern Paratethys geological remnants in the Pontic basin which may provide crucial information on mechanisms that divided the Miocene Seaway into the Pleistocene Black and Caspian Seas (e.g., Esin et al., 2016). Palynology is a well-known tool for land-sea correlation and for paleoecological studies of these regions (e.g., Koreneva and Kartashova, 1978; Filippova, 2002; Filippova et al., 2010; Grothe et al., 2014); however, there are few previous palynological studies of the Late Miocene Sarmatian interval (23.7 to ca. 8 Ma) in the Eastern Paratethys. There are also few Late Miocene records of the organic-walled dinoflagellate cysts that are sensitive indicators of sea-surface salinity (Mertens et al., 2012). Therefore, a sample of organic-rich Miocene clay from below Karangatian lagoonal sediments at the "Eltigen" neostratotype near Kerch (ca. 45^o 12' 51.83" N, 36^o 24' 7.86" E) has been studied to obtain the first information on the pollen, terrestrial and algal spores, and dinoflagellate cysts in the Sarmatian clay bed of the Eastern Crimean Peninsula. This paper is the first known report on the recovery of well-preserved pollen-spore assemblages and common but less well-preserved dinocyst assemblages at this site that may be compared with the Peninsula Zheleznyi Rog and Taman records for Taman Peninsula (Filippova, 2002) and Upper Badenian-Sarmatian assemblages in western Ukraine (Gedl and Peryt, 2011).

Methodology

During the IGCP 521 field trip in 2007, Andrey Chepalyga excavated a large sample of dark gray, silty clay sediment from below the surface layer near the top of the anticlinal Sarmatian clay bed at the south end of the 3.5 km-long cliff exposure between Eltigen and Lake Tobechik on the Kerch Peninsula. A subsample of 10 g dry weight was processed for palynological study in the CREAIT laboratory by Helen Gillespie at Memorial University of Newfoundland, using standard methods for Quaternary marine palynology (Mudie et al., 2011). The sample was first disaggregated in Calgon solution; then the palynomorphs and other particulate organic matter were extracted by chemical treatment with cold 10% hydrochloric acid to remove carbonates, after which cold 52% hydrofluoric acid was used to digest the silicates. *Lycopodium* tablets were added to allow estimates of palynomorph abundances, and palynological residues were sieved on a 10 micrometer screen to remove remaining abundant, very fine debris. Residues were mounted in glycerine gel and examined at x400 with a Zeiss Research Microscope and interference contrast objectives, to a count of 1,000 specimens.

Results

Initial results show that the Eltigen Sarmation clay contains an abundance of sporomorphs (91,597 pollen and spores/g dry sediment) in a dense matrix of amorphogen (c. 50%) with c. 25% poorly-sorted wood fragments. Much lower amounts of organic walled dinoflagellate cysts (3,279/g) are present, together with smaller amounts of algal spores or coenobia (Fig. 1n).

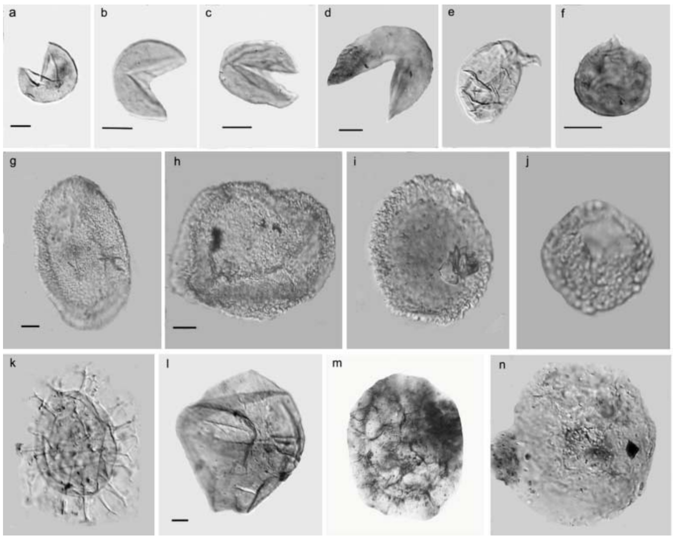

Figure 1. Light microscope images of some key pollen, dinoflagellate cysts, and algal remains in the sample from the Sarmatian clay bed at Eltigen. a,b: *Cupressus*; c,d: *Glyptotrobus*; e,f: *Taxodium*; g,h: *Tsuga* spp.; i: *Tsuga canadensis*; j: *Sciadopitys*; k: *Sp*

This palynofacies is typical of a coastal delta-front setting like that off the modern Danube Delta, except for the absence at Eltigen of foraminiferal linings and other zooclasts. The pollen assemblages are greatly dominated (77%) by coniferophyte pollen, primarily *Pinus* and *Picea* spp. but also notable amounts of *Abies*, *Cathaya*, *Tsuga* (3 species, Figs. g-i), and *Sciadopitys* (Fig. 1j), and swamp cypresses including *Cryptomeria*, *Glyptostrobus*, and *Taxodium* (Figs. 1a-f); there is a trace amount of *Gingko biloba.* A relatively low diversity (ca. 14 identified taxa), temperate deciduous tree flora comprise about 13% of the pollen-spore assemblage, with *Juglans*, *Carya*, and *Betula* as the main taxa. Non-arboreal taxa, including aquatics (*Typha*, Cyperaceae, *Nipa*), comprise only 3% of the pollen-spore assemblages in comparison to the predominance of Poaceae, and Asteraceae pollen in the modern sediments of the region. Pteridophytes comprise c. 4% of the pollen-spore total, dominated by *Leiotriletes* and *Osmunda*, with traces of *Cicatricosisporites* and *Plicatella*-type spores probably being reworked elements. Small amounts (<1%) of mosses are represented by *Sphagnum* and *Diphasiastrum* spores. Sparse amounts of algal remains comprise a *Cosmarium*-type desmid, a Charaphyte oospore, *Botryococcus* and an unknown cenobial alga (Fig. 1n). The low diversity (c. 16 taxa) organic-walled dinoflagellate cysts (dinocysts) are relatively poorly preserved compared to the pollen and spores, with many specimens being oxidized, torn, or crumpled, making identification difficult. The dinocyst assemblage is dominated by gonyaulacoid species, with the main species being *Systematophora placacantha* and *Spiniferites pseudofurcatus* (Fig. 1k), and including *Achomosphaera* sp., *Nematosphaeropsis* sp., and *Operculodium* spp., which today occur only in the marine-influenced Marmara and Black Sea sectors of the Ponto-Caspian Seas. *Lingulodinium machaerophorum* with long processes indicates a salinity >8 psu. The Eltigen cyst flora shows much lower diversity than the Late Miocene flora at North Ossetia (Filippova et al., 2010) to the east of Kerch Strait where *Deflandrea* and *Tuberculodinium* are common. The Eltigen dinocyst flora also share few elements with the Sarmatian flora at Zheleznyi Rog; the latter contain *Galeacysta etrusca* and *Spiniferites bentorii* morphotypes that characterize the brackish water (<11 psu) lacustrine Pontian-stage floras of the Paratheyan Seas. None of the floras contain cruciform taxa that mark the Ponto-Caspian basins today. The Eltigen cyst flora also differ from the Late Badenian flora at Kudryntsi, (W. Ukraine) in lacking *Polysphaeridium* and *Impagidinium* spp., which are typically marine elements, and in having 25% heterotrophic taxa, including the protoperinioids *Quinquecuspis* (or *Lejeunecysta*, Fig. 1l) and *Selenopemphix nephroides* and the cyst of a colonial dinoflagellate *Polykrikos* (Fig.

1m). These occurrences of *Quinquecuspis* and cysts of *Polykrikos* may be new records for these typically Quaternary taxa.

Conclusions

The kerogen composition of the Sarmatian clay sample is typical of a delta-front setting, supporting models of widespread development of large fluvial systems in the late Middle Miocene. The pollen-spore assemblages indicate a mixture of European and East Asian coniferous forest elements in a warm humid climate that supported swamp cypresses. Comparable forests but more deciduous tree elements and larger amounts of *Quercus* characterized the humid climatic phases on the Taman Penisula, but the dinocysts at Zheleznyi Rog included more typical brackish water Paratethyan species. The palynological data from a bulk sediment sample of the Sarmatian clay bed at the Eltigen exposure indicate that further studies are strongly recommended to resolve details of paleo-climatic and oceanographic events prior to the late Neogene uplift of the Kerch-Taman arch. Overall, however, the initial results support the model proposed by Esin et al. (2016) for the evolution of the Eastern Paratethys, with the Eltigen site reflecting pre-drainage conditions that separated the Black and Caspian Seas.

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PALYNOLOGY OF SURFACE SAMPLES, UKRAINIAN SHELF, NW BLACK SEA: FIRST REPORT

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Keywords: pollen, dinoflagellate cysts, algal remains, paleoceanography, pollution

Introduction

Marinopalynology studies were made using 15 surface sediment samples from the Ukrainian shelf, NW Black Sea, as part of an environmental monitoring program EMBLAS (Environmental Monitoring of the Black Sea) within the European Marine Strategy Framework Directive. The purpose of the EMBLAS studies is to prepare for more effective protection of the waters of the European seas in the future. The palynological samples are from water depths of 13 to 52 m and include nearshore to outer shelf locations between the Danube Delta (Fig. 1, sites 5-7) and the Crimean Peninsula (Fig. 1, site 12).

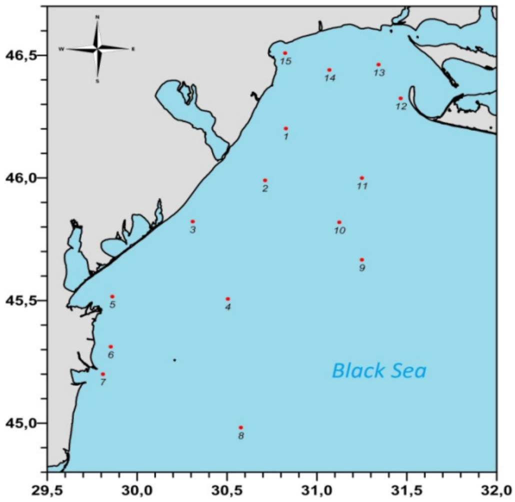

Figure 1. Map of surface sample distribution, Ukrainian shelf, NW Black Sea.

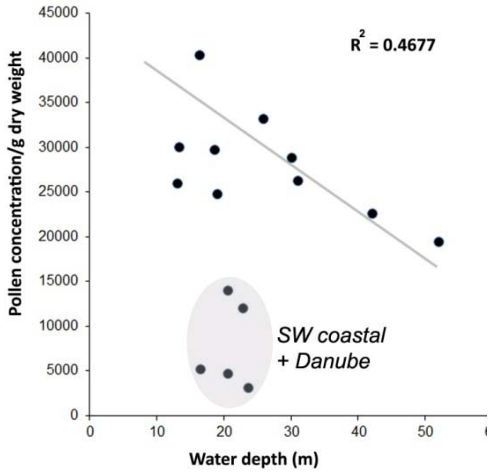

Figure 2. Pollen concentration vs. water depth for samples in Figure 1.

This is a region of quasi-permanent anticyclonic gyres formed by the Rim Current seaward of sites 8 and 9 (Fig. 1) and of strong mixing with large but annually variable amounts of discharge from the Danube, Dniester, Bug, and Dnieper rivers. The palynological data include pollen and terrestrial spores that originate from vegetation onshore and are transported to the sea by wind and river transport (Mudie et al., 2011). The data set also includes: (1) resting spores of organic-walled dinoflagellate cysts that are sensitive indicators of salinity (Mertens et al., 2012) and eutrophication (Giosan et al., 2012; Mousing et al., 2013); (2) remains of aquatic algae, including freshwater species; (3) fungal spores that can indicate soil erosion, and (4) microforaminiferal linings derived from benthic foraminifera. The results of the surface sample investigation will be used in planning for improved protection of the Black Sea environment though better understanding of pollution sources (from air or river discharge) and the potential for increased outbreaks of harmful algae (HABs), including toxic dinoflagellates.

Methods

Surface sediment samples for this study were obtained on 2016 cruises of RV "Mare Nigrum," where concurrent oceanographic measurements also included water temperature, salinity, transparency, pH, dissolved oxygen, and chlorophyll-a. Palynomorphs were prepared for microscope study using the Kiev University method of sample treatment, which is based on the method used at Sapienza University of Rome. First, 10% HCl is used to remove carbonate from the sediment sample of 2 g dry weight after addition of 2 *Lycopodium* tablets and boiling for 10 minutes. After washing with distilled water until neutral pH, 15% $Na_4P_2O_7$ is used to disperse the sediment particles to remove clays after boiling for 10 minutes. After washing with distilled water, cold 40% HF is used to remove silicates by chemical digestion. Residues are mounted on microscope slides in glycerine gel.

Results

Although the grain size analysis shows that about half of the samples are coquina with large quantities of shell fragments >10 mm maximum diameter, all the palynology samples produced moderate to large amounts of terrestrial pollen and spores (3179-40,400 grains/g pollen), and smaller amounts of non-pollen palynomorphs (NPP), including dinoflagellate cysts (dinocysts), aquatic algae, fungal spores, and organic microforaminiferal linings. A large diversity of pollen taxa was obtained (70 taxa: mostly arboreal species but including 32 kinds of herbs and 17 aquatic plants). All samples were dominated by bisaccate tree pollen, mainly *Pinus* spp., and by wind-transported herb pollen (Poaceae, chenopods, *Artemisia*, and other tubuliform Asteraceae typical of agricultural areas and steppe grassland), with small amounts of 17 water-transported aquatic herb species. This pattern suggests a strong influence of wind transport from boreal forests north of the coastal region where the land has long been largely cleared for agriculture. Few pollen species distribution patterns can be discerned, e.g., the presence of *Ephedra* seems to mark the Dnieper drainage, and overall there is a lesser dominance of *Fraxinus*, *Salix*, and *Ambrosia* pollen than prevails off the Danube Delta riparian forest area. Overall, there is a weak correlation (R^2 <0.2.5) between pollen concentration and water depth (proxy for distance offshore), but if the group of five Danube + SW nearshore samples (Fig. 2) are removed from the statistics, a correlation of $R^2 = 0.4677$ is found to mark the expected exponential decrease of pollen concentration with water depth/distance offshore.

Overall, the low presence of aquatic algae (*Pediastrum/Botryoccus*) and fungal spores indicate minimal fluvial influence and fluvial soil erosion at the study sites. Dinoflagellate cyst concentrations, including HAB species *Lingulodinium machaerophorum* and *Operculodinium centrocarpum*, are relatively low. Dinoflagellate species diversity number is also low (N = 9) compared to values of N= 17-30 reported by Marret et al. (2015) using a cold processing method with sieving. The "Mare Nigrum" dinocyst concentrations/g show no clear correlation with water depth (Fig. 3), or with salinity (between 7.64 and 18.29 psu), temperature (from 7.48-11.3 ^{o}C) or oxygen, and they show little correlation with % sand contrary to the classical patterns reported for macrotidal shelf seas. However, after removal of two outlying samples (Sites 6 and 12), a relatively strong correlation ($R^2 = 0.697$) is found between dinocyst concentration and chlorophyll-a values (Fig. 4). This is the first quantitative confirmation of a link between dinocyst and diatom populations (= Chla-a proxy values) that are predated on some plankton-stage dinoflagellates, including *L. machaerophorum* motile stage. Overall, the numbers and diversity of the "Mare Nigrum" zoomorphs, including microforaminiferal linings seems low: (0)50-2031 linings/g compared to Danube shelf data with values of 60-2839/g (Frail-Gautier and Mudie, 2014: Table 2), but more work is required for a large group of Unknown NPP.

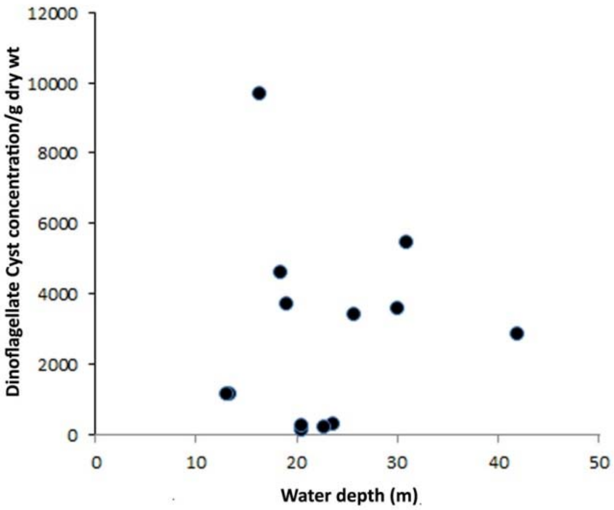

Figure 3. Dinocyst concentration/g vs. water depth for samples in Figure 1.

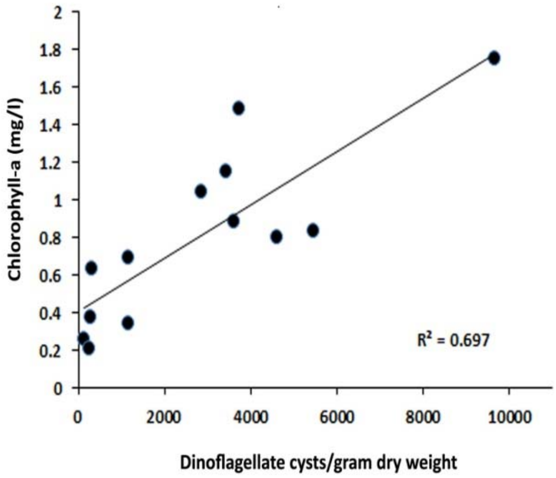

Figure 4. Dinocyst concentrations vs. chlorophyll-a values for 13 of 15 sites in Figure 1.

Conclusions

The initial results of the marinopalynological study point to the importance of offshore wind transport of particulate organic matter, probably by strong northern winds, and relatively smaller amounts of fluvial transport. The method chosen for palynological processing of coarse-grained coquina-type sediments is excellent for pollen-terrestrial spore recovery, but it results in under-representation of dinocysts and microforaminifera. The dinocysts recovered include HAB species that can be toxic for shellfish and perhaps should be monitored using less processing without boiling. Regardless, the initial results indicate an important link between dinocyst concentrations and chlorophyll-a values. This link with high Chl-a was suggested by Marret et al. (2015) for the Danube and Sevastopol gyre regions but has not previously been statistically validated.

Acknowledgments

This paper is a contribution to EMBLAS “Environmental Monitoring in the Black Sea” project. It also contributes to the IGCP 610 project “From the Caspian to Mediterranean: Environmental change and human response during the Quaternary.” The third author thanks the staff of “Mare Nigrum” for help in obtaining sediment material.

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POLLEN-BASED RECONSTRUCTION OF THE PLIO-PLEISTOCENE VEGETATION AND CLIMATE CHANGE IN THE NORTH CAUCASUS

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Keywords: Akchagylian-Apsheronian paleoenvironments, Northwestern Caspian region

Introduction

Upper Pliocene to lower Pleistocene Akchagylian and Apsheronian deposits are widely distributed within the southeastern part of the East European Plain (Svitoch, 2014), including the North Caucasus. Economic activity in this oil and gas province requires an understanding of environmental changes and the discovery of analogues for the latter. Among the methods, pollen analyses play an important role since they provide information on changes in flora and climate. This study uses material from the North Caucasus to the west of the northern Caspian region (the Caucasus Mineralnye Vody region, the Tersko-Sunzhensky area, and the foothills of Dagestan), places where the palynology of the Akchagylian and the Apsheronian has not been previously studied in detail (Naidina, 1999). On the basis of pollen assemblages in sediment cores and outcrops from the North Caucasus, climatic fluctuations and related changes in vegetation can be recognized for the interval between 3.6 and 0.8 Ma. Evidence from the pollen studies shows that climatic warming in the North Caucasus occurred at around 3.2 Ma, coinciding with a period of warming in the Mediterranean.

Methodology

Samples from several outcrops within the basin of the Terek and Sunzha were investigated. The pollen data are based on the results of palynological analyses of hundreds of samples selected from several outcrops that have already been characterized faunally. Material from four cores around Pyatigorsk and a core from the Kizlyar area in the Dagestan foothills was also studied. Representative counts were made of pollen and spore grains. A paleogeographical analysis of the arboreal flora was applied based on the interpretation of the pollen data. Reconstructions of vegetation and climatic conditions were made according to the ecological requirements of the plant groups present.

Results

Several Synthesized Pollen Complexes (SPCs) have been allocated in the Akchagylian and Apsheronian of the North Caucasus region (Naidina and Richards, 2016). A comparison of the Akchagylian SPCs of the Tersko-Sunzhensk area with the Caucasus Mineralnye Vody (CMV) region has shown that they display somewhat different elements of arboreal type. Judging from the SPCs in the Tersko-Sunzhensk area, there is a dominance of pollen from broad-leaved trees. In the SPCs from the CMV region, there is a predominance of pollen from pine and forest-taiga forms.

Reconstructions of the environments suggest that the vegetation cover was directly related to the climate. Broad-leaved oak forests predominated during the Akchagylian of the Tersko-Sunzhensky area, and it was apparently somewhat warmer than in the CMV region, where coniferous forests dominated, including Tsuga and broad-leaved varieties. In all probability, the observed differences are due to topographic variations, resulting from forests growing at different altitudes. This may be related to the glaciation of the Greater Caucasus (Kozhevnikov, 1986), which led to the altitudinal limits for broad-leaved forests being lowered.

Results of the pollen studies confirm that there was also a well-defined series of vegetation zones deployed from north to south over the area of the eastern part of the North Caspian region. To the north, taiga forest dominated (Kuznetsova, 1966), whereas in the southwest of the North Caspian region, a treeless steppe landscape persisted (Kovalenko, 1971). In the south of the North Caucasus, the steppe was replaced by forests of spruce and pine with areas of broad-leaved forests, and by broad-leaved oak forests mixed with conifers in the foothills. Late Akchagylian and Early Apsheronian times were characterized by an intensification of the continental climate and increasing aridity. Steppe landscapes predominated.

The development of vegetation in the Plio-Pleistocene was influenced less by the biological evolution of plants, and more by their geographical distribution. In the Akchagylian, several subtropical and tropical elements disappeared, and a more moderate, temperate flora became established. The changes in the vegetation cover resulted from alternating phases of climatic humidification and aridification.

According to pollen data, a noticeable change in the ratio of basic floral elements coincides with the beginning of the Akchagylian around 3.6 Ma. In the Mediterranean, the same time was marked by increased seasonality, humidity, and lower winter temperatures (Suc, 1984). Between 2.6 and 2.3 Ma, corresponding to the Mid-Akchagylian, there was a cooling. Extended distributions of dark-coniferous tree species and reduction in thermophilic elements testify to this change in climatic conditions. The warming identified at the end of the Early Akchagylian about 3.2 Ma in two SPCs probably relates to the "Mid-Pliocene Warm Period" (Leroy et al., 1999).

Conclusions

The palynological assemblages from the studied areas show that at the beginning of the Akchagylian and the Gilbert/Gauss paleomagnetic inversion, there was a cooling and a change in the main floral elements. The second, more significant cooling, at 2.6-2.3 Ma, corresponds with the beginning of the Mid-Akchagylian, the Gauss/Matuyama paleomagnetic inversion, the maximum stage of the Akchagylian transgression, and coniferous-broad-leaved forest landscapes. Climatic warming occurred at around 3.2 Ma in the North Caucasus, coinciding with the period of warming in the south of western Europe and the "Mid-Pliocene Warm Period." This evidence is the first sign of this event yet found in the Caspian region.

Acknowledgments

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PLIOCENE-QUATERNARY SAMTSKHE-JAVAKHETI VOLCANIC HIGHLAND, LESSER CAUCASUS – AS A RESULT OF MANTLE PLUME ACTIVITY

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Keywords: Volcanic highland, mantle plume, volcanic edifices, melting, mega volcano

Introduction

In the SW part of the Lesser Caucasus, at the Pliocene-Quaternary, the Samtskhe-Javakheti subaerial volcanic highland (elevation 1500-2500 m) was formed, which is located discordantly on mid-Eocene sediments. In Georgian territory, the highland occupies more than 4500 km^2, however, its larger part is located to the south in Turkey and Armenia.

The study of the Samtskhe-Javakheti volcanic highland has lasted for some decades. Among the researchers, N. Skhirtladze (1958) has made a valuable contribution. In the formation of the highland, three large episodes of magmatic activity should be noted: (1) Early Pliocene – when dacite-andesitic volcanic tuffs of 700-1100 m thickness and flows (i.e. Goderdzi suite) were formed; (2) Late Pliocene-Early Pleistocene – when dolerite flows of 100-250 m thickness were formed; and (3) Mid-crust Pleistocene-Holocene volcanic activity, when the Abul-Samsari linear volcanic ridge was formed to the south of the dolerite flows.

Based on field, petrologic, petrochemical, and isotopic studies, we consider that all three stages of the Samtskhe-Javakheti volcanic highland formation were connected with the activity of mantle plume flows (Morgan, 1972) and not with melting processes of the residual subduction of oceanic crust in the mantle as is considered at present (Neill et al., 2013). Our consideration is confirmed by the results of a new experimental modeling (CNRS/IRD/Blaise Pascal University): the melting of the subducted oceanic crust into the mantle. According to the experiment, an oceanic crust submerged into the mantle at the beginning is melting, although in the Mg-rich environment a perovskite ($MgSiO_3$) mineral envelope is permanently formed at a melting point that is significantly higher than that of the mantle. It melts fully already at the border of the lower mantle and outer core, in the area of layer D, where the temperature increases to 1000° C.

Field, petrological, and geochemical investigations

A large part of the highland is built up by the Goderzi suite, which is represented by volcanic lava-breccias, pyroclastic rocks, andesite-basalt lava flow and ash fall, as well as huge deposits of andesite-dacitic composition. Formation of the series was conditioned by several cycles of volcanic eruptions in the range of 5.2 to 2.6 Ma (zircon U-Pb dating), with a mantle source in the magma chamber (Chang et al., 2013). The question about the magmatic center of the Goderzi suite is still debated, but it is clear that it was a huge formation. Based on physical volcanology, the analogy of such a structure is considered super/mega volcanoes. The evidence of such structure includes the following: a large volume of volcanic material

(>1500 km^2); great thickness (700-1100 m in average); large size of the volcanic breccias (diameter >1 m); substantial scale of lava flows (length 35 km, thickness 30-80 m); and great thickness of volcanic ash horizons, 300 cm in some places (Fig. 1).

According to the descriptions above, a volcano yielding the Goderdzi suite was not an ordinary formation but a mega volcano (Okrostsvaridze et al., 2016). In addition, taking into consideration all petro- and geochemical parameters, these rocks do not belong to the island arc formations.

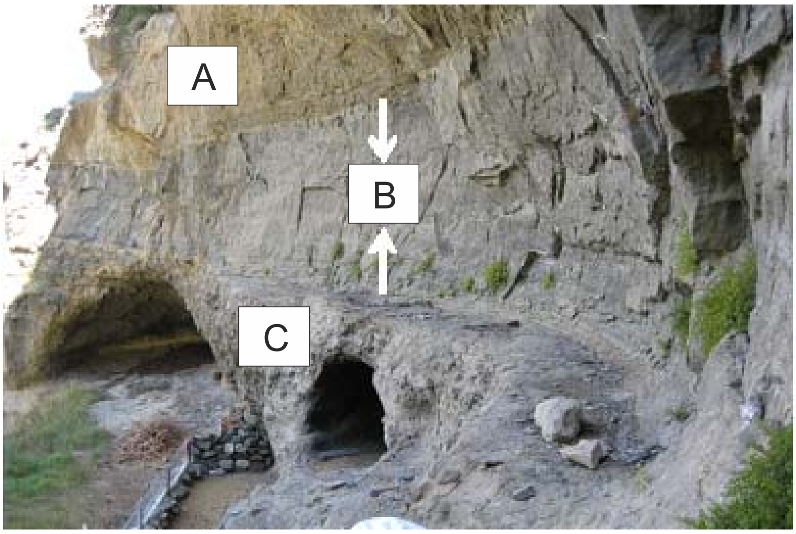

Figure 1. Exposure of a thick layer of volcanic ash at the northern benches of Vani kettles. A- medium-grained tuffs, B – grey volcanic ash, C – coarse-grained volcanic tuffs.

Basaltic flows of the Javakheti volcanic plateau of 100-250 m thickness were formed as a result of the second magmatic activity of this volcanic highland, Late Pliocene-Early Pleistocene (2.4-1.6 Ma; Chang et al., 2013). The strata are dark grey, fully-crystalline, coarse-grained, weakly differentiated massive rocks, mainly consisting of olivine, mafic labradorite, monoclinic pyroxene, and titano-augite. According to petrochemical data, they are more related to mid oceanic ridge basalts than to island arcs. The content of SiO_2 in these flows varies in the range of 49-51% and that of MgO varies within 6-8%. The $^{143}Nd/^{144}Nd$ parameter varies in the range of +0.51703 to +0.52304, and the $^{87}Sr/^{88}Sr$ parameter – from 0.7036 to 0.7042. By all these characteristics, these are typical continental basalt strata, the genetic relation of which to mantle plumes is doubtless.

The third and last magmatic activity of the Samtskhe-Javakheti volcanic highland, which took place from mid-Pleistocene to Holocene (0.35-0.025 Ma; Chang et al., 2013) is a classic example of a “hot spot” (Okrostsvaridze, 2011). As a result of this magmatic activity, the Abul-Samsari linear volcanic ridge was formed, which stretches in the S-N direction for 40 km with an 8-12 km width and containing more than 20 volcanic edifices. According to the Sr and Nd isotopic parameters ($^{143}Nd/^{144}Nd$ = +0.52504; $^{87}Sr/^{88}Sr$ = 0.0421), the magmatic source of this ridge was the mantle reservoir; formation of its volcanic edifices occurred from the southern to the northern direction over time. At the same time, volcanic activity decreased. To the south of the Abul-Samsari ridge, the highest (elevation 3305 m) and oldest (0.35-0.30 Ma) volcano Didi Abuli (Big Abuli) is located. To the north, the heights and ages of volcano edifices gradually increase. Further north, the youngest volcano Tavkvetili is located (elevation 2583 m, age 0.025-0.30 Ma). Unlike other volcanoes, it still has a crater. One can see from this brief description that the Abul-Samsari ridge shows all the signs that characterize an intraplate volcanic ridge.

Discussion

If we assume the results obtained, then the history of geological development of the region becomes more interesting because of a close genetic relation between a Paleozoic granite-gneiss crust (Artvini-Bolnisi platform), Paleogene volcanic arc formations (Akhaltsikhe depression), and the products of Pliocene-Quaternary mantle activity (Samtskhe-Javakheti volcanic highland). Such a circumstance makes it possible to reconstruct an important geological process in the future, such as thermochemical interaction of mantle plumes and a subduction zone.

In addition, as the modern studies show, as a result of thermochemical interaction of mantle plumes and lithosphere, important metallic ores are formed. A newly-formed powerful hydrothermal system accumulates associations of Cu-Ni-Pt, Fe-Pt, Au-As, Ag-Sb, Sb-Hg, and other metals at the barriers of basaltic strata. It should be noted that such an accumulation of metals is observed in the upper horizons of the Goderdzi suite, which forms the basis for their study in detail.

As for the problem of the Javakheti mantle plume generation, maybe it is a marginal manifestation of the northern flow of the Eastern Africa mantle plume.

Conclusion

Based on the results of petrologic, petrochemical, and isotopic studies, we believe that all three stages of the formation of the Javakheti volcanic highland were related to the activity of a mantle plume; therefore, it is possible for the highland to be viewed as a relatively small-scale magmatic province. This consideration is confirmed by the following important factors of mantle plume manifestation within the highland: super/mega volcanoes – magmatic activity forming the Goderdzi suite; continental flood basalts – dolerite flows of Javakheti volcanic plateau; intraplate linear volcanic ridge – Abul-Samsari volcanic ridge.

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QUATERNARY CONTINENTAL FLOOD BASALTS OF THE JAVAKHETI VOLCANIC PLATEAU, LESSER CAUCASUS - REASON OF MASS EXTINCTION?

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Keywords: Javakheti Volcanic Plateau, continental flood basalts, mass extinction

Introduction

An eastern block of the Samtskhe-Javakheti volcanic province of the Lesser Caucasus is called the volcanic plateau of Javakheti; it is bordered on the western (Samtskhe) block by an active regional fault. Over 5.2 million years, in comparison with the western block, it has submerged by about 130 m (Okrostsvaridze et al., 2016). Both blocks of this volcanic province have almost similar geological structure, although in the Quaternary, the Javakheti submerged block has been covered with thick dolerite flow, the so-called Akhalkalaki suite (Skhirtladze, 1958). As a result of field, petrologic, petrochemical, and isotopic work conducted by us, it was established that these formations are typical continental flood basalts (traps), which are genetically related to mantle plume flows (White and McKenzie, 1989) and not to melting products of the residual subduction oceanic crust as has been considered.

Geology, petrochemistry, and isotopic geology of the Javakheti flood basalts

The Javakheti volcanic plateau was formed on Paleozoic continental crust of Artvin-Bolnisi bloc. There, the micro-plateaus of Akhalkalaki, Tsalka, Gomareti, and Dmanisi are distinguishable, in which basaltic flows are fully identical petrographically and geochemically. Thicknesses of these flows are almost equal and vary in the range of 100-270 m on average. The flows are grey, fully crystalline, coarse-grained, and weakly differentiated massive rocks (Fig. 1), which mainly consist of olivine, basic labradorite, monoclinic pyroxene, and titanoaugite

Figure 1. A general view of continental flood basalt of the Dashbashi canyon (upper reaches of the Khrami River) (left) and a detail photograph (right).

By petrochemical data, they are more related to mid oceanic ridge basalts than to islands arcs. Content of SiO_2 in these strata varies in the range of 49-51%, and that of MgO varies within 6-8%. The $^{143}Nd/^{144}Nd$ parameter varies in the range of +0.51703 to +0.52304, and the $^{87}Sr/^{88}Sr$ parameter ranges from 0.7036 to 0.7042 (Okrostsvaridze, 2011). Magmatic zircons of the Javakheti plateau basalts have been dated by the U-Pb method. The results obtained vary in the range of 2.4-1.6 Ma (Chang et al., 2013).

The temporal link between the mass extinction and injection of continental flood basalt

The temporal link between the mass extinction and large igneous provinces is well known. It is notable that the best-constrained examples of death-by-volcanism record the main extinction pulse at the onset of (often explosive) volcanism, suggesting that the rapid injection of vast quantities of volcanic gas (CO_2 and SO_2) was the trigger for a truly major biotic catastrophe (Bond and Wignal, 2014). Based on the results of our work, we consider that the extinction of many vertebrates living in the area of the Javakheti volcanic plateau and habitats of the Dmanisi Paleolithic site among them, might have been caused by mass extinction from gases released as a result of powerful volcanic eruptions.

Conclusion

Based on the data from analyses of the results of geological work conducted at the Javakheti volcanic plateau, we believe that the upper segment of the plateau represents typical continental flood basalts. During the pulsating formation of these flood basalts, large amounts of poisonous gases were released. It should be noted that continental flood basalts of the Javakheti volcanic plateau are the youngest formation of the earth's continental crust (2.4-1.6 Ma). The formation of these flood basalts coincides in time with the beginning stage of hominin evolution in the region. That is why every big pulsation of its magmatic source could have disastrously affected the biological world in general, and hominins, in particular. Based on the above information, one can conclude that other important areas of mass extinction may be discovered in the Javakheti region in the future.

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UNIQUE CAVE CITY VARDZIA, GEORGIA – GEOLOGY, DESTRUCTION PROCESSES AND PROTECTIVE MEASURES

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Keywords: cave city, volcanic tuff flow, destructive processes, protective measures

Introduction

Vardzia is a unique cave city of the 12th century combining an urban, defensive, and monastic complex hewn into the volcanic tuff flow of Pliocene andesitic-dacitic composition. In 1283, after a strong earthquake, the cave complex was severely damaged, but it did not cease operation. Results of geological investigation showed that the Vardzia area has a complex geological structure. It is situated on the eastern slopes of the Erusheti ridge, hewn into a 900 m long tectonic block, which is detached from the main rocks and is gradually subsiding towards the Mtkvari gorge. In addition, the Vardzia block is split into several microblocks by a joint set, and thereby its stability lessens. The matter is made worse by the fact that an active deep fault runs along the Vardzia complex in the Mtkvari gorge and presents a potential earthquake source. For this reason, it is clear that this important monument of Georgian cultural heritage is in danger of gradual natural destruction and earthquake hazards.

Methodology

The work was carried out with the application of classical geological methods as well as high sensitivity modern tools. To determine the exact hypsometric location and vertical displacement, a differential high accuracy DGPS, Leica Viva GS15, was used. At the same time, monitoring of the dynamics of the front part of Vardzia is being carried out continuously by stationary IBIS-FM radar.

Geological characterization of the Vardzia region

Vardzia region is constructed of subaerial Pliocene volcanogenic-sedimentary rocks of andesitic-dacitic composition: the so-called Goderdzi suite (Fig. 1).

Figure 1. Panoramic view of the Vardzia region. In white color is the volcanic flow of andesitic-dacitic composition. At the top of the flow is the upper part of the Goderdzi suite. At right can be seen the Vardzia cave city.

This suite is located discordantly on the mid-Eocene tuff-breccias and sandstones and is also discordantly covered by a thick flow series of Quaternary dolerites (Skhirtladze, 1958). The Goderdzi suite is strictly divided into two major parts: the lower part with a thickness of 200-250 m is built up of pyroclastic formations in which mainly dark, weakly cemented, coarse material of hypersthenic and 2-pyroxene andesitic and andesitic-dacitic composition prevails. Somewhere in this coarse tuff suite one can mark rare cenotypal thin-layered pyroxene andesitic flows; above this part, there is a 20-80 m thickness of slightly welded, fine-grained andesitic-dacitic tuff flow (the Vardzia horizon). It was within the segment of the volcanogenic rocks where the Vardzia complex was hewn beginning in the 12th century.

The Vardzia horizon presents fine-grained andesitic-dacitic, slightly welded tuffs (Branney and Kokelaar, 2002). It is well observed in relief because of its whitish color. Its thickness in the Vardzia section is 40-60 m and is different in the northern and southern directions. It should be noted that the horizon outcrops mainly on the left benches of the Mtkvari River, while it is marked fragmentarily on the right ones. Tuffs of the Vardzia flow are rather soft rocks. They make one's fingers dirty, although it is impossible to crush them by hand. Their color changes from lateritious-pink to light grey-white. In the petrographic sense, these tuffs can be divided into three parts: lithoclastic, porphyroclastic, and cementing materials.

Tectonic structure of the Vardzia region

The tectonic structure of the Vardzia region is rather complex (Gamkrelidze, 2000). There, tectonic faults of two types can be distinguished (Fig. 2): (1) faults produced by regional geological processes and (2) those conditioned by local gravitational phenomena.

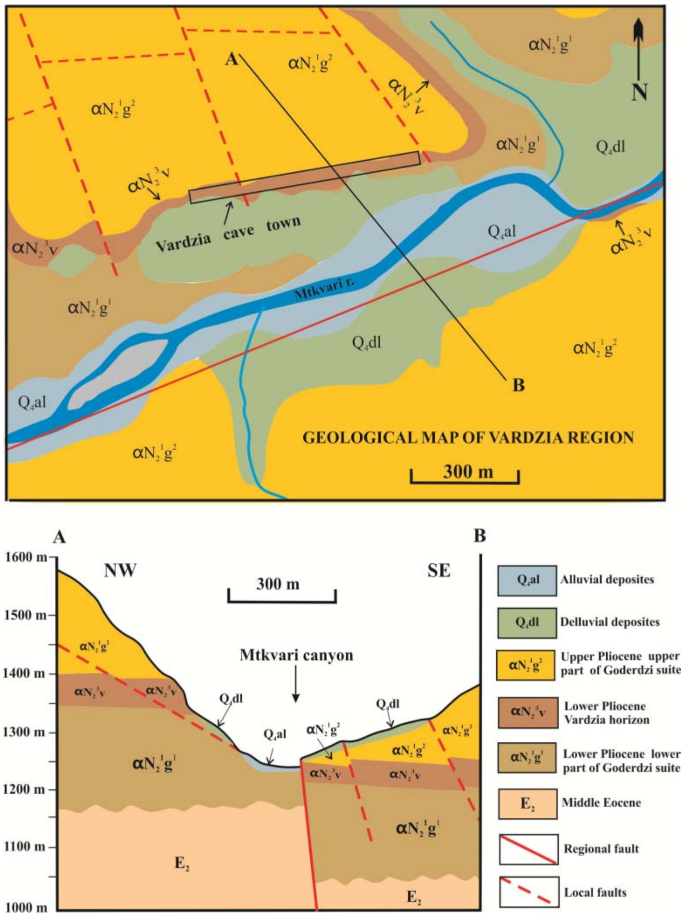

Figure 2. The geological map of the Vardzia area, and its cross section.

The basic tectonic structure of the area is a deep fault, which traces SW-NE and actually runs along the Mtkvari River gorge. Along the fault, the Vardzia area is divided into two large geoblocks: a western block – Vardzia (Erusheti) and an eastern block – Javakheti. After the Vardzia horizon was formed (beginning of the Pliocene), a significant vertical displacement was created along the fault.

We determined the exact heights asl of the upper border of the Vardzia horizon in the exposures on both sides of the Mtkvari River using a high accuracy differential GPS. As a result, the Vardzia horizon in the Vardzia complex is situated higher in comparison with the right riverside by 127 m (Okrostsvaridze et al., 2016). Apparently, the center of Vardzia's destructive earthquake in 1283 was located right along this fault.

Destruction processes

Destructive processes of the cave city of Vardzia conditioned the type of rocks in which it is built and its complex tectonic structure. It is hewn into the weakly cemented volcanic tuff flow of andesitic-dacitic composition. Tuffs of the Vardzia flow are rather soft rocks, and therefore they suffer constant weathering and destruction. These rocks can be cut even with a simple iron knife, and this very factor must have been one reason to excavate the Vardzia complex into these rocks.

No less important a role is played by the destructive processes of the Vardzia complex tectonic structure. The 900 m long tectonic block of Vardzia, which is detached from the main rocks and is gradually subsiding towards the Mtkvari gorge, is split into several microblocks (Fig. 3), and therefore its stability is reduced even further. Also, strong erosional processes taking place along the Mtkvari gorge cause significant destruction.

Figure. 3. Microblocks in the SW part of the Vardzia area: the light colored, fine-grained, andesitic-dacitic welded tuffs.

Conclusion

This study has shown that Vardzia is hewn into the weakly cemented volcanic tuff flow of andesitic-dacitic composition, and therefore, it suffers constant weathering and destruction. Also, the tectonic structure of the Vardzia region is rather complex. Exact measurements carried out with GPS showed that the 900 m long Vardzia block has sunk by 30.6 m in comparison with the adjacent block. In addition, Vardzia's situation is made worse by the fact that an active deep fault runs along the Vardzia complex in the Mtkvari gorge and represents a potential earthquake source. If we take into consideration the rather strong erosional processes taking place along the Mtkvari gorge, it is clear that this important monument of Georgian cultural heritage is in danger of gradual natural destruction and earthquake hazards. The only factor contributing to the relative stability of the Vardzia cave city is the somewhat harder basalt-andesitic lava-flow existing beneath it.

Protective measures

Due to the fact that the Vardzia region is characterized by a complicated tectonic and geological construction, protective measures are difficult. We consider that fortification of the sliding blocks with traditional concrete reinforcement constructions should be used. Besides, clefts that are present in the andesitic-dacitic slightly welded tuffs should be sewn up using high temperature by heating them over 1000°. At places where these clefts are wide, they should be filled with the same material brought from other exposures, and afterwards be heated.

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GEOMETRY AND KINEMATIC EVOLUTION OF A THRUST-TOP BASIN: AN EXAMPLE FROM THE WESTERN PART OF THE KURA FORELAND FOLD AND THRUST BELT, GEORGIA

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Keywords: Kura foreland fold and thrust belt, seismic reflection profile, thrust-top basin, fault-propagation fold, structural wedge

The active Kura foreland thin-skinned fold and thrust belt, which is one of the best examples of collision-driven far-field deformations, is associated with the Arabia-Eurasia convergence. The Kura foreland fold and thrust belt developed formerly as a foreland basin (Oligocene-Lower Miocene or Oligocene-Upper Miocene) and is located between the Greater Caucasus and Lesser Caucasus orogenes (Forte et al., 2010; Mosar et al., 2010; Alania et al., 2016; Adamia et al., in press; Tsereteli et al., submitted). Our study area is the western part of the Kura foreland fold and thrust belt.

Fault-related folding theories (Suppe and Medwedeff, 1990; Shaw et al., 2005) were used for structural interpretation of the S-N trending seismic profiles. Identification of stratigraphic units at depth for seismic profiles was based on outcrop and deep-well data correlations. Interpreted seismic profiles across the Udabno, Tsitsmatiani, and Berebisseri synclines (in the Georgian part of the Kura foreland fold and thrust belt) show that they are thrust-top (or piggyback) basins. Seismic reflection data reveal the presence of growth fault-propagation folds and some structural wedges (or duplex). The evolution of the Udabno, Tsitsmatiani, and Berebisseri basins is compared with simple models of thrust-top basins whose development is controlled by the kinematics of competing growth anticlines. Growth anticlines are mainly represented by fault-propagation folds. The geometry of growth strata in associated footwall synclines and the sedimentary infill of thrust-top basins provide information on the thrusting activity in terms of location, geometry, and age. Analysis of growth strata geometry in seismic profiles documents the evolution of deformation, showing that it has been continuous over the last ~16-15 Ma together with the thrust system kinematics. The growth stratigraphy (Middle Miocene and Pliocene-Pleistocene) consists of shallow marine and thick continental sediments. Pre-growth strata are represented by Upper Eocene and Oligocene-Lower Miocene thick, deep, and shallow marine sediments (Alania et al., 2016). The Pliocene-Pleistocene growth strata are hydrocarbon-bearing, and the Mtsarekhevi oil field is located within the study area.

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VEGETATIONAL AND CLIMATIC CHANGES RECORDED IN POLLEN ASSEMBLAGES OF THE LATE HOLOCENE DEPOSITS FROM LAKE CHOKRAK (CRIMEA)

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Keywords: palynology, laminated lake sediments, paleoclimate, Kerch Peninsula

Introduction

Lake Chokrak (45°27´N, 36°17´E) is a salt lake in the north of the Kerch Peninsula. It was separated from the Sea of Azov by a sandbar during the Late Holocene (Dikarev, 2010) as evidenced by the fine-laminated lacustrine deposits overlying the marine sediments. The climate of the study area is arid and continental (the annual amount of precipitation does not exceed 300 mm). The lake is surrounded by halophytic vegetation, which is replaced inland by a wormwood-grass steppe with an admixture of forbs. A multidisciplinary study of the lake sediments has been carried out recently, including ^{14}C-dating, lithological and microfaunal analyses (Kelterbaum et al., 2012). The aim of this investigation is to obtain a high-resolution pollen record in order to reconstruct environmental dynamics for the part of the Crimean Peninsula where such data are limited.

Methodology

A new pollen study (with a 5-cm sampling resolution) has been performed on the 11-meter core "CH1" collected from the western part of Lake Chokrak within a Ukrainian-Russian-American project (1995-1999) with G. Kukla as a Principal Investigator. Twenty samples have been analyzed in the interval with visible lamination (0.5-1.5 m). The processing of the samples involved heating of a 2-gram sample in a 10% solution of HCl, followed by boiling in a 15% solution of sodium pyrophosphate, and cold treatment with a 40% solution of HF. The organic residues were mounted on slides in glycerine. The counted pollen sum varied between 431 and 785 (543 pollen grains on average). The surface pollen sample from the mud of the lake (AP = 27%, NAP = 72%, spores = 1%) contains pollen of conifers, *Alnus*, *Betula*, broad-leaved trees, various shrubs, Poaceae, *Artemisia*, Chenopodiaceae, Asteraceae, and a diversity of herbs.

Results

Pollen results show that the majority of the obtained palynotypes originate from the vicinity of the lake (*Artemisia* spp., Chenopodiaceae, Poaceae, and Herbetum mixtum). Nevertheless, the pollen assemblages contain far-transported tree pollen from the Crimean Mountains and adjacent regions. Such anthropogenic indicators as pollen of Cerealia, *Chenopodium album*, *Plantago lanceolata*, and *P. media/major* are also observed in the samples. On the basis of correlation with the available pollen investigation in Crimea (Gerasimenko, 2007), it is suggested that the studied interval may correspond to 800-1800 yrs AD.

The pollen assemblage from the lowermost deposits (1.4-1.5 m) reflects a meadow steppe vegetation (the low pollen values of xerophytic herbs and relatively high values of Asteraceae and other forbs). The latter include Apiaceae, *Centaurea* spp., Boraginaceae, Brassicaceae, Fabaceae, Lamiaceae, *Plantago lanceolata*, Rosaceae, Rubiaceae, and *Thalictrum* sp. A considerable amount of Cerealia pollen, 1%, as well as the highest pollen values of *Pinus*, 41%, have been observed here. Far-transported pollen of *Abies* and *Picea* is present.

Dinoflagellate cysts of *Spiniferites* sp., algae *Cymatiosphaera* sp., and foraminiferal linings have also been found unfrequently. This points to a limited influence of marine water.

The next phase (depth interval 1.1-1.4 m) may correspond to the Medieval Climatic Optimum that can be inferred from the highest pollen values of thermophilous deciduous trees, including abundant pollen of *Quercus* spp., *Fagus* spp., and *Ulmus* sp., and a few pollen grains of *Juglans regia*, *Carpinus orientalis*, *Tilia cordata*, and the warmth-loving bush *Thelycrania sanguinea*. Pollen of grasses gradually increase upwards (up to 9%), whereas Chenopodiaceae pollen decrease to its minimum at the same level (16%). Pollen of mesophytic *Thalictrum* and *Filipendula* are present through the described interval. Re-deposited pollen of *Carya*, *Juglans*, and *Carpinus* can be attributed to the development of erosional processes in the Miocene limestone rocks surrounding the lake at this time. Pollen grains of aquatic plants *Potamogeton* and *Typha latifolia* appearing within this depth interval indicate an input of fresh water. Only a few dinoflagellate cysts appear in this depth interval. As evidenced by a comparison with the surface pollen sample, the climate during this phase was warmer and somewhat wetter than at present.

The following phase (depth interval 0.95-1.1 m) represents a transition from a warmer to a cooler climate as indicated by a gradual decrease in the pollen sum from broad-leaved trees. At the same time, the humidity increases (appearance of far-transported pollen of wet-loving *Picea* and *Alnus*, and pollen occurrence of *Salix* and Cyperaceae). Pollen values of grasses and herbs also decrease at this level. Low numbers of dinoflagellate cysts and foraminiferal linings have been found in these samples.

The next short phase (depth interval 0.9-0.95 m) corresponds to a rapid shift in the composition of vegetation that is evidenced by a drastic decrease in arboreal pollen and the disappearance of pollen of thermophilous trees (*Ulmus*, *Tilia*, and *Carpinus orientalis*). These deposits evidently correspond to the beginning of the Little Ice Age.

The climate became slightly warmer and wetter during the next short phase (depth interval 0.8-0.9 m), as it is evidenced by a new increase in pollen of broad-leaved trees, hazel and alder, as well as by an increase and diversification of herbal and grass pollen, and a decrease in pollen of *Artemisia* and Chenopodiaceae. No dinoflagellate cysts and foraminiferal linings have been found at this level. This indicates that marine water did not reach the lake at this time. The composition and percentages of pollen taxa are similar to those of the surface pollen sample, thus, the climate was close to the present one. A slight warming is recorded in the middle of the Little Ice Age in the other pollen archives (Bezusko et al., 1988; Gerasimenko, 2007).

The last phase (depth interval 0.5-0.8 m) marks a return to cool and xeric conditions that is evident from the lowest pollen values of broad-leaved trees and alder, and a drastic increase in Chenopodiaceae pollen. Pollen of Cerealia and other anthropogenic indicators is present through this interval. Dinoflagellate cysts of *Echinidinium* and *Spiniferites* and a foraminiferal lining appear in these samples. This phase may correspond to the second coldest and driest part of the Little Ice Age.

Conclusions

The obtained results show a significant potential for reconstruction of environmental changes in the study area on the basis of pollen data from the Lake Chokrak sediments. Absolute dating and correlation with the other paleoecological proxies are necessary in order to corroborate the obtained outline of climatic changes.

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SOILS OF SCYTHIAN SETTLEMENTS AS PALEOENVIRONMENTAL ARCHIVES IN THE AREA OF LATE HOLOCENE MIGRATION PATHWAYS THROUGH THE EAST EUROPEAN STEPPE

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Keywords: paleosol, paleoenvironmental reconstruction, ancient settlement, Late Holocene

Introduction

Paleoenvironmental reconstructions are crucially important for understanding the migration incentives of ancient civilizations. The steppe areas of Southern Russia show a correlation between migration waves and certain paleoclimatic rhythms (Demkin, 1997). Old settlements are among the important geoarcheological phenomena that allow the use of paleopedological methods for paleolandscape reconstructions. Soils deeply buried under ancient constructions, especially ramparts and mounds, maintain features that developed under climatic conditions preceding burial, and in this way, they can be considered valuable paleoenvironmental archives. Settlements and burial mounds of the Late Holocene are widespread in the forest-steppe, steppe, and semi-desert areas of the East European Plain, and they are well documented by archaeologists. There are numerous paleolandscape reconstructions based on buried Holocene soils (Demkin, 1997; Khohlova et al., 2007, Khokhlova, 2012). Though many time slices are not characterized, in some cases reconstructions are conflicting. It is especially important to provide detailed reconstructions for critical points of landscape evolution when short climatic cycles caused noticeable changes in environmental parameters reflected in buried soils. It would then be possible to link such critical points of soil evolution with the migration pattern of steppe tribes.

Study area and methodology

The Borisovka settlement of the Early Iron Age (2500 years BP) is situated 40 km to the west of Belgorod city in the northern forest-steppe area of the East European Plain. It was a part of the Scythian civilization in which Iranian-speaking tribes occupied an extensive belt of territory in the northern Black and Azov sea areas within the Don and Danube river basins. The settlement is situated on a narrow promontory formed by a junction of several gullies with steep slopes heading toward the Vorskla River valley. Elevation above local erosion basis reaches 50 m. The radiocarbon age of charcoal in the lower part of a rampart mound confirms the Early Iron Age date of the construction (2450±40 years BP; 2540±100 years cal BP (CalCurve: IntCal_13 (Ki-18174) (Chendev et al., 2014).

To retrieve environmental trends, the soil chronosequence was studied based on 2 m deep profiles of surface soil and a soil buried beneath the rampart with a preserved height of 1.5 m. Both soils were formed on the surface with the same lithology (Late Pleistocene carbonate loess heavy loams), same elevation (~200 m asl), and only 10 m apart from each other (Fig. 1).

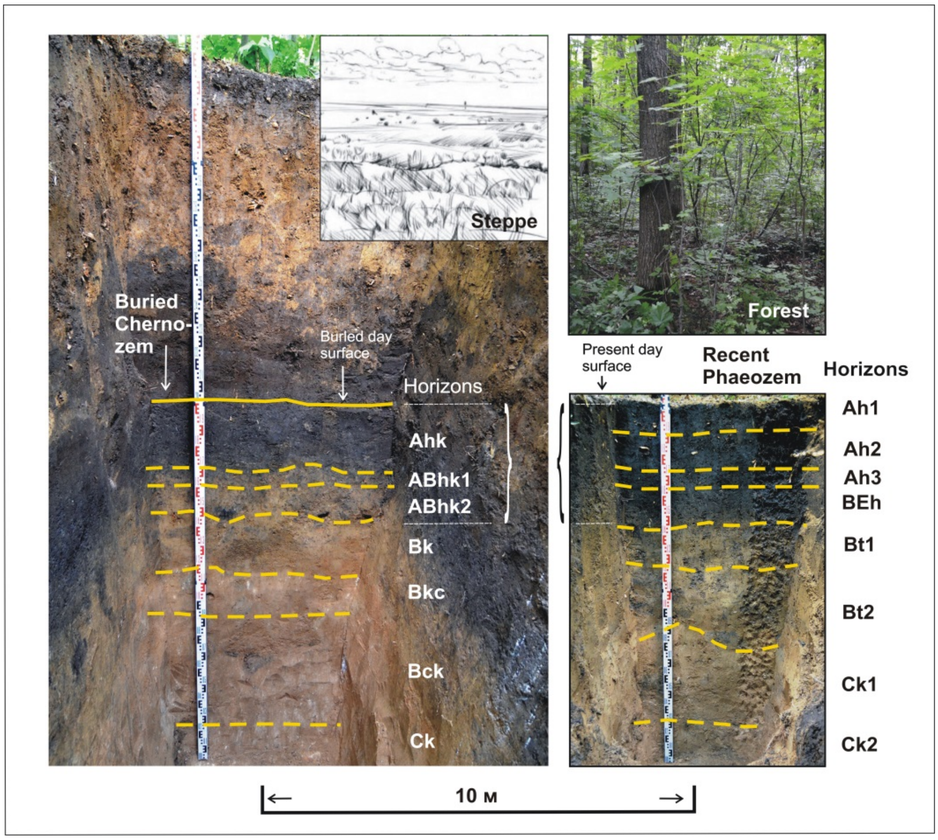

Figure 1. Soil chronosequence of modern Luvic Faeozem and Chernozem, buried under Scythian fortification ~2500 years ago.

These confirmed that the differences in soil features in the chronosequence are related to differences in the modern bioclimatic parameters and those of the Early Iron Age, thus showing the Late Holocene bioclimatic trend for the studied area. Both soils have been examined morphologically according to the FAO Guide for Soil Description (IUSS, 2006: 109) and classified according to the WRB (IUSS Working Group WRB, 2014). Soil samples for hierarchical morphological (mesomorphology, micromorphology, SEM) and analytical studies have been taken from all horizons.

Results

The area in close proximity to the Borisovka settlement is covered by small-leaved forest with an admixture of oak that is typical for the East European forest steppe. The modern surface soil is represented by Luvic Retic Greyzemic Phaeozem (Loamic) on carbonate loess with the following sequence of horizons: Ah1-Ah2-Ah3-BEh-Bt1-Bt2-Ck1-Ck2. Total thickness of the humus layer is 51 cm. The lower part of the humus layer (BEh; 42-51 cm) shows greyzemic features, abundant in uncovered sand and silt grains, indicating ongoing degradation of a former thick humus layer. A sequence of the Bt horizons goes down to 115 cm with well-formed clay and humus-clay cutans covered by siltans. Carbonate loess follows below. Polygenetic features of soil, developed under steppe conditions in the past, are presented by krotovinas in the lowermost part of the solum (180-190 cm).

The buried soil differs substantially from the surface one. It is represented by Haplic Chernozem (Pachic) on carbonate loess with the following horizon sequence: Ahk-ABhk1-ABhk2-Bk-Bkc-Bck-Ck. The thickness of the humus layer is 52 cm. From the surface, the humus horizons show high effervescence with HCl due to diagenetic enrichment by $CaCO_3$

from the rampart earth. Carbonate neoformations start from 30 cm and are represented mostly by pseudomicellia, nodules, and carbonate cutans. All horizons show numerous krotovinas indicating long-term steppe pedogenesis. There are no signs of clay illuviation in the middle part of the solum.

Conclusions

Soil chronosequences reveal critical points in Late Holocene landscape evolution. A climatic shift in the Sub-Atlantic resulted in a forest steppe advance into typical steppe areas. Soils of the Early Iron Age are represented by Chernozems formed under the steppe environment of that time. They lack cutans and have a thick humus layer, abundant carbonate neoformations, and numerous krotovinas. Modern surface soils (Luvic Phaeozems) display clear features of forest pedogenesis: clear greyzemic features in the upper part of the solum, well developed cutans in Bt horizons, and deeply washed carbonates. On the other hand, they are polygenetic and retain signs of their former steppe pedogenesis: (1) the lower humus horizon (BEh – 42-51 cm) is a former transitional ABhk2 horizon retained from a former Chernozem soil. Both horizons of the modern (BEh) and buried soils (ABhk2) are situated at a similar depth from the surface – 40-50 cm; and (2) krotovinas in the lower part of the solum also indicate a former steppe environment.

Buried soils are valuable paleoenvironmental archives that can reveal the Late Holocene landscape evolution trends. Further research is needed to link these environmental trends with the migration incentives of ancient tribes.

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COASTAL LAWS IN TURKEY

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Keywords: Turkish Republic Constitution Law, Turkish Civil Law

Turkey's strategic location, straddling the continents of Europe and Asia, has made it a cradle of civilization since the Stone Age. Known as Asia Minor in antiquity, the region that makes up modern day Turkey can be easily divided into a number of relatively distinct geographical zones: the central landmass of Anatolia and its various coastal areas. Turkey's land mass is 774,815 sq km, and the country has a coastline some 8333 km long. Three sides of its area are surrounded by seas: the Mediterranean, Aegean, and the Black Sea. Environmental conditions such as climate, topography, ecosystem, and the characteristics of habitation are different in the various coastal regions of Turkey. Therefore, several problems appear in the applications related to coastal planning.

In coastal regions of Turkey, many factors have violated the public benefit. Sea and water pollution have prevented the public from accessing the coastline; contradictions and insufficiencies in legal arrangements, coastal erosion, infilling coastal areas for the purpose of land reclamation and new property acquisition, and unbalanced construction have caused unplanned urban areas, scattered buildings, environmental buildings, and the destruction of water sources; coastal regions possess insufficient social and technical infrastructure, uncontrolled urbanization, and insufficient provision of services; and unbalanced development in coastal areas has resulted in land occupation that encroaches on the seascape.

In Turkey, according to Turkish (Coastal Law, 1992), the coastline is a natural line that changes due to meteorological events on the sea, and in lakes and rivers. These are formed by fusion of the points at which the water touches the land in places other than those of flood stage. The coast is an area between the coastline and shore border line. The shore line is a land-based boundary running at least 100 m distant from the coastline of seas, lakes, and rivers and that creates an area called the shore buffer zone. Detecting the shore border line is necessary in order to make practical plans for shore lines. In accordance with the Turkish Republic Constitution Law, the coasts are at the disposal of the government. In utilizing the shore lines of the seas, lakes, and rivers, one must first consider the public benefit. In accordance with Turkish Civil Law, places with no property or constructions for public benefit are under no ownership and can never be subject to private land acquisition. According to the Coastal Law, identification of the shore border line is required to be able to make plans and implement them on the coast and shore line (Sazak, 2009).

In this paper, the first Reconstruction Law of 1972, the last Turkish Coastal Law of 1992, and the last additions and revisions of Turkish Coastal Law in 2005 will be examined as part of an investigation into the problems presented by changes in ecosystem in the coastal zones of Turkey.

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PALEOCLIMATIC EVENTS OF THE LATE PLEISTOCENE AND THEIR REFLECTION IN THE STRUCTURAL AND MATERIAL COMPOSITION OF LOESS-SOIL COMPLEXES (SOUTHERN PART OF THE EASTERN EUROPEAN PLAIN)

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Keywords: loess, paleosols, lithology, mineralogy, Quaternary paleogeography

Introduction

Nowadays, global warming on Earth is an important scientific issue. To address this complex and important environmental issue, it is necessary to consider paleoclimatic changes during the Late Pleistocene and the impact of glaciations on loess-soil complexes through their structure and composition. Loess sediments are one of the most common types of continental Quaternary deposits. According to A.A. Velichko (Velichko, 2012), the major solution of paleoclimatic and paleogeographic issues of the Quaternary period is significantly associated with research into loess-soil complexes, which formed during the Late Cenozoic under conditions of repeated cooling and warming, and global sea-level fluctuations. Consequently, we have studied particle size and mineral composition of the loess-soil complexes within reference sections of the southern part of the East European Plain (the Azov Sea and the Lower Volga region) and compared their features with the ages and zones of ancient glaciations to identify paleoclimatic events through the characteristics of structure and composition of loess and soil sediments.

Study region and methodology

Loess deposits are widespread in Ukraine (up to 80% of the territory) and Russia (17% of the territory). The loess cover of the Azov Sea region (Donbass) and the Lower Volga region (the Volga-Akhtuba floodplain) is intermittent (insular nature of spread) and confined in the first case, to the area of rising neotectonic movements, and in the second, to the newest tectonic depression area of primary downward movement of crustal blocks.

The paleodelta of the ancient Volga River in some periods of the Late Pleistocene was located in the Volga-Akhtuba floodplain, into which the Caspian Sea waters repeatedly rose during the vast transgression due to the melting of glaciers and permafrost on the Russian Plain (Lysenko, 1961, 1967; Bulavin, 1972; Trofimov, 2001). Here, in the composition of the Late Pleistocene deposits, researchers recognize Late Khazarian and Khvalynian transgressions of the Caspian Sea, as well as separate polyfacies sediments corresponding to the Atelian regressive stage, during intervals of which the process of loess formation occurred (Nikolayev, 1957).

In this study we analyzed particle size distribution and the mineralogical and petrographic composition of loess and loess-like sediments of the Azov Sea and Lower Volga regions.

Results

In the Azov Sea region, loess sediments of the Late Pleistocene (Q_{III}) and Holocene (Q_{IV}) occur in large fields on the plateau-like tops with absolute elevations from 300 to 350 m and above, and thickness varying widely, sometimes reaching 10 m or more. They usually contain 1-3 buried soil horizons (depending on the completeness of the section), separated by 2-3 loess horizons. The particle size of their composition is dominated by silty (about 60%) and clay fractions, which in the classification of clastic rocks correspond to highly clayey siltstone. The content of the sand, mostly a fine-grained fraction (0.25-0.05 mm), is usually small (1-2%), but in some places, sections contain intervals with up to 15-20%, with a sharp predominance of the fine sand (0.8-2%) fraction. Due to the high content of clay material and sometimes a higher sandy component, loess sediments of the Azov Sea region in a geological context can be termed loess-like formations. The sandy-silty component is represented by angular, rarely angular-rounded fragments of quartz (40-50%), less frequently by feldspar (15-20%), rarely mica (muscovite, chlorite and sporadically biotite), and more rarely carbonate (fragments of carbonate rocks, singly biogenic detritus).

The mineral composition of the heavy fraction is predominantly epidote (32-42%), a zoisite-amphibole, wherein the content of hornblende is 4-12%, with a low content of resistant elements—zirconium (9.5%), and minerals: tourmaline (3.1%), garnet-almandine (1-7%), anatase (1-6%), and single rutile (0.2-1%). Carboniferous and Neogene (Scythian clays N_2^2) deposits underlying the loess-like formations have a different composition in the heavy fraction: dominated by resistant minerals such as rounded grains of zircon, almandine, rutile, and others. The predominance of unstable minerals (epidote, zoisite, hornblende) in the loess-like formations and a sharp contrast with the heavy fraction composition of underlying sediments indirectly indicates that the most likely source of fine-clastic material was periglacial deposits of the Don glaciation (Q_{III}), clastic material of which was brought by aeolian transport (Ryabchenko, 1957; Lysenko, 1961). Previously, it was revealed (Sudakova and Nemcova, 2004) that cooling stages are correlated with the activation of river flow, causing the increase in terrigenous transport from the nearby territory, traces of which are reflected in the mineral composition of the heavy fraction with a predominance of unstable minerals that are attributable to the epidote-zoisite-hornblende mineral assemblage. Episodes of warming are correlated with a decrease in river runoff and are reflected in the composition of the heavy fraction with a predominance of resistant minerals, attributable to the almandine-zircon-staurolite-kyanite mineral assemblage. A component high in clay (less than 0.005 mm) with some fine silt (0.01-0.005 mm) can be explained by the development of a process resulting in the transformation (Sergeev and Minervin, 1960) of the initial deposit during manifestations of cryo-hypergenesis under the significant influence of physical weathering, and to a lesser extent on manifestations of soil formation processes, i.e., a significant predominance of chemical weathering.

The shape acquisition of loess sediments is a result of enrichment with products of weathering and soil formation processes in the regions with a dry and warm climate, mainly caused by the accumulation of calcium carbonate, which is low in solubility and does not leach out of the soil. The presence of large amounts of calcium ions in soil solutions causes coagulation of the colloidal fraction of the sediment, promoting the acquisition of a silty-cloddy structure.

The middle part of the Srednyaya Akhtuba section (described in Kurbanov et al. in this volume) is represented by a loess-like formation of the late Pleistocene (Q_{III}) and Holocene (Q_{IV}) – mainly clay siltstone (up to 35-45% of the clay material), passing down the section through the clay interlayer to sandstones of marine origin. The distribution of sand, mainly fine material with a particle size 0.1-0.05 mm, is extremely irregular and intermittent; in most intervals of the section, the content is 0.7%, while in the bottom of the section, it is up to 12%.

The loess-like formation is underlain by coastal unconsolidated sandstones of medium-grained, well- or moderately-sorted, silty (12-24%), clay (6.3-9%).

The mineral composition of the siltstone is marked with variations in the content of silica (from 20 to 39%) compared with the underlying marine quartz sandstones (81-83%), and minor variations in the content of feldspars (13-22%) with quantitative predominance of plagioclase (11-15%) over potassium feldspar (3-8%). Within the clay component, the content of which varies widely (from 12-44%), we detect a high content in certain intervals of the section of Ca-Mg smectite (10-12%) and mixed-formations of smectite-kaolinite, smectite-chlorite, and smectite-hydromica series (10-14%), which indirectly indicates the presence of cross-sectional changes of camouflaged pyroclastics or apopyroclastics, that significantly influenced the quantitative content of the clay material in the sediments of loess-soil complexes due to conversion of ash particles, and partly due to the loess-shaping process, while the original clastogenic material is being brought by aeolian transport.

Conclusions

Synthesis and analysis of currently existing hypotheses on the origin of loess sediments allows us to say that it can be divided into two stages. The first stage is characterized by dust accumulation of silt (0.05 to 0.005 mm) and partly pelitic (from 0.005 to 0.001 mm) material, which may occur in various ways, and the second is the conversion of accumulated sediment to loess material possessing one or other specific features (Ryabchenko, 1957; Nikolayev, 1962). Since the second half of the twentieth century, many researchers have found that the original silty (silt and partly pelitic) material for loess sediments formed as a result of physical weathering in glacial and periglacial regions. The most intensive accumulation of it took place in periods of cooling due to frost weathering processes – cryohypergenesis – dispersion (grinding) of the initial substrate to silty and pelitic fractions (Sergeev et al., 1982). In interglacial time, during periods of warming within the zone of loess sedimentation, soil formation was active, resulting in horizons of paleosols. The time of maximum manifestation of cryolithogenesis during the Quaternary coincides with the maximum glaciation in the East European, West Siberian, North American, and North China platforms. It can be said that almost the entire globe has been subject to relatively short, but frequent, changes in morphological and climatic conditions, which is reflected in significant and frequent fluctuations of global sea level and the formation of loess deposits (Velichko, 2012).

On European territory, the era of loess-soil complex formation is associated with periglacial areas and planetary cooling and warming in the Late Cenozoic (Minervin, 1982; Minervin and Sergeev, 1998; Velichko, 2012). The presence in one section of several horizons of loess with fossilized soils indirectly indicates that their formation took place under conditions of short-term paleoclimatic change, which have been repeatedly renewed during the Late Pleistocene. In climate aridity, amid global cooling and low stands of global sea level, the loess-accumulation process was active, while humid climate resulted in the formation of soils on the loess deposits during warming and high stands of the global sea level, which is reflected in the change of the particle size distribution and mineral content of the global loess-soil complexes. As a result of these complex processes, the particle size distribution and mineral component of loess-soil complexes are among the most important indicators of climate change, as well as their genesis and physical and mechanical properties. Nevertheless, structure and composition of loess sediments of the southern part of the East European plain (Azov Sea region and Lower Volga) are poorly described in the scientific literature, with almost no materials on their similarities and differences. A more detailed study of the mineralogical and lithological characteristics of Quaternary loess sediments of the two regions will identify similarities and differences in their properties, as well as clarify the influence of paleoclimatic changes during the Late Cenozoic on their structure and composition.

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MALACOFAUNA OF THE KERCH STRAIT DURING THE LATE PLEISTOCENE-HOLOCENE: PALEOGEOGRAPHICAL ANALYSIS

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Introduction

The Kerch Strait between the Black Sea and the Sea of Azov is about 40 km long and 4-15 km wide. The relief of the strait's bottom is complex, with a large central trench (60-70 m deep), which is separated from adjacent marine areas and Taman Bay by underwater thresholds (20-30 m deep). The bedrock of the strait is formed from Miocene clays, which are capped with different loose Pleistocene formations. Both the study of the Kerch Strait's Quaternary sediment structure and the analysis of mollusks contained there were started by Andrusov (1918). Based on materials from the drilling of the strait's floor, he highlighted four phases of development, each characterized by its own type of malacofauna: (1) ancient freshwater Caspian-phase (with *Didacna crassa*); (2) an ancient marine phase (with *Tapes calverti*); (3) a new freshwater Caspian-phase (with *Monodacna pseudocardium*); and (4) a new marine phase (with Azov fauna). After the work of Arkhangel'sky and Strakhov (1938), these phases have come to correspond with the Old Euxinian, Karangatian, New Euxinian, and Black Sea/Flandrian transgressions.

Karangatian stages of the Black Sea belong to the late Pleistocene and Holocene. A large amount of literature is devoted to the geology of the Kerch Strait (Andrusov, 1918; Arkhangel'sky and Strakhov, 1938; Blagovolin, 1960; Nevesskaya, 1965; Fedorov, 1963, 1978; Popov, 1983; Yanko et al., 1990; Svitoch et al., 1998). Malacofaunal analysis has appeared in several publications (Nevesskaya, 1965; Fedorov, 1963, 1978; Popov, 1983; Svitoch et al., 1998; Yanina, 2012). There is no unity among researchers with regard to the reconstruction of paleogeographic development in the Kerch Strait. We carried out a malacofaunistic analysis of the two borehole cores that were drilled on the Tuzla Spit. In addition, we used biostratigraphic analysis results of coastal outcrops, which were studied by us earlier for the purpose of paleogeographic reconstructions (Svitoch et al., 1998; Yanina, 2012).

Results and discussion

Sediments of the Karangatian transgression refer to the beginning of the Late Pleistocene and are characterized by a community of Mediterranean-type mollusks. In the Tuzla cross-section, which becomes open at the base of the spit, under a loess-like layer with a series of buried soils (thickness is 8 m) the core contained a section in which we studied the Karangatian fauna. From top to bottom were discovered: (1) dark gray, silty sediment with fragments and rarely whole shells (thickness is 0.7 m); (2) coquina with gray sand filler, spots and streaks of iron accumulation, containing Mediterranean-type mollusks *Paphia senescens*, *Cardium tuberculatum*, *Chione gallina*, *Mytilus galloprovincialis*, *Ostrea edulis*, *Cerastoderma glaucum*, and *Solen vagina* (thickness is 0.5 m); (3) light gray, micaceous, well sorted, fine-grained sand, ferruginous in the roof, and with mollusk shells of the same species composition with the dominance of *Mytilus galloprovincialis*, which often forms interlayers and large lens (thickness is 1.2 m); (4) brown, well sorted, fine-grained and medium-grained sand with interbedded siltstone at the base of the basal layer of gravel and boulders, and with shells of the mollusk *Mytilus galloprovincialis* (thickness is 0.7 m) in the roof. The succeeding deposits are Neogene (Svitoch et al., 1998; Yanina, 2012). The composition of mollusks indicates a marine development stage of the strait with a salinity of water above that of the modern Black Sea, which is based on the presence of the stenohaline Mediterranean-type mollusks *Paphia senescens* and *Cardium tuberculatum* in the complex; currently, these species are absent in the fauna.

At the core bottoms (45-40 m), which we studied, sediments of the New Euxinian stage of the Black Sea development are described. They include representatives of the freshwater (*Viviparus*, *Valvata*, *Unio*, *Dreissena polymorpha*) and slightly brackish (*Monodacna caspia*) malacofauna. The complex indicates a low water level within the Black Sea which corresponds with the regressive New Euxinian basin and a significant influence from freshwater inflow in the area of the modern Kerch Strait, apparently caused by estuary area promotion of the Don River here and the Khvalynian water discharge of the Caspian Sea through the Manych-Kerch Strait.

Above this section of the core, slightly brackish species witness the rare addition of oppressed shells of the euryhaline Mediterranean-type species *Cardium (Cerastoderma) edule lamarcki*, indicating the first encroachment of the Kerch Strait area by Black Sea transgression water. This phase of development corresponds to the Bugazian phase of the Black Sea Holocene transgression development, which was established by Nevesskaya (1965). Unstable composition of mollusks in different depth intervals (from 40 to 30 m) of the core indicates an unstable level of the Black Sea transgression mode with increasing or decreasing influence of freshwater entry from the Don. The degree of increase in Mediterranean-type euryhaline species in the composition of the faunal complex is an indicator of a gradual transgression increase and filling in the area of the strait by sea waters.

From a depth of the core above 20 m, part of the faunal communities have already received widespread euryhaline and moderately euryhaline Mediterranean-type species *Chione gallina*, *Paphia rugata*, *Cardium (Cerastoderma) edule lamarcki*, *Ostrea edulis*, and *Spisula subtruncata*. Species composition of mollusks indicates widespread marine waters in the strait. Obviously, it shows a clear connection with the Kalamitian stage in the development of the Black Sea Holocene transgression, established by Nevesskaya (1965), or the Novochernomorskaya (New Black Sea) transgression which was highlighted in the Black Sea history by Fedorov (1963). This transgression, according to the conclusion of Fedorov, was the stage with the highest sea level (2-3 m above the present) in the Holocene and the highest salinity for the Holocene epoch and florescence of Mediterranean-type species development there. According to Nevesskaya's ideas (1965), the increase in sea level, salinity level, and increase in molluscan species diversity in the Holocene was gradual. Our research supports Fedorov's conclusion about the Novochernomorskaya (New Black Sea) Holocene transgression. Calibrated radiocarbon dates for this stage, obtained from the shells of *Cardium (Cerastoderma) edule lamarcki* and *Chione gallina*, are 6020 ± 140 (LU-8110) and 5530 ± 120 (LU-8108).

Late Holocene faunistic complexes were studied in the bottom sediments of Taman Bay (Yanina, 2012). Numerous *Cardium exiguum* dominate in the complex from the base of the silt in the inner part of the bay, rarer *Cardium (Cerastoderma) edule lamarcki*, *Abra ovata*, *Retusa truncatula* (most euryhaline among Mediterranean-type species) penetrated into the

Black Sea with the beginning of the Holocene transgression, which indicates conditions of a semi-isolated lagoon type basin without inflow of freshwater. The number of *Cardium (Cerastoderma) edule lamarcki* increases higher in the core and new marine species (*Loripes lacteus*, *Paphia discrepans*, *Mytilus galloprovincialis*, *Chrissalida interstincta*, *Cyclope neritea*, and *Nassa reticulate*) appear. They indicate a gradual penetration of marine water into the bay thereby increasing its salinity.

Comparison of species composition of mollusk shells from the bottom of the Holocene deposits of Taman Bay and the Kerch Strait shows their similar structure: the predominance of *Cardium (Cerastoderma) edule lamarcki*. However, in the Kerch Strait, these communities are identified as early Holocene: Bugazian-Vityazevian stage by L.A. Nevesskaya, Drevnechernomorskaya (Old Black Sea) by P.V. Fedorov, and in Taman Bay, they appeared much later. The studied material provides evidence for non-simultaneous emergence and distribution of the same species of mollusks in various parts of the Black Sea basin.

Conclusions

Part of the Kerch Strait malacofauna from the late Pleistocene to Holocene traces the development of different ecological groups: marine (euryhaline and stenohaline) → freshwater and slightly brackish → marine (euryhaline and moderately euryhaline); different fauna are formed in different ages: the Karangatian, the New Euxinian, and the Black Sea fauna, which respectively characterize large paleogeographic stages in the history of the Black Sea and the Kerch Strait. The malacofaunal development had a migratory nature. Marine Mediterranean-type Karangatian fauna had a connection with the major interglacial (Eemian) transgression of the Ocean, and in the regressive epoch was replaced by freshwater and slightly brackish fauna, the origin of which is connected to rivers, estuaries, and Caspian waters which were received through the Manych Strait. To the beginning of the Holocene, the New Euxinian basin transgressed, although its level remained low (about minus 30 m). Slightly brackish fauna of the Caspian type were widespread.

Salinization and invasion of marine mollusks began in the New Euxinian basin with the gradual development of the Ocean Holocene transgression and the entry of Mediterranean waters. Stages in the emergence and development of marine mollusks until the current state are well evident in the material, which has been studied by us. Widespread Mediterranean-type species of mollusks led to the displacement of the brackish New Euxinian fauna to desalted estuarine areas, where they develop even today.

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RETROSPECTIVE DATA ABOUT UNDERWATER LANDSCAPES AND THE MEIOBENTHOS IN THE NORTHEASTERN PART OF THE BLACK SEA

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Introduction

The significance of *Mytilus galloprovincialis* in the development of the macro- and meiobenthos was studied earlier by Kiseleva (1979) and Sergeeva (1985). Uneven spatial distribution of Bivalvia mollusks (*Mytilus galloprovincialis* and *Modiolula phaseolina*) on the sea bottom causes the difference in taxonomic structure and quantitative characteristics of macro- and meiobenthos within the limits of their eponymous communities. In addition, localization of the zones of sulphidic sediments of different genesis in some regions of the sea also affects the distribution of benthic fauna. Unique direct underwater surveys of benthic landscapes that we conducted in April of 1988 in the submarine benthic laboratory allowed us to obtain a picture of the actual distribution of some benthic communities.

In the present work, a retrospective of information on the bottom landscapes of the Cape of Big Utrish area (northeastern part of the Black Sea) is presented. The spatial distribution and condition of the *Modiolula phaseolina* community for the period 1988 were described based on direct underwater visual observations. The structure of the meiobenthos within the boundaries of this biocenosis was studied.

The presented data may be useful for examining the modern characteristics and identifying changes in the distribution of *Modiolula phaseolina*, the population structure of meiobenthos, and overall landscapes of this area.

Methodology

We conducted the direct underwater surveys of benthic landscapes in the waters off the Cape of Big Utrish when we took part in a cruise during 6-19 April 1988 with colleagues from the Base "Hydronaut" (Sevastopol) and VNIRO (Moscow). Direct visual underwater study of landscapes and distribution of the benthic macrofauna were performed through the portholes of the submarine benthic laboratory (SBL "Benthos-300"). Observations were conducted along 11 transects directed perpendicular to the shore and one parallel transect relative to the shoreline. The study area was limited along the coast to the south by the Cape of Small Utrish and to the north by the township of Sukko. The length of perpendicular transect was more than 4 miles. The total length of the route was 72 miles, all within the depth interval 44-111 m. The movement of the SBL along the transects was independent or in towed mode from the fishing vessel (FV) "Gordyi."

Additionally, on the basis of visual assessment of different zones in the study area, some stations were selected for geological, hydrochemical, and microbiological tasks and for research into the macrobenthos and meiobenthos.

The bottom sediments were collected using the sampler "Ocean-50," with an area of 0.25 m^2. For analysis of the taxonomic and quantitative structure of the meiobenthos at the 11 stations, two-three samples were taken using a tube of 16.61 cm^2 from the surface of the monolith of sediment. Taxonomic richness and number of meiobenthos were determined for the total area of 2-3 tubes.

Results

In the surveyed area, the seabed topography was characterized by three types: smooth flat, weakly wavy, and hilly.

The percentage coverage of the square of the bivalve mollusks (*Mytilus galloprovincialis*, *Modiolula phaseolina*) and the nature of their settlements (single, druses, aggregations), and other macrofauna (Porifera, Polychaeta, Ascidiacea, etc.) varied widely within the study area.

In the zone of mixing of the biocenoses of mussel and phaseolina (depths of 44-54 m), we observed an uneven distribution of mussels. Single specimens and aggregations in the form of druses comprising a few specimens, or ridges of different diameters and lengths were observed. Coating of the sea floor by mussels varied from 0 to 30%. Sulfidic black spots and stains of mold of various sizes were noted locally on the surface of the bottom. The *Modiolula phaseolina* biocoenosis was distributed more deeply with uneven development of the dominant species. Its settlements were formed in ridges of different length (10 m and more) and with a width of about 1 m and also as spots with a diameter of 1.5-2 m. The orientation of the ridges of phaseolina were strictly parallel to one another, but the spaces between them uninhabited by mollusks were equal to the width of the ridges or exceeded their 1.5-2 m at times. On the surface of the spaces uninhabited by mollusks were a huge number of burrows of Polychaeta (*Terebellides stroemi* and *Melinna palmata*) and Anthozoa (*Pachycerianthus solitarius*). Coverage of the sea bottom by phaseolinae ranged from 3 to 90%.

On the basis of quantitative development and distribution of the zoobenthos in the investigated area, three characteristic zones were highlighted on the bottom: the Central with a width of 3 miles, located abeam of Cape Big Utrish; the Southern, adjacent to the south of the Central zone and bounded by the Cape of Small Utrish; and the Northern, adjacent to the north of the Central zone and bounded by the village of Sukko.

Meiobenthos was investigated at 11 stations in the upper zone (44-52 m) in the *M. phaseolina* community, where there was a mixture of settlements of mussels and phaseolina, and in its central part (72-76 m).

Within the composition of meiobenthos we registered representatives of 16 higher taxa: Foraminifera (soft-shelled and hard-shelled forms), Cnidaria, Nematoda, Polychaeta, Oligochaeta, Kinorhyncha, Turbellaria, Nemertini, Mollusca (Bivalvia, Gastropoda, Loricata), Crustacea (Harpacticoida, Ostracoda, Amphipoda, Isopoda), and Acarina. The taxonomic richness in the studied stations was close (9-11 higher taxa) (Fig. 1). However, the composition of the groups of organisms varied. In general, the free-living nematodes dominated at all stations. In the upper zone of the community, at depths of 43-44 m, they accounted for 52% of the total number of meiobenthos, whereas at a depth of 52 m, the share of nematodes was only 19%, but Foraminifera and Ostracoda were leading (36 and 31%, respectively).

In the central area of the community, the nematodes invariably played a dominant role in the meiobenthos. Their share amounted to 50-87% of the total number of meiobenthos. Subdominants at some stations were the turbellarians (25%) and hard-shelled foraminiferans (25%). Soft-shelled foraminiferans were observed only at station 15.

In contrast to the taxonomic richness, the density of meiobenthos in the study area was varied (Fig. 1). The overall density of settlements of meiobenthos in the study area ranged between 147-867 thousand ind./m^2. The minimum values were recorded in the upper area of the phaseolina community.

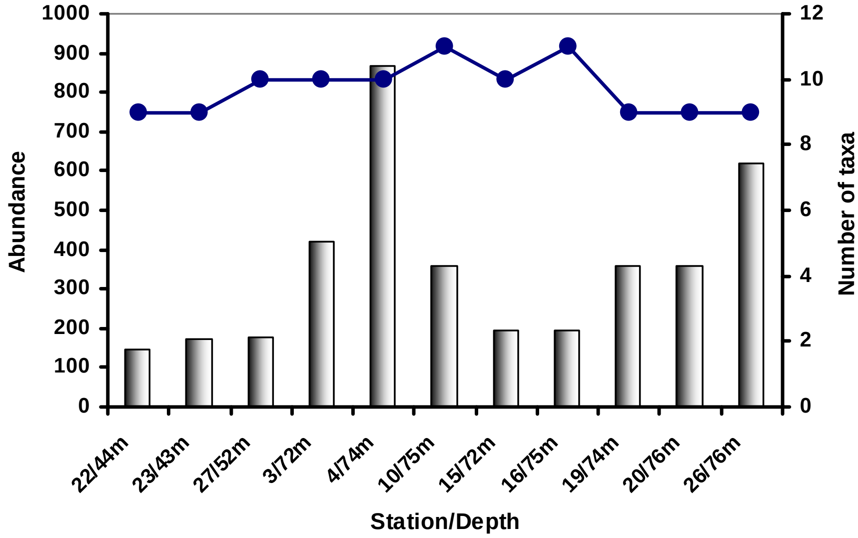

Figure 1. Abundance (thousand ind./m^2) and taxonomic richness of meiobenthos in the studied area (06-19.04.1988).

Conclusions

The development of the *M. phaseolina* community in April of 1988 in the study area was normal. *M. phaseolina* populations were concentrated in large ridges or rounded spots. It can be assumed that these spots were the initial stage of formation of new ridges of phaseolina. The ridges were located parallel to the shore. They alternated with spaces without mollusks.

In composition, the meiobenthos were represented by 16 higher taxa. Taxonomic richness in the studied stations was close (9-11 higher taxa). In general, the free-living nematodes were dominant at all stations. In the upper zone of the community, at depths of 43-44 m, they accounted for 52% of the total number of meiobenthos, whereas at a depth of 52 m, the share of nematodes was only 19%, but Foraminifera and Ostracoda were leading (36 and 31%, respectively).

The percentage of free-living nematodes in the depth range of 72-76 m amounted to 50-87% of the total number of meiobenthos. Turbellarians (25%) and hard-shelled foraminiferans (25%) were the subdominants at some stations. The overall density of meiobenthos settlements within the study area ranged between 147-867 thousand ind/m^{-2}. The minimum values were recorded in the upper area of the phaseolina community.

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WESTERN GEORGIA AS A REFUGE FOR TERTIARY ELEMENTS OF EURASIAN FLORAS (USING THE EXAMPLE OF THE FAMILY HAMAMELIDACEAE)

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Keywords: Colchis refuge, Late Cenozoic, relict taxon, Hamamelidaceae, history of development

In Georgia, deposits of Upper Cenozoic age are widely distributed. All stages of the Neogene and Pleistocene have been dated by mollusk fauna and contain the remains of plants, represented by macrofossils, pollen, and spores. During most of the Miocene, more or less homogeneous vegetation was distributed over the whole territory of Georgia, and it developed without sharp fluctuations (Ramishvili, 1982). But from the Early Sarmatian, distinct differences can already be observed in the dynamics of vegetation in Eastern and Western Georgia. Nevertheless, the composition of flora continued to be relatively of the same type.

The situation sharply changed at the end of the Middle Sarmatian, which was the turning-point in the geological history of the Caucasus. As a consequence of crustal movements, the Trancaucasian intermountain depression transformed into dry land and was split into two sections by the Dzirula massif, eastward of which Kurian Bay originated. The territory of Georgia adjoining this bay became the area of accumulation for continental sediments. The character of the climate and vegetation also changed in connection with the process of xerophytization, which began in the Upper Sarmatian in the eastern part of Georgia. In the west, the so-called Rionian Bay formed, where marine deposits continued to accumulate until the end of the Pleistocene. The territory adjoining the Rionian Bay, hemmed in by high mountains, became isolated from the rest of the South Caucasus. A warm and humid climate prevailed here, helping to preserve rich forest vegetation. Thus, from the end of the Middle Sarmatian, the Colchis refuge took shape. Many Tertiary species have survived there up to the present time.

So, it is possible to conclude that Western Georgia is a unique region both from the botanical and geological point of view. On one hand, it is the refuge for elements of Tertiary floras, and on the other, it is the stratotypical region of the Eastern Paratethys, on the territory of which the Black Sea Upper Cenozoic is represented by a full series of deposits.

After the Sarmatian, our knowledge about the flora of Georgia is based mainly on the materials from Western Georgia. The study of pollen assemblages from successive layers of the Neogene allows us to reconstruct both the general picture of vegetation development and its separate components. Such investigations possess not only local significance, but they are indispensable for an accurate understanding of the history of Tertiary floras, whose relicts have been preserved within the territory of Western Georgia longer than in other regions of Europe and non-tropical Asia. From this point of view, special attention must be paid to the taxa, which in the past were widely distributed over the whole landmass of Eurasia and now occupy only narrow or discontinuous areas. The Hamamelidaceae is one such taxon, regarded now as a more ancient family. The largest and richest center of its distribution (about 50% of species) is East and Southeast Asia. Most of the genera are endemic or have narrow areas of distribution, and only *Hamamelis*, *Fothergilla*, and *Liquidambar* are represented in Asia and America (Skvorzova, 1975).

In the Cenozoic flora of Georgia, the family Hamamelidaceae was represented by 32 taxa, which belonged to 15 genera and 3 subfamilies: Hamamelidoideae, Exbucklandioideae, and Altingioideae. Twenty-two species have been identified by pollen grains and 8 by macroremains. In the history of Hamamelidaceae development within the territory of Georgia, three main stages can be distinguished. The first stage embraced the Eocene, Oligocene, and Middle Miocene. In this period, there existed 4 genera: *Hamamelis*, *Corylopsis*, *Sycopsis*, and *Liquidambar.* The second stage, Sarmatian and Meotian, can be considered the peak of flourishing for the family. During this time, representatives of the Hamamelidaceae played a significance role in the vegetation communities of Western Georgia. The third stage in the development of the Hamamelidaceae was the time of decline and extinction, which began in the Pontian and extended until the Middle Pleistocene.

Analysis of the rich literature shows that during the development of the family Hamamelidaceae within the territory of Eurasia, three stages can be distinguished (Shatilova and Stuchlik, 2001; Shatilova and Mchedlishvili, 2007). In the different regions of the continent, some phases of these stages were not synchronous, but transpired during different stretches of geologic time. In Asia and Europe, the evolution of the Hamamelidaceae closely mirrors that of the Turgaian flora.

In Georgia, the development of the Hamamelidaceae proceeded along the lines of evolution in the subtropical vegetation in the subtropical vegetation. Due to the isolated position of Western Georgia, this formation was preserved here longer than in other regions of Eurasia, and it can be traced up until the end of the Kimmerian. With the disappearance of evergreen forests, a great number of representatives of the Hamamelidaceae family became extinct. During the Kuyalnitsian and Gurian, only a few genera continued to exist in the composition of the deciduous polydominant communities, distributed across the plains and lower mountain belt.

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PETROGRAPHIC CHARACTERISTICS OF THE PRODUCTIVE SERIES OF THE ABSHERON PENINSULA ON THE BASIS OF SEM-ANALYSIS AND OPTICAL MICROSCOPY

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Keywords: Kirmaki valley, Surakhany, Sabunchi, Balakhany, suite, Post-Kirmaki, clays, sands, carbonates, deposits

Introduction

The productive oil-bearing stratum of the Absheron peninsula is the main reservoir of commercial oil reserves; it is represented by thick deposits consisting of alternating clays, silt, aleurites, aleurolites, sands, sandstones, loams, and conglomerates.

Research into the lithology and petrography of the Productive Series was carried out on its outcrop in the Kirmaki valley, where detailed sedimentological and lithological investigations were conducted (Fig. 1).

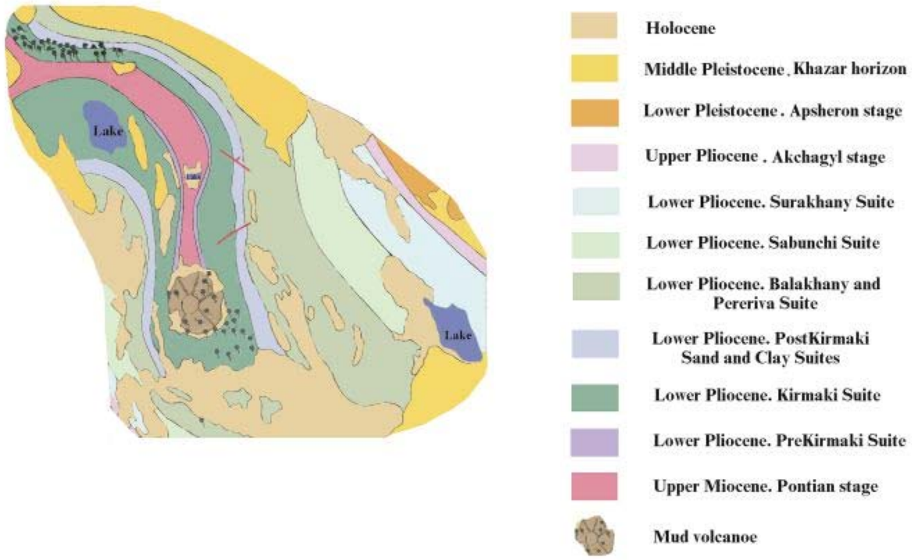


Figure 1. Geological map of the Kirmaki Valley.

The results obtained showed an extremely wide range and frequency of sedimentation conditions, which change in the vertical section of the Lower Pliocene (Aliyeva, 2002, 2008).

At the present time, deposits of the Productive Series of the Absheron peninsula are divided into 2 parts (Aliyev and Daidbekova, 1955).

1. Upper division (from the top downward):

(a) The Surakhany suite is characterized by clays, sandy clays, and clay sands up to 65% and the rest (35%) are sands.

(b) The Sabunchi suite, in contrast to the Surakhany, contains much less clean sand (up to 20%) and the rest (80%) comprises clays, clay sands, and especially sandy clays.

(c) The Balakhany suite is composed of 76% sand fraction. The sands are mainly medium-grained. The carbonate content ranges up to 20% in general. The percentage content of quartz ranges up to 80%.

(d) The "Pereriva" suite reveals a content of sands and sandstones reaching up to 93%, and only 7% is represented by clay sands.

2. Lower division (from the top downward):

(a) The PostKirmaki clay suite is characterized by a high content of the <0.1 mm fraction; the content of this fraction within suites varies from 30 to 80%, on average it equals 55%.

(b) The PostKirmaki sand suite. The first two fractions: > 0.25 mm and 0.25 mm-0.1 play a dominant role in the sands of the suites. In some cases, the fraction content of 0.25-0.1 mm reaches up to 40%, and the fraction content of > 0.25 mm reaches up to 30-35%. Quartz content increases up to 65% in the light fraction composition.

(c) The Kirmaki suite deposits are represented by small amounts of the first two fractions and a high content of the third fraction, i.e., the particles with sizes of <0.01 mm. The quartz content decreases to 35-40%.

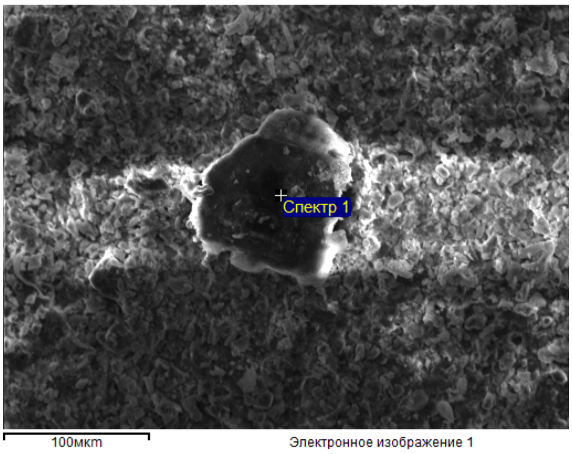
(d) The PreKirmaki suite shows a mechanical composition of sands of this suite that is comparable to "the first pereriva" sands, and it is very different from the sands of the Kirmaki suite by its significant content of fractions > 0.25 mm and 0.25-0.1 mm. The quartz content ranges from 50 up to 65%, the feldspar from 20 up to 30%, and different rock fragments from 10 up to 15%.

(e) The Kala suite comes out at the surface nowhere. It is known only from drilling results.

Results

We have set ourselves the task of revealing the main regularities of the change in mineralogical composition within the Productive Series deposits during sedimentation as determined by petrographic research on rocks using the Scanning Electron Microscope (SEM-analysis) and optical microscopy.

Using the SEM and EDS Oxford Instruments, we investigated several rock samples from the different types taken from several suites of the Productive Series (Figs. 2-4).



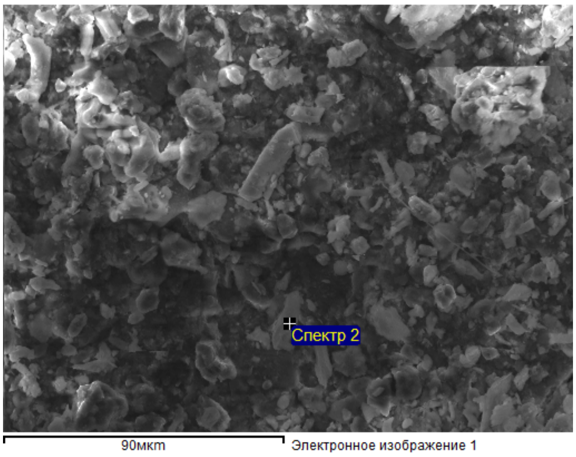


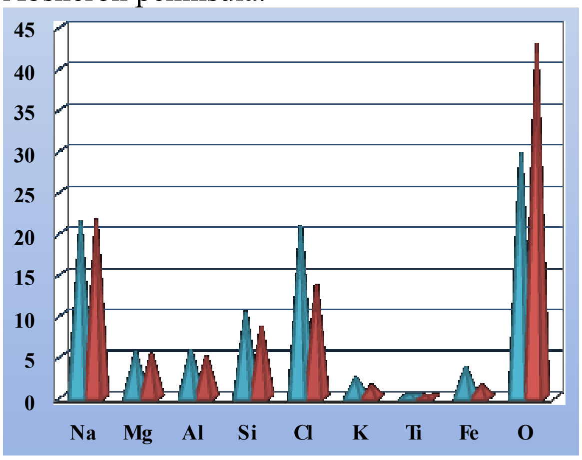
Figure 2. Photo of the samples under the SEM.

sample № 198 spectrum 1				
element	weight %	atomic %	compounds %	formula
Na	21.44	21.58	28.91	Na_2O
Mg	5.5	5.24	9.12	MgO
Al	5.74	4.92	10.84	Al_2O_3
Si	10.37	8.55	22.19	SiO_2
Cl	20.84	13.6	0	
K	2.38	1.41	2.87	K_2O
Ti	0.33	0.16	0.54	TiO_2
Fe	3.64	1.51	4.69	FeO
O	29.75	43.03		

sample № 198 spectrum 2				
element	weight %	atomic %	compounds %	formula
Na	1.79	1.72	2.41	Na_2O
Mg	9.62	8.77	15.95	MgO
Al	12.48	10.25	23.58	Al_2O_3
Si	17.21	13.58	36.81	SiO_2
S	0.18	0.12	0.44	SO_3
Cl	1.11	0.7	0	
K	0.5	0.28	0.6	K_2O
Ca	0.46	0.26	0.65	CaO
Fe	14.34	5.69	18.45	FeO
O	42.31	58.63		

Figure 3. The elemental compositions of the particles in sample 1 and 2 with help of EDS.

The rocks were taken from the Productive Series outcrop in Kirmaki valley, located on the Absheron peninsula.



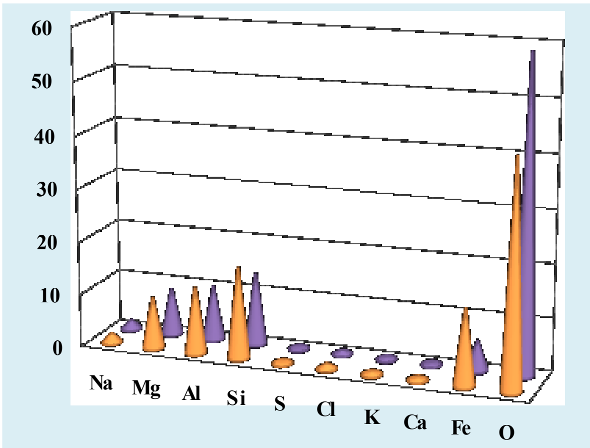


Figure 4. Diagrams of elemental content in sample 1 and 2.

The results are as follows:

1. Due to research on grain roundness in the sand rocks of each suite, it has become clear that the grains of the PostKirmaki and Balakhany suites have the most roundness. Based on the degree of grain roundness, one may talk of the saturation of rock by fluids.

2. The difference in mineral composition of the sand rocks of various suites has been determined. The greatest content of pyrite has been revealed in the PostKirmaki suite and Kala suite (up to 80%); in other suites, its content is sharply decreased. It has been noted that there is a complete absence of pyrite in the middle division of the Balakhany suite. The pyrite existence indicates a reducing medium; it is the lack of oxygen during deposition of these rock formations that is the reason for the full absence of fauna.

3. The content of hydromicas and montmorillonite in clay rocks of the suites has been studied. It has been established that the montmorillonite group minerals is predominant in the clay rocks of the PostKirmaki Clay and Sabunchi suites. Hydromicas predominate in the Kala suite.

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NORTHWESTERN BLACK SEA REGION AT THE LGM: SEARCHING FOR THE SEA IMPACT ON HUMAN ADAPTATION

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Keywords: bison hunters, Anetivka, human occupation

Introduction

In the context of discussions into the human response to global climate change in the northwestern Black Sea region during the last 30 kyr, the Last Glacial Maximum (LGM) is traditionally viewed as the key period marking the state of the ecosystem just on the eve of the fundamental and rapid climatic fluctuations of the Pleistocene-Holocene boundary. The subject of the current contribution is to highlight peculiarities in the mode of life and subsistence strategy of populations in the northwestern Pontic steppes during the LGM and to delineate the basic features of human adaptation to severe climatic conditions in the period under study.

Paleogeography

Peculiarities of the Black Sea basin, its shoreline localization at the early Neoeuxinian stage (which includes the LGM), and specific features of the paleogeography of its shelf were recently discussed (see more details in Yanko et al., 2011). Most researchers agree that the maximal stage of the Last Glaciation resulted in a significant decrease in river flow, and the connection between the Marmara and Black seas was interrupted; the Black Sea was transformed into a brackish early Neoeuxinian lake, the shoreline of which was located about -100 m below the present (Yanko-Hombach et al., 2007) .

Adjacent areas of the steppe zone of Ukraine as well as a huge part of the modern northwestern shelf of the Black Sea at that time belonged to the southern part of the periglacial steppe region characterized by xerophytic grassy vegetation (Artyushenko, 1970: 163). The proportion of grasses in spore-pollen diagrams from this region is up to 95%, and representatives of *Artemisia* and Chenopodiaceae species were absolutely dominant in this group (90-98% of all grasses). Arboreal vegetation is very scarce and represented by species well adapted to an arid and cool climate – pine, birch, and alder (Arap et al., 1990).

The lower parts of big rivers (Dniester, Pivdennyi Bug, and Dnieper) were characterized by a mixture of meadow steppe landscapes with a higher proportion of arboreal vegetation where pollen of deciduous trees is also represented (up to 2%). Reconstruction of landscapes of the Black Sea shelf indicates that during the LGM, now submerged parts of the big rivers were associated with lowlands, sometimes marshy, with a higher proportion of meadow grasses and bushes (Yanko et al., 2011: Fig. 8).

Prehistoric bison, *Bison priscus*, the typical inhabitant of the periglacial steppe area, was the main component of the local mammalian faunal complex, alongside horse and saiga. Further to the north, one can observe also remains of reindeer and other tundra species (arctic fox, woolly rhinoceros, and others) (Bibikova, 1985). Available paleontological data provide no direct information about mammalian fauna from the now submerged part of the region under study.

Human occupation of the region

During the LGM, the northwestern part of the Black Sea shelf was explored by bison hunters, and the peculiarities of procurement of this large gregarious game produced the occupation system and mode of life of the population of this area. Roundup collective hunting, which was the most fruitful way of procuring bison herds, required the concentration of a large number of people engaged in this process. The key archaeological sites of the region – Anetivka 2 (Pivdennyi Bug river flow) and Velyka Akkarzha (Lower Dniester region) – mark places of such agglomeration.

In the case of Anetivka 2, the peculiarities of spatial distribution of flint artifacts, faunal remains, and other findings (ocher, quartz, kaolin, charcoal, and others) alongside the topography of the site were the reasons for its principal investigator, Vladimir Stanko, to interpret it as the place of preparation for and implementation of a series of rites during the course of a special festival devoted to successful bison hunting. Among the activities which could be archaeologically traced within the Anetivka 2 assemblage and planigraphy are: preparation of collective hunting, production of hunting weapons and tools for meat processing, preparation of 'decorations' for a festival (arrangement of bison skulls and bones, production of ritual weapons, body coloration using ocher kaolin, and decorative elements, festivities (including meat consumption, bone storage, dancing on them, etc.) (Stanko, 1999).

The site was occupied probably several times per year for several days or a couple of weeks just for such hunting and ritual occasions, while the rest of the year, hunters spent foraging in adjacent territory, surviving by procuring smaller non-gregarious game and by collecting plants. This is confirmed by the discovery of about 30 Late Paleolithic archaeological sites located within walking distance from Anetivka 2, near the Bakshala River, a Southern Bug tributary. Non-durable, repeated concentrations of large groups at a certain place for a special purpose probably was the reason why the flint assemblage of Anetivka 2 displays consolidation of features typical for the local population (inhabitants of Anetivka 13, which is associated with the previous climatic stage) and newcomers (Sagaidak type) (Stanko, 1997a: Fig. 23).

One can observe a similar tendency toward integration of local and recently arrived components from Crimea and the Lower Dnieper region that is also traceable in the flint assemblage of Velyka Akkarza (Lower Dniester region), another basic site of LGM bison hunters of the northwestern Pontic region (Stanko, 1997b; Sapozhnikov, 2002: Fig. 97). In contrast with Anetivka 2, this site displays no signs of ritual activity and cult, while there is no doubt that the site occupation was connected with bison herd procurement by a population inhabiting a series of nuclear structures and visiting this place during the warm period of the year for several weeks (Sapozhnikov, 2002).

Conclusion

Available archaeological and paleogeographic data about human occupation in the northwestern Black Sea region at the LGM indicate that the epicenter of human activity was located at a significant distance from the coeval shoreline, and very far from the Black Sea coast at the period under study. The northern periphery was rather intensively explored by bison hunters, among which were descendants of local inhabitants of the region during the previous phase and newcomers. Extensive procurement and overkills of bison soon brought about a decrease and further disappearance of this species.

Information about human occupation in the submerged part of the northwestern Black Sea shelf at the LGM is restricted to paleogeographic data and scarce oral communications about the presence of flint artifacts in a series of underwater core samplings made during the last third of the twentieth century. This hypothesis is also confirmed by connections between the populations of Crimea, the Lower Dnieper region, Romanian Dobrudja, and the Middle Dniester region, which could be traced archaeologically. In spite of attempts to model potential distribution of archaeological sites in submerged areas and verify it in the course of underwater fieldwork, we still have no artifacts from this part of the region under study (Kadurin and Kiosak, 2013).

Peculiarities of paleogeography in the submerged shelf allow us to suggest that this area was hardly suitable for bison herds and, consequently, for implementation of traditional systems of living space exploitation as was practiced in the northern area. Nevertheless, the contemporary state of the source base provides very restricted possibility to discuss further details of human occupation of the submerged northwestern Black Sea shelf during the LGM.

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DEEP-SEA HOLOCENE SEDIMENTS OF THE MEDITERRANEAN SEA, THE BLACK SEA, AND THE CASPIAN SEA

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Introduction

In accordance with the goal declared by the IGCP 610 Project, a comparative study of Holocene sediments in the Mediterranean, Black, and Caspian seas, formed under the conditions of post-glacial environmental changes, may serve as a model for a better understanding of the Quaternary history of the development of these closely interconnected basins. The accumulation of Holocene sediments occurred in different, changing environments on the surrounding land and in the seas. Differences in climatic conditions manifested themselves in changes of temperature and the degree of atmospheric moisture, and in turn, the water balance of the bodies of water. Seas lying in different climatic zones are distinguished by physical (temperature, salinity), chemical (salinity, composition, gas regime), and biological (diversity, productivity) water properties, the trajectory of their change over time, as well as by the presence, nature, and time communication between them. The last determined the mode of development of the reservoirs. All this leads to a complicated system of formation for Holocene sediments, their composition, and incompleteness of the chronicle Therefore, the aim of our work is a comprehensive comparative analysis of the stratigraphy, structure, sections, composition, conditions of formation, and paleogeography of the Holocene sediments.

Methodology

The work is based on several dozen sections of Upper Quaternary deposits up to a length of 3-5 meters. They were selected from the bottom of continental slopes and adjacent deep-sea basins at depths from several hundred meters to 2-3 km in the southern part of the Eastern Mediterranean, the western half of the Black Sea, and the Derbent depression of the Middle Caspian. The processing of core material was performed for macro and micro descriptions, the content of $CaCO_3$ and organic carbon definitions, Fe forms, and granulometric analysis. The age division of the cores was made on the basis of foraminiferal, diatom, spore-pollen, and nannoplankton analysis, and using our own and literature data on radiocarbon analysis.

Results

The Eastern Mediterranean. Holocene sediments crown the section of Upper Quaternary deposits. The age of the base is defined at the level of 10-11 ^{14}C ka BP (Thunell et al., 1977; Robinson et al., 2006). In the composition of the horizon, three layers were identified (Fig. 1).

The lower layer, corresponding to the beginning of the Holocene (Preboreal), was composed of clayey calcareous silt (protosapropel) with traces of activity of small mud-eaters, slightly enriched by organic matter. The middle layer revealed dark-green sapropel S1. It has a fine color and "mottled" texture due to the substantial processing of mud-eaters. Some of them up to a length of 3 mm and a diameter of less than 1 mm are light brown in color and are enriched with biogenic and terrigenous silt and sandy material.

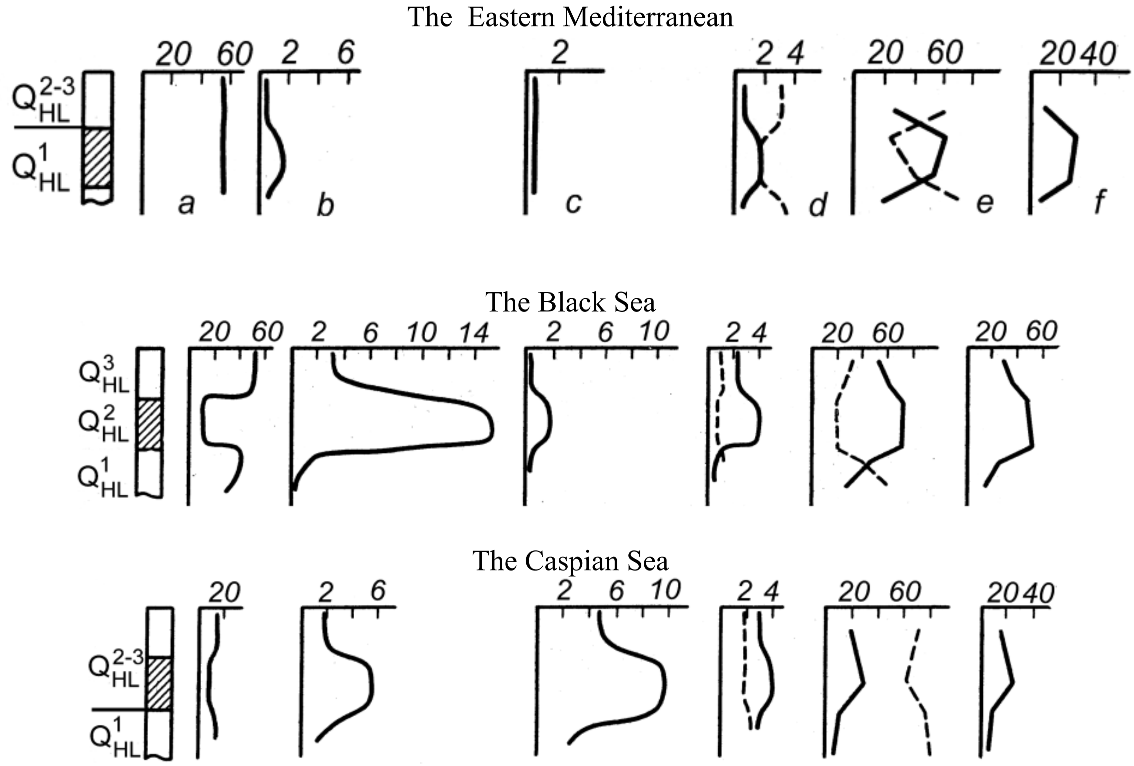

Figure 1. Structure and composition of the Holocene sediment.
Content, %: a – $CaCO_3$; b – C_{org}; c – $SiO_{2\ amorf.}$; d – forms of Fe (FeO – solid line, Fe_2O_3 – dotted line); e – arboreal (solid line) and grassy (dotted line) pollen; f – deciduous pollen; hatching – sapropel.

A significant proportion of the sapropel represents coccolithophores, foraminifera, and pteropods. Concentrations of TOC in the sapropel reach 3%, while in the host sediments, they are less than 0.5%. Sapropel and mud are characterized by almost the same high carbonate and low amorphous silica content. The thickness of the sapropel reaches 10-20 cm; the age of the lower boundary is ca. 9 ^{14}C ka BP, and the upper limit is 7 ^{14}C ka BP (Thunell et al., 1977; Robinson et al., 2006), i.e., it belongs to the lower Holocene (Preboreal to lower Atlantic period). The upper layer (middle to upper Holocene) is oxidized light brown calcareous silt with mottled coloration. It contains a black manganese silt interlayer, above which lies a thin tephra interlayer with an age of ca 3.5 ^{14}C ka BP, associated with the eruption of Santorini (Thunell et al., 1977), which effectively separates the middle and upper Holocene.

Biostratigraphy studies were based on microfaunal and microfloral analyses. In the composition of the planktonic foraminifera, we identified "warm-water" and "cold-water" complexes. The first includes *Globigerinoides ruber*, *G. succulifer*, *G. rubescens*, *Hastigerina aequilateralis*, *Orbulina universa*, *Globoquadrina dutertrei*; the second includes *Globigerina pachyderma*, *G. quinqueloba*, *G. bulloides*, and *Globorotalla scitula*. The composition of benthic foraminifera also revealed two complexes that agree with the complexes of planktonic foraminifera. The first, "cold-water," includes the following types of *Bulimina*-*Cassidulina* and Rotaliida-Miliolida groups: *Bolivina dilitata*, *B. albatrossi*, *Cassidulina carinata*, *Hofkeriana alata*, *Bulimina marginata*, *B. costata*, *B. gibba*, *B. spinifera*, *Brizalina catanensis*, *Trifarina anguloza*, *Uvigerina auberiana*, *Gavelinopsis* sp., *Epistominella rugose convexa*, *Cibicidoides floridanus*, *Miliolinella circularis*, *Hyalinea baltica*; the second, “warm-water”, includes *Uvigerina mediterranea*, *Cassidulina crassa*, *C. oblonga*, *Bolivina pseudoplicata*, *Globobulimina pseudospinescens*, *Bulimina exilis*, *Nonion barleeanum*, *Hoeglundina elegans*, *Gyroidina umbonata*, *G. neosoldanii*, *G. altiformis*, and *Melonis formosum*.

Diatoms were categorized on the base of marine, brackish, and freshwater species. Given the high salinity of the Mediterranean Sea, a significant number of freshwater species in Holocene sediments must be due to their removal from the land and redeposition. Marine and brackish-water diatoms are divided into three ecological groups: the littoral, the neretic, and the oceanic species. The neretic type is dominant – up to 43% of all valves recovered. There are *Cyclotella caspia*, *Thalassiosira decipiens*, *Coscinodiscus marginatus*, *Actinoptichus undulatus*, *Thalassionema nitzschioides*, *Hyalodiscus subtilis*, and *Chaetoceros* sp. The littoral forms include benthic and planktonic species living at shallow depths. They are richer than other groups in species diversity (28 taxa), but the number of valves number up to 28.5%. Among them, the most frequent are *Paralia sulcata* and species of the genera *Grammatophora*, *Cocconeis*, *Diploneis*, and *Lyrella*. Oceanic forms make up 28% of the total number of folds and belong to 8 species: *Thalassiosira atiqua*, *Th. excentrica*, *Th. oestrupii*, *C. asteromphalus*, *C. oculusiridis*, *C. radiatus*, and *Rhizosolenia calcar-avis*. They reach their maximum density in the upper part of the section. As for the composition of pollen and spores, we observed changes in the context of the relation of representatives of herbaceous and arboreal pollen associated mostly with shifts between moist and arid climatic periods.

In the composition of foraminifera in the lower layer (protosapropel), there is a transition from the dominance of cold-water species to an increase in the warm-water complex. Among diatoms, neretic species quantitatively predominate (*Thalassiosira decipiens*, *Coscinodiscus marginatus*, *Chaetoceros* sp.), and oceanic species appear. In the composition of the spore-pollen complex, herbaceous pollen dominates, but the role of pollen from conifers is increased. In the sapropel S1, the nature of the fauna and flora changes dramatically. Among the planktonic foraminifera, the warm-water complex dominates, which accounts for 45-90%. The number of benthic foraminifera also contains the warm-water complex, but it is reduced to a minimum. The composition of diatoms shows a sharp jump in species diversity mainly due to benthic forms. Most of them (genera *Grammatophora*, *Diploneis*, *Lyrella*) first appear in this interval and are characteristic of the modern Mediterranean Sea. Neretic species predominate, but a more prominent role relative to the underlying horizon is played by oceanic diatoms: *Thalassiosira oestrupii* and *Coscinodiscus asteromphalus*, which are absent below. In general, marine diatoms dominate. Compared to the lower layer, the composition of the pollen shows a dominance of arboreal pollen (45-70%), and the share of pollen from broad-leaved trees accounts for up to 40% of its population, with a rich species diversity. Chenopodiaceae (10-34%), Asteraceae (4-16%), *Artemisia* (2-6%), cereals (2-4%), and motley grass dominate among the herbaceous pollen. The given spectrum indicates a hot and fairly humid climate, when forests existed on the African coast, along with steppes. In the upper layer (middle-upper Holocene), foraminifera also indicate the warm-water complex now living in the Mediterranean Sea. In the composition of diatoms, brackish-water species disappear, and the marine group contains the most prevalent oceanic forms: *Thalassiosira excentrica*, *Th. oestrupii*, *Coscinodiscus madiatus*, and others, all living in the sea at present and the most thermophilic. The character of the pollen spectrum is also close to modern. In its structure, the value of herbaceous pollen and pollen of conifers again increases, which indicates aridization of the climate.

The Black Sea. The sequence of Holocene sediments in the Black Sea also consists of 3 layers (Fig. 1). The lower layer is represented by gray clay silt of the upper part of the Novoeuxinian horizon. It begins with a pronounced lime sludge with a content of $CaCO_3$ up to 70%, the base of which has an age ca 10 ^{14}C ka BP (Major et al., 2002). Among the diatoms, the cold-water planktonic species *Stephanodiscus astraea* with a small admixture of other freshwater species (*Cyclotella ocellata*, *C. kuetzingiana*) dominate and even form separate interlayers. In the pollen composition, as well as in the underlying Pleistocene clays, grasses dominate (*Artemisia*, Chenopodiaceae, Gramineae, single *Ephedra* are isolated). Arboreal pollen is represented by pine with a small admixture of deciduous trees. Toward the end of Novoeuxinian time, the value of grass pollen is reduced, and trees, including broadleaf, increase. The thickness of this horizon reaches 50-70 cm. Accumulation of this layer can be identified with the Preboreal and Boreal periods of the Lower Holocene. Average (Drevnechernomorian) layer is represented by sapropel with a TOC content of 15-20%. It differs in its microlaminated texture formed by laminae of clay and organic material. Its characteristic feature is the presence near the base of numerous interlayers of aragonite. In the composition of the biogenic residues in the sapropel, there are a few thin calcareous interlayers of the coccolithophorids *Brarudosphaera bigelowi* and rarely other species.

The composition of diatoms changes from a freshwater complex to a euryhaline, brackish-marine and marine one with a broad representation of the taxa: *Coscinodiscus*, *Thalassiosira*, *Actinocyclus*, *Chaetoceros*, and Silicoflagellatae. Arboreal pollen reveal a large variety of broad-leaved trees, and conifers dominate in the spore-pollen spectrum. The composition of the grass pollen is also more diverse. The thickness of sapropel varies from 30 cm to 50 cm, and the age measured at the lower aragonite interlayer was ca 6.8 ^{14}C ka BP. According to the analysis of coccoliths from the lower part of the next higher layer, the upper boundary of the sapropel has an age of between 2.8 and 3.5 ^{14}C ka BP. Judging by the nature of the paleontological remnants and determinations of chronometric age, the accumulation time of the sapropel corresponds to the Atlantic period of the Holocene. The top layer is referred to as the Novochernomorian horizon (upper Holocene) and presents a clay-limestone layered with silt, mostly including occolithophorid *Emiliania huxleyi* mixed with some other Mediterranean species. The composition of diatoms is the most diverse. The first species to appear include *Asteromphalus robustus*, *Coscinodiscus granii*, *C. marginatus*, *Grammatophora hamulifra*, *Thalassiosira excentrica*, *T. excentrica* var. *fasciculata*, and *Proboscia alata*. Extensive development is shown by *Rhizosolenia calcar-avis*. The spore-pollen spectrum is dominated by pollen of tree species. Compared to the previous layer, the value of the pollen of broad-leaved trees decreases, and pine grows. There are two intervals, within which there is an increase in the grass pollen. The role of the latter increases towards the end of Novochernomorian time.

The Caspian Sea. Holocene sediments in the Caspian Sea are represented by 3 layers (Fig. 1). The boundary of the lower layer (the Mangyshlakian horizon) is marked by a threetime increase in $CaCO_3$ content (from 13% to 39%). It is a grey calcareous clayey silt, in which there is a large number of chemogenic carbonate crystals in the form of high-magnesium calcite with hydrotroilite impurities. TOC was determined to be 1-2.5%. The composition of diatoms in the base layer includes the dominant neretic marine-brackish species *Actinocyclus ehrenbergii*. In fewer numbers are the freshwater-brackish species *Gyclotella kutzingiana*, *Stephanodiscus astraea*, a single marine species *Rhizosolenia alata*, and *Coscinodiscus radiatus*. In some cores, there are quite diverse benthic freshwater and brackish-water species of the genera *Diploneis*, *Fragillaria*, *Synedra*, and others. The abundance of brackish species indicates low salinity waters during the accumulation of the host sediments. The complex is dominated by temperate species, attracting the attention of temperate warm-water species, among which are numerous endemic species (*Actinocyclus paradoxus*, *Thalassiosira caspica*, and *Th. incerta*).

Compared to the underlying Khvalynian sediments (in which the pollen of herbs and xerophytes dominate), the pollen spectrum shows that the proportion of woody plants (to 12-14%) together with isolated pine and birch are increasing. Upward within the layer, the amount of pollen of deciduous and broad-leaf trees increases. The share of herbs falls to 65-75% of the pollen (Chenopodiaceae 33-57%, *Artemisia* 12-32%, *Ephedra* 3-7%). The content of spores also increases (12-23%). The composition of the spectrum is characterized by the upward increase of pollen of *Artemisia* and deciduous trees and a reduction in the amount of Chenopodiaceae. The recovered spectrum indicates arid conditions, but it points to a slight humidifying of climate at the end of the interval. The thickness of the Mangyshlakian layer reaches 50-100 cm. Correlation with sections of the shelf suggests that its accumulation began about 10 ^{14}C ka BP (Bezrodnikh and Sorokin, 2016). The top layer (the Novocaspian horizon) with a thickness up to 20-50 cm is composed of green-grey clay silt with patches of thin interlayers enriched in diatoms. In its middle part there is a green laminated sapropel in which there are clay, diatomaceous, and sapropelic microlayers with a total capacity up to 10-15 cm. This part has a high content of TOC (up to 6%) and low $CaCO_3$ (less than 10%). The upper part of the layer is composed of laminated clay-diatom silt. The horizon is characterized by the overall predominance of marine planktonic species of diatoms, among which *Coscinodiscus radiatus* usually dominates. In subordinate amounts, the sediments contain marine species *C. gigas*, *Rhizosolenia calcar-avis*, *Rh. alata*, *Thalassiosira excentrica*, a marine-brackish species *Actinocyclus ehrenbergii*, *Cyclotella caspia*, *C. striata*, and *Coscinodiscus jonesianus*.

Representatives of the benthic marine and freshwater species are rare and, as a rule, characteristic of the North Caspian. Therefore, the described complex is dominated by planktonic oceanic and, to a lesser extent, neretic species over benthic species; there is a predominance of marine species and a much smaller number of marine-brackish species. The composition of diatom flora also indicates a predominance of cosmopolitan species, a smaller number of temperate species, and isolated endemic species (*Chaetoceros diversicurvatus*, *Stephanodiscus binderanus*). The spore-pollen spectrum contains the maximum number of tree pollen (25%), the floristic composition of which is quite diverse. Noted among the broad-leaved species are oak, elm, hornbeam, and hazel. Conifers are represented mostly by pine. Among the grasses, the spectrum is dominated by pollen of *Artemisia* (34-38%) and Chenopodiaceae (25-28%). The described spectra indicate a substantial participation of forests in the vegetation of the land because of a moister climate, especially during the accumulation of the sapropel. The sapropelic horizon with the marine diatom complex can be associated with shelf deposits containing the marine mollusk *Cerastoderma glaucum*, which testifies to the synchronicity of their appearance in the Caspian Sea. Their age was determined to be 4-5 ^{14}C ka BP. If so, the sapropel was formed during the second half of the Atlantic period.

Conclusion

The results indicate the similarities and differences in the development of the Holocene natural environment in the Eastern Mediterranean, Black, and Caspian seas as embodied in the structure and composition of their deep-sea sediments. The results are due to both the general orientation of the natural process in the post-glacial period, and the specifics of the sedimentation in each of the basins in terms of climate change and development of the post-glacial transgression. The similarity of the Holocene horizon in the three seas manifests itself in their tripartite structure, the formation of sapropel deposits, and similar changes in the composition of microfauna and flora associated with climate change on the land and in the waters themselves. The differences are expressed in the different lithological composition of sediments; in the ratio of terrigenous, biogenic, and chemogenic material at different stages of development; and in the degree of enrichment of sapropel organic matter (less than 3% in the Mediterranean Sea, to 15-20% in the Black Sea, to 6% in the Caspian Sea) as a result of varied bio-productivity. The diversity of fauna and flora and the combination of its components over time are also significantly different. For example, in the Mediterranean Sea under conditions of high salinity, the context reveals constantly present planktonic and benthic foraminifera, coccolithophorids, pteropods, diatoms, pollen, and spores. In the Black Sea, in terms of its development from an isolated lake reservoir to a sea basin, it is the diatoms and pollen in the top section with added coccolithophorids. Finally, in the fully isolated Caspian Sea, the main paleontological reference points are diatoms and pollen and spores. The data of radiocarbon dating indicate a rejuvenation of the age of the individual layers, especially sapropel, from west to east (9-7 ka BP in the Mediterranean Sea, 7-3.5 ka BP in the Black Sea, and less than 5 ka BP in the Caspian Sea) reflecting a delay in the onset of the Holocene climatic optimum.

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COLLECTIONS OF THE CENTRAL SOIL MUSEUM AS A FOUNDATION FOR SOIL-ECOLOGICAL MONITORING OF THE CASPIAN-BLACK SEA-MEDITERRANEAN CORRIDOR TERRITORY

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Soil retains a peculiar form of landscape memory. All significant ecosystem changes get imprinted into the soil profile as a result of changes in external environmental factors. Consequently, by looking at a soil's structure, it is possible to read a landscape's history and, oftentimes, the history of people's culture over thousands of years. From this point of view, the comprehensive study of soils, along with other elements of the natural environment, is imperative in understanding the history of Eurasia, natural changes, and their effect on humans.

The natural environment is not all that influences humans. As a result of anthropogenic activity, changes in soil and the soil cover have taken on characteristically new changes in the last few decades. To gauge the scale of the changes in the ecological potential of soils and to construct a model for prognosis of the consequences of these changes, the organization of soil-ecological monitoring is necessary. The main goal of soil-ecological monitoring is the observation of the parameters of soil functioning at polygons and the creation of regional databases of the ecological potential of soils in the general soil-ecological monitoring system. One of the main objectives of organizing monitoring, on which its effectiveness depends, is optimally choosing reference points. Big opportunities for choosing defining points and organizing monitoring are given by the soil collections of the Dokuchaev Central Soil Museum. The monoliths and samples collected using the same method and having one space-time link preserve priceless information about soils at the moment of their collection.

The monolith collections of the V.V. Dokuchaev Central Soil Museum were put together over the course of 110 years and contain over two thousand units. A soil monolith is a sample of structurally undisturbed soil, typically 20x100x5 cm in size. The museum holds monoliths of soils of the main Eurasian landscapes, including landscapes of the Caspian-Black Sea-Mediterranean Corridor (Table 1).

Table 1. List of the museum's soil monoliths from the territory of the Caspian-Black Sea-Mediterranean Corridor

Country	**Number of soil monoliths stored in the museum**	**Country**	**Number of soil monoliths stored in the museum**
Russia:		Armenia	18
Volgograd Oblast	19	Azerbaijan	8
Voronezh Oblast	44	Bulgaria	6
Kalmykia	14	Georgia	35
Krasnodar Krai	15	Kazakhstan	102
Kabardino-Balkaria	3	Turkmenistan	24
Rostov Oblast	13	Ukraine	130
Stavropol Krai	16		
Republic of Crimea	35		

Currently, a database of monoliths of defining point soil models is being created at the museum for the purpose of monitoring. The following criteria were used to distinguish models of natural and arable soils for the purpose of monitoring (Table 2).

Table 2. Criteria for distinguishing soil models for the purpose of monitoring

<table>
<tr><th>For natural soils</th><th>For arable soils</th></tr>
<tr><td colspan="2">Distinctive and most representative soils
Closest conformity with the morphological structure, content, and soil properties of the “main model”</td></tr>
<tr><td>Soil climax conditions conforming with the climatic norm</td><td>Soil condition conforming with the model of highly fertile soil</td></tr>
<tr><td>Absence of processes and clear signs of secondary soil changes</td><td>Absence of clear signs of soil degradation</td></tr>
<tr><td>Consistent ecosystem conditions and absence of signs of intentional or indirect changes to soil formation factors and chemical pollution in the territory</td><td>Consistent land usage</td></tr>
<tr><td colspan="2">Presence of data on morphological structure, content, and soil properties.</td></tr>
<tr><td colspan="2">Exact temporal and geographic link to the location of soil sample collection.</td></tr>
</table>

Along with soil monitoring, the condition and productivity of the plant community and level of groundwater must be observed on the polygons. A passport must be created for each site and must contain a complete morphological description and photo of the profile. A monolith and soil samples must be collected for permanent storage, a characterization of the soil metagenome is desirable. Depending on parametric characteristics, the following time intervals for soil monitoring have been established (Aparin et al., 2016):

- visual-comparative diagnostics of the soil-vegetative cover conditions – every three years;
- soil humidity and pH surveying in the root zone (0-30) – every three years;
- nutritional element distribution (N, P, K) – every nine years;
- survey of heavy metal and radionuclide content in layers 0-5, 5-10 – every nine years
- determining biological activity – every three years;
- determining biological cycle elements and carbon content in the forest floor and humus-accumulative horizon – every nine years.

Possible radical changes in the soil cover and plant community conditions (e.g., fire, plowing, mechanical disturbances) can reveal a need to conduct a new series of studies of the basic parameters of soil-ecological monitoring.

Based on the collections of the museum, there have already been studies of the changes in diagnostic parameters of the functional-ecological condition of the chernozems of Volgograd and Voronezh Oblast over 70 and more years (Lawrence et al., 2005; Gurin et al., 2012).

Besides the monolith collection, the museum also holds a cartographic collection containing the first editions and authors’ manuscript maps beginning in the 1880s, which characterize areas of the Caspian-Black Sea-Mediterranean Corridor. Before the museum even opened, all the exhibits having to do with soil were carefully collected and demonstrated in various exhibitions in Russia—Moscow (1895), Nizhniy Novgorod (1896), Saint Petersburg (1897, 1898, 1899)—and abroad—Paris (1889 and 1900), and Chicago (1893). Soil maps, as with the exhibited soil samples, played a major role in the propaganda of soil science in European and American countries.

The first scientific data on the soils of the Corridor belong to V.V. Dokuchaev (Fig. 1). Dokuchaev's first visit to northern Caucasus was in 1878. A year later, he published the fundamental work "Cartography of Russian Soils" in which, based on his own methodology of studying natural phenomena, he systematized the materials on studying the content, properties, origin, and geography of the soils of the European part of Russia.

Figure 1. V.V. Dokuchaev with members of the forest department during a trip through the Caucasus in 1895-1896.

In the work *Russian Chernozem*, Dokuchaev writes: "Crimea and Caucasus, these favored corners of Russia, are still terra incognita to us in the soil sense (as in many others). Such shortage is even more noticeable in the fact that these areas, being absolutely isolated and having extremely variable physical conditions (soil, age, climate, vegetation, elevation, terrain, etc.) on relatively small territories could provide an amazing and, one could say, sole material for answering the more difficult and interesting questions in the field of soil science" (Dokuchaev, 1883). The result of the Caucasus expeditions was Dokuchaev's drafting of the first soil map of the Caucasus and completion of the studies of the laws of natural areas. V.V. Dokuchaev demonstrated the finished materials on his last Caucasus tours and collection of soils and subsoils of the Caucasus and Transcaucasia at the international exhibition in Paris (1900), for which he received the highest award of the exhibition – the Grand Prix.

An updated version of "The Soil Map of European Russia," put together by Professors N.M. Sibirtsev, G.I. Tanfiliev, and A.R. Ferkhmin (1900) based on Professor V.V. Dokuchaev's work, was displayed at the international exhibition in Paris, and later became the most valued exhibit of our museum as a monument to the history of science at the First and Second

International Congress of Soil Scientists. The exposition contains one more exhibit of this exhibition – the terrain map of the Poltava Governorate (in gypsum) put together using Tillo's hypsometric map and Dokuchaev's soil map. The map shows a typical steppe surface indented with ravines and valleys. This map shows the connection between a territory's terrain and soil type and destroyed the existing impression at the time that a steppe is a flat plain.

The museum holds two of Dokuchaev's maps, also originals: "The Schematic Map of the Chernozem Region of Russia and Adjacent Regions" and "The Soil Map of the Nizhniy Novgorod Governorate," which also served as exhibits at the Paris Exhibition (1900), the Columbian Exhibition in Chicago (first two), and the Second International Soil Science Congress. The museum's collections also hold later cartographical material related to the Caspian-Black Sea-Mediterranean Corridor.

To come to a deep understanding of natural changes and their effect on the past and future of humanity within the territory of Eurasia, it is imperative to give attention to every side of the existing vastness of scientific material in the field.

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THE IMPACT OF REGIONAL GEOPHYSICAL FACTORS ON HUMAN BLOOD COUNTS IN THE CASPIAN LOWLAND

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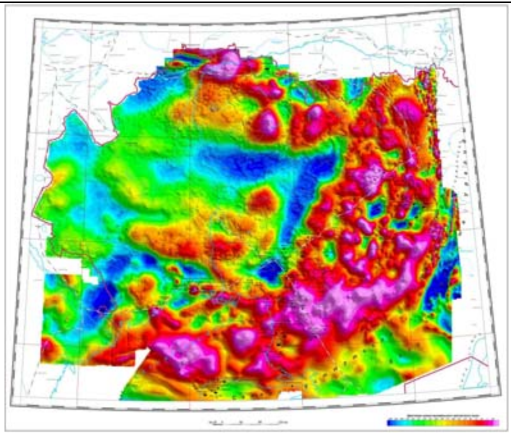
Keywords: magnetic anomalies, erythrocytes, hemoglobin, ferritin

Introduction

The three inland Eurasian seas, the Mediterranean, Black Sea, and Caspian Sea, share a common geological history as they are all remnants of a giant Tethys Sea basin that once occupied a huge area of Europe, North Africa, and West and South Asia. The Caspian Sea is an extreme member of this descending series. Its bottom, especially in the middle part, is divided by a network of seismic faults located in three directions – northwestern, meridional, and northeastern, and is characterized by intensive geomagnetic and gravity anomalies that are well pronounced in the Caspian Lowland (Fig. 1a) (Segalovich et al., 2007).

a



b

Figure 1. a. Caspian Depression and north Caspian Sea from space: (https://en.wikipedia.org/wiki/Caspian_Depression#/media/File:Caspian_Depression_NASA_(edited).jpg); b. Anomaly magnetic field of the Caspian Depression (Kiinov et al., 2013: http://www.geoken.com/files/ams.pdf).

The majority of the anomalies are characterized by intensities up to 300-500 nTl (Kiinov et al., 2013) and have cellular structure (Fig. 1b) related to diapiric tectonics.

These anomalies are characterized by elevated electrical conductivity due to insufficient dielectric strength in certain local volumes. Anomalous development of the variable magnetic field of the Earth exerts an influence on the magnetic field of any living organism, including humans, as it changes parameters of their biomagnetic field (Khlebtsova, 2007).

It is well known that the body of adult humans contains five liters of circulating blood. The latter consists of shaped elements, in particular erythrocytes (red blood cells, or RBCs), which contain hemoglobin (Hb) that represents a complex iron-containing protein. Hb is capable of reversibly binding oxygen and providing for its transfer from the lungs into the tissues; hemoglobin has a large magnetic moment because its molecule contains 62-70% of total body iron. As such, the magnetic field of the Earth may easily affect the magnetic moment of Hb.

The main goal of our research is to analyze the overall picture of the blood in people living within the Caspian Lowland in order to find out whether there are deviations from normal in their blood parameters.

Study area, material and methods

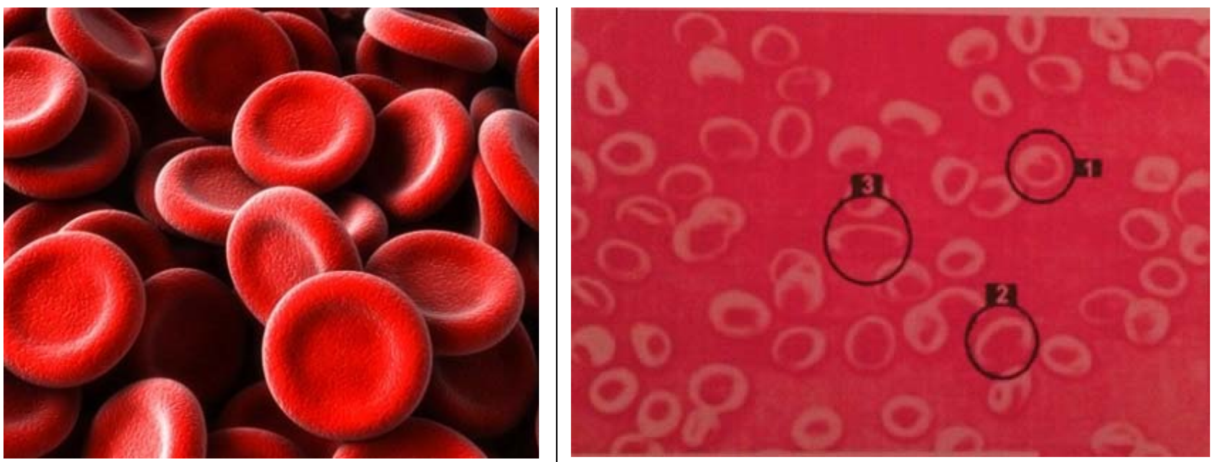
The study area includes a number of districts located in the Caspian Lowland within Kazakhstan, where people from different age categories, mainly children, were observed from 1992 to 2000, in particular, 1500 inhabitants of Dengizsky (now Kurmangazy district) of Guryev (now Atyrau region) in 1992-1994; 200 inhabitants of Makat district of Atyrau region in 1998; and 150 inhabitants of Zhyloysky district of Atyrau region in 2000.

Methods used include: questioning and inspection of patients by general and specialized medical doctors together with computer diagnostics of organs and systems by the Nakatani method (http://peresvetmed.ru/st-mz-nakatani.html). Only persons without poor health habits (e.g., smoking, alcohol, etc.) and those not working in hazardous professions were examined. In order to eliminate hereditary factors, whole families based on II-III degrees of kinship—i.e., the child, parents, grandparents of the father and mother, and great grandparents—were observed.

Blood tests were conducted by automatic hematology analyzer Cell-Din RUDY (http://service-instrument.ru/?p=111), and blood images were obtained by SEM.

Results and discussion

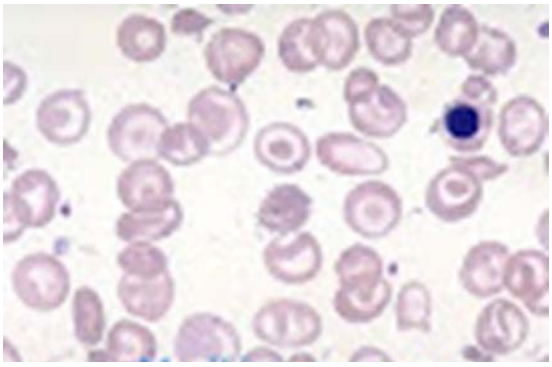
It was discovered that the blood in observed patients is characterized by a change of RBCs, mainly involving their size (microcytes) and form (torocytes, ovalocytes); the presence of target blood cells typical for the blood of patients with thalassemia (Fig. 2), also called Mediterranean disease; violation of erythrocyte membrane integrity; yet, with all these abnormalities, there were still normal amounts of ferritin, which is the main reserve of iron in the body.



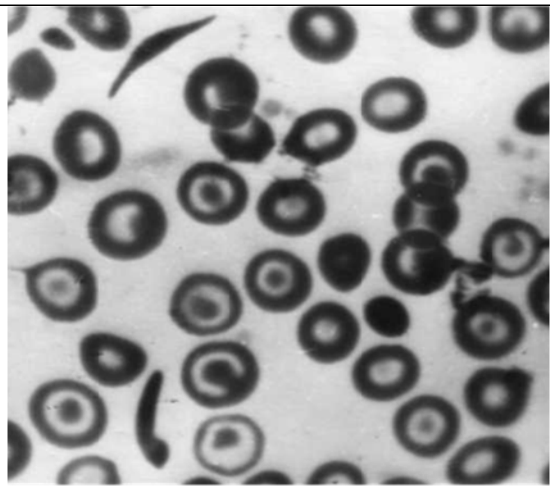
A b

Figure 2. Smear of RBCs from a patient without (a) and with (b) thalassemia living in Atyrau, Kazakhstan. Key: 1 = target RBC, 2 = torocyte, 3 = elliptocyte.

Approximately 95% of the people (mainly children) permanently residing in the area under study suffer from chronic low-grade anemia of unknown etiology, with low Hb (hemoglobinopathies, Fig. 3) (Lesnichy and Taumanova, 2011).



a



b

Figure 3. Typical smear of RBCs of a patient having hemoglobinopathy (thalassemia) and permanently residing: a. in some areas of the Mediterranean coast characterized by an elevated level of the natural magnetic field (after Tokarev, 1983), and b. in Dagestan (courtesy of Prof. Shamov). The pictures seem to be quite similar.

It is well known that deformations of RBCs occur during many pathological processes, being caused by changes connected with the intracellular Hb (hemoglobinopathy). But if ferritin is recorded at normal levels, an iron deficiency should be excluded, as in our case, because meat is the main foodstuff in the area under study (Lesnichy and Taumanova, 2011).

It must be noted that when patients change their residence, moving away from their current location, their Hb normalizes and often rates of peripheral blood cells together with complete convalescence take place (Taumanova, 2015, 2016).

Conclusions

The combination of the above forms of erythrocytes (microcytes, ovalocytes, and target blood cells) together with a normal amount of ferritin is typical for hemoglobin disorders, particularly a low form of thalassemia. The complete recovery of the patients after they change residence suggests that their blood disorders relate to the specific area of residence only. All together, this enables us to suggest that changes in the blood of humans in the study area may be produced by the Earth's magnetic anomalies that affect the substantial magnetic moment of RBCs.

Acknowledgments

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FIRST OPTICALLY STIMULATED LUMINESCENCE DATING RESULTS OF LOWER VOLGA SEDIMENTS (SREDNYAYA AKHTUBA SECTION)

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Keywords: luminescence dating, OSL, Lower Volga, geochronology, Caspian Sea, Holocene, Pleistocene, chocolate clays

Introduction

The Lower Volga is unique for understanding Caspian Sea Pleistocene history, and for correlating Caspian region paleogeographical events with glaciations of the East European plain and global climate change in the Quaternary (Yanina, 2012). Sections of recent deposits are representative because of their completeness, presence of both marine and subaerial sediments, and because of paleontological richness. That is why the Lower Volga region has been studied for many years by many researchers (Fedorov, 1957; Moskvitin, 1962; and others). Extensive material about the paleogeography of this region has been gained from the results of their basic research.

Chronology of paleogeographic events is one of the most controversial issues in the study region. There are currently age estimates of different stages, obtained by electron paramagnetic resonance spectroscopy (Molodkov, 1992), thermoluminescence, uranium-ionium (Arslanov et al., 2016), and radiocarbon (Arslanov et al., 2013; Tudryn et al., 2013; Svitoch, 2009), which often give contradictory results. The main purpose of this research is to obtain new dating results for the reference section of Srednyaya Akhtuba (Volgograd region, the left bank of the Akhtuba River). This location was selected for study as it most fully reflects the events of the late Pleistocene (see stratigraphic characteristics in Kurbanov et al., this volume).

Methodology

Complex paleogeographic analyses were conducted during the study of the reference section, and stratigraphic, lithological, paleopedological, and paleofaunal characteristics were obtained for the section during this study. Special attention was paid to sampling for OSL dating.

Samples were taken from each layer, with 15 cm distance from the boundaries between layers in order to exclude the mutual influence from radiation properties of the sediments. Sampling was carried out with plastic pipes of 5 cm diameter and a length of 30-35 cm. They were fully pounded into the deposits with a hammer at right angles to the side of the section and then packed in lightproof bags to avoid exposure to the sun. Some samples were selected during the night in the absence of sunlight in lightproof bags.

The OSL method is based on the principles of quantum mechanics, according to which energy accumulates in the crystal lattice of weathered minerals (usually quartz and feldspar) after their sedimentation. The amount of this energy can be measured and then divided by the rate of energy accumulation in the sediment. Laboratory processing of samples consists of determining the rate of energy storage in the sediments (dose rate) and the amount of stored energy (equivalent dose).

OSL dating was carried out in the DTU Nutech and Aarhus Nordic Luminescence Lab. Sample preparation for the measurements took place in the laboratory under red LED illumination. The samples were sieved to recover a fraction of 90-180 µm. The resulting material was sequentially treated with 10% HCl to remove carbonates, 10% H_2O_2 to remove organics, and 10% HF to clean the grains of any clay silicate coating. Quartz and feldspar grains were divided for each sample with heavy liquid of 2.58 g/m^3 density.

The luminescent signal was measured using quartz for the more recent Early Khvalynian and Atelian deposits and using feldspar for the loess-soil horizons, each employing an automated Risø TL/OSL-reader. The laboratory exposure was performed using a ^{90}Sr/^{90}Y source installed in the reader, with a capacity of 0.045 Gy/s.

A purity check was conducted previously for each sample to verify the results of quartz and feldspar separation; it consisted of quartz aliquot stimulation by infrared radiation. It is necessary to conduct a separation again if there is a fixed signal, as the infrared radiation responds only to feldspar. Since such signal was not recorded in any of the samples, we can affirm a successful separation.

For feldspar signal measurement, the Post-IR IRSL protocol was used (Thiel et al., 2011). Aliquots were submitted to preheating at 320°C followed by infrared stimulation at 50°C and measuring again at 290°C. Repeated measurement data were used to calculate the equivalent dose. The measurements for the quartz signal were performed with a standard SAR-protocol (Murray and Wintle, 2000).

Results

As a result, 11 OSL dates (Table 1) were obtained, covering ages from 720 years ("control" age) to 112 thousand years.

Table 1. Dating results

Riso laboratory №	*Altitude (m, a.s.l.)*	*Sediment*	*Age (ka)*	*Uncertainty (ka)*	*Equivalent dose (Gy)*	*Number of aliquots*	*Annual dose rate (Gy/ka)*
150801	16.8	modern soil	0.72	0.11	1.16	19	1.62
150806	14	upper part of chocolate clay	13.02	0.61	41.14	17	3.16
150807	12.7	lower part of chocolate clay	15.02	1.00	46.85	12	3.12
150809	11	paleosol #1	26.99	1.58	34.48	14	1.28
150810	8.6	alluvial sand	35.54	3.11	27.50	21	0.77
150812	7.3	alluvial sand	36.78	3.58	48.15	15	1.31
150814	6.5	untypical sandy loess	48.68	3.14	91.40	16	1.88
150822	1.8	paleosol #2	68.28	4.31	207.79	5	2.97
150824	0.4	loess-like	87.62	4.39	274.74	7	3.18
150827	-0.1	paleosol #3	102.50	5.16	325.53	6	3.18
150829	-0.8	loess-like	112.63	5.40	331.45	5	2.94

Seven of them were based on quartz, and four dates were derived from feldspar. Equivalent dose measurements using different aliquots give predominantly normal or log-normal distribution values (typical for them) (Fig. 1).

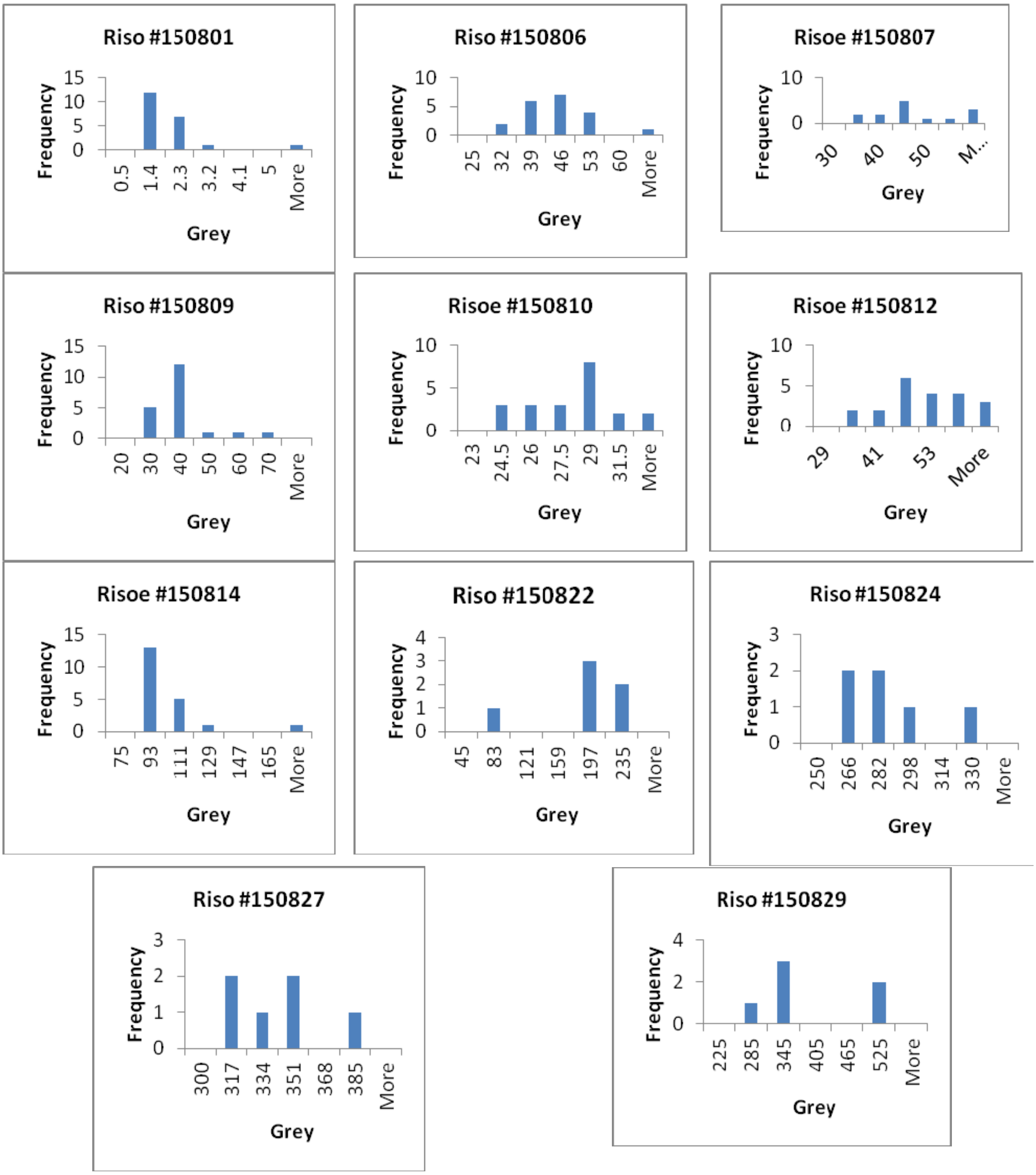

Figure 1. Results of measurements.

Conclusions

We obtained the first geochronological scheme of paleogeographic events for the Late Pleistocene of the Lower Volga region based on OSL using 11 dates obtained by the authors.

There are five stages of development in this territory during the Late Pleistocene (Fig. 2): Late Khazarian (MIS 5e; Mikulino or Eemian interglacial), Hirkanian (MIS 5d-a; the transition from the Mikulino interglacial to the Valdai glacial stage), Atelian (MIS 4-3 and the last glacial maximum, LGM), Khvalynian (MIS 2; degradation of glaciation), and Late Khvalynian to Holocene (the end of MIS 2 and MIS 1).

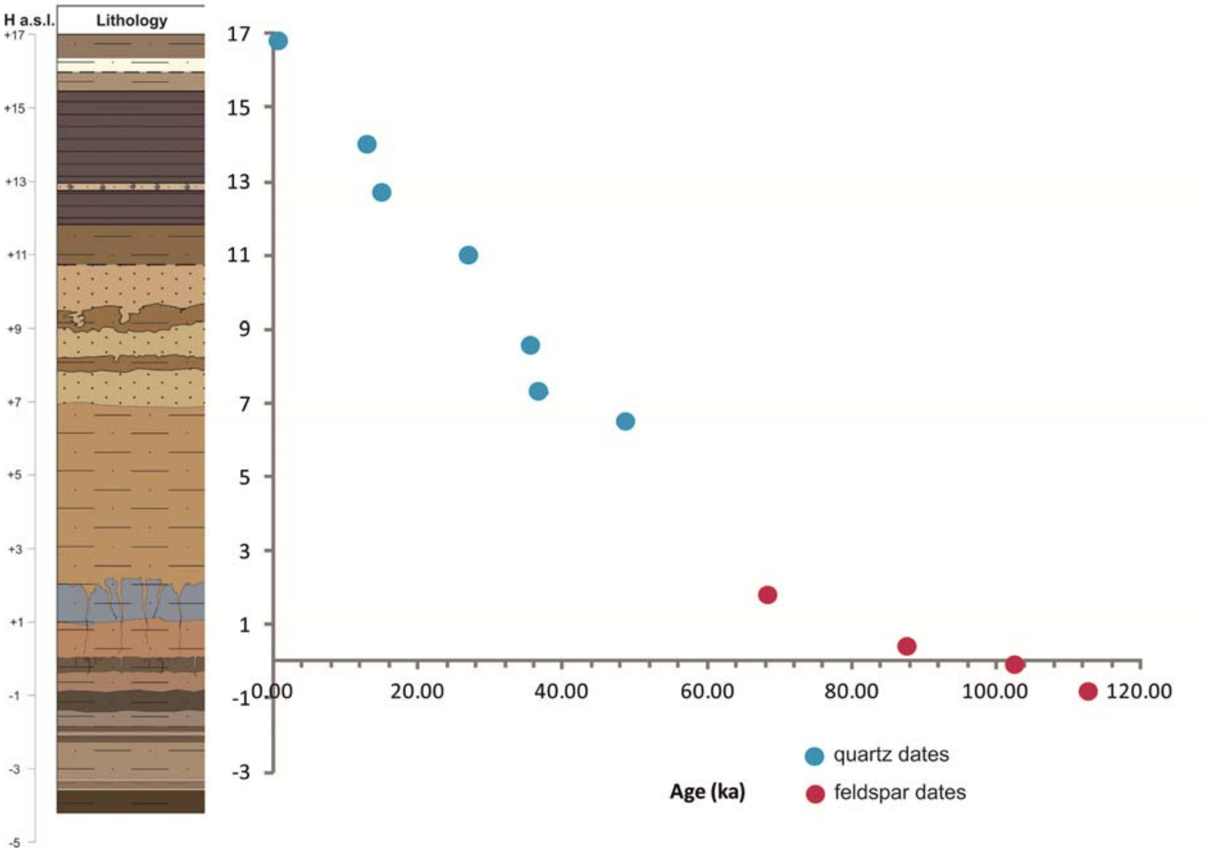

Figure 2. Scheme of the site and obtained OSL dates.

The age of the chocolate clays, which are widespread in the Lower Volga region, is usually considered as arguable and highly rejuvenated. Due to this research, the results of OSL dating of the chocolate clays confirms their average radiocarbon and uranium-thorium dating results.

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ANTHROPOLOGY OF THE CAUCASUS IN THE PALEOLITHIC

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Keywords: human evolution, migration, Western Asia, paleoanthropology, Dmanisi

In the territory of the Caucasian region, the first human beings appear during the Early Pleistocene. Since the 1930s until the present day, archaeologists have discovered several tens of cave sites as well as sites and workshops of the open type belonging to the Acheulian period. The most ancient site of Dmanisi (Georgia) actually offers the most complete anthropological material. This means the remains of several skulls, one of which is particularly complete (D2700), and a lower jaw. On the basis of the last publication of A. Vekua and coauthors (Vekua et al., 2002), these remains belong to the *Homo erectus* taxon, although they also have a number of primitive characteristics that bring them close to *Homo ergaster* or even to *Homo habilis*. These finds are dated 1.85 million years ago.

From where could such ancient humans appear in the territory of the Caucasus? Most probably, their way lay through the Middle East and Western Asia from the cradle of the all mankind – Africa.

Between 2 to 1.5 million years ago, on the African continent, the evolutionary course of the Hominidae brought about the formation of a human of a new type – *Homo ergaster* (the term meaning "working human"). This species possessed a brain volume of about 700-900 cm^3.

Exactly during this time interval, humans left the African continent for the first time. The eastern migration route seems the most plausible. Moving through the southern territories of Eurasia, the most ancient humans evidently tried to make their way to the north. One of the routes to the northern part of Eurasia lay through the Caucasian isthmus, where it was possible to pass between the Caspian and Black seas. The remains of the Dmanisi humans confirm the supposition of the primacy of the eastern route of migration.

Archaeological and anthropological finds of the Acheulian period tell us that, once they reached the Caucasus around 1.5 million years ago, humans settled and lived there during all the following periods.

It has been a long time since archaeologists attributed the right branch of a lower jaw with its third molar tooth from Azykh Cave (Azerbaijan) to the paleoanthropological finds of the Pleistocene. Analysis allowed us to find about 13 odontological and craniometric traits on the basis of which the Azykh hominin is close to *Archanthropus* or the "preneanderthals" (Kharitonov and Batsevich, 1997). In the Acheulian layers of the cave of Kudaro I (Georgia), three teeth (two fragments of incisors and a premolar tooth) have also been found, which A.A. Zubov ascribes to *Archanthropus* (Zubov, 1980).

The natural environment of the Caucasus during the Pleistocene was variable in different areas because of three factors: the more humid climate of the Black Sea Caucasus, the more continental climate of the Caspian Caucasus, and the Transcaucasian uplands. According to V.P. Liubin, except the data about cave bear hunting of the primitive population of the highlands, it is possible to notice some rudiments of fishing and hunting of game birds among Acheulian faunistic materials.

Reasoning about how Acheulian people settled on the Caucasian isthmus, Liubin came to the conclusion that their movement to the north happened during the Middle Pleistocene, considering biostratigraphic data and chronometric dates. The route around Colchis along the eastern side of the Surami (Likhi) Range on a strip of more open territories was the most probable line of their initial movements (Liubin, 1998).

We can say that the Acheulian humans, having moved into the Caucasian region, lived there until the beginning of the last glacial period. Currently, we know of more than 200 Mousterian sites from the Caucasian region. Probably, humans continued to live there also during the beginning of the last glacial period.

In addition to the large quantity of archaeological material related to the Mousterian culture, in some sites, archaeologists have found human remains. In the mid-1970s, during the excavation of the cave site of Sakazhiya (Georgia), a fragment of an alveolar process of the left half of the maxilla with a canine, both premolars, the first molar, and an isolated first lower molar were found. According to the authors of the find, the whole range of traits observed in the human remains discovered in Sakazhiya cave site indicates a proximity to the *Palaeoanthropus*.

However, along with particular features, traits most likely typical of early *Neoanthropus* can be observed: this is a high palatomaxillary arch and the relative narrowness of the piriform opening (Gabuniya et al., 1978). To the neanderthaloid finds, we can as well attribute the right upper first molar tooth found in the cave site of Dzhruchul (Georgia) (Lazukov, 1981).

In the cave of Barakay (North Caucasus), skull fragments, a lower jaw and some teeth of a fossil human have been found. The biological age of the hominin, considering the condition of his dental system, can be estimated at around 2-3 years. The jaw has no mental protuberance, the massiveness of the body is great. By his craniometric and cranioscopic features, the hominin found in Barakay Cave is more similar to the Western European Neanderthal than to their Western Asian analogues (Kharitonov and Batsevich, 1997).

The anthropological analysis of the bones of the fossil hominin from the Mousterian layer of Mezmaiskaya Cave (North Caucasus), which has been done recently, turned out to be quite difficult, as the biological age of the hominin has been estimated at no more than two months. In spite of the age problems, the researchers of the find suppose that the hominin of Mezmaiskaya Cave has a Neanderthal type of postcranial skeleton (Kharitonov and Romanova, 2000).

Within the territory of the Caucasus, a few human remains from the Upper Paleolithic are also well known. In the North Caucasus near the town of Maykop, in the Upper Paleolithic site of Satanai Grotto (Gubsky No. 7), the skull of a fossil hominin was found. The skull most probably belongs to a female individual, and its frontal bone is considerably developed, its retreating forehead and the small height of the calvarium make it similar to other Upper Paleolithic skulls from Central and Western Europe (e.g., Oberkassel, Dolní Věstonice III) (Romanova and Kharitonov, 1984).

It has been accepted to attribute to the Upper Paleolithic also the remains of a human of modern type from Akhshtyrskaya Cave (second upper left molar and three foot bones) (Kharitonov and Batsevich, 1997).

Conclusion

In conclusion, we would like to note that, most probably, the territory of the Caucasus occupied by humans in the early Pleistocene was part of the extensive Eurasian region of hominid evolution. Paleoanthropological finds allow us to consider a strong proximity of the Caucasian hominids to Western Asian forms. In turn, the Western Asian region, during the Acheulian period, was a territory where constant migratory processes interfered with allopatric speciation.

Because of this, it is possible to consider the Caucasus as an area mainly inhabited by metis or transitional erecto-neandertaloid and erecto-sapientoid forms of hominines. Actually, the sapiens forms of hominids appeared in the Caucasus not earlier than the second wave of migration of early *Homo sapiens* from the African continent, and most probably they have no autochthonic origin.

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PALEOANTHROPOLOGICAL RESEARCH INTO THE EARLY MEDIEVAL COPTIC CEMETERY OF WADI NAQLUN IN THE FAYOUM OASIS (EGYPT)

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Keywords: sex and age structure, craniology, osteology, mortality, monastery of Wadi Naqlun

Introduction

Paleoanthropological research can and should be a connecting link between archaeology and ethnography. This has a particular meaning when the lifetime ethnic origin of the studied human remains is known.

The present research gives some information about the physical type (at the population level) of the founders of different ethnic cultures. The study of ethno-genetic processes without anthropological research is almost impossible, as far as such research gives answers to questions regarding the genetic mechanisms (migrations, genetic drift) of the formation of different ethnos.

The ethnic history of any group is also interesting to paleoanthropologists, e.g., studying the bone remains of ethnic Russians, Maris, or Tatars, can allow us to estimate which anthropological components made up this ethnic group and where are the nearest genetically related peoples.

Materials and methods

With the present work, we have studied the bones remains of early medieval Copts (6th-8th c. AD) from the Fayoum Oasis (Egypt).

The ethnic attribution of the skeletonized, frequently mummified, remains to the Copts is confirmed by the fact that they have been found during excavations in the territory of a Coptic monastery Wadi Naqlun (Deir al-Malak) and, on many of them, elements of Coptic monastic clothes were preserved. Research has been carried out together with the Center for Egyptological Studies of the Russian Academy of Sciences in January-February and June, 2002.

We have taken measurements and then calculated various indices of skeletal proportions, as well as robustness and strength indices of the limb bones. Variations in the values of various indices are presented in the work of Y.Y. Roginsky and M.G. Levin, and E.N. Khrisanfova (Roginsky and Levin, 1978; Khrisanfova, 1978). The intravital body length was reconstructed with the use of Bunak, Dupertuis, and Hadden formulae (Alekseyev, 1966). Measuring of the craniological material with subsequent calculation of angles and indices was carried out according to the procedure that is generally accepted in anthropology (Alekseyev and Debets, 1964).

Results

Sex and age structure

In total, during the time spent in the Fayoum Oasis, we succeeded in studying the remains of 48 individuals from the local cemetery. More than a half (58.3%) are male. Quite a low percentage (16.7%) represents child mortality. The remaining 25% of the skeletons belonged to women (Fig. 1).

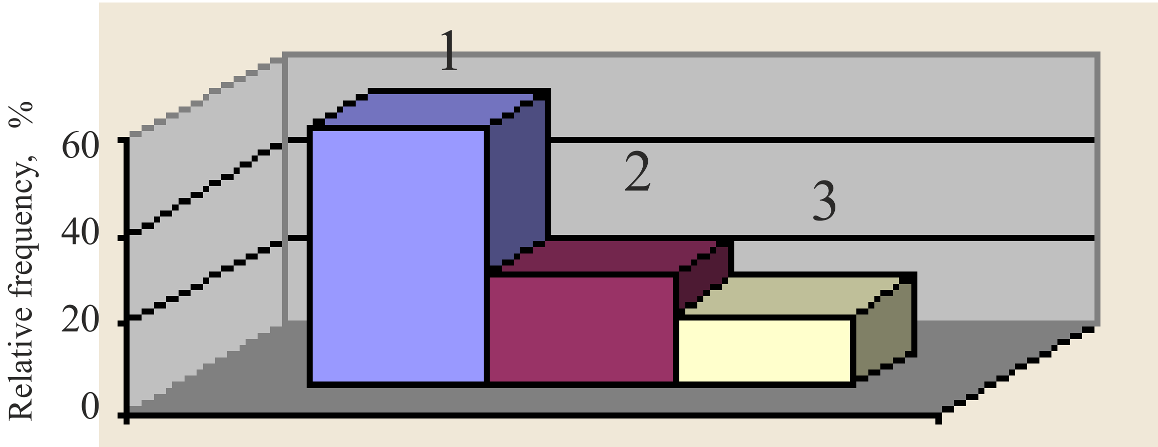

Figure 1. Sex and age structure of the groups from Wadi Naqlun: 1 – male, 2 – female, 3 – children.

For men, as well as for women, an early mortality is registered, i.e., about 50% of the adult population died at an age between 15 and 30. Among men, there are individuals who reached an old age (Figs. 2, 3).

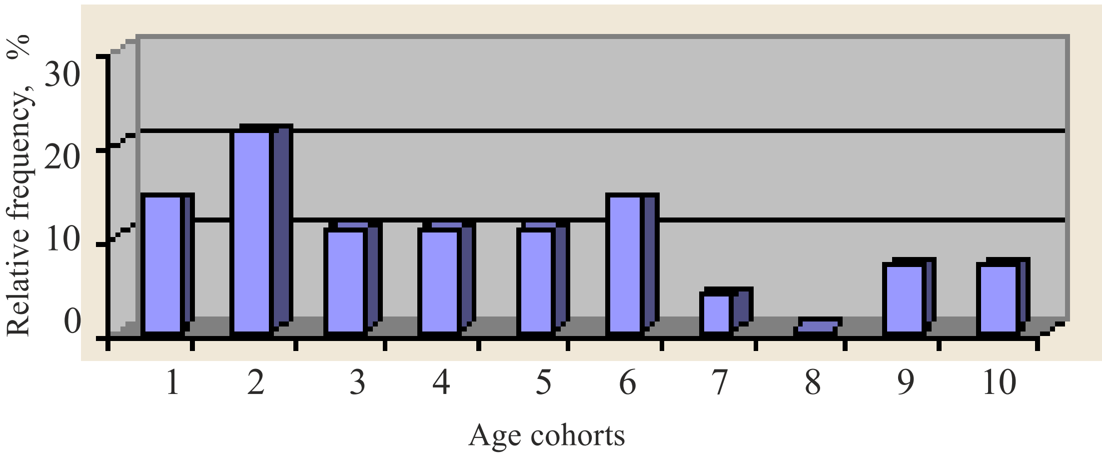

Figure 2. The relative frequency (percentage ratio) of male death by age cohorts.

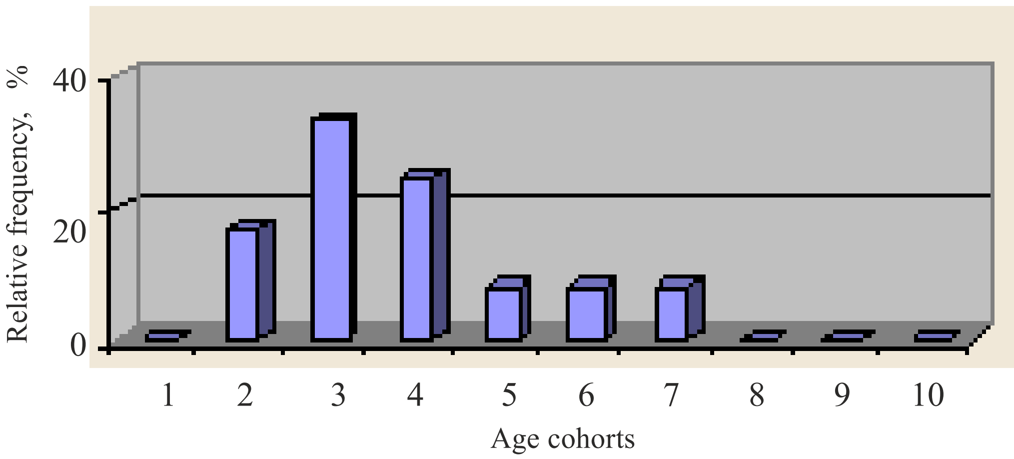

Figure 3. The relative frequency (percentage ratio) of female death by age cohorts.

The average life expectancy (average age at death) of men was 37 years and 7 months; for women, it was 34 years and 2 months. More than half of the children died at an age between 1 and 3. The age range for cohorts in Figures 2 and 3: 1 = 15-20 years old; 2 = 20-25 years old; 3 = 25-30 years old; 4 = 30-35 years old; 5 = 35-40 years old; 6 = 40-45 years old; 7 = 45-50 years old; 8 = 50-55 years old; 9 = 55-60 years old; 10 = more than 60 years old.

Craniology and osteology

We studied 30 adult skulls according to the standard craniological program, 20 of which belonged to males and 10 to females. The most important measurements and indexes of the shape of the skull and its components are given in Table 1.

Table 1. Average values for craniological characteristics

Feature	**Male**	**Female**
1. Longitudinal diameter (mm)	180	174
8. Transversal diameter (mm)	138	131
17. Height diameter (mm)	134	131
45. Malar diameter (mm)	129	126
48. Upper facial height (mm)	71	69
43. Upper facial breadth (mm)	103	101
46. Middle facial breadth (mm)	95	89
48/45 Upper facial index	55	54.6
54/55. Nose index	49	47.6
52/51. Orbit index	82	87.6
8/1. Scull index	76.8	75.5
17/1. Heght - Length Index	74.5	76.1
17/8. Heght - Breadth Index	96.5	100.2
Nasomalar angle	141°	139°
Zygomaxillar angle	126°	123°

Male

Considering the average skull index, male skulls are mesocranic. However, considering individual data, among the samples there were both brachycranic (nos. 5,9,17,20,32), and dolichocranic skulls (nos. 4,15,25,28,30). Considering the high indices for the braincase, we can notice that, in general, male skulls are moderately high. From the top, the shape of brachycranic skulls is spheroid, of dolichocranic skulls pentagonoid.

The male facial skeleton according to the upper facial index is leptenic, i.e., men had a relatively narrow face. The orbital index corresponds to the average size of the orbits, though skulls with low orbits were found (nos. 9,14,30), as well as high orbits (nos. 5,15,17,20,26,33). The nose, in most of the cases, showed average sizes. Only individuals nos. 14 and 20 had a narrow nose. Horizontal profiling in men is quite well pronounced, especially in the middle part of the face. A similar profiling is characteristic in the Europeoids. However, it is possible to find individuals with a little flattened profiling of the front part of the skull (nos. 9,30).

Female

The skull index characterizes female skulls as mesocranic with a tendency toward dolichocranic. According to their high indices, the female skulls are relatively high and uniform. According to facial indices we notice a relative facial narrowness, high orbits, and an average size for the nose. In comparison with the males, the female face is more profiled.

As to the osteological material of the present research, we have studied the skeletons of 6 males, 2 females, and more than 50 separate long bones from group burials. Preliminary research has shown that the average height of males calculated using V.V. Bunak's formula is equal to 164.8 cm, and that of females is 156.2 cm.

Conclusion

In characterizing the present group, it is possible to notice a considerably higher number of men. Most probably, this depended on the fact that the studied cemetery was found in the male monastery of Wadi Naqlun. The average life expectancy of the men from the studied group is higher than that of the women, which is typical of the Middle Ages. Among the early medieval population of this territory, a high mortality in people younger than 30 has been generally observed.

On the basis of craniological research, it is possible to conclude that there may be a genetic heterogeneity in the male population and a relatively high homogeneity in the female one.

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MALACOFAUNA OF THE VOLGA DELTA BASINS AND THEIR PALEOGEOGRAPHICAL IMPORTANCE

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The modern Volga delta is a large (~ 21,000 sq km) natural system (Fig. 1).

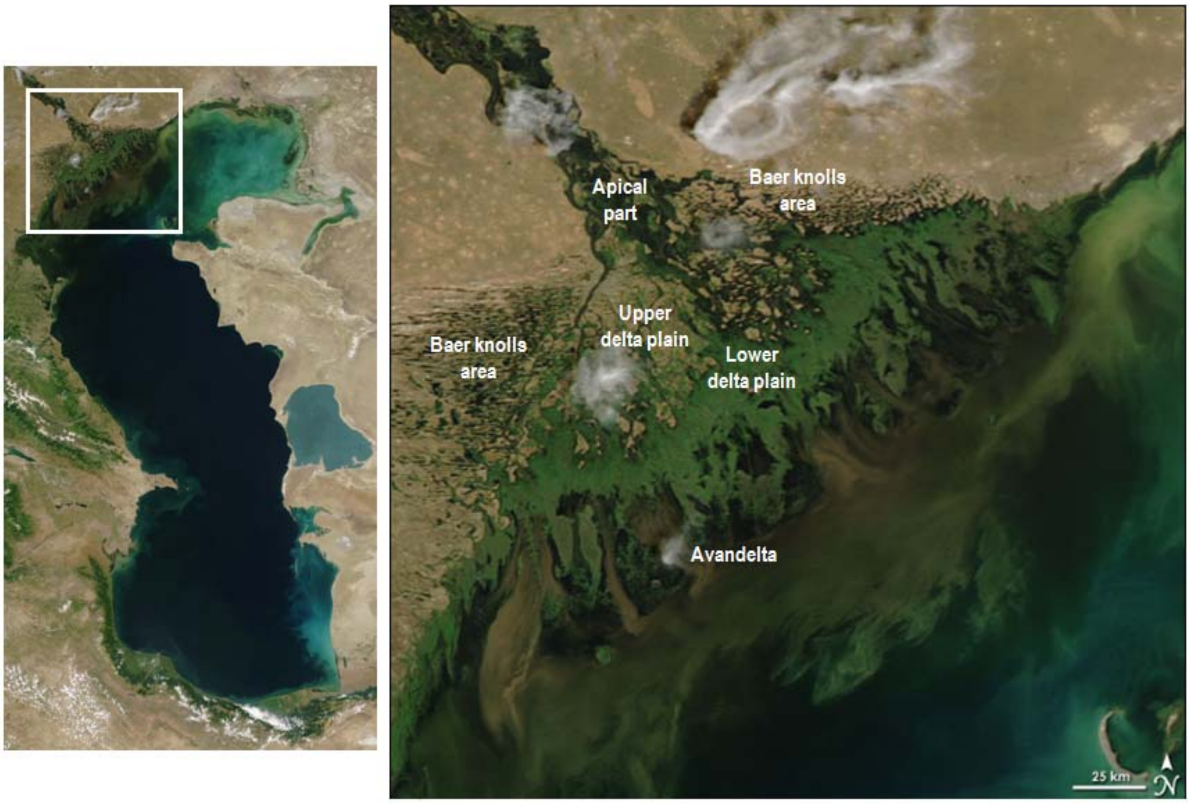

Figure 1. Structure of the Volga Delta (after Rusakov, 1990).

The structure of the delta and typification of deltoid basins are described in some publications (Belevich, 1963; Gorbunov, 1971; Korotaev, 2002; etc.). We studied the modern biocenoses of mollusks from various basins of the delta for the purpose of using them to reconstruct the paleogeography and evolution of the Volga delta basins under conditions of fluctuating Caspian Sea level. We used published data as well.

The apical part of the delta is a transitional zone between the Akhtuba flood plain and the delta. The abundance of meander lakes and small number of branches, and islands with average height over the low-flow level of about 3-4 m are characteristic of this zone. The width of this zone is 40-50 km. The Upper delta plain is a zone containing numerous lakes–ilmens and multiple branches both stable and changeable in size. Liman type ilmens with depths not exceeding 1-2 m are located between the Baer knolls in the eastern and western parts of the delta. Kultuk ilmens with depths of no more than 1 m were formed from small gulfs near the sea area of the delta. Their sizes vary from several hectares to several square kilometers. The height of islands is from 1.5 to 3 m. The width of this zone is 30-50 km. For the lower delta plain, even more intensive branching of channels, the existence of kultuk-ilmens, and a very limited number of Baer knolls are characteristic. The height of islands is from several tens of centimeters to 2 m. The width of the zone is 6-20 km. The transitional area between the delta plain and the avandelta begins below the mouths of the deltoid channels. Here, the greatest amount of sediment is deposited, and new islands and future ilmen are formed. The water area of the basins is greater than the area of the islands. The avandelta zone is 20-45 km wide and is situated between an area of islands and the two-meter isobath. Depths less than 1 m prevail. In this zone, there aren't enough islands but many underwater braids. Behind the 2-meter isobath, the shallow zone of the sea – called the "zone of sea approach" to the delta – begins.

Delta basins possess a different malacofauna composition depending on the hydrological and hydrochemical modes, as well as other factors. The biodiversity of the mollusks of the delta is represented by the Gastropoda and Bivalvia classes, each of which includes representatives of freshwater and brackish-water fauna. They, in turn, have both a Caspian and Azov-Black Sea origin. In a predeltoid site of the Lower Volga, a sandy bottom prevails, and the depth and speed of the current are great. The character of the fauna is defined by these conditions. On sandy bottoms without silt, the psammophilous biocenosis is widespread. Rare *Dreissena polymorpha* are noted in its structure, and their quantity increases together with increasing gravel material. Increasing silty sediments lead to the formation of pelophilous biocenoses. The mollusks *Sphaerium corneum*, *Viviparus*, *Anodonta piscinalis*, *Unio tumidus*, and *U. pictorum* belong to pelophilous species. In a coastal strip among thickets of the highest water vegetation, the phytophilous biocenosis develops. In inundated basins, and varying in the degree of isolation from the river bed, there are changes in structure of the malacofauna occupying them. There is a gradual loss of river species (*Sphaerium solidum*, *Pisidium supinum*, *Anodonta complanata*) and their replacement by representatives of other systematic groups, so branchiate mollusks give way to pulmonary mollusks (*Limnea stagnalis*, *Radix auricularia*, *Phisa fontinalis*, and *Acroloxus lacustris*).

Long, narrow ilmens with silted bottoms between Baer knolls are almost lifeless, the mollusks *Unio* and *Anodonta* are occasionally encountered; but in the strongly overgrown coastal zone, there are a lot of coastal forms (*Planorbis*, *Physa*, *Succinea*). Ilmens with a larger area, with the best supply of oxygenated sediments, are more populated with mollusks. *Dreissena polymorpha*, *Anodonta complanata*, *Sphaerium corneum*, *Pisidium*, *Viviparus viviparus*, and *Valvata piscinalis* are found on oozy soil, and on sandy sites rare small *Unio pictorum* are spread. Shallow, strongly overgrown ilmens with bottoms containing silt and vegetal remains, are characterized by mollusks only in the coastal zone; they are generally *Planorbis*, *Pisidium*, *Physa*, and *Lymnea*.

Channels and sleeves of the delta are populated generally by a biocenosis of sandy-oozy ground sediments in which *Viviparus* prevails. Channels and sleeves are rich with Caspian fauna: *Monodacna edentula*, *Adacna vitrea*, *Ad. laeviuscula*, and *Hypanis plicatus.* All Caspian species living in the Volga delta are considerably euryhaline (fluctuations of salinity from 0.3-0.4 to 12-13 psu reflecting the Caspian composition of salts) and are oxyphilous (Birshtein, 1968). Kultuks with sandy-oozy grounds are a habitat for numerous freshwater mollusks (*Unio pictorum*, *Anodonta complanata*, *Viviparus viviparus*, *Valvata piscinalis*, *Sphaerium corneum*, *Pisidium*, and *Dreissena polymorpha*) together with which the Caspian elements *Monodacna edentula* and *Adacna laeviuscula* quite often appear. In the 1960s, the Ponto-Azov mollusk *Monodacna colorata*, acclimatized in the Volga reservoirs, then appeared and settled in the delta (Vorobiev and Pirogov, 1969). *Lithoglyphus naticoides* and *Dreissena bugensis*, which also have an Azov origin, got through the Volga-Don Canal by means of the river ships (Pirogov, 1974).

In an area of mixed freshwater (from the Volga) and brackish waters (from the Caspian Sea avandelta) that is characterized by extensive fields of sandy-oozy sediments, *Unio pictorum*, *Viviparus viviparus*, *Valvata piscinalis*, *Sphaerium corneum*, *Pisidium* sp., *Dreissena polymorpha*, *Theodoxus pallasi*, *Monodacna edentula*, and *Adacna laeviuscula* were settled; on sandy bottoms, rare *Anodonta complanata* appear. At the border of the brackish-water zone and that of 0.9-2.0 psu, a number of freshwater species (*Viviparus viviparus*, and *Sphaerium corneum*) drop out. The pre-estuarial space of the sea is populated with low numbers of brackish-water species (*Monodacna*, *Adacna*, *Hydrobia*, *Lithoglyphus*, and *Dreissena*) with which freshwater mollusks of the genera *Unio*, *Anodonta*, *Valvata*, *Dreissena*, and *Theodoxus* are encountered. With an increase in salinity to 2.5 psu, the majority of freshwater types perish. In the salinity zone to 6 psu, *Dreissena polymorpha*, *Monodacna edentula*, *Adacna laeviuscula*, *Hypanis plicatus*, and *Theodoxus pallasi* live. With a further increase in salinity, *Dreissena polymorpha* drops out. In this zone, the typical Caspian species *Monodacna edentula*, *Adacna laeviuscula*, *Hypanis plicatus*, *Dreissena caspia*, *Dr. andrusovi*, *Didacna trigonoides*, *Micromelania caspia*, and *Clessiniola variabilis* develop; *Hydrobia ventrosa* and *Monodacna colorata* are represented, too. The Azov-Black Sea invasive species *Cerastoderma glaucum*, *Abra ovata*, and the Caspian endemics, *Didacna*, appear.

According to published data (Chugunov, 1923; Idelson, 1941; Zhadin, 1952; Pirogov, 1974; Abdurakhmanov et al., 2002), it is possible to track the changes in the delta with the falling of the Caspian Sea level, which began in the 1930s. This phenomenon is the "visual aid" for paleogeographic reconstruction. The delta strongly moved forward into the sea; the area of many islands increased and they merged with the continent, while some small canals dried up. Kultuks of the avandelta turned into ilmens. At first, there were seaside ilmens with oozy and sandy bottom sediments rich in Caspian species. A large number of *Dreissena* was noted. However in 1950-1960, their presence strongly declined, up to a total disappearance in the many ilmens; *Viviparus* became dominant, and *Unio* were quite numerous. During the process of deltaic increase, ilmens were silted in and became stagnant. In ilmens completely separated from the delta and strongly silted, the benthos grew poor, but with their overgrowing, the phytophilous fauna (*Lymnaea* prevailing) developed. When the level of the Caspian Sea rose, the reverse process began.

Thus, studying the sequence of mollusk complexes in the sections or in the borehole cores, we have the opportunity to reconstruct the development of the delta during past epochs so as to reveal fluctuations in the level of the Caspian Sea.

Acknowledgments

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CORRELATION OF THE PALEOGEOGRAPHIC EVENTS OF THE CASPIAN SEA AND RUSSIAN PLAIN IN THE LATE PLEISTOCENE: NEW DATA

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Keywords: Caspian Sea, Russian Plain, boreholes, Lower Volga area, OSL dating, ^{14}C dating, correlation

Introduction

The problem of correlation between transgressive-regressive oscillations in the Caspian and glacial events on the Russian Plain is of great importance and complexity in Pleistocene paleogeography. It has been thoroughly studied previously by a number of researchers. A review of the varied views on this problem has been published in a previous paper (Yanina, 2012). At the present moment, there is no unequivocal opinion on the correlation of Caspian events with glacial-interglacial changes on the Russian Plain. According to the view of the present authors, many factors (neotectonic movements, sedimentation in the basin, the restructuring of the hydrographic network, etc.) have affected the transgressive-regressive rhythm of the Caspian Sea, chief of which is the global climate rhythm. This work presents new data obtained by the authors during the last two years. They allow us to specify relationships and synchronization of events in the Caspian Sea and on the East European Plain.

Materials and methods

The authors have carried out analyses of the sections Srednyaya Akhtuba and Nizhnee Zaimische-Cherniy Yar from the Lower Volga Region and boreholes cores from the northern Caspian Sea. We studied the facies-lithologic structure of the sections and the cores, and the composition and stratigraphic distribution of mollusks in the Upper Pleistocene sediments. We determined the dating of Lower Volga deposits by the method of optically stimulated luminescence (OSL) conducted by the Northern Luminescent Laboratory of the University of Aarhus. For the upper part of the section, the dating of Lower Khvalynian and the Atelian deposits was carried out using quartz, and for the underlying loessic and soil horizons, it was done using feldspar. Paleogeographic evidence on glacial-interglacial events on the Russian Plain is based on published sources.

Results

The section at Srednyaya Akhtuba includes the reference horizon of chocolate clays of the Khvalynian transgression, the polyfacies thickness of the Atelian continental deposits, and the three pronounced ancient soils. These thicknesses reflect different paleogeographic stages in the development of the region. All of them are dated (see the paper in this book).

The lower part of the section contains three soil horizons. The lowest soil horizon has no date, but on the sandy loams overlying it, an OSL date of 112,630±5400 years was obtained. The second soil horizon was dated to 102,500±5160 years, and the upper soil was dated to 68,280±4170 years. The loess-like sandy loams lying between them (the 2nd and 3rd soil horizons) were dated to 87,620±4100 years. Judging by the resulting dates, the soil horizons were formed during warm intervals of MIS 5 (5e, 5c, and 5a, respectively). In the history of the Caspian Sea, this period (MIS 5) was followed by the Late Khazarian-Girkanian transgressive-regressive stage (Yanina et al., 2014).

The upper horizon of the soil is broken by frost cracks and wedges that are filled with the Atelian sediments lying above it. According to our representations, they were formed during the Late Valdai (Kalinin, MIS 4) glacial period of Eastern Europe. In the Caspian Sea, the Atelian regression developed. The dating obtained by us for the top part of this layer (48,680±3100 years) testifies to the complete formation of these deposits in the first half of MIS 3. In the structure of the cores of marine boreholes, we also established the Atelian regressive horizon (Bezrodnykh et al., 2015b); the radiocarbon dates determined for it lie in the range of 45-40 ky, which will be coordinated with the data obtained using the OSL method.

This thickness is capped by alluvial deposits, on which OSL dates of 36,780±3000, 35,500±2800, and 27,000±1580 years were obtained. The formation of alluvial sediments happened due to an increase in erosion, which the Caspian Sea underwent. We conclude that it was the period of an early stage of the Khvalynian transgression of the Caspian Sea (MIS 3) (Bezrodnykh et al., 2015a,b). Their radiocarbon dates of 31.5-28.5 ky are comparable with the OSL dates. It was the epoch of interstadial Valdai warming. Alluvial sediments are overlain by a layer of subaeral loessic deposits, apparently a result of a regressive phase in the development of the Khvalynian basin and the LGM (MIS 2). In the boreholes, an accumulation of sandy and dusty sediments was noted as corresponding to this time. The age (^{14}C) interval of this event was 22-19 ky (Bezrodnykh et al., 2015a).

The thickness of the Caspian Lower Khvalynian deposits is represented by chocolate clay with the sand pro-layer containing numerous *Didacna protracta*, *D. ebersini*, *Dreissena rostriformis*, and *Dr. polymorpha*. For chocolate clays overlying the pro-layer of sand, an OSL date of 13,000±500 years was obtained; the lower pro-layer of chocolate clays was dated to 15,000±1000 years. In the paleogeographic relationship, the period of accumulation of chocolate clays corresponds to the time of degradation of the Late Valdai (Ostashkovo, MIS 2) glaciations of Eastern Europe. These data are in a good agreement with the results of radiocarbon dating of malacofauna from sandy pro-layers in the thickness of chocolate clays from the Nizhnee Zaimische-Cherniy Yar sections (13,450±130 to 14,940±380 years) and other sites of the Lower Volga area (Svitoch and Yanina, 1997; Arslanov et al., 2016; Makshaev and Svitoch, 2016). In the boreholes, clay sediments of brown coloring are noted. According to ^{14}C dating, their age interval is 17.6-16.1 ky (Bezrodnykh et al., 2015a).

Conclusions

New data allow us to propose some correlations between the transgressive-regressive oscillations in the Caspian Sea and glacial events on the Russian Plain. (1) Contrary to previous representations, it appears that each peak of warming of MIS 5 in the Lower Volga area led to an interval of soil formation. (2) OSL and ^{14}C dating confirm the development of the Atelian regression of the Caspian Sea during the epoch of Kalinin (MIS 4) glaciations of Eastern Europe, and they fix its end during an epoch of interstadial warming (MIS 3). (3) The first stage of the Khvalynian transgression took place during the second half of the interstadial warming of MIS 3. (4) The LGM in Eastern Europe was reflected in the development of a falling sea level in the Caspian Sea. (5) The epoch of degradation of the Late Valdai (Ostashkovo) glacial stage (MIS 2) corresponded to the time of sea-level rise in the Caspian Sea and the accumulation of the full thickness of the Khvalynian chocolate clays.

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SYNTHESIS OF THE IGCP 610 RESULTS: SOME CONTROVERSIES AND PARADOXES

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Keywords: Caspian Sea, Black Sea, water budget, climate change, paleodata, model of random walk

Introduction

As a result of many years of work in the framework of successive projects, including IGCP 521 and 610, a large set of multidisciplinary data has been accumulated. It is a time to synthesize these data. By doing this, one can see at least one fundamental problem, namely, the earth science data do not correspond to empirical ones. This may be related to logical errors in the construction of arguments and judgments, imperfection of currently available scientific methods, or insufficient accuracy of the instruments used, as well as the inadequacy of the adopted idealization, that is, an incorrect theory axiomatization. This can also be a result of the fact that some aspects of science are picked up by investigators individually despite of all efforts made by the management of IGCP 521 and 610 to integrate different areas of research. For example, geological and paleontological records indicate that during last 20 ka the Black Sea level fluctuated in a gradual but oscillating manner (Balabanov, 2007; Yanko-Hombach, 2007; Yanko-Hombach et al., 2014) while mathematical modeling shows that such fluctuations were not possible (Esin and Esin, 2014). The existence of these contradictions, called by us paradoxes, is discussed in the present paper, which encourages a new round of research that could lead to a deeper understanding of climate change theory.

Methodology

Two methodologies were used in our investigations. The first one included geological and paleontological investigations of coastal outcrops (mainly stratotypes) and bottom sediments for reconstruction of the climate and hydrological regime of the Caspian and the Black seas. The second one applied different mathematical techniques (simple models and Earth system models) for the same purposes (Kislov et al., 2014; Kislov, 2016). The results obtained hardly if never corresponded to each other.

Results, discussion, and conclusions

Paradox no. 1. According to geological data, there were several epochs, such as the Late Khvalynian one, when the Caspian Sea level was so high that its water spilled into the Black Sea. It is clearly indicated by the presence of Caspian fauna in the form of mollusks (Yanina, 2012) and foraminifera (Yanko, 1990) in the Black Sea. It is not clear what source of additional water could have filled up the basin. For realization of an event such as the Late Khvalynian transgression, inflow of approximately ~300-1000 km^3/year (several additional Volga Rivers) would be required. This paradox puts forward the contradiction between full-flowing rivers, the fact of transgression, and at the same time the presence of spillover into the Black Sea, all of which lacks an explanation for the origin of the water source.

Paradox no. 2. According to geological data, there were rather large and irregular fluctuations (secular-scale, decade-scale) of both the Caspian and Black sea levels. Sometimes, they can be correlated with climate events (Martin and Yanko-Hombach, 2011) but more often not; they appear to be self-generating events. We can assume that this paradox will eventually be resolved somehow by a logical (quantitative) explanation based on the concept of accumulation of small random fluctuations leading to the slow variations in the volume of the seas (the principle of Brownian motion) (Kislov, 2016).

Paradox no. 3. Some authors (Aksu et al., 2016) claim a large water discharge from the Black Sea into the Sea of Marmara via the Bosphorus Strait at the beginning of the Holocene while others (Balabanov, 2007; Yanko-Hombach, 2007; Martin and Yanko-Hombach, 2011; Yanko-Hombach et al., 2014) insist on the fluctuating character of the Black Sea level at the same time interval. These hypotheses contradict each other because, from a mathematical point of view, they could not co-exist simultaneously.

All three paradoxes will be discussed in the presentation. It will be shown that Paradox no. 2 can be explained somehow, while Paradoxes no. 1 and no. 3 are much more difficult to explain, although some preconditions for the solution of these problems do exist. These preconditions will be addressed by the authors.

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THE KARANGATIAN EPOCH (MIS 5E) IN THE BLACK SEA BASIN

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Keywords: Mediterranean transgression, MIS 5e, foraminifera

Introduction

Black Sea Quaternary history shows an alternation of transgressive and regressive stages that are related to global climate change; they appear pronounced due to semi-isolation from the World Ocean. In warm periods, the Black Sea was connected to the Mediterranean Sea (i.e., World Ocean) via connecting seas and straits. In cold periods, it became isolated or connected to the Caspian Sea via the Manych outlet. During transgressions, sea level rose as did salinity. During regressions, when it dropped below the Bosphorus sill, the basin was transformed into an isolated lake. During transgressions, organisms migrated into the Black Sea from either the Mediterranean or Caspian. Such migrations affected assemblage structure and increased the number of species, especially in the case of Mediterranean transgressions. During regressive stages, the number of species dropped, and only some holeuryhaline Mediterranean species could survive the lowering of salinity (Yanko-Hombach, 2007).

The first Quaternary penetration of Mediterranean water into the Pontic basin occurred at the end of Chaudian (Karadenizian) time, ca. 580-505 ka BP. Penetrations were repeated again and again in the Late Oldeuxinian (ca. 287.0-292.6 ka BP), Middle and Late Uzunlarian (ca. 235.6-198.7 ka BP), Karangatian (ca. 122.9-73.7 ka BP), Tarkhankutian (ca. 40-27 ka BP), and Holocene (9.4 ka BP-present) times.

Sediments with abundant Mediterranean mollusk shells were initially described by N.I. Andrusov in 1925 on Cape Karangat, Kerch peninsula, in the early XX century. He called them Tyrrhenian, as they were similar to those in the Tyrrhenian beds that form a coastal terrace in the Mediterranean. This similarity enabled him to conclude that the Mediterranean and Black Sea basins were connected to each other. Later, the Tyrrhenian beds were renamed Karangatian by A.D. Arkhangel'sky and N.M. Strakhov (1938) and were studied by numerous scientists including the present authors.

The purpose of the present study is to provide detailed stratigraphy and reconstruction of the sea level and salinity changes of the Black Sea during the course of the Karangatian transgression using foraminifera and lithological properties of the sediments as the main tools. As such, this presentation describes in detail the Karangatian transgression that was the most prominent compared to all others, increasing salinity in the Pontic basin to at least 30 psu, which is 1.5 times higher than the average salinity in the Black Sea today. Clear traces of this transgression are preserved in coastal outcrops exposed in tectonically elevated terraces of the Kerch and Taman peninsulas, and in the Caucasus. They are also found in numerous cores and drill holes recovered from the Black Sea bottom.

Materials and methods

Material has been continuously collected since 1971. In the Black Sea, 112 Pleistocene outcrops (including all Eo- and Neopleistocene stratotypes) located on elevated terraces of the Kerch-Taman Peninsula and Caucasus (Fig. 1) (Yanko, 1990; Yanko et al., 1990) as well as

56 boreholes (Yanko and Gramova, 1990) and ~4000 gravity/vibracores on the shelf, were studied (Figs. 1, 2).

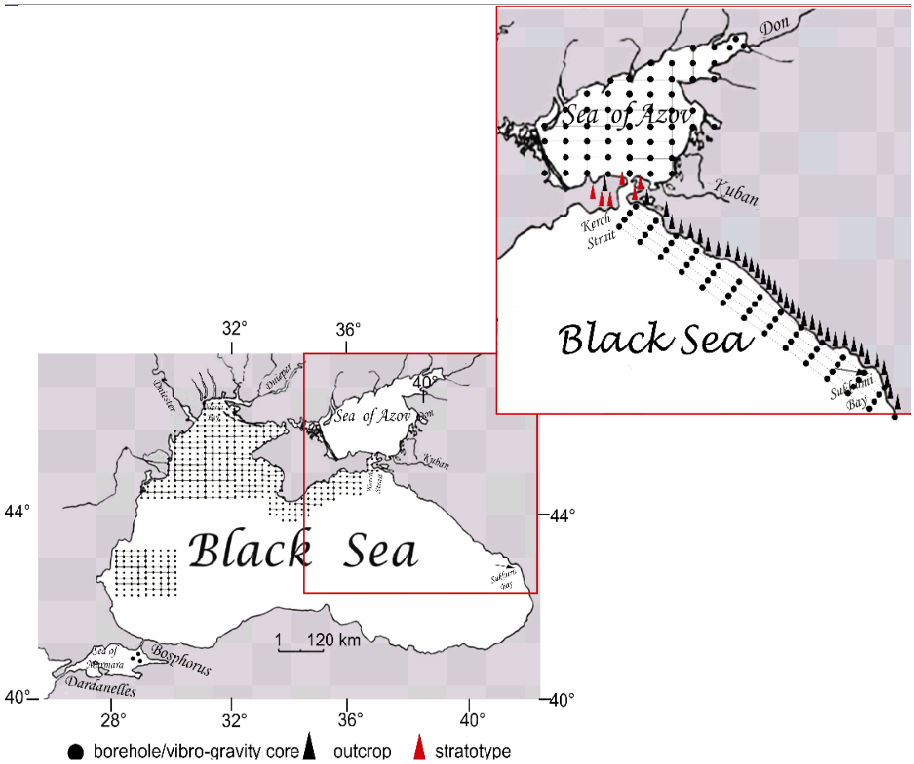

Figure 1. Studied area with schematic location of outcrops, drill-holes, gravity and vibrocores.

In addition, eighteen boreholes from the Bosphorus Strait, Sea of Marmara, Izmit Gulf, and Sakarya were investigated (Meric et al., 1995). The Eastern Mediterranean foraminifera were studied in the course of the EU AVICENNE project (Yanko et al., 1998).

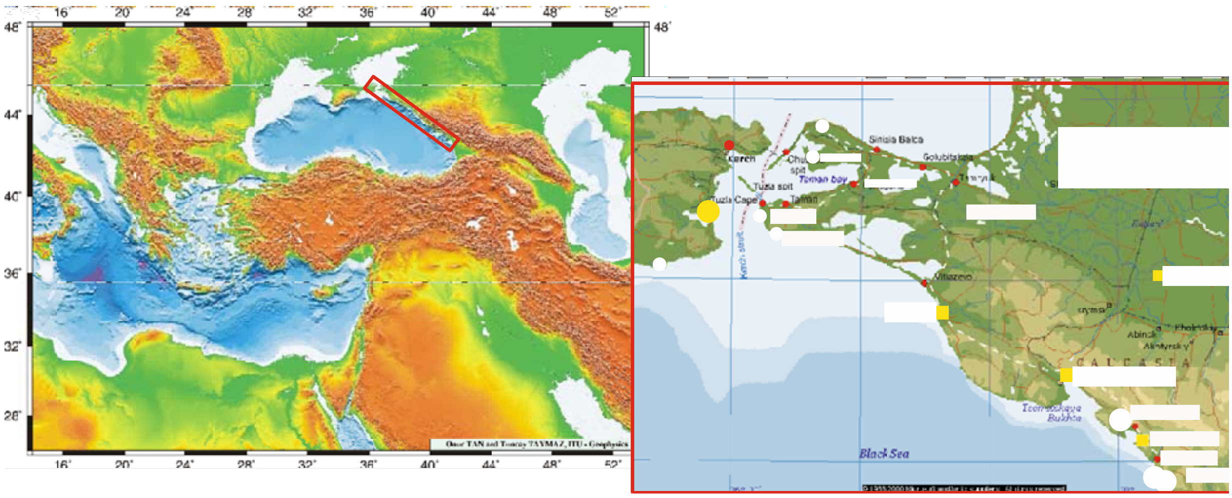

Figure 2. A - Caspian-Black Sea-Mediterranean Corridors, B - study area with Karangatian outcrops (marked by circles).

Materials from the Eastern Mediterranean, the Sea of Marmara, and the Caspian Sea were used as supporting evidence for the origin of the Black Sea foraminifera as described in Yanko-Hombach (2007). Representative collections of foraminifera from studied basins are now stored in the Museum of Natural History, Paris; the Paleontological Museum of Odessa at I.I. Mechnikov National University, Odessa, Ukraine; and at the Avalon Institute of Applied Science, Winnipeg, Canada. At present, 350 species are on file.

The foramifera were divided into dominant (>50% of a given population) and accessory species. Species that occur at >50% of all studied locations are considered to be widely distributed, 49-10% = frequent, 9-1% = rare, and <1% = trace. According to their ecological preferences, foraminifera are divided into oligohaline (1-5 psu), strictoeuryhaline (11-26 psu), polyhaline (18-26 psu), euryhaline (1-26 psu), shallow (0-30 m), relatively deep (31-70 m), and deep (71-220 m) species (Yanko-Hombach, 2007: Table 1).

Our ecostratigraphic technique is largely based on the alternation of foraminiferal assemblages and their ecological characteristics in geological sections supported by ^{14}C and palynological assays. An increase in the number of Mediterranean immigrants, especially strictoeuryhaline and polyhaline species, in sediment sequences indicates an increase of Mediterranean influence and salinity and vice versa. The complete replacement of Mediterranean immigrants by oligohaline Caspian species shows separation between the Black Sea and Mediterranean, followed by desalination of the Black Sea.

The most complete marine sequence of the Karangatian transgression is found in the Eltigen section on the Kerch peninsula, in a cliff 3-4 km long on the western coast of the Kerch Strait (Yanko et al., 1990; Dodonov et al., 2001). The Karangatian marine deposits, 20-25 m thick, overlie Sarmatian Clays (Late Miocene) and are overlain by Late Pleistocene loesses, 7-8 m thick, with one or two weakly developed paleosols. The composition of the Karangatian deposits in Eltigen shows nine sedimentary units corresponding to six cycles of sea-level and salinity change.

Unit 1 reveals a lagoonal facies formed in isolation from the sea, such as bluish clays with one oligohaline foraminiferal species: *Mayrella brotzkajae*. The closest recent assemblage (D) inhabits the Danube delta today Yanko-Hombach, 2007, Table 1). The paleosalinity was 2-3 psu; the paleowater depth <3 m. U/Th dating (LU-4202) yielded 127±8.9 ka (Dodonov et al., 2000).

Unit 2 contains clayey silt interbedded with sand and clay. It was deposited during a transition from continental to marine conditions, and it is subdivided into subunits 2a and 2b. The foraminiferal assemblage includes 8 species. The closest recent assemblages to Units 2a and 2b inhabit today the Berezansky (B) and Khadzhibeisky (Kh) limans, respectively. The paleosalinity increases upwards from 2 psu to 12 psu. The paleowater depth was >5 m. The U/Th dates (LU-4203) yielded 107±7.7 ka (Dodonov et al., 2000).

Unit 3 represents an open lagoon facies consisting of bioturbated greenish-gray sands and clays. The number of foraminiferal species increases from 7 to 12 in subunits 3a and 3b, respectively. Similar assemblages inhabit today the Khadzibeisky liman (Kh) and Odessa Bay (Od-1), respectively, indicating an increase in paleosalinity from 11 psu to 19 psu, and a paleodepth >12 m.

Unit 4 comprises fluvial and sandy clays; it overlies Unit 3 and is marked by an unconformity that formed in the open bay surf area (subunit 4a). In subunit 4b, it changes to cross-bedded sands and then (to the north) to clays. A similar assemblage is found in the Sea of Azov (A) today. The number of foraminiferal species increases from 6 (subunit 4a) to 9 (subunit 4b) indicating an increase in paleosalinity from 12 psu to 15 psu, respectively. The paleowater depth was >12 m.

Unit 5 incorporated cross-bedded gravel, sand, and sandy limestone formed in the surf area (subunit 5a), and horizontal, non-layered, poorly- or well-sorted deposits formed in a lagoon. The number of foraminiferal species is three. Similar assemblages today inhabit the limans permanently connected to the sea and having insignificant river input, such as Berezansky (B) and Golovitsa (G). Paleosalinty varies between 2 psu and 7 psu, paleowater depth is >9 m. While clays show a lagoonal genesis, the sands were formed under lacustrine conditions.

Unit 6 is composed of coarse- to fine-grained bioclastic sands; it overlies Unit 5 with an unconformity enriched in bivalve shells, and gravelites with gentle and steep bedding. The foraminiferal assemblage includes 45 species, most of which do not live in the Black Sea today but are widely distributed in the Aegean Sea (A). Genetically, they were formed in coastal areas with medium hydrodynamic activity, and long shore currents that sometimes change their direction. *Cardium tuberculatum* appears among the mollusks, together with other Mediterranean mollusks (23 species). All of them have large, thick, and well ornamented shells. They form bioherms. There is no similar foraminiferal assemblage in the Black Sea today. The closest one in existence today inhabits the Aegean Sea at water depths up to 80 m and salinity of 32.6 psu. Bioherms are indicators of shallow warm water, an absence of turbidity, and a medium hydrodynamic regime formed under salinity at least 25 psu. The U/Th dates yield 80-100 ka (Dodonov et al., 2000).

Unit 7 is represented by limestones, bioherms, and bioclastic sands overlying the lower unit with an unconformity. In the middle part of Unit 7, there is a clay diapir of Sarmatian age. Bioherms consist of *Ostrea*, *Serpula*, algal, and Bryozoan limestones. The foraminiferal assemblage includes 44 species (subunit 7a).

Unit 8 contains pink sands and shelly gravelites that were formed in a coastal zone. The number of foraminiferal species is 11. The closest example among recent assemblages today inhabits the Sea of Azov (A). The paleosalinity was about 13 psu and paleodepth >15 m.

Unit 9 is represented by loams with two to three horizons of fossil soil indicating continental conditions of sedimentogenesis. No foraminifera are present.

In summary, there is clear stratification of the outcrop revealing six transgression-regression cycles in the levels and salinity changes. Progressive distribution of bioherms to the north the transgression was developing from the south to south-east. In the course of the transgression, the salinity increased from 0.2 to 30 psu, and then dropped to 12 psu. An increase in salinity indicates that the Black and Mediterranean seas were connected to each other. A decrease in salinity indicates restricted connection between the basins and even their isolation from each other. In other outcrops of Karangatian sediments, the above-mentioned development cannot be traced in all its completeness. As a rule, it is possible to trace some stages and correlate them to each other.

Conclusions

The Karangatian transgression raised the Black Sea level to at least the present elevation. This transgression was not gradual but oscillating in nature. It occurred during the Mikulino (MIS 5e) interglacial, corresponding to the central European Eemian interglacial, and it is usually compared with the Alpine Riss-Würm interglacial.

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This study is a contribution to IGCP 610 project "From the Caspian to Mediterranean: Environment change and human response during the Quaternary."

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FORAMINIFERA AS INDICATORS OF ENVIRONMENTAL STRESS IN MARINE ECOSYSTEMS: NEW EVIDENCE FROM THE UKRAINIAN BLACK SEA SHELF

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Keywords: Danube, riverine discharge, superficial sediments, assemblage changes

Introduction

The marine environment is the ultimate destination of most terrestrial runoff, the majority of which comes from rivers that bring into the sea a vast amount of freshwater enriched with organic and inorganic compounds, including nutrients, waste products, and sediments. All this imposes enormous pressure, referred to here as environmental stress, on marine ecosystems. The stress influences taxonomic diversity, population structure, and productivity of marine organisms that depend on marine habitats for their life support.

The Black Sea bottom ecosystem is extremely sensitive to environmental stress. Any change in environmental parameters acts upon benthic organisms on the threshold principle, changing their taxonomic composition and assemblage structure. A reliable group of organisms is required to estimate the influence of stress on bottom ecosystems and trace its effects in space and time. Such organisms must be: benthic, taxonomically representative, widely distributed, hard-shelled, abundant, small-sized, and short lived. Together, these factors would provide a representative data-set to be successfully used for population statistics. Benthic foraminifera totally satisfy these requirements. They are ubiquitous in marine environments.

The main goal of this paper is to investigate the distribution of foraminifera on the Ukrainian shelf of the Black Sea in order to find out whether the benthic ecosystem here is under environmental stress, and if so what are the main factors responsible for it. To accomplish this goal, the following objectives were established: (1) to examine the taxonomic composition and quantitative distribution, of foraminifera, (2) to correlate them with environmental (oceanographic and sedimentological) parameters, (3) to identify the main factors responsible for the environmental stress and their priority, and (4) to identify assemblages and species-indicators of environmental stress.

Study area, materials, and methods

The study area includes the northwestern Black Sea shelf adjacent to the Ukrainian coast. Fifteen stations were sampled on board the Romanian research vessel "Mare Nigrum" on 17-21 May 2016 within the framework of the EMBLAS project (Fig. 1A) and compared with previously studied material (Fig. 1B, C).

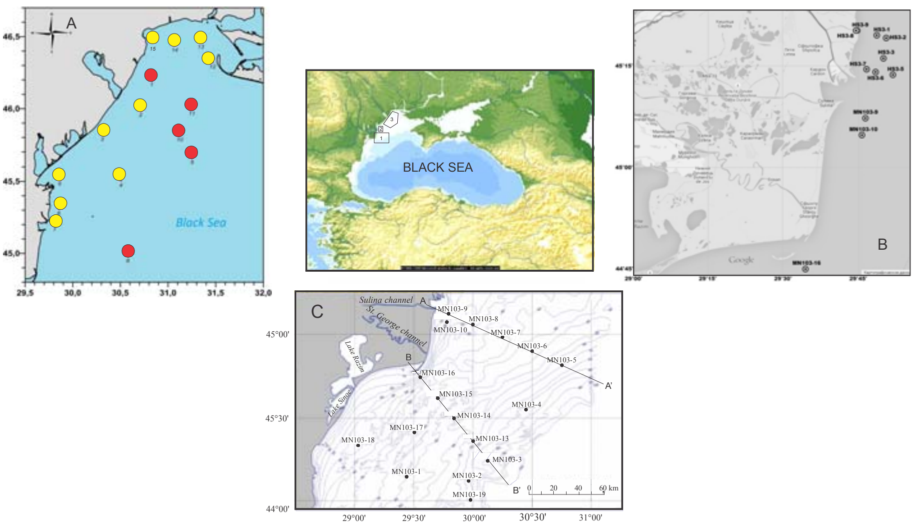


Figure 1. Study areas and location of sampled stations. A – present study in the framework of the EMBLAS project: yellow and red circles indicate stations of Cluster A and B (Fig. 6), respectively; B and C: previously studied areas in the framework of projects 40/13 and WAPCOAST, respectively.

Sediments were recovered using a 0.1 m^2 van Veen Grab. The transparency (Tr) was measured by Secchi disk. Other hydrological parameters were measured by Neil Brown Instrument Systems (CTD) with a General Oceanic rosette equipped with eleven Niskin bottles and electronic sensors: the water depth (D), salinity (S), temperature (T°C), pH, dissolved oxygen (DO), oxygen saturation index (SI), and oxygen-reduction potential (Eh). The grain-size analysis of the superficial (0-2 cm) sediment layer was performed by sieving and elutriation methods described in Logvinenko and Sergeeva (1986). Based on the results, the Median Diameter (Md) and Coefficient of Sorting (So) were calculated for each sample.

For the foraminiferal analysis, the sediment samples were collected from the superficial (0-2 cm) undisturbed sediment column recovered by grab. For staining of living forms, the samples were stored in 4% formalin solution buffered with sea water in the proportion 3:1 and 20 g of $Na_2B_4O_7$ per liter, then transferred to the laboratory where they were treated.

At each station, the total assemblage, including live (stained) and dead (empty) tests of foraminifera, was calculated together and expressed as the number of tests (abundance) per 50 g of dry sediment as described in Yanko and Troitskaya (1987) and Yanko et al. (1998). We used the total assemblage because (1) the very low number of living specimens did not allow a relevant statistical study of their distribution, (2) the presence of living specimens among all identified species indicated that they most probably live in the study area and therefore their empty tests are autochthonous, and (3) the total assemblage better characterizes the seasonal population dynamics (Debenay et al., 2001). Large samples were randomly split with a splitter into sub-samples. At least 300 specimens (for population statistics) whenever possible were picked up by hand under the binocular microscope. No heavy liquid for separation of tests from sediments was used. Broken forminiferal tests as well as their fragments and old tests (re-crystallized, worn down, filled with sediments) were considered as reworked and excluded from the analysis. For each species, the relative abundance was calculated and expressed as a percentage.

The grain-size analysis was performed in the laboratory of the Ukrainian Scientific Centre of Ecology of the Sea, while foraminiferal analyses were performed in the Micropaleontological Laboratory of Odessa I.I. Mechnikov National University, Ukraine.

In order to discover a possible interrelation between foraminiferal and environmental parameters, cluster, correlation, factor analyses, and multidimensional scaling were applied using the "Statistica 7" package. The correlations between parameters were considered as significant at $p < .05000$ and the 95% confidence limit, and only these correlation coefficients are provided in the paper.

Results and discussion

The factor analysis of hydrological parameters using the method of principal components followed by the varimax orthogonal rotation procedure (varimax normalized) identified two main factors with total eigenvalues of 78%. This value corresponds to a relatively high representation of the variables by the three factors model, and as such, it is statistically satisfactory. The contribution of each factor to the total eigenvalue is 47.7%, 17.5%, and 12.7%, respectively. The highest loadings to Factor 1 have Tr, DO, SI, and pH; Factor 2 – D and S; and Factor 3 – Eh and Chl. Factor 1 and Factor 2 are located in opposite corners on the Factor Diagram while Factor 3 occupies an intermediate position.

The most powerful is Factor 1. It has the highest loading to SI, which has positive correlation with Tr, T°C, DO, and pH but does not have any correlation with D. Transparency (Tr) is usually a function of turbidity. The area under study is under the strong influence of the Danube River discharge that accounts for about 75% of the total river discharge into the Black Sea. According to the model of Grégoire et al. (1998), most of the freshwater and fine suspended sediments initially move north in late spring-summer. This enables us to suggest that **Factor 1 is an influence of the Danube discharge on the marine bottom ecosystem.** Factor 2 has the highest loading to D and S. This enables us to suggest that Factor 2 is related to **distance from the shore and salinity**. Factor 3 has positive loading to Chl but negative to Eh, representing eutrophication of the bottom environment related to consumption of oxygen by decaying phytoplankton.

The grain-size distribution of the superficial sediments does not show any specific pattern and looks rather spotty (Fig. 2) except for the pelite fraction >0.005 that increases with depth (r=0.61).

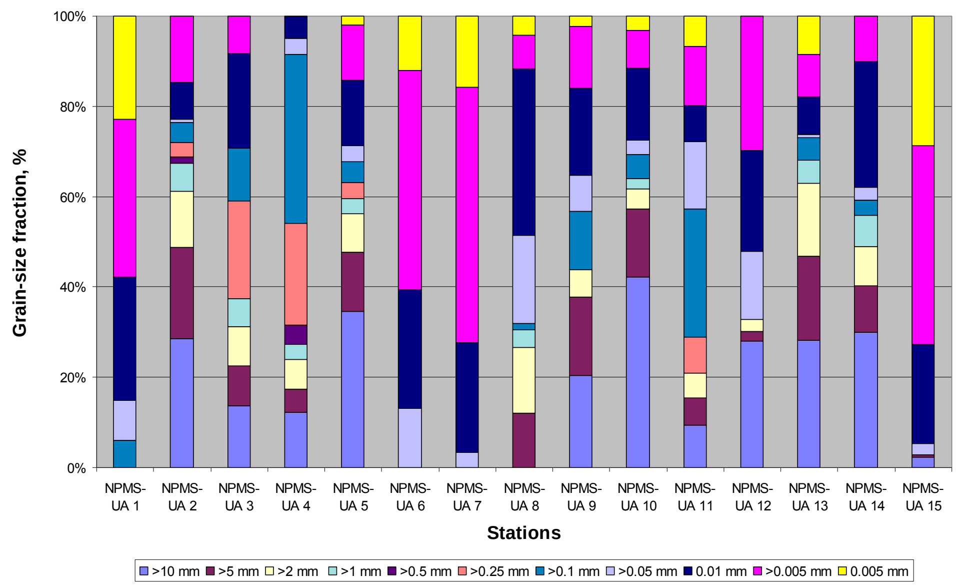


Figure 2. Grain-size distribution of sediments in the superficial (0-2 cm) layer of sediments.

Only benthic foraminifera were discovered. Their relative abundance per station along the depth gradient is shown in Fig. 3.

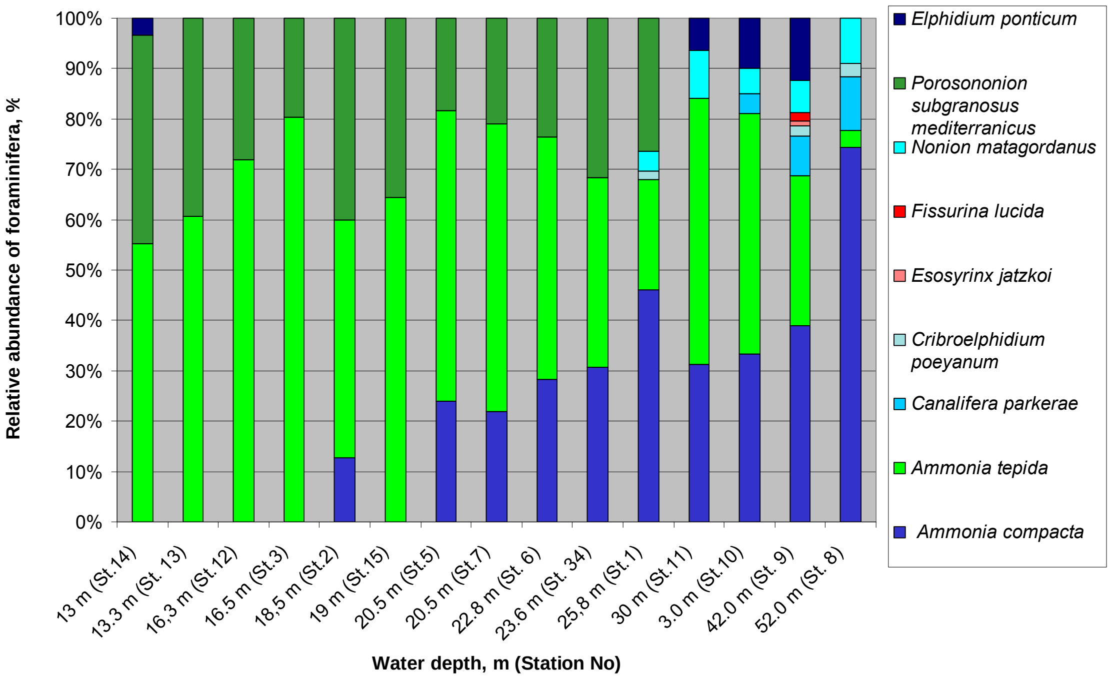


Figure 3. Relative abundance of foraminifera along the depth gradient: green – holeuryhaline (1-26 psu), blue – stricteuryhaline (11-26 psu), and red – polyhaline (18-26 psu) species.

Foraminifera are represented by nine species from two orders, and eight genera. All species are calcareous, no agglutinated forms are present.

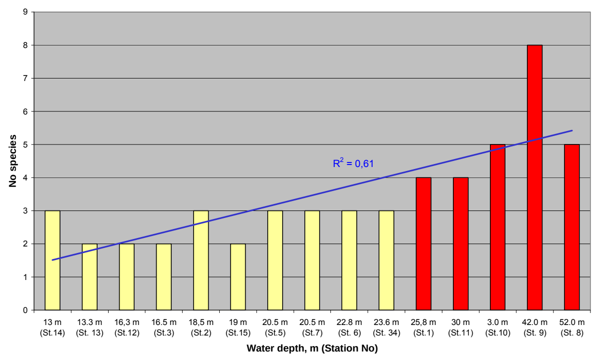


Figure 4. Number of foraminiferal species along the depth gradient. In yellow – stations of Cluster A.

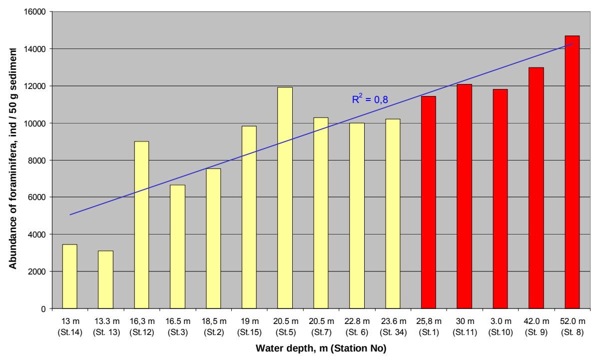
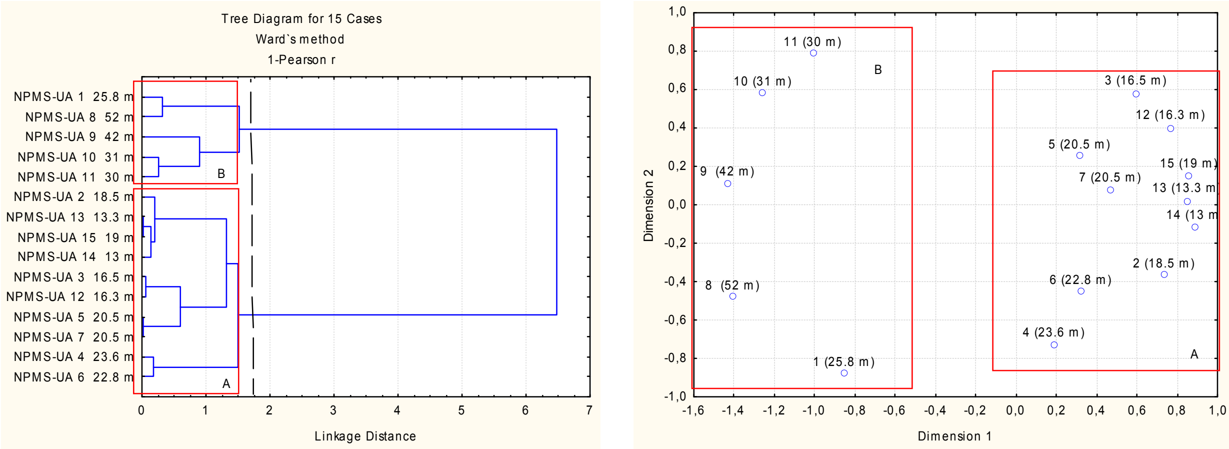


Figure 5. Abundance of foraminiferal species along the depth gradient. In red – stations of Cluster B.

The number of species increases from two to eight per station towards the sea (Fig. 4). Their abundance repeats this pattern, increasing from 3456 to 14,688 individuals per 50 g sediment (Fig. 5).

For groupings of stations that showed similar taxonomic compositions and quantitative characteristics of foraminifera, the Q-mode cluster analysis was applied. The data matrix consisted of 15 objects (stations) and nine variables (relative abundances of foraminifera), and it was standardized by objects. Ward's method was used to optimize the minimum variance within clusters. The Pearson's correlation coefficient was used as a measure of similarity. The resulting cluster dendrogram (Fig. 6a) and MDS plot (Fig. 6b) enabled us to distinguish Cluster A and Cluster B.



A B

Figure 6. Grouping of stations with similar compositions of foraminiferal species: A. Dendrogram from a Q-mode cluster analysis based on species population in which the separation of three clusters including A and B can be recognized; B. MDS plot of stations showing groups distributed on a metric scale suggesting that the dendrogram of Figure 6a should be "trimmed" at Linkage Distance 1.8 (dotted vertical line). For clarity, the cruise number “NPSM-UA” has been omitted from the station numbers.

Cluster A includes stations NPMS-UA 2, 3, 4, 5, 7, 12, 13, 14, and 15 located closer to the shore at water depths of 13-23.6 m that are mostly affected by Factors 1 and 3, i.e., the Danube discharge and eutrophication. Cluster B includes stations NPMS-UA 1, 8, 9, 10, and 11 located farther from the shore at water depths of 25.8-52 m that are mostly affected by Factors 2, i.e., salinity. Compared to Cluster B, Cluster A is characterized by the lowest average values of Tr, DO, SI, and S, and a lower number of species (2-3) compared to Cluster B (4-8), as well as a lower average abundance of foraminifera (8192 ind/50 g sediment) compared to Cluster B (12,591 ind/50 g sediment). The species *Ammonia tepida* dominates in Cluster A, while *Ammonia compacta* dominates in Cluster B, providing the name for the assemblages, respectively. The former expresses negative correlation with depth (r=0.81), while the latter positively correlates with depth (r=0.9), salinity (r=0.56), and silt (r=0.6) fraction (>0.05 mm).

There is almost no correlation of foraminiferal distribution with type of substrate. Out of nine species, only *Elphidium ponticum* and *Fissurina lucida* show positive correlation (r=0.52-0.61) with the silt fraction, while *Nonion matagordanus*, on the contrary, negatively correlates with it (r=-0.52). Abundance of foraminifera positively correlates with the silt fraction (r=0.58) but negatively (r=-0.61) to the coarse sand fraction. This is related to the amount of food, which is more abundant in a silty substrate.

Foraminiferal chracteristics in both Clusters show that all stations are located in the area of permanent environmental stress. This is indicated by low number of species and dominance of holeuryhaline species well adapted to stressful conditions. This stress is caused by the Danube discharge, which brings a vast amount of organic material upon which phytoplankton, and particularly dinoflagellates (Mudryk et al., this volume), quickly reproduce. The stress decreases towards the sea but only to a certain extent.

The shallow foraminiferal assemblage of Cluster A is identical to the assemblage of the Danube delta front (5-25 m depth) in its Ukrainian and Romanian parts (Fig. 1B and C). The relatively deep foraminiferal assemblage of Cluster B is very similar to that of the Danube prodelta (Fig. 1C) (Yanko et al., 2014, in press; Kondaryuk et al., 2015).

Conclusions

Foraminiferal characteristics show that the Danube discharge of water and sediments enriched with organic and inorganic compounds imposes environmental stress on the bottom ecosystem. The stress is expressed in a decrease in diversity and species richness as well as dominance of few holeuryhaline species (*A. tepida* and *P. subgranosus mediterranicus*) that appear to be tolerant of the stress. The intensity of the stress is a function of distance from the shore and turbidity: the closer to the shore, the more intense is the environmental stress—strong (assemblage *A. tepida*), weak (assemblage *A. compacta*). The boundary between the first and second degree of intensity of the riverine influence on bottom ecosystems can be located at isobath -25 m, which coincides with the distal zone of the delta front. This study is still in progress and will be reported elsewhere.

Acknowledgments

This paper is a contribution to the projects: EMBLAS "Environmental Monitoring in the Black Sea," BS-ERA.NET 076 "Water Pollution Prevention Options for Coastal Zones and Tourist Areas: Application to the Danube Delta Front Area," WAPCOAST (2010-2012), and "Control of observation during the operation of deep water navigable course of the Danube-Black Sea: sea part" under agreement No. 40/13 with the Ukrainian Scientific Research Institute of Ecological Problems, Kharkov. It also contributes to the IGCP 610 project "From the Caspian to Mediterranean: Environment change and human response during the Quaternary." The authors thank Georgiy Zolotarev from the Ukrainian Scientific Centre of Ecology of the Sea for providing data on grain-size analysis. The second author thanks the staff of "Mare Nigrum" for their help in obtaining sediment material.

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NEW RESULTS ON THE STRATIGRAPHY OF QUATERNARY SEDIMENTS OF THE MANYCH DEPRESSION

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Introduction

The Manych Strait connection between the Black Sea and Caspian Sea in the Pleistocene witnessed a great event in the history of the Ponto-Caspian region. The strait is located within the geological structure of the Manych Depression, which is extended sublatitudinally from the west coast of the northern Caspian to the northwest of the Azov Sea. The existence of the Manych strait makes available essentially an archive of information on stratigraphy and paleogeography. There were several stages when marine waters spilled over from the Black Sea to the Caspian, and alternatively. Due to the alternation of sedimentary layers, it is possible to correlate Pleistocene deposits and paleogeographic events. Nowadays, there are many materials and data about the history of the Manych strait. In the profile, it is possible to distinguish marine deposits interbedded with lacustrine and alluvial formations, and subaerial deposits on top. The main question is the paleogeographical reconstruction. We try to solve this problem using our new data and elaborating upon available information.

Study region and methodology

In February 2016, in collaboration with the Institute of Geography (Russian Academy of Science) and the Faculty of Geography (Lomonosov Moscow State University), complex geomorphologic and paleogeographic work was carried out in the central part of the depression on the northern coast of Manych-Gudilo lake. The geomorphology of the ridge-relief of the central Manych depression was characterized with geomorphological profiling and mapping of the territory. Hand hammer drilling (8 boreholes, max. depth 12 m) was performed into the covering Holocene sediments on different geomorphological levels of the depression. From the core (3 cm in diameter), continuous sampling was then made for spore-pollen, lithological, and geochemical analyses. The main results were obtained through cable drilling of 2 cores (depth of each 45 m). These cores were continuously sampled for different kind of analyses: lithological, geochemical, macro- and microfaunistic, geochronological (^{14}C, U-Th, OSL), magnetic, and paleomagnetic.

Results

The stratigraphic subdivision of the core is based on facies-lithology and macro-malacofaunistic analysis (Fig. 1).

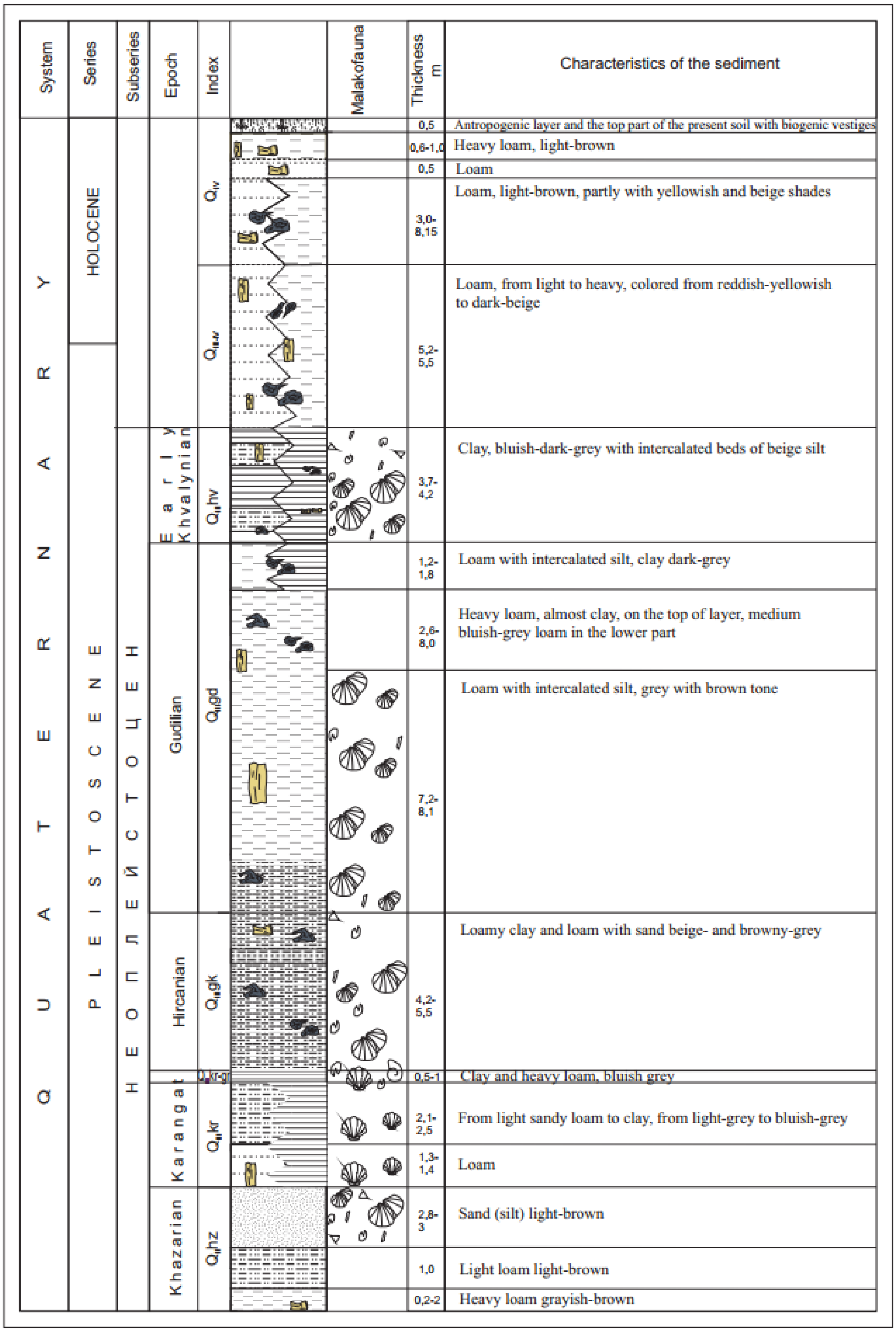

Figure 1. Section structure, core MH-1.

In the lower part of both cores, there is a barren formation of interbedded layers of sand and clay. The bottom line is precise, and below it lies a marine Karangatian formation (MIS 5) of sand and clay with well-preserved Black Sea marine mollusk shells (*Cardium edule*, *Paphia senescens*, *Ostrea edulis*, *Loripes lacteus*, *Chione gallina*, *Chlamys glabra*). Higher in the core, there is a loam-clay layer including both Black Sea (euryhaline species: *Cardium edule*, *Abra ovata*) and Caspian (*Didacna cristata*) fauna. Above lies a layer with clay deposits including shells of *Didacna* (*Didacna hyrcana*, *D. cristata*) which represent the Hyrcanian transgression of the Caspian Sea. Upwards through the precise borderline, there are silty-loam deposits with shells of freshwater mollusks (genera *Viviparus*, *Valvata*, *Dreissena*, *Lymnaea*). These shells attest to the period of the freshwater Burtass lake. Burtass lacustrine deposits are overlain by continental loam with an abundance of carbonates and visible gypsum nodules. This layer is covered by aqueous loam with detritus and shell fragments. On the top of the section lies the subaerial original silty layer.

The preliminary scheme of the sequence of paleogeographic events in the Pleistocene is compiled in Fig. 1. The beginning of the Late Pleistocene is marked by the penetration of marine water deep within the Manych depression during the Black Sea's interglacial transgression (Karangatian trangression, MIS 5e). The character trait of marine water throughout this period is relatively high salinity (18-20 psu) that favors the development of Black Sea mollusks. During the transition to the glacial epoch (MIS 5d-a), the marine waters of Karangat Bay had begun to retreat back into the Black Sea basin. In the end of this stage, there was a strait called the Hyrcanian, which had desalted brackish waters (8-10‰) of the Caspian Sea. The marine epoch in the central part of the Manych depression changed to the durable lacustrine phase of development in the second half of the Late Pleistocene (MIS 4-3), and Burtass lake existed there. In the beginning of its existence, it was flowing through (this is because of the majority of fresh- and calmwater mollusks at the base of the layer).

During the continental stage, there was active erosion damage of the Burtass deposits. Throughout this period were created specific landscape forms – extended ridges – which finally took shape in the epoch of degradation of the last glaciation as Khvalynian water moved into the Black Sea basin. After the closing of the Khvalynian strait, the continental epoch began; this subaerial stage has been continuous until today.

Conclusions

Preliminary data show the difficult history of the development of the Manych depression. Understanding of the evolution of the landscape in the Ponto-Caspian region is useful for the prediction of future events. At present, the main aim is the detailed laboratory study of the cores we extracted in order to obtain more accurate and detailed information. After this work, we will be able to produce an improved reconstruction of the history of landscape development in this region.

Acknowledgments

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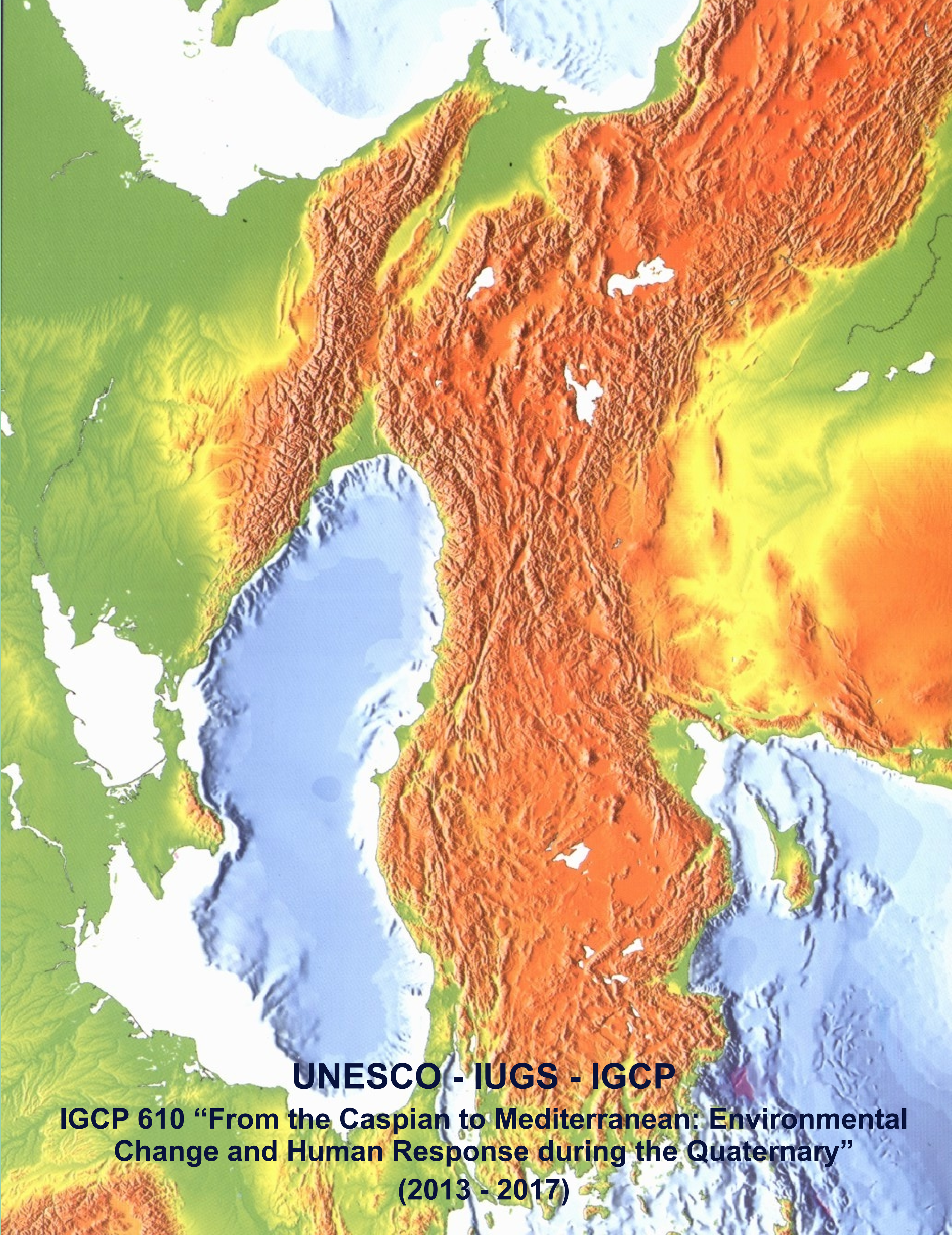

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