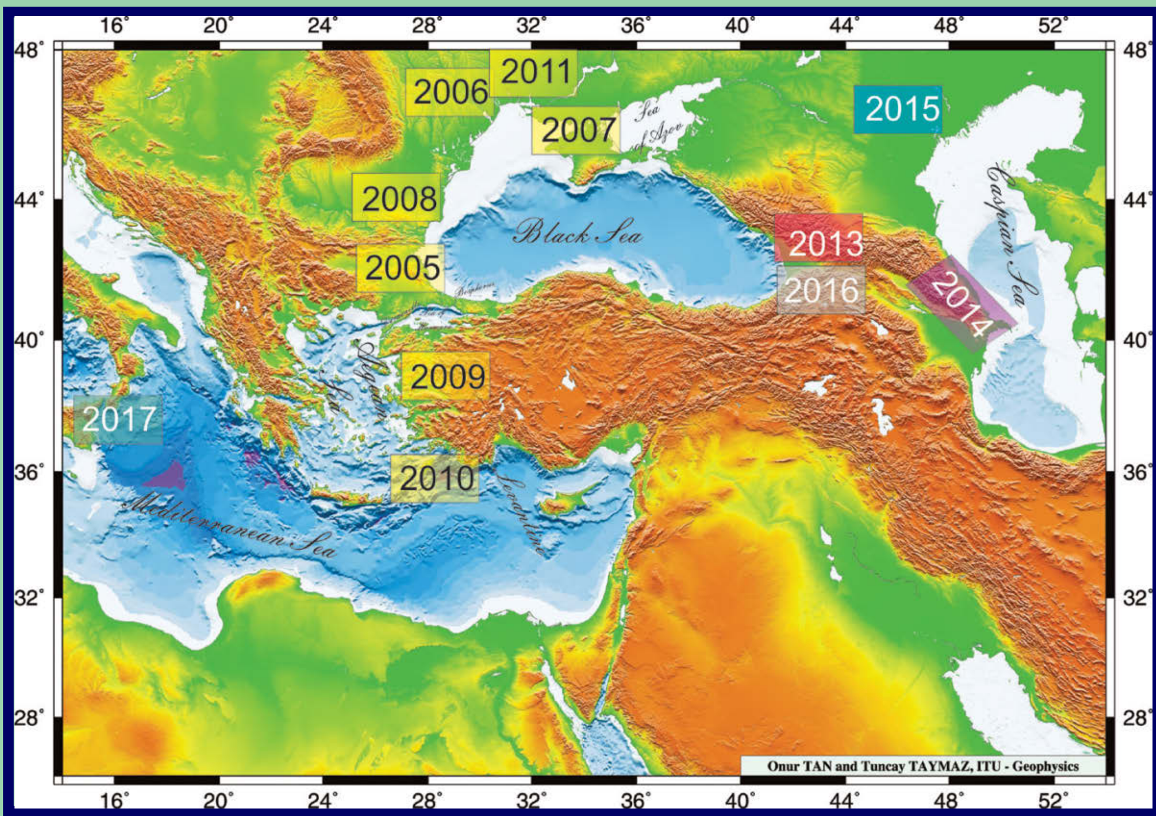
University of Palermo, Department of Marine and Earth Sciences (DiSTeM), Italy

October 1-9, 2017

INTERNATIONAL GEOSCIENCE PROGRAMME



PROCEEDINGS

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

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

Joint Plenary Conference and Field Trip of IGCP 610 and INQUA IFG POCAS October 1-9, 2017, Palermo, Italy

PROCEEDINGS

Organizers:

University of Palermo

Department of Marine and Earth Sciences (DiSTeM)

Sponsors:

UNESCO

IUGS

IGCP

Avalon Institute of Applied Science, Winnipeg, Canada

University of Palermo

Paleontological Society

PROCEEDINGS

IGCP 610 Fifth Plenary Conference and Field Trip

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

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

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

PALERMO UNIVERSITY PRESS

ISBN 978-88-940049-1-5

Cited as: A. Gilbert, and V. Yanko-Hombach (Eds.), 2017. Proceedings of UNESCO - IUGS – IGCP 610 and INQUA IFG POCAS Joint Plenary Conference and Field Trip, October 1-9, 2017, Palermo, Italy. University of Palermo, 258 p. ISBN 978-88-940049-1-5.

CONTENTS

ORGANIZING AND EXECUTIVE COMMITTEE

President	Enrico DI STEFANO, Italy enrico.distefano@unipa.it
Executive Director	Valentina YANKO-HOMBACH, Ukraine, Canada valyan@onu.edu.ua valyan@avalon-institute.org
Chairman of the Organizing Committee	Antonio CARUSO, Italy antonio.caruso@unipa.it
Executive Secretary	Claudia COSENTINO, Italy claudia.cosentino@unipa.it
Technical Director	Fabrizio LIRER, Italy
Administrator	Irena MOTNENKO, Canada irmot@avalon-institute.org
Members	Claudia COSENTINO, Italy Antonella MACCOTTA, Italy Alessandro BONFARDECI, Italy Alessandro INCARBONA, Italy
Field Trips	Antonio CARUSO, Italy Luca CAPRARO, Italy Alessandra NEGRI, Italy

SCIENTIFIC COMMITTEE

Valentina YANKO-HOMBACH, Canada, Ukraine	Antonio CARUSO, Italy
Agata DI STEFANO, Italy	Annachiara BARTOLINI, France
Fabrizio LIRER, Italy	Enrico DI STEFANO, Italy
Francisco SIERRO, Spain	Alexander KISLOV, Russia
Allan GILBERT, U.S.A.	Nicolae PANIN, Romania
Alessandra NEGRI, Italy	Olena SMYNTYNA, Ukraine
Maria MARINO, Italy	Mehmet Celal ÖZDOĞAN, Turkey
Timothy HERBERT, U.S.A.	Richard NORRIS, U.S.A.
Hayrettin KORAL, Turkey	Tamara YANINA, Russia

AIMS AND SCOPE

The meetings of IGCP 610 and INQUA Focus Group POCAS (SACCOM 1709F) will be carried out jointly in order to bring the international communities of both projects together to solve a number of contentious issues involving stratigraphy, geochronology, geological history, archaeology, and anthropology of the Caspian-Black Sea-Mediterranean Corridor [“CORRIDOR”].

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 "CORRIDOR" for a deeper understanding of Eurasian history, environmental changes and their relevance, as well as past and future impacts on humans.

The main goal of the INQUA Focus Group POCAS created within the INQUA SACCOM for the term 2017-2020 is to study the Ponto-Caspian stratigraphy and geochronology during the Quaternary. The main activities of POCAS are oriented toward solving existing contradictions employing, if needed, new work in the field via a wide range of multidisciplinary scientists and modern research methods and equipment.

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 Projects incorporate 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, Eastern and Western 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.

Five IGCP 610 Plenary Conferences and Field Trips were planned in the following regions: 2013 – Western Georgia; 2014 – Azerbaijan; 2015 – Russia (Northern Caspian); 2016 – Eastern Georgia (Inner Kartli and Kakheti regions); and 2017 – Palermo, Italy. They were 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).

They are focused on observation of geological characteristics of Quaternary and Pliocene 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 Fifth Plenary Meeting and Field Trip of IGCP 610 and the First Meeting of POCAS Focus Group will be concentrated on the Plio/Pleistocene geological history of the central Mediterranean of southern Italy (Sicily and Calabria). This subject is very important in shedding light and achieving a better understanding of climate evolution during the Plio/Quaternary in all parts of the Corridor.

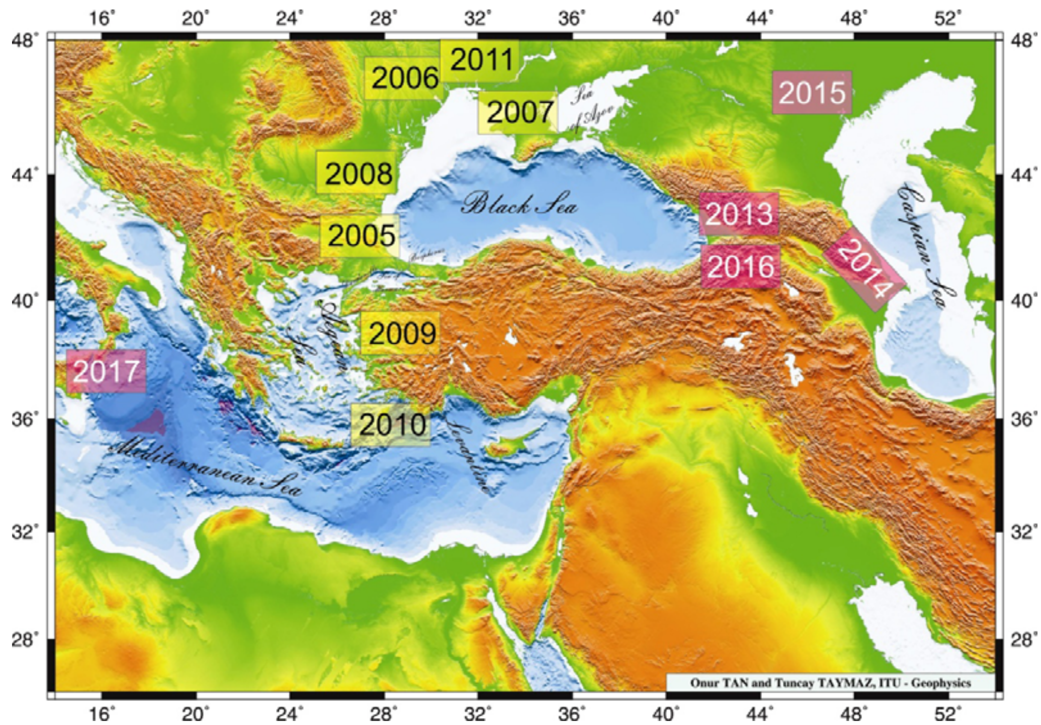


Figure 1. The Caspian-Black Sea-Mediterranean “CORRIDOR”: in yellow are the locations of IGCP 521-INQUA 501 meeting and field trip sites (2005-2011); in other colors are sites studied by the ongoing IGCP 601 Project: 2013 – Tbilisi, Western Georgia; 2014 – Baku, Azerbaijan; 2015 –Astrakhan’ (Volga Delta),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

The Conference will be held in the beautiful setting of the Botanical Garden of Palermo (http://www.ortobotanicoitalia.it/sicilia/palermo/), one of the oldest in Italy. In its more than two hundred years of activity, it has promulgated the study of many tropical and subtropical species throughout the Mediterranean.

The two days of the Conference will be devoted to oral presentations and posters, and five days will be devoted to geological field trips that focus on the GSSPs of the Zanclean, Piacenziano, Gelasian, and Calabrian stages of the Plio-Pleistocene.

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 of subjects covered by the conference as previous IGCP 610, IGCP 521, and INQUA 501 meetings have done.

The meeting will cover eight days in total. Two days (2-3 October) will be spent in Plenary Sessions, and five days (4-8 October) will be dedicated to the Field Trips.

WELCOME

On behalf of the Organizing and Executive Committees as well as the University of Palermo, Italy, and Avalon Institute of Applied Science, Canada, we are delighted to welcome you to the Joint Meeting and Field Trip of IGCP 610 and INQUA POCAS Focus Group that will be held in Palermo, Italy, on 1-9 October 2017.

It is expected that the joint conference 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 Joint Meeting has been organized and sponsored by the University of Palermo, Italy, and Avalon Institute of Applied Science, Winnipeg, Canada; with very moderate financial contributions from IGCP, INQUA, and the Paleontological Society.

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

We wish you a very pleasant stay in Italy.

Sincerely,
Organizing and Executive Committees

VENUE

Palermo is a city of southern Italy, the capital of both the autonomous region of Sicily and the Metropolitan City of Palermo. The city is noted for its history, culture, architecture, and gastronomy. It is over 2700 years old and played an important role throughout much of its existence. Palermo is located in the northwest of the island of Sicily, right by the Gulf of Palermo in the Tyrrhenian Sea. The city was founded in 734 BC by the Phoenicians as Ziz ('flower'). Palermo then became a possession of Carthage before becoming part of the Roman Republic, then the Roman Empire, and eventually part of the Byzantine Empire, all over the course of a thousand years. The Greeks named the city Panormus meaning 'complete port'. From 831 to 1072, the city was under Arab rule during the Emirate of Sicily, when the city first became a capital. The Arabs shifted the Greek name to Balarm, the root for Palermo's present-day name. Following the Norman reconquest, Palermo became the capital of a new kingdom (from 1130 to 1816), the Kingdom of Sicily and the capital of the Holy Roman Empire under Frederick II Holy Roman Emperor and Conrad IV of Germany, King of the Romans. Eventually Sicily would be united with the Kingdom of Naples to form the Kingdom of the Two Sicilies until the Italian unification of 1860.

The population of Palermo’s urban area is estimated by Eurostat to be 855,285, while its metropolitan area is the fifth most populated in Italy with around 1.2 million people. In the central area, the city has a population of around 676,000 people. The inhabitants are known as Palermitani or, poetically, panormiti. The languages spoken by its inhabitants are the Italian language, Sicilian language, and the Palermitano dialect. Palermo is Sicily's cultural, economic, and tourist capital. It is a city rich in history, culture, art, music, and food. Numerous tourists are attracted to the city for its good Mediterranean weather, its renowned gastronomy and restaurants, its Romanesque, Gothic, and Baroque churches, palaces and buildings, and its nightlife and music.

Palermo is the main Sicilian industrial and commercial center: the main industrial sectors include tourism, services, commerce, and agriculture. In fact, for cultural, artistic, and economic reasons, Palermo was one of the largest cities in the Mediterranean and is now among the top tourist destinations in both Italy and Europe.

It is the main seat of the UNESCO World Heritage Site of Arab-Norman Palermo and the Cathedral Churches of Cefalù and Monreale. The city is also going through careful redevelopment, preparing to become one of the major cities of the Euro-Mediterranean area. Roman Catholicism is highly important in Palermitano culture. The Patron Saint of Palermo is Santa Rosalia, whose Feast Day is celebrated on 15 July. The area attracts significant numbers of tourists each year and is widely known for its colourful fruit, vegetable, and fish markets at the heart of Palermo, known as Vucciria, Ballarò, and Capo.

The University of Palermo (UNIPA) is a consolidated cultural, scientific and teaching presence in central-western Sicily (Fig. 2).

Figure 2. The main building of the Palermo University.

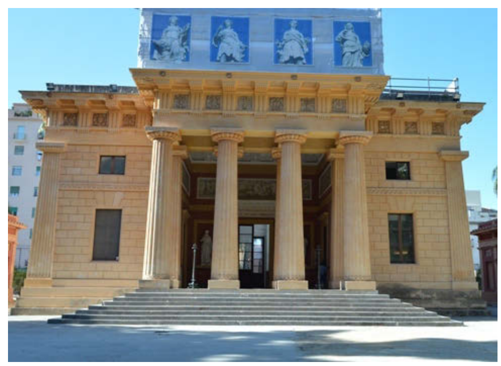


Figure 3. Botanical Garden.

Its 5 Schools and 20 Departments cover the most important domains of contemporary scientific and technological knowledge.

The university was established in 1806 when Ferdinand III of Bourbon, King of Naples and the Two Sicilies, transformed the Palermo Academy of Studies into a university, granting it the power to bestow degrees in Theology, Medicine, Law, and Arts – a conquest the city had awaited for centuries. The seal on the decree bears the stamp that has become the present-day university's institutional logo: the Trinacria flanked by Minerva, representing the arts, and by Mercury, representing sciences. But the events that led to the foundation of the university go back much further in time.

In 1550, the Jesuit College was created, which was destined to achieve a role of absolute dominance in the reality of the times. The imposing Collegio Massimo was constructed with extreme rapidity; it is now the seat of the Regional Library that proved to be second only to that in Munich. The Jesuits obtained from the Pope the right to bestow degrees in Philosophy and Theology.

A new page opened on the first of December 1767, when the Jesuits were expelled from the Bourbon Kingdoms of Naples and Sicily and all their goods, including libraries, were confiscated. On 31 July 1778 the King set up a Deputation, which he charged with the task of reorganizing the Study in Palermo. The regulations of the new Academy were characterized by the fact that in addition to the teaching "of words" the instruction "of things" was introduced, e.g. geometry, economics, agriculture, and commerce. This was the embryo of the future university.

The Academy awarded the "baccalaureate" at the end of two years' study, the "licence" after the third year, and finally the degree on termination of the course of study, which lasted from three to five years. The Palermo Study achieved a number of successes, including the creation in 1790 of the Botanical Garden and the foundation of an Astronomical Observatory, with the result that Sicily was able to find its place in the circuit of European culture, making marked progress in higher education. The Academy's first official set of regulations was approved in 1783, when it was allotted its own funds and given full didactic, administrative and disciplinary autonomy.

The constitution in Palermo of a full-scale University was ordained by royal despatch dated 3 November 1805, and the diploma signed by King Ferdinand III of Bourbon, which gave the Academy the title of Royal University of Studies, arrived on 12 January 1806.

UNIPA's great transformation came in 1860, when Garibaldi arrived on the scene. The present-day non-religious form of University was thus created, thanks to the Pro-Dictator Mordini, who also forged links with the European higher education system – this eventually led to the foundation of the School of Engineers and Architects.

This was the beginning of the process by which UNIPA became what it is today, a mega-university with twelve faculties distributed in various manner throughout the territory, with University Poles in other central-western provinces of Sicily.

About 122 courses (first and second cycle) are yearly offered as well as 44 master and specialization and 23 PhD courses, targeted at the training of specific professional figures, often in cooperation with external institutions and companies, a galaxy which attracted 11,085 first-year students in the 2013/2014 academic year. The University General Hospital is a local health corporation that works in synergy with the Faculty of Medicine. It provides beds, day-hospital beds, and a first-aid service.

Palermo University has 20 Departments, where researchers study every day to find new solution to the questions posed by nature, science and society. From Information Technology to Biology, from Mathematics to Medicine, to Social Sciences and Preservation of Cultural Heritage, the University works to make its contribution of innovation and progress to the international scientific community and the world of production.

In the laboratories – many of which are open to the local community – the first step of collaboration between researchers in the academic world and in the business world are taken, basic and applied research is carried out, and young brains are given the chance to turn their intuitions to good account. Here, scientific research finds its application in robotics, pharmaceutical industry, ecology, and medical diagnostics. Successful technological transfer implies the full synergy of innovative technologies, scientific expertise, production systems and processes. Actually, it is necessary to implement a full-fledged system including the "know-how," production processes, goods, services, and organizational and operational skills.

In order to achieve this goal, the University of Palermo has set up a network of University labs (UniNetLab) for testing and transferring new technologies to SMEs.

UniNetLab is the natural evolution of single consolidation actions of some University labs. It aims at the technological innovation of enterprises for the economic recovery of Southern Italy. The University labs' integrated system has been conceived to create synergies among the different types of expertise available. It is also meant to be a centre of reference for other activities of technological transfer between the Universities and research entities operating in our region, in view of using financial resources better and reaching the necessary critical mass of operators in the sector.

In operational terms, UniNetLab ensures scientific and administrative coordination among the various research units. Nevertheless, each unit is autonomous as to the relations with enterprises which, therefore, can directly apply to the single facilities whose expertise they are interested in.

More information about university can be obtained at www.uninetlab.it

The meeting will be held at the "Lanza Conference Hall," Botanic Garden (http://www.ortobotanico.unipa.it/). The Botanic Garden (Fig. 3) is among the oldest modern centers for botanical studies in the Mediterranean region. The park houses a greenhouse (glasshouse), seed and dried plant repository, catalogue archive, and more than ten hectares of outdoor gardens in the busy centre of what is today Sicily's largest city. The Orto Botanico, bordering the Kalsa district, is home to hundreds of tropical and semi-tropical plants from around the world, many of which were introduced into Europe by this unique organization, now administered by the University of Palermo. The medieval kings of Sicily had vast gardens around the palaces known as the Cuba and the Zisa, but in terms of modern botany, the Orto Botanical was founded with 18th century biological principles in mind. The Royal Academy of Studies, the university of its day, first established a botanical institute at Palermo in 1779 under the auspices of the government of King Francesco I of the Two Sicilies. Requiring more space, the Botanical Gardens were transferred to their present location, next to the Villa Giulia park, in 1786. The Neo-Classical structures visible today were begun three years later, based on designs by Trombetta, Marabitti, and the famous Venanzio Marvuglia. The sculptor Vitale Tuccio created the two sphinxes flanking the steps leading to the main building. These works have been recently restored. One section of the gardens is arranged based on the Engler system, the other on the Linnaean system.

ACKNOWLEDGMENTS

We gratefully acknowledge the support and hospitality of the Italian organizers, the University of Palermo, for hosting the Joint Meeting and Field Trip of IGCP 610 and INQUA POCAS Focus Group, 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, INQUA, and the Paleontological Society.

We are indebted also to Prof. Antonio CARUSO, Chairman of the Organizing Committee, for the extraordinary efforts in organizing the conference and field trips. Particular appreciation is extended to Dr. Luca Capraro, Prof. Alessandra NEGRI, Prof. Agata DI STEFANO, and Prof. Maria MARINO for arranging the Field Trips and preparing the Field Trip Guide. Furthermore, we are also very grateful to Dr. Claudia COSENTINO and Dr. Alessandro BONFARDECI for their technical support.

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.

Prof. Dr. Valentina Yanko-Hombach
Co-Leader of IGCP 610 and INQUA POCAS Focus Group
Executive Director of the Joint Meeting

PART I

IGCP 610 PROGRESS REPORT (2013-2016)

Yanko-Hombach, V. [1, 2]

[1] Odessa I.I. Mechnikov National University, 2 Dvoryanskaya Str., Odessa 65082, Ukraine
valyan@onu.edu.ua
[2] Avalon Institute of Applied Science, 976 Elgin Avenue, Winnipeg MB R3E 1B4, Canada
valyan@avalon-institute.org

Website address(es) related to the project

http://www.avalon-institute.org/IGCP610/index.php - main
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-INQUA POCAS community includes about 260 scientists from 21 countries: Azerbaijan, Belgium, Bulgaria, Canada, Georgia, Germany, Greece, France, Israel, Italy, Kazakhstan, Latvia, Romania, Russia, The Netherlands, Switzerland, Turkey, Turkmenistan, UK, Ukraine, and USA.

The IGCP 610 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, five years of IGCP 610 activity have been carried out in strict agreement with the Working Plan [http://www.avalon-institute.org/IGCP610/work_plan.php].

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

The International Focus Group POCAS [IFG] "Ponto-Caspian stratigraphy and geochronology" was created within the INQUA SACCOM for the term 2017-2020. It is devoted to the study of the geology of the Ponto-Caspian region during the Quaternary as a single geographic entity, bypassing linguistic/political/disciplinary boundaries, linking continents (Europe and Asia) more closely, and encouraging East-West dialogue and cooperation among researchers.

The main activities of IFG POCAS are oriented toward solving the existing contradictions, employing new work in the field if needed. This will be done by involving a wide range of multidisciplinary scientists and modern research methods and equipment. The major challenge will be the involvement of young scientists as well as graduate and undergraduate students to participate in the research and integration of available and newly obtained data. It is of great importance to do this because, so far, there are few specialists (particularly in the developing countries) trained in modern methods and techniques (e.g., isotopic analysis, geochemistry, paleontology, and different types of dating).

The planned activities include:

1. A number of annual workshops and training schools that will be organized by IFG POCAS. Organization of annual workshops oriented toward discussion of the most debated and diverse outcomes in geomorphology, stratigraphy, paleogeography, paleontology, and geochronology. These workshops will allow us to get closer to a more reasonable and realistic understanding of the evolution of the natural environment in this vast region. The first workshop was held in Moscow, Russia, in spring of 2017. It laid out a plan for future activities. The workshop was focused on disputed issues and the identification of the main ways to solve them. A great number of young researchers and students from developing countries was involved.

2. Establishing the Information Internet-Portal on the geological history of the region within the SACCOM website, linked to the most important published materials, including maps. This will allow young scientists to become readily familiar with the main problems under discussion.

3. Establishing an open database of multilingual literature, published and stored in archives. This will include also rare classic papers published in the pre-Soviet and Soviet period. A translation of the most important works is planned.

4. Establishing the open GIS database – Geoportal. This will contain the existing sections of Quaternary deposits that will be linked to the regional interactive map as well as to publications where they are described. The Geoportal will be supplemented by tools enabling interactive work with layers, bridging publications, adding sections, building profiles, etc. This will dramatically increase progress in the generalization of the currently obtained results. Any researcher will be able to find specific data that he/she needs and largely eliminate the current problem of absence of translations of works provided by Russian researchers; these works represent a massive amount of data that surpass all other publications.

2. Plenary Conferences and Field Trips of IGCP 610

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).

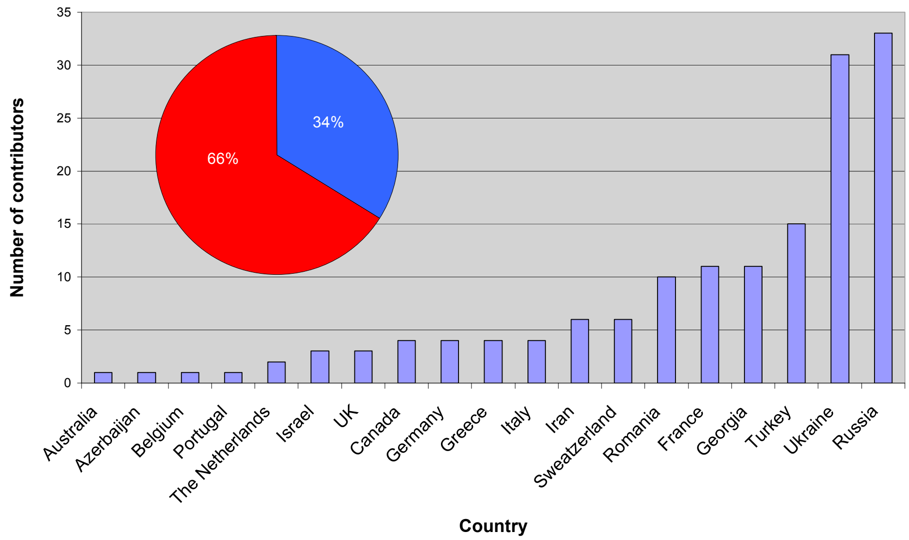


Figure 1. Number of countries and contributors to IGCP 610 First Plenary Conference and Field Trips. The circle shows the percentage of scientists from developing (red) and developed (blue) countries, respectively.

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, Russia, 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, Russia, 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 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).

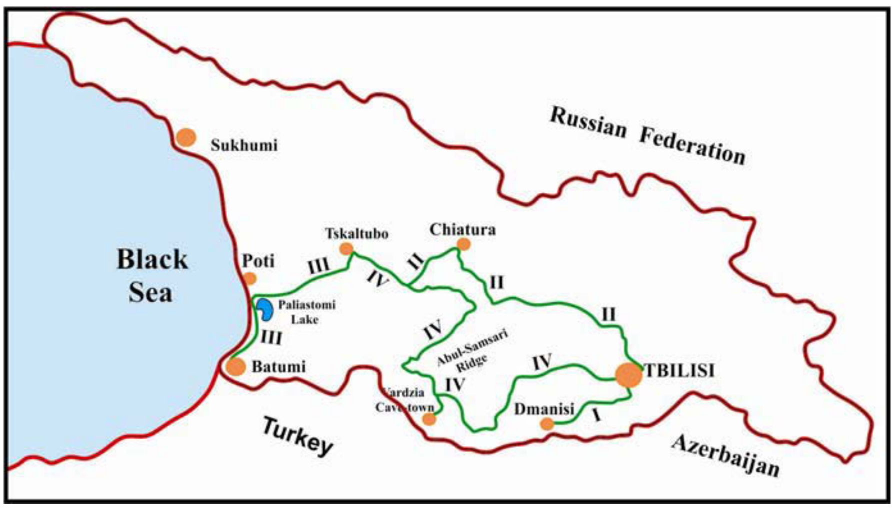


Figure 2. Map of Georgia with geological and archaeological sites visited during the Field Trips of IGCP 610 in 2013. Field Trip I (15 October 2013): Mtskheta, Chiatura Paleolithic sites, Sataplia dinosaur footprints, and cave state reserve. Field Trip II (16 October 2013): Mtskheta, Chiatura Paleolithic 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).

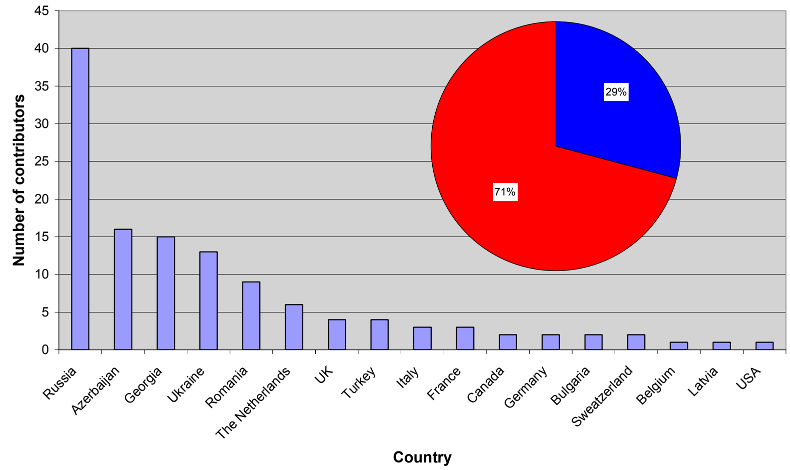


Figure 3. Number of countries and contributors to the IGCP 610 Second Plenary Conference and Field Trips in Baku, Azerbaijan. The circle shows the percentage of scientists from developing (red) and developed (blue) countries, respectively.

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 and 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.

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).

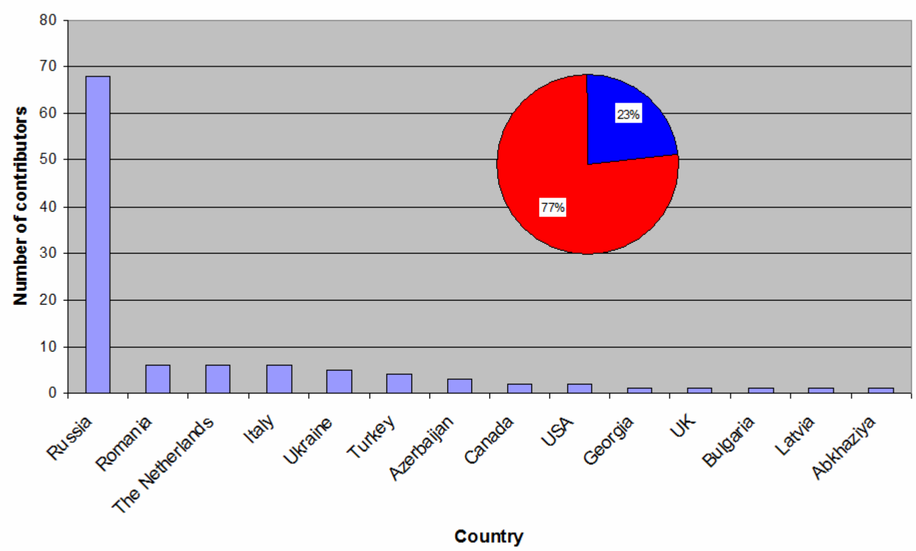


Figure 5. Number of countries and contributors to IGCP 610 Third Plenary Meeting and Field Trips. The circle shows the percentage of scientists from developing (red) and developed (blue) countries, respectively.

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. Therefore, it was decided to run the meeting and field trips in Eastern Georgia with purpose to focus on the pre-Pleistocene and Pleistocene geological history of the Eastern Paratethys remnants.

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 (Yanina et al., 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 (Fig. 6; Yanina et al., 2015).

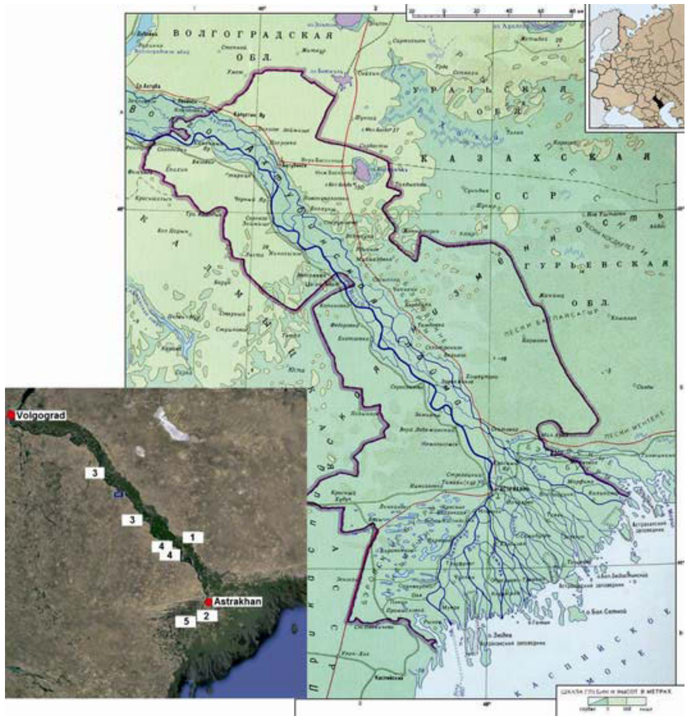


Figure 6. Map of the Lower Volga region with geological and archaeological sites visited during the Field Trips.

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.

The Fourth Plenary Meeting and Field Trip of IGCP 610 was organized by the Georgian National Academy of Sciences (GNAS), Ilia State University, Georgia, and Avalon Institute of Applied Science, Canada, and hosted by the by the GNAS. President of the conference was Academic GNAS Irakli Gamkrelidze, President of GNAS, Georgia. Executive Director was Prof. Valentina Yanko-Hombach. The Meeting and Field Trip were held in Tbilisi and Eastern Georgia, respectively (Fig. 7; Gamkrelidze et al., 2016).

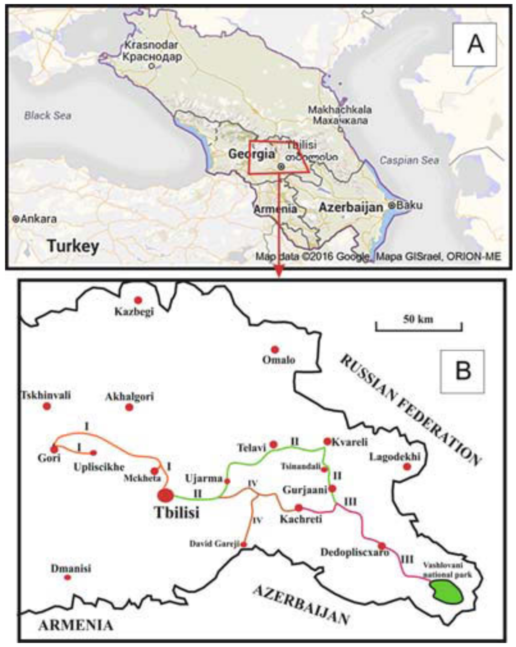


Figure 7. Map of the Eastern Georgia region with geological and archaeological sites visited during the Field Trips.

It focused 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

The 218-page Proceedings of the Fourth Plenary Meeting (Gilbert and Yanko-Hombach, 2016) contain contributions from 107 scientists from two continents and 17 countries; 89% of the contributors are from developing countries (Fig. 8).

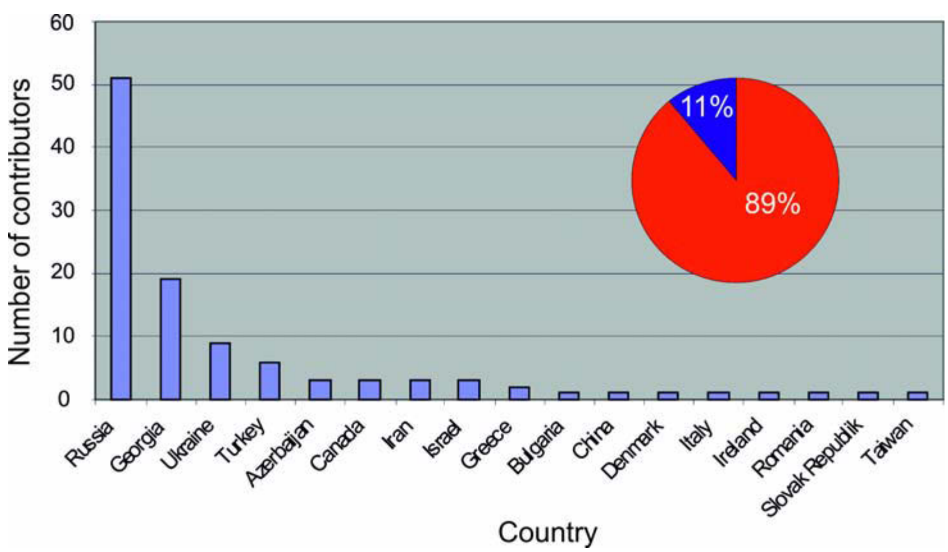


Figure 8. Number of countries and contributors to IGCP 610 Fourth Plenary Meeting and Field Trips. The circle shows the percentage of scientists from developing (red) and developed (blue) countries, respectively.

About 50% of participants are female. This particular conference was characterized by an especially high number of young scientists and students.

The two days of Technical Sessions were organized into five panels with 25 Oral and 31 Poster presentaions. Panel 1 was titled “GENERAL QUESTIONS OF THE CORRIDOR”—moderators: Nikolay Esin (Russia) and Alexander Kislov (Russia)—and included four ORAL presentations including a key-note talk “Geological structure of Georgia and geodynamic evolution of the Caucasus” given by Academician GNAS Gamkrelidze, I. (Georgia). Three other presentations covered syntheses of the IGCP 610 results, pointing out some controversies and paradoxes; general tectonic/geologic framework of the Caspian Sea and its water connection with the Black Sea and Mediterranean; and the evolution of the Akchagylian Sea area and coastline based upon mathematical modeling. Panel 2 was titled “RECENT ECOSYSTEMS AND PROCESSES”—moderators: Nelly Sergeeva (Russia) and Valentina Yanko-Hombach (Ukraine, Canada)—and included 5 ORAL presentations that covered a range of topics on the glacier variation dynamics in East Georgia under the impact of modern climate change; porosity and deterioration of stone building material in Istanbul; collections of the Central Soil Museum as a foundation for soil-ecological monitoring of the Caspian-Black Sea-Mediterranean Corridor territory; foraminifera as indicators of environmental stress in marine ecosystems; and retrospective data about underwater landscapes and the meiobenthos in the northeastern part of the Black Sea given by Turkish, Russian, Ukrainian, and Canadian scientists. Panel 3: QUATERNARY AND UPPER NEOGENE PALEONTOLOGY, PALYNOLOGY, AND STRATIGRAPHY OF THE CORRIDORS—moderators: Nikolay PANIN (Romania) and Petra MUDIE (Canada)—included ten ORAL presentations that covered a range of topics on Western Georgia as a refuge for Tertiary elements of Eurasian floras (key-note); palynoclimatostratigraphy of the Pleistocene deposits in Trlica Cave; pollen-based reconstruction of the Plio-Pleistocene vegetation and climate change in the North Caucasus; the last interglacial vegetation patterns on the northern margins of the Black Sea; Middle Miocene marine mollusks in northernmost Anatolia and their biostratigraphic responses to changing paleogeography; the Karangatian epoch (MIS 5e) in the Black Sea basin; malacofauna of the Kerch Strait during the Late Pleistocene-Holocene: paleogeographical analysis; Quaternary molluscan faunas of the Sinop peninsula; new data on the stratigraphy of Quaternary sediments of the Manych depression; analysis of South Caspian deep sedimentation from marine cores given by the Ukrainian, Turkish, Russian, Canadian, and Iranian scientists. PANEL 4: PALEOENVIRONMENTAL AND PALEOGEOGRAPHIC RECONSTRUCTIONS OF THE CORRIDORS—moderators: Tamara YANINA (Russia) and Elmira ALIEVA (Azerbaijan)—included six ORAL presentations devoted to pedogenetic response to climatic fluctuations within the last glacial-interglacial cycle in the lower Volga basin; new data on correlation of the paleogeographic events of the Caspian Sea and Russian Plain in the late Pleistocene; history of Caspian Sea level oscillations in the late Pleistocene; pioneer dendroclimatological research in western and southwestern Turkmenistan; and clay mineral provenance of lower Khvalynian deposits in the Middle and Lower Volga River valley; and new results on structure of the Srednyaya Akhtuba reference section given by Russian and Turkmenistan scientists. PANEL 5: ANTHROPOLOGY, ARCHAEOLOGY, AND HISTORY—moderators: Sergey VASILIEV (Russia) and Olena SMYNTYNA (Ukraine)—included four ORAL presentations covering anthropological records of the Caucasus in the Paleolithic (key-note); re-assessing East Mediterranean sea-level trends: 3000 years of archaeological indicators in Greece and Israel; the origin of artifacts of bone and shell from the Khvalynsk Eneolithic cemeteries (Northern Caspian region); soils of Scythian settlements as paleoenvironmental archives in the area of Late Holocene migration pathways through the East European steppe; and paleoanthropological research into the early medieval Coptic cemetery of Wadi Naqlun in the Fayoum Oasis (Egypt) given by Israeli, Greek, Italian, Ireland, and Russian scientists.

The POSTER session included 25 presentations. Each presenter was allotted five minutes to present his or her poster orally. Poster sessions covered a wide range of subjects on magnetometric investigations, remote sensing, palynology; hydrology and landscape characteristics, sea-level rise, climate change, paleoenvironmental reconstructions, petrography, facies analysis, geochemistry, mud volcanism, diatom analysis, Quaternary continental flood basalts, the unique Cave City of Vardzia in Georgia, geometry and kinematic evolution of a thrust-top basin, vegetation and climatic changes, coastal laws in Turkey, paleoclimate, loess-soil complexes, petrography based on SEM-analysis and optical microscopy, sea impact on human adaptation, optically stimulated luminescence dating, malacofauna, and paleogeography of the Corridor given by Romanian, Turkish, Bulgarian, Canadian, Ukrainian, Taiwanese, and Russian scientists.

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 Fifth Plenary Meeting and Field Trip in 2017. A majority of participants voted to organize it in Italy with a goal to study GSSP outcrops.

The four days of field trips (by bus) (Fig. 7) were led by prominent Georgian geologists and archaeologists described above.

The 19-page Field Trip Guide describes the large sequences of freshwater-continental sediments of the Miocene, Pliocene, and post-Pliocene that fill all major depressions of the Kartli and Kakheti depressions, a variety of uplift regimes during the Quaternary, and archaeological and historic sites within Eastern Georgia (Gamkrelidze et al., 2016; http://www.avalon-institute.org/IGCP610/pdf/Field_Trip_Guide_IGCP_610_2016.pdf).

A special Volume of *Quaternary International* “IGCP 610 III” collected about 15 articles presented at the meeting. It is planned for publication in 2017.

The project was highlighted at the First National television channel of Georgia and GNAS website (http://science.org.ge/newsite) where letters of gratitude from conference participants should be uploaded. It generated much public information showing its significant impact.

Overall, the meeting provided an excellent opportunity for international discussion of different methods and interpretations used to analyze the history of a huge geographical area from the Caspian to the Mediterranean during the full duration of the Quaternary. It also emphasized the importance of studying the Pre-Quaternary geological history in order to reveal continuity in its development. The meeting encouraged an exchange of data and publications, as well as encouraged future collaboration between physical and social scientists over the Globe. It brought together multidisciplinary scientists from all over the world, and in the process enhanced West-East scientific dialogue by providing a supportive background for collaboration regarding the correlation and integration of discoveries on the influence on humans of climatically/tectonically induced sea-level changes and coastline migration. The meeting encouraged the younger generation to engage in the multidisciplinary study of the region using advanced analytical techniques and methodologies for geoarchaeological investigations.

Archaeological and historic sites were observed in Mtskheta (listed as a World Heritage site by UNESCO); the Graklianis Hill near Kaspi that shows evidence of human presence possibly going back 300,000 years. The site contains a temple to a fertility goddess from the 7th century BC, a pit-type burial cemetery from the Early Bronze Age, and the remains of a building from around 450-350 BC; the building consists of three rooms with three storage rooms. The site had been occupied between the Chalcolithic and the Late Hellenistic periods. In 2015, a mysterious script was discovered on the altar of a fertility goddess's temple, predating those previously known in the area by at least a thousand years; Uplistsikhe, "The Lord's Fortress," is an ancient rock-hewn town in Eastern Georgia some 10 km east of the town of Gori. Built on a high rocky prominence on the left bank of the Mtkvari River, it contains various structures dating from the Early Iron Age to the Late Middle Ages, and it is notable for the unique combination of various styles of rock-dwelling cultures from Anatolia and Iran, as well as the co-existence of pagan and Christian architecture. Uplistsike is identified by archaeologists as one of the oldest urban settlements in Georgia. More information about field trips can be obtained from the Field Trip Guide (Gamkrelidze et al., 2016).

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)
- School-seminar for young researchers "Methods of deltaic systems study in the South of Russia" held at the Faculty of Geography of Moscow State University in March 2017. There were 5 lectures and presentations by leading researchers in the deltaic regions of the southern Seas of Russia: (1) T. A. Yanina. A comprehensive study of the Volga Delta; (2) N. S. Bolikhovskaya. Palynological method in the solution of questions of climatostratigraphy and Holocene landscape-climatic reconstructions of the deltaic regions of the South of European Russia; (3) E. N. Badyukova. The value of data on morphology, distribution, and structure of the Baer Knolls to clarify their genesis; (4) V. I. Myslivets, A. V. Porotov. The methodology of studying the Holocene history of development in estuarine parts of river valleys of the Northern Black Sea; (5) P. N. Terskiy. Hydrological investigations in the Volga Delta.

4. Field Studies (2013-2017)

The field studies were performed in the:

Caspian region:

- Middle and Lower Volga region. In the Middle Volga region (works manager R. Makshaev) in the territory of Saratov and in the northern part of the Volgograd region, sediments of the Khvalyn transgression of the Caspian Sea in the outcrops along the river were studied. In the Lower Volga region (supervisors T. Yanina and R. Kurbanov) in the territory of the Volgograd region, the key sections of the Caspian Pleistocene Srednyaya Akhtuba, Leninsk, Raigorod were studied; in the territory of Kalmykia—section of the Tsagan-Aman; in the Astrakhan region—section of

Seroglazka. All studied sections have a complex structure, which is typical of a large valley, periodically flooded by the Caspian Sea. Stratigraphic reference points are deposits containing Caspian malacofauna Didacna Eichwald. The key sections most fully reflect the history of transgressive-regressive events in the Caspian Sea and its relation to glacial-interglacial events on the Russian plain. Comprehensive stratigraphic and palaeogeographic analysis of the sediments from the outcrops and radiocarbon dating of mixed-age sediments (H. Arslanov), thorium-uranium (V. Kuznetsov), and OSL (R. Kurbanov, N. Sychev, N. Tkach) were done; OSL was conducted for the first time on the Lower Volga. In the outcrop Seroglazka, sediments lying below the Volga River water edge revealed by borehole drilling to the depth of 40 meters (works manager R. Kurbanov). The core is currently being studied.

- A borehole was drilled to a depth of 20 m (works manager R. Kurbanov) in order to study the Holocene history of the Caspian Sea and the influence of Volga deltaic systems on the sea level fluctuations in the territory of the modern Volga delta. By now, we have an algological study of the core (E. Schtyrkova).
- Expeditionary investigations covered the Eastern coast of the Caspian Sea (supervisor R. Kurbanov). The work was conducted in Turkmenistan in the Gulf of Kara-Bogaz-Gol and the Uzboy River, and in Kazakhstan, on the Mangyshlak Peninsula. The studies were preliminary in nature; in subsequent years they will continue. For arid regions of Turkmenistan and Kazakhstan, dendrochronological and dendroclimatic studies have been carried out (A. Berdnikov and R. Kurbanov). The resulting chronology shows a significant climate response and is potentially suitable for paleogeographic reconstructions.
- Field investigations (supervisor R. Kurbanov) were held in the Manych valley. The natural outcrops in the Eastern Manych valley near the Chograysky dam, near the settlement Zunda-Tolga, in the cliffs of lake Manych-Gudilo were studied. Burtasskie (middle of the Late Pleistocene), Khvalynian, and Holocene sediment exposures occur in these outcrops. In the Manych valley, deep boreholes were drilled (70-40 m) which yielded a full core. Two boreholes were drilled in the central part of the Manych depression, in the area of lake Manych-Gudilo. Four boreholes were drilled in the eastern part of the depression. The core is currently being studied by complex of methods.
- The cores of two boreholes from of the North Caspian Sea (supervisor T. Yanina and V. Sorokin) were studied by lithological, malacofaunal, partially palynological and geochronological methods. The study allowed us to add to the picture of paleogeographic development of the Caspian Sea in the Late Pleistocene and the reaction of its natural environment to the global climate events.
- Malacofauna is an important component of the ecosystem of the Caspian Sea. Evolution of the biodiversity of mollusk fauna of the Caspian Sea during the last 10 kyr was analyzed using the results of field investigations within different areas. The biodiversity of mollusks depends on the parameters of the aquatic environment, which reflect climate changes followed by the transformation of regional water balance. The result was a change in thermal conditions, level and salinity of water bodies. Biodiversity of the New Caspian basin and water bodies of the Volga River delta were strongly affected by the anthropogenic factor, i.e., the biological invasion and acclimatization of Azov-Black Sea species which appeared to be much more competitive than the Caspian Sea autochthones. The present-day areas of Caspian endemics are smaller than potential areas of their distribution. Anthropogenic

transformation of natural ecosystems of the Caspian Sea region destroys their uniqueness, thus contributing to the global loss of biodiversity.

- Field investigations to identify the evolution of the natural environment during the Holocene have been made in the Don delta and in the Rostov region (supervisor R. Kurbanov). The borehole to a depth of 20 m penetrated the Holocene sediments of the Delta. The core is currently being studied by a complex of methods.
- Field studies were conducted in the Kuban delta (head V. Dikarev) in order to study the geomorphologic situation, obtain information about the evolution of the delta's natural systems in the period from the Late Pleistocene to modern times in terms of different scales of climate change. Field studies covered the deltaic region of Kuban in the Azov and Black seas. Here natural outcrops of recent deposits were studied. In the delta, there are archaeological sites of importance for paleogeographic reconstruction of the studied natural region, so the expedition team carried out geoarcheological observations (V. Dikarev and A. Porotov). In different parts of the modern Kuban delta (near the villages of Achuevo and Tikhovsky), two boreholes were drilled to a depth of 20 m each. Based on the complex of methods of the core study, paleogeographic reconstructions were performed.
- An important feature of work in 2016-2017 was the active participation of students and young scientists along with the professionals, who made a significant contribution to knowledge of the environment of the region. The youth involvement in the implementation of plans was at all stages of work—from field research and collecting field materials for analytical processing, discussion of results, and participation in writing of papers and preparation of presentations. It should be noted that the use of materials of expeditions by students in their qualification works.
- In Turkmenistan, Cheleken geological sections have been studied and samples from the Bakinian, Urundzhikian, Khazarian, and Khvalynian strata were collected.

Black Sea

- On the Kerch Strait coast, Holocene geological sequences were investigated.
- On the Kerch Peninsula, the outcrop at Eltigen (Late Pleisticene) was studied and dating of sediments by OSL was performed.
- The northwestern part of the Black Sea shelf adjacent to the Romanian part of the Danube delta was investigated on board the Romanian research vessel “Mare Nigrum” focusing on the investigation of how the Danube River discharge influences environmental conditions and benthic ecosystems on the Black Sea shelf using foraminifera to delineate affected areas (supervisor V. Yanko-Hombach).
- This study examined the relationship between the distribution of meiobenthos and concentrations of hydrocarbon gases, primarily methane, in the sediments of the northwestern part of the Black Sea. Based on the dual analysis of abiotic characteristics (physical and chemical parameters of the water column, gasmetrical, geochemical, lithological, mineralogical properties of the sediment) and biotic ones (quantitative and taxonomic composition of foraminifers, nematodes, and ostracods), the possibility was explored of using meiobenthos as an indicator of gaseous hydrocarbons stored under the seabed (supervisor V. Yanko-Hombach).
- In Iznik Lake (Turkey), Middle Pleistocene geological sequences were studied.

- In Moldova, Crimea, the Taman peninsula, Eastern Thrace, the Bosporus coast and Aşaği Pinar, and the Danube delta, particular attention was paid to geoarchaeological evidence

An important feature of this work is the active participation of students and young scientists along with the professionals; they made a significant contribution to the quest for knowledge of the regional environment. This youth involvement in the implementation of plans was at all stages of work: field research and collecting field materials for analytical processing, discussion of results, participation in the writing of papers, preparation of presentations, and use of materials of expeditions for their BSc and MSc diplomas. The fieldwork projects permitted the collection of several hundred samples that were treated in different laboratories by various techniques. In particular, the first optical luminescence dates of strata in geological sections were obtained.

5. IGCP 610 special sessions at large 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 of 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)

2016: Symposium “From the Caspian to the Mediterranean: Environmental change and human response during the Quaternary: IGCP610” at the 35th International Geological Congress (Cape Town, South Africa, August 2016)

2016: Special session "SSP4.5 From the Caspian to Mediterranean: Environmental Change and Human Response during the Quaternary (IGCP 610)" at the European Geosciences Union General Assembly (Vienna, Austria, April 2016)

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

2014: Peer-Reviewed Conference Proceedings of IGCP 610 Second Plenary Conference

2014: Field Trip Guide of IGCP 610 Second Plenary Conference

2015: Special Volume of the journal *Quaternary International* devoted to IGCP 610 studies

2015: Peer-Reviewed Conference Proceedings of IGCP 610 Third Plenary Conference

2015: Field Trip Guide of IGCP 610 Third Plenary Conference

2016: Peer-Reviewed Conference Proceedings of IGCP 610 Fourth Plenary Conference.

2016: Field Trip Guide of IGCP 610 Fourth 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"
- Uncovering the Mediterranean salt giant (MEDSALT) COST Action CA15103
- 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 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 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 the 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 the delta front to the outer shelf on soft and hard-shelled meiobenthos (nematodes, polychaetes, foraminifera, ostracoda, etc.) and mollusksDeveloping 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

- Development 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 to 1310 in 2015, and 1350 in 2016 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

The Project has 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.

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

It has 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.

It has 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; it has also 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
- To publish the paper summarizing IGCP 610 activities in *Quaternary Perspective*

References

Aliyeva, E., and Kengerli, T., 2014. *Field Trip Guide of IGCP 610 Second Plenary Conference and Field Trip "From the Caspian to Mediterranean: Environmental Change and Human Response during the Quaternary" 12-20 October 2014, Baku, Azerbaijan.* Nafta-Press, Baku, 186 p. ISSN 2218-9165.

Gamkrelidze, I., Okrostsvaridze, A., and Gagnidze, N., 2016. *Field Trip Guide of the IGCP 610 First Plenary Conference and Field of IGCP 610 Project "From the Caspian to Mediterranean: Environmental Change and Human Response during the Quaternary" 2-9 October 2016 , Tbilisi, Georgia.* Published by the Georgian National Academy of Sciences, 19 p. ISSN 978-9941-0-9178-0

Gilbert, A., and Yanko-Hombach, V. (Eds.), 2013. *Proceedings of UNESCO - IUGS – IGCP 610 "From the Caspian to Mediterranean: Environmental Change and Human Response during the Quaternary" First Plenary Conference and Field Trip, Ilia State University, October 12-19, 2013, Tbilisi, Georgia*. LTD "Sachino", Tbilisi, 182 p. ISBN 978-9941-0-5991-9.

Gilbert, A., Yanko-Hombach, V. (Eds.), 2014. *Proceedings of UNESCO - IUGS – IGCP 610 "From the Caspian to Mediterranean: Environmental Change and Human Response during the Quaternary"* Second Plenary Meeting and Field Trip, 12-20 October 2014, Baku, Azerbaijan. International Scientific Journal "Stratigraphy and Sedimentology of Oil-Gas Basins" No.1. Nafta-Press, Baku, 186 p. ISSN 2218-9165.

Gilbert, A., Yanko-Hombach, V., and Yanina, T. (Eds.), 2015. *Proceedings of UNESCO - IUGS - IGCP 610 "From the Caspian to Mediterranean: Environmental Change and Human Response during the Quaternary"* Third Plenary Meeting and Field Trip, September 22-30, 2015, Astrakhan, Russia. Publishing House "Krasnogorskiy" of the Moscow county, 220 p. ISBN 978-5-906731-24-1.

Gilbert, A., and Yanko-Hombach, V. (Eds.), 2016. *Proceedings of UNESCO - IUGS - IGCP 610 "From the Caspian to Mediterranean: Environmental Change and Human Response during the Quaternary" Fourth Plenary Meeting and Field Trip, October 2-9, 2016, Tbilisi, Georgia.* Published by the Georgian National Academy of Sciences, 218 p. ISSN 978-9941-0-9178-0

Okrostsvaridze, A., Janelidze, Z., and Tushabramishvili, N., 2013. *Field Trip Guide of the IGCP 610 First Plenary Conference and Field of IGCP 610 Project "From the*

Caspian to Mediterranean: Environmental Change and Human Response during the Quaternary" 12-19 October 2013, Tbilisi, Georgia. Tbilisi: LTD "Sachino", 16 p. ISBN – 978-9941-0-6000-7.

Yanina, T., Svitoch, A., Kurbanov, R., Vasiliev, D., and Pigarev, E., 2015. *Field Trip Guide of the IGCP 610 Thirdst Plenary Conference and Field of IGCP 610 Project "From the Caspian to Mediterranean: Environmental Change and Human Response during the Quaternary" 22-30 September 2015, Astrakhan, Russia.* Publishing House "Krasnogorsckiy" of the Moscow county, 44 p. ISBN – 978-9941-0-6000-7.

Yanko-Hombach, V. 2016. Editorial to IGCP 610 Special Volume of *Quaternary International* 409: 1-7.

PART II. PROCEEDINGS

BIONOMY OF THE SOUTH CASPIAN BASIN IN THE PLIOCENE-PLEISTOCENE

Ali-Zadeh, A.,[1] *and Aliyeva, E.* [2]

[1, 2] Geology and Geophysics Institute of the Azerbaijan National Academy of Sciences,
H. Javid Avenue 119, Baku, AZ1143, Azerbaijan
[1,2] e_aliyeva@gia.ab.az

Keywords: ostracods, mollusk shell material, oxygen, carbon isotopes, Sr/Ba and Ca/Mg ratios

Introduction

This article addresses questions related to changes in the bionomic conditions of the South Caspian during the Pliocene-Pleistocene. We have examined both microelemental and isotopic compositions of oxygen and hydrogen within the shelly material of Caspian Plio-Pleistocene mollusks and ostracods. Conclusions about the stages of brackish-saline and cold-warm basin development were reached on the basis of the paleontological, biogeochemical, and isotopic data from the shell material of the mollusks and ostracods.

The Bionomic Conditions in the Early Pliocene basin

Carbon isotope values in the shelly material of the Productive Series ostracods—as per the Cyprideis littoralis (Brady) study findings—are within the 0.5-7.5‰ range, while Sr/Ca varies from 1 to 8 (Aliyeva et al., 2008). This finding testifies to considerable salinity variation in the Lower Pliocene Caspian Sea.

Curves for δC13 and Sr/Ca indicate a clear separation into three parts (Fig. 1).

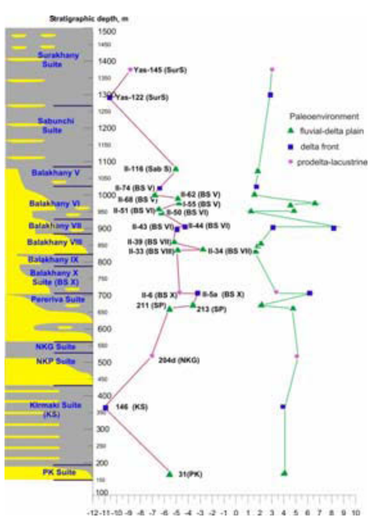


Figure 1. Sr/Ca (green) and the $\delta^{13}C$ (pinkish) values in the Lower Pliocene ostracod shells.

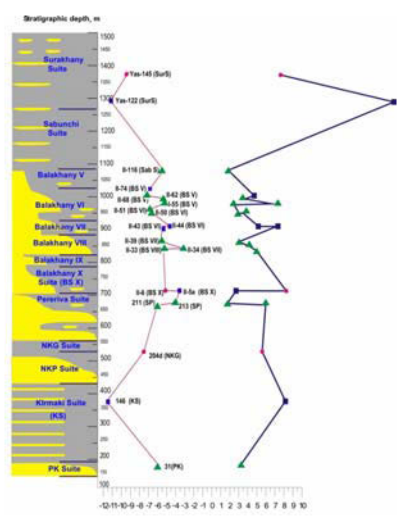


Figure 2. Ca/Mg (blue) and $\delta^{18}O$ (pinkish) values in the Lower Pliocene ostracod.

The lower part corresponds to the lower suites of the PS (from the PreKirmaki to the PostKirmaki Sand) and demonstrates biogeochemical indications of the highest salinity in the basin throughout the Lower Pliocene. The mid portion of the curves—encompassing the PostKirmaki Clay, the Fasila and the Balakhany suites—is characterized by abrupt leaps in biogeochemical parameters, which points to frequent changes in the salinity of the basin. The sedimentological data confirm the frequent and abrupt changes in the depositional environment in the middle of the Lower Pliocene.

The upper portions of the Sr/Ca and $\delta^{13}C$ curves—that correspond to the Surakhany Suite—display a substantial reduction in the basin salinity of the Productive Series at the end of the Lower Pliocene (Fig. 2). The temperature regime of the Lower Pliocene Sea and its salinity were subject to dramatic variations judging from the biogeochemical data (Fig. 2).

Oxygen isotope value variations reach 10‰—from 2‰ to -12‰—while the Ca/Mg values change from 2 to 20 (Aliyeva et al., 2008). From our point of view, the Caspian basin had the warmest temperature regime at the early and late stages of the Lower Pliocene. Evidently, we can speak about a cooling in the Caspian area in the middle part of the Lower Pliocene that encompasses the interval from the Facial Suite to the Sabunchi Suite, inclusively. The end of the Lower Pliocene was marked by an evident warming.

The Bionomy of the Akchagylian Sea (Late Pliocene)

The poor organic world of the Early Pliocene Caspian basin was replaced by the rich complex of the Akchagylian Sea as a result of penetration by external saline waters that brought with them fauna from other basins. Possibly, the salinity of the Akchagylian Sea was high at the beginning of Akchagylian time; equally possible, it was declining gradually (Ali-Zadeh, 1954). The euryhaline cold-water and warm-water forms, such as the *Cardiidae*, the *Mactridae*, and the *Potamides*, appeared in the basin at the beginning of Akchagylian time. From the Black Sea fauna, only three species were able to adapt to the Caspian Akchagylian Basin, and of those three, only *Cardium edule* inhabits the present-day Caspian. This shows that the salinity of the Akchagylian Sea was higher than that of the present-day Caspian Sea but lower than that of the Black Sea.

The basin had been strongly desalinated and especially so in its peripheral parts by the end of Akchagylian time. That resulted in the growth there of freshwater species (*Dreissena*, *Unio*, and *Paludina*). There were also strongly saline areas in the territory of the present-day Trans-Caspian, where the organic world was very poor.

The study findings provide evidence that the central part of the Akchagylian Sea experienced predominant reducing conditions that accounted for the formation of a stressed faunal complex.

According to K. Ali-Zadeh (1954), the depth of the Akchagylian Sea reached 400 m. Evidently, the Akchagylian Basin was deeper than that of the Productive Series.

As regards the temperatures of the Akchagylian Sea, we have evidence relating to the cooling mentioned above. This is proven by biogeochemical data. The Mg content of mollusk shells indicates a sharp temperature drop in the shallow-water area of the Akchagylian Sea in comparison with the Early Pliocene basin, namely, down to 13-14° C (Sultanov and Isayev, 1982).

The Bionomy of the Absheronian Sea (Early Pleistocene)

At the end of Akchagylian time and the beginning of Absheronian time, most of the stenohaline Akchagylian fauna became extinct, and only the euryhaline forms remained; they were eventually transformed into the typical Absheronian fauna (Andrusov, 1923). The shallowing and decrease in salinity of the basin accompanied the formation of a poor and stressed complex in Early Absheronian time. The transgression in the mid-Absheronian, higher salinity, and deepening of the basin created favorable conditions for extensive speciation and a flourishing of the fauna in the Middle Absheronian (Sultanov, 1964).

However, the continuing uplift of the mountain systems that surrounded the depressions made the basin smaller again in the Late Absheronian. A high sediment supply led to a further shallowing of the Absheronian Sea, and the increased river discharge from the emerging network of major alluvial arteries—such as the Kura, the Aras, the Samur, and other small rivers—caused the extinction of relatively saline-water species and genera living in the Middle Absheronian Sea. Those processes also caused the extinction of the endemic Absheronian fauna and the emergence of the specific Pleistocene mollusk fauna at the boundary with the Middle Pleistocene.

The frequent changes in bionomic conditions within the Absheronian Sea are also confirmed by biogeochemical studies of shells of the ostracod *Trachyleberis pseudoconvexa* from the mid-Absheronian sediments of the Shikhovo outcrop on the Absheron Peninsula (Amirov, 2007; Aliyeva and Amirov, 2008) (Fig. 3); these studies point to the strong variability of the salinity regime and temperatures of the Absheronian Sea. Sr/Ba ratio values vary widely from 5 to 26 with the average one equalling 15.

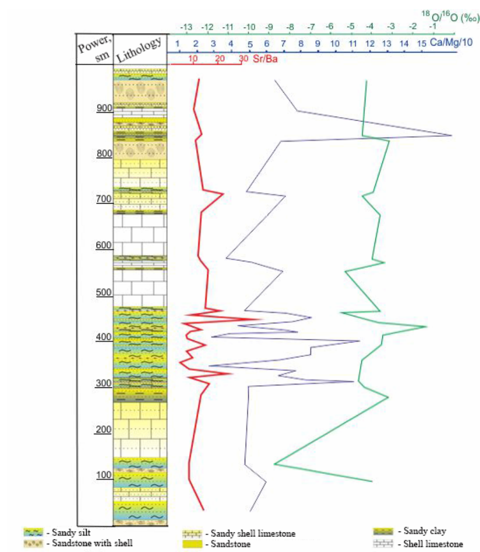


Figure 3. Ca/Mg (blue), $\delta^{18}O$ (green), and Sr/Ba (red) values in *Trachyleberis pseudoconvexa* shell material along the Absheronian sedimentary succession (Amirov, 2007; Aliyeva and Amirov, 2008).

With the exception of the peak value of -8.7‰, the oxygen isotope ratio values vary from 5.5‰ to 1.5‰ in the ostracod shell material. Given the fact that change in the O^{18}/O^{16} ratio in shell carbonate for 1‰ means change in the water temperature for 3° C, one can assume that the difference between the lowest and the highest temperatures was approximately 20°; these changes were most likely seasonal variations.

A tendency toward insignificant lowering of the O^{18}/O^{16} ratio upward within the section testifies to a slight warming during Absheronian time that is also confirmed by the data on Ca/Mg ratios.

The Bionomy of the Middle-Late Pleistocene-Holocene Basins

Based on the Sr/Ba variations in the Pleistocene-Holocene Caspian *Didacna* shell material, we were able to conclude that the salinity of the PaleoCaspian decreased considerably during Bakunian time in comparison with Absheronian time, and that the salt balance of the

Absheronian Sea was substantially higher than that of the Caspian during the Holocene (Fig. 4).

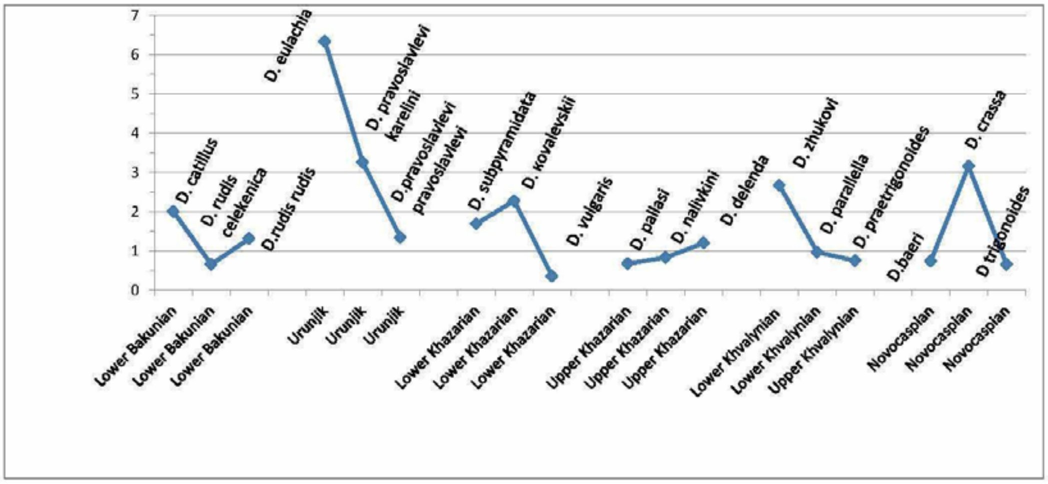


Figure 4. Sr/Ba ratio values in the shells of Pleistocene-Holocene *Didacna* of Azerbaijan.

Regarding the temperature variations in the shallow-water regions of the Lower, Middle, and Upper Pleistocene basins of the Caspian, we note that, judging from the oxygen isotopic composition data on the shells of Bakunian *Trachyleberis pseudoconvexa*, the median annual temperatures of the Bakunian Sea exceeded those of the Absheronian Sea. For instance, the median oxygen isotope ratio is -2‰ for the Absheronian forms while it is -4.7‰ for the Bakunian forms (Amirov, 2007; Aliyeva and Amirov, 2008).

While the highest water temperatures should have been approximately equal in both seas ($\delta^{18}O$ equals 5.5‰), the Bakunian Sea had higher temperatures in the cold seasons compared with the Absheronian Sea. The highest content of the heavy oxygen isotope equals -4.1‰ and +1.5‰, respectively.

Conclusions

The findings from the study of bionomic conditions in the Pliocene-Pleistocene basins reveal multiple variations in the temperature regime of the PaleoCaspian that were accompanied by substantial biocoenosis composition alterations.

The waters of the Akchagylian Sea had the highest salinity, while the sea at the end of the Productive Series time (the Lower Pliocene) had the lowest salinity. There is a tendency for salinity to decrease in the Akchagylian Basin towards the Pleistocene. During the Pleistocene, with the exception of the Urunjik Sea, the salinity of the Caspian Sea changed within a narrow range and was close to that of the present-day Caspian Sea.

References

Aliyeva, E., Huseynov, D., Babazadeh, A., Kaufman, A.J., and Nummedal, D., 2008. Microfossils records of climatic and depositional environment changes in Lower Pliocene Caspian succession. *33rd International Geological Congress, 6-14 August, Oslo.* Abstract Book.

Aliyeva, E., and Amirov, E., 2008. Climatically forced Caspian Sea level changes as it recorded in Pleistocene succession. Microfossils records of climatic and depositional environment changes in Lower Pliocene Caspian succession. *33rd International Geological Congress, 6-14 August, Oslo*. Abstract Book.

Ali-Zadeh, K.A., 1954. *Akchagylskiy yarus Azerbaidzhana* [*The Akchagylian Stage of Azerbaijan*]. *Izd-vo AN Azerbaidzhanskoy SSR*. (In Russian)

Amirov, E., 2007. *Sekvens – stratigrafiya i populyasii ostrakod v chetvertichnom periode zapadnogo borta Yuzhno-Kaspiyskoy vpadini* [*Sekvens Stratigraphy and Ostracod Populations in the Quaternary Period of the South Caspian Basin's Western Flank*]. Avtoreferat kandidatskoy dissertasii, Baku, p. 35.

Andrusov, N.I., 1923. *Apsheronskiy yarus* [*The Apsheronian Stage*]. *Trudy Geologicheskago komiteta NS* 110. (In Russian)

Sultanov, K.M., 1964. *Apsheronskiy yarus Azerbaidzhana* [*The Apsheronian Stage of Azerbaijan*]. Azerbaidzhanskoe Gosudarstvennoe Izd-vo, Baku. (In Russian)

Sultanov, K.M., and Isayev, S.A., 1982. *Paleobiogeokhimiya molliuskov Azerbaidzhana* [*Paleobiogeochemistry of the Mollusks of Azerbaijan*]. Izd-vo "Elm," Baku. (In Russian)

MAGNETOMETRIC AND ELECTROMETRIC INVESTIGATIONS IN THE SALSOVIA SUBMERGED ARCHAEOLOGICAL SITE

Anghel, S. [1], and Paraschivoiu, M. [2]

GeoEcoMar, Dimitrie Onciul 21-25, 024053, Bucharest, Romania
[1] soanghel@geoecomar.ro
[2] paraschivoiumarius@geoecomar.ro

Keywords: magnetometer, electrometer, magnetometry, resistivity

Introduction

The fortress at Salsovia functioned as a military camp in the first half of the III century A.D. (Antonini Itinerary and Tabula Peutingeriana), and later it was an annex to the Romanian Military Legions. To the south of the fortress, on a linear plateau, there was a civil settlement deployed from three parts of natural valleys with steep banks in the Roman era (Fig. 1).

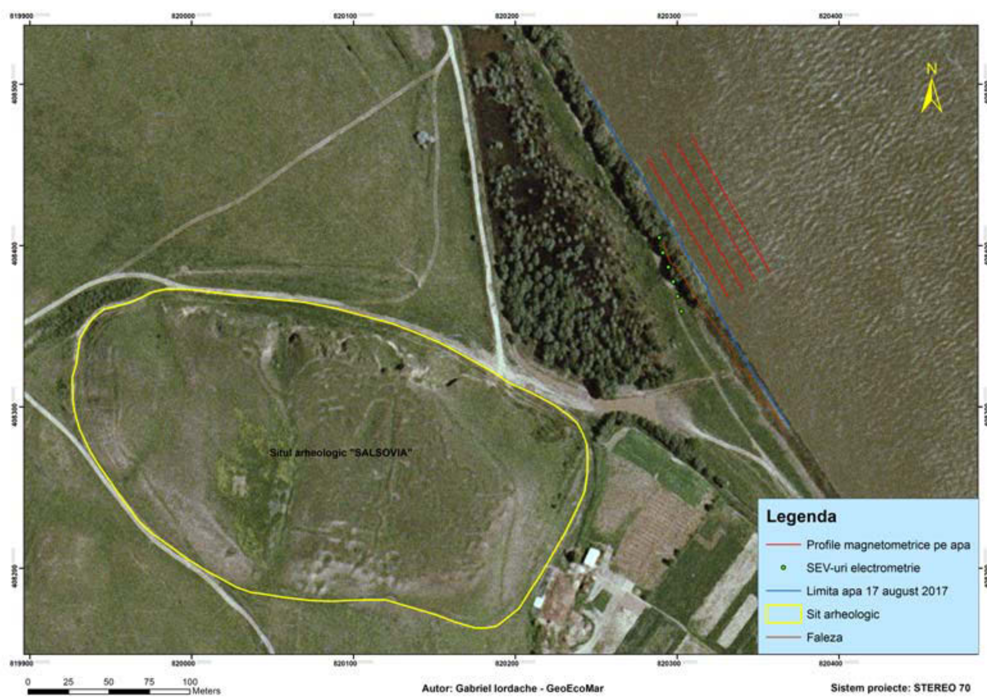


Figure 1. Topographic map for the Salsovia area, Romania, showing the remains of the ancient city.

The castrum was probably destroyed in the time of Valens. Occupation resumed near the fortress in the early feudal period (after the probable destruction of the castrum in the time of Valens) as a rural settlement was developed based on the testimony of recovered coins dating to the 19th to 11th centuries (Rusu, 1991).

Description of the analyzed magnetic field data

The magnetic data was acquired on the water (Danube River) within the submerged zone using marine equipment designed for that purpose (G822 device with cesium) with a gradient array (Fig. 2).

Figure 2. Photos showing the device used for data acquisition and also the submerged area that was investigated.

The area of investigation was 100 by 50 meters, and it was located in the NW part of the site, having a grid density of 10 by 10 meters.

Analysis of the electrometric data

The resistivity measurements were done with an AGI superSting resistivity meter. We planned to acquire two profile, but due to bad weather conditions, only one were done (Georgescu and Gavrilă, 1989). The profiles had a length of 50 meters and a depth of 6 m, and they were obtained using the vertical electrical profiling (VSP) method with a Schlumberger array (Radulescu et al., 2006). The vsp points were located 10 m apart, the MN distance was 2 meters, and the AB distance started at 2 meters, then it was enlarged by 4 meters each time until it reached 12 m during the course of the measurements (Fig. 3).

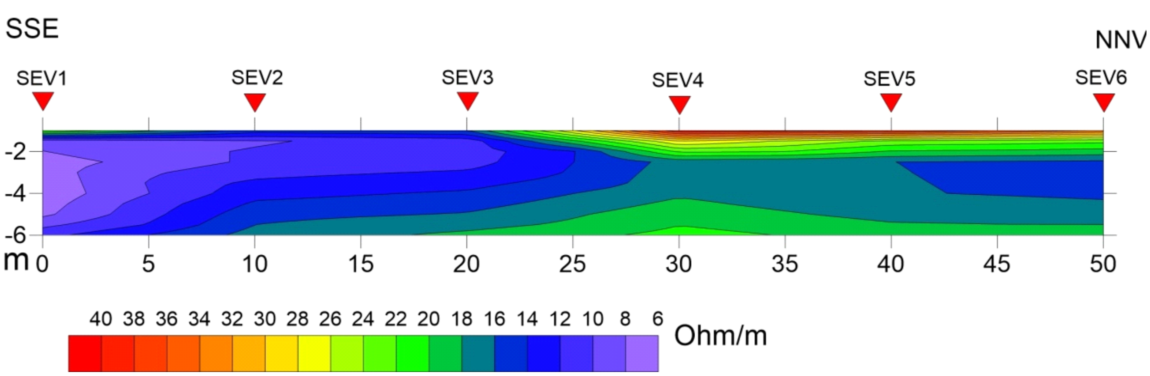


Figure 3. Apparent resistivity section.

Analysis of the magnetic data

The resultant magnetic gradient map (obtained using Oasis montaj) can be seen in Fig. 4

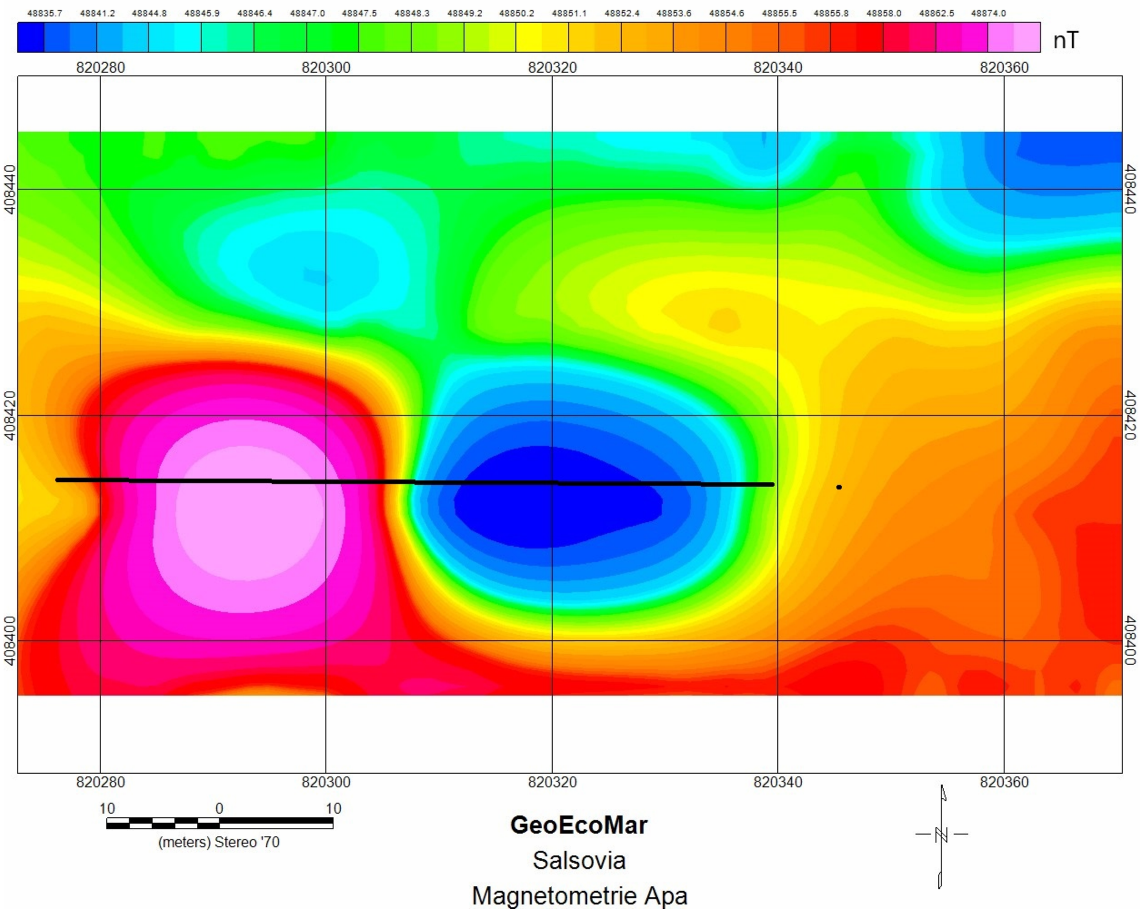


Figure 4. Magnetic gradient anomaly map; black line shows the area were the modeling using PotentQ was done

The grid values are in meters and the anomaly values are displayed in the color legend bar in nT. We observe the first positive anomaly near the negative anomaly that is located in the southern part of the area. This anomaly correlates well with the existing city remains because it is a continuation of Fig. 1 and indicates a continuation of the wall. Modeling using PotentQ (Fig. 5) has also shown a buried structure that can be approximated to the remains of a wall (Buselli et al., 1990).

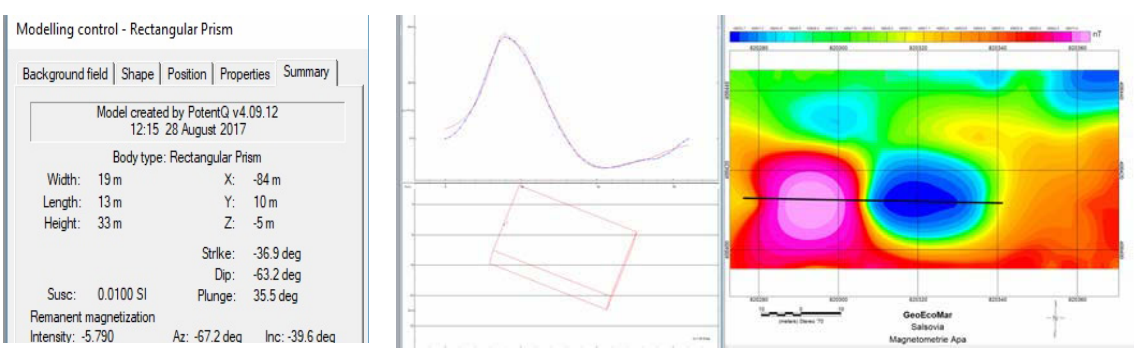


Figure 5. The model magnetic anomaly and the resultant buried structure.

Conclusions

Magnetic measurements were carried out within a submerged area of the Salsovia archaeological site. After the data analysis, we have established the most probable orientation of a buried wall and created an hypothesis that requires more investigation to explore its validity. We also established the depth of the site and the fact that the VSP investigations need to be redone with a shallower depth as target (Project nr.16450502/2017).

References

Buselli, G., Barber, C., Davis, G.B., and Salama, R.B., 1990. Detection of groundwater contamination near waste disposal sites with transient electromagnetic and electrical methods. *Geotechnical and Environmental Geophysics* 2: 27-40.

Georgescu, P., and Gavrilă, I., 1989. Influence of electrical prospecting arrangement on apparent resistivity anomalies. *Revue Roumaine de Géologie, Géophysique, et de Géographie, série de Géophysique* 33, 1.

Rădulescu, V., Rădulescu, F., and Stan, I., 2006. Geoelectrical measurements applied to the assessment of groundwater quality. *Geo-Eco-Marina* 12: 107-110.

Rusu, A.A., 1991. Romanian churches from Hateg district up to a 1700. *Acta Terrae* 1, 129-142.

INFORMATION ON THE CIRCUMSTANCES OF PALEOGEOGRAPHIC FORMATION OF THE PRODUCTIVE SERIES BASIN OF EASTERN AZERBAIJAN AND ON THE FIRST PLIOCENE SEA LEVEL FLUCTUATION

Amrahov, R.R.[1], *Amrahova, Kh.R.* [2], *and Amrahova, S.A.* [3]

[1,2] ANAS, Institute of Geology and Geophysics, AZ1143 Baku, Azerbaijan
[1,2] geoeducation_aze@yahoo.com
[3] Azerbaijan State Oil and Industrial University, Baku, Azerbaijan
[3] sakina_rasad@yahoo.com

Keywords: South Caspian Basin, Balakhany suite, transgression, regression, delta

This paper proposes to study the paleogeographic formation conditions of the Early Pliocene Productive Series basin based on the example of the Balakhani suite, which gradually accumulated during a pivotal period of the region's geological evolution. It was at that time that the Early Pliocene basin underwent a long-running transgression process and, as a result, was transformed into a large intracontinental reservoir. During that transgression event, the level of the Productive Series basin increased about 600 m. According to the latest estimations, the Balakhani transgression phase of the basin's general evolution comprised certain micro- and meso-periods (Khalifa-zade and Talibli, 2014).

Recently, E.H. Aliyeva (2005) studied different sections of the region's Productive Series strata, especially in the Yasamal and Girmaki valleys, as well as the Bahar and Araz deposits within the Azerbaijani sector of the Caspian Sea area. Implemented through methods of sequence stratigraphy, these studies yielded a number of conclusions regarding (1) facies and cyclic composition of sections and (2) identifiable microcycles and highly sensitive ultramicrocycles within the Productive Series deposits.

It deserves mentioning that according to E.H. Aliyeva, the emergence of ultramicrocycles within the Productive Series deposits was connected with changing climate. When conducting sequence stratigraphic analysis of the Bahar deposit's Fasila (depositional break) suite and horizons VII, VIII, IX and X, Aliyeva (2005) identified a range of alluvial, delta, underground delta, and lake deposits and their corresponding microcycles. She was the first scientist to demonstrate evidence of facies that could be used to correlate high and low eustasy within the Lower Pliocene sea.

Region-wide level fluctuations of the Productive Series basin were determined through lithostratigraphic, facies-genetic, and cyclic analyses of the deposits. The research results prove that the structure of the Productive Series deposits is rather transgressive and that the lower lithostratons wedged out with west- and eastward movement of the basin. The research has also identified regional cycles within the composition of the strata (Khalifa-zade et al., 2006).

The Lower Pliocene sea of the Southern Caspian depression used to represent a graben-like deep sea located within an arid climatic zone (Khalifa-zade et al., 2007). In such basins, rapid high-altitude change in sea level largely depends on volumes of incoming continental runoff, tectonic movements, and finally solar exposure. From this perspective, the Lower Pliocene basin belongs to this kind of sea. As distinguished from oceanic basins, its level had changed considerably even within a short period of time as influenced by a number of the above-cited factors. These dynamics are clearly evidenced by up to a 3 m rise in the Caspian Sea level during the period of 1929-1995 (Khalifa-zade et al., 2006).

Continuous transgression of the Productive Series basin resulted in its east- and westward extension through 1.9·106 years of basin evolution. On the other hand, the described transgression used to bear a stepped and phased character and developed along an ascending line. The magnitude of the resulting eustasy largely depends on the dimensions and hypsometric characteristics of the transgressed territory. This research resulted in the development of a scheme to cover the 1.9·106 years of PS basin level fluctuation within the boundaries of the South Caspian depression (Khalifa-zade et al., 2006). The final development stage of the upper Early Pliocene sea was characterized by a threefold increase in its total water capacity, which resulted in the formation of a normal sea as soon as the Early Pliocene (Akchagylian stage). It should be mentioned that this enormous transgression process resulted in the sinking of the Lower Kur depression, Shamakhi-Gobustan zone, and Caspian lowland. At the same time, it cannot be excluded that there occurred a number of short-term regression events within the long-running record of the Balakhani transgression. This assumption is confirmed by the architecture of oil-gas bearing horizons X, IX, VIII, VII, VI, and V. All this information was obtained through a facies-genetic analysis of the Productive Series sections, be it a revealed section or one exposed by deep wells.

Starting from the Balakhani suite's horizon VI, the area covered by the Lower Pliocene sea increased (Aliyeva, 2005). As demonstrated by the results of the suite's facies-genetic analysis, the Balakhani period was marked by up to a 600 km widening of the upper Early Pliocene sea, which at that time already consisted of fluvial, delta, underground delta, and lake zones that are typical for the structure of a normal sea (Aliyeva, 2005; Khalifa-zade and Mursalov, 2008; Khalifa-zade and Talibli, 2008; Khalifa-zade and Rustamova, 2013). Besides acquiring new paleogeographic and paleomorphological data on the evolution of the Early Pliocene in Eastern Azerbaijan, the above research activities are significant for having detected the distribution regularities of natural reservoirs, collectors, and shielding formations within the Productive Series sections.

References

Aliyeva, E.H., 2005. Reservoirs of the Lower Pliocene Productive Series at the western flank of the South Caspian Basin. *Lithology and Mineral Resources* 40(3): 67–278.

Khalifa-zade, Ch.M., and Mursalov, V.A., 2008. Paleogeographic model of the Balakhani Suite on the western flange of the South Caspian Region. *Geology and Geophysics, Baku* 10:6-10. (In Russian)

Khalifa-zade, Ch.M., and Rustamova, R.E., 2013. New data on the paleogeographic model of productive series basin on the base of dissemination of turbidity sandy system within South Caspian depression. *Azerbaijan National Academy of Sciences Proceedings, Earth Sciences* 1.

Khalifa-zade, Ch.M., and Talibli, A.R., 2008. New data on the saline origin of the Lower Pliocene Basin in the Lower Kur Depression. *Mining-Geology Magazine, Kazakhstan* 3-4. (In Russian)

Khalifa-zade, Ch.M., and Talibli, A.R. 2014. New data on paleogeographic formation environment of the western flange of the southern Caspian. *News of Azerbaijan Geophysics*.3-4: 4-9. (In Azerbaijani)

Khalifa-zade, Ch.M., Talibli, A.R., and Mursalov, V.A., 2006. Early Pliocene molasse formation of Azerbaijan and its facies-cyclic composition. *News of Baku University, Geological Series* 3. (In Russian)

Khalifa-zade, Ch.M., Mursalov, V.A., and Talibli, A.R. 2007. Some actual problems related to level fluctuations of the first Pliocene Sea in Eastern Azerbaijan. *News of Azerbaijan Geophysics* 1. (In Azerbaijani)

THE ROLE OF COASTAL GEOMORPHOLOGY IN INTERPRETING THE HISTORY OF THE NORTHERN CASPIAN PLAIN IN THE LATE PLEISTOCENE

Badyukova, E.N.

Faculty of Geography, Lomonosov Moscow State University, 1 Leninskie Gory,
Moscow, Russia, 119991
badyukova@yandex.ru

Keywords: embedded or blind deltas, chocolate clays, lagoons, nearshore, palaeogeography

The relief of the Northern Caspian plain is very varied. The major rivers of the Volga and Ural interfluve are the Bolshoy Uzen, Maly Uzen, Kushum, and many smaller ones, the mouths of which are located in the Caspian Lowland. During floods, they overflow into vast depressions and form large lakes (Fig. 1).

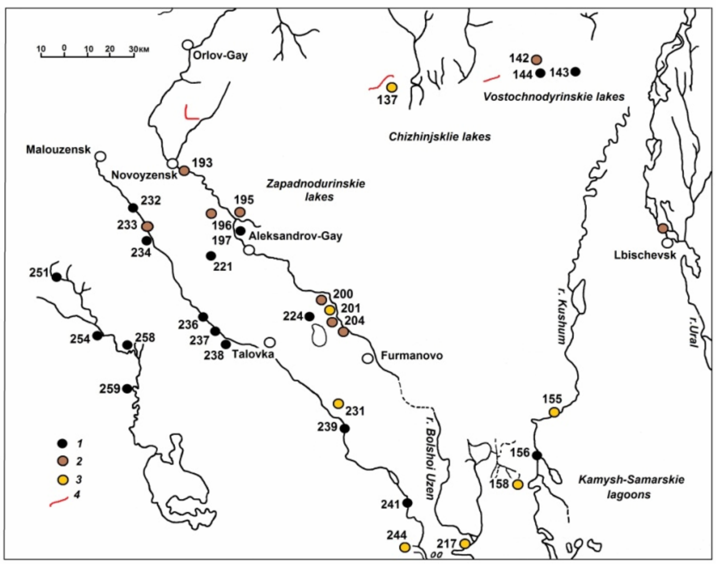


Figure 1. Region of investigation within the Volga-Ural interfluve. 1 – Early Khvalynian shells found near animal burrows. In outcrops: 2 – chocolate clays; 3 – marine sands. 4 – Early Khvalynian coastline (according to Zhukov, 1945, with additions).

The lakes are connected to each other and extend for tens of kilometers along the borders of the array of Volga-Ural Sands, as if they were spreading along the line of natural obstacles. The flat lake bottoms are often characterized by erosive relief: narrow depressions that look like river channels and long shafts and hillocks with heights of 2-3 m. In addition to these forms of relief, the so-called embedded or blind deltas are widespread on this plain. They are confined to the mouths of inland rivers, which end blindly near the Volga-Ural Sands. In these deltas, channels are deeply incised into the marine plain. From the surface, the plain is composed of loam, and below lie chocolate clays (CC) with sandy interbeds, which are revealed in many outcrops (Figs. 2, 3).

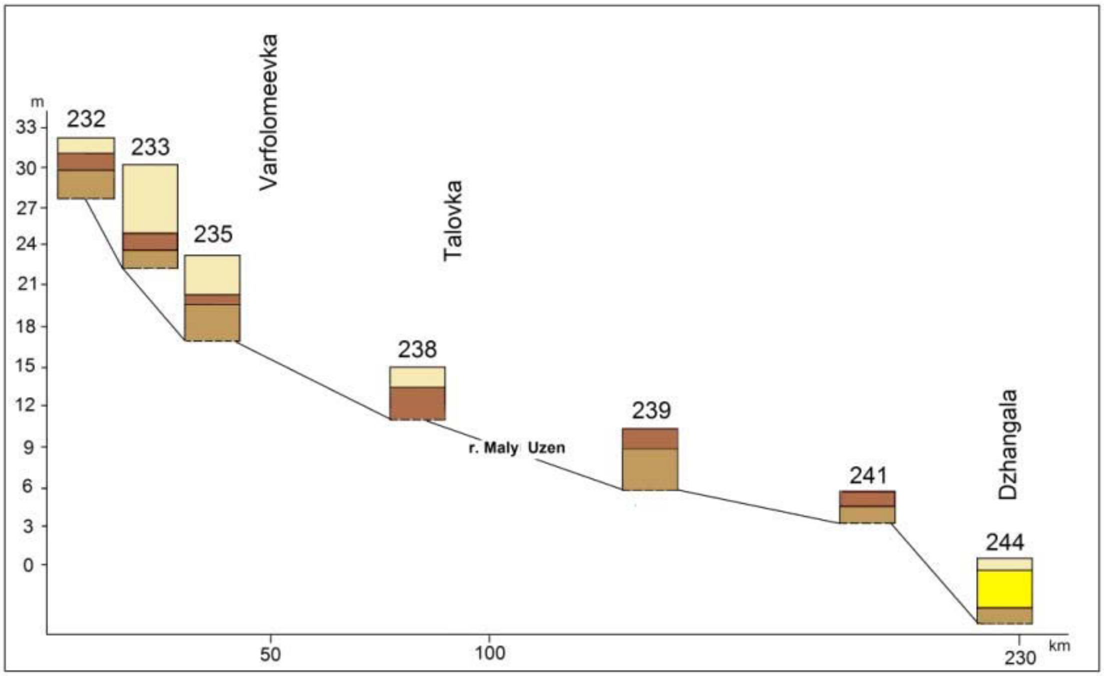


Figure 2. Outcrops along the Maly Uzen River

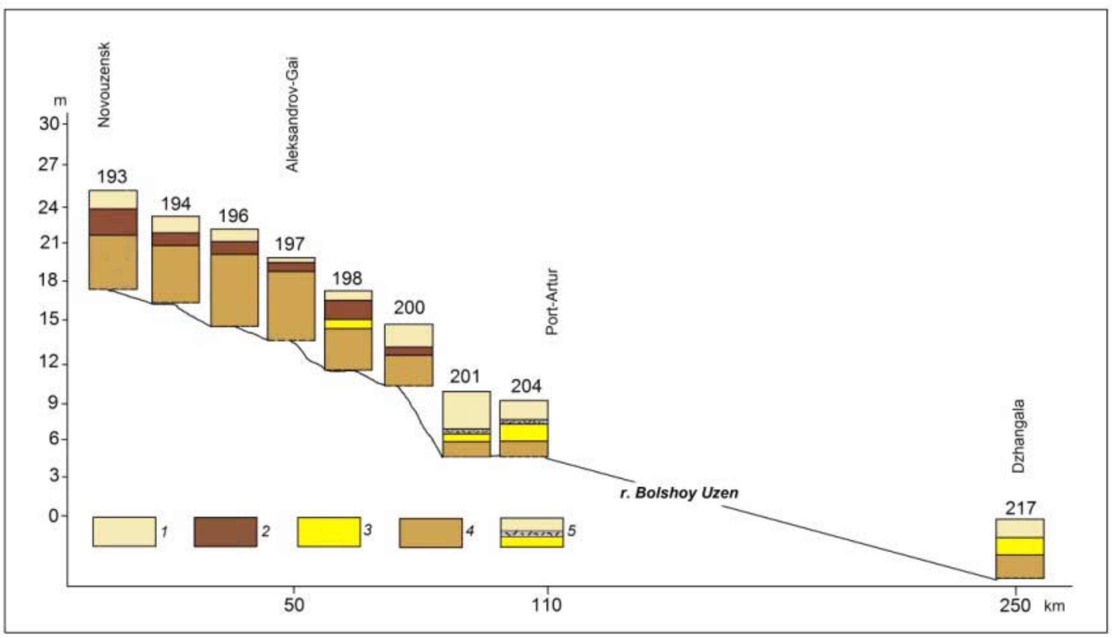


Figure 3. Outcrops along the Bolshoy Uzen River. Legend for Figs. 2 and 3: 1 – Q $_{3\text{-}4}$ (subareal sandy loam and loam, alluvium deposits); 2 – Q $_3$ m (marine Khvalynian deposits – chocolate clays, silty clay, loam); 3 – marine Khvalynian sand; 4 – Q $_2$ (subareal deposits of different genesis; so-called Atel); 5 – paleosols.

According to Zhukov (1945), Doskach (1956), and Foteeva et al. (1963), a tectonic structure is located here. However, this structure is not confirmed by geophysics, and the authors identify it only by geomorphological characteristics. They believe that during the Early Khvalynian regression, the structure blocked the path of rivers to the south; due to the low water level of the rivers, this barrier proved to be insurmountable. This led to the separation of the rivers from the sea and the formation of embedded or blind deltas.

However, analysis of the existing literature on the rivers of the Volga-Ural interfluve has shown that all rivers are snow-fed. They are shallow during the summer, and in the spring they have a short, rapid flood stage. Huge spills formed when the amplitude of the water level ranged from 2 to 12 m. Valleys are well developed (width 8-10 km), and in their lower reaches, the channels are embedded 10-15 m (Aref'eva, 1956). These data do not allow us to speak about the shallowness of the rivers and about the possibility of their departing from a regressing Caspian Sea.

The nature of the sediments making up the Northern Caspian Plain and its geomorphologic structure allow us to offer another version of the origin of such deltas. Directly beneath subaerial deposits in the outcrops lie CC (and their counterparts—sandy loam, loam), which in turn are also deposited upon subaerial sediments of a different genesis. In the scientific literature, the lower subaerial sediments below CC considered to have been formed during the deep Atel regression (-100 to -120 m). But then, if we understand the CC as deposits of lagoons (Badyukova, 2010), one must then explain the long meridional distribution of these sediments almost from the surface to a distance of more than 300 km. In some cases, in the outcrops along the rivers and in boreholes there is substitution of clays by marine sands, i.e. by sediments of coastal bars. It is unlikely that the sea was so shallow and without wave activity over such a stretch. In addition, throughout this distance, the nature of the Early Khvalynian deposits does not change, despite the varying depths of the sea. This is absolutely impossible, because with increasing sea depths there are regular and commensurate changes in granulometric composition within the deposits—from coarse-grained to more fine-grained.

In the Northern Caspian Plain, numerous oscillations of Caspian Sea level led to the formation of coastal plains and a series of lagoon-transgressive terraces (Badyukova, 2010). In this scenario, the distribution of CC over a great distance along the meridional direction is understandable. The paragenesis of the sediments is observed: lacustrine deposits lying almost from the surface, are replaced along the strike by the marine sand of coastal bars (Fig.4). So the Early Khvalynian deposits are the only deposits of the lagoon-barrier systems that were successively formed during the general background of the Caspian Sea regression.

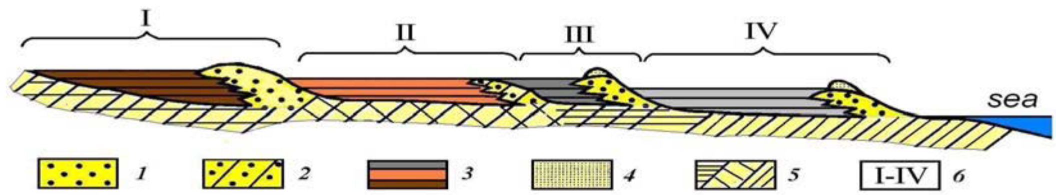


Figure 4. 1 –sediments of a barrier bar; 2 – buried bar; 3 – lagoon deposits (sand, silty sand, silty clay, chocolate clays); 4 – eolian deposits; 5 – underlying deposits of an early age and origin, including marine, alluvial-deltaic, continental; 6 – I-IV–series of lagoon-transgressive terraces

Perhaps a tectonic structure that, according to Doskach (1956), closed the river's path to the south is one of the bars that formerly were fringed lagoons. In some sections, one can observe the replacement of CC by sand (Fig. 2 - № 244, Fig. 3 - № 204). Sand deposits are most likely the deposits of the former bars, too. Currently, only numerous lakes remain of these former lagoons.

It should be noted that in all outcrops in the Northern Caspian Plain and Lower Volga, there are no deposits representing the Caspian Sea level rise after the Atel regression. Moreover, throughout the Volga-Ural interfluve, subaerial strata of varied genesis are preserved beneath thin Early Khvalynian marine deposits. But these subaerial sediments would have been inevitably eroded during the Early Khvalynian transgression, which is considered to have followed the deep Atel regression. The fact is that when sea level rises, a new profile of equilibrium for the underwater coastal slope is formed, and this condition always leads to its erosion (Leontiev, 1961). From all these data, there should be only one conclusion—there was no deep Atel regression and no Great Khvalynian transgression. This conclusion confirms the previous assumption. We wrote that this transgression was, in fact, a gradual regression after the large Khazarian transgression, and it was accompanied by positive oscillations of the Caspian Sea (Badyukova, 2015, 2016).

During the Late Khvalynian, when, as the author suggests, flow from the Caspian to the Black Sea resumed, the water from the lagoons in the form of wide shallow flows rushed from NE to SW and later into the Manych Strait. In the author's opinion, at this time connection of between the Caspian and Black Seas existed (Badyukova, 2011). Traces of this flow are seen in the many positive relief forms, in particular the Baery Knolls (Badyukova, 2017), and negative relief forms in the Northern Caspian Plain, which combines flow and non-flow features. These landforms are characteristic of the bottom of flows. When the lagoonal water level dropped, river channels were cut off, and as a result, embedded or blind deltas were formed.

Acknowledgments

This study was supported by the Russian Scientific Foundation (Project № 16-17-10103) and is a contribution to the IGCP 610 project "From the Caspian to Mediterranean: Environment change and human response during the Quaternary."

References

Aref'eva, V.A., 1956. Gidrologicheskaya kharakteristika stepnoj zony Volgo-Uralskogo mezhdurechya [Hydrographic characteristic of the steppe zone of the Volga-Ural interfluve]. *Trudy instituta geografii* 69: 93-126. (In Russian)

Badyukova, E.N., 2010. Some scientific problems in Volga Delta and adjacent areas: Genesis of Chocolate Clays and Baery Knolls, age of the Khvalyn trangressions. *Stratigraphy and Sedimentology of Oil-gas Basins* 6(2010-2): 46-55.

Badyukova E.N., 2011. Funkzionirovanie paleoproliva Manych v pozdnem pleistotsene-nachale golotsena [The Manych paleostrait in the Late Pleictocene-Early Holocene]. *Geologia i poleznye iskopaemye Mirovogo okeana* 4: 17-29. (In Russian)

Badyukova, E.N., 2015. Istoria kolebaniy urovnia Kaspia v Pleistotsene (byla li velikaya khvalynskaya transgressiya?) [History of Caspian Sea level oscillation in the Pleistocene (if there was a Great Khvalynian transgression and deep Atelian regression?)] *Bulleten komissii po izuchenij chetvertichnogo perioda* 74: 111-120. (In Russian)

Badyukova, E.N., 2016. History of Caspian Sea level oscillations in the Late Pleistocene (if there was a Great Khvalynian transgression and a deep Atelian regression?). In A.S. Gilbert and V. Yanko-Hombach (eds.), *Proceedings of the Fourth Plenary Conference of IGCP 610 "From the Caspian to Mediterranean: Environmental Change and Human Response during the Quaternary" (October 2-9, 2016; Tbilisi, Georgia)*, pp. 22-25. Tbilisi, Georgian National Academy of Sciences.

Badyukova, E.N., 2017. Genesis of the Baery knolls developed in the Northern Caspian Plain *Quaternary International* (in press, available online 1 March 2017).

Doskach, A.G., 1956. O genezise rel'efa Volgo-Uralskogo mezhdurechya [On the genesis of the relief of the Volga-Ural interfluve] *Trudy instituta geografii* 69: 2-36. (In Russian)

Foteeva, N.I., 1966. O paleogeograficheskom strukturno-geomorfologicheskom znachenii "vrezannykh" khvalynskikh delt v Severnom Prikaspii [On the paleogeographic structural and geomorphological value of embedded Khvalynian deltas of the Northern Caspian Plain]. *Strukturno-geomorfologicheskie issledovaniia v Prikaspii* 7: 407-418. (In Russian)

Leontiev, O.K., 1961. *Geomorfologiia morskikh beregov* [*Foundations of Seacoast Geomorphology*]. Moscow, MSU. (In Russian)

Zhukov, M.M., 1945. Pliosenovay i chetvertichnay istoriya severnoi chaste Caspiscoy nizmennosty [Pliocene and Quaternary history of the northern part of the Caspian lowland].V knige *Problemy zapadnogo Kazakhstana* [*Problems of Western Kazakhstan*] 2. Moscow, Nauka. (In Russian)

METHODS AND EQUIPMENT FOR CONDUCTING FIELD RESEARCH INTO SURFACE LAYER CHARACTERISTICS BY SOUNDING IN THE SHORT-WAVE RANGE OF RADIO WAVES IN ORDER TO STUDY ENVIRONMENTAL CHANGE

Belov, S.Yu. [1], and Belova, I.N. [2]

[1] M.V. Lomonosov Moscow State University, Physics Department, 1, Leninskie gory, 119991, Moscow, Russia
Belov_Sergej@mail.ru
[2] A.M. Obukhov Institute of Atmospheric Physics, Russian Academy of Sciences, 3 Pyzhevsky Lane, 119017, Moscow, Russia
Belova_Ija@mail.ru

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

Introduction

The problem of remotely diagnosing a "rough" earth surface and dielectric subsurface structures in the short-wave radio wave band in order to document evidence of environmental change is considered here (Belov and Belova, 2015c). A new incoherent method for estimating the signal-to-noise parameter is proposed. Consideration is carried out on an example for an ionospheric case. This range makes it possible to diagnose a subsurface layer of the earth, since the scattering parameter is also determined by inhomogeneities in the dielectric permeability of subsurface structures (Belov and Belova, 2016). By using this method to organize a monitoring program through sounding, it is possible to identify the areas of variation for these media, for example, for assessing seismic hazard, hazardous natural phenomena, changes in ecosystems, and also some extreme events of anthropogenic nature (Belov, 2017). Also, these techniques can be used to develop a system for monitoring and forecasting emergencies of a natural and man-made nature, as well as for (1) assessing the risks of emergencies, (2) geological, archaeological, and environmental research, and (3) studying the geology if needed, in the field, via modern research methods and equipment (Belov et al., 2016).

The idea underlying the method for determining this parameter is that, by having synchronous information about a wave reflected from the ionosphere and one reflected from the earth and the ionosphere (or having passed through the ionosphere twice when probing from a satellite), it is possible to extract information about the scattering parameter. This paper describes how results are obtained from the recording of quadrature components of the signal using ground measurements from a coherent sounding in the short-wave range of radio waves.

A comparative analysis was performed, and it showed that, according to the analytical (relative) accuracy of the definition of this parameter, the new method is an order of magnitude better than the widely used standard method. Evaluation of the analytical errors in estimating this parameter prompt us to recommend the new method instead of the standard one.

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 (Mirkotan et al., 1999):

$$\begin{aligned} E(t) &= E_0(t) + E_P(t) = E_{00} \cdot e^{i\cdot(\omega_0 \cdot t - \varphi(t))} + E_P(t) = \\ &= R(t) \cdot e^{i\cdot(\omega_0 \cdot t - \Phi(t))} = \left[E_C(t) + i \cdot E_S(t)\right] \cdot e^{i\cdot\omega_0 \cdot t}, \end{aligned} \tag{1}$$

where $\varphi(t)$, $\Phi(t)$, $R(t)$, $E_m(t)$, m = c,s – shown to slow random processes on the period $T = \dfrac{2\cdot\pi}{\omega_0}$; E_{00} = Const. Scattering parameter is the ratio (Mirkotan and Belov, 1998):

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

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, and $\Phi(t)$ 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, 2016a):

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

$I_n(x)$ is the Bessel function of the n^{th} order of a purely imaginary argument (Alpert, 1960).

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

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

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, 2016b).

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:

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

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):

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

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:

$$\varepsilon_{R2}(\beta) = \frac{\pi}{8}\cdot\frac{\left[\left(1+\beta^2\right)\cdot I_0\left(\beta^2/2\right)+\beta^2\cdot I_1\left(\beta^2/2\right)\right]^3}{\beta^2\cdot\exp\left(\beta^2\right)\cdot I_1\left(\beta^2/2\right)}\cdot\Delta\left(Z_{R2}\right);$$
$$\varepsilon_{E4}(\beta) = \frac{\left(1+\beta^2\right)^3}{6\cdot\beta^4}\cdot\Delta\left(Z_{E4}\right); \tag{7}$$
$$\varepsilon_{R4}(\beta) = \frac{\left(1+\beta^2\right)^3}{4\cdot\beta^4}\cdot\Delta\left(Z_{R4}\right).$$

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 $\Delta(Z_K)$ to focus on the errors due to differences in functional dependencies (3) – (5).

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

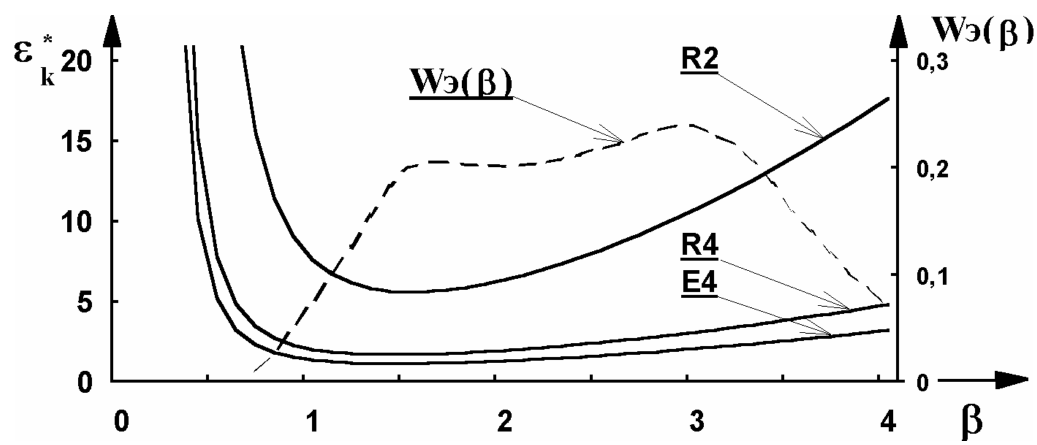


Figure 1. Dependency Graphs ε_K^*, K = R2, R4, E4 (solid curves) and the experimental distribution Wэ(β) (dashed curve) (F2-layer, 4.5 – 9.5 MHz, single signal).

Experimental distribution Wэ(β) 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. We note that behind the coherent E4 technique there remains the possibility of optimizing the statistical error by means of a corresponding special digital processing of the ionospheric signal (Belov, 2016d).

A 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. 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, 2016c).

The experimental setup for simultaneous recording of ionospheric signals of different multiplicity

To obtain the necessary experimental data, a pulse method of coherent reception is used. This method allows the registration of low-frequency quadrature components of the ionospheric signal $E_c(t)$, $E_s(t)$. To determine signal modulation functions, the envelope $R(t)$ and the phase $\Phi(t)$ are possible using these components. The equipment of coherent reception allows one to register directly the envelope and the phase of the reflected signal from the ionosphere (Belov and Belova, 2015b).

It is necessary to allow separation and simultaneous recording parameters of different multiplicities. All of the above-identified ways to modernize the equipment of the coherent reception make it possible to study the properties of multiple reflections. The installation uses a scheme of registration for low-frequency quadrature components of the ionospheric signal E_c(t), E_s(t) and envelope R(t). Modernization of the installation provides the registration of the above-mentioned parameters simultaneously for signals of different multiplicity with the aid of a computer. This is achieved using a special multi-channel strobbing (gating) system and registration. Fig. 2 is a block diagram of the installation with the scheme of registration and strobbing. Installation allows simultaneous recording of the parameters of multiple ionospheric reflections.

Conclusion

This paper presents the experimental equipment developed by the first author of the ground-based measuring complex for conducting a coherent sounding of the scattering capacity of the earth's surface in the short-wave radio wave band to estimate the signal-to-noise parameter. A new incoherent method for estimating the signal-to-noise parameter is proposed.

A comparative analysis was performed, and it showed that, according to the analytical (relative) accuracy of the definition of this parameter, the new method is an order of magnitude better than the widely used standard method. 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 goals, such as diagnosing properties of the medium using this radio band, which is of interest for documenting environmental change, for archaeological research, and geological study, if needed, in the field via modern research methods and equipment (Belov and Belova, 2015a).

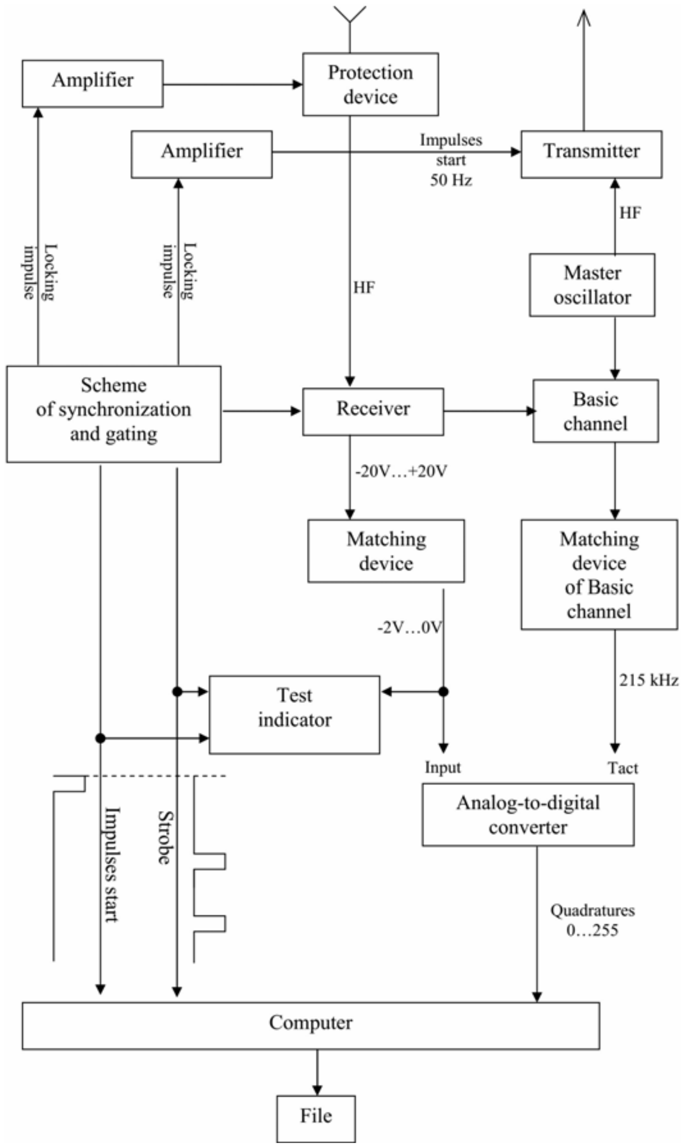


Figure 2. Functional diagram of the experimental installation.

References

Alpert, Ya.L., 1960. *Rasprostranenie radiovoln v ionosfere* [*Distribution of radio waves in an ionosphere*]. AN USSR, Moscow. (In Russian)

Belov, S.Yu., 2016a. The analysis of monitoring data of the parameter scattering power the earth's surface in the short-wave range of radio waves. *Data Intensive System Analysis for Geohazard Studies, Geoinformatics Research Papers* 4(2), BS4002, DOI:10.2205/2016BS08Sochi, p. 50.

Belov, S.Yu., 2016b. Experimental research of characteristics of coherent and incoherent information processing in the remote sensing of the atmosphere and the “rough” surface of the earth in the short-wave range of radio waves. *Russian Physics Journal* 59(12-3, part 2): 121-124. (In Russian)

Belov, S.Yu., 2016c. Kosmicheskiy monitoring kharakteristik pribrezhnykh territoriy dlya obespecheniya ekologicheskoy bezopasnosti zondirovaniyem v korotkovolnovom diapazone radiovoln. [Space monitoring of the characteristics of coastal territories to ensure ecological safety using sounding in the short-wave range of radio waves]. *Ecology. Economy. Informatics*, pp. 27-41. Rostov-on-Don, SFU. (In Russian)

Belov, S.Yu., 2016d. Programma registratsii kvadraturnykh komponent n-kratnogo otrazhennogo ot zemnoi poverhnosti radiosignala [The program of registration quadrature a component of the n-fold reflected radio signal from a terrestrial surface]. The certificate on registration of the right to the software No. 2016612172 of 19.02.2016. (In Russian)

Belov S.Yu., 2017. Monitoring of parameters of coastal Arctic ecosystems for sustainability control by remote sensing in the short-wave range of radio waves. The Arctic Science Summit Week, 31 March-7 April 2017, Prague, p. 161.

Belov, S.Yu., and Belova, I.N., 2015a. Environmental aspects of the use of remote sensing of the earth's surface in the short-wave range of radio waves. In: A.S. Gilbert, V. Yanko-Hombach, and T. Yanina (Eds.), *Proceedings of the Third Plenary Conference of IGCP 610 "From the Caspian to Mediterranean: Environmental change and Human Response during the Quaternary", September 22-30, 2015, Astrakhan, Russia*, pp. 29-31. Moscow, MSU.

Belov, S.Yu., and Belova, I.N., 2015b. Funktsional'naya shema eksperimentalnoi apparatury kogerentnogo priema v zadachah monitoringa poverhnosti zemli metodom distantsionnogo zondirovaniya v korotkovolnovom diapazone radiovoln [Functional diagram of the experimental apparatus of coherent reception in the tasks of monitoring land surface remote sensing in the short-range radio waves]. *Applied Aspects of Geology, Geophysics and Geo-ecology, Using Modern Information Technology. Maikop*, pp. 53-58. (In Russian)

Belov, S.Yu., and Belova, I.N., 2015c. Monitoring poverhnosti zemli metodom distantsionnogo zondirovaniya v KV-radiodiapazone [Monitoring of the Earth's surface by method of remote sensing in SW range]. *Ecology-2015, Arkhangelsk*, pp. 6-7. (In Russian)

Belov, S.Yu., and Belova, I.N., 2016. 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. In: A.S. Gilbert and V. Yanko-Hombach (eds.), *Proceedings of the Fourth Plenary Conference of IGCP 610 "From the Caspian to Mediterranean: Environmental Change and Human Response during the Quaternary", October 2-9, 2016,* Tbilisi, pp. 26-29. *Tbilisi, Georgia*. Georgian National Academy of Sciences.

Belov, S.Yu., Belova, I.N., and Falomeev, S.D., 2016. Monitoring of coastal ecosystems by method of remote sensing in the short-wave range of radio waves. *Managing Risks to Coastal Regions and Communities in a Changing World*. St. Petersburg, DOI: 10.21610/conferencearticle_58b4316d2a67c.

Mirkotan, S.F., and Belov, S.Yu., 1998. On the perturbation parameter of nonuniform fluctuating ionospheric plasma. *Journal of Communications Technology and Electronics* 43(11): 1290-1291.

Mirkotan, S.F., Belov, S.Yu., and Zaharov, V.I., 1999. Distantsionnaia diagnostika rasseivayushei sposobnosti "sherohovatoi" zemnoi poverhnosti v korotkovolnovom diapazone radiovoln [The distant diagnostics of the "rough" Earth surface scattering power in the SW range]. *Radiotekhnika i electronika* 44(10): 1190-1194. (In Russian)

THE FIRST EXPERIENCE OF DENDROCLIMATOLOGICAL RESEARCH IN THE EASTERN PART OF THE KAZAKH UPLAND (SARYARQA)

Berdnikova, A.A. [1], and Dolgova, E.A. [2]

[1] Lomonosov Moscow State University, Faculty of Geography, Moscow, Russia
[1]alinaberdnikowa@yandex.ru
[2] Institute of Geography RAS, Moscow, Russia
[2]dolgova@igras.ru

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

Introduction

A large peneplain formation called the Kazakh Upland (or Saryarqa) is situated in Kazakhstan. It consists of elevated plains and low mountain granite oases (Karkaraly, Kent, Kyzylarai, Ulytau, etc.). This area was uplifted and the mountains created when the ancient Paleozoic shield was cracked by a rising granite batholith. The rocks and cliffs have been here ever since, and for many thousands of years, the untamable steppe wind and precipitation has sculpted the rocks into unique shapes.

The climate of this territory is continental with high summer temperatures and 300-350 mm of annual precipitation. 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. Tree rings are natural archives that store information about environmental conditions of the past. Previously, tree rings have been successfully used for hydroclimate reconstructions. Such reconstructions have indicated possible climatic causes for many social cataclysms in human history. In such arid and semi-arid regions as Central Kazakhstan, tree rings are especially useful for hydroclimate reconstructions, explaining around 60-80% of the variability of instrumental records. Paleogeographic reconstructions based on the information stored in tree rings can reveal the main climatic characteristics—evaporation and precipitation—so that existing instrumental records can be extended back into earlier millennia, revealing aspects of climate for periods of intensive human activity.

The aim of this study is to create a paleoclimate reconstruction for the Central Kazakhstan region using our new tree-ring chronology.

Study region and methodology

The region of research is situated 245-255 km to the east of Karaganda city (one of the biggest cities in Kazakhstan). Flora is rich and varied here. Birch forest occupies 10% of the wooded area, and aspen forest takes up to 2%; the coniferous species dominate, with pine trees occupying 71.3% of the wooded area. Such forests are relicts of wet periods. For this reason, *Pinus sylvestris ssp. kulundensis* was the main target of our research. Although old trees are rare here, we have found 6 key sites with pines old enough to extend the existing climatic records. One hundred and eighty samples were extracted at two polygons: Karkaraly and Kent.

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 human activities. Two 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 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 within closed canopy forests (Cook and Holmes, 1986). For our study area, all of these chronologies were close, so we used 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.

Results

We have created 6 tree-ring width chronologies for living trees (*P. sylvestris ssp. k.*). The resulting chronology (MAIN) covers the last 376 years (Fig. 1).

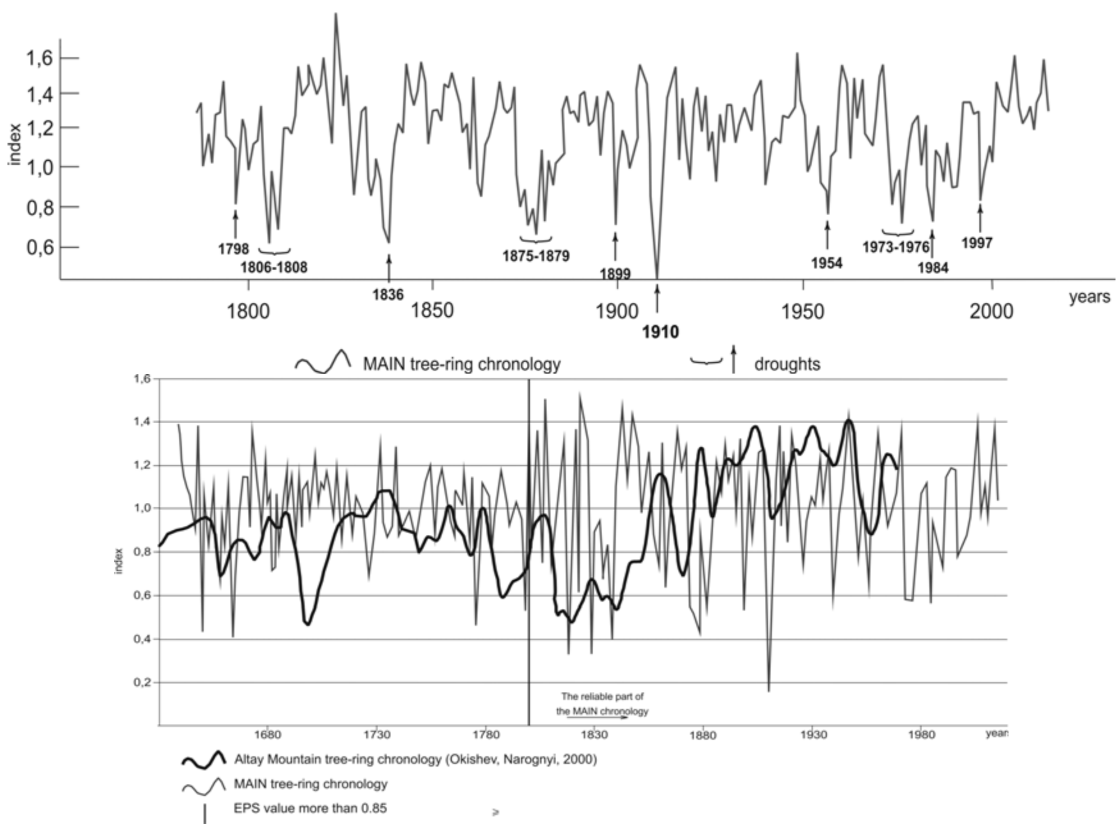


Figure 1. Dendroclimatological interpretation of the resulting MAIN tree-ring chronology for the eastern part of the Kazakh Upland.

An EPS value more than 0.85 is reached only since 1803, which is an indicator of the reliability of the chronology. That's why our reconstruction covers the last 212 years. The chronology shows a negative climatic signal with summer temperatures and a significant positive climatic signal with the amount of precipitation in July and August, and this confirms the sensitivity of these trees to droughts. We pinpointed the years of maximum depression in growth of pine and correlated them with the droughts known by meteorological observations (since 1902) and historical sources.

Evaluation reveals that the maximum number of depressions within the pine chronologies during the period from 2015 to 1803 is registered in the years 1997, 1984, 1976-1973, 1954, 1910 (which was the strongest drought in this area), 1899, 1879-1875, 1836, and 1808-1806 (Fig. 1). Amplified reaction to aridity can be connected with warming and increased transpiration, which have been occurring during the last decades. We offer an example of using the obtained chronology for correlation of global events; a high conformity was found between our chronology and that of the Altay Mountains since the second part of the XIX century (Fig. 1). This may mean some differences in the removal of the influence of the Little Ice Age.

Conclusions

Our study has shown that the dendroclimatological method is promising for hydroclimate reconstructions in the Central Kazakhstan region.

We found trees more than 350 years old. The wood samples of *P. sylvestris ssp. k*. 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 summer. In addition, we found a negative temperature response in the same months. So we can say with confidence that the limiting factor is the amount of precipitation.

We plan to continue this research by correlating our chronology with archaeological research.

Acknowledgments

The authors are grateful to R.N. Kurbanov for fieldwork organization and collaboration. The research was supported by the Grant RSF No 16-17-10103.

References

Briffa, K.R., and Jones, P.D., 1990. Basic chronology statistics and assessment. In *Methods of Dendrochronology: Applications in the Environmental Sciences*, E.R. Cook and L.A. Kairiukstis (eds.), pp. 137-152. International Institute for Applied Systems Analysis (IIASA). Kluwer Academic Publishers, Dordrecht.

Cook, E.R., 1985. A Time-series Analysis Approach to Tree-ring Standardization. Ph.D. Dissertation, University of Arizona, Tucson.

Cook, E.R., and Holmes, R.L., 1986. Guide for computer program ARSTAN. Adapted from Users Manual for Program ARSTAN. In: R.L. Holmes, R.K. Adams, and H.C. Fritts (Eds.), *Tree-Ring Chronologies of Western North America: California, Eastern Oregon and Northern Great Basin*. Laboratory of Tree-Ring Research, University of Arizona, Tucson, pp. 50-65.

Cook, E.R., Kairiukstis, L.A., 1990. *Methods of Dendrochronology: Applications in the Environmental Sciences.* Kluwer Academic Press, Dordrecht.

Rinn, F., 2003. *TSAP-Win: Time Series Analysis and Presentation for Dendrochronology and Related Applications. Version 0.55 User Reference.* RINNTECH, Heidelberg

Stokes, M.A., and Smiley, T.L., 1968. *An Introduction to Tree-ring Dating*. The University of Chicago Press, Chicago.

Wigley, T.M.L., Briffa, K.R., and Jones, P.D., 1984. On the average value of correlated time series, with applications in dendroclimatology and hydrometeorology. *Journal of Applied Meteorology and Climatology* 23(2): 201-213.

THE MAIN STAGES OF VEGETATION AND CLIMATE EVOLUTION IN THE KUBAN RIVER DELTA REGION DURING THE LAST 7.4 AND THEIR CORRELATION WITH SEA-LEVEL FLUCTUATIONS OF THE BLACK SEA

Bolikhovskaya, N.S. [1]*, and Porotov, A.V.* [2]

[1, 2] M.V. Lomonosov Moscow State University, Faculty of Geography, Moscow, Russia, 119991;
[1] nbolikh@geogr.msu.ru
[2] alexey-porotov@yandex.ru

Keywords: Middle and Late Holocene, NE Black Sea Region, palynological records, ^{14}C dating

Introduction

Environmental dynamics of the inland sea coasts in response to global and regional climate fluctuations throughout the Holocene is still commanding major attention in the context of developing a paleogeographical basis for forecasting environmental responses to the climate changes under currently persisting conditions. A conventional approach to such problems is based on a specific elaboration of the existing paleoclimatic reconstructions using detailed palynological data and radiocarbon (^{14}C) dates obtained from Holocene deposits, the newly obtained data being correlated with the existing schemes of relief evolution and sea-level fluctuations. As to the Black Sea coasts, the sea-level changes throughout the Holocene have been summarized in a few recent papers (Balabanov, 2009; Martin and Yanko-Hombach, 2011; and others).

Material and results

On the Taman Peninsula, a detailed palynological analysis supplemented with ^{14}C dates has been performed on the Holocene sequences of the Kuban River delta. The studied series included liman, fluvial, lacustrine, swamp, and subaerial formations deposited during the last 7000 years. The reconstructed history of paleoclimatic events is based on pollen data obtained from a series of sediments, 12-m thick, penetrated by borehole 1. The borehole was positioned in the inner part of the delta close to the Kuban channel, where it branches into two arms flowing into the Sea of Azov and the Black Sea, respectively. The sequence made it possible to obtain detailed characteristics from 14 stages in the climate and vegetation evolution through the Middle and Late Holocene until 1000–800 ^{14}C yr BP (Bolikhovskaya et al., 2014). Those reconstructions were substantiated and supplemented with analyses of pollen assemblages recovered from deposits penetrated by boreholes on adjacent parts of the delta. The detailed studies of pollen assemblages obtained from the Holocene sections at the Black Sea delta of the Taman River permitted the tracing of changes in zonal vegetation types and transformations in the zonal and intrazonal plant formations on the Taman Peninsula that resulted from global and regional climate fluctuations, as well as from changes in edaphic conditions. Characteristic features of the environmental changes and landscape restructuring have been traced over the interval from ~7400 to 400 cal yr BP; they permitted us to recognize 17 phases in the climate and vegetation evolution during the Middle and Late Holocene. The paleoclimatic record thus obtained reveals a regular succession of stages in environmental change, their chronology, and characteristics of the former landscapes and climates. All this information forms the basis of the concept developed by N.S. Bolikhovskaya (Bolikhovskaya et al., 2017, in press), in which the author attempts to interpret the climate-controlled Black Sea level fluctuations over the last ~7.4 cal ka on the basis of pollen assemblages and climate- and chronostratigraphy (Table 1) (Bolikhovskaya et al., 2017, in press).

Table 1. Holocene vegetation and climatic stages in the Taman Peninsula and their ages according to ^{14}C dating and interpretations of the pollen record, and correlations with sea-level fluctuations (N. Bolikhovskaya).

^{14}C and interpreted ages of vegetation and climate stages, years BP		Zonal vegetation (from pollen)	Climate	Correlation with supposed transgressive and regressive phases
Conventional	Calibrated			
	<300 – subrecent	All the subrecent samples (soil, estuary, alluvial) indicate steppes with patches of broadleaf and pine forests	More humid than at present	Trend to transgression
301±24 430±20	580–305/440	Herb-grass steppe; locally forests of fir, spruce, pine, and birch; meadows and abundant aquatic vegetation	Relatively cool and dry	Regression
510±80	830/730–580	Forest-steppe with a notable presence of mixed coniferous - broadleaf forests	Warm and relatively humid, increasing in humidity	Transgression
1000–900/800	900–830/730	Grass and *Artemisia*-Chenopodiaceae steppe	Increasing aridity and warming	Regression
1300–1000	1230–900	Forest-steppe with patches of beech-hornbeam-oak forests	Relatively humid and warm	Transgression
1650–1300	1540–1230	Dominance of herb-grass and *Artemisia*-Chenopodiaceae steppe; broadleaf tree species disappear almost completely after the middle of this phase	Dry and relatively cold	Korsunian regression
2300–1650	2280–1540	A combination of broadleaf beech-oak-hornbeam forests and forest-steppe	Warm and humid: 3rd maximum of humidity	Nymphaean transgression
2500–2300	2590–2280	Vegetation transitional from steppe to forest-steppe	Relatively warm and dry	Phanagorian regression
2800–2500	2910–2590	Herb-grass and *Artemisia*-Chenopodiaceae steppe	Warm and dry	

3200–2800	3430–2910	Forest-steppe dominated by steppe and meadow-steppe herb-grass communities; alder and willow forests, small areas of beech-hornbeam-oak forests	Relative cooling and increase in humidity	Transgression
3500–3200	3780–3430	Grass steppe, *Artemisia*-Chenopodiaceae, and herb-grass steppes, locally with broadleaf (hornbeam-oak) and alder forests	Warm and dry	Regression
3950–3500	4400–3780	Broadleaved forests (oak-beech-hornbeam and beech-hornbeam-oak) with patches of coniferous and broadleaf stands	Warm and humid: 2nd maximum of humidity	Maximum phase of Dzemetinian transgression
4100–3950	4660–4400	Grass, herb-grass, and *Artemisia*-Chenopodiaceae steppes; floodplain forests of alder, poplar, and willow; reduced broadleaf stands of oak-hornbeam-elm	Relative cooling and increasing aridity	Regression
4300–4100	4900–4660	A combination of forest and forest-steppe communities with forests of former edificators	Warm and relatively less humid	Kalamitian transgression
4500–4300	5160–4900	Broadleaf forests, mainly of beech, oak, and hornbeam, with patches of coniferous-broadleaf stands and alder and willow groves	Warm and humid: 1st maximum of humidity	
5900–4500	6730–5160	Forest-steppe with patches of beech-oak-hornbeam forests	Warm and relatively more humid	
5940±50 > 6500	7400–6730	Steppe with meadow and marsh communities and patches of hornbeam-oak stands	Warm and dry	Pontian regression

The comparison performed shows five transgressive phases in sea-level changes corresponding to relatively warm and wet natural conditions tentatively reconstructed for the following time intervals: ~6730–4660 cal yr BP (corresponding to the Kalamitian transgression); ~4400–3780 cal yr BP (Dzemetinian transgression maximum); ~2280–1540 cal yr BP (Nymphaean transgressive phase); ~1230–900 and ~830/730–580 cal yr BP. A transgressive phase identified in the interval of ~3430–2910 cal yr BP is noted for its relatively cool and wet climate. There have been seven regressive stages of sea level distinguished in our paleoclimatic record; four of them most probably featured a relatively warm and dry climate, namely ~7400–6700 cal yr BP, ~3780–3430 cal yr BP, ~2910–2280 cal yr BP (the latter corresponds to the so called Phanagorian regression), and ~900–830/730 cal yr BP. The other three phases of relatively lower sea level are indicated by palynological data in the intervals ~4660–4400 cal yr BP, ~1540–1230 cal yr BP, and ~580–305/440 cal yr BP (the last one corresponds to the Little Ice Age); they were mostly dry and relatively cool.

Conclusions

The comparison between the reconstructed stages in the climate evolution throughout the Middle and Late Holocene on the NE Black Sea coasts, on one hand, and the suggested transgressive and regressive phases in the Black Sea level fluctuations, on the other, have provided corroborative evidence for low-amplitude variations in sea level being climate-controlled. On the basis of the data obtained, changes in humidity may be considered the main climatic factor exerting control over the regime of the Azov-Black Sea levels.

Acknowledgments

This paper is a contribution to the RGS Project No № 03/2017-P, to the IGCP 610 Project, and to the GM Project on the theme “Paleoclimates, the natural environment development and long-term prediction of environmental change.”

References

Balabanov, I.P., 2009. *Paleogeograficheskiye predposylki formirovaniya sovremennykh prirodnykh uslovij i dolgosrochny prognoz razvitiya golocenovykh terras Chernomorskogo poberezh'ya Kavkaza* [*Paleogeographical Prerequisites in the Formation of the Modern Environments and the Long-term Forecast of the Development of Holocene Terraces on the Black Sea Coast of the Caucasus*]. Vladivostok: Dal'nauka. (In Russian)

Bolikhovskaya, N.S., Porotov, A.V., Kaitamba, M.D., and Faustov, S.S., 2014. Razvitiye prirodnoj sredy i klimata na territorii Chernomorskoy del'ty Kubani v posledniye 7 tysyach let [Reconstruction of the changes of sedimentation environments, vegetation, and climate within the Black Sea part of the Kuban River Delta area for the last 7000 years]. *Vestnik of Moscow University.* Series 5. Geography 1: 64–74. (In Russian)

Bolikhovskaya, N.S., Porotov, A.V., Richards, K., Kaitamba, M.D., Faustov, S.S., and Korotaev, V.N., 2017. Detailed reconstructions of Holocene climate and environment changes in the Taman Peninsula (Kuban River delta region) and their correlation with rapid sea-level fluctuations of the Black Sea. *Quaternary International* 2017 (in press).

Martin, R.E., and Yanko-Hombach V., 2011. Rapid Holocene sea-level and climate change in the Black Sea: An evaluation of the Balabanov sea-level curve. In: I.V.Buynevich, V. Yanko-Hombach, A.S. Gilbert, and R.E. Martin (Eds.), *Geology and Geoarchaeology of the Black Sea Region: Beyond the Flood Hypothesis*, pp. 51–58. GSA Special Papers 473. Boulder, Colorado, Geological Society of America.

PLANKTONIC FORAMINIFERAL AS PROXIES OF THE HOLOCENE CLIMATIC VARIABILITY (TYRRHENIAN, MEDITERRANEAN SEA)

Bonfardeci, A. [1]*, Caruso, A.* [2]*, Cosentino, C.* [3]*, and Scopelliti, G.* [4]

[1-4] Dipartimento di Scienze della Terra e del Mare (DiSTeM), Via Archirafi 22, 90123, Palermo, Italy
[1] aalessandro.bonfardeci@unipa.it
[2] bantonio.caruso@unipa.it
[3] cclaudia.cosentino@unipa.it
[4] dgiovanna.scopelliti@unipa.it

Keywords: stable isotopes, millennial-scale climatic variability, southern Tyrrhenian, Holocene

Introduction

The focus of this study is the paleoclimatic reconstruction of the southern Tyrrhenian between ~9.2 and 2.9 ka, through the study of planktonic foraminiferal assemblages and stable isotopes, and comparing data with other coeval intervals. Several authors have studied the climatic sensitivity of Holocene planktonic foraminifera in different parts of the Mediterranean. Planktonic foraminifera produce good records of Holocene climatic variability, especially as regards the sub-orbital events such as Bond events (Bond et al., 1997) and other cooling/warming oscillations. Therefore, the obtained eco-biostratigraphy has allowed us to analyze how climatic forcing influenced sea surface temperature (SST) and water column structure during the Holocene in this sector of the southern Tyrrhenian Sea.

Methodology

A sedimentary core (196 cm long) was collected in the Gulf of Palermo at the base of the upper continental slope (990 m bsl) and sub-sampled every 2 cm. Micropaleontological and geochemical analyses were performed on 98 samples, and three AMS ^{14}C dates were determined. Micropaleontological analyses consisted of qualitative and quantitative characterization of the planktonic foraminiferal assemblages, in the size fraction greater than 125 µm. Geochemical analyses were performed on 8–10 specimens of *Globigerina bulloi*s.

Results

The calibrated AMS 14C ages, together with planktonic foraminiferal fluctuations and *G. bulloides* oxygen isotope records, were used to develop an age model of the studied interval. In order to obtain additional age control points, the studied records were also tuned to the NGRIP δ^{18}O (GICC05) (Svensson et al., 2008) and GISP2 ice core temperature (Alley, 2000) records (Fig. 1).

Twenty species and eco-morphotypes were recognized in the planktonic foraminiferal assemblage and grouped depending upon their climatic and feeding affinity. The warm-water species, minus the typical cold-water species, were used to obtain the paleoclimatic curve, whilst the herbivo-rous/carnivorous ratio has permitted us to reconstruct the trophism of the southern Tyrrhenian. In particular, between ~8 and 6.4 ka, an important warming phase was recognized, clearly indicated by the increase of Globigerinoides gr. ruber and G. gr. quadrilobatus. This interval corresponds to the deposition of Sapropel S1b-equivalent stage (Sprovieri et al., 2003; Lirer et al., 2013; Siani et al., 2013), when high SSTs and oligotrophy characterized the entire Mediterranean region, especially during the summer seasons. Between ~5.9 and 4.2 ka, another warming phase occurred in the Gulf of Palermo, differing from the previous one due to the enhanced winter mixing of the water column, testified by the high abundance of deep dweller species, such as Globorotalia truncatulinoides and

Globorotalia inflata left coilings. The last important warming phase corresponds to the Minoan Warm Period, briefly interrupted by a rapid cooling event (at ~3.5 ka).

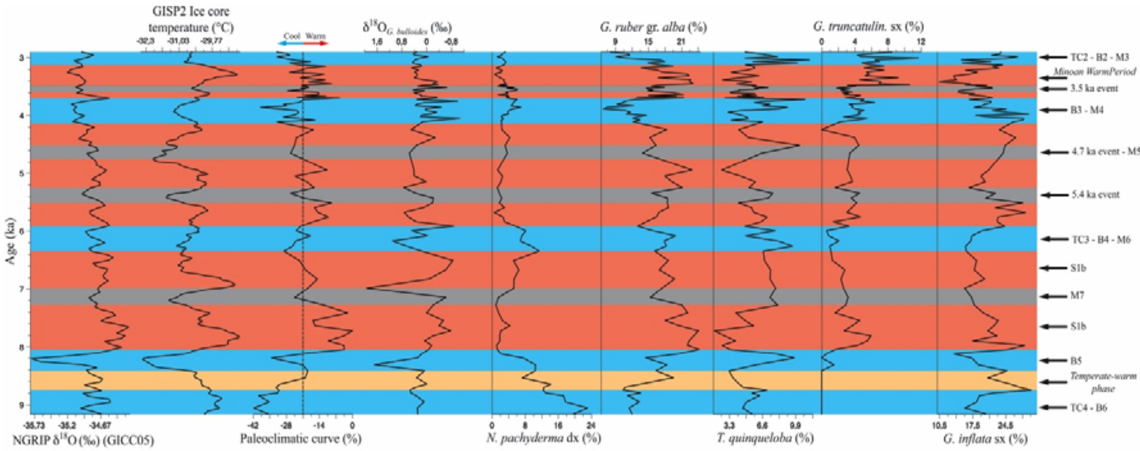


Figure 1. NGRIP δ^{18}O (Svensson et al., 2008), GISP2 ice core temperature (Alley, 2000) and C4 core paleoproxies. Climatic events are listed on the right of the plot. Blue, red and orange horizontal bars indicate the cold-cool, warm and temperate-warm climatic phases, respectively.

Among these warm climatic phases, several rapid cold-cool events were recognized. In particular, Neogloboquadrina pachyderma and Turborotalita quinqueloba represent the best cold-water indi-cators, increasing in abundance during the Bond events (B2, B3, B4, B5, B6) and other rapid cool-ing events that characterized the western (M3, M4, M5, M6, M7) (Frigola et al., 2007) and central Mediterranean (TC2, TC3, TC4) (Cacho et al., 2001) during the 9.2–2.9 ka interval.

Conclusions

Planktonic foraminifera and oxygen isotope variations highlight the climatic oscillations of the relatively stable Holocene stage. These oscillations are linked to the North Atlantic millennial scale climatic variability that forced cool/high productivity periods and warm/oligotrophic conditions. In particular, during the ~8–6.4 (S1b-equivalent), ~5.9–4.2, and ~3.7–3.2 (Minoan Warm Period) ka intervals, warm surface waters characterized the Gulf of Palermo. On the contrary, during rapid climatic phases, centered at 9.1, 8.2, 7.2, 6.2–5.9, 5.4, 4.7, 3.9, 3.5, and 3 ka, cool/high productivity conditions occurred in this sector of the southern Tyrrhenian.

References

Alley, R.B., 2000. The Younger Dryas cold interval as viewed from central Greenland. *Quaternary Science Reviews* 19(1–5): 213–226.

Bond, G., Broecker, W., Johnsen, S., McManus, J., Labeyrie, L., Jouzel, J., and Bonani, G., 1993. Correlations between climate records from North Atlantic sediments and Greenland ice. *Nature* 365(6442): 143–147.

Cacho, I., Grimalt, J.O., Canals, M., Sbaffi, L., Shackleton, N.J., Schönfeld, J., and Zahn, R., 2001. Variability of the Western Mediterranean Sea surface temperature during the last 30,000 years and its connection with the northern hemisphere climatic changes. *Paleoceanography* 16(1): 40–52.

Frigola, J., Moreno, A., Cacho, I., Canals, M., Sierro, F.J., Flores, J.A., Grimalt, J.O., Hodell, D.A., and Curtis, J.H., 2007. Holocene climate variability in the western Mediterranean region from a deepwater sediment record. *Paleoceanography* 22(2): PA2209.

Lirer, F., Sprovieri, M., Ferraro, L., Vallefuoco, M., Capotondi, L., Cascella, A., Petrosino, P., Insinga, D.D., Pelosi, N., Tamburrino, S., and Lubritto, C., 2013. Integrated stratigraphy for the late Quaternary in the eastern Tyrrhenian Sea. *Quaternary International* 292, 71–85.

Siani, G., Magny, M., Paterne, M., Debret, M., and Fontugne, M., 2013. Paleohydrology reconstruction and Holocene climate variability in the South Adriatic Sea. *Climate of the Past* 9: 499–515.

Sprovieri, R., Di Stefano, E., Incarbona, A., and Gargano, M.E., 2003. A high-resolution record of the last deglaciation in the Sicily Channel based on foraminiferal and calcareous nannofossil quantitative distribution. *Palaeogeography, Palaeoclimatology, Palaeoecology* 202(1–2): 119–142.

Svensson, A., Andersen, K.K., Bigler, M., Clausen, H.B., Dahl-Jensen, D., Davies, S.M., Johnsen, S.J., Muscheler, R., Parrenin, F., Rasmussen, S.O., Röthlisberger, R., Seierstad, I., Steffensen, J.P., and Vinther, B.M., 2008. A 60,000 year Greenland stratigraphic ice core chronology. *Climate of the Past* 4: 47–57.

ANTHROPOLOGICAL CHARACTERISTICS OF THE ADAPTATION OF THE FAYOUM OASIS POPULATION (EGYPT) IN THE GRECO-ROMAN PERIOD

Borutskaya, S.B. [1], Vasilyev, S.V. [2] , and Kharlamova, N.V. [3]

[1] Leninskye Gory 1, Lomonosov Moscow State University, Moscow 119991, Russia,
[1,2,3] vasbor1@yandex.ru
[2,3] Leninskiy prospekt 32a, Institute of Ethnology and Anthropology, Russian Academy of Science, Moscow 119361, Russia

Keywords: anthropology, adaptation, odontology, Ancient Egypt, Greco-Roman period, dental pathology and anomaly

Introduction

The study of dental pathology is crucial for understanding the diet, lifestyle, and health of the medieval population of the Fayoum oasis of Egypt. This study is focused on dental pathologies of the Fayoum population in late antiquity. Anthropological material was collected during excavations of a necropolis at the archaeological site of Deir al-Banat, located in the southeastern part of the Fayoum oasis.

The earliest burials in the necropolis date to the very end of the Ptolemaic period—1st century BC. These burials were conducted according to traditional ancient Egyptian beliefs and funerary customs that include artificial mummification of the body, use of anthropoid coffins, etc. After a while, the Egyptians adopted Christianity as their main religion. The Christians of Egypt are known as Copts, a name that derives the word '*qubt*', which is the Arabic transcription of the Greek *'aigyptios'* (Egyptian). Over time, the term 'Copts' began to be used to create opposition between the Christian and Muslim populations. As long as marriage between Muslims and Christians was not generally approved by both communities, the Coptic population remained isolated. We can assume that medieval and modern Copts have an indigenous Egyptian origin.

Since 2003, archaeological and anthropological research at the necropolis of Deir al-Banat has been conducted by the Center for Egyptological Studies of the RAS, the Anthropology Department of the Lomonosov Moscow State University, and the Center for Physical Anthropology of the Institute of Ethnology and Anthropology of the RAS in cooperation with the Institute of Bioarchaeology (Department of Ancient Egypt and Sudan) of the British Museum. In 2006, intact graves of Greco-Roman and medieval date were discovered. Most of the graves were robbed, but luckily for the anthropologists some skeletal remains were not significantly disturbed. The current study describes the dental pathology of the Fayoum population buried at the necropolis of Deir al-Banat based upon human remains from graves dating back to Greco-Roman time.

Materials and methods

During the excavations, around 100 burials were attributed to the Greco-Roman period. Skulls of 33 individuals from these burials were studied for dental pathology. 20 of them belonged to men, 11 to women, and 2 to children. The study program included standard macroscopic data collection methods to record dental caries, enamel hypoplasias, periodontitis, odontogenic osteomyelitis, tooth enamel trauma, and antemortem tooth loss (AMTL) with reduction of alveolar processes of the upper jaw and alveolar arch of the lower jaw (Rochlin, 1965; Ortner and Putschar, 1981). Crowding, disturbance of tooth eruption, and dentition change were noted among the anomalies. The percentages of pathologies were counted per individual, for male and female groups, and in total.

Results, discussion and conclusion

Table 1. Deir al-Banat human skeletal remains of Greco-Roman time (1 BC-4 AD): Dental pathology (%)

Dental Pathology / Anomaly	Total	Male	Female
Enamel hypoplasia	35.5	25.0	54.5
Caries	29.0	30.0	27.3
Periodontitis	32.3	35.0	27.3
Odontogenic osteomyelitis	9.7	15.0	-
AMTL and reduction of alveolar bone	38.7	40.0	36.4
Teeth enamel trauma	12.9	10.0	18.2
Severe teeth attrition	9.7	15.0	-
Crowding	12.9	15.0	9.1

The main pathologies noted on the human remains representing the Fayoum population buried at the necropolis of Deir al-Banat are the following: enamel hypoplasia, caries, periodontitis, and AMTL with subsequent reduction of alveolar bone.

The frequent enamel hypoplasia may have been caused by scarce food resources despite the fact that the studied population lived in an oasis. Apparently, in earlier times, like today, poor food availability could be explained by poverty and failure to feed a family. Notably, enamel hypoplasia affected women almost twice as much as men.

The high percentage of caries seen across the total group (an almost equal percentage for men and women) can be explained by the type of nutrition. It is generally assumed that the incidence of caries can be increased by starchy plant foods (Temple and Larsen, 2007).

A high percentage of periodontitis is observed for both men and women. This disease presents together with severe osteoporosis of the alveolar bone and frequent exposure of tooth roots. It can be connected with poor nutrition, probable lack of certain elements in food and water, frequent illnesses, and other etiologies. Tooth loss (mainly molars and premolars) could be a consequence of the diseases listed above. The result of tooth loss is reduction of the alveolar processes of the upper jaw (often even up to the level of the palate) and the alveolar arch of lower jaw. The percentages of this pathology are almost equal for men and women.

Other dental pathologies are rare. Some of them, for example odontogenic osteomyelitis, were recorded only for males. Besides this, men also suffered severe tooth attrition and disturbance of tooth eruption and dentition change. A low percentage of crowding and tooth enamel trauma was recorded for both males and females. It should be noted that calculus was not recorded in the studied sample from the late antique population (unlike the medieval group), and this can also be connected to dominant plant nutrition.

References

Ortner, D.J., and Putschar, W.G.J., 1981. *Identification of Pathological Conditions in Human Skeletal Remains*. Washington, D.C., Smithsonian Institution Press.

Rokhlin, D.G., 1965. *Bolezni drevnikh liudei* [*Diseases of Ancient Men*]. Moscow-Leningrad, Nauka. (In Russian)

Temple, D.H., and Larsen, C.S., 2007. Dental caries prevalence as evidence for agriculture and subsistence variation during the Yayoi period in prehistoric Japan: Biocultural interpretations of an economy in transition. American Journal of Physical Anthropology 134: 501-512.

LATE GLACIAL TO HOLOCENE BLACK SEA EVOLUTION BASED ON MICROFAUNAL AND STABLE OXYGEN ISOTOPE RECORDS

Briceag, A. [1], Yanchilina, A. [2], Ryan, W.B.F. [3], Stoica, M. [4], and Melinte-Dobrinescu, M.C. [5]

[1,5] National Institute of Marine Geology and Geo-ecology, GeoEcoMar, 23-25 Dimitrie Onciul Street, RO-024053 Bucharest, Romania
[1] andrei.briceag@geoecomar.ro
[5] melinte@geoecomar.ro
[2,3] Lamont-Doherty Earth Observatory of Columbia University, Palisades, NY 10964, USA
[2] billr@ldeo.columbia.edu
[3] nyanchil@ldeo.columbia.edu
[4] University of Bucharest, Faculty of Geology and Geophysics, 1 Nicolae Balcescu Street, Bucharest, Romania
marius.stoica@g.unibuc.ro

Keywords: ostracods, foraminifera, ^{14}C dating, glacial period, red sediments

The Black Sea is a semi-enclosed marginal basin that connects with the Mediterranean Sea through the Bosphorus Strait, Marmara Sea, and Dardanelles Strait. Besides its connection with the Mediterranean Sea, in Late Pliocene-Pleistocene times, the Black Sea experienced a period of connection with the Caspian Sea through the Manych Corridor due to the meltwaters from the Scandinavian ice sheets (Fedorov, 1977; Chepalyga et al., 2004; Bahr et al., 2006; Major et al., 2006).

In the deeper parts of the Black Sea basin, i.e., below 200 m water depth, Ross and Degens (1974) identified three litho-stratigraphic units (from young to old): Unit 1 (the microlaminated coccolith ooze, deposited under marine conditions), Unit 2 (the sapropel mud, corresponding to an anoxic phase), and Unit 3 (the lacustrine lutite deposited during the freshwater or oligohaline stage).

In the early Holocene, water composition in the Black Sea evolved from brackish to marine; biotic turnover mirrors this change. The transition of the Black Sea from an inland lake to a marine basin during the last glacial/deglacial episode is still generating discussion in the scientific community. In this study, high resolution microfaunal analyses coupled with isotopic and calcium carbonate performed on an AMS ^{14}C dated core, 09 SG 13, revealed changes that occurred in the Black Sea from the Last Glacial Maximum through the transition to the present-day semi-enclosed marine basin. In the sedimentary record, this deglaciation accumulated allochthonous continentally-derived red sediments, simultaneous with the global Heinrich Event 1, 18 to 15 kyr BP. These sediments are characterized by depleted $\delta^{18}O$ and Mn, an increased Ti/Ca ratio, as well as higher values of kaolinite and illite, probably indicating that their origin is from a more northern location (i.e., the Alps and the Fennoscandinavian Ice Sheet) (Yanchilina et al., in prep.).

In the studied core, situated at 200 m water depth, two lithological units, respectively the youngest Unit 1 (Coccolith Mud) and the oldest Unit 3 (Lacustrine lutite), were identified, with the base dated 24.5 kyr BP (into the later part of Marine Isotope Stage 2, MIS 2, glacial period). Since Unit 2 is missing, either the water depth was not sufficient to develop the sapropel facies or it was naturally eroded. This gap extends between the Younger Dryas and the mid-Holocene when the brackish Neoeuxinian lake transformed into a saltwater sea. Judging from the ostracods, this transformation is represented by the disappearance of the fresh-brackish ostracod taxa (Caspian in origin) and by the appearance of brackish-marine ones (Mediterranean in origin). The core contains a red-clay and silt interval belonging to the post-glacial meltwater pulse of the Heinrich Event 1. In this sequence, the sedimentation rate increased by a factor of four. The oxygen isotopes are very light (<–6 ‰) in the glacial period, reach < –7 in the meltwater pulse, and then gradually become heavier and stabilize on a plateau of –4 in the Younger Dryas. The oxygen isotopes show the development of a strong vertical stratification in the Neoeuxinian lake in the post-glacial Bølling/Allerød warming period, stratification that is not present in the glacial period or red-clay interval. The glacial cold period is marked by the presence of the cold-water ostracod species *Candona fabaeformis*, while the post-glacial warming is indicated by the warm-water ostracod *Erpetocypris* sp. In the upper part of the core, in Unit 1, a brackish ostracod assemblage with low diversity and abundance was identified. This interval is characterized by the presence of polyhaline ostracods (Boomer et al., 2010; Ivanova et al., 2012) with Mediterranean origin (i.e., *Hiltermannicythere rubra*, *Cytheroma variabilis*, and *Palmoconcha granulata*). The ostracods from this assemblage tolerate salinities between 17–21 ‰ and characterize a sub-littoral environment.

The aim of this study is to refine the last 25,000 years of Black Sea stratigraphy and to decipher the paleoenvironmental and paleoecological conditions by the integration of the fossil record (i.e., micro- and macrofauna) with the oxygen isotope fluctuations, $CaCO_3$ values, and AMS ^{14}C dating. Detailed micropaleontological studies, based on ostracod and foraminifera analyses, are also presented herein.

Acknowledgments

The authors thank the whole crew of the research vessel "Mare Nigrum" (owner GeoEcoMar) for the support given during the scientific cruises on the Black Sea. We are in debt to Prof. Dr. Werner Piller, who kindly helped us perform micropaleontological studies by SEM, in Graz University. We are in debt to the late General Director of GeoEcoMar, Dr. Gheorghe Oaie, who provided the studied cores, to Dr. Irina Catianis for her assistance with measurements of organic matter and carbonate content, and to the late geologist Constantin Ungureanu, who helped us with the sedimentological studies. This research was financially supported by the National Project Nucleu PN 16 45 02 01.

References

Bahr, A., Arz, H.W., Lamy, F., and Wefer, G., 2006. Late glacial to Holocene palaeoenvironmental evolution of the Black Sea, reconstructed with stable oxygen isotope records obtained on ostracod shells. *Earth and Planetary Science Letters* 241: 863–875.

Boomer, I., Guichard, F., and Lericolais, G., 2010. Late Pleistocene to Recent ostracod assemblages from the western Black Sea. *The Journal of Micropaleontology* 29: 119–133.

Chepalyga, A.L., Sadchikova, T.A., Leonova, N.B., Nesmeyanov, S.A., and Pirogov, A.N., 2004. Caspian-Black Sea water exchange along Manych-KerchWatergate in the Late Pleistocene. In *Ekologiia antropogena i sovremennosti: priroda i chelovek" Sbornik statey Mezhdunarodnoi Konferentsii* [*Ecology of the Anthropogene and Contemporaneity: Nature and Man. Papers from the International Conference (24–27 September 2004, Volgograd-Astrakhan)*]. Humanistica, St. Petersburg, pp. 50–53. (In Russian)

Fedorov, P.V., 1977. Late Quaternary history of the Black Sea and southern seas of Europe. In: P.A. Kaplin and F.A. Shcherbakov (Eds.), *Paleogeografiia i otlozheniia pleistotsena iuzhnykh morei SSSR* [*Paleogeography and Deposits of the Pleistocene of the Southern Seas of the USSR*], pp. 25–32. Nauka, Moscow. (In Russian)

Ivanova, E.V., Murdmaa, I.O., Karpuk, M.S., Schornikov, E.I., Marret, F., Cronin, T.M., Buynevich, I.V., and Platonova, E.A., 2012. Paleoenvironmental changes on the northeastern and southwestern Black Sea shelves during the Holocene. *Quaternary International* 261: 91–104.

Major, C.O., Goldstein, S.L., Ryan, W.B.F., Lericolais, G., Piotrowski, A.M., and Hajdas, I., 2006. The co-evolution of Black Sea level and composition through the last Deglaciation and its paleoclimatic significance. *Quaternary Science Reviews* 25(17–18): 2031–2047.

Ross, D.A., and Degens, E.T., 1974. Recent sediments of the Black Sea. In: Degens E.T. and Ross D.A. (eds.), *The Black Sea: Geology, Chemistry, and Biology*. American Association of Petroleum Geologists, Tulsa, Oklahoma, pp. 183–199.

Yanchilina, A.G., Ryan, W.B.F., McManus, J.F., and Kenna, T. (in prep). The drainage of the meltwater from the Alps and Fennoscandinavian Ice Sheet into the Black Sea.

UNIQUE MARINE TERRACE SYSTEM OF THE CRIMEAN AND BLACK SEA BASINS: STRATIGRAPHY, ARCHAEOLOGY, AND THE OLDEST OLDOWAN MIGRATIONS TO EUROPE

Chepalyga, A.L.

Institute of Geography RAS, 29 Staromonetny Lane, Moscow, Russia
tchepalyga@mail.ru

Keywords: the highest Black Sea terraces, Lower Pleistocene, Calabrian, Gelasian, Piacentian, 18 terraces, 3 terrace tiers, the oldest land-use

During the last four years, nine expeditions and detailed interdisciplinary studies were carried out in the Echkidag-Karadag-Sudak region of Crimea. Unique materials related to geomorphology, geology, lithology, paleontology, stratigraphy, and paleomagnetism were collected, including space and UAV images with the construction of high resolution digital elevation models.

As a result, a new concept for the Black Sea terrace system was developed (Chepalyga, 2015), and the marine genesis of the South Coast terraces has been proved on the basis of the classical terrace system of N.I. Andrusov (1912).

Within the framework of the new concept of the Black Sea terraces, the number of established terrace levels is now 12 main terraces up to a height of 200 m asl, of which 6 terraces are Neopleistocene and 6 terraces are Eopleistocene in age (0.8–1.8 Ma) (Chepalyga, 2015).

Based on recent research in 2016–2017, this terrace system is essentially supplemented and structured within the framework of the new concept of Black Sea terraces (Chepalyga, 2015). It includes already 18 terrace levels. These studies are continuing and probably will be supplemented by new terrace levels and details of their structure.

The allocated 18 marine terraces are grouped into three different tiers (a group of separated terraces) with six terraces levels in each:

- Lower terrace tier (LTT) with a height of 0 to 65 m: terraces I–VI;
- Middle terrace tier (MTT) in height from 75 to 200 m: terraces VII–XII;
- Upper terrace tier (UTT) with a height of 200 to 350 m and above: terraces XIII–XVIII.

These terrace tiers and levels differ not only in height but also in age, terrain conservation, terrace deposits, and fossils, as well as in relation to the corresponding Black Sea basins: Karangatean, Uzunlarean, Paleoeuxinean, Chaudean, Gurean, and Kuyalnik, and possibly Kimmerian. The age of the terraces is based on paleomagnetic data, geomorphology, and the fauna of mollusks and mammals (for the LTT) (Fig.1).

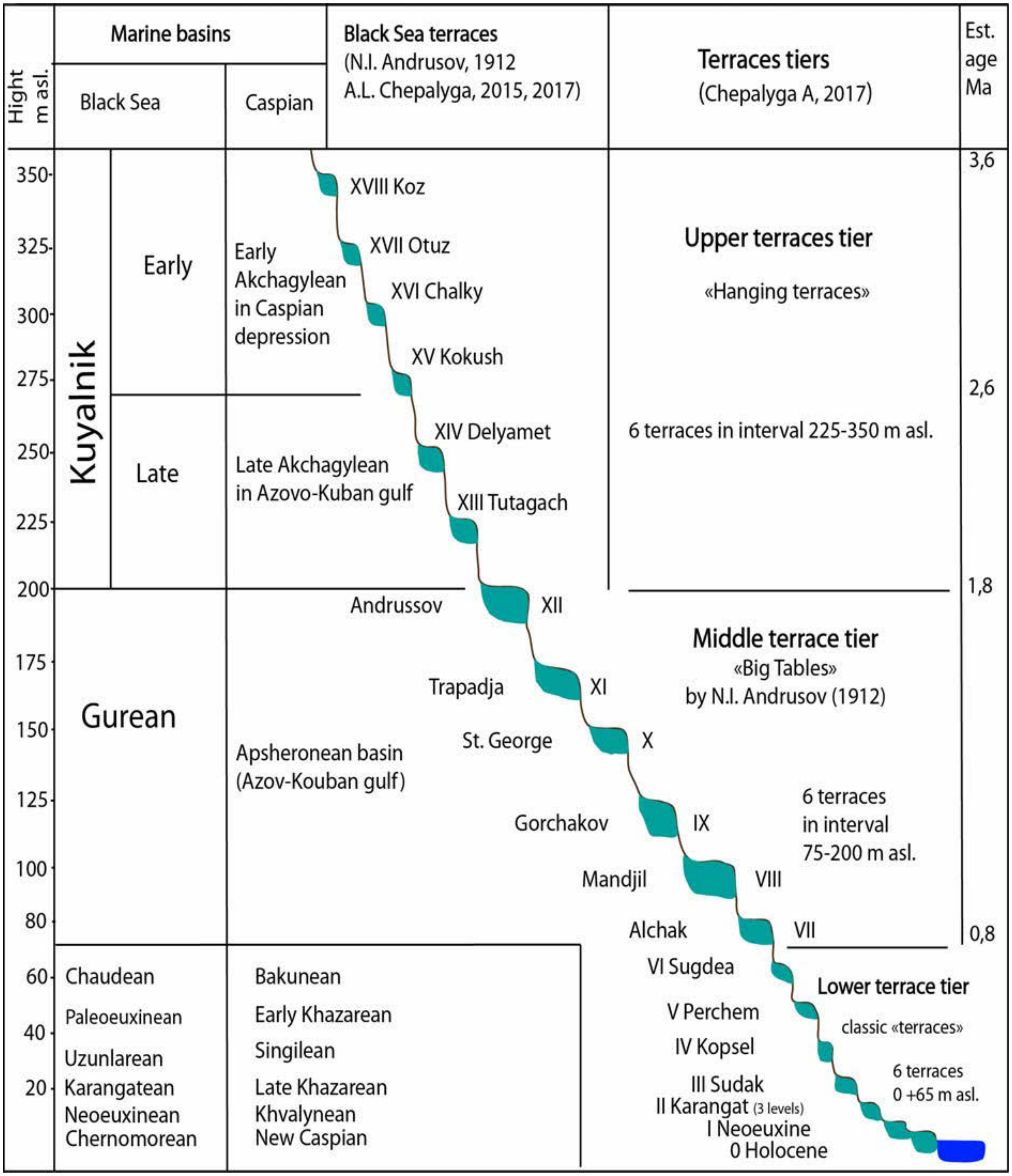


Figure 1. Marine terraces of SE Crimea and Black Sea basins.

The lower terrace tier (LTT) is represented in the coastal zone at the foot of the Crimean Mountains within an altitude range of 0 to 65 m asl. In this tier, six main terrace levels are distinguished with alternating cyclic surface heights of about 12–15 m. The time cyclicity is about 100 thousand years and is close to the global tiers of the oxygen-isotope scale of N. Shackleton: isotope stages 5, 7, 9, 11, 13–15, and 17.

These are classical terraces, whose Neopleistocene (last 0.8 Ma) age in the stratotype sections was determined by microfauna, mollusk fauna, and small mammals. The width of the terrace sites reaches 50–150 m.

0 Black Sea terrace, height 0–2 m asl, Holocene

I Neoeuxinean terrace, 3–5 m, Late Pleistocene, connected with the Neoeuxinean basin on the Black Sea shelf;

II Karangatean terrace, the last interglacial with three sublevels:

> IIa Meganom terrace, 6–8 m, accumulative, cap lowered below sea level, age about 80 thousand years (OIS 5a);
>
> IIb Sokol terrace, 8–10 m, (socle height +2 to +3 m), age about 100 thousand years (OIS 5c);
>
> IIc Novosvet terrace, 10–15 m, (socle height +8 m), age 125 thousand years (OIS 5e).

III Sudak terrace, 20–25 m, Uzunlarean basin;

IV Kopsel terrace, 35–40 m, Paleoeuxinean basin;

V Perchem terrace, 50 m, Late Chaudean basin;

VI Sugdea terrace, 63–65 m, Early Chaudean basin, covered by reddish-brown fossil soils.

The middle terrace tier (MTT) occupies a central position in the middle part of the terrace stairs, approximately in the middle of the mountain slope at an altitude range from +75 to +200 m asl. The width of terrace areas is maximal in comparison with the LTT, amounting to 200–300 m, and the thickness of terraces with subhorizontal bedding reaches 15–20 m. Such terraces are marked by N.I. Andrusov under the name "Large Tables" and have a wide distribution on the south coast of Crimea. Six terraces of this stage are located at a height interval of about 25 m. This is double the interval of the terraces of the LTT. If we extrapolate it to the time interval of the LTT, then its doubling is possible, i.e., the terraces of the MTT are replaced every 25 m vertically and 200 thousand years in time. Then the age of the LTT terraces can be in the range of 0.8–2.0 million years; this is the age of the Gurean brackish-water basin (Eopleistocene). This is confirmed by preliminary paleomagnetic data, according to which the deposits of terraces VII, VIII, IX, and XII have predominantly the reverse magnetization of the Matuyama epoch, older than 780 thousand years.

VII Alchak terrace, 75 m, the lowest and youngest of the terraces of the MTT, but its age according to paleomagnetic data goes back to the Matuyama chron (Eopleistocene, more than 0.78 million years). In the system of terraces of N.I. Andrusov, this terrace belonged to the II Mandjil level (the "Southern Table" of the II terrace).

VIII Mandjil terrace, 100 m, the most dominating and occupies a central position in its MTT tier, differing in its maximum width of 200–300 m and capacity of terrace deposits of up to 17 m. The name Mandjil is appropriately applied to the 100-meter level of the terrace (Chepalyga, 2015).

IX Gorchakov terrace, 125 m high, also occupies a central position among the terraces of the MTT, and the thickness of its sediments reaches 20 m.

X St. George terrace, 150 m, is located in the middle of the terrace staircase of the MTT, colored by red fossil soils.

XI Trapdja terrace, 175 m, was first described by N.I. Andrusov (1912) as the "Southern Table" I of the High Terrace of Sudak (170 m asl).

XII Andrusov terrace, 200 m, the highest of those described by N.I. Andrusov (1912) as "Great Tables," namely the "North Table" I of the High Terrace of Sudak. It is a table mountain: the remains of Byuk-Trupaja (203 m asl), the twin mountain (Andrusov, 1912) of the previous terrace XI.

The upper terrace tier (UTT) in the upper part of the Crimean Mountain slope rises to the summit part of the slope escarpment at altitudes from 200–225 m to 350 m asl and higher. There are also surface gradients up to 15–20 degrees. Accordingly, the width of the terraces is sharply reduced. The terraces are so narrow that their type can be described as "hanging terraces," more weakly expressed in relief. This type of terrace is highlighted by us in the region for the first time. The thickness of the terrace deposits is 10–12 m and more.

On the basis of preliminary data, the following 6 terraces of the UTT can be identified. All stratotypes and geomorphotypes are located in the Echki-Dag massif on the left side of the ravine. Tutagach is confined to two erosion landslide circuses: the Lower and Upper.

XIII Tutagach terrace, 225 m, the name of the ravine Tutagach. The morphotype is assigned to the narrow terrace of the Lower Circus Tutagach;

XIV Delyamet terrace, 250 m, the name of the Delyamet-Kaya (peak Echki-Dag). The geomorphotype is established over the Lower Tutagach tiers, and the stratotype is located on the western slope of the terrace platform;

XV Kokush terrace, 275 m, the name of the Kokush-Kaya peak. Geomorphotype and stratotype are assigned to the eastern slope of the Upper Tutagach Tiers;

XVI Chalky terrace, 300 m, the name is from the Chalky Bay and the Chalky-dag mountain range.

XVII Otuz terrace, ~325 m, named after the Otuz river;

XVIII Koz terrace, ~350 m, named after the Koz river.

The six established terrace levels reveal the high altitude cyclicity detected in the MTT at a height of 25 m, which can also be extrapolated to a terrace tier of 200 thousand years, provided that the same rate of uplift of the Crimean Mountains is maintained. This allows us to assume the age of the terraces in the range from 2 to 3.5 million years, i.e., Paleo-Pleistocene (Gelasian) and Upper Pliocene (Piacenzian), and correlate these terraces with the Kuyalnyk Basin of the Black Sea.

This system can become the basis for a reconstruction of the stratigraphy and history of the Black Sea basins, as well as the process of raising the Crimean Mountains during the Pliocene-Quaternary neotectonic stage (the last 5–6 million years). This terrace system is a good base for correlation with the Mediterranean Pleistocene and Pliocene.

As a result of the discovery in the sediments of terraces VII-XI (Eopleistocene = Calabrian) of multilayered sites of the Oldowan culture (Chepalyga et al., 2015), it is possible to reconstruct the initial peopling of Europe through the Caucasus and Crimea along the Northern Black Sea Corridor (Chepalyga, 2015). In the future, it will be possible to date the appearance of the first settlements and stages of development of the Oldowan type culture on the border of Asia and Europe in connection with the geologic history of the Black Sea (Figs.2, 2a).

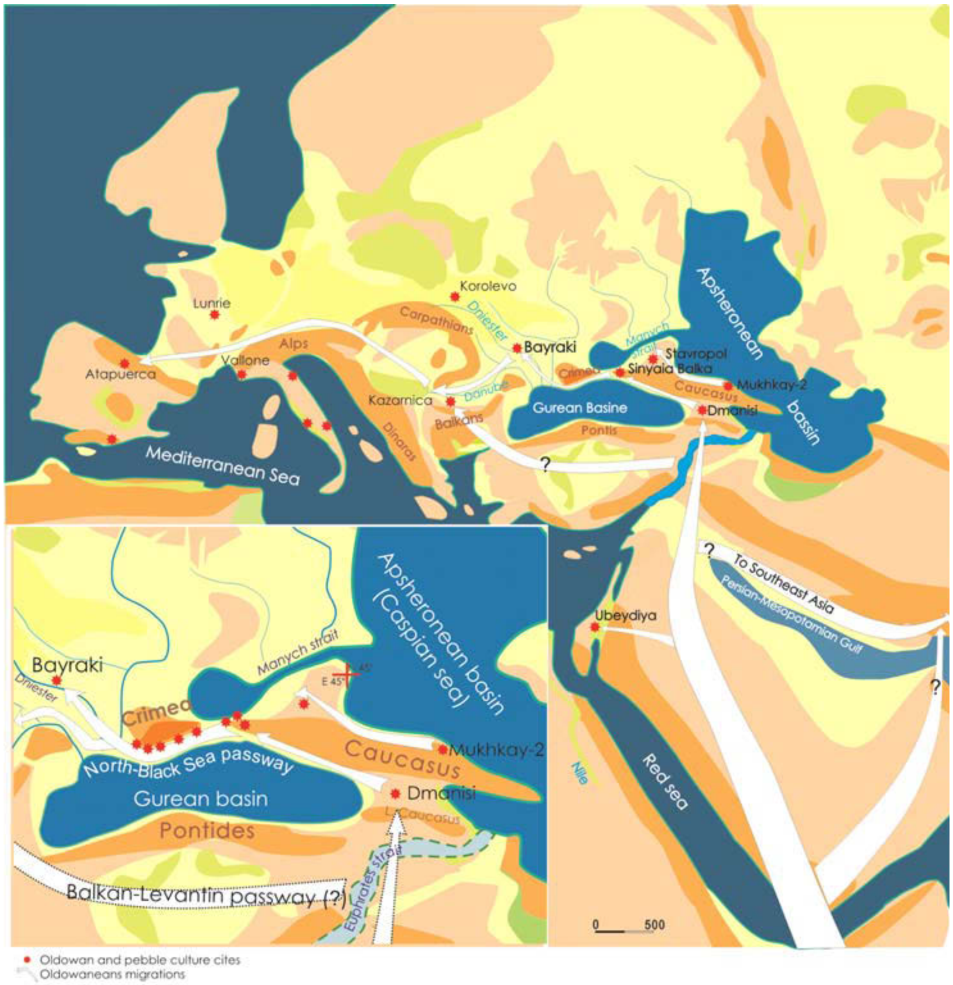


Figure 2. Oldowan migrations via the Near East, Caucasus, and Crimea to Europe 2.0–1.0 Ma BP. Figure 2a (inserted). North Black Sea Corridor showing the earliest migrations to Europe.

References

Andrusov, N.I., 1912. Terrasy okrestnostey Sudaka. *Zapiski Kievskogo obshestva estestvoispytateley*. v.22, I.2. (In Russian).

Arkhangel'sky A.D., and Strakhov N.M., 1938. Geologicheskoe stroenie i geologicheskaya istoria razvitia Chernogo morya [*Geological Structure and History of the Black Sea*]. Izd. AN SSSR, Moscow. (In Russian)

Chepalyga, A.L., 2015. Novaya konceptsia chernomorskikh terras yugo-vostochnogo Kryma. *Biulleten' Komissii po izucheniiu chetvertychnogo perioda* 74: 5–22. (In Russian)

Chepalyga, A.L., Anisutkin, N.K., and Sadchikova, T.A., 2015. Pervye mnogosloynye stoyanki oldovanskoy kultury v Krymu: geologia, arheologia, paleoekologia. *Biulleten' Komissii po izucheniiu chetvertychnogo perioda* 74: 90–104. (In Russian)

Chepalyga, A.L., 2015. New data on the North Black Sea corridor of the first European migrations: discovery of multilayered Oldovan sites in Crimea. In: A.S. Gilbert, V. Yanko-Hombach, and T. Yanina (Eds.), *Proceedings of the Third Plenary Conference of IGCP 610 "From the Caspian to Mediterranean: Environmental change and Human Response during the Quaternary"* (September 22-30, 2015; Astrakhan, Russia), pp. 57–58. Moscow, MSU.

THE ROLE OF THE BLACK SEA SHELF TECHNO-GEOLOGICAL SYSTEM IN THE INTEGRATED MANAGEMENT OF RATIONAL RESOURCE USE

Chepizhko, O.V. [1]*, Kadurin, V.M.* [2]*, and Kadurin, S.V.* [3]

[1, 2, 3] Odessa I.I. Mechnikov National University, Dvoryanskaya str., 2, Odessa, Ukraine, 65082
[1] avchep@i.ua
[2] vl.kadurin@gmail.com
[3] kadurins@gmail.com

Keywords: ecological, model, environment, monitoring, elaboration, project

Main provisions of the techno-geological system (TGS)

Studies in the management of natural processes are becoming more and more relevant. Improvements to such systems are possible by deciding upon the problem in need of control and paying attention to anthropogenic activities and processes. Implementation of long-term quantitative forecast of TGS changes under different technogenic impacts is the most important task.

The main study goal is understanding the Black Sea Shelf Techno-Geological System (TGS) as a system of technogenic impacts that influence the geological environment and determine perspectives on growth and the ways processes can be managed.

The main theoretical models of the TGS are constructed on generalized representations of separate parts of the common systemic processes and events. These models are based on the laws of matter and energy flow, and as such, the main theoretical models are described by some abstract TGS. As a result, there is no need to determine specific parameters of the geo-system and the influence of technical impacts, as this model can be constructed based on a generalized imagination of the TGS structure and the nature of the connections between the parts of that system.

The TGS is the new system that includes:

1. Natural self-organized systems (geological environment);

2. Technogenic systems, i.e., systems under the control of a man-made management system.

TGSs are complicated systems, and the management of that type of system can be provided on a modeling principal. These models should allow us to predict short-term and long-term outcomes of different natural and man-made influences on the geological environment, separately and in common, and to forecast local changes in natural conditions under environmental changes and marine resource extraction (Volkova, 2001; Safranov et al., 2012; Prangishvili, 2000; Egorova et al., 2012). Any geological environment forms a special equilibrium with natural conditions. Under those conditions, the natural equilibrium has a relative level of stability, and even under some external disturbance factors, the equilibrium can be retained—this is the dynamism of the geological environment. The technogenic disturbances are sometimes more powerful. They possess a greater level of variety, some forms of which do not exist in nature at all. Synthetic materials are a good example. As result, the spatial study of the reactions of geological environments to local influences should be the basis of any project exploring marine resource extraction, and especially for mining on the area of the shelf.

Geological part of the GTS. The physical, chemical, and hydrodynamic factors that are studied by specialists in marine geology, lithology, and geochemistry are the main geological factors in the analysis of the Black Sea shelf GTS (Adamenko at al., 2010; Emelianov, 2004;

Chepizhko at al., 2013The description of these factors is the same as in other geological sciences. The main difference is the emphasis on the evaluation of the technical impact due to intensive anthropogenic activity in the shelf area. In that case, analyzing and forecasting of TGS changes have a special task that is focused on saving the natural geological environment through the evaluation and implementation of specific resource-saving actions (Emelianov et al., 2004;Safranov at al., 2012; Golodkovskaya, 1988; Chepizhko, 2012).

In the wide diversity of geological processes, only a few could be defined as having an appropriate level of influence on the geological environment as on the ecological-geological system. That complex of processes includes factors of ecological-geological conditions that are represented by endogenous and exogenous particularities of the area's development and are at the cause of geological formation. These are: (1) geological structure, (2) structural-tectonic features, (3) geochemical conditions, (4) geophysical conditions, and (5) present geological processes (Fig. 1).

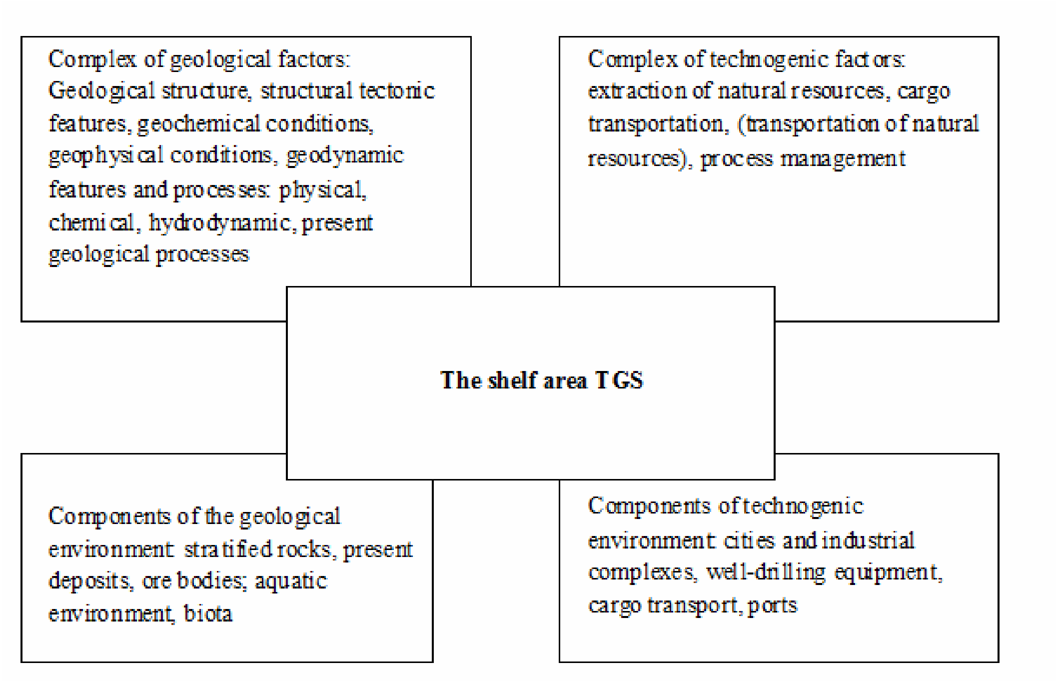


Figure 1. The structure of the shelf area TGS.

Contemporary understanding of ecological geology has demonstrated that the condition of biological organisms is significant for geological environment evaluation because it is one of the basic nature-forming elements (Emelianov et al., 2004; Kobolev, 2016; Gozhyk et al., 2006; Egorova et al., 2012; Shnyukov, 1999; Chen and Grimison, 1989; Spadini et al., 1996).

Technogenic part of the GTS

The main reason why the GTS has formed on the shelf areas in common, and on the Black Sea shelf especially, is connected with the high natural resource potential and related technogenic activity. These activities include fishing, geological survey and exploration, oil and gas production, cargo transportation (especially oil and gas transportation), recreation, and traditional crafts in the seashore zone. Oil and gas production and transportation can have a great negative influence on biological resources, which are the basis for fishing and recreation. As a result, there is an opportunity for conflict between different branches of economic activity, endangering the stable existence of the marine ecosystem. The absence of an integrated marine natural resources management system leads not only to the exhaustion of marine natural resources but also to negative results in the economy of coastal countries (Adamenko et al., 2010; Emelianov et al., 2004; Safranov et al., 2012; *Nuuk Declaration*, 1993; Resolution of Ukrainian Cabinet Ministers, 2009; Torata et al., 2005).

Organization and management of the shelf area TGS

The dynamic of processes and development within the TGS is constant, such that the whole system is continuously moving. Changes in external conditions lead to changes in the principal drivers and outcomes of TGS system development. As a result, new systems with other qualitative and quantitative parameters and properties are constantly emerging. Conformity between external factors and system goals is the main requirement for retaining a stable organizing system structure (Volkova, 2001; Safranov et al., 2012; Prangishvili, 2000; Golodkovskaya et al., 1998; Smirnov. 2002; Chepizhko et al., 2013, 2017).

The main goal of the shelf area TGS organization is determined by the geological environment and goals of human activity. But each system has its individual qualitative and quantitative parameters; this means that, together with the main global goal, each system organization should have its individual development goal. The system organization expresses the dynamics and direction of development.

Sea shelf areas, which are natural objects, have a system-type organization. But human activity (transportation, fishing, oil and gas production, etc.) is not a common system. That complex (a set of connections and relations) is still not at a point where it can be integrated for beneficial results. This means that the management of marine economic activity is in the process of formation, but there have been no results yet.

The complex management of marine resource development must come from an ecosystem approach that is based on the main social and economic reasons for saving the oceans and seas with a long-term perspective. On an international level, that ecosystem approach for the management of oceans and seas was presented in the Nuuk Declaration, which was submitted by the Ministers of Foreign Affairs on 12 May 1993 (*Nuuk Declaration*, 1993).

Next, there are the positions presented in the Marine Doctrine of Ukraine extending to the year 2035, which was approved by the Cabinet of Ministers of Ukraine on 7 October 2009:

The integral approach to marine activity in common and its differentiation in different directions should be based on changes in priority and depending upon the geopolitical situation;

Conducting of integrated marine research focused on Ukrainian interests, and the development of a marine environment and coastal zone monitoring system (Resolution CM Ukraine, 2009).

That Doctrine secures at the legislative level some important positions governing marine activity, marine economic activity, government directions of marine politics, the goals and tasks of those politics, the marine potential of Ukraine, marine cargo transportation, and other matters. The adoption of the Marine Doctrine is a big step toward the development of a new position in Ukraine concerning questions of marine law. But there are some mechanisms and procedures that should be proposed for using that Doctrine.

System organization is the required condition and basis for any system and determines the purpose of creation, main characteristics, and stable operation under external influences. It means that the organization of any system is an integral part of the environment, and vice-versa, environment is the main factor for the purpose of organization, the principals, and features to be created (Prangishvili, 2000; Golodkovskaya et al., 1998; Smirnov, 2002; Chepizhko et al., 2013). System organization is the main reason for the creation, development, improvement, and stable operation, and such organization reflects the dynamics and level of system stability.

Management processes take a special place in system organization. Management is the property of any system that allows one to determine a mass of elements as if it were an organic whole. The management technique is a complex of purposeful actions that includes assessment of the situation and condition of the object, and choice of management actions and their implementation. Management is the external influence on system operation for reaching some desired goal. The next steps should be taken into account during the management process: goal determination; the ways of deciding upon goals; feedback and establishment of monitoring; forecasting; and improving and correcting the means of reaching the goals (Korolev, 1995; Safranov et al., 2012; Golodkovskaya et al., 1988; Smirnov et al., 2002; Chepizhko et al., 2013, 2017).

Two sub-systems can be defined within management—control and manageability. The manageable sub-system, or object of management, is the part of the whole management that is located under a systematically organized plan of action from a managerial person. The control sub-system or managerial person has managerial powers and can utilize them.

Management is the process of directional influence from a control sub-system (managerial person) to a manageable sub-system (object of management). The process of influence goes through direct and feedback channels. Direct channels conduct the managerial influence. That influence can have material, energy, or informational characteristics. The feedback channel conducts information about management results, that is, the information about new conditions within the manageable sub-system after direct influence.

Practical importance of the Black Sea shelf TGS in the integrated management of resource implementation

The zoning of the Black sea shelf can be based on the contradiction in understanding between activities of resource extraction and the necessity to save the natural environment of the shelf area. The natural system-forming components of the TGS are represented by elements of the geological environment together with its biological parameters (total biomass). The technological system-forming components include different types of economic activity: the influence of coastal cities, marine cargo transportation, port constructions, oil and gas production and transportation, and the exploration of different types of natural resources. These components can be added as basic parameters and can be mapped so that the mapping of the main locations of technological influence on the shelf area can be the basis for ecological zoning and ecological-geological assessment of prospects for a development strategy on the shelf area.

Another important thing is the detection of marginally acceptable levels of technological influence on the geological environment and those elements that lead to changes in the GTS (Safranov et al., 2012; Chepizhko, 2012). Decision-making regarding that task is possible with detailed forecasting of the TGS's operation. Monitoring of the geological environment can be one of the methods for solving that problem (Korolev, 1995; Chepizhko, 2012; Spadini et al., 1996).

Lithodynamic systems that possess sources of solid and liquid material, biological and chemical transformations, and the accumulation of sediments can be defined as one of the main criteria for Black Sea shelf zoning. There are many different pollutants that enter the shelf area together with river flows and aerosols. Because of their connection with sediments, all that material intrudes into and is collected within the water and bottom deposits.

Lithodynamic systems are undergoing technological activity, and as such, redistribution and re-accumulation of sediments and pollutants is taking a place.

Ecological-geological survey of the shelf area forms part of a complex regional geological study. Geological survey of the shelf area is the first stage of marine geological work that started with regional geophysical study conducted in order to gain geological and geophysical information for maps, sections, and tables. This information should be the foundation for an integrated environmental study and the determination of a rational natural management strategy. The scale of the geological survey depends on the tasks.

The technical-geological system (TGS) will be established on ecological-geological survey results for the forecasting of geological processes, the search and exploration of natural resources, and other significant capacities.

References

Adamenko, O.M., Rudko, G.I., Krochak, M.D., and Chepizhko, O.V., 2010. *Geologija zosnovami geomorfologii* [*Geology with Basic Geomorphology*]. Chernivci, Buker. (In Ukrainian)

Chen, W.-P., and Grimison, N.L., 1989. Earthquakes associated with diffuse zones of deformation in the oceanic lithosphere. *Tectonophysics* 166(1–3): 133–150.

Chepizhko, O.V., 2012. *Monitoring geotechnogennykh system. Conspekt lektsiy* [*Geotechnical Systems Monitoring. Lecture Notes*]. Odessa, Odessa University Publication. (In Ukrainian)

Chepizhko, O.V., Kadurin, V.M., and Shatokhina, L.M., 2013. Stvorennya techno-geologichnikh system v upravlinny geodynamichnimy systemamy [Techno-geological systems creation in geodynamical systems management]. *Visnyk Odes`kogo Nacionalnogo Univeritetu. Geografichni ta geologichni nauky* [*Bulletin of Odessa National University. Geographical and Geological Sciences*] t. 18, vol 1(17): 102–107. (In Ukrainian)

Chepizhko, O.V., Kadurin, V.M., Kadurin, S.V., and Volkova, O.I., 2017. Formuvannya effektyvnogo upravlinnya techno-geologichnikh system nadrokorystuvanni: realnist i perspectivy [The effective techno-geological management system formation: reality and perspectives]. *Mineralni resursy Ukrainy* [*Mineral Resources of Ukraine*] N1: 11–16. (In Ukrainian)

Egorova, T.P., Gobarenko, V.S., Janovskaya, T.B., and Baranova, K.P., 2012. Stroenie lythosfery Chernogo moray po rezultatam 3D gravitatsionnogo analiza i seismicheskoy tomografii [The Black Sea lithosphere structure based on 3D gravity analyses and seismic tomography]. *Geofizichniy zhurnal* [*Geophysical Journal*] 35(N5): 38–59. (In Russian)

Emelianov, V.A., Mitropolsky, A.U., and Nasedkin, E.I., 2004. *Geoekologiia chernomorskogo shel'fa Ukrainy* [*Ukrainian Black Sea Shelf Geoecology*]. Kiev, Academperiodica. (In Russian)

Golodkovskaya, G.A., Voronkevich, S.D., Goldberg, V.M., and Ershov, E.D., 1988. Problemy ratsionalnogo ispolzovaniya, upravleniya i okhrany okrugauchey sredy [The problems of rational use of the environment, management, and saving]. *Problem yratsionalnogo ispolzovaniya geologicheskoy sredy* [*The Problems of the Rational Use of the Geological Environment*]. Moscow, Nauka. pp. 103–106. (In Russian)

Gozyk, P.F., Maslun, N.V., and Plotnikova, K.A., 2006. *Stratigrafiya mezokaynozoyskikh vidkladiv pivnichno-zahidnogo shelfu Chornogi moray* [*Mesozoic and Cenozoic Deposits and Stratigraphy on the Northwestern Shelf of the Black Sea*]. Kiev, Institute of Geology, NAN of Ukraine. (In Ukrainian)

Kobolev, V.P., 2016. Plum tectonichniy aspect riftogenezu ta evolutsii megazapadiny Chernogo moray [The plum tectonical aspect of Black Sea mega-depression rift genesis and evolution]. *Geologiya i mineral'nye resursy Mirovogo Okeana* [*Geology and Mineral Resources of the World Ocean*] 2: 16–36. (In Ukrainian)

Korolev, V.A., 1995. *Monitoring geologicheskoy sredy. Uchebnits dlya vuzov* [*Geological Environment Monitoring*]. Moscow, MGUPub. (In Russian)

NUUK Declaration on Environment and Development in the Arctic, Second Ministerial Conference on the Arctic Environment, 1993. Minister of Foreign Affairs, Copenhagen. See also *http://www.eclife.ru/laws/inter/1993/04.php.*

Prangishvili, I.V., 2000. Systemniy podkhod i obchesystemniy ezaconomernosty [The system approach and common system regularities]. *Systemy i problemi upravleniya* [*Systems and Management Problems*]. Moscow, SINTEG. (In Russian)

Resolution of Ukrainian Cabinet of Ministers, 2009. Pro zatverdgennja Mors`koi doktriny Ukrainy na period do 2035 roku [On the Marine doctrine of Ukraine approval for 2035 year period]. Postanova kabinetu Ministriv Ukrainy [Decree of Ukrainian Cabinet of Ministers] from 07 Oct 2009. N 1307. Kiev. http://zakon3.rada.gov.ua/laws/show/1307-2009-%D0%BF. (In Ukrainian)

Safranov, T.A., Konikov, E.G., and Chepizhko, O.V., 2012. *Otsink atetsnogennogo vplivu na geologichne seredoviche* [*Technogenic Influence on the Assessment of the Geological Environment*]. Odessa, Ecologija. (In Ukrainian)

Shnyukov, E.F., 1999. Geologiya poleznikh iskopaemikh Chernogo moray [Black sea mineral geology]. *Geologija i poleznije iskopaemie Chernigi moray* [*Geology and Mineral Resources of the Black Sea*]. Kyiv. pp. 3–12. (In Russian)

Smirnov, E.A., 2002. *Teoriya organizatsii. Uchebnoe posobie* [*Organization Theory. Schoolbook*]. Moscow, INFRA-M. (In Russian)

Spadini, G., Robinson, A., and Cloetingh, S., 1996. Western versus Eastern Black Sea tectonic evolution: pre-rift lithospheric controls on basin formation. *Tectonophysics* 266(1–4): 139–154.

Torata, S., Fukuoka, K., Sugiyama, T., Yoshimura, K., Ohuchi, J., and Tsuboya, T., 2005. Monitoring of Geological Disposal. *Current Status and Technical Possibilities*. Tokyo, Radioactive Waste Management Funding and Research Center (RWMC).

Volkova, V.N., 2001. *Izistorii teorii system i systemnogo analiza* [*From the History of Systems and System Analysis Theory*]. St. Petersburg, St. Petersburg Mining University. (In Russian)

INFLUENCE OF SPECIFIC NATURAL CHARACTERISTICS OF THE DNIEPER RAPIDS REGION ON THE DEVELOPMENT OF ANCIENT POPULATIONS

Demchenko, O.V.

Department of Archaeology and Ethnology of Ukraine, Faculty of History, Odessa I.I. Mechnikov National University, 12 Yelisavetynska St, Odesa, 65000
olya.demchenko@mail.ru

Keywords: the Mesolithic, the Neolithic, paleoecology, landscape, hydrology

Introduction

The analysis of the natural component of an ancient population's development is surely important for any archaeological research. With the paleoecological method, one can not only identify but also solve problems that are not solvable using an archaeological method based on evidentiary material analysis.

Speaking about the classic definition of archaeological culture, one of the main mandatory criteria is a certain territory that was populated by people with common material and spiritual development features. However, sometimes there are situations when the living areas of a population within the same culture are essentially different. As a consequence, despite the overall cultural connection of technology, ceramics, anthropological content, etc., a number of unique characteristics emerge in part of the population that have been formed as a result of adaptation to a natural niche they occupied. The same situation exists, we believe, in the bearers of the Kukrek Culture and the resulting Sur-Dnieper Culture. They chronologically correspond with the Late Mesolithic and first half of the Neolithic. The population we consider here mainly occupied territories of the Dnieper Rapids region and the Azov region. This article is dedicated to a part of that area, the Dnieper Rapids region, because it was different from the Azov region not only in its natural characteristics, but also in its specificity and uniqueness within the entire territory of Ukraine. The Dnieper Rapids region incorporates the Dnieper vale area, including the current territory of Dnipro City, and along the stream of the Dnieper River down to Khortytsia Island in Zaporizhzhia. This area is about 100 km long.

The general characteristics of the natural conditions in this region are described in detail by Demchenko (2014, 2015, 2016), therefore the aim of this article is to separate those natural characteristics and resources that set specific elements of people's life support system apart and make a qualitative difference between the Dnieper Rapids region and Azov region. In order to describe specific characteristics of the region and determine their influence on the people's life support system, we have developed a working scheme that includes several topics: landscape, hydrology, climate, flora, and fauna. We will briefly describe some aspects of those topics to demonstrate the difference between the Dnieper Rapids region and the Azov region, and then find out how nature has influenced the fact that there are significant differences in the life of ancient people within one culture.

Climate and paleobotany

Speaking about the present time, the Dnieper Rapids and Azov regions are part of the steppe ecoregion of Ukraine, with the typical flora and fauna. During the Late Mesolithic to Neolithic, the situation was very different from the current one because of climate changes in the early Holocene. An important feature of the Dnieper Rapids region in the Late Mesolithic-Neolithic is a high share of forest flora in the palynological spectra. It registers 23% in the Boreal period and grows to 62% in the Atlantic (Artyushenko et al., 1973: 32).

The softer and warmer the climate, the wider will be the variety of forest flora species. According to the division of paleogeographic zones based on percentage of separate groups of flora in the pollen spectra established in the research literature, the situation in the Dnieper Rapids region during the Boreal was typical for forest steppe landscapes (for the forest steppe ecozone: woody pollen = 5–30%; herb and bush pollen = 60–85%; spore pollen = up to 20%). The percentage of forest flora in the region during the Atlantic is typical for the forest ecoregion (woody pollen = 40–85%; herb and bush pollen = 5–60%; spore pollen = 5–35%). Such characteristics differ from the data obtained in the Azov region, where the share of woody pollen during the Boreal ranged from 2.5% to 5.6% (Bezus'ko, 2006: 16), while for the Dnieper Rapids region, it was equal to 23%. The share of forest flora in the Holocene Optimum varied from 15.9% to 26.5%, (Bezus'ko, 2006: 17), but in the Dnieper Rapids region, it was up to 62%. Unlike the Azov region, the Dnieper Rapids region had enough forest tracts within river vales as well as obviously at watersheds probably thanks to its specific paleolandscapes, hydromorphology, and, in some way, locality.

Landscape and hydrology

The region has specific features because this area is a place where the Dnieper River breaks through the Ukrainian crystalline shield, and the river flows past this section in a meridional direction; in the riverbed are many islands, large separated rocks, rapids, and sandbars. Moreover, the landscape itself was canyon-like. First of all, we consider the presence and availability of certain groups of manufacturing resources as landscape characteristics. They are, among others, flint, talc schist (talc magnesite), and various granitoids.

The main technological raw material for tool manufacturing in the Late Mesolithic and Neolithic was flint, as in the previous age. The beds of high-quality flint in Ukraine are located in several regions (in the Middle Dniester, Volhynia, Middle Desna, Donbas, and Crimea Mountains), but there are no beds of this raw material in the Dnieper Rapids region (Nuzhnyiy, 1989: 152; Nikitenko and Kutsevol, 2016: 5); here, flint is present only in the form of low-quality gravel. For the Dnieper Rapids region in the Late Mesolithic to Early Neolithic, it is typical to find a significant share of microlithic flint processing technology, maximal utilization of flakes (many retouched flakes), and a highly developed technology of bone and horn processing; consequently, there was a great number of tools for their processing. Such a set of tools can be explained by the absence of local flint beds and the need to exploit the material to its maximal economic utilization. The lack of high-quality flint stocks has in some way elevated the search for alternative raw materials for tool manufacturing. Because of that, we think we can explain the high amount of items made of bone and horn (one of highest in Ukraine).

At the same time, the number of talc schist beds in the Dnieper Rapids region encouraged in the Neolithic age an increase in items manufactured from this stone. From steatite (talc schist) have been manufactured shuttles, fishing sinkers, hook fragments, etc. Small steatite items can also be found in other territories, but the Dnieper vale is the only region where a great amount of stone dishes was found. They are represented by a group of items. Their production, in consideration of their sizes, depended on the availability of large-size stones. There are also beds in other territories: the Dnieper region, Azov region, Kryvyi Rih area, etc. Yet, I. S. Nikitenko performed a mineral-petrographic analysis of schist items and said that complicated bedding conditions for this stone in the Kryvyi Rih and Azov region made it impossible for local resources to have supplied 100% of the tool material. In the Neolithic, he believes, the Dnieper Rapids region was most suitable for stone extraction. Thanks to a strongly developed beam system in the region, the talc schist could be extracted in open beds (Nikitenko, 2012).

Besides the talc schist, the population used other local stones for tool manufacturing. Most of those tools are disk-shaped stone objects. The disks could be small (about 5 cm in diameter) and big (12 cm and more in diameter). There is still no single consensus on the functional purpose of these objects. Assumptions have been expressed about the use of these disks for woodworking and digging. Recently, a petrographic analysis was performed on the 27 disk-shaped stone tools from the Late Mesolithic and Neolithic settlements in the Dnieper Rapids region (Nikitenko and Kutsevol, 2016: 6). It was proven that the local mountain rocks of the Dnieper and Sur granitoid complexes were used in their manufacturing. The utilization of almost all local rock beds is evidence of the fact that there were no special requirements for raw material features. The popularity of the local granitoids and their substitute rock beds can also be explained by their relict sandwiched structure that makes easier the splitting of flat pieces in the required form. The results obtained demonstrate the fact that an active utilization of mountain rocks in the Dnieper Rapids region began in the Neolithic (Nikitenko and Kutsevol, 2016: 12).

Paleozoology

Considering the faunal complexes of the Dnieper Rapids region, we believe we must briefly describe the problem of the region's Neolithization, namely, the question of the existence of cattle breeding in the Early Neolithic. We believe the hypothesis of the existence of a reproducing economy by bearers of Sur-Dnieper Culture is true, but its development level depended on the natural conditions and resource base of areal. In addition, the existence of reproducing forms of economy within this culture in far southern regions with regard to the Dnieper Rapids region is fully proved and described in papers of N. S. Kotova (Zhuravl'ov Kotova, 1996: 6; Kotova, 2006: 61–74). The small amount of bones in the settlements of the Dnieper Rapids region belonging to domestic animals can be evidence of exchange processes with the population of neighbour territories, but not of a developed cattle breeding. In addition, most of the artifacts are multi-layered; this means part of the bones could have derived from upper layers dated to later periods. In any case, if cattle breeding was developing in the Early Neolithic, its role was minimal. Cattle breeding played the smallest role for the Neolithic cultures of Ukraine (it produced up to 10% of meat provisions). In the Late Mesolithic to the first half of the Neolithic, the economy of the Dnieper Rapids region was based on a complex of household activities built on fishing, with hunting and collecting. During this period, the exploitation of freshwater resources developed, and it decreased only in the second half of the Neolithic due to an increase in demographic pressure on the farming territory and the movement of people with a developed breeding economy from neighboring territories.

Taking into consideration the above, the problem of the transition to a food-producing economy looks very doubtful and requires additional proof. We've found those proofs in isotopic analysis of buried bones. The available materials help reconstruct the diet of the people of the Dnieper Rapids region from the Epipaleolithic to the Chalcolithic (Potyekhina et al., 2014). The results of research into the Mesolithic burials of Vasylivka II (connected with ancient inhabitants of the Sur-Dnieper Culture) demonstrate more intensive consumption of freshwater fish by Mesolithic fishers compared to the population of this territory in the Epipaleolithic. In addition, the exploitation of more food resources by the population is more significant than it was in the previous age (Potyekhina et al., 2014: 13). The greater significance of fishing for human nutrition is typical for the Early Neolithic. In the regions of Central Eurasia where people consumed mostly river fish and other water animals in the Early Neolithic (Iron Gate), the results of stable isotopic level reveals a $\delta^{13}C$ from –20 to –23%, but in the rapids part of the Dnieper vale, the isotopic ratio $\delta^{13}C$ is more negative (–23.71 to –24.1%) (Potyekhina et al., 2014: 16). This indicates the greater significance of fishing in the life of people starting from the Late Mesolithic and its ultimate development in the Early Neolithic.

Conclusions

The specific natural characteristics of the Dnieper Rapids region consisted of a unique landscape and hydrological aspects that differed contrastingly from neighboring territories. First, one can see it in the great number of island elements within the Dnieper riverbed that were actively used by ancient people, who understood their economic importance. As a result, it made possible the creation of an original settlement strategy with systematic and cyclical seasonal movements within the region. The global climate warming and moistening together with a developed river and ravine-gully system of the Dnieper Rapids region, and natural borders created unique conditions that facilitated development, growth, and biodiversity. It is likely that the Dnieper Rapids region was a kind of "forest-steppe oasis"—a refugium with the features of various geographic zones. The forest flora could have been concentrated here, surviving under paleoclimatic conditions that would not have existed in neighboring territories. After the overall improvement of conditions, the plants could be extended to those neighboring territories. During the warmest and moistest period of Holocene, the Atlantic, humid and mesophilic forests developed here, as well as within river vales and likely at watersheds. Different paleoecological situations in the Dnieper Rapids region and the Azov region caused the radical differences in the economic activities within the same culture: the existence of recovering economy (cattle breeding) was a typical feature for the Azov region, while the population of the Dnieper Rapids region had an appropriation economy based on fishing. As it turned out, under certain natural-ecological conditions, especially in sections with higher concentrations of plant and animal resources (and the Dnieper Rapids region was a case in point), the traditional methods of obtaining food provided social stability equal to that of recovering economy forms, or even more effective. The so-called "reservoir effect" arising from a high level of freshwater fish and coastal animal consumption is connected with the first half of the Neolithic and almost missing in the Late Neolithic and transitional Neolithic-Chalcolithic age. This can be explained by the presence of cattle breeding in the Late Neolithic-Chalcolithic around the rapids. We believe it could be connected with the arrival in the Dnieper Rapids region of the bearers of the Azov-Dnieper Culture bringing developed farming, which provoked major changes in the economy together with increased population density. A similar picture seems to correspond to the concept of Eastern Neolithization of Ukraine. The manufacturing resources of the region are not evenly distributed. Therefore, for example, the lack of quality flint beds caused the widespread use of local rocks (magnesite, granite, amphibolite, migmatite, quartz, etc.) and bones in tool manufacturing. The sum of the above-mentioned characteristics became the basis for a hypothesis about the fact that simply ecological differences have had a significant or even determining influence on the individuality of material culture and economy of the rapids region population within one cultural tradition.

References

Artyushenko, A.T., Pashkevych, H.A., Paryshkura, S.Y., and Kareva, E.V., 1973. Paleobotanicheskaya kharakteristika opornykh razrezov chetvertichnykh (antropogenovykh) otlozheniy sredney i yuzhnoy chasti Ukrainyi [*Paleobotanical Characteristics of the Supporting Sections of Quaternary (Anthropogenic) Sediments of the Middle and Southern Part of Ukraine*]. Naukova Dumka, Kyiv. (In Russian

Bezus'ko, L.H., 2006. Palinolohichna kharakterystyka vidkladiv neolitu ta eneolitu bahatosharovoho poselennya Kam''yana Mohyla (Zaporiz'ka oblast', Ukrayina) [Palynological characteristics of the Neolithic and Aneolithic deposits of the multi-layered settlement Kamyana Mohyla (Zaporizhzhia oblast, Ukraine)]. Naukovi zapysky natsional'noho universytetu Kyyevo-Mohylyans'ka Akademiya [*Scientific Notes of the National University of Kyiv-Mohyla Academy*] 54: 11–19. (In Ukrainian)

Demchenko, O.V., 2014. Paleoheohrafycheskye uslovyya obytanyya pozdnemezolytycheskoho – neolytycheskoho naselenyya Dneprovskoho Nadporozh'ya [Paleogeographic conditions of the Late Mesolithic-Neolithic population of the Dnieper Rapids Region]. *Istorychni etyudy* [*Historical Sketches*] 4: 189–193. (In Russian)

Demchenko, O.V., 2015. Rekonstruktsiya pizn'omezolitychnoyi – neolitychnoyi istoriyi Dniprovs'koho Nadporizhzhya. Paleoekolohichnyy pidkhid [Reconstruction of the late Mesolithic-Neolithic history of the Dnieper Rapids Region. Paleoecological approach]. *Zapysky istorychnoho fakul'tetu etyudy* [*Notes of the Faculty of History*] 26: 37–57. (In Ukrainian)

Demchenko, O.V., 2016. Prirodnoe okruzhenie i adaptivnaya strategiya naseleniya Dneprovskogo Nadporozh'ya v pozdnem mezolite-neolite [Natural environment and adaptive strategy of the population of the Dnieper Rapids Region in the later Mesolithic-Neolithic period]. *Stratum Plus* 2: 227–244. (In Russian)

Kotova, N.S., 2006. Rannee zhyvotnovodstvo stepnoho Podneprov'ya y Pryazov'ya [Early livestock farming of the steppe Dnieper and Azov Sea]. *Materialy ta doslidzhennya z arkheolohiyi Skhidnoyi Ukrayiny* [*Materials and Research on Archaeology of Eastern Ukraine*] 4: 61–74. (In Russian)

Nikitenko, I.S., 2012. Pro syrovynu tal'kovykh vyrobiv doby neolitu z Dniprovs'koho Nadporizhzhya [On the raw materials of the Neolithic antique tales from the Dnieper Rapids Region]. *Naukovyy visnyk Natsional'noho hirnychoho universytetu* [*Scientific Bulletin of the National Mining University*] 5: 12–17. (In Ukrainian)

Nikitenko, I.S., and Kutsevol, M.L., 2016. On raw materials of Neolithic stone hoes from the Dnieper Rapids area. *Scientific Bulletin of National Mining University* 4(154): 5–12.

Nuzhnyiy, D.Yu., 1989. O svoeobrazii pamyatnikov kukrekskoy kulturnoy traditsii v Dneprovskom Nadporozhe [On the originality of the monuments of the Kukrak culture tradition in the Dniprovsky Nadporozhye]. Kamennyiy vek: pamyatniki, metodika, problemyi [*Stone Age: Monuments, Methods, Problems*]: 145–154. (In Russian)

Potyekhina, I.D., Lilli, M., Bad, Ch., 2014. Analiz paleodiyety stabil'nykh izotopiv u populyatsiyakh epipaleolitu – eneolitu Seredn'oho ta Nyzhn'oho Podniprov''ya [Paleodietary analysis of stable isotopes in populations of the Epipaleolithic-Eneolithic of the Middle and Lower Dnieper valley]. Istorychna antropolohiya ta bioarkheolohiya Ukrayiny [*Historical Anthropology and Bioarchaeology of Ukraine*] 1: 5–20. (In Ukrainian)

Zhuravl'ov, O.P., and Kotova, O.P., 1996. Tvarynnytstvo neolitychnoho naselennya Ukrayiny [Animal husbandry of the Neolithic population of Ukraine]. *Arkheolohiya* [*Archaeology*] 2: 3–17. (In Ukrainian)

MONITORING OF CLIMATE OSCILLATIONS IN THE MEDITERRANEAN SEA OVER THE LAST TWO MILLENNIA USING PLANKTONIC FORAMINIFERA

Dentici, M.P. [1], Lirer, F. [2], Bonomo, S. [3,4], Bellucci, L. [5], Cascella, A. [6], Caruso, A. [7], Lubritto, C. [8], and Pappone, G. [9]

[1,9] Università degli Studi "Parthenope" di Napoli, Dipartimento di Scienze per l'Ambiente, Isola C4 Centro Direzionale, 80143, Napoli, Italy
[1] mariapaola.dentici@uniparthenope.it
[9] gerardo.pappone@uniparthenope.it
[2,3] Istituto per l'Ambiente Marino Costiero (IAMC) - CNR, Calata Porta di Massa, 80133, Napoli, Italy
[2] fabrizio.lirer@iamc.cnr.it
[3,4] sergio.bonomo@cnr.it
[4] Istituto di Biomedicina ed Immunologia Molecolare "Alberto Monroy" (IBIM), Consiglio Nazionale delle Ricerche, Via Ugo La Malfa 153, 90146, Palermo, Italy"
[5] Istituto Scienze Marine, ISMAR– CNR, Consiglio Nazionale delle Ricerche, Via Gobetti 101, 40129, Bologna, Italy
luca.bellucci@ismar.cnr.it
[6] Istituto Nazionale di Geofisica e Vulcanologia, Via della Faggiola 32, 52126 Pisa, Italy
eantonio.cascella@ingv.it
[7] Università di Palermo, DiSTeM Via Archirafi 20-22, 90123, Palermo, Italy
antonio.caruso@unipa.it
[8] Dipartimento di Scienze e Tecnologie Ambientali Biologiche e Farmaceutiche (DiSTABiF), Seconda Università di Napoli, Via Vivaldi 47, 81100, Caserta, Italy
carmine.lubritto@unicampania.it

Keywords: Planktonic foraminifera, stable isotopes, decennial-scale climatic variability, Sicily Channel, Holocene

Introduction

This study is part of the NextData project and the main goals are: 1) the paleoclimatic reconstruction of the last millennia in the Mediterranean Sea; 2) the biotic and abiotic characterization of possible paleoanalogs of the present day climatic conditions; 3) the reconstruction of the sea surface temperature (SST) from marine fossil archives over the last two millennia using planktonic foraminiferal and stable isotopes oscillations. High-resolution studies of the climate of the last 2000 years can be used to examine temporal and spatial patterns of natural climate variations, that are roughly similar to those of today (Fritz et al., 2000). The last two millennia contain in fact marked regional to global-scale variations in temperature and are an important 'test bed' for understanding the climate system and improved projections of future climate (Alley et al., 2007; Hegerl et al., 2011; Mann et al., 2005). For these reasons, several authors have studied planktonic foraminiferal climatic sensitivity of the last two millennia in different parts of the Mediterranean Sea. Planktonic foraminifera are the most commonly used proxies for paleoceanographic and paleoclimatic sea-surface reconstruction (Capotondi et al., 2016) because their distribution and abundance are strongly linked to surface-waters properties (Kucera, 2007). Thus, the statistical analysis of foraminiferal assemblages can provide a reliable and detailed record for paleoclimatic reconstructions (Capotondi et al., 1999). The presence of time-spaced Quaternary tephra beds in Mediterranean successions represent an additional, independent tool for dating and correlating marine sedimentary archives (Lirer et al., 2014 and references therein). In this study, we present a new high-resolution quantitative study of planktonic foraminiferal distribution throughout 1400 yr from the composite core SW104_ND2-ND2 collected from the Sicily Channel continental shelf, central Mediterranean Sea.

Methodology

The present study was focused on the composite marine sequence of two cores (SW 104_ ND2 and ND2) recovered at 89 m water depths in the eastern part of Sicily Channel, during the NextData 2013 oceanographic expedition onboard of R/V URANIA-CNR (Fig. 1).

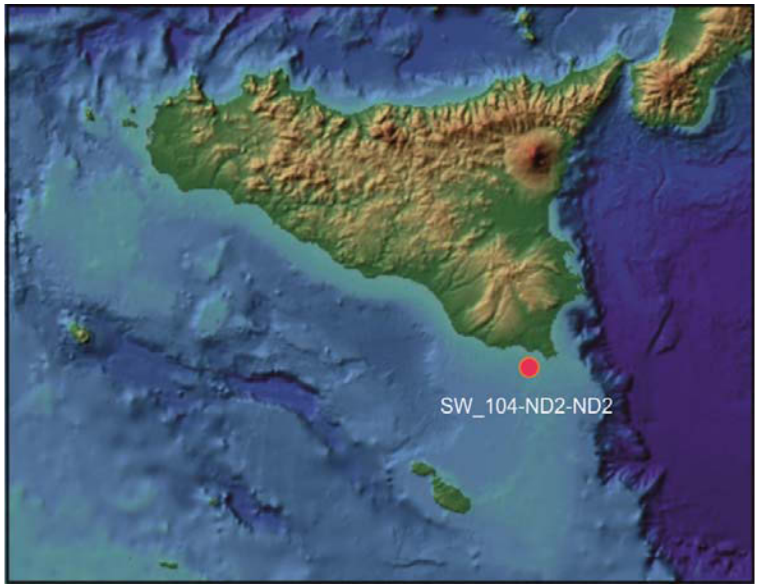


Figure 1. Location of the studied cores.

The first one is 117 cmbsf length, and the second is 452 cmbsf length. The composite core was sampled every centimeter for the first 117 cmbsf and every 2 cm back to the base of the core. Micropaleontological, AMS 14C radiocarbon analysis and radionuclides ^{210}Pb and ^{137}Cs analysis were used to obtain the age model of the studied interval. Micropaleontological analyses consisted of qualitative and quantitative characterization of the planktonic foraminiferal assemblages, in the size fraction greater than 90 µm. The correlation between the two cores (SW 104_ ND2 and ND2) is based on the planktonic foraminiferal distribution patterns. Finally, a composite record of 463 cm was obtained.

Results

The calibrated AMS ^{14}C ages, together with planktonic foraminiferal fluctuations, were used to develop an age model of the studied interval. Based on the radiometric ages, the studied marine record covers the last 1400 yr, thus the high sedimentation rate provides an excellent dataset to reconstruct Mediterranean climatic variability. Twenty planktonic foraminiferal species were recognized and grouped in relation to their specific environmental characteristics according to the purpose of this study. In particular, the planktonic foraminiferal paleoclimate curve was constructed following Capotondi et al. (2016) to document the main climatic oscillations recognized in literature over the last 1400 yr in the central Mediterranean Sea. It represents the algebraic sum of warm-water species percentages (expressed as positive values) and cold-water species percentages (expressed as negative values), based on ecological preferences and modern habitat characteristics. In addition, the herbivorous/carnivorous ratio has permitted us to reconstruct the trophism of the study area. The paleoclimatic curve shows an alternation of cool and warmer periods, and the abundance fluctuations of *Globorotalia truncatulinoides* and *G. inflata* reflect sunspot variabilities. In order to obtain additional age control points, the obtained curves were also tuned with the Total Solar Irradiation (TSI) of

Steinhilber et al. (2012) and with the paleoclimatic curve of the Santa Barbara Basin (Fisler et al., 2008) (Fig. 2).

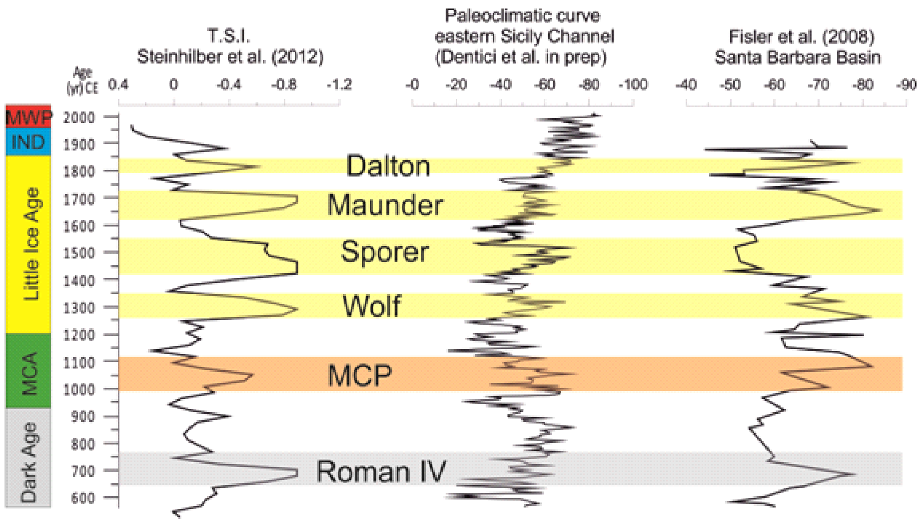


Figure 2. Paleoclimatic curve and comparisons

Several climatic periods were identified (i.e., the Dark Age, the Medieval Cold Period, the Medieval Warm Period, and the Little Ice Age, with the Wolf, Spörer, Maunder and Dalton cold events). In detail, the Dark Age is the oldest interval recognized in the studied core. The first phase, from the base of the core to ~650 CE, is characterized by warmer conditions well documented by high frequencies of *G. ruber* white variety (Fig. 3). At ca. 650 CE, the negative trend of the paleoclimatic curve associated with a net turnover between carnivorous and herbivorous-opportunistic planktonic foraminiferal species, allows us to identify a marked cooling event, chronologically related to the Roman IV cold period (Figs. 2 and 3). The Medieval Climate Anomaly is marked by a progressive increase of the carnivorous planktonic foraminiferal species versus the herbivorous-opportunistic species that testify to generally warm conditions (Fig. 3).

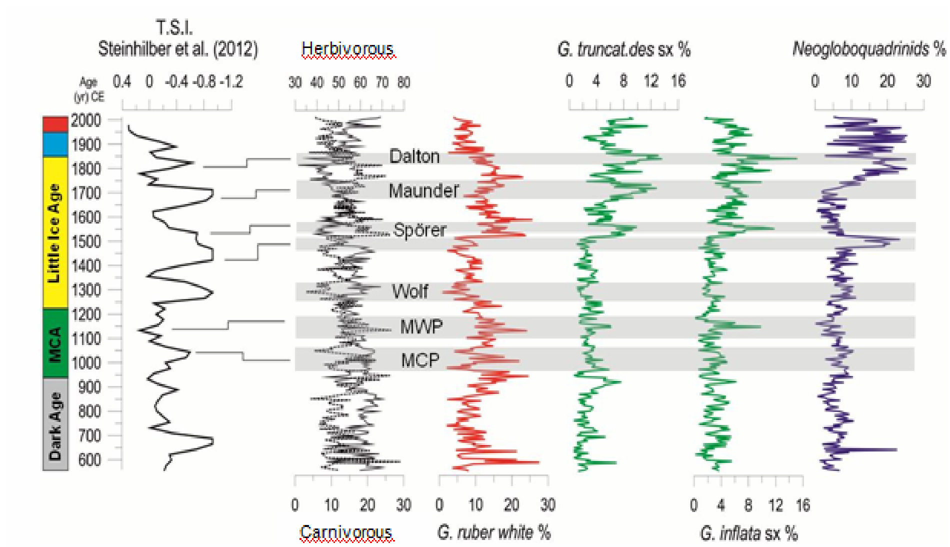


Figure 3. Planktonic foraminifera paleoclimatic proxies

Deteriorating climate conditions are, however, documented from 1000 to 1150 CE, when Neogloboquadrinids, considered as cold planktonic taxa, increased in abundance according to the paleoclimatic curve shift vs cooler conditions (Figs. 2 and 3). From 1150 CE, a further increase in the percentage of the warm water taxon G. ruber, testify instead to an important 'warmest' event corresponding to the well-known Medieval Warm Period (MWP) (Fig. 2).

The Little Ice Age starts at approximately 1200 CE and in the study record is well documented by a turnover from carnivorous to herbivorous-opportunistic planktonic foraminiferal species, testifying a net change in nutrient availability in the water column (Fig. 3). In addition, three significant shifts of the planktonic foraminiferal paleoclimatic curve vs cooler conditions, allowed us to identify the Wolf, Spörer and Maunder solar minima (Fig. 2).

Conclusions

The planktonic foraminiferal abundance curves allow the reconstruction of the climatic oscillations characterizing the last 1400 years of the Mediterranean history. The high sedimentation rate and the good response of the planktonic foraminifera species have allowed us to consider the Sicily-Malta continental platform an excellent marine area for high resolved climatic reconstruction of the last 1400 years.

References

Alley, R.B, Berntsen, T., Bindoff, N.L., Chen, Z., Chidthaisong, A., Friedlingstein, P., Gregory, J.M,, Hegerl, G.C., Heimann, M., Hewitson, B., Hoskins, B.J., Joos, F., Jouzel, J., Kattsov, V., Lohmann, U., Manning, M., Matsuno, T., Molina, M., Nicholls, N., Overpeck, J., Qin, D., Raga, G., Ramaswamy, V., Ren, J., Rusticucci, M., Solomon, S., Somerville, R., Stocker, T.F., Stott, P.A., Stouffer, R.J., Whetton, P., Wood, R.A., and Wratt, D., 2007. Summary for policymakers. In: S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller (Eds.), *Climate Change 2007: The Physical Science Basis; Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge.

Capotondi, L., Borsetti, A.M., and Morigi, C., 1999. Foraminiferal ecozones, a high-resolution proxy for the late Quaternary biochronology in the Central Mediterranean Sea. *Marine Geology* 153(1–4): 253–274.

Capotondi, L., Girone, A., Lirer, F., Bergami, C., Verducci, M., Vallefuoco, M., Afferri, A., Ferraro, L., Pelosi, N., and De Lange, G.J., 2016. Central-Mediterranean Mid-Pleistocene paleoclimatic variability and its association with global climate. *Palaeogeography, Palaeoclimatology, and Palaeoecology* 442: 72–83.

Fisler, J., and Hendy, I.L., 2008. California Current System response to late Holocene climate cooling in southern California. *Geophysical Research Letters* 35, L09702. doi:10.1029/2008GL033902

Fritz, S.F., Ito, E., Yu, Z., Laird, K.R., and Engstrom, D.R., 2000. Hydrologic variations in the Northern Great Plains During the Last Two Millennia. *Papers in the Earth and Atmospheric Sciences* 41.

Hegerl, G., Zwiers, F., and Tebaldi, C., 2011. Patterns of change: whose fingerprint is seen in global warming? *Environmental Research Letters* 6(4): 044025.

Kucera, M., 2007. Planktonic foraminifera as tracers of past oceanic environments. In: C. Hillaire-Marcel, and A. de Vernal (Eds.), *Proxies in Late Cenozoic Paleoceanography*. Developments in Marine Geology 1. Elsevier, Amsterdam, pp. 213–262.

Lirer, F., Sprovieri, M., Vallefuoco, M., Ferraro, L., Pelosi, N., Giordano, L., and Capotondi, L., 2014. Planktonic foraminifera as bio-indiators for monitoring the climatic changes that have occurred over the past 2000 years in the southeastern Tyrrhenian Sea. *Integrative Zoology* 9(2): 542–554.

Mann, M.E., Rutherford, S., Wahl, E., and Ammann, C., 2005. Testing the fidelity of methods used in proxy-based reconstructions of past climate. *Journal of Climate* 18: 4097–4107.

Steinhilber, F., Abreu, J.A, Beer, J., Brunner, I., Christl, M., Fischer, H., Heikkilä, U., Kubik, P.W., Mann, M., McCracken, K.G., Miller, H., Miyahara, H., Oerter, H., and Wilhelms, F., 2012. 9,400 years of cosmic radiation and solar activity from ice cores and tree rings. *Proceedings of the National Academy of Sciences of the United States of America* 109(16): 5967–5971.

.

GLOBAL GEOLOGICAL PROCESSES IN THE CASPIAN-MEDITERRANEAN REGION DURING THE MIOCENE-PLEISTOCENE

Esin, N.V. [1], *Esin, N.I.*[2], *and Yanko-Hombach, V.*[3,4]

[1, 2] Shirshov Institute of Oceanology, Russian Academy of Sciences, 1-g Prostornaya Str., Gelendzhik, Krasnodar region, Russia 353467
[1] ovos_oos@mail.ru
[2] esinnik@rambler.ru
[3] Odessa I.I. Mechnikov National University, 2 Dvoryanskaya Str., Odessa 65082, Ukraine.
valyan@onu.edu.ua
[4] Avalon Institute of Applied Science, 976 Elgin Ave., Winnipeg, MB, Canada R3E 1B4
valyan@avalon-institute.org

Keywords: Messinian Salinity Crisis, Paratethys seas, Manych, Bosporus, Dardanelles and Gibraltar straits

Introduction

In the Miocene, during the time interval from 12 to 5 million years ago, global hydrodynamic and lithodynamic processes occurred in the Caspian-Mediterranean region, the consequences of which were generally positive for the development of modern civilization. These include several time-shifted processes of formation of the Paratethys seas and their sudden disappearance; the formation of the Bosporus, Dardanelles, and Manych straits; evaporation of water in the Mediterranean Sea and its secondary infilling with ocean water; the formation of the Gibraltar Strait; vertical movements of the earth's crust caused by changes in pressure on the bottom of the Mediterranean Sea; and the formation of the deep-sea basin of the Black Sea. All these processes were interrelated and exerted a certain influence on each other. In the 1970s, a mathematical model that described the main changes in the Mediterranean Sea and the formation of the Gibraltar Strait during the Messinian Salinity Crisis was developed (Yesin [Esin] et al., 1986, 1987). In recent years, a model describing the flow of freshwater from the Black and Caspian seas into the Mediterranean based on new geological material has been proposed (Garcia-Castellanos et al., 2009). A model for the formation and subsequent disappearance of the Paratethys seas was also recently presented (Esin et al., 2016). In the present report, these processes are shown in their geologic sequence, and their mutual influence is considered, taking into account the action of physical laws.

The dynamics of the level of the Paratethys seas, the formation of the Bosporus, Dardanelles, and Manych straits

The first Sarmatian Sea was formed in a vast depression around the Black and Caspian seas. The exit of water from this depression was closed by a mountain range with a height of about +120 m relative to the current level of the ocean. During the melting of the glaciers, the depression was filled by water to the minimum elevation of the mountain ridge. In the process of further water flow into the sea, water began to pour over the mountain into the Mediterranean Sea. The stream of water formed the bed of a river, which crossed the mountain range. The elevation of the river bed actually controlled the water level in the Paratethys seas.

Note, that only fresh water came into the Paratethys seas. Calculations show that if salty water from the ocean had penetrated into the depression, then its bottom would have been covered by a salt layer with a thickness of hundreds of meters by now.

The Messinian Salinity Crisis in the Mediterranean Sea

The Mediterranean Sea is a basin with a large negative value for its freshwater balance. At present, it is –1700 km^3/year. The sea was being replenished with water from the Atlantic Ocean. Before the Messinian crisis, water flowed into the Mediterranean Sea through straits in the north of Africa. But approximately 5.6 million years ago, these straits were covered with sediment and ceased to exist. According to modern concepts, the drying of the sea began 5.6 million years ago and ended 5.33 million years ago (Garcia-Castellanos et al., 2009), then the sea was refilled with Atlantic water through the new Strait of Gibraltar.

A powerful flow of freshwater in the Dardanelles Strait with the penetration of the Akchagyl fauna (3.3–1.8 million years ago) was investigated (Taner, 1982). This discovery was difficult to explain because it contradicted other geologic evidence. But in fact it is not mysterious. By the time of the Akchagyl transgression, the straits of the Bosporus and Dardanelles already existed, and through them Black Sea water freely flowed into the Mediterranean Sea. In order for this to happen, it was not necessary to raise the level of the Caspian Sea to +100 m. Water could flow and at a lower level. By the results of our calculations, the level of this sea could be at levels from +50 to +80 meters.

Based on results from drilling and seismo-acoustic investigation in the Gibraltar Strait, Garcia-Castellanos et al. (2009) presented a very interesting conclusion about the extremely rapid filling of the Mediterranean Sea by ocean water after the Messinian Salinity Crisis. According to their ideas, the erosion of the bottom of the strait could have reached 0.4 m per day, and the rate of rising in the Mediterranean Sea level could have been 10 m per day. A drawback in the calculations is as follows: if the current level of the Mediterranean Sea had quickly dropped by 1500 meters, then flow of water through the cross section of the Gibraltar Strait of 10000 m x 200 m would have poured from the ocean into the Mediterranean Sea, which could raise the sea level at a rate of up to 10 m per day. But the process was really different. At first, water filled the Mediterranean Sea from two rivers, the sections of which are represented in Fig. 1.

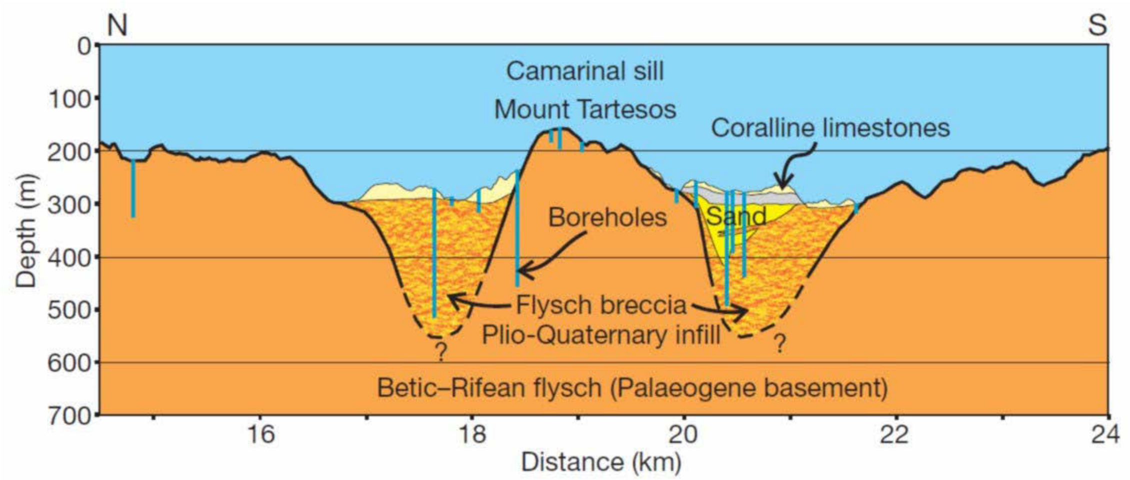


Figure 1. Seismo-acoustic section across the Strait of Gibraltar. Readily visible are the channels of the two rivers and the general rectilinear section through the strait.

Then, the width of the strait began to increase due to the appearance of a rectangular section of the strait. At this stage, the flow of water in the strait increased sharply, and the water levels in the ocean and in the sea could be equalized. At this point, the unilateral flow stopped: when the depth of the strait was not 200 m (as now) but, for example, 50 m. From the theory of "rapid" filling of the sea follows that a layer of evaporites up to 3 km thick could not have formed in a few months. This requires hundreds of thousands of years of water evaporation. Consequently, if the theory of the "rapid" filling of the Mediterranean is recognized as correct, then it should be assumed that a layer of evaporites was formed during the slow closure of straits passing through northern Africa.

The mutual influence of the Mediterranean, Black, Caspian, and ancient Paratethys seas on each other

Some interaction between the Paratethys and Mediterranean seas began about 10 million years ago, when the level of the Sarmatian Sea rose above the mountain between the Black and Mediterranean basins and "fresh" water flowed into the Mediterranean Sea. At this time, the erosion process began, as a result of which the straits of the Bosporus and Dardanelles were formed. The Mediterranean Sea actively assisted this process. Its level performed periodic glacioeustatic fluctuations with an amplitude of about 100 m. Due to this, the basis of erosion was periodically increased, which initiated the process of deepening the bottom of the straits, i.e., the process of erosion in the straits.

When the bottom of the straits fell below the transgressive level of the ocean, the flow of freshwater in the strait increased, approximately, from 100 to 200 km^3/year and more. With this magnitude of freshwater inflow in the eastern part of the Aegean Sea, there was a strong freshening of water and a freshwater fauna appeared.

During the Messinian Salinity Crisis, a considerable amount of freshwater flowed into the eastern basin, and the area of the formed lake varied from 100,000 to 200,000 km^2.

Hypothesis on the mechanism of the deep Black Sea basin formation

Many geologists studying the geology of the Black Sea conclude that the Black Sea basin was formed about 5 million years ago (Muratov, 1975). Before that, the sea was shallow. In our opinion, the creation of a deep-water basin is connected with the Messinian salt crisis of the Mediterranean Sea. During the drying of the sea, the pressure on the bottom decreased, and it began to rise. At the same time, the bottom dragged the magma from neighboring areas from all directions. This created a negative pressure, which led to the immersion of the coast. This pressure dragged the earth's crust beyond the sea down. Thus, a force directed downward operated on the earth's crust. This force, together with the force of gravity, overcame the frictional force, and in the present territory of the Black Sea, there was a rapid slide down a huge mass of precipitation (crustal depression). Precipitation fell several kilometers, creating a deep basin with area of about 400 thousand km^2. Thus, we hypothesize that, in this process, an important role was played by the forces created during the rising of the Mediterranean Sea bottom.

Conclusions

This article analyzes the impact of the Paratethys seas, and later, the Black and Caspian seas, on the evolution of the Mediterranean Sea. It is shown that these seas supplied freshwater to the Mediterranean Sea from the middle Miocene to the Holocene. During the Messinian Salinity Crisis of the Mediterranean Sea, in the eastern basin of this sea, there was a lake of freshened water with an area of 100 to 200 thousand km^2. The results obtained with regard to freshwater intake are in full agreement with the conclusions of the article by Çağatay et al. (2006), which was based on evidence from geologic materials. We propose that local rivers could not make a significant contribution to the water freshening in the eastern basin of the Mediterranean Sea. At all stages of the development of the Mediterranean Sea, the main contribution to freshening was made by waters entering this sea from the Paratethys seas. It should also be noted that only freshwater flowed into the Paratethys seas (beginning from the formation of the closed Sarmatian Sea). If water from the oceans were to enter them, a layer of salt would have formed on the bottom of the Paratethys seas, as was the case in the Mediterranean Sea during the Messinian Salinity Crisis.

In our opinion, the deep-water basin of the Black Sea was formed during the Messinian Salinity Crisis as a reaction to vertical movements of the earth's crust. The report also shows the mechanism of strait formation as well as the mechanism for the formation of the deep-sea basin of the Black Sea.

Acknowledgments

This study was funded by RFBR according to the research project № 16-35-00441 mol_a. This is a contribution to the IGCP 610 project "From the Caspian to Mediterranean: Environmental change and human response during the Quaternary."

References

Çağatay, M.N., Görür, N., Flecker, R., Sakınç, M., Tünoğlu, C., Ellam, R., Krijgsman, W., Vincent, S., and Dikbaş, A., 2006. Paratethyan–Mediterranean connectivity in the Sea of Marmara region (NW Turkey) during the Messinian. *Sedimentary Geology* 188–189: 171–187.

Esin, N.V., Yanko-Hombach, V., and Esin, N.I., 2016. Evolutionary mechanisms of the Paratethys Sea and its separation into the Black Sea and Caspian Sea. Quaternary International DOI: 10.1016/j.quaint.2016.06.019

Garcia-Castellanos, D., Estrada, F., Jiménez-Munt, I., Gorini, C., Fernàndez, M., Vergès, J., and De Vicente, R., 2009. Catastrophic flood of the Mediterranean after the Messinian salinity crisis. Nature 462(7274): 778–781.

Muratov, M.V., 1975. Osnovnye etapy istorii razvitija oblastei, okruzhaushih Chernoe more [The main stages of the development history of the areas surrounding the Black Sea]. In *Zemnaia kora i istoria razvitia Chernomorskoi vpadiny* [*Earth's Crust and History of Development of the Black Sea Basin*], pp. 125–131. Nauka, Moscow. (In Russian)

Svitoch, A.A., 2014. *Bol'shoi Kaspii: stroenie i istoriia razvitiia* [*The Great Caspian Sea: Structure and History*]. Moskovskii gosudarstvennyi universitet imeni M.V. Lomonosova, Moscow. (In Russian)

Taner, G., 1982. Die molluskenfauna und pliorane stratigraphie das halbinsel gelibolu [The mollusk fauna and pliorane stratigraphy of the Gelibolu peninsula]. *Communications de la faculté des sciences de L'Université d'Ankara, série C1, Géologie* 25: 1–27. (In German)

Yesin (Esin), N.V., Dmitriyev, V.A., Shimkus, K.M., and Ovchinnikov, I.M., 1986. A model for the messinian events in the Mediterranean sea. *International Geology Review* 28(1): 10–14. DOI:10.1080/00206818609466245

Yesin (Esin), N.V., and Dmitriyev, V.A., 1987. On the possible mechanism of formation of the Messinian evaporites in the Mediterranean Sea. *International Geology Review* 29(3): 258–263. DOI: 10.1080/00206818709466143

STUDIES ON THE DYNAMICS OF THE BLACK SEA COAST AND VERTICAL MOVEMENTS OF THE SHELF IN THE LATE PLEISTOCENE-HOLOCENE

Esin, N.I. [1], Ocherednik, V. [2], and Esin, N.V. [3]

[1, 2, 3] Shirshov Institute of Oceanology, Russian Academy of Sciences, 1-g Prostornaya Str., Gelendzhik, Krasnodar region, Russia 353467
[1]esinnik@rambler.ru
[2] poekperementarium@gmail.com
[3] ovos_oos@mail.ru,

Keywords: vertical movements of the earth's crust, local changes in Black Sea level, reconstruction, mathematical modeling

This work is a complex of theoretical and model studies of the dynamics of vertical movements of the Black Sea coast and individual shelf sections in the late Pleistocene-Holocene. The choice of research subject is conditioned by the desire to explain the numerous contradictions that have arisen in the literature devoted to the reconstruction of the Black Sea level on the basis of geologic research data. The authors of this work hold the opinion that the regional curves of sea-level variation are not correct due to the presence of multidirectional tectonic deformations in various structural zones. A number of works by Soviet, Russian, and foreign researchers, as well as current satellite altimetry data (for example, Blagovolin, 1975; Glazyrin, 2013) testifies to the significant velocities of vertical movements of the earth's crust (relative to the velocity of eustatic sea-level changes) and their significant variability depending upon geographic location. In this regard, according to the age and hypsometric position of sea-level indicators, it is possible to construct only local curves that reflect the evolution of the sea level relative to a particular section of the coast or shelf. About ten local curves of the Black Sea level in the Holocene are known in the literature. There is also an extensive set of data on the determination of the age and position of sea level with geographic reference (for example, Balabanov, 2009), on which it is possible to construct additional local curves.

The method of dividing the local sea-level curves into eustatic and tectonic components was developed within the framework of dissertation research by N.I. Esin (2014). The technique makes it possible to reveal the dynamics of vertical movements of the earth's crustal blocks, which has not been studied before. The report presents the application of this technique to data on local changes in Black Sea level during the Holocene. The mathematical model of abrasion, developed in the 60-80s in the P.P. Shirshov Institute of Oceanology of the USSR Academy of Sciences (Esin et al., 1980) was used to reveal the dynamics of vertical tectonic movements in the Late Pleistocene. The model makes it possible to reconstruct local changes in sea level from data on the forms of transverse profiles of bedrock and shelf rocks, subject to the availability of dated terraces. The above methods of separating eustatics from tectonics are applied to the curves of local changes in the level of the Black Sea obtained in this way.

The evaluation of the effect of vertical movements of the earth's crust on changes in relative sea level is of interest for understanding the complex mechanism of the formation of the sea-level regimes of the inland seas. Study of the dynamics of neotectonic movements along the Black Sea coast is necessary to predict their future variability. In addition to expanding fundamental knowledge of the patterns of development of the Black Sea coast, the results can be used to develop recommendations for improving the strategy of economic development and methods of protecting the coast.

Acknowledgment

The reported study was funded by RFBR according to research project № 16-35-00441 mol_a.

References

Balabanov, I.P., 2009. *Paleogeograficheskie predposylki formirovanija sovremennykh prirodnykh uslovij i dolgosrochnyj prognoz razvitija golotsenovykh terras chernomorskogo poberezh'ja Kavkaza* [*Paleogeographic Prerequisites for the Formation of Modern Natural Conditions and a Long-term Forecast for the Development of the Holocene Terraces of the Black Sea Coast of the Caucasus*]. Moscow-Vladivostok: Dal'nauka. (In Russian)

Blagovolin, N.S., 1975. Morfostruktury i sovremennye vertikal'nye dvizhenija zemnoj kory [Morphostructure and modern vertical movements of the earth's crust]. In: Y.D. Bulanje, M.V. Muratov, S.I. Subbotin, and B.K. Balavadze (Eds.), *Zemnaja kora i istoriya razvitija chernomorskoy vpadiny* [*Earth's Crust and History of Development of the Black Sea Basin*], pp. 7–45. Nauka, Moscow. (In Russian)

Glazyrin, E.A., 2013. Sostoyanie nedr pribrezhno-shel'fovoy zony Azovo-Chernomorskogo i Kaspijskogo bassejnov Rossiyskoy Federatsii [The subsurface status of the coastal-shelf zone of the Azov-Black Sea and Caspian Sea basins in Russian Federation]. In: E.A. Glazyrin, A.A. Marfin, and E.G. Gross, *Informacionnyi bjulleten', Gosudarstvenny nauchny tsentr FGUGP "JUZHMORGEOLOGIYA."* Gelendzhik. (In Russian)

Esin, N.I., 2014. *Dinamika urovnya Chjornogo morja v poslednie 20 tysjach let* [*The dynamic of the Black Sea level during the last 20,000 years*]. PhD thesis. P.P. Shirshov Institute of Oceanology, Russian Academy of Sciences, Moscow. http://www.ocean.ru/disser/index.php/dissertatsii.

INTEGRATING HIGH RESOLUTION MID-PLEISTOCENE SEA SURFACE TEMPERATURE AND PRODUCTIVITY ESTIMATES FROM ALKENONE PROXIES WITH MARINE AND TERRESTRIAL CLIMATE SIGNALS

Herbert, T.D.[1], Bassinot, F.[2], Bertini, A.[3], Combourieu Nebut, N.[4], Girone, A.[5], Maiorano, P. [6], Marino, M. [7], Nomade, S.[8], and Toti, F. [9]

[1] Brown University, Dept. of Earth, Environmental and Planetary Sciences, Providence RI 02912 U.S.A.
timothy_herbert@brown.edu
[2,8] Laboratoire des Sciences du Climat et de l'Environnement, Gif-sur-Yvette, France
[2] franck.bassinot@lsce.ipsl.fr
[8] sebastien.nomade@lsce.ipsl.fr
[3] Dept. Earth Sciences, Florence University, Florence, Italy
[3] adele.bertini@unifi.it
[9] francesco.toti@unifi.it
[4] HNHP UMR 7194 CNRS, Muséum National d'Histoire Naturelle, Paris, France
nathalie.nebout-combourieu@mnhn.fr
[5,7] Dept. Earth and Geoenvironmental Sciences, Bari University Aldo Moro, Bari, Italy
[5] angela.girone@uniba.it
[7] maria.marino@uniba.it

Keywords: paleotemperatures, organic geochemistry, orbital cycles, Mediterranean paleohydrology

Introduction

We present the first continuous alkenone-based reconstruction of surface ocean conditions in the Mediterranean for the mid-Pleistocene time interval (Montalbano Jonico section, southern Italy). Previous work has demonstrated that alkenone unsaturation parameters recorded by outcropping hemipelagic marine sediments faithfully record Mediterranean conditions in the Plio-Pleistocene (Cleaveland and Herbert, 2009; Herbert et al., 2014).

Methods

High resolution (0.5–1 ka) organic geochemical analyses were carried out at Brown University. Lipid biomarkers were extracted from 3–5 g of dried sediment using a Dionex Accelerated Solvent Extraction system. Alkenone parameters ($U^{k'}_{37}$ index, C_{37}total index, ratio of C_{37}:C_{38} alkenones) were quantified using gas chromatography with an FID detector. All samples yielded measureable quantities of alkenones.

Results

The $U^{k'}_{37}$ unsaturation index records large (4–6°C) swings in sea surface temperature (SST) on a glacial to interglacial basis. Interglacial temperatures approximate Holocene conditions, in contrast to early Pleistocene interglacials, which were significantly warmer than today. Two independent alkenone-derived proxies for haptophyte biological activity record changes in surface fertility, which is highly correlated to the northern hemisphere precessional index. We interpret these changes as driven by alternations in estuarine vs. lagoonal circulation in the basin, forced by cycles in wet vs. arid conditions in northern Africa and southern Europe. The productivity proxies form the basis for tuning the age model of the Montalbano Jonico section to the precessional index. MIS 19 is reconstructed as warm and wet, while MIS 21 appears warm and dry. We then use the $U^{k'}_{37}$ and alkenone productivity proxies to extract more information from high resolution pollen, marine microfossil, and foraminiferal-derived stable isotope data sets acquired on the same samples. Strong qualitative similarities exist; for example, peaks of sinistral *N. pachyderma* coincide with unusually cold periods reconstructed from alkenone paleothermometry, and the abundance of *G. ruber* correlates positively with warm SST. Pollen assemblages appear influenced more by hydrological variations than by SST, although warm conditions did favor a more diverse flora. Comparison to stable isotope results suggests a large imprint of local hydrology in addition to temperature and global ice volume changes.

Conclusions

Interpretation of alkenone results suggest a strong external control on Mediterranean SST in the interval of MIS 20–18 (similarity to North Atlantic SST and global $\delta^{18}O$) but an important regional control on freshwater input to the basin. Because alkenone unsaturation index uniquely reflects SST, it can be used to deconvolve non-temperature related signals from other proxy data sets, yielding a nuanced and improved interpretation of multi-proxy reconstructions of the mid-Pleistocene Mediterranean region.

References

Cleaveland, L.C., Herbert, T.D., 2009. Preservation of the alkenone paleotemperature proxy in uplifted marine sequences: a test from the Vrica outcrop, Crotone, Italy. *Geology* 37(2): 179–182.

Herbert, T.D., Ng, G., and Peterson, L.C., 2014. Evolution of Mediterranean sea surface temperatures 3.5–1.5 ma: regional and hemispheric influences. *Earth and Planetary Science Letters* 409: 307–318.

TECTONICS, FLUID DYNAMICS AND CASPIAN SEA LEVEL CHANGE: GEOLOGICAL AND ENVIRONMENTAL ASPECTS

Huseynov, D. A. [1], Aliyeva, E.H-M. [2], and Kengerli, T.N. [3]

[1-3] Institute of Geology and Geophysics, National Academy of Sciences of Azerbaijan, H.Javid av., 119, Baku, Az 1143, Azerbaijan
[1] d_huseynov@yahoo.com
[2] e_aliyeva@gia.ab.az
[3] ikangarli@gmail.com

Keywords: mud volcano, fluid dynamics, seismicity, methane, gas hydrates, oil, mass extinction

Seismicity and fluid dynamic activity in the form of mud volcanism in the Caspian region corresponds to phases of Caspian Sea level falls. At the same time, measurements in geodetic test areas and GPS measurements show almost meridional waves of rise and subsidence of block structures in the Caspian region that were responsible for alternating periods of compression and tension in the Caspian Sea depression. The extension phases correspond to sea-level falls. It is remarkable that the rhythms in these vertical movements correlates with phases of seismic and mud volcanism activity, variations in oil and gas production, and sea-level fluctuations.

The high-rank rhythms influence hydrocarbon production and ecology. Recently, reliable and informative data on the periodicity in dynamics of fluid processes were obtained from satellite-based monitoring of Caspian Sea surface. The spectral analysis of the satellite image of the Caspian Sea surface revealed the active fluid dynamics in underwater mud volcanoes and faults. The images clearly show the mass release of hydrocarbons registered as hydrocarbon films on the sea surface and changes in water transparency (Huseynov, 2011). This cataclysm is related to the seismic, mud volcanic, and solar activation at the end of 2000 beginning of 2001. The South Caspian region experienced several strong earthquakes (M up to 6.8) and a record-breaking number (21) of mud volcanic eruptions at that time (Aliyev et al., 2009). The decrease in the seismic and fluid intensity was synchronous, which is reflected in a self-cleaning of the Caspian Sea water column. This resulted in degradation of the hydrocarbon film in a few months (Guliyev and Huseynov, 2004).

It is very important to note that during the spring of 2001 in the Caspian Sea, the death of a huge mass of anchovies and macro-eyed sprats, which live at a depth of 50–100 m and more in an open, deep part of the sea, was observed (Katunin et al., 2002). This largescale phenomenon during the period of the migration of sprats had no analogues in the last life of the Caspian Sea and has caused significant damage to industrial fishing. The death of sprats was observed in the area of the Middle Caspian Sea and near the western coast of the South Caspian Sea. The extinction of sprats had not been marked along the east coast of the South Caspian Sea, where the numbers of submarine mud volcanoes are much less.

There are special places for fluid dynamics and environment of the Caspian Sea and surrounding areas that have gas hydrates associated with submarine volcanism. Large accumulations of gas hydrates are confined to bottom sediments of the Caspian Sea mud volcano crater fields and to volcano bodies (Ginzburg et al., 1993; Diaconescu et al., 2001).

The Caspian Sea, being an inland closed basin, is very sensitive to climatic and tectonic events expressed in sea-level fluctuations. In regressive stages, as a result of sea-level fall and reduction of hydrostatic pressure, the decomposition of gas hydrates and release of great volumes of HC gases consisting mainly of methane are observed.

From the data of deep drilling and seismo-acoustics, deep seismic mud volcanic activity in the South Caspian basin has been ongoing since the Lower Miocene. The greatest intensity was reached at the boundary of the Miocene and Pliocene and was associated with a dramatic Caspian Sea level lowering in the Lower Pliocene of up to 600 m, which led to the isolation of the PaleoCaspian from the Eastern ParaTethys (Mamedov, 2008; Aliyeva, 2005). Catastrophic reduction of the size of the PaleoCaspian with increasing mud volcanic activity caused the oversaturation and increased toxicity of the water by methane, which led to a mass extinction of mollusks, fishes, and other groups of sea inhabitants. In the Upper Pliocene and Quaternary, mud volcanism occurred under conditions of a semi-closed sea periodically connected with the Pontian and Mediterranean basins. Those stages of Caspian Sea history are characterized by the revival of the Caspian organic world.

References

Aliyev, Ad.A., Guliyev, I.S., and Rahmanov, R.R., 2009. Catalogue of Mud Volcanoes Eruptions of Azerbaijan (1810–2007), 2nd edition. Baku, Nafta-Press.

Aliyeva, E.G.-M., 2005. Reservoirs of the Lower Pliocene Productive Series at the western flank of the South Caspian Basin. *Lithology and Mineral Resources* 40(3): 267–278.

Diaconescu, C.C., Kieckhefer, R.M., and Knapp, J.H., 2001. Geophysical evidence for gas hydrates in the deep water of the South Caspian basin Azerbaijan. *Marine and Petroleum Geology* 18(2): 209–221.

Ginzburg, G.D., Guseynov, R.A., Dadashev, A.A., Ivanova, G.A., Kazantsev, S.A., Solov'yev, V.A., Telepnev, E.V., Askeri-Nasirov, R.Ye., Yesikov, A.D., Mal'tseva, V.I., Mashirov, Yu.G., and Shabayeva, Yu., 1993. Gas hydrates of the southern Caspian. *International Geology Review* 34(8): 765–782.

Guliyev, I.S., and Huseynov, D.A., 2004. Dynamics of fluids in the South Caspian Basin. *Doklady Earth Sciences* 395A(3): 338–342.

Huseynov, D.A., 2011. The modern fluid dynamics of the Absheron peninsula Caspian water area as possible indicator of oil-and-gas content of transit zone and it reflection on satellite data. *Oil Industry of Azerbaijan* 8b: 17–27. (In Russian)

Katunin, D., Golubov, B., and Kashin, D., 2002. Hydrovolcanism and degassing of earth bowel as the possible reason of scale death of sprats on the Middle Caspian Sea during 2001 spring. In *Abstract Book of the 7th International Conference "Gas in Marine Sediments," October 7–12*. Nafta-Press, Baku.

Mamedov, P.Z., 2008. Deep structure and tectonic evolution of the South Caspian depression. In *Geology of Azerbaijan,* Vol. VII, pp. 6–158. Nafta Press, Baku. (In Russian)

NARROW SHELF CANYONS VS. WIDE SHELF CANYONS IN THE BLACK SEA

Jipa, D.C. [1], *and Panin, N.* [2]

National Institute of Marine Geology and Geoecology,
23-25 Dimitrie Onciul Street, RO-024053, Bucharest, Romania
[1] jipa@geoecomar.ro
[2] panin@geoecomar.ro

Keywords: submarine valleys, relief energy, sea level variation, Paleo-Danube River, Danube Deep Sea fan

The characteristics of the Black Sea canyons depend on the relief energy of the coasts with which they are associated. The canyons located in front of the mountainous Black Sea coasts (Crimean, Caucasian, and Pontic mountains) are associated with narrow shelf areas. They are the present-day active Black Sea canyons (Fig. 1).

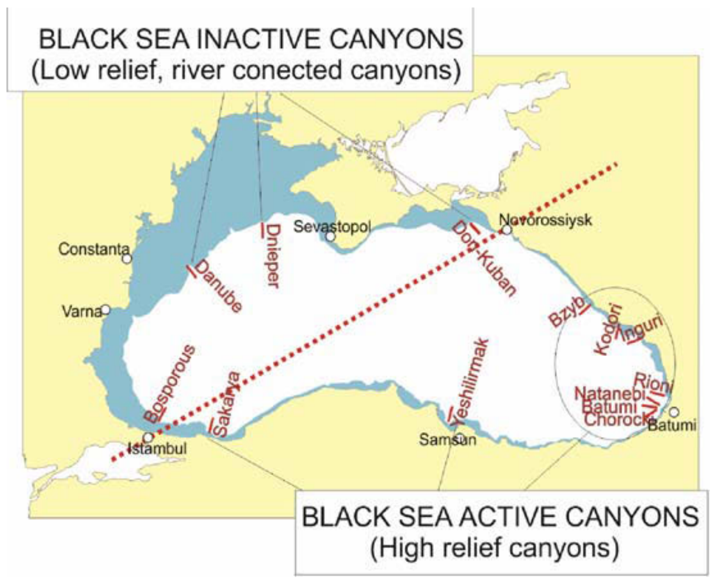


Figure 1. Present day active and passive submarine canyons in the Black Sea.

This type of submarine valley, deeply cut into the shelf, shows steep walls and high gradient thalwegs. Their sedimentary load is coarser-grained and supplied by closely discharging rivers (Bilashvili, 2007).

On the Black Sea's low-relief, accumulative coasts with wide shelves from the northwestern and western part, the largest canyons of the Black Sea Basin (the Danube and Dnieper canyons) occur. Located in front of low relief energy coasts, these canyons have been supplied with finer-grained sediments and their deep-sea fan systems differ from those of mountainous coasts. In contrast to the canyons of the mountainous coasts, the Danube and Dnieper canyons are presently inactive. Only during periods of lowstands did the Danube and Dnieper paleo-rivers cross the shelf and supplied sediment to their respective submarine canyons.

Systems of paleo-river channels have been identified on the wide shelves, evidencing the development of the canyons (Fig. 2).

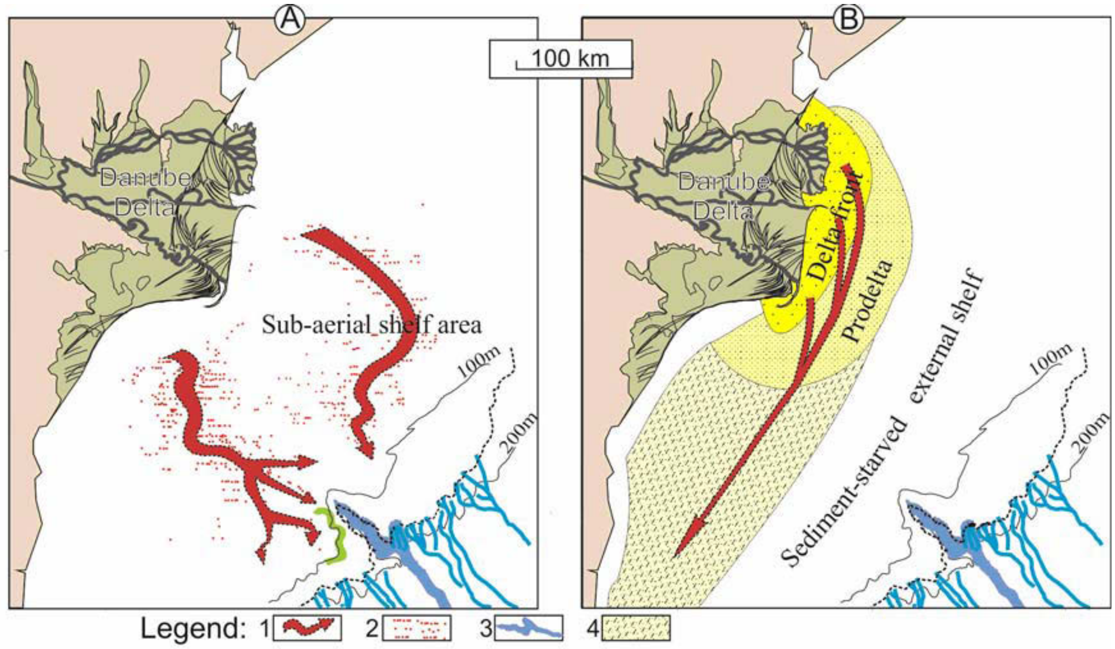


Figure 2. The river-shelf canyon system from the northwestern Black Sea, in the lowstand (last Black Sea water level drop) (A) and highstand (present day) (B) setting. 1 – sediment transport trend, 2 – discrete fluvial channels (seismoaucustic data, Popescu et al., 2015), 3 – the Danube submarine canyon, 4 – Danube-born sediment drift.

The history of the Danube Canyon, the morphologic link between the Paleo-Danube River and the extensive Danube Fan, can be traced to the end of Upper Neogene time.

Sea level variation is the second important factor that controlled the Black Sea canyons' development over time. The activity of the mountainous coast and narrow shelf canyons was not discontinued by the Quaternary sea-level declines. In contrast, the canyons of the wide shelf type are active during lowstands and inactive at highstands.

The Bosporus Canyon is different among the Black Sea submarine canyons. Situated off the eastern outlet of the Bosporus Strait, this is a submarine valley incision system associated with Mediterranean water inflow, with no connection to a river.

References

Bilashvili, K., 2007. Dynamics of the deltaic canyon area of the River Chorokhi, Georgia. In: V. Lykousis, D. Sakellariou, and J. Locat (Eds.), *Submarine Mass Movements and Their Consequences*, pp. 251–258. Advances in Natural and Technological Hazards Research 27. Springer, Dordrecht.

Panin, N., and Jipa D., 2002. Danube River sediment input and its interaction with the North-western Black Sea. *Estuarine, Coastal and Shelf Science* 54(3): 551–562.

Popescu, I., Panin, N., Jipa, D., Lericolais, G., and Ion, G., 2015. Submarine canyons of the Black Sea basin with a focus on the Danube Canyon. In F. Briand, ed., *Submarine Canyon Dynamics in the Mediterranean and Tributary seas: An Integrated Geological, Oceanographic and Biological Perspective*, pp. 103–121. CIESM Monograph 47. CIESM Publisher, Monaco.

FIRST DISCOVERIES OF OLIGOCENE DIATOMIC FLORA IN THE SECTION OF PIRAKASHKUL (SHAMAKHI-GOBUSTAN ZONE)

Kerimova, N.T.

ANAS, Geology and Geophysics Institute, H. Cavid Avenue 119, Baku, Azerbaijan, AZ 1143
nayila_kerimova@mail.ru

Keywords: marine plankton, brackish-marine, plankton, freshwater, diatoms, series, upper, lower, lithofacies, sand-clay, flora, fauna, species

Introduction

The studied section belongs to a Maikopian series of rocks (Fig. 1).

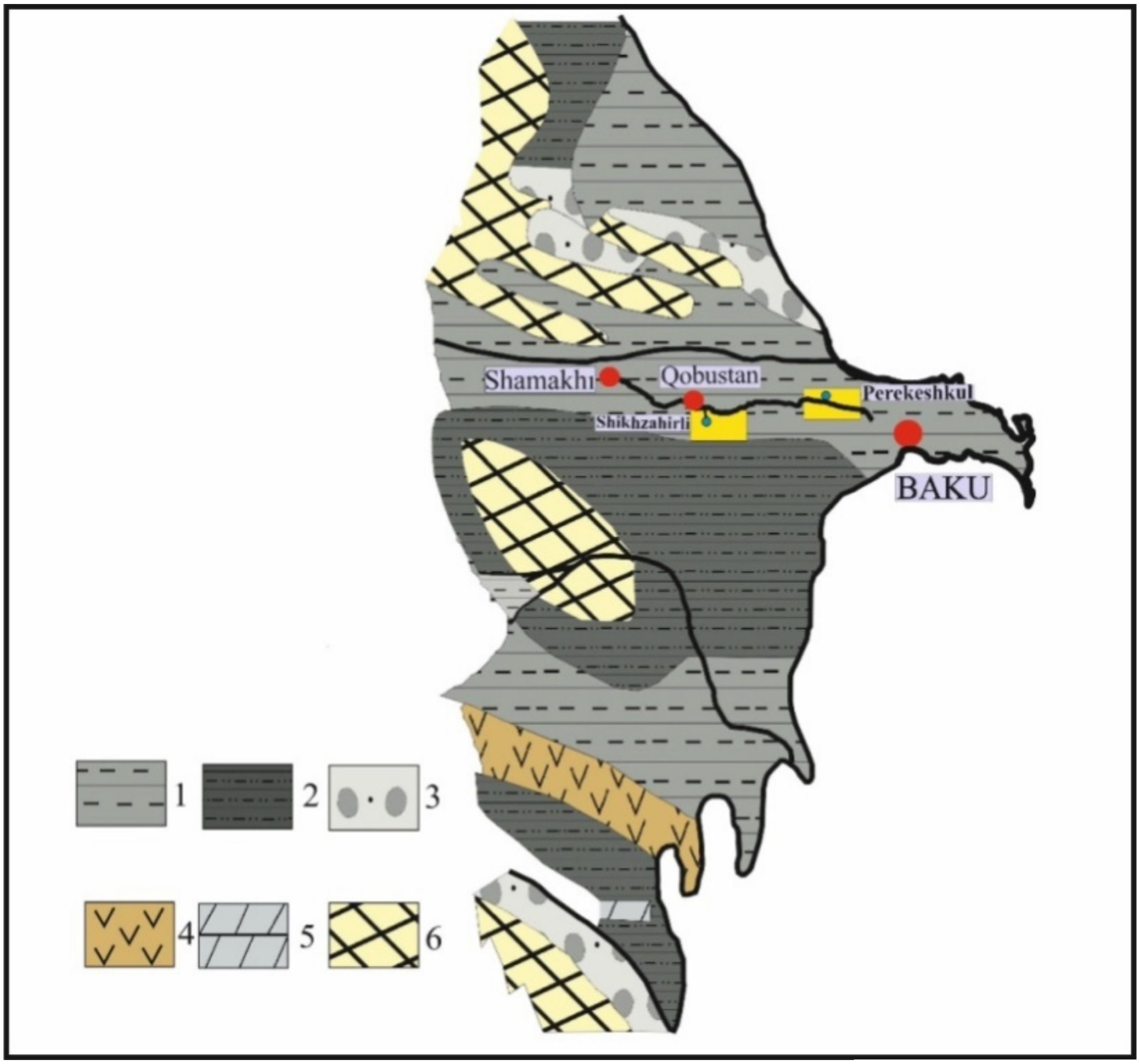


Figure 1. Lithofacies within the bottom division of Azerbaijan MS. 1 – clayey, 2 – sandy-clayey, 3 – conglomerate, 4 – tuffogenic. 5 – malmrock, 6 – onshore.

It is situated in the vicinity of Pirakashkul village on the southeastern limb of the Eastern Jangi syncline. The total thickness of this Oligocene (Lower Maikopian) section is 616.5 m. The section is divided into two horizons: (1) the lower 215 m thick horizon comprising clays, rarely sandstones and marls, and (2) the upper 380 m thick horizon represented by lilaceous and fulvous clays with interlayers of flag-like sandstone with concretions. According to plankton foraminifers—*Globigerina wfainalis* Subb., *G.* ex gr. *bulloides*, and *Globanomalita micra* (Cole) as defined by Ali-Zadeh and Babazadeh (1967)—the 36 m thick Khadumian horizon represented by clays with interlayers of yellow sandstones is distinguished within the deeper part of the section (packs 1, 2).

Based on sporo-pollen analysis outcomes of the Maikopian complex, E.D. Zaklinskaya (1953) had distinguished the following four stages of faunal change: (1) two Lower Maikopian stages represented by the lower horizon (Khadumian stage) with *subtropical flora* and the upper horizon revealing *subtropical with elements of temperate flora*; (2) a Middle Maikopian stage represented by *subtropical with a considerable share of temperate flora*; and (3) an Upper Maikopian stage represented by *temperate with elements of subtropical flora* showing predominantly mixed-broadleaved forests.

According to palynological data, the studied section is divided into two parts: (1) a bottom Lower Maikopian segment (Rupelian) represented by *subtropical Mediterranean with elements of warm-temperate flora*; and (2) a top Lower Maikopian segment represented by *subtropical Mediterranean with elements of temperate flora*.

During the Oligocene epoch, the Shamakhi-Gobustan zone used to be confined to the border between areas of temperate-warm humid and subtropical-subtropical humid climate of the northern hemisphere. Its flora structure used to be seasonal and rich with a lower intensity of changes (Bayramova and Taghiyeva, 2009).

Discussion of outcomes

Samples were proportionally collected from an entire section. 16 samples were tested in a laboratory (Fig. 2).

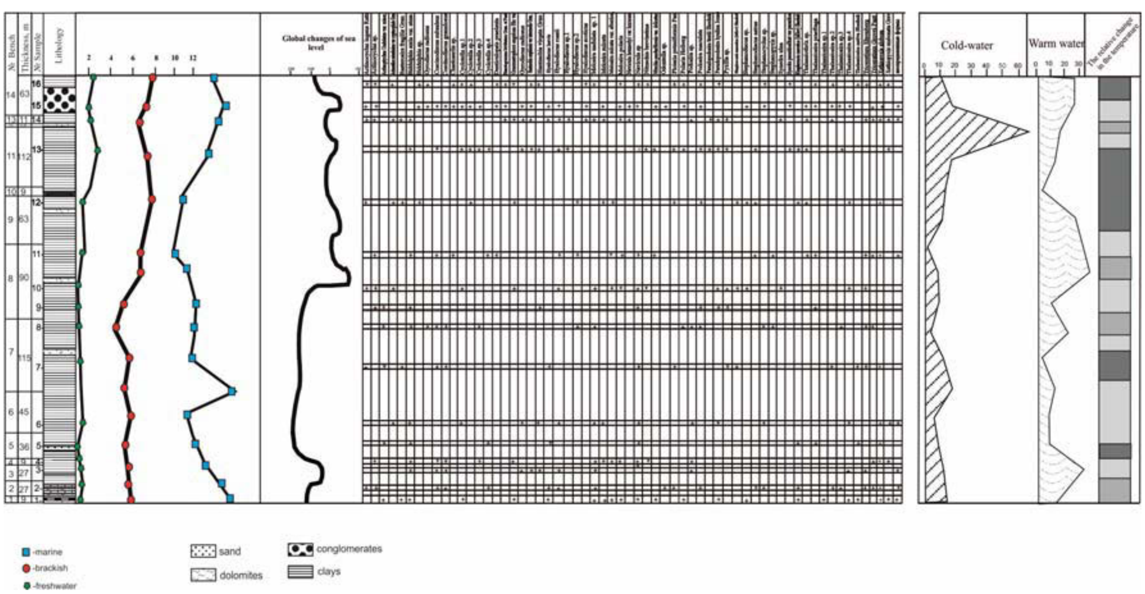


Figure 2. Lithological section of Pirakashkul Maikopian outcrops and development scheme of diatoms.

The diatomic flora of the section are represented by 61 taxa of specific and intraspecific rank (36 species) belonging to 31 genera.

Nearly all samples contain diatomic algae, as well as Tertiary spicules and dinoflagellates. Many forms have been defined as to genera, but there remain some diatoms that were defined as to species. The entire section is rich with non-Tertiary species and marine littoral diatomic algae. Large accumulations of marine species are detected in the bottom and top parts of the complex. Minor quantitative reduction of marine diatoms is observed closer the section's central deposits (samples 4, 5, 6), but starting with sample 9, the number of marine species increases again.

Widespread is an undefined species from the genus *Thallassiothrix*? sp. (Bukry, 1973). With their largest amount detected in samples 11–16, these diatoms represent a typical form for the Oligocene-Miocene. Considerable accumulations of at least 5 new, notably large (45 μ to 150 μ) forms of *Thallassiosira* were detected in samples 6–16. As none of them is present elsewhere in the Maikopian basin, it is presumed that these forms are of a marine littoral origin, which backs up previously derived speculation on the prevalence of marine flora over freshwater species. Different forms of *Cyclotella*, *Hualodiscus*, *Stephanopyxis*, *Stephanodiscus*, and *Biddulphia* (Kerimova, 2017) also remain unspecified.

The following species from the warm-water diatom genera have been defined: *Hualodiscus rosii*, *Hyalodiscus laevis*, *Melosira polaris*, *Melosira sulcate*, *Melosira undulata* sp.1, *Podosira maculata*, *Triceratium* Ehrenberg, *Triceratium* Grovei Pant., and *Biddulphia auria* var. *atusa*. Large accumulations of these species are observed in the section's bottom (samples 1–7). Then, the amounts decline towards the center and recover in the upper successions (samples 13–15).

Psychrophiles are represented by the following species: *Actinoptychus undulatus* var. Minor, *Hantzschia virqata* Grun, *Synedra parasitica, Navicula hennedyi* var. *luxuosa*, *Xantiopyxis globosa*, *Xanthiopyxsis umbonata*, *Denticula praelauta*, *Nitzchia panduriformis* var. *delicates*, *Podosira* sp., *Eunotogramma bivittatum*, etc. Moderate amounts of these marine species are commonly detected within the structure of the entire complex. The temperature dynamics of the section are demonstrated by a histogram presented in Fig. The grey color indicates relative change in temperature (the lower the temperature is, the more saturated is the grey).

The obtained outcomes indicate good consistency with the World Ocean level curve during the Oligocene (Fig. 2). As seen from the section's interpretation, marine forms became dominant during the periods of rising ocean level, whereas the sea-level declines normally led to a growth of brackish-water species. Miserable representation of freshwater species doesn't allow us to demonstrate any regularity.

Conclusions

Diatomic flora of Pirakashkul is represented by marine species inhabiting oligotrophic waters. Most species can be characterized as cosmopolites according to their geographic confinement. We may conclude that the marine environment used to prevail in Pirakashkul with periods of predominantly brackish-water conditions. The following percent composition of the Pirakashkul section's diatomic flora can be derived: marine forms – 88%, brackish water forms – 10%, and freshwater forms – 2% (Fig. 3).

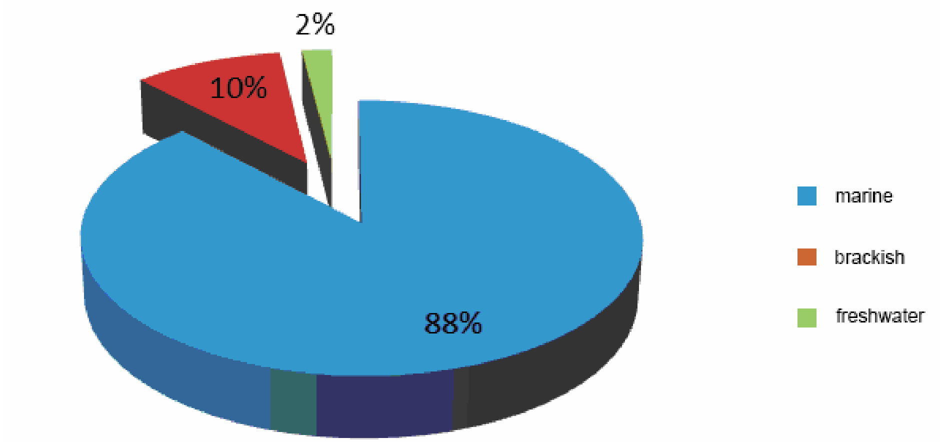


Figure 3. Percent composition of diatomic algae in the Pirakashkul Lower Maikopian section

As indicated by substantial numbers of psychrophiles, temperature of the Early Maikopian basin used to be generally low. Only occasionally, it increased to 15–25°C, as proven by the complex of diatoms.

References

Ali-Zadeh, Ak.A. (Ed.), 2015. *Geologiya Azerbaijana* [*Geology of Azerbaijan*]. Publishing house "Elm," Baku, vol. I, 290 p.. (In Russian)

Ali-Zadeh, Ak.A., and Babazade, A.D., 1967. *O novikh kardiidakh akchaqilskogo yarusa Shamakhinskogo rayona. Voprosy stratigrafii i fauni mezozoysko-kaynozoyskikh otlojeniy Azerbaijana* [*New Cardioids of the Akchagylian Stage of Shamakhi District. Problems of Stratigraphy and Fauna of the Mesozoic-Cenozoic Deposits of Azerbaijan*]. "Nedra", Moscow. (In Russian)

Bayramova, Sh.Sh., and Taghiyeva, Y.N., 2009. Palinostratigrafiya i paleogeografiya maykopa Apsheronskogo rayona (po razrezu Perekyushkyul), [Palinostratigraphy and Paleogeography of the Absheron District's Maikopian Formations (Pirakashkul section). *Stratigraphy and Sedimentology of Oil-Gas Bearing Basins* 1: 24–32. (In Russian)

Bukry, D., 1973. Phytoplankton stratigraphy, Central Pacific Ocean, Deep Sea Drilling project Leg 17. U.S. Geological Survey, La Jolla, California, pp. 871–889.

Kerimova, N.T., 2017. The diatom study of the Maikop sediments on the western flank of the South Caspian depression (along the Shikhzaghirli section of the Shamakhi-Gobustan area) and some paleoecological conclusions. *Stratigraphy and Sedimentology of Oil-gas Basins* 1: 11–24.

Zaklinskaya, E.D., 1953. *Opisanie nekotorykh vidov pyl'tsy spor, vydelennykh iz tretichnykh otlozheniy Pasekovskogo kar'era Voronezhskoy oblasti*. [Description of Some Types of the Pollens and Spores Derived from Tertiary Deposits of the Pasekov Quarry in Voronej]. *Trudy Instituta geol. AN SSSR* 142. Geol. Seria 59. Izdatel'stvo AN SSSR, Moscow. (In Russian)

PALEOENVIRONMENTAL RECONSTRUCTIONS AT THE PLEISTOCENE- HOLOCENE BOUNDARY IN THE BLACK SEA BASED UPON BENTHIC FORAMINIFERA

Kondariuk, T.

Department of Physical and Marine Geology, 2 Shampansky Per., Odessa I.I. Mechnikov National University, Odessa 65058, Ukraine

Keywords: salinity, Neoeuxinian lake, transformation, radiocarbon dating

Introduction

There are several contradictions regarding the transformation of the Late Pleistocene (Neoeuxinian in local terminology) lake into a marine basin. The first one regards the age of the transformation; the second one is its character; and the third is the salinity of the Neoeuxinian lake.

The varied age estimates for the transformation range as follows (non-calibrated): 7.2 ka BP (Ryan et al., 1997), 7.8 ka BP (Lericolais et al., 2007), 8.4 ka BP (Major et al., 2002; Ryan et al., 2003), 8.9 ka BP and 9.5 a BP (Yanko and Troitskaya, 1987; Yanko-Hombach, 2007; Yanko-Hombach et al., 2014), ~10 ka BP (Balabanov et al., 1981; Inozemtsev et al., 1984), and 10.5 ka BP (Aksu et al. 2002). We use "conventional ^{14}C ages because (1) uncertainty surrounds the marine reservoir correction required for Black and Caspian seawater, where living mollusks are much older or younger than the global ocean average of +410 years used for most marine shell-based calibration curves, and (2) controversy and compounding of error are introduced when the early Black Sea lake is classified as 'freshwater', requiring no marine reservoir correction" (Yanko-Hombach et al., 2014: 102).

The character of the transformation from one basin to another varies from rapid (Yanchilina et al., 2017) and catastrophic (Ryan et al., 1997; Ryan, 2007) to gradual (Hiscott et al., 2002, 2007), and gradual but oscillating (Yanko and Troitskaya, 1987; Yanko-Hombach, 2007).

The salinity of the Neoeuxinian lake also varies from fresh (Ryan et al., 1997; Ryan, 2007) to fresh but slightly brackish (Yanchilina et al., 2017), and totally brackish with a salinity range between 7 and 12 psu (Marret et al., 2009; Yanko-Hombach et al., 2011, 2014).

The main goal of this paper is to shed more light on the questions above using benthic foraminifera as the main tool.

The Study Area

The study area includes the northwestern shelf of the Black Sea that lies on the margin of the East European platform and has a gentle slope of 0.001-0.002º. It is the widest (125-240 km) shelf in the basin and comprises 94% of the total shelf geomorphologic province, or about 30% of the Black Sea's total area. The bottom relief is smooth due to sediment discharge and distribution provided by major lowland European rivers, such as the Danube, Dnieper, Dniester, and Southern Bug that discharge together 56.8 million tons of sediments annually (Panin and Jipa, 2002). There are no known expressions of active tectonic movements that would strongly influence the ancient shoreline positions and deposition of sediments resulting in a shallow buildup of Quaternary sediments and a high variety of lithounits or facies (Dolukhanov et al. 2009); this enables us to trace the transformation from one basin to another.

Materials and methods

Materials for this study were collected from the Ukrainian, Romanian, and Bulgarian parts of the northwestern shelf in different years and from various facies (Figs. 1, 2).

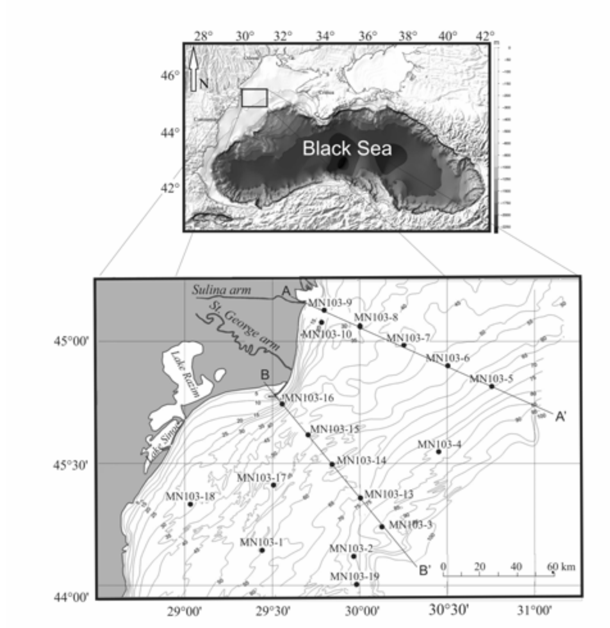


Figure 1. Study area and location of sampled stations on the Romanian shelf of the Black Sea.

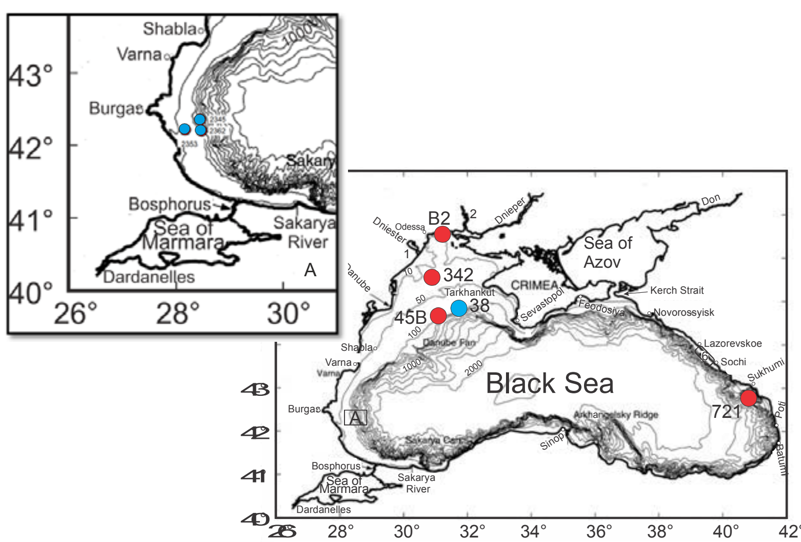


Figure 2. Map of the Black Sea and adjacent regions, showing the extent of the shelf areas, the connections to the Marmara and Aegean seas via the Bosphorus and Dardanelles Straits, and locations of key reference cores with ^{14}C ages. Red circles mark the location of cores described by Yanko-Hombach et al. (2014); blue circles are cores recently studied by the author.

Results and Discussion

As a first step, the distribution of foraminifera was studied in the surface samples from the Romanian and Ukrainian shelf adjacent to the Danube delta; this was chosen as a model area to trace the change in foraminiferal assemblages along the salinity gradient. It was found that the alternation of foramininferal assemblages *Ammonia ammoniformis - A. compacta - A.*

tepida and the disappearance of polyhaline Lagenida in shoreward assemblages suggest that salinity is the leading factor affecting their distribution. Other factors, e.g., eutrophication and oxygen depletion, may play a secondary role, while the type of substrate does not contribute significantly to the distribution of species (Kondariuk et al., 2015; Yanko-Hombach et al., 2017).

In the cores (Table 1), changes in foraminiferal assemblages similar to those observed in recent assemblages were discovered at the Late Pleistocene-Holocene boundary.

Table 1. Selected cores from different facies zones of the Black Sea shelf.

Core No	Latitude N	Longitude E	Water depth, m	Length, cm
2353	42° 05' 4"	28° 03' 8"	67	3.2
2362	42° 11' 7"	28° 26' 5"	102	5.0
2345	42° 24' 2"	28° 19' 0"	122	3.0
38	44° 66'	31° 17'	192	1.1
B2	45° 43' 09"	30° 34' 28"	30.8	72.5
45B	44° 40' 16"	31° 17' 30"	107	75
342	46° 37' 38"	31° 24' 56"	+2	10.5
721	42° 59' 35.5"	41° 2' 79"	14.9	27.5
2/86	41° 31' 30"	8° 59' 32"	103	3.1

The late Neoeuxinian assemblages are dominated by oligohaline *Ammonia novoeuxinica*, *Mayerella brotzkajae*, and *Elphidium caspicum*, all of Caspian genesis. In sedimentological sequences, they coexist with mollusks *Dreissena polymorpha*, *Monodacna caspia*, and ostracoda *Leptocythere bacuana* and *Loxoconcha lepida* (Yanko and Gramova, 1990) that tolerate salinity up to 13 psu in the Caspian Sea today (Nevesskaya, 1965; Shornikov, 1972). According to the studied cores, the reconstructed salinity of the Late Neoeuxinian lake is facies-dependent and ranges from ~6 psu in the shallow areas affected by river discharge to 13 psu in its deeper parts. No Mediterranean species are present among the foraminifera, mollusks, and ostracoda.

Mediterranean species appear upwards in the cores at about 9.5 ka BP where *Ammonia novoeuxinica* is slowly replaced by *A. tepida* and then by *Ammonia compacta* and *A. ammoniformis*. Other holeuryhaline (e.g., *Haynesina anglica*) and strictoeuryhaline (e.g., *Cribroelphidium poeyanum*) and even polyhaline (including Lagenida representatives) species appear increasingly towards the sea. The number of species and specimens at the Pleistocene-Holocene boundary increases but never sharply.

Conclusions

According to our data, the age of the Pleistocene-Holocene boundary in the Black Sea is ~9.5 ka BP. The boundary is characterized by a smooth change in the quantitative and qualitative composition of foraminifera and is clearly marked by the appearance of the first Mediterranean immigrants above the boundary. If the salinity of the Neoeuxinian lake had changed sharply due to an abrupt Mediterranean transgression as emphasized by Ryan et al. (1997) and Yanchilina et al. (2017), then the abundance and diversity of foraminifera would have changed rapidly, and a substantial number of species would be expected in the Early Holocene sediments. However, this is not the case; the number of species gradually increases from 2-3 species to a maximum of 13 in the lower Holocene (Bugazian) beds.

The Neoeuxinian lake could not be fresh because foraminifera are not adapted to freshwater. Species discovered in the Neoeuxinian sediments live today in the Caspian Sea, and the salinity of the lake can be as high as 13 psu.

Changes in foraminiferal assemblages at the Pleistocene-Holocene boundary depend on the facies. They are more pronounced in marine than in shallow facies, especially in the areas influenced by paleoriver discharge. This difference may be responsible for the differences in opinion on the nature of the transformation in hydrologic regime at the Pleistocene-Holocene boundary. Those scientists who study cores from the outer shelf can get an impression about rapid environmental change, while those who work with cores recovered from the inner shelf would never consider such a transformation as rapid. Instead, they would insist that the transformation was gradual but oscillating. In this regard, more comparative work is needed.

Acknowledgments

This study is a part of the EU FR6 HERMES and EU-WAPCOAST BS-ERA.NET 076 projects and contributes to the IGCP 610 project sponsored by UNESCO and IGU.

References

Aksu, A.E., Hiscott, R.N., Kaminski, M.A., Mudie, P.J., Gillespie, H., Abrajano, T., and D. Yaşar, 2002. Last glacial-Holocene paleoceanography of the Black Sea and Marmara Sea: stable isotopic, foraminiferal and coccolith evidence. *Marine Geology* 190(1-2): 119–149.

Balabanov, I.P., Kvirkveliya, B.D., and Ostrovsky, A.B., 1981. *Noveishaya istoriia formirovaniya inzhenerno-geologicheskikh uslovii i dolgosrochnyi prognoz razvitiia beregovoi zony poluostrova Pitsunda* [*Recent History of the Development of Engineering-Geological Conditions and Long-Time Forecast for the Coastal Zone of the Pitsunda Peninsula*]. Metsniereba, Tbilisi. (In Russian)

Dolukhanov, P., Kadurin, S., and Larchenkov, E., 2009. Dynamics of the coastal North Black Sea area in Late Pleistocene and Holocene and early human dispersal. *Quaternary International* 197(1-2): 27-34.

Hiscott, R.N., Aksu, A.E., Yaşar, D., Kaminski, M.A., Mudie, P.J., Kostylev, V.E., MacDonald, J.C., Işler, F.I., and Lord, A.R., 2002. Deltas south of the Bosphorus Strait record persistent Black Sea outflow to the Marmara Sea since ~10 ka. *Marine Geology* 190: 95-118.

Hiscott, R.N., Aksu, A.E., Mudie, P.J., Kaminski, M.A., Abrajano, T., Yaşar, D., and Rochon, A., 2007. The Marmara Sea gateway since ~16 ky BP: Non-catastrophic causes of paleocenographic events in the Black Sea at 8.4 and 7.15 ky BP. In V. Yanko-Hombach, A.S. Gilbert, N. Panin, and P. Dolukhanov, eds., *The Black Sea Flood Question: Changes in Coastline, Climate and Human Settlement*. Springer, Dordrecht, pp. 89-117.

Inozemtsev, Yu.I., Lutsiv, Ya.K., Sobotovich, E.V., Kovalyukh, N.N., and Petrenko, L.V., 1984. Geochronologiia i fatsialnie kompleksi golotsena Chernomorskoi oblasti [Holocene geochronology and facies complexes of the Pontic area]. In E.F. Shnyukov, ed., *Izuchenie geologicheskoi istorii i protsessov sovremennogo osadkoobrazovaniia Chernogo i Baltiiskogo morei* [*Study of the Geological History and Processes of Recent Sedimentation in the Black and Baltic Seas*], Part 1, pp. 103–113. Naukova Dumka, Kiev. (In Russian)

Kondariuk T.O., Yanko-Hombach, V., and Kovalishina, S.P., 2015. Foraminifera as indicators of environmental stress in marine ecosystems: New evidence from the Romanian and Ukrainian shelf (Black sea). GSA Annual Meeting in Baltimore, Maryland, USA (1-4 November 2015).

Lericolais, G., Popescu, I., Guichard, F., Popescu, S.-M., and Manolakakis, L., 2007. Waterlevel fluctuations in the Black Sea since the Last Glacial Maximum. In V. Yanko-Hombach, A.S. Gilbert, N. Panin, and P. Dolukhanov, eds., *The Black Sea*

Flood Question: Changes in Coastline, Climate and Human Settlement. Springer, Dordrecht, pp. 437-452.

Major, C., Ryan, W.B.F., Lericolais, G., and Hajdas, I., 2002. Constraints on Black Sea outflow to the Sea of Marmara during the last glacial-interglacial transition. *Marine Geology* 90: 19-34.

Marret, F., Mudie, P., Aksu, A., and Hiscott, R.N., 2009. A Holocene dinocyst record of a two-step transformation of the Neoeuxinian brackish water lake into the Black Sea. *Quaternary International* 193(1-2): 72-86.

Nevesskaya, L.A., 1965. *Pozdnechetvertichnye dvustvorchatye molliuski Chernogo Moria; ikh sistematika i ekologiia* [*Late Quaternary Bivalve Molluscs of the Black Sea; Their Systematics and Ecology*]. Trudy Paleontologicheskogo Instituta Akademii Nauk SSSR, vol. 105. Nauka, Moscow. (In Russian)

Panin, N., and Jipa, D., 2002, Danube River sediment input and its interaction with the north-western Black Sea: Estuarine, Coastal and Shelf Science 54: 551–562.

Ryan, W.B.F., 2007. Status of the Black Sea flood hypothesis. In V. Yanko-Hombach, A.S. Gilbert, N. Panin, and P.M. Dolukhanov, eds., *The Black Sea Flood Question: Changes in Coastline, Climate and Human Settlement*. Springer, Dordrecht, pp. 63-88.

Ryan, W.B.F., Pitman, W.C., III, Major, C.O., Shimkus, K., Moskalenko, V., Jones, G.A., Dimitrov, P., Görür, N., Sakınç, M., and Yüce, H., 1997. An abrupt drowning of the Black Sea shelf. *Marine Geology* 138(1-2): 119-126.

Ryan, W.B.F., Major, C.O., Lericolais, G., and Goldstein, S.L., 2003. Catastrophic flooding of the Black Sea. *Annual Review of Earth and Planetary Sciences* 31: 525-554.

Shornikov, E.I., 1972 Voprosy ekologii azovo-chernomorskikh ostracod [Questions about the ecology of Azov-Black Sea Ostracoda]. *Biologia Moria*, pp. 53-88. (In Russian)

Yanchilina, A.G., Ryan, W.B.F., McManus, J.F., Dimitrov, P., Dimitrov, D., Slavova, K., and Filipova-Marinova, M., 2017. Compilation of geophysical, geochronological, and geochemical evidence indicates a rapid Mediterranean-derived submergence of the Black Sea's shelf and subsequent substantial salinification in the early Holocene. *Marine Geology* 383: 14-34.

Yanko, V.V., and Troitskaya, T.S., 1987. *Pozdnechetvertichnye foraminifery Chernogo moria* [*Late Quaternary Foraminifera of the Black Sea*]. Nauka, Moscow. (In Russian)

Yanko, V., and Gramova, L., 1990. Stratigrafiya chetvertichnykh otlozhenii kavkazskogo shel'fa i kontinental'nogo sklona Chernogo moria po mikrofaune–foraminifer i ostrakod [Stratigraphy of the Quaternary sediments of the Caucasian shelf and continental slope of the Black Sea based on microfauna of foraminifera and ostracoda]. *Sovetskaia Geologiia* 2: 60-72. (In Russian)

Yanko-Hombach, V., 2007. Controversy over Noah's Flood in the Black Sea: geological and foraminiferal evidence from the shelf. In V. Yanko-Hombach, A.S. Gilbert, N. Panin, and P. Dolukhanov, eds., *The Black Sea Flood Question: Changes in Coastline, Climate and Human Settlement*. Springer, Dordrecht, pp. 149-203.

Yanko-Hombach V., Mudie P., and Gilbert A.S. 2011. Was the Black Sea catastrophically flooded during the post-glacial? Geological evidence and archaeological impacts. In J. Benjamin, C. Bonsall, Dr. C. Pickard, and A. Fischer, eds., Underwater Archaeology and the Submerged Prehistory of Europe, Oxbow Books, pp. 245-262.

Yanko-Hombach, V., Mudie, P.J., Kadurin, S., and Larchenkov, E., 2014. Holocene marine transgression in the Black Sea: New evidence from the northwestern Black Sea shelf. *Quaternary International* 345: 100-118.

Yanko-Hombach, V., Kondariuk, T., and Motnenko, I., 2017. Benthic foraminifera indicate environmental stress from river discharge to marine ecosystems: example from the Black Sea. *Journal of Foraminiferal Research* 47(1): 70-92.

NEOTECTONICS IN THE MARMARA REGION, NW TURKEY

Koral, H. [1], and Emre, H. [2]

Istanbul University, Engineering Faculty, Department of Geological Engineering, 34850 Avcilar Istanbul, Turkey
[1] hkoral@istanbul.edu.tr
[2] emre@istanbul.edu.tr

Keywords: Morphotectonics, Neogene sequences, basin geometry, North Anatolian Fault

Introduction

NW Turkey lies in an Alpine type-collision zone that began during the late Mesozoic (e.g., Şengör and Yilmaz, 1981).). The region is a site of several post-collisional basins, and geologic maps show that these basins have different sedimentary sequences along with differing ages. It is noted that the age of these basins becomes progressively younger towards the north. Compared to those in the south, young basins are located adjacent to the strands of the NAFZ. Neotectonic features of the Marmara region have been investigated by evaluating the morphotectonic, stratigraphic, and tectonic features.

Morphotectonic features

The Marmara region exhibits many morphological features indicative of Quaternary tectonics, ranging from diverted river systems, transected and displaced ridges, to the abrupt changes in topographical morphology (e.g., Emre et al., 1998; Koral, 2007; Yilmaz et al., 2010;). The morphotectonic signatures prominently indicate active or recent tectonic features. It is striking that topographic profiles of the region show subtle morphological changes along an E-W orientation, but more obvious changes along a N-S orientation. Deep and narrow depressions in the profiles mostly point out the locations of NAFZ splays. The highest point in the region is the Uludağ Mountain (Mysian Olympus) with a peak elevation of 2543 m, where metamorphic and igneous units of the region are exposed at the surface and juxtaposed by Mesozoic or Tertiary units. It is also noted that topographic height decreases from the south to north, and the decrease is stepwise.

Neogene sequences and their correlation

Sedimentary sequences of the Neogene in the Marmara Region are arbitrarily defined as being of northern, central, and southern zones. These zones are separated from each other by morphological highs. For example, the northern zone is delimited from the central zone by the E-W running Samanli (Armutlu) high and the Gemlik-Bandirma high. Likewise, the central zone is separated from the southern zone by the Uludağ High (Mysian Olympus).

In the east of the northern zone, for instance, the Yalakdere sequence begins with coarse clastics (5–10 cm) at the bottom, lying unconformably on Eocene volcanics. It continues upward with pebbly and sandy horizons with cross-bedding, interlayered first with clayey and then clayey sandstone beds. They have clayey sandstone facies at the bottom, becoming marl and lime-rich upward, and ending with a marl and limestone horizon at the top. At the southern extension of this zone, in the vicinity of Sugören village, a thin coal horizon occurs in clayey limestone beds. The Upper Pliocene-Pleistocene age-fluvial clastics, marine terraces, and thick Holocene alluvium overlie the older units with angular unconformity. These sequences occur in E-W oriented basins that are almost parallel to the northern branch of the North Anatolian Fault.

In the central zone, along Gemlik Bay and İznik Lake, the Neogene sequences lie unconformably on Miocene age volcanics, Jurassic limestone, or Triassic volcanics, and they occur at different morphological heights. They commonly have clastics at the bottom, interlayered with clayey horizons, and they continue upward with lacustrine limestones. These units are overlain above an angular unconformity by unconsolidated clastic sediments in the west, where a branch of the NAFZ is located.

In the southern zone, the Neogene sequences exhibit sedimentary facies distinctly different from those in the northern and central zones, and they occur in N-S-extending basins. In the Domanic area, for instance, there is thin-medium thick marl and limestone. In the Tunçbilek area, the lower part of the sequence has medium thick sandy and clayey facies with coal horizons, becoming dominated by marl, shale, and limestone. The Harmancik sequence begins with blocky conglomerates, turning into limestone dominant facies and fine-grain volcanoclastics upward.

The Neogene sequences in the region exhibit quite abrupt and distinct changes in facies in a N-S direction from one basin to another, though such changes are less prominent in an E-W direction. In other words, change in facies is rather insignificant along an E-W extension, but it is notable along the N-S orientation. Besides, the Neogene units become progressively older from the north to the south. The sequences also occur at different morphological heights. The sequences in the south lie at higher topographic altitudes than those in the north. For instance, the northern zone is at heights of 100–200 m, the central zone lies at heights of 400–600 m, and the northern zone is located at heights greater than 800 m.

Conclusions

The Neogene sequences of the Marmara region that exhibit differences in sedimentary facies indicate involvement of syn-depositional and post-depositional tectonic effects through space and geologic time. At the base of the sequences, thick layers of blocky clastics indicating chaotic sedimentation in contrast to normal depositional layers are observed. Their transition to and interfingering laterally with finer grain clastics are indicative of local tectonic effects. The overlying limestones and marl suggest a deepening of the basin through time. Volcanoclastic contributions vary from one sequence to another. These suggest that there was not a very large Neogene basin covering most of the study area, but each basin had an independent neotectonic history, differing from the nearby basin. The depositional conditions during the Oligocene-Middle Miocene were controlled by region-wide extensional tectonics. This is contemporaneous with the start of extensional tectonics and intruding magmatic plutons into the older collisional metamorphics—metamorphic massifes—in the northwestern Anatolian micro-plate. These igneous bodies were emplaced in NE-SW orientations into the basement rocks, suggesting an extension perpendicular to their long axis. The upper part of the Neogene sequences indicates that the tectonic activity continued up into the Quaternary as manifested by repeated coarse and sometimes blocky clastics, some areas becoming topographically positive and providing a source for depressions. This part of the Neogene sequence may be an indication of the early arrival of the NAFZ in the area and the counter-clockwise rotation of the Anatolian micro-plate. It may also represent a major change in tectonic regime, namely from an extension-dominated tectonic regime to a strike-slip-dominated tectonic regime, and this is manifested by a ubiquitous unconformity between the Upper Miocene and Pliocene-Pleistocene age units in the sequence. At present, occurrences of contrasting depositional environments and their different economic values in near or at short distance sites also indicate that these sequences were brought side-by-side after the completion of the deposition. This post-depositional activity is related to the development and continuing activity of the NAFZ into the present, which is supported by the morphology.

References

Koral, H., 2007. Sea-level changes modified the Quaternary coastal lines in the Marmara region, NW Turkey: What about tectonic movements? In: V. Yanko-Hombach, A.S. Gilbert, N. Panin, and P. Dolukhanov (Eds.), *The Black Sea Flood Question: Changes in Coastline, Climate, and Human Settlement*, pp. 571–601. Springer, Dordrecht.

Emre, Ö., Erkal, T., Tchepalyga (also Chepalyga), A., Kazanci, N., Keçer, M., and Ünay, E., 1998. Doğu Marmara Bölgesinin Neojen-Kuvaternedeki evrimi [Neogene-Quaternary evolution of the Eastern Marmara region]. *MTA Journal* 120: 233–258. (In Turkish)

Şengör, A.M.C., and Yılmaz, Y., 1981. Tethyan evolution of Turkey: a plate tectonic approach. Tectonophysics 75: 181–241.

Yaltirak, C., 2002. Tectonic evolution of the Marmara Sea and its surroundings. *Marine Geology* 190: 493–529.

Yilmaz, Y., and Gökaşan, E., and Erbay, A.Y., 2010. Morphotectonic development of the Marmara Region. *Tectonophysics* 488: 51-70.

WAVE CLIMATE VARIATION IN THE BLACK SEA

Kosyan, R.D. [1], and Divinskii, B.V. [2]

[1,2] Shirshov Institute of Oceanology, Russian Academy of Sciences.
353467 Gelendzhik, 1g Prostornaya, Russia
[1] rkosyan@hotmail.com
[2] divin@ocean.ru

Keywords: Wave climate, Black Sea, numerical modeling, spatiotemporal variability

Introduction

Wind waves are among the main factors affecting marine transport development and exploration of the shelf, as well as determining various dynamic processes in the coastal zone of the sea that impact coastal infrastructure, ecology, and recreation potential. Though it is a closed sea, the Black Sea is part of the global climatic system. The fact that climate variation is no longer doubted by anyone has, however, not resolved the debates over the nature of these variations and possible tendencies of climatic fluctuations. The main objective of this work is to analyze in detail the spatiotemporal variability of the Black Sea wave climate, document trends in the dynamics of the Black Sea wave climate over the period from 1979 to 2015, and also investigate long-term oscillations in the power of wind waves by studying their frequency spectra.

Basic data

Mathematical modeling is a modern tool used to study surface waves. In this research, we use the MIKE 21 SW spectral wave model developed at the Danish Hydraulic Institute (DHI, 2007). The main physical parameters used in the modeling of the Black Sea wave climate are: (1) full spectral model using non-stationary formulation of the problem; (2) the spectral frequencies are distributed logarithmically in a range of periodicities from 1.6 to 16.5 s; (3) directional resolution of the model is 15?, which is a compromise between the recommended values for swell (2-10°) and wind waves with a wider angular spectrum (10-30°); and (4) the following physical mechanisms are taken into account: (a) four-wave interaction; (b) wave energy dissipation due to surfing, breaking, and bottom friction; and (c) refraction.

The reanalysis data ERA-Interim prepared by the European Centre for Medium-Range Weather Forecasts (http://apps.ecmwf.int) were used in our work as the initial wind fields. The domain considered in the study is delimited by the following boundaries: latitude 40° N and 47° N, longitude 27° E and 42° E. The spatial resolution by latitude and longitude is 0.25°, and the time resolution is 3 hours.

Verification of the spectral wave model was performed using data from direct experimental observations. We used the field data covering almost the entire sea, which were obtained using the following instruments: Datawell Waverider buoys, ADCP, string wave recorders installed on stationary platforms, and satellite measurements (altimetry). The DHI MIKE 21 SW spectral wave model was successfully verified for Black Sea conditions and can be used as an instrument to study its wave climate.

Results

The main results of our study are as follows:

1. We obtained a large dataset consisting of the fields of calculated parameters of wind waves in the Black and Azov seas with a time step of 1 hour covering a period of 37 years (from 1979 to 2015).

2. The southwestern part of the Black Sea is characterized by the greatest wave potential. The mean power of wind waves in the southwestern part of the Black Sea reaches 8-10 kW per meter of the wave front, and it decreases to 2-3 kW/m in the eastern part of the sea.
3. Spatial inhomogeneity in the distribution of the power of wind waves over the Black Sea can be clearly seen (Fig. 1). Interannual fluctuations are most significant in the western part of the sea. The central and eastern parts of the sea are more homogeneous.

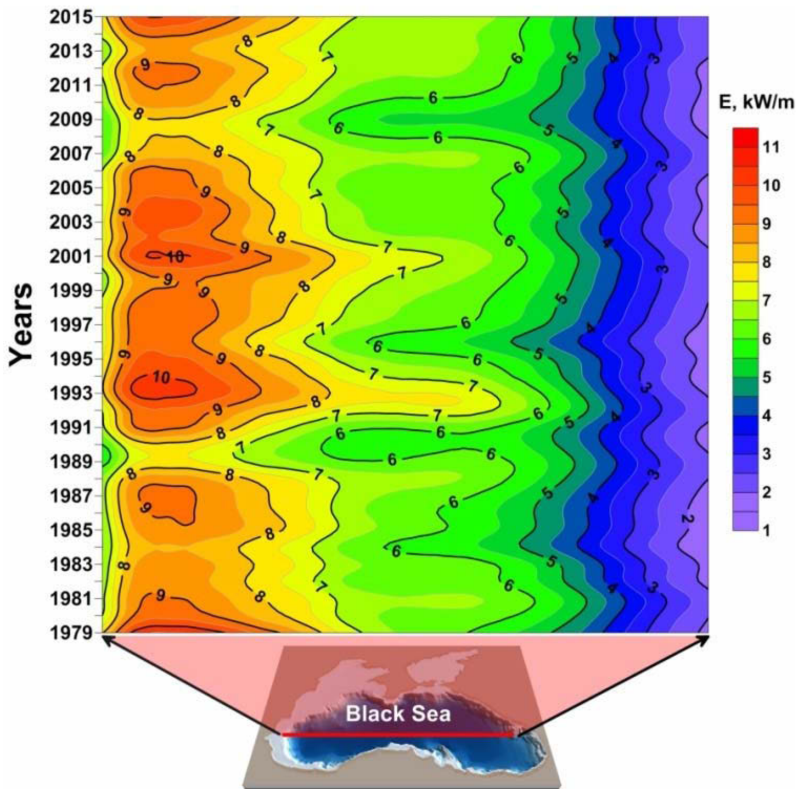


Figure 1. Meridional section of annual mean power of wind waves (kW/m) from 1979-2015.

4. The total annual power of waves in the western region of the Black Sea exceeds 2-3 times the power of waves in the eastern part of the sea. The contribution of strong storms (exceeding 20 kW/m) is also spatially inhomogeneous: in the western part, the contribution of strong storms to the total potential is on average 37%, in the central part it is 31%, and in the eastern part it is 24%. In other words, the wave climate in the western part of the sea is determined by strong and extremely strong storms, while the dominating role in the eastern part belongs to moderate storms.
5. During the last 37 years, redistribution of wave energy with respect to the directions of its propagation has been observed over the Black Sea. In the western part of the sea, this fact is reflected by an increase in the frequency of waves with northeastern directions, while the northwestern waves decrease. In the eastern part of the sea, the contribution of wind waves from the southeastern direction increases, and the northwestern waves become weaker.
6. We revealed the peculiarities related to the time structure of the power of wind waves and indices of atmospheric circulation. The period of maximum correlation between the power of wind waves and the North Atlantic Oscillation indices is 0.5 year, and

the period of maximum correlation with the Arctic Oscillation indices is 1.8 years. Both correlations are negative. We especially note powerful fluctuations with a period of one year, which are equally related to the wind waves over the entire Black Sea and the North Atlantic Oscillation index.

Acknowledgments

This work was initialized by the Russian Science Foundation, project no. 14-17-00547. The processing of experimental data used for this paper was supported by the Russian Science Foundation, project no. 14-50-00095. Analysis of the results was supported by the Russian Foundation for Basic Research (Project 17-05-00183).

References

DHI Water & Environment. 2007. *MIKE 21, Spectral Wave Module*. Hørsholm, Denmark.

GEOACOUSTIC AND GAS GEOCHEMICAL SIGNS OF HYDRATE PRESENCE ON THE CONTINENTAL SLOPE NORTH-EAST OF THE BLACK SEA

Kruglyakova, R. [1], *and Shevtsova, N.* [2]

[1,2] AQ "Yuzhmorgeologiya," 353461, Gelendzhik, Russia
[1] kruglyakova@ymg.ru
[2] shevnata@mail.ru

Keywords: "bright spot," pockmarks, BSR (bottom simulating reflections), bottom sediments, anomalies of methane

Introduction and methodology

Within the framework of the State Geological Survey of the continental slope and the abyssal zone of the Black Sea on sheets K-37-C (Mzymta canyon) and K-37-XVI (Abyssal 16), a complex of geological and geophysical studies have been carried out, including seismic (CDP), gravimetric, and magnetometer survey; a low-frequency continuous seismic profiling (low NSP); benthic geoacoustic profiling; side scan sonar (SSS) by MAK-1M complex; and gas geochemical investigations of bottom sediments (105 stations) (Fig. 1).

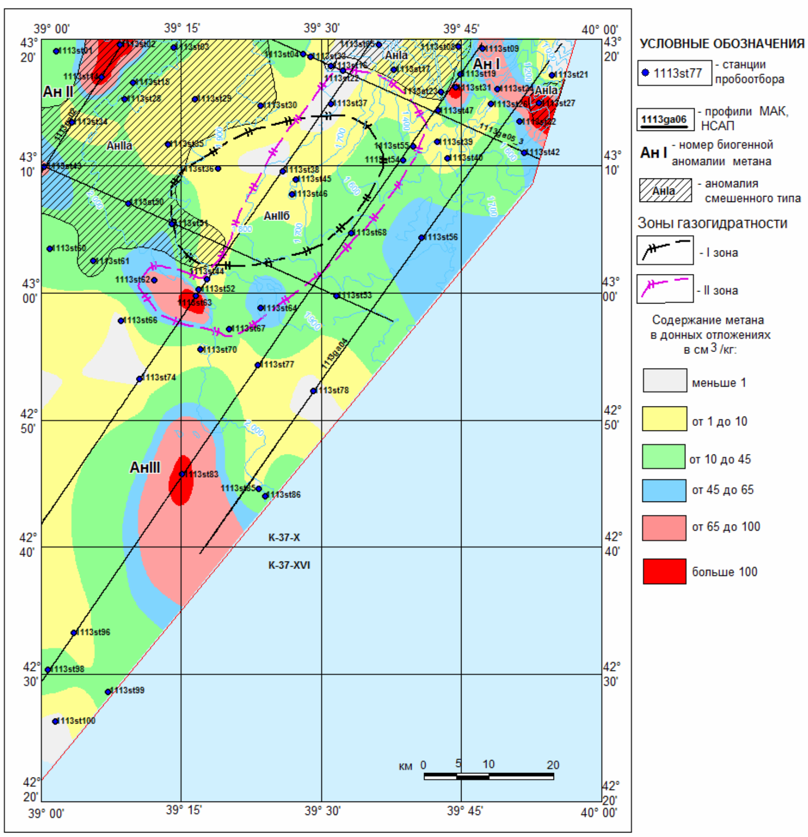


Figure 1. The distribution of methane in the bottom sediments of the northeastern Black Sea.

Bottom sediments were sampled by gravity corer (penetration depth up to 370 cm) and grab corer. Deposits encountered were represented by Novochernomorean, Drevnechernomorean, and Neoeuxinian sediments. Analysis of hydrocarbon gas and carbon dioxide (200 samples) was carried out at two depth intervals (I: to 100 cm; II: from 100 to 370 cm).

Results

In the bottom sediments, two types of methane anomalies were recognized biogenic and mixed (biogenic-thermogenic). Sediments of almost the entire area, with the exception of local spots, are highly gas-saturated and represent an extensive biogenic anomaly with a high content of methane (from 10 to 140 cm^3/kg), unsaturated hydrocarbons, and background content of methane homologues. The area is divided into three local concentration anomalies of methane — AnI, AnII, and AnIII (Fig. 1). Biogenic-thermogenic methane anomalies (AnIa, AnIIa) are probably related to the possible migration of fluids from the local structures: Adler in the Adler depression, Ryabinkina on the Shatsky bank, and Glubokovodnaya in the Eastern Black Sea basin. These local structures were detected by seismic profiling.

Within the studied area, two zones of gas hydrate presence were identified: I—in Lower Pleistocene (Chaudinean) deposits, and II—in Upper Pleistocene-Holocene (Neoeuxinian-Chernomorean) deposits (Fig. 1).

Gas hydrates in the sediment thickness. The first zone with signs of gas hydrate presence was detected by the geoacoustic-acoustic anomaly of a "bright spot" reflecting horizon BSR (bottom simulating reflections), pockmarks, and landslides.

In the area between stations 1113st14 and 1113st34 (8 km) in the profile 1113ga01 obtained by the MAK-1M profilogram, the "bright spot" anomaly was observed with a length of 1.1 km (Fig. 2).

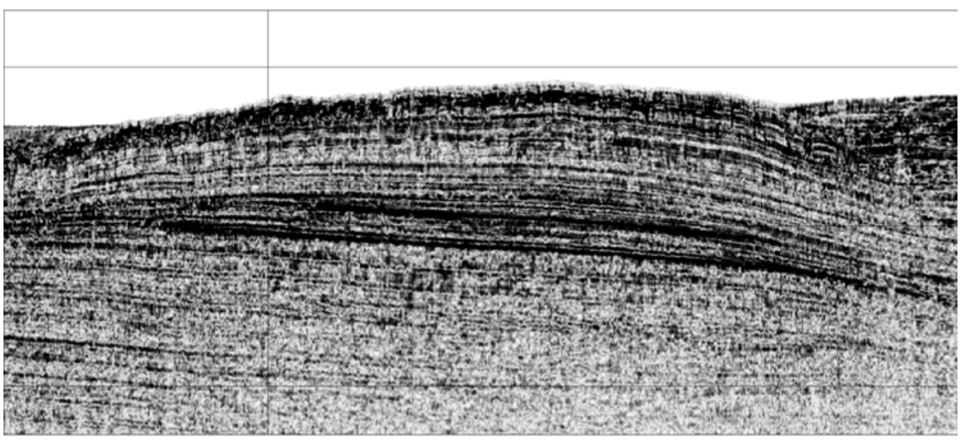


Figure 2. Profile 1113ga01 obtained using sub-bottom profiler MAK-1M illustrating an acoustic "bright spot" anomaly

Such amplitude anomalies indicate the presence of accumulations of free gas in the surface sediments under the regional impermeable beds. Impermeable beds are hydrate content layers that prevent the recovery of methane in the upper layers of the sediment. The anomaly of the "bright spot" is in the area of biogenic-thermogenic methane anomalies (AIIa, Fig. 1). Drevnechernomorean sediments of station 1113st14 (see interval 260 cm) are characterized by an extremely high content of methane (CH_4 = 110 cm^3/kg).

Within the contrasting anomalies of methane (AIIa) on the sonogram MAK 1M (between stations 1113st51 and 1113st53 of the profile 1113ga05), pockmarks are noted, which form a sort of circular structure with a diameter of about 1 km (Fig. 3). Ring structures are fluid-conducting structures that are poorly understood. Nevertheless, at the bottom of the Black

Sea, E. Shnyukov has discovered a circular structure about 12 km in diameter (Shnyukov, 2013; Shnyukov et al. 2014). On the sub-bottom profilogram in the area of 1113st51, near the ring structure, an acoustic anomaly of the "bright spot" type with a length of 270 m was observed (Fig. 3b).

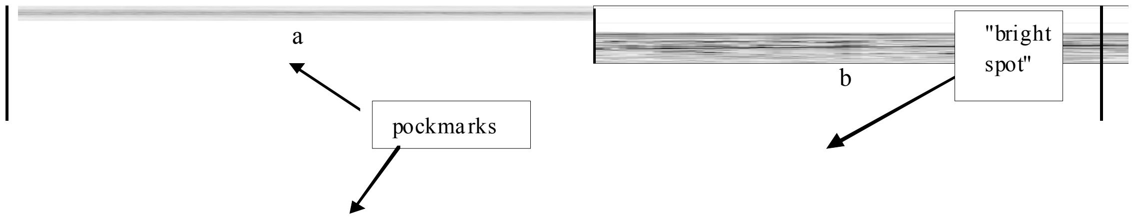


Figure 3. Sonar and profiler (MAK-1M) images along the profile 1113ga05 illustrating (a) a pockmark ring structure and (b) a "bright spot" acoustic anomaly

Profile 1113ga03 obtained using sub-bottom profiler MAK-1M shows the expressed acoustically hard horizon (from the surface to the 350 m horizon) in the area of stations 1113st55, 1113st54, and 1113st68 in the field of methane anomalies AII and II zone of gas hydrates with a length of 8.9 km (Fig. 4).

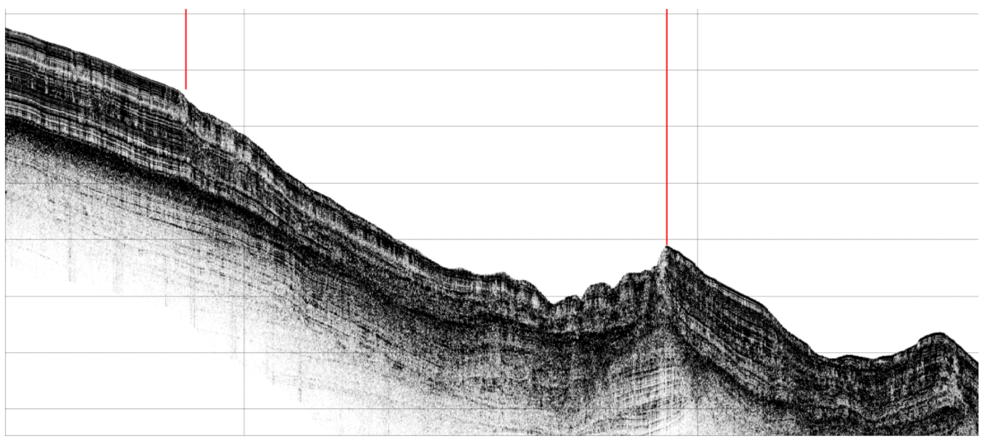


Figure 4. Detail of profilogram on the 1113ga03 profile, illustrating the reflective BSR horizon (gas hydrate layer) and a gas dome (station 1113st54).

One can say with great certainty that it reflects the BSR (bottom simulating reflections) horizon, hydrate content layer, under which there is an acoustic turbidity, i.e., gas-saturated sediments with local accumulations of free gas. It is known that the reflection of BSR repeating a bottom surface configuration, but which isn't the result of multiple reflections, is one of the main acoustic signs of the availability of gas hydrates in bottom sediments.

On the continental slope of this area, the BSR horizon occurs almost everywhere. It should be noted that the thermodynamic conditions here are favorable for the formation of methane gas hydrates. The gas saturation of the upper sedimentary sequence is displayed on the MAK-1M profilogram as acoustically transparent, turbid clarified layers, gas pockets, gas domes, lenses, and gas-saturated layers. The area represents the accumulative surface of a paleo-cone of Mzymta River drift, transportation and accumulation of accumulative turbidite on the continental slope, the foot, and the abyssal plain. According to geoacoustic research, landslide processes, which are also indirect signs of the presence of hydrate content layers in the sediment, are recognizable.

Gas hydrates in the surface layer of bottom sediments (II zone). All Drevnechernomorean sediments are characterized by extremely high methane content— from 0,007 up to 140 cm^3/kg on average content - 28.5 cm^3/kg. Within anomalies II (AnII) at several stations in the sediment, indirect signs of gas hydrate presence are observed. Gas hydrates here may be in the dispersed state. Geologists visually observed indirect evidence of gas hydrates in the sediments after getting them on board the ship—high gas saturation, swelling, watering, layering, bubble gas emission, and cracking with the formation of gaping fractures up to 1 cm. Deformation of the sediment structure and the high gas saturation are signs of the destruction of micro-crystals of gas hydrates. Thickness of the watering zone and the destruction of the sediment structure is observed from 30 to 80 cm in the Drevnechernomorean sediments, in which sapropel interlayers form thin lenses. alternating with clay material, and the layers are sometimes deformed or broken. Sapropel is a screen for the migration of methane into the above lying layers of sediment; under the sapropel, biogenic (and possibly migrational) methane is accumulated.

Contrasting anomalies of biochemical methane in the surface layers of bottom sediments result from the genesis of biogenic methane by a complex of methane-generating microorganisms in the Drevnechernomorean sediments, high gas saturation of the upper Holocene sedimentary cover, gas intake on the degassing channels, and seepage of methane from hydrate content layers.

Consequently, in the first few meters of bottom sediments and at the top of the sedimentary cover in Lower Plestocene deposits of the northeastern Black Sea continental slope, areas of gas hydrate accumulation are marked. Here exist all the conditions for the formation of natural gas hydrate—a high content of methane, low temperature (9.5° C), high pressure (water depth from 1302 m to more than 2000 m), and the presence of layers of sand and silt. It is known that in the deep zone of the Black Sea, gas hydrates in the bottom surface layer may be formed at depths greater than 725 m (Akhmetzhanov et al., 2007; Egorov et al., 2011).

Acknowledgments

This work was performed as part of the State contract №44 / 01 / 13-56 Rosnedra "Geological survey of scale 1: 200 000 sheets of K-37-C (Mzymta canyon), K-37-XVI (Abyssal 16)."

References

Akhmetzhanov, A.M., Ivanov, M.K., Kenyon, N.H., and Mazzini, A. (eds.), 2007. Deep-water Cold Seeps, Sedimentary Environments and Ecosystems of the Black and Tyrrhenian Seas and the Gulf of Cadiz; Preliminary Results of Investigations during the TTR-15 Cruise of RV “Professor Logachev” June-August, 2005. Intergovernmental Oceanographic Commission Technical Series 72. UNESCO, Paris.

Egorov, V., Artemov, Yu., and Gulin, S., 2011. The Methane Seeps in the Black Sea. Environment-forming and Ecological Role. (Ed. G.G. Polikarpov.) SPC "ECOSEA-Hydrophysics," Sevastopol. (In Russian)

Shnyukov, E.F., 2013. Mud volcanoes of the Black Sea as a prospecting indicator of methane gas hydrates. Lithology and mineral resources 48(2): 114-121.

Shnyukov, E.F., Stupina, L., Rybak, E., Maslakov, N., Kruglyakova, R., Andreev, V., and Gusakov, I., 2014. Mud Volcanoes of the Black Sea. Catalog. State Scientific Center of OmGOR, Logos, Kiev. (In Russian)

NEW RESULTS ON CHRONOLOGY OF LATE PLEISTOCENE PALEOGEOGRAPHICAL EVENTS OF NORTHERN CASPIAN SEA (OSL DATING)

Kurbanov, R.N. [1], Murray, A.S. [2], and Yanina, T.A. [3]

[1,3] Faculty of Geography, Moscow State University, Moscow, Russia, 119991
Institute of Geography RAS, Moscow, Russia, 119017
[1] roger.kurbanov@gmail.com
[2] didacna@mail.ru
[2] Nordic Laboratory for Luminescence Dating, Department of Geoscience, University of Aarhus, Risø Campus, Denmark, DK-4000
anmu@dtu.dk

Keywords: OSL-dating, Khvalynian transgression, geochronology, Northern Caspian

Introduction

The problem of periodizing the evolutionary history of the natural environment is one of the most important at the present time. For the Caspian region, the lack of factual data on the chronology of the paleogeographic events of the Late Pleistocene is the cause of the current lack of consensus about the scale, duration, and position of individual transgressive and regressive stages. So, the discussion continues about the age of the largest transgressive epoch of the Late Pleistocene of the Caspian Sea, the Khvalynian. Age estimates by specialists vary in range from 70 thousand (Rychagov, 2014) to 20 thousand years (Dolukhanov et al., 2010; Arslanov et al., 2016), while the Late Khvalynian stage is included in the framework of the Holocene (Svitoch, 2009). Obtaining a modern geochronologic scheme for the evolution of the natural environment of the Caspian region is, in our view, the primary task for creating a reliable basis for paleogeographic correlations and reconstructions.

Methodology

Three sections of the Lower Volga region (Fig. 1), the stratotypic region of the Late Pleistocene for the Caspian region, were chosen to determine the age of the Early Khvalynian transgression: Srednyaya Akhtuba, Raigorod, and Leninsk.

Figure 1. Stages of the Kvalynian transgression and position of dated sections.

All three sections are characterized by the presence of a thick stratum of "chocolate clays" containing Khvalynian fauna (Yanina et al., 2017).

Our chronology is based on age determination using the method of optically stimulated luminescence (Murray and Wintle, 2000) on samples of quartz and feldspar in the sand-size range (from 90 to 250 microns). The samples were prepared according to standard procedure. The fine and medium sand fractions selected after sieving were treated with 10% HCl and H_2O_2, followed by 10% and 40% HF. Luminescence dating was performed using Risø TL/OSL reader.

Results

The OSL signal from the quartz was homogeneous, the dose regeneration coefficients were satisfactory (1.02 ± 0.04, $n = 16$), and the samples of modern analogues, as well as the ratio of the signal over quartz and feldspar, was indicated by a sufficient zeroing of the signal. Our results show that the Early Khvalynian "chocolate clays" from the three sections are characterized by an age from 12 to 17 thousand years (9 dates). The age estimates obtained for the marine Khvalynian sediments were confirmed by dating of the overlying kashtanozem soils (from 0.16 to 8 thousand years) and the underlying loess-soil series (20–25 thousand years) for all three sections studied.

Conclusions

The obtained results confirm the young age of the transgressive stage of the Early Khvalynian era, when the layers of chocolate clays of the northern part of the Lower Volga region were formed. In this case, the absolute sampling altitudes (9.33, 8.51, and 6.98 m) indicate that the position of sea level was above these elevations, and the sedimentation rate was about 50 cm/year.

Acknowledgements

This work was supported by the Russian Science Foundation, project 17-77-10134.

References

Arslanov, Kh.A., Yanina, T.A., Chepalyga, A.L., Svitoch, A.A., Makshaev, R.R., Maksimov, F.E., Chernov, S.B., Tertychniy, N.I., and Starikova, A.A., 2016. On the age of the Khvalynian deposits of the Caspian Sea coasts according to ^{14}C and ^{230}Th/^{234}U methods. *Quaternary International* 409A: 81–87.

Dolukhanov, P.M., Chepalyga, A.L., and Lavrentiev, N.V., 2010. The Khvalynian transgressions and early human settlement in the Caspian basin. *Quaternary International* 225(2): 152–159.

Murray, A.S., and Wintle, A.G., 2000. Luminescence dating of quartz using an improved single-aliquot regenerative-dose protocol. *Radiation Measurements* 32(1): 57–73.

Rychagov, G.I., 2014. Khvalynskii etap v istorii Kaspiyskogo moray [The Khvalynian stage in the history of the Caspian Sea]. *Vestnik MGU, Ser. Geografiya* 3: 3–9. (In Russian)

Svitoch, A.A., 2009. Khvalynian transgression of the Caspian sea was not a result of water overflow from the Siberian proglacial lakes, nor a prototype of the Noachian flood. *Quaternary International* 197(1–2): 115–125.

Yanina, T.A., Svitoch, A.A., Kurbanov, R.N., Murray, A.S., Tkach, N.T., and Sychev, N.V., 2017. Opyt datirovamiya pleystotsenovykh otlojeniy Nizhnego Povolzhya metodom optichesk-stimulirovannoy luminesentsii [An experience of optically-stimulated luminescence dating of Pleistocene sediments of the Lower Volga region]. *Vestnik MGU, Ser. Geografiya* 1: 3–9. (In Russian)

.

OSL CHRONOLOGY OF THE LATE QUATERNARY LOESS-SOIL SERIES IN THE EASTERN AZOV SEA REGION

Kurbanov, R.N. [1,2], Zhou, L. [3], and Sychev, N.V. [4]

[1,4] Faculty of Geography, Moscow State University, Moscow, Russia, 119991
[3] Institute of Geography RAS, Moscow, Russia, 119017
[1,3] roger.kurbanov@gmail.com
[3] Department of Geomorphology and Quaternary Geology, Peking University, Beijing, China
lpzhou@pku.edu.cn

Keywords: Loes-soil formation, OSL-dating, geochronology, Late Quaternary

Introduction

An absolute age was obtained for the first time using the OSL method for the Beglitsa section, which reflects the Late Pleistocene evolution of the loess-soil series (LSS) of the Eastern Azov Sea. There has been a great need to obtain a chronometric chronology for the loess-soil formation of the South East European Plain, a reference region for the reconstruction of the history of the landscape and climate evolution of the off-glacier area (Velichko, 2017). The existing scheme for the pedostratigraphy of the Don-Azov region is based on complex data: correlation with the underlying LSS marine-alluvial sediments of known age, paleofaunistic definitions of loess and paleosols, paleomagnetic data, and the results of radiocarbon dating (Konstantinov, 2016).

According to this scheme (Velichko, 2012), the formation of the main phase, paleosols, and pedocomplexes (PC) corresponds to the following thermochrons of Late Pleistocene and marine isotopic stages: 1. Brianskaia paleosol = the Bryansk interstadial, MIS 3: 57–29 ka; 2. Mezinsky PC = Mikulino (Eemian) interglacial, MIS 5e: ~130–115 ka; 4. Kamensky PC = Kamenskoe Interglacial, MIS 7: ~191–243 ka; 5. Inzhavinsky PC = Lihvinskoe interglacial, MIS 9: ~300–337 ka; 6. Voronsky PC = Muchkapian interglacial, MIS 13: ~478–533 ka.

According to its properties, the early (Salyn, MIS 5e) phase of the Mesin soil complex is attributed to common chernozems, which are developed in the given territory under modern conditions. The soil of the late phase of the Mesin soil complex was formed under conditions that were more arid than current conditions in the area, and it corresponds to the Early Valday-Krutitsk interstadial (MIS 5c). The sand-enriched paleosol, which is compared with the Bryansk (MIS 3) interstadial, is defined as a sod, poorly developed. The Late Valday period includes the main phase of loess formation (the so-called Desinsky horizon of the composite stratigraphic scheme). According to the physico-chemical properties and homogeneity of the macrostructure, this horizon corresponds to the extreme cryoarid conditions of the Late Valday Periglacial (MIS 2). Only at a depth of about 3.5 m do the results of micromorphological analysis reveal an increase in macroporosity, probably reflecting some increase in the closeness of the grass cover. Presumably, this horizon in the context of Beglitsa indicates a short-term decrease in aridity and corresponds to the Pulkovo level of the composite scheme (Velichko, 2017).

Methodology

The Beglitsa section most fully characterizes the Late Pleistocene stage of development of the Eastern Azov region. Here, above the marine sandy loamy-clay deposits with Khazar fauna, there is a subaerial stratum with a twin Mesinsky pedological complex and a thick Valday loess, and the soil of the Bryansk interstadial can be traced. The OSL dating for this section will allow us to determine the chronometric age of the deposits with the greatest detail and reliability. Samples were taken at night in opaque containers; we took into account the experience of the first attempt at dating in 2015, when for most samples there were not enough grains of quartz in the size fractions of 90–180 and 180–250 microns.

Results

Within the framework of the RSF project 14-17-00705, a geochronologic scheme for the Late Pleistocene of the Eastern Azov Sea was obtained. OSL dating confirmed the reconstruction of A.A. Velichko and the age of the main stages of development of the region's natural environment (Fig. 1).

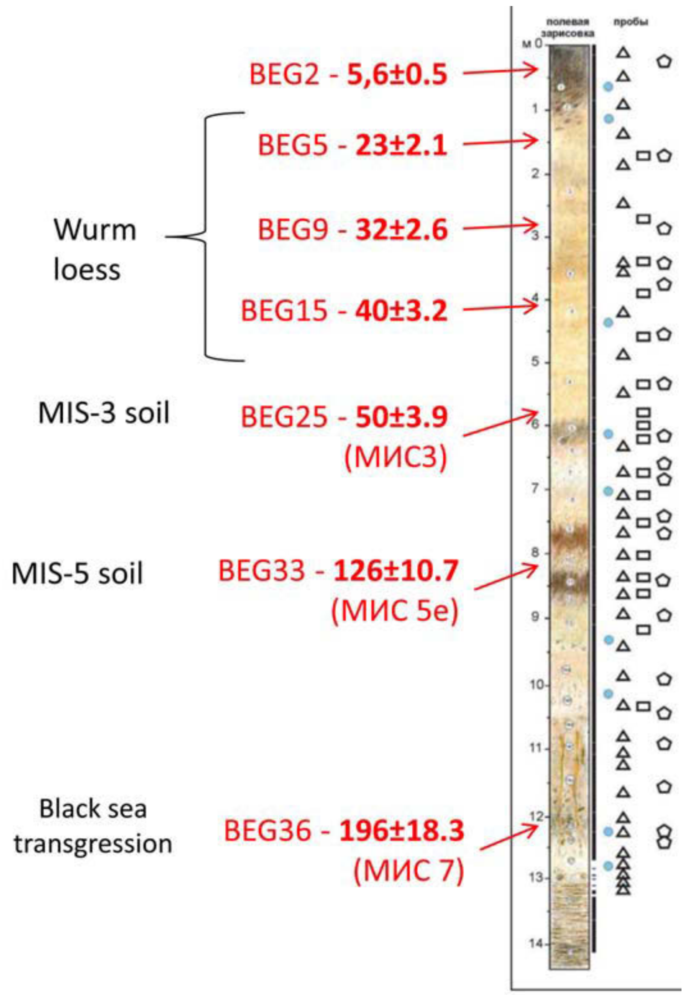


Figure 1. OSL-dating results for Beglitsa section

1. The modern soil is characterized by a date of 5.6 ± 0.5 ka; 2. The Valday loess yielded three dates, increasing successively with depth: 23 ± 2.1; 32 ± 2.6, and 40 ± 3.2 ka, which indicates active loess accumulation processes under conditions of cooling during the late stage of the Bryansk interstadial; 3. The warmest time during MIS 3, marked in the sections of the Bryansk paleochrone, dates back to 50 ± 3.9 ka. 4. The general cooling that occurred during MIS 4 was marked by active loess accumulation and is dated to 88.54 ± 4.95 ka; 5. For the warmest stage of the Mikulino (Eemian) interglacial, the Salyn paleosol (MIS 5e), a date of 124.12 ± 6.55 ka was obtained, and for the underlying loess deposits, 155.81 ± 7.94 ka. 6. Extremely interesting is the age of the underlying loess-soil series marine-alluvial sediments in the Beglitsa section with Late Khazarian fauna described earlier (Mammuthus trogontherii Pohl., Mammuthus cf. Chosaricus); the resulting date was 196 ± 18,300 ka corresponding to

the late stages of MIS 7, and the formation of the strata was apparently connected with the final stages of the Uzunlarian transgression of the Pontus.

Acknowledgements

This work was supported by the Russian Science Foundation, project 14-17-00705.

References

Konstantinov, E.A., Velichko, A.A., Kurbanov, R.N., and Zakharov, A.L., 2016. Middle to Late Pleistocene topography evolution of the North-Eastern Azov region. *Quaternary International* on line: doi.org/10.1016/j.quaint.2016.04.014.

Velichko, A.A., Morozova, T.D., Borisova, O.K., Timireva, S.V., Semenov, V.V., Kononov, Y.M., Titov, V.V., Konstantinov, E.A., and Kurbanov, R.N., 2012. Stanovleniye zony stepey yuga Rossii (po materialam stroyeniya lessovo-pochvennoi formtsii Dono-Azovskogo regiona) [South Russian steppe-zone formation (based on the structure of the loess-soil formation of the Don-Azov region]. *Doklady Akademii nauk* 455(4): 464–467. (In Russian)

Velichko, A.A., Borisova, O.K., Zakharov, A.L., Kononov, Y.M., Konstantinov, E.A., Kurbanov, R.N., Morozova, T.D., Panin, P.G., and Timireva, S.V., 2017. Smena landshaftnykh obstanovok na yuge Russkoi ravniny v pozdnem Pleistotsene po rezultatam issledivaniya lessovo-pochvennoy serii Priazovia [Lanscape evolution of the South Russian plain in the Late Pleistocene based on research of the loess-soil series of the Azov Sea region]. *Izvestiya RAS, Ser. Geograficheskaya* 1: 74–83. (In Russian)

CHEMICAL COMPOSITION OF LOWER KHVALYNIAN DEPOSITS IN THE MIDDLE AND LOWER VOLGA REGION

Makshaev, R.R.

Lomonosov Moscow State University, Faculty of Geography, Moscow, 119991, Russia
mcshaev@yahoo.com

Keywords: Late Pleistocene, Northern Caspian lowland, clay minerals, rare elements

Introduction

Khvalynian deposits of the northwestern part of the Caspian lowland differ from the older Pleistocene formations of the Caspian. The main reason for this is the facies of chocolate clays, which accumulated in the Volga estuary and the northwestern part of the Khvalynian basin between 18–13 cal ka BP. Many researchers have specified the features of the Lower Khvalynian deposits, their distribution, mode of occurrence, and origin, but the records on their material composition are not so extensive.

Material and methods

The aim of this work is to determine the chemical composition of chocolate clays in different parts of the investigated area. Several key sections (Svetly Yar, Sr. Akhtuba, Novoprivolnoe, and Vykhlyancevo) were selected within the Middle and Lower Volga. The data on the main chemical compounds and elements were obtained for 10 samples from those key sections using ICP-AES and ICP-MS methods.

Results

Al_2O_3 (aluminum oxide) predominates in all samples, with its concentration varying from 14–17% (Fig. 1).

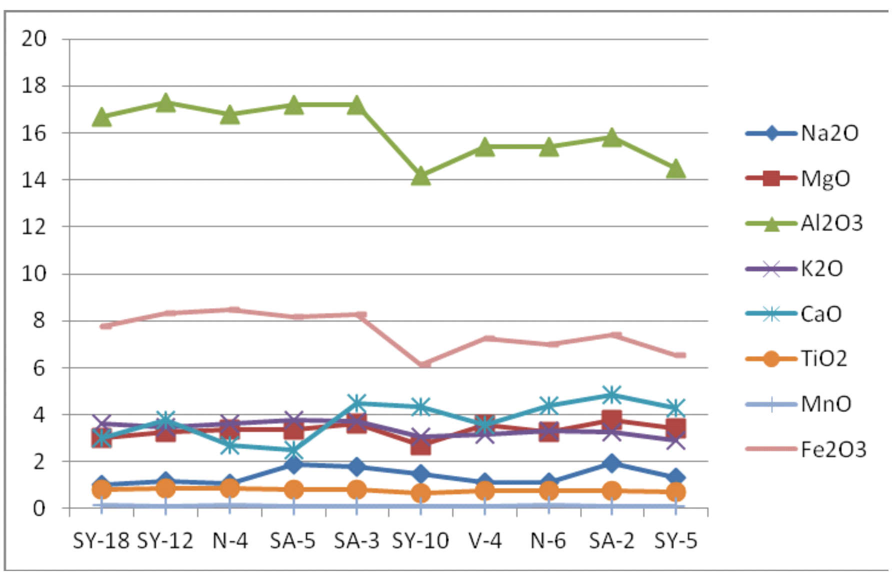


Figure 1. Major oxide composition of chocolate clays (weight (%).

The concentration of Fe_2O_3 (iron oxide) varies within the range of 6–8.5%. For CaO (calcium oxide), the variability is in the range of 3–5%. Concentrations of K_2O (potassium oxide) and Mg_2O (magnesium oxide) for all samples are approximately the same and reach 3.3% on average. The remaining oxides (TiO_2, Na_2O, MnO) account for less than 2.5% in total.

For samples taken from the base of the chocolate clays, the maximum concentrations of Al^2O^3, Fe^2O^3, and K^2O are registered. In the middle and upper parts, the concentration of these oxides decreases, but their ratio remains approximately the same. Also, at the base of the chocolate clays, a low concentration of $CaCO_3$ (2.8%) is noted, while in the middle and upper parts, this concentration increases to 4.5% on average..

Table 2. Trace-element concentrations of chocolate clays (concentrations in ppm).

Sample / Element	lower part				mid part				upper part	
	SY-18	SY-12	SA-5	N-4	SY-10	V-4	N-6	SA-3	SY-5	SA-2
Zn	102.9	105.9	108.6	106.6	78.8	97.8	92.4	108.3	89.6	91.8
Sr	159.1	177.1	220.6	162.6	200.8	191.2	162.8	223.4	223.1	236.7
Mo	0.88	0.71	0.89	1.09	0.83	0.75	0.81	0.80	1.14	0.97
V	127.6	144.3	135.4	139.2	109.4	127.6	122.4	138.7	115.4	127.5
U	2.65	2.85	2.75	2.80	2.42	3.02	2.39	2.94	2.66	2.92
Cu	44.6	50.3	43.3	48.6	34.6	42.8	42.2	45.6	43.6	45.6
Ni	67.9	69.1	64.5	70.0	57.8	65.8	71.3	65.0	63.2	66.9
Co	22.4	22.6	22.6	22.6	17.1	20.3	21.5	22.9	18.8	20.2
Cr	95.1	103.6	99.4	103.4	85.0	101.4	95.9	101.8	91.7	100.6
Be	2.5	2.6	2.7	2.6	1.8	2.2	2.1	2.4	2.1	2.3
Ba	485.5	573.3	469.0	560.1	446.4	461.5	490.7	518.0	494.9	539.5
Pb	17.6	17.3	18.5	18.4	15.6	15.2	16.0	17.3	15.9	16.3
V	127.6	144.3	135.4	139.2	109.4	127.6	122.4	138.7	115.4	127.5
Rb	132.5	118.9	138.9	130.8	102.9	119.8	113.6	144.8	101.9	119.2
Cs	6.1	6.3	6.6	6.5	5.0	5.9	5.7	6.4	4.9	5.8
Y	24.5	25.5	24.1	25.0	20.3	22.1	23.8	24.3	21.8	22.3
Ga	23.5	23.4	24.4	24.8	17.3	21.0	20.3	24.7	19.2	20.4
Se	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8

The concentration of Sr, which belongs among the active elements, gradually increases toward the upper parts of the Lower Khvalynian sediments. This behavior corresponds with the features of the active hydrodynamic regime, which contributed to the washing-out of this element. In the middle and upper parts of the Lower Khvalynian sediments, Sr began to accumulate gradually, which may reflect more tranquil conditions in the sedimentation process. One of the most mobile elements is Zn (Perelman, 1975). Its concentration in the Lower Khvalynian sediments gradually decreases toward the upper parts. High Zn concentrations are usually determined by the clay mineral smectite (Khrustalev, 1978). In the Lower Khvalynian sediments, Ba is represented more widely than other microelements. Ba is relatively low in mobilility and often accumulates under coastal-marine conditions. Its presence can be related to the presence of the mineral witherite (BaCO3), which forms small isomorphic clusters together with aragonite.

Conclusion

According to the concentrations of the basic compounds, it is possible to distinguish 3 layers that are generally correlated with the lithologic differentiation of the chocolate clays, which may reflect changing conditions of sedimentation. In early stage of clay accumulation, the prevalence of aluminum oxide and iron oxide among other oxides reached 17–8%, respectively. Later, this group of oxides gradually decreased, whereas the proportion of calcium oxide increased. The color of chocolate clays is determined by the presence of a large amount of iron oxide in their composition. The main sources of iron oxide are illite and chlorite.

Acknowledgments

This work is supported by the RSCF (Project 16-17-10103) and IGCP 610.

References

Arbuzova, S.K., 1970. Mineralogicheskie osobennosti khvalynskikh glin v bassejne nizhney Volgi [Mineralogical features of Khvalynian clays in the Lower Volga River basin]. *Bulletin of the Commission for the Study of the Quaternary* 37: 41–46. (In Russian)

Khrustalev, Yu.P., 1978. Zakonomernosti sovremennogo osadkonakoplenija v Severnom Kaspii [*Regularities of Modern Sedimentation in the Northern Caspian*]. Rostov University Press, Rostov-on-Don. (In Russian)

Perelman, A.I., 1975. Geohimiya landshaftov [*Geochemistry of Landscapes*]. Nauka, Moscow. (In Russian)

PALEOCLIMATIC RECONSTRUCTION FROM MARINE RECORDS OF THE CENTRAL AND WESTERN MEDITERRANEAN AREAS OVER LAST FIVE MILLENNIA USING PLANKTONIC FORAMINIFERA

Margaritelli, G.[1,2], and Lirer, F.[3]

[1,3] Istituto Ambiente Marino Costiero (IAMC) – CNR, Calata Porta di Massa, Interno Porto di Napaoli,80133, Napoli, Italy
[1,2] GiuliaMargaritelli@hotmail.it
[2] fabrizio.lirer@iamc.cnr.it
[2] Dipartimento di Fisica e Geologia – Università di Perugia, Via Alessandro Pascoli, 06123 Perugia, Italy

Keywords: paleoclimate, last millennia, planktonic foraminifera

Introduction

The Mediterranean basin represents a hot spot for paleoclimatic reconstruction for the last millennia, but unfortunately, temporally and spatially high-resolution climate information and reconstructions from marine archives are still limited. Planktonic foraminifera have been used to reconstruct the climate evolution of the last five millennia from marine sediment cores of the western and central Mediterranean Sea. In particular, we provide a comparison between planktonic foraminiferal paleoclimatic curves obtained from different environmental areas of the Mediterranean basin (Fig. 1): (i) the western Sicily Channel (core water depth 475 mbsf); (ii) the Minorca Basin (core water depth 2117 mbsf); (iii) the north Tyrrhenian Sea (core water depth 87.2 mbsf); (iv) the central Tyrrhenian Sea (core water depth 93 mbsf) and south Adriatic Sea (1103mbsf). These results are compared with paleoclimatic curves from outside the Mediterranean marine areas to evaluate the geographical extent of the recognized climatic variability.

Figure 1. Location map of the study cores from the Mediterranean Sea. Core C5 (Margaritelli et al., 2016), C90 (Lirer et al., 2013; 2014), HER-MC-MR (Cisneros et al., 2016), and cores ND11, ND9, ND2, ND14Q, ND18 from this work.

Methodology

The planktonic foraminiferal paleoclimate curve was calculated following Capotondi et al. (2016). It represents the algebraic sum of warm-water species percentages (expressed as positive values) and cold-water species percentages (expressed as negative values) based on ecological preferences and modern habitat characteristics reported in Hemleben et al. (1989) and Pujol and Vergnaud Grazzini (1995). Warm-water species are *Globigerinoides ruber* (white and pink varieties), *G. sacculifer*, *G. quadrilobatus*, *Globigerinella siphonifera*, and *Orbulina universa*. The cold-water species are *Globigerina bulloides*, *Globigerinita glutinata*, *Turborotalita quinqueloba*, *Globorotalia truncatulinoides*, *G. inflata*, and *Neogloboquadrina pachyderma* (dex). Negative and positive values of the curve allow qualitative estimates for cold and warm surface water, respectively.

Results

The planktonic foraminiferal paleoclimatic curves document an overall warm and stable climatic condition from 3500 BCE to 750 BCE, corresponding to low amplitude oscillation in the $\Delta^{14}C$ residual and to a period where the NAO index does not show a particular trend and/or main oscillation. From 750 BCE to ca. 250 BCE, the Mediterranean and extra-Mediterranean paleoclimatic curves document a transition-cooling phase, which becomes consistent at ca. 250 BCE, corresponding with the sharp global cooling related to the Greek solar minimum. This short time interval (750 BCE to ca. 250 BCE) corresponds to the well-known Sterno-Etrussia excursion in the terrestrial magnetic field.

The global cooling over the last two millennia, related to the decrease in insolation, is documented by the parallelism of all planktonic foraminiferal paleoclimatic curves, which show an isochronous response of Mediterranean and extra-Mediterranean planktonic foraminifera. This long-term cooling trend parallels the progressive trend *vs* negative anomaly in the $\Delta^{14}C$ residual and the shift of the NAO index trend toward positive values, which reach their maximum cooling during the Little Ice Age at ca. 1800 CE (Maunder Minimum). At ca. 550 CE, the planktonic foraminiferal paleoclimate curves show a further cooling phase, which corresponds in age to the Late Antique Little Ice Age (LALIA), considered as an additional environmental factor contributing to the establishment of important changes in human culture. At 1800 CE, the paleoclimatic curves show a turnover *vs* the modern warm climate condition.

Conclusions

This comparison will provide a more complete high-resolution picture of climate changes in the Mediterranean region, while validating the use of planktonic foraminifera as a tool for global paleoclimate reconstruction over the last five millennia.

Acknowledgments

We acknowledge financial support from the Italian Project of Strategic Interest NEXTDATA (http://www.nextdataproject.it) “A national system for recovery, storage, accessibility and dissemination of environmental and climatic data from mountain and marine areas.”

References

Capotondi, L., Girone, A., Lirer, F., Bergami, C., Verducci, M., Vallefuoco, M., Afferri, A., Ferraro, L., Pelosi, N., and De Lange, G.J., 2016. Central Mediterranean Mid-Pleistocene paleoclimatic variability and its association with global climate. *Palaeogeography Palaeoclimatology Palaeoecol*ogy 442: 72–83.

Cisneros, M., Cacho, I., Frigola, J., Canals, M., Masqué, P., Martrat, B., Casado, M., Grimalt, J.O., Pena, L.D., Margaritelli, G., and Lirer, F., 2016. Sea surface temperature variability in the central-western Mediterranean Sea during the last 2700 years: a multi-proxy and multi-record approach. *Climate of the Past* 12: 849–869.

Hemleben, C., Spindler, M., and Anderson, O.R., 1989. *Modern Planktonic Foraminifera*. Springer-Verlag, New York.

Lirer, F., Sprovieri, M., Ferraro, L., Vallefuoco, M., Capotondi, L., Cascella, A., Petrosino, P., Insinga, D.D., Pelosi, N., Tamburrino, S., and Lubritto, C., 2013. Integrated stratigraphy for the late Quaternary in the eastern Tyrrhenian Sea. *Quaternary International* 292: 71–85.

Lirer, F., Sprovieri, M., Vallefuoco, M., Ferraro, L., Pelosi, N., Giordano, L., and Capotondi, L., 2014. Planktonic foraminifera as bio-indicators for monitoring the climatic changes that have occurred over the past 2000 years in the southeastern Tyrrhenian Sea. *Integrative Zoology* 9: 542–554.

Margaritelli, G., Vallefuoco, M., Di Rita, F., Capotondi, L., Bellucci, L.G., Insinga, D.D., Petrosino, P., Bonomo, S., Cacho, I., Cascella, A., Ferraro, L., Florindo, F., Lubritto, C., Lurcock, P.C., Magri, D., Pelosi, N., Rettori, R., and Lirer, F., 2016. Marine response to climate changes during the last five millennia in the central Mediterranean Sea. *Global and Planetary Change* 142: 53-72.

Pujol, C., and Vergnaud Grazzini, C., 1995. Distribution patterns of live planktic foraminifers as related to regional hydrography and productive systems of the Mediterranean Sea. *Marine Micropaleontology* 25(2–3): 187–217.

THE CLIMATE RECORD OF MARINE ISOTOPE STAGE 19 FROM MARINE AND TERRESTRIAL SIGNALS IN THE ALBORAN AND IONIAN BASINS

Marino, M.[1]*, Bassinot, F.*[2]*, Bertini, A.*[3]*, Combourieu Nebut, N.* [4]*, Girone, A.*[5]*, Herbert, T.* [6]*, Maiorano, P.* [7]*, Nomade, S.* [8]*, and Toti, F.* [9]

[1,5,7] Dept. Earth and Geoenvironmental Sciences, Bari University Aldo Moro, Bari, Italy
[1] maria.marino@uniba.it
[5] angela.girone@uniba.it
[7] patrizia.maiorano@uniba.it
[2,8] Laboratoire des Sciences du Climat et de l'Environnement, Gif-sur-Yvette, France
[2] franck.bassinot@lsce.ipsl.fr
[8] sebastien.nomade@lsce.ipsl.fr
[3.9] Dept. Earth Sciences, Florence University, Florence, Italy
[3]adele.bertini@unifi.it
[9] francesco.toti@unifi.it
[4] HNHP UMR 7194 CNRS, Muséum National d'Histoire Naturelle, Paris, France
[4] nathalie.nebout-combourieu@mnhn.fr
[6] Department of Earth, Environmental and Planetary Sciences, Brown University, Providence, USA
[5] timothy_herbert@brown.edu

Keywords: MIS 19, calcareous plankton, pollen, oxygen and carbon isotopes, Mediterranean

Introduction

Marine Isotope Stage (MIS) 19 (0.78 Ma) is the mid-Pleistocene interglacial considered the best analogue of MIS 1 due to their similar orbital configuration (extraordinarily low eccentricity and obliquity maximum close to the precession minimum) and (paleo)climatic signal (Tzedakis et al., 2012). A strong likeness between the climate trends through Termination IX (I) and the onset of full interglacial 19 (1) has been recently suggested (Maiorano et al., 2016) based on marine and terrestrial biological proxies at the inland marine succession of Montalbano Jonico. New investigations are ongoing to improve such evidence in this sedimentary section, which is a reference for the Lower-Middle Pleistocene boundary. New studies have been carried out through the MIS 20–19 interval along the deep-sea sediments of the Western Mediterranean Ocean Drilling Program Site 976 (Alboran Sea) with the aim to compare the response of calcareous plankton (nannofossils and foraminifera) and terrestrial vegetation (pollen) to climate changes in two different oceanographic settings.

Methods

High resolution (0.5–1 ka) quantitative analyses were performed on calcareous plankton and pollen assemblages in the same samples used to measure the stable oxygen and carbon isotope ratios carried out on *Melonis barleanum* and *Cassidulina carinata* at the Montalbano Jonico section and on *Globigerina bulloides* at Site 976. An original astronomical tuning of the $\delta^{18}O$ record adjusted by the Ar/Ar dating of tephra V4 (773.9 ±1.3 ka, Petrosino et al., 2015) falling within MIS 19 was performed at the Montalbano Jonico section using the strong analogies between MIS 1 and MIS 19c in terms of orbital forcing and CO_2 level (Simon et al., 2017; Bassinot et al., in prep). The $\delta^{18}O$ record at Site 976 was tuned to that of Montalbano.

Results

$\delta^{18}O$ records show significant climate oscillations, which clearly depict stages and substages at both study sections. Key taxa of the calcareous planktonic assemblages record distinct patterns that are mainly related to sea surface water temperature changes and to water exchange rates between the Atlantic Ocean and Mediterranean Sea during glacial-interglacial phases and short-term climate episodes at the Termination IX and throughout the MIS 19/18 transition. Variations in turbidity and salinity as well as mixing and stratification or nutrient content in the sea surface waters were reconstructed based on the pattern of selected nannofossil and foraminiferal taxa. Among pollen assemblages, the Mediterranean/Temperate broad-leaved deciduous forest taxa exhibit higher abundances during interglacials and interstadials when warm-water calcareous planktonic taxa increase. While, the expansion of steppes and semi-desert vegetation cover, as well as the incursion of polar-subpolar calcareous planktonic taxa, occur during cooler periods. In the Montalbano record, unequivocal evidence of the shallow water analog of ghost sapropel i-cycle 74 (784 ka) has been documented based on minima in $\delta^{13}C$ and $\delta^{18}O$, and the occurrence of planktonic and benthic taxa indicating water column stratification and oxygen deficiency at the sea bottom (Maiorano et al., 2016; Bassinot et al., in prep). In contrast, such a paleoceanographic event is not recorded at Site 976.

Conclusions

The patterns of climate changes evidenced by geochemistry and terrestrial/marine biological proxies through MIS 20–18 are comparable in both Alboran and Ionian basins. They also document a strict connection between the Mediterranean Sea and Atlantic Ocean at the glacial-interglacial and millennial scale offering new insights for the comprehension of MIS 19 climate dynamics (beginning and duration) and similarities with the Holocene.

References

Bassinot, F., Nomade, S., Marino, M., Maiorano, P., Dewilde, F., Esguder, G., Pereira, A., Blamart, D., Girone, A., Scao, V., Toti, F., Bertini, A., Simon, Q., Combourieu-Nebout, N., Bourlès, D., and Ciaranfi, N., in prep. High-resolution foraminifer stable isotope record of MIS 19 at Montalbano Jonico, southern Italy: A window into Mediterranean climatic variability during a low-excentricity interglacial and the Early-Middle Pleistocene transition. *Quaternary Science Reviews*.

Maiorano, P., Bertini, A., Capolongo, D., Eramo, G., Gallicchio, S., Girone, A., Pinto, D., Toti, F., Ventruti, G., and Marino, M., 2016. Climate signatures through the Marine Isotope Stage 19 in the Montalbano Jonico section (Southern Italy): A land-sea perspective. *Palaeogeography, Palaeoclimatology, Palaeoecology* 461: 341–361.

Petrosino, P., Jicha, B.R., Mazzeo, F.C., Ciaranfi, N., Girone, A., Maiorano, P., and Marino, M., 2015. The Montalbano Jonico marine succession: An archive for distal tephra layers at the Early-Middle Pleistocene boundary in southern Italy. *Quaternary International* 383: 89–103. http://dx.doi.org/10.1016/j.quaint.2014.10.049

Simon, Q., Bourlès, D.L., Bassinot, F., Nomade, S., Marino, M., Ciaranfi, N., Girone, A., Maiorano, P., Thouveny, N., Choy, S., Dewilde, F., Scao, V., Isguder, G., Blamart, D., and ASTER Team, 2017. Authigenic $^{10}Be/^{9}Be$ ratio signature of the Matuyama-Brunhes boundary in the Montalbano Jonico marine succession. *Earth and Planetary Science Letters* 460: 255–267.

Tzedakis, P.C., Channell, J.E.T., Hodell, D.A., Kleiven, H.F., and Skinner, L.C., 2012. Determining the natural length of the current interglacial. *Nature Geoscience* 5: 138–141.

SMALL MAMMAL FAUNAS FROM THE MIKULINO (=EEMIAN) MARINE AND LIMAN DEPOSITS OF THE BLACK SEA

Markova, A.K.

Institute of Geography Russian Academy of Sciences, 29 Staromonetny, Moscow, Russia, 119017
amarkova@list.ru

Keywords: small mammals, Mikulino Interglacial, Black Sea, marine and liman deposits, Karangat transgression

Introduction

Up to now, there have been only rare finds of small mammal remains from the marine and liman (brackish estuary) Pleistocene deposits located in the Mediterranean. In Eastern Europe (in the Black Sea region), some unique localities related to the different intervals of the Pleistocene have been found. Two of them correlate with the Eemian (=Mikulino) Interglacial and with the Karangat transgression of the Black Sea. In these localities the small mammal bones were recovered together with the rich brackish-water mollusk remains and in secure geological context.

Material

These very important finds of small mammal and brackish-water mollusk remains have been discovered in only two localities in Eastern Europe: in the Novonekrasovka locality (the lower Danube basin) and in the El'tigen locality (Crimea, the Kerch Peninsula). Both of these localities are associated with the Karangat transgression of the Black Sea. The name of this last-interglacial transgression was proposed by Arkhangel'sky and Strakhov (1938) after the Cape Karangat Stratotype on the Kerch Peninsula (Fig.1).

Figure 1. Stratotype section of the Karangat transgression. Karangat Cape, Eastern Crimea (photo by A.L. Chepalyga).

The Novonekrasovka locality is situated on the eastern coast of Yalpug lake, in the lower Danube basin of Ukraine (Fig.2).

Figure 2. Novonekrasovka section, Yalpug Lake: second Danube terrace, Ukraine (photo by A.K. Markova).

Results

The structure of this section reveals a thickness with two paleosols interlayered by loess deposits that cover the liman-deltaic deposits. The lower paleosol has the features of the Mesin soil complex which is widely distributed along the Russian Plain and correlated with the Mikulino (=Eemian) Interglacial (Velichko et al., 1985).

The height of the terrace is 14-16 m and its width is about 1 km. This terrace is the second terrace of the Danube. The brackish-water mollusks include *Didacna danubica*, *Didacna ultima*, *Hypanis fragilis*, *H. plicatus*, *Dreissena polymorpha*, and *Turricaspia lincta* (Mikhailesku, 1990). In the same stratum, the small mammal remains of *Arvicola* ex gr. *terrestris* (130), *Microtus arvalis* (9), and *Microtus* sp. (11) were found (Mikhailesku and Markova, 1992). The mollusk fauna correspond to the Karangat transgression of the Black Sea, which is correlated with the Mikulino (= Eemian) interglacial. The small mammal fauna include a few species that could be explained by the taphonomy of this locality. The water vole *Arvicola* is a typical inhabitant of the coasts of water reservoirs (rivers, lakes, etc.), and the common vole *Microtus arvalis* prefers the meadow biotopes. The dental morphology of the water vole *Arvicola* is typical for the Mikulino interglacial (Markova, 2000).

The El'tigen locality was discovered in the coastal section of the Kerch' Peninsula, Crimea, Russia (Fig. 3).

Figure 3. The lower part of the El'tigen section, eastern Crimea (photo by C.D. Mikhailesku).

Here, Karangat marine deposits (20-25 m thick) are represented in the cliff along the western side of the Kerch Strait. These deposits cover Sarmatian clays and are overlain by Late Pleistocene loesses with two poorly resolved paleosols.

The structure of the Karangat deposits in the El'tigen section shows three sedimentary cycles that correspond to sea-level oscillations. The complex study of this section was organized by Dr. A. Dodonov and includes not only geologic, palaeontologic, and paleopedologic research, but also paleomagnetic studies and the dating of the deposits by the U-Th method (Dodonov et al., 2000). It was established that the fossiliferous strata have the following dates: 127 ± 8.9 ka for cycle I, and 107 ± 7.7 ka for cycle II (by the U-Th method). The paleomagnetic Blake Event was found in the fossiliferous strata, which also confirms the Mikulino (= Eemian) age of this layer (Dodonov et al., 2000).

The small mammal fauna and brackish-water mollusks were recovered from cycle I. Malacofauna include *Paphia senescens*, *Mytilus edulus*, *Cerithium vulgatum*, *Acanthocardia tuberculata*, *Gerastoderma edule*, and others (Dodonov et al., 2000). Small mammal fauna include *Ochotona pusilla* (2), *Spermophilus* sp. (10), *Spalax microphtalmus* (2), *Ellobius talpinus* (13), *Eolagurus luteus* (9), *Lagurus lagurus* (3), *Arvicola* ex gr. *terrestris* (4), *Microtus obscurus* (210), and *Microtus (Stenocranius) gregalis* (3) (Markova, 2000). The dental morphology of the most diagnostic species such as the water vole *Arvicola* and steppe and yellow lemmings (*Lagurus* and *Eolagurus*) is typical for fauna of the last interglacial as has been revealed by numerous data from the Russian Plain (Markova, 2007). The ecology of the small mammal fauna from El'tigen reveals steppe environmental conditions near the locality. All of the species found in the locality prefer open dry biotopes.

Conclusion

The unique small mammal and brackish-water mollusk localities of Mikulino (= Eemian) age in marine and liman-deltaic deposits of the Black Sea permits us to demonstrate a direct correlation between the events in the Black Sea and on the continent. The morphology of small mammal remains found in these localities is typical of the Mikulino and similar to other Mikulino small mammal finds of the Russian Plain (Markova, 2000). The brackish-water mollusks are diagnostic for the Karangat transgression of the Black Sea. Such data could form the basis for the correlation of the principal events on the continent and the marine basins.

This paper was prepared in the frame of the Institute of Geography of the Russian Academy of Sciences theme 69.2. "Mammal faunas of Northern Eurasia in the Late Pleistocene – Holocene: taxonomy, diversity and evolution."

Acknowledgments

This paper was prepared in the frame of the Institute of Geography of the Russian Academy of Sciences theme 69.2. "Mammal faunas of Northern Eurasia in the Late Pleistocene – Holocene: taxonomy, diversity and evolution".

References

Arkhangel'sky, A.D. and Strakhov, N.M., 1938. Geologicheskaya struktura i istoria razvitia Chernogo Moria. [*Geological Structure and History of Development of the Black Sea*]. USSR Academy of Sciences Press, Moscow and Leningrad. 226 (In Russian)

Dodonov, A.E., Tchepalyga, A.L., Mihailesku, C.D., Zhou, L.P., Markova, A.K., Trubikhin, V.M., Simakova, A.N. and Konikov, E.G., 2000. Last-interglacial records from central Asia to the northern Black Sea shoreline: Stratigraphy and correlation. *Geologie en Mijnbouw/Netherlands Journal of Geosciences* 79(2–3): 303–311.

Markova, A.K., 2000, The Mikulino (=Eemian) mammal faunas of the Russian Plain and Crimea. *Geologie en Mijnbouw/Netherlands Journal of Geoscience*s 79(2-3): 293–301.

Markova, A.K., 2007. Pleistocene mammal faunas of Eastern Europe. *Quaternary International* 160(1): 100-–111

Mikhailesku, C.D., 1990. *Proiskhozhdenie limanov del'ty Dunaya* [*The Origin of Limans in the Danube Delta*]. Kishinev, Shtiintsa (In Russian)

Mikhailesku, C.D., and Markova, A.K., 1992. *Paleogeograficheskie etapy razvitia fauny yuga Moldovy v Antropogene* [*Paleogeographical Stages of Faunal Development in the Anthropogene stages of the Southern Moldova*]. Kishinev, Shtiintza (In Russian)

Velichko, A.A., Markova, A.K., Morosova, T.D., Udartzev, V.P., and Chepalyga, A.L., 1985. Problemy korrelatsii Pleistotsenovykh lednikovykh, periglatsial'nykh i pribrezhnykh formatsii na Russkoi ravnine [The problems of correlation of Pleistocene glacial, periglacial and coastal formations on the Russian Plain]. In Velichko A.A., ed., *Kraevye obrazovania lednikovykh pokrovov* [*Marginal Deposits of Continental Ice-sheets*], pp. 123–126. Nauka, Moscow (In Russian)

MICROFORAMINIFERAL LININGS AS A PROXY FOR PALEODELTA AND PALEOSALINITY ANALYSIS: DANUBE DELTA EXAMPLE

Mudie, P.J., [1] and Yanko-Hombach, V. [2]

[1]Natural Resources Canada, Geological Survey Atlantic, 1 Challenger Drive, Dartmouth, NS B2Y 4A, Canada; mudiep@ns.sympatico.ca

[2] Department of Physical and Marine Geology, 2 Shampansky Per., Odessa I.I. Mechnikov National University, Odessa 65058, Ukraine
valyan@onu.edu.ua

[3] Avalon Institute of Applied Science, 976 Elgin Ave, Winnipeg MB R3E 1B4, Canada
valyan@avalon-institute.org

Introduction

Microforaminiferal linings are the acid-resistant, chitin-like linings of small (<150 μm) foraminiferal tests that are recovered in organic residues after palynological processing of sediments or acid treatment of rock samples. These palynomorphs are considered reliable indicators of brackish and marine paleoenvironments, and they are a proxy for foraminiferal production when carbonate preservation is reduced (Mathison and Chmura, 1995). Presence or absence of microforaminiferal (abbrev. microforam) linings is an important criterion used in palynofacies models to distinguish the transition from coastal lakes across delta front, prodelta, and shelf sub-environments (Fig. 1).

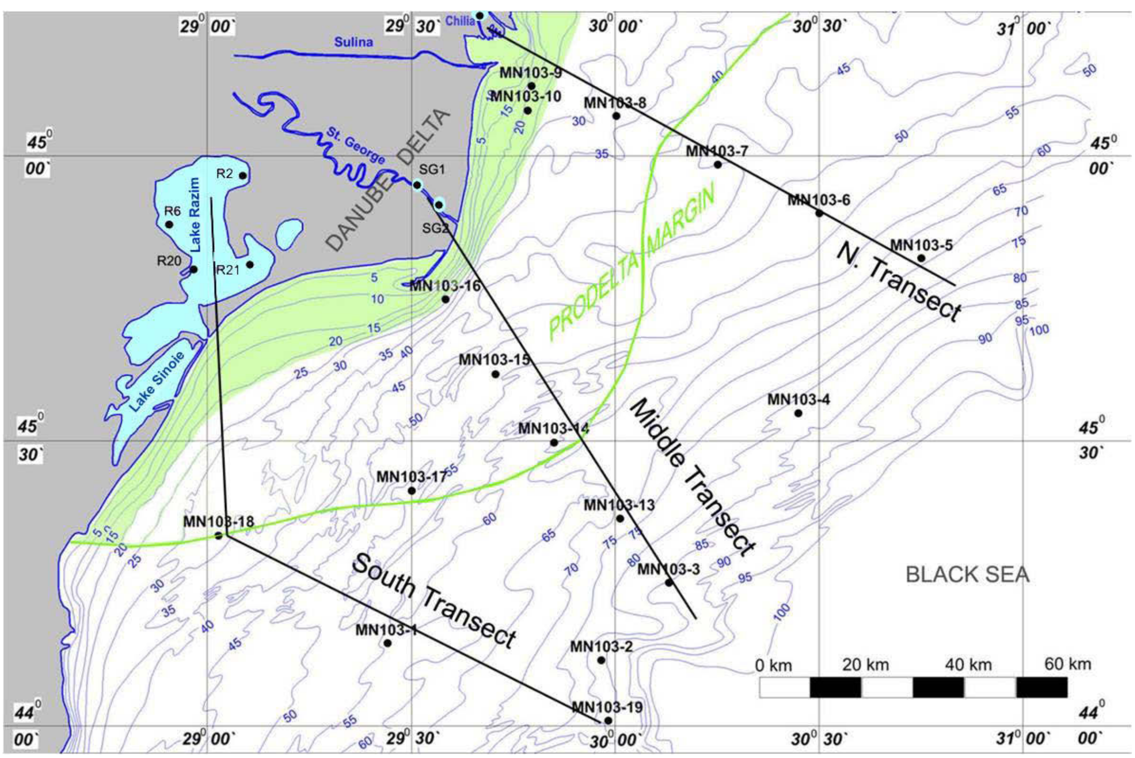


Figure 1. Map of the NW Black Sea study area showing bathymetry, locations of sample sites along coast-offshore transects, and approximate boundaries of the delta front (green shade), prodelta (green line), and shelf environments.

Microforam linings also mark Miocene marine incursions into the Pannonian Basin and into the Caspian-Black Sea - Mediterranean Corridor; they are important for validating paleosalinity models of Paratethyan Sea basin inter-connections.

In this paper, we investigate the relationship between the morphology of the microforams and foraminiferal assemblages in seabed samples collected concurrently along transects off the Danube Delta, in the northwestern Black Sea. Paired comparisons are made of the morphology, abundance, and preservation state in test linings and the foraminiferal populations from the same samples along a surface salinity gradient from coast to outer shelf. This is the first study linking the organic linings with known Black Sea foraminiferal taxa and showing the quantitative relationship between the two paleosalinity proxies.

Material and methods

The study area (Fig. 1) is on the NW Black Sea shelf, between latitudes 44.0^{o} and 45.1^{o} N, and from longitude 29.0^{o} to 30.75^{o} W, in water depths mainly from 17.5 to 80.5 mbsl. Samples for palynological and microbenthos comparisons were collected with a van Veen grab or a multicorer on WAPCOAST cruise MN103 of R/V "Mare Nigrum" in Spring, 2012. Concurrent CTD, dissolved oxygen (DO), and nutrient data (see Yanko-Hombach et al., 2017) revealed a freshwater plume (5 to 17 psu) on top of shelf water of salinity 17.8 to 18.5 psu, and a strong stratification creating hypoxic conditions below c. 15 m.

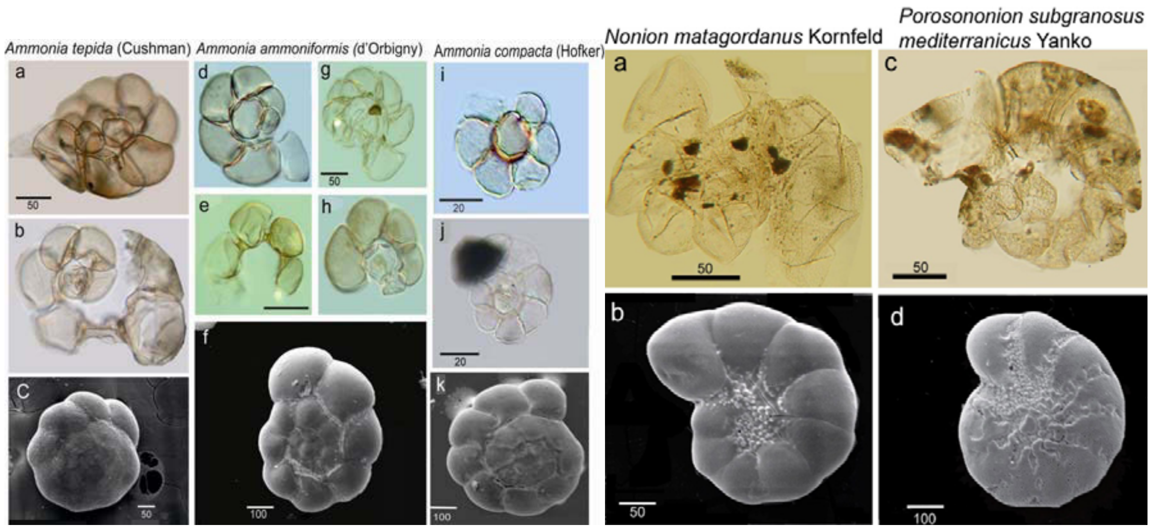
Surface sediment samples (0 to 2 cm depth) at 17 sites were taken for palynology (2 to 5 cm^3 volume) and for microfossil studies (c. 150 cm^3 volume), then stored at room temperature. Six additional palynological samples were obtained from grab samplers at shallower (2 to 6 m depth) coastal sites, including the Chilia and St. George distributaries of the Danube Delta and Lake Razim, which is a microtidal lagoon (Fig. 1) with water salinity less than 2 psu. Laboratory processing of palynology samples follows the standard methods for marine palynology reported by Mudie et al. (2011), and uses *Lycopodium* tables to estimate abundances/g sediment of microforaminiferal linings. Microscope studies for palynology used a Zeiss Research Microscope with Normarski Interference Contrast objectives. Foraminifera were prepared for study by staining with Rose Bengal and washing on a 63 µm sieve; then they were studied by binocular and SEM microscopy as reported in Yanko-Hombach et al. (2017).

Results

Microforaminiferal lining morphology and benthic foraminiferal sources

Three categories of microforaminiferal linings were found in surface samples off the Danube Delta: trochospiral, planispiral, and linear morphotypes. The trochospiral morphotypes were further grouped into large (>50 µm) and small (<50 µm) forms. The small trochospiral forms correspond to the linings of *Ammonia compacta* (Fig. 2i-k) that have a dimpled surface texture without conspicuous pores.

The Rotalid foraminifera *Ammonia tepida* (trochospiral) and *Porosononion subgranosus* (planispiral) that dominate the assemblages on the delta front (Sta. 9, 10, 16) have microforam linings distinguishable by their shape, porosity, and chamber structure (Figs. 2 and 3). *A. tepida* has a large trochospiral lining that is strongly microperforate (Fig. 2a-c), and the *Porosononion* lining is subspherical and irregularly, coarsely granulo-porate (Fig.3c). The trochospiral linings in the prodelta sites (Sta. 7, 8, 18) show greater morphological diversity, including test linings of *A. compacta* and *A. tepida* (Fig. 2) and planispiral linings of *Nonion matagordanus*, which can have a subspheroidal shape and regularly fine-granular surface (Fig. 3a).



Figures 2 (L) and 3 (R). Light microscope images (from PJM) of the most common foraminiferal linings in the NW shelf samples compared to SEM images (from VY-H). Left panel: *Ammonia* species, demonstrating the range from well-preserved specimens (top row) to less well-developed on poorly preserved linings (Fig. 2 b,e,h). Note the large amount of fine pyrite in specimen h, from the deepest water site MN103-19; specimen g has a *Lycopodium* spore on the inner chamber. Right panel: Planispiral species, apparently with ingested acid-resistant organic particles.

These features match the prodelta foraminiferal assemblage with diverse *Ammonia* spp., common *Nonion matagordanus*, less *Porosononium*, and occasional uni-, bi-seriate, and single-chambered taxa. The shelf sites have microforam linings dominated by large trochospiral forms corresponding to *Ammonia ammoniformis* (Fig. 2d-h), with rare uniserial linings. This palynomorph assemblage corresponds to the shelf assemblage of Yanko-Hombach et al. (2017), which is dominated by *Ammonia ammoniformis*, with common *N. matagordanus* and maximum species diversity, including some single cell and uniserial taxa.

Abundances and distribution of organic linings compared to microfauna

Abundances of foraminifera/g and microforaminiferal linings/g for the three transects (Fig. 4) show that the lining number was essentially the same as the foraminiferal abundance (for sites 9, 7, 5, 4, 13), or they exceeded the foraminifera by a factor of 2 to a maximum of 9 at delta front site 16.

Most freshwater (<2 psu) sites had neither linings nor foraminifera, but two sites in the microtidal Lake Razim contained a uniserial microforam lining of unknown affinity. The northern transect off the Sulina distributary, where sediment is finer-grained, had the largest number of near-matches in lining vs. test abundances, while the southern transect furthest from the delta discharge showed consistently high lining numbers but a steady decrease in lining abundances offshore. The highest lining abundances are not correlated with sediment texture, and they possibly indicate development of anomalously small (<63 μm) foraminifera in the polluted NW Black Sea waters where Yanko-Hombach et al. (2017) showed that deformities in foraminiferal tests are common.

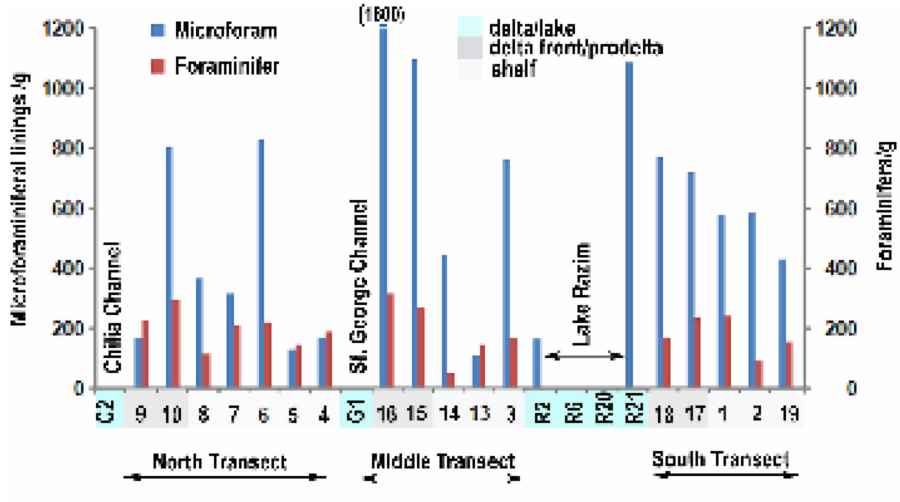


Figure 4. Abundances of microforaminiferal linings and foraminifera in surface sediments along three transects from the coast to outer shelf.

Anomalous lining morphologies include opening of normally coiled specimens (Fig. 2b) and incomplete chamber development (Fig. 2e). Some high lining counts may reflect inflated values resulting from duplication of torn lining fragments in species with weakly acid-resistant linings. Oxygen deficiency in the bottom water is also indicated by fine pyrite inclusions in 20 to 50% of the linings in water shallower than 60 m and >50% in water deeper than 100 m.

The composition of benthic foraminifera in the MN103 microfossil samples (Yanko-Hombach et al., 2017) indicates biologically stressful bottom water conditions resulting in low species diversity and richness along a coast-to-shelf gradient of species. The distribution of the total microforam linings/g shows no correlation with water depth or distance offshore, suggesting a widespread cross-shelf mixing of linings from inner and outer shelf populations. There is a weak (R^2 = 0.35) polynomial relation between lining abundance and surface salinity that also suggests mixing of linings from inner and outer shelf foraminiferal populations. Based on raw counts of all *Ammonia* species linings, however, there is a relatively strong relationship (R^2 = 0.67) between total numbers of trochospiral linings and water depth. The trend shows gradual rise in trochospiral microforams across the delta front and prodelta, with a peak around 45 mbsl that declines to values of 0 at 78 m and in deeper water.

Discussion

Previous studies of microforaminiferal linings in the Caspian-Black Sea-Mediterranean corridor (Mudie et al., 2011) showed that variable amounts (5 to >500 linings/g dry sediment) occur in surface sediments from the Eastern Mediterranean to the Caspian Sea. A simple classification of nine microforam lining types was presented, and it was noted that linings were absent in freshwater lakes, salt-flats, and deep anoxic basins.

Our new data confirms the absence of linings in the delta channels and at half of the Lake Razim coastal lagoon sites. The occurrences of a few *Ammonia compacta* linings and some unidentified lining morphotypes at two Lake Razim sites may reflect dredging disturbance or storm overwash. The high lining abundances (average 489/g; range 168 to 1737/g) may reflect the eutrophic waters of the region but higher abundances (2,000–8,000/g) are recorded for Louisiana marshlands (Mathison and Chmura, 1995). In general, the nearshore to offshore progression of foraminifera from *A. tepida* to *A. compacta*, then to *A. ammoniformis*, and the seaward increase of polyhaline Lagenida in the assemblages (Yanko-Hombach et al., 2017) is reflected in the occurrences of trochospiral microforam linings that are most strongly correlated with water depth. There is also a weak link between total lining abundances and surface water salinity. Overall, the assemblages of microforam linings reflect the dominance of benthic foraminifera tolerant of fluctuating salinity on the delta front (*A. tepida* and *P. subgranosus mediterranicus*), and common occurrence of *Nonion matagordanus* in the shelf beyond the prodelta, but uniserial, biserial, and single-chambered species are rare or absent. The sparseness of the non-coiled linings in the palynological assemblages distinguishes the deltaic-shelfal setting from saltmarsh environments.

Acknowledgments

This paper is a contribution to EU BLACK SEA ERA.NET-WAPCOAST 076 project "Water pollution prevention options for coastal zones and tourist areas: Application to Danube Delta front area." It also contributes to the IGCP 610 “From the Caspian to Mediterranean: Environmental Change and Human Response during the Quaternary” project sponsored by UNESCO and IGU.

References

Mathison, S.W., and Chmura, G.L., 1995. Utility of microforaminifera test linings in palynological preparations. *Palynology* 19(1): 77–84.

Mudie, P.J., Leroy, S.A.G., Marret, F., Gerasimenko, S.P., Kholief, S.E.A., Sapelko, T., and Filipova-Marinova, M., 2011. Nonpollen palynomorphs: Indicators of salinity and environmental change in the Caspian–Black Sea–Mediterranean corridor. In: I.V. Buynevich, V. Yanko-Hombach, A.S. Gilbert, R.E. and Martin (Eds.), *Geology and Geoarchaeology of the Black Sea Region: Beyond the Flood Hypothesis*. Geological Society of America Special Paper 473, pp. 89-115. Boulder, Colorado, Geological Society of America,.

Yanko-Hombach, V., Kondariuk, T., and Motnenko, I., 2017. Benthic foraminifera indicate environmental stress from river discharge to marine ecosystems: Example from the Black Sea. *Journal of Foraminiferal Research* 47(1): 70–92.

NEW DATA ON THE DISTRIBUTION OF PALYNOMORPHS IN SURFACE SEDIMENTS OF THE UKRAINIAN PART OF THE NORTHWESTERN BLACK SEA SHELF

Mudryk, I.

Department of Physical and Marine Geology, 2 Shampansky Per., Odessa I.I. Mechnikov National University, Odessa 65058, Ukraine
inowl@ro.ru

Keywords: pollen, dinoflagellate cysts, non-pollen palynomorphs, outer shelf, pollution

Introduction

Marinopalynology studies were made using 27 surface sediment samples from the outer Ukrainian Shelf, NW Black Sea, beneath the Rim Current, as part of the HERMES project (Hotspot Ecosystem Research on the Margins of European Seas). The palynological samples are from water depths of 71–746 m and include outer shelf locations from the outer Paleo-Dniester and Paleo-Dnieper Valleys (Fig. 1).

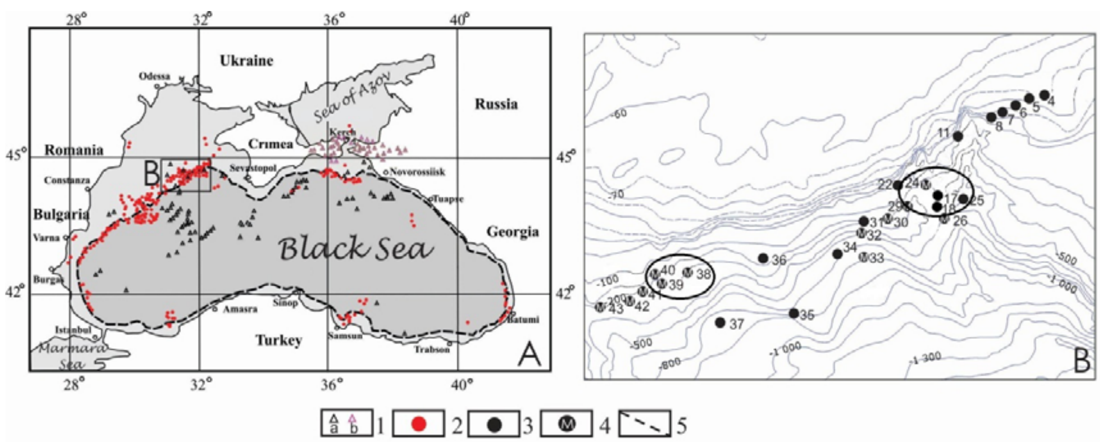


Figure 1. Map of Black Sea (A) showing study area (B) and the location of stations sampled for palynology. 1 = mud volcanoes; 2 = gas seepages; 3,4 = sampled stations; 5 = 100 m isobath (modified after Yanko et al., 2013). Ovals show clusters of high *Alnus* tree pollen; circles mark drainage of Dniester (west) and Dnieper (right) rivers

In addition to pollen and spores of terrestrial plants, the palynological data also include: (1) resting spores of organic-walled dinoflagellate cysts that are sensitive indicators of salinity (Mertens et al., 2012) and eutrophication (Giosan et al., 2012); (2) remains of aquatic algae, including freshwater species; (3) fungal spores that can indicate soil erosion, and (4) microforaminiferal linings derived from benthic foraminifera (Mudie et al., 2011).

Methods

Surface sediment samples for this study were obtained in September 2008 on cruises of the Ukrainian Research Vessel "Vladimir Parshin." Palynomorphs were prepared for microscopic 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 and discussion

All the palynology samples produced moderate to large amounts of terrestrial pollen and spores (9,666−35,828 grains/g pollen), and smaller amounts of non-pollen palynomorphs (NPP), including dinoflagellate cysts (dinocysts), aquatic algae, fungal spores, and microforaminiferal organic linings. A large diversity of pollen taxa was obtained (60 taxa: mostly arboreal species but including 25 kinds of herbs and 10 aquatic plants). All samples were dominated by bisaccate tree pollen, mainly *Pinus* spp., and by wind-transported herb pollen (Poaceae, chenopods, *Artemisia*, and other Asteraceae typical of agricultural areas and steppe grassland), with small amounts of 10 species of water-transported aquatic herbs. This pattern suggests a strong influence of wind transport to outer shelf pollen assemblages.

Overall, there is an inverse correlation between pollen concentration (total number/g) and water depth/distance offshore. The best-fit correlation is for an exponential decrease of pollen concentration with depth and distance from the shoreline. In the samples from shallowest depths closest to the shore, there is a high concentration of tree and grass pollen that may reflect strong influence of fluvial transport in addition to wind. In the samples more distant from the shore, wind-transported herb pollen dominate.

In two groups of samples close to the shelf edge (Fig.1, Sta. 38, 39, 40 and 17, 18, 24, 25), there is a sharp increase in the concentration of pollen, especially pollen of riparian trees such as *Alnus*. This pattern probably reflects the drainage of large rivers and cross-shelf pollen transport in submarine valleys. The group of samples from the southwestern part of the study area (Fig.1, Stations 38, 39, 40) may correspond to the Dniester River, while transport from the Dnieper River is seen in the group of samples from the northeastern part of the study area (Fig.1, Sta. 17, 18, 24, 25).

Non-pollen palynomorphs found in the samples are mainly dinoflagellate cysts, and crustacean eggs, with lesser numbers of fungal spores and microforaminiferal linings, in addition to rare algae such as *Pediastrum coenobia* (freshwater indicator) and Cyanobacteria (*Gloetrichia*) that indicate eutrophic surface water. Concentrations of foraminiferal linings/g decrease in the samples with depth downslope, with no linings being found at depths greater than c. 300 mbsl. Dinoflagellate cyst (dinocyst) concentrations are high (average 1678/g), ranging from 577 to 4510/g but showing no correlation with water depth along the shelf and upper continental slope. *Lingulodinium machaerophorum* is the dominant species in most samples (20–85%), with *Peridinium ponticum* sometimes being dominant (33–44%) in deeper water sites. Several kinds of copepod eggs are present (large spiny and microgranulate types). Fungal spores are mostly unicellar types, with rare *Glomus*.

Conclusions

The method chosen for palynological processing of coarse-grained coquina-type sediments on the outer shelf is excellent for pollen-terrestrial spore recovery, but it results in under-representation of dinocysts and microforaminifera. The dinocysts recovered include HAB species, e.g., *Alexandrium* that can be toxic for shellfish and perhaps should be monitored using less harsh processing methods without boiling in HCl that can damage thin-walled palynomorphs.

References

Giosan, L., Coolen, M.J.L., Kaplan, J.O., Constantinescu, S., Filip, F., Filipova-Marinova, M., Kettner, A.J., and Thom, N., 2012. Early Anthropogenic Transformation of the Danube-Black Sea System. *Nature Science Report* 2, 582; DOI:10.1038/srep00582.

Mertens, K.N., Bradley, L.R. Takano, Y., Mudie, P.J., Marret, F., Aksu, A.E., Hiscott, R.N., Verleye, T.J., Mousing, E.A., Smyrnova, L.L., Bagheri, S., Mansor, M., Pospelova, V., and Matsuoka, K., 2012. Quantitative estimation of Holocene surface salinity variation in the Black Sea using dinoflagellate cyst process length. *Quaternary Science Reviews* 39: 45–59.

Mudie, P.J., Leroy, S.A.G., Marret, F., Gerasimenko, S.P., Kholief, S.E.A., Sapelko, T., and Filipova-Marinova, M., 2011. Nonpollen palynomorphs: Indicators of salinity and environmental change in the Caspian–Black Sea–Mediterranean corridor. In: I.V. Buynevich, V. Yanko-Hombach, A.S. Gilbert, R.E. and Martin (Eds.), *Geology and Geoarchaeology of the Black Sea Region: Beyond the Flood Hypothesis*. Geological Society of America Special Paper 473, pp. 89-115. Boulder, Colorado, Geological Society of America,.

.

RECONSTRUCTING VEGETATION CHANGES AND CLIMATE FROM POLLEN OF THE LATE PLIOCENE TO EARLY PLEISTOCENE IN THE NORTH CAUCASUS

Naidina, O.D.

Geological Institute RAS, 7 Pyzhevsky per., Moscow, Russia 119017
onaidina@gmail.com

Keywords: Akchagylian-Apsheronian paleoenvironments, northwestern Caspian region

Introduction

Pollen and spores have been analyzed in Akchagylian-Apsheronian deposits in the southeastern part of the Russian Plain within the northwestern Caspian Sea region, including the North Caucasus. On the basis of pollen assemblages in outcrops and sediment cores from the eastern and central North Caucasus, climatic fluctuations and changes in vegetation can be recognized during Plio-Pleistocene time (Naidina and Richards, 2016). The aims of this investigation are to present the Plio-Pleistocene stratigraphy of the North Caucasus region, document changes in vegetation and climate, and show how these are linked with sea-level changes of the paleo-Caspian Sea.

Relationships between the Russian stratigraphic regional stages and the European Plio-Pleistocene stages remain under discussion. According to the stratigraphic framework for Western Europe (Cita et al., 1999), the base of the Piacenzian in the Mediterranean is located at the base of the small-scale carbonate cycle 77 of Punta Picola, Italy, which coincides with the Gilbert-Gauss boundary at 3.6 Ma and with the base of the Akchagylian in the North Caucasus (Zubakov and Borzenkova, 1990). The West European Gelasian stage begins above the Gauss/Matuyama boundary at 2.58 Ma. The Akchagylian and Apsheronian regional stages have not been consistently defined stratigraphically. A three-fold subdivision of the Akchagylian is the most widely used. The base of the Akchagylian in the North Caucasus region occurs at the base of the Piacenzian, coinciding with the boundary between the Gilbert and Gauss paleomagnetic intervals at 3.6 Ma and with the beginning transgression of the paleo-Caspian Sea. The maximum transgression of the sea occurred in the Gelasian at 2.58 Ma, and this is reflected by the presence of extensive Akchagylian deposits around the Caspian region. The Akchagylian-Apsheronian boundary coincides approximately with the top of the Olduvai paleomagnetic episode close to 1.8 Ma, although the interpreted age of the Akchagylian to Apsheronian contact varies within the literature (e.g., Svitoch, 2014). The top of the Apsheronian is close to the boundary between the Matuyama and Brunhes paleomagnetic epochs at around 0.8 Ma. In the present work, the most widely accepted ages based on paleomagnetic data are used.

Methodology

This study uses material from the central and eastern parts of the North Caucasus (the Caucasus Mineralnye Vody region, the Tersko-Sunzhensky area, and the foothills of Dagestan). Palynology (pollen and spores) was used to reconstruct past vegetation and climate. The pollen data are based on results of the palynological analysis of hundreds of samples selected from several outcrops that have already been characterized faunally (Naidina, 1999). The cores were taken by drilling. Material from several cores around Pyatigorsk and a core from the Kizlyar area in the Dagestan foothills were also studied.

Results

In deposits formed during the lower part of the Akchagylian stage, four complexes (SPCs) are allocated within the studied sections. Frequent Cheno-Amaranthaceae pollen in SPC-1 suggests that predominantly steppe vegetation occurred, and that climatic conditions were cool and dry at the start of the lower Akchagylian stage. Increased coniferous pollen in SPC-2 suggests an expansion of boreal forest under a cool but relatively humid climate. A subsequent increase in arboreal pollen in SPC-3 demonstrates the more widespread occurrence of mixed forest and a warmer and more humid climate. SPC-4 shows that broad-leaved forest continued to thrive. The prevalence of pollen from pan-holarctic and American-Euroasiatic groups, and also the presence of subtropical taxa testify to a warm and humid climate. 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).

Five SPCs have been recognized for the first time in the mid-Akchagylian of the Tersko-Sunzhensky area, principally in the Chachen-Aul and Aldy outcrops, each of which illustrates a distinct phase of vegetation development. In the mid-Akchagylian at around 2.6 Ma, there were coniferous pine forests and broad-leaved forests with fir trees and with *Tsuga*, and the climate was cooler than at the end of the lower Akchagylian. By the end of the Akchagylian, the vegetation consisted of mixed coniferous and broad-leaved forests alternating with steppe, suggesting a cool climate with variable humidity. In the lower Apsheronian, high peaks of Cheno-Amarantaceae and Poaceae pollen are indicative of open herbaceous vegetation, probably relating to cold and dry climate in the foothills at a time when mountain glaciations were known in the Greater Caucasus (Kozhevnikov et al., 1977). The upper Akchagylian and lower Apsheronian deposits were characterized by treeless landscapes due to an intensification of the continental climate and increasing aridity. The results of pollen studies confirm that there were not only altitudinal vegetation belts during the lower to mid-Akchagylian, but also a well-defined series of vegetation zones occurring from north to south over the area of the north Caspian region in the paleo-Volga and paleo-Ural drainage basins. In the south, in 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 Caucasus foothills.

Conclusions

Pollen analysis has revealed that at the beginning of the Akchagylian there was a cooling and a change in the main floral elements. The second significant cooling corresponds with the beginning of the mid-Akchagylian and with the maximum stage of the Akchagylian transgression. At this time, there were developed coniferous-broad-leaved forest landscapes. Climatic warming occurred at around 3.2 Ma in the North Caucasus that coincided with a period of warming in the Mediterranean (Suc, 1984) and with the “Mid-Pliocene Warm Period.” This evidence is the first yet found of this event in the Caspian region.

The evidence establishes that the development of vegetation in the Plio-Pleistocene was influenced by their geographical distribution. Coniferous and broad-leaved forests developed at times of maximum Akchagylian transgression and in response to cool temperatures and increased humidity. Contractions of the paleo-Caspian Sea were associated with increased aridity and the development of steppe landscapes. Analysis of arboreal flora show that a more temperate flora formed during the Akchagylian.

Acknowledgments

This paper is a contribution to the IGCP 610 project sponsored by UNESCO and IGU.

References

Cita, M.B., Rio, D., and Sproveri, R., 1999. The Pliocene series: chronology of the type Mediterranean record and standard chronostratigraphy. In J.H. Wrenn, J.-P. Suc, and S.A.G. Leroy, (eds.), *The Pliocene: Time of Change*. American Association of Stratigraphic Palynologists Foundation, Dallas, pp. 49-63.

Kozhevnikov, A.V., Milanovskii, E.E., and Sayadyan, Yu.V., 1977. *Ocherk stratigrafii antropogena Kavkaza* [*Sketch of a Stratigraphy of the Antropogen of the Caucasus*]. Izd. AN ArmSSR, Erevan-Leningrad. (In Russian)

Leroy, S.A.G., Wrenn, J.H., and Suc, J.-P., 1999. Global setting to comparative charts of regional events. In: J.H. Wrenn, J.-P. Suc, S.A.G. Leroy (Eds.), *The Pliocene: Time of Change*. American Association of Stratigraphic Palynologists Foundation, Dallas, pp. 1-12.

Naidina, O.D., 1999. Climatostratigraphic interpretations of the Upper Pliocene palynological data of the southeastern East-European plain. In: J.H. Wrenn, J.-P. Suc, S.A.G. Leroy (Eds.), *The Pliocene: Time of Change*. American Association of Stratigraphic Palynologists Foundation, Dallas, pp. 179-184.

Naidina, O.D., and Richards, K., 2016. Pollen evidence for Late Pliocene-Early Pleistocene vegetation and climate change in the North Caucasus, North-Western Caspian region. *Quaternary International* 409, Part A: 50-60.

Suc, J.-P., 1984. Origin and evolution of the Mediterranean vegetation and climate in Europe. *Nature* 307(5950): 429-432.

Svitoch, A.A., 2014. *Bol'shoy Kaspiy: stroenie i istoriia razvitiya* [*The Great Caspian Sea: Structure and History*]. Moscow: Izdatelts'vo Moskovskogo universiteta. (In Russian)

Zubakov, V.A., and Borzenkova, I.I., 1990. *Global Palaeoclimate of the Late Cenozoic*. Developments in Palaeontology and Stratigraphy, 12. Elsevier: Amsterdam.

MARINE GEOHAZARDS IN THE BLACK SEA AND THEIR MONITORING

Oaie, G., Seghedi, A. [1], and Rădulescu, V. [2]

[1,2] NRDI GeoEcoMar, 23–25 D. Onciul St., 024053 Bucharest, Romania
[1] seghedi@geoecomar.ro
[2] vladr@geoecomar.ro

Keywords: active fault, seismic source, tsunami, early warning system

Introduction

The main natural hazards in the western part of the Black Sea basin include submarine earthquakes, or earthquakes produced in the immediate vicinity of the sea, submarine landslides, tsunami waves, tectonic activity along active faults, potential gas eruptions from sea bottom sediments, and extreme meteorological events. With its characteristic low topography, the Romanian Black Sea shore is vulnerable to potential tsunami-type hazards. Numerical, historical, and instrumental data indicate that tsunami-type waves occurred in the Black Sea in historical times consequent to earthquakes with magnitudes >6 on the Richter scale. Discussing the earthquakes followed by tsunami-type events recorded since the 1st century BC in the the Black Sea, Papadopoulos et al. (2011) concluded that the tsunami hazard in the Black Sea is low to moderate, but not negligible.

In order to monitor marine hazards, a new center dedicated to Black Sea hazards has been operating in the NW Black Sea area since 2013. This center, Black Sea Security System, was founded using structural funds within a cross border cooperation program between Romania and Bulgaria.

Methodology

Geological, geophysical, and tectonic studies were used to reveal the complex structure of the coastal area of Dobrogea and the Black Sea continental shelf of Romania and northern Bulgaria. Seismological studies indicate that some faults are active, demonstrating the existence in the western Black Sea basin of processes that might generate natural hazards that threaten the coastal area.

Results

From the system of NW-SE major faults in the area of Dobrogea, seismological studies indicate that the Intramoesian Fault and Voiteşi fault were active in historical times.

Referred to as the Shabla Fault by Bulgarian authors, the Intramoesian Fault is a trans-lithospheric fault separating the Moesian Platform into two main regions with distinct basement and geophysical properties (Săndulescu and Visarion, 2000), crustal thickness (Rădulescu et al., 1976), and seismicity (Cornea and Polonic, 1979); its trace is underlined by seismic epicenters (Rădulescu et al., 1976; Cornea and Polonic, 1979). Fault plane solutions indicate strike-slip displacement, with a normal component, suggesting an extensional model of the stress field; the dominant rupture plane is NW-SE (Constantinescu et al., 1976). The Intramoesian Fault is an active transcrustal fault, as demonstrated by the earthquake at Călăraşi on March 3rd 1994, at a depth of 40 km below the Moho.

South of the Intramoesian Fault, several E-W trending faults occur between Shabla and Varna, the Kaliakra Fault Zone being the most active structure of the Shabla Seismic Zone (Ranguelov and Gospodinov, 1995; Matova, 2000). It is characterized by strong earthquakes (M>6) occurring at shallow depth (1-16 km) with a relatively high frequency of occurrence.

According to historical data, every 400–600 years, a strong earthquake with a magnitude in the range of 7.0 affected the coastal territories. The last earthquake, with an estimated magnitude of 7.2, produced considerable damage in 1901. Recently published data on active faults in this area, based on onshore drilling and offshore acoustic and seismic profiles, have identified a number of activated fault segments. The Kaliakra Fault Zone is related to significant faulting and deformation of Mesozoic and Paleozoic sediments along N-S to NNE-SSW and E-W faults, the width of the deformation zone varying from 1–3 km to 6–8 km. Some of the peripheral associated faults are mapped onshore, along the coastal area.

An important fault onshore in Dobrogea, usually overlooked by most researchers, was interpreted as as a flexure-induced fracture—the Voiteşti flexure (Alexandrescu and Baltres, 2007). Trending N-S from Tulcea through Mangalia to Kaliakra, this fault was active in historical times, as indicated by negative movements of the Dobrogea sea-shore, enabling the sea to advance inland to form numerous embayments and drown various parts of archaeological sites at Histria and Callatis (Alexandrescu and Baltres, 2007).

With the proven vulnerability of the Black Sea area to extreme natural events, the first major initiative related to a regional early-warning system for marine geohazards that create risk for the western Black Sea coastal area has been functional since June 2013. The system is managed by two National Data Centers from Romania (GeoEcoMar, Constanţa Branch) and Bulgaria (IO-BAS HQ, Varna). The real-time, automatic deep-sea gauge has two modules, involving sea stations and on-shore coordination centers.

Conclusions

As seismic activity on major faults can produce tsunami-type hazards in the Black Sea, a real-time warning system for marine geohazards has been established in the NW part of the Black Sea. The Black Sea Security System is an integrated multi-parameter system that provides long time series of physical and bio-chemical data regarding the properties of the water masses and local meteorological parameters. The main target of the Black Sea Security System is to elaborate risk assessments and to send early-warning notifications to the authorities. The system scheme enables monitoring the evolution of an ongoing marine risk situation. Specially-designed software used to analyze the data series acquired in the centers has the ability to simulate tsunami wave generation due to potential sources in the area of the Black Sea basin, the propagation of tsunami waves, and also to assess the inundation of Bulgarian-Romanian coastal areas.

References

Alexandrescu, P., and Baltres, A., 2007. Cutremure in Dobrogea [Earthquakes in Dobrogea]. *Pontica* XL: 74–83. (In Romanian)

Constantinescu, L., Constantinescu, P., Cornea, I., and Lăzărescu, V., 1976. Recent seismic information on the lithosphere in Romania. *Revue Roumaine de Géologie, Géophysique, Géographie* 20: 33–41.

Cornea, I., and Polonic, G., 1979. Data regarding seismicity and seismotectonics of the eastern part of the Moesian Platform. *Studii și cercetări de geologie, geofizică, geografie, Serie Geofizică* 17(2): 167–176. (In Romanian)

Matova, M., 2000. Recent geological activity along the northeastern Bulgarian Black Sea coast. *Geological Quarterly* 44(4): 355–362.

Papadopoulos, G.A., Diakogianni, G., Fokaefs, A., and Ranguelov, B., 2011. Tsunami hazard in the Black Sea and the Azov Sea: a new tsunami catalogue. *Natural Hazards and Earth System Sciences* 11: 945–963.

Ranguelov, K.B., and Gospodinov, D., 1995. Tsunami vulnerability modelling for the Bulgarian Black Sea coast. *Water Science and Technology* 32 (7): 47–53

Rădulescu, D., Cornea, I., Săndulescu, M., Constantinescu, P., Rădulescu, F., and Pompilian, A., 1976. Structure de la croute terrestre en Roumanie. Essai d'interpretation des études sismiques profondes. *Anuarul Institutului de Geologie şi Geofizică, Geologie* L, 5–36.

Săndulescu, M., and Visarion, M., 2000. Crustal structure and evolution of the Carpathian-Western Black Sea areas. *First Break* 18(3): 103–108.

EVALUATION OF GEOLOGIC HAZARDS FOR THE TRANS-CAUCASUS CASPIAN OIL AND GAS PIPELINES IN THE ABUL-SAMSARI VOLCANIC RIDGE SECTION

Okrostsvaridze, A.[1,2], Bluashvili, D. [3], Kilasonia, E. [4], and Gogoladze, S. [2]

[1] Faculty of Natural Sciences and Engineering
avtandil.okrostsvaridze@iliauni.edu.ge
[2] Institute of Earth Sciences of the Ilia State University, 0162 Tbilisi, Georgia;
salome.gogoladze.2@iliauni.edu.ge
[3] Faculty of Mining of the Georgian Technical University, 0179 Tbilisi, Georgia
datoblu@yahoo.com
[4] Georgian National Academy of Sciences, 0177 Tbilisi, Georgia,
eterikilas@mail.ru

Keywords: Caspian oil and gas pipelines, Georgia, seismic and volcanic hazards

Introduction

The Caspian region has the potential to become one of the major oil and gas producing areas in the world. The Republic of Georgia, situated in the central part of the Caucasian region, provides a natural pipeline corridor from the Caspian region to the west. The Baku-Supsa (BS) and the Baku-Tbilisi-Ceyhan (BTC) oil pipelines, as well as the Baku-Tbilisi-Erzurum South Caucasian natural gas pipeline (SCP) traverse this corridor through Georgia (Fig. 1). The BTC and SCP were designed to withstand volcano-seismic events of the Quaternary Abul-Samsari volcanic ridge.

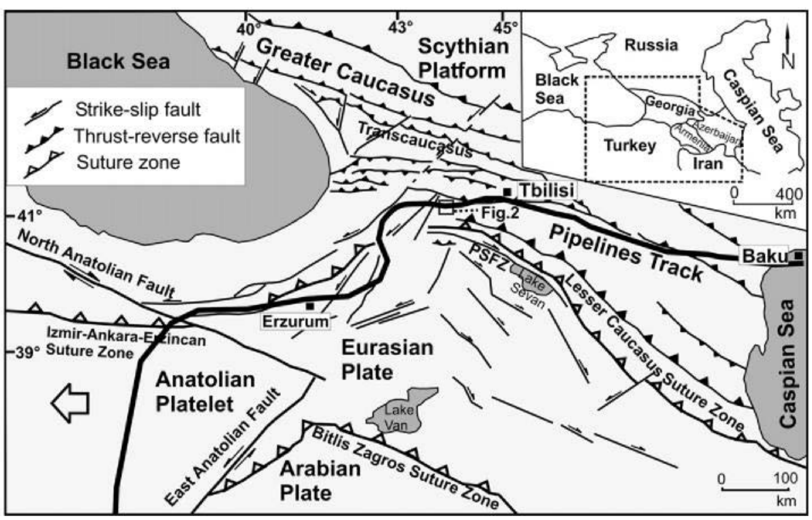


Figure 1. Geodynamic framework of the Caucasian region with indication of the BTC and SCP pipeline tracks. PSFZ = Pambak-Sevan Fault Zone Adapted after Koçyigit et al. 2001. The study area is indicated by a square.

Studied area

Tavkvetili and Shavnabada volcanoes at the northernmost edge of the Abul-Samsari Ridge, extremely close to the pipeline corridor (Fig. 2); studies of these volcanoes have a long history (Skhirtladze, 1958).

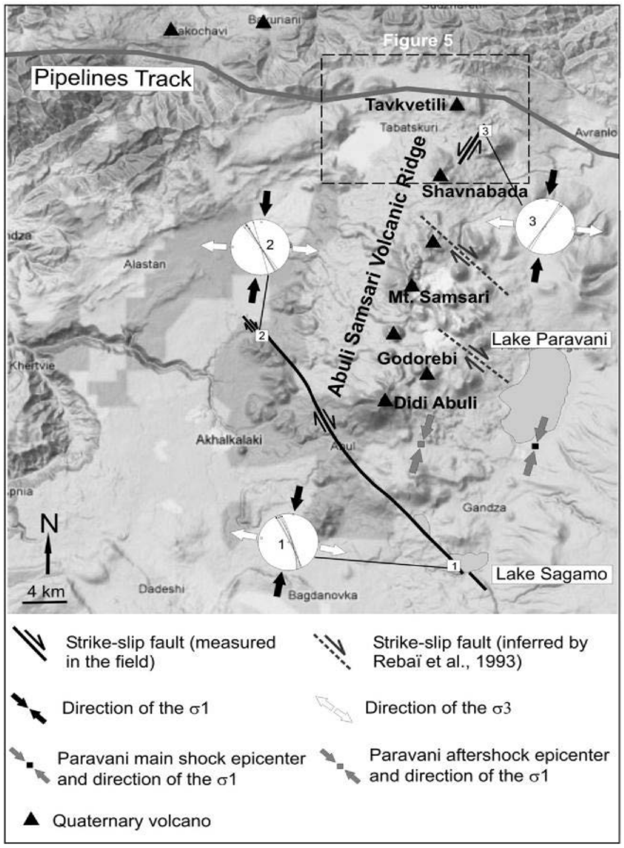


Figure 2. Map of the Abul-Samsari Ridge showing fault plane stereograms along the main faults with indication of the related stress regime. Left-lateral strike-slip faults, N-S to NNW-trending normal faults associated with late Pleistocene-Holocene volcanoes (Pasquarè et al., 2011).

Tavkvetili volcano is a scoria cone, up to 2582 m in elevation, with a well-preserved summit crater 200 m in diameter. Several lava flows outpoured from the vent and flowed northward and southward 4 km away.(see Fig. 2). Tavkvetili dacite is aphyric with a glassy black groundmass; the lava flows are a few decimeters to meters thick. These textural characteristics suggest that this lava had a low viscosity during emplacement. Shavnabada volcano is located 6 km south of Tavkvetili and shows two vents (Fig. 2). The northern vent has produced a scoria cone up 2929 m in elevation. The southern vent is a small shield cone with a distinguishable summit crater and radial lava flow field. Shavnabada andesite is also aphyric with a glassy black groundmass. Tavkvetili and Shavnabada are among the youngest volcanoes of the Abul-Samsari Ridge (Okrostsvaridze et al., 2016). Also, our geomorphologic observations indicate the absence of periglacial activity on the slopes, and well-preserved summit craters suggest that volcanic activity probably postdates the last glacial retreat (<10,000 BP).

Results

As a result of our analysis, the Baku-Tbilisi-Ceyhan (BTC) oil pipeline, as well as the Baku-Tbilisi-Erzurum South Caucasian natural gas pipeline (SCP) were designed in such a way that they significantly reduce the risk posed by the newly-identified geohazards. However, since the consequences of long-term shut-down would be very damaging to the economies of western Europe, we conclude that the regionally significant BTC and SCP warrant greater protections, described in the final section of our work. The overall objective of our effort is to present the results in a matrix framework that allows the technical information to be used further in the decision-making process, with the goal of reducing any uncertainty for the final decision.

Discussion

Based on the results of our structural study, we believe the approximately N-S directed σ1 has major implications for volcanic reactivation, which might occur in the form of fissural eruptions and successive growth of localized vents along an about N-S tectonically-controlled direction. Since the pipeline right of way is immediately north of Tavkvetili Volcano, there could be increased volcanic risk that was not addressed in the initial design.

This work is making it possibile to identify and quantify geologic hazards threatening the strategic Caspian oil and gas pipelines through the Republic of Georgia, in the vicinity of the Middle-Late Pleistocene-Holocene Abul-Samsari Volcanic Ridge. As regards seismic hazards, we identified a major NW-SE trending strike-slip fault; based on the analysis of fault planes along this major transcurrent structure, and approximately N-S trend of the maximum horizontal compressive stress. σ1 was determined, which is in a good agreement with data instrumentally derived after the 1986, M 5.6 Paravani earthquake and its aftershock. The strong alignment of volcanic vents along the N-S trend is particularly notable and suggests a magma rising controlled by the N-S directed σ1 (Fig. 2).

Conclusion

The conclusion of the analysis is that the BTC and SCP were designed in such a way that risks posed by the newly-identified geohazards in the vicinity of the Abul-Samsari Ridge were reduced significantly. No new measures are recommended for the pipeline itself as a result of this study. The regionally significant BTC and SCP may warrant greater protections, since the consequences of longterm shut-down in the event of a lava flow or large landslide engulfing the valve station would be very damaging to the economies of western Europe. The additional protections recommended in this case would include an upgrading of the road system that leads to the pipeline service roads, in order to allow delivery of construction equipment and materials. This upgrade could happen in the near future, or be considered part of the overall response action after a volcanic or seismic event leads to a loss of this section of the pipeline.

Finally, the risk communication in this paper has not been applied to volcanic and seismic risk assessments. We believe that the risks, damages, and costs should be framed in a quantitative way, then simplified displays such as those provided here should be considered for a meaningful discussion about mitigation measures and to provide firm support for decisions. Moreover, we think the proposed methodology has wide applications, beyond the geographical area we have addressed in our research.

References

Koçyiğgit, A., Yılmaz, A., Adamia, S., and Kuloshvili, S. 2001. Neotectonics of East Anatolian Plateau (Turkey) and Lesser Caucasus: Implication for transition thrusting to strike-slip faulting. *Geodinamica Acta* 14(1–3): 177–-195.

Okrostsvaridze, A., Popkhadze, N., Bluashvili, D., Chang, Y. H., and Skhirtladze, I., 2016. Pliocene-Quaternary Samtskhe-Javakheti Volcanic Highland, Lesser Caucasus as a result of mantle plumes activity. Gilbert, A.S., and Yanko-Hombach, Valentina, eds., *Proceedings of the Fourth Plenary Conference of IGCP 610 "From the Caspian to Mediterranean: Environmental Change and Human Response during the Quaternary" (October 2-9, 2016; Tbilisi, Georgia),* Georgian National Academy of Sciences, Tbilisi, pp. 127–-131.

Pasquarèe, F.A., Tormaey, D., Vezzoli, L., Okrostsvaridze, A., and Tutberidze, B., 2011. Mitigating the consequences of extreme events on strategic facilites: Evaluation of volcanic and seismic risk affecting the Caspian oil and gas pipelines in the Republic of Georgia. *Journal of Environmental Management* 92(7): 1774-–1782.

Skhirtladze, N. I., 1958. Postpaleogenovyj effuzivnyj vulkanizm Gruzii [*Post-Paleogene Effusive Volcanism of Georgia*]. Tbilisi, Akademiâ Nauk Gruzinskoy SSR (In Russian).

LATE MIOCENE VOLCANIC ASH LAYERS OF THE INTERMOUNTAIN DEPRESSION OF THE EASTERN CAUCASUS: THE PRODUCTS OF THE MEGACALDERA EXPLOSION?

Okrostsvaridze, A. [1,2], Gagnidze, N. [3], Bobrova, I. [4], and Skhirtladze, I. [5]

[1,4,5] Faculty of Natural Sciences and Engineering of the Ilia state University, 0162 Tbilisi, Georgia
[2] Institute of Earth Sciences of the Ilia state University, 0162 Tbilisi, Georgia
[1,2] avtandil.okrostsvaridze@iliauni.edu.ge
[4] iulia.bobrova.1@iliauni.edu.ge
[5] irakli.skhirtladze.1@iliauni.edu.ge
[2] Institute of Earth Sciences of the Ilia state University, 0162 Tbilisi, Georgia
[3] Al. Janelidze Institute of Geology of I.Javakhishvili Tbilisi State University, 0157 Tbilisi, Georgia
nona.gagnidze@tsu.ge

Keywords: Volcanic flow, ignimbrite, U-Pb dating, megacaldera

Introduction

The Caucasus is a central segment of the Mediterranean Alpine-Himalayan collisional orogenic system and consists of the Greater and Lesser Caucasus orogens and intermountain depression. There are numerous layers of volcanic ashes in the late Miocene marine sediments (dated paleontologically) of the Eastern Caucasus intermountain depression. The ashes consist primarily of hornblende, pyroxene, and volcanic glass (Skhirtladze, 1964). The thickness of the layers varies between 5 m to several decimeters, while their distribution area is wide and includes the Kartli and Kakheti regions in Georgia and the western region of Azerbaijan (Fig. 1).

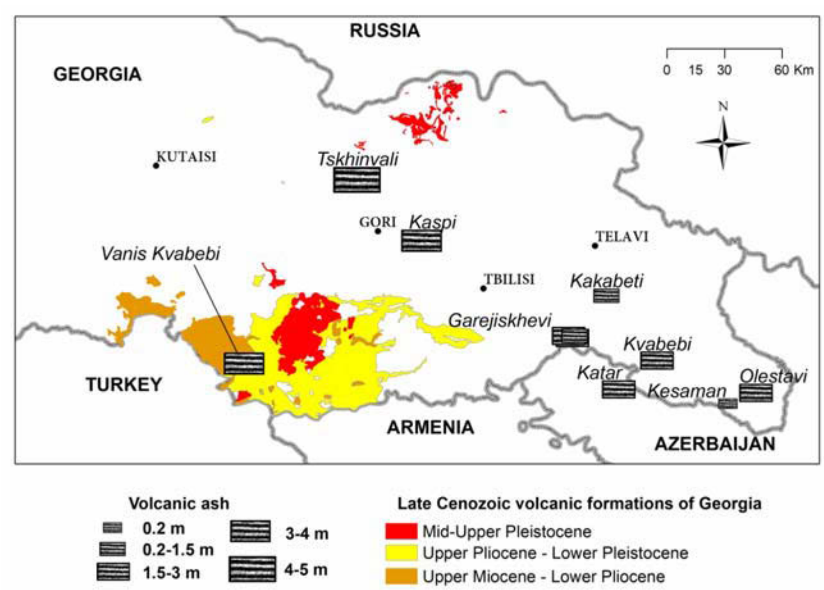


Figure 1. Schematic map of distribution of the Late Cenozoic volcanic formations and Late Miocene volcanic ash layers in the intermountain depression of the Eastern Caucasus.

Description of volcanic ash layers

The volcanic ash layers are dark grey, quite dense, and at the same time light rocks that chemically correspond to andesite. The mineral composition is quite simple and is mainly represented by isometric 0.5–1.7 mm diameter grains of volcanic glass, andesine, and hornblende.

The thickest layer is marked at the village Sarabuki near the town Tskhinvali, where it exceeds 5 m and is andesitic according to its composition. The thickness of volcanic ash layers reduces to the east, and at the village Metekhi railway station, in the Nadarbazevi gorge, it amounts to 2.5–3 m. In the east, particularly in Kakheti, the thickness of these layers further diminishes, and in the Gareji ravine, it ranges between 1–1.5 meters, and further to the east at the "Kvabebi area," thickness of the volcanic ash layers is 50–80 cm. In the upper Miocene sediments, the volcanic ash of andesitic composition is recorded in Azerbaijan, namely at the village Kasman, where it amounts to 10–20 cm (Skhirtladze, 1964).

The source of the above-described volcanic ash isn't clear, however, due to its age and distribution geometry, it is necessary to look for its source in the Lesser Caucasus, particularly at the Samtskhe-Javakheti volcanic highland, and not in the Greater Caucasus. It is known that in the Greater Caucasus, subaerial volcanic activity started only in the middle Pleistocene (Skhirtladze, 1958).

Samtskhe-Javakheti volcanic highland

The Samtskhe-Javakheti volcanic highland has an area of more than 5000 km^2 (1500–2000 m asl), however, a large part of it is located in the south within the territories of Turkey and Armenia. Three main magmatic intervals of activity should be marked in the formation of the highland: (1) Upper Miocene to Lower Pliocene, when huge 700–1000 m thick dacite-andesitic volcanic tuffs (so-called Goderdzi formation) were formed; (2) Upper Pliocene-Lower Pleistocene, when 120–270 m thick continental flood basalts were formed; and (3) Mid-Upper Pleistocene, when the Abul-Samsari linear continental volcanic ridge was formed (Okrostsvaridze et al., 2016).

The question about the magmatic center of the Upper Miocene – Lower Pliocene Goderdzi formation is still debated, but our detailed investigations allow us to conclude that its magmatic center was a megavolcano, which was located at the present-day Turkish-Georgian border. One of the megacaldera structures of this volcano is located in the Niala valley within the territory of Georgia (15x22 km, 2800–2200 m asl), which is injected by post-volcanic andesitic extrusives and known as Gumbati mountain (2996 m asl). At present, the Niala valley caldera is covered with Quaternary sediments, bounded by andesitic lava flows, and open to the eastern direction. From Niala's caldera, ignimbrites of andesitic composition flow out, so-called Vardzia ignimbrites (Ustiev and Jigauri, 1971), and extend more than 35 km to Khertvisi castle, with a thickness of 30–80 m (Okrostsvaridze and Popkhadze, 2016).

It should be noted that in the Goderdzi formation of the Mtkvari River valley, 2–3.5 m thick volcanic ash layers were observed lying 270 m hypsometrically above the Vardzia ignimbrite flow (Fig. 2), which shows similarity to those in the Eastern Caucasus intermountain depression in chemical, mineralogical, as well as by structural-textural features. We used the U-Pb method of dating for the Vardzia ignimbrite flow zircons and received very interesting results.

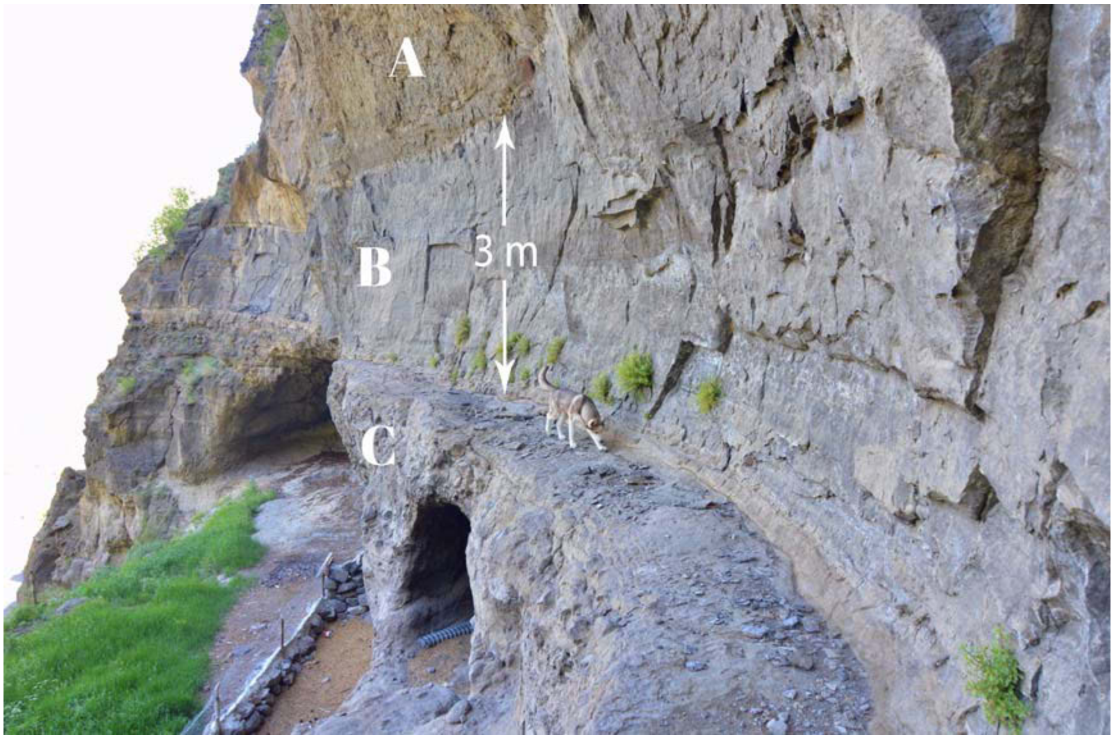


Figure 2. Exposure of the volcanic ash layer of the Vanis Kvabebi, Vardzia formation. A = medium-grained tuffs, B = andesitic volcanic ash, C = coarse-grained tuffs.

U-Pb dating results on the zircons

The dating of the zircons from the Vardzia ignimbrites flow was done at National Taiwan University using U-Pb method and using LA-ICP-MS equipment. The 72 zircon grain samples were taken from three main parts of the flow: in the end of the flow (at 35 km), near Khertvisi Castle (13GEO-04); in the central part of the flow (at 15 km), near the Vardzia cave city (13GEO-05); and at the beginning of the flow (at 2 km), near Arzameti Castle (13GEO-06). The results are as follows: 13GEO-04 = 7.50±0.42 Ma; 13GEO-05 = 7.54±0.21 Ma; 13GEO-06 = 7.52 ± 0.21 Ma. Thus, according to these data, the Vardzia ignimbrite flow represents at the Late Miocene formation, which crystallized around 7.5 Ma ago.

Discussion

Based on analysis of the information available to us, we believe that the Goderdzi formation is the product of megavolcano activity. There is no doubt that volcanic ash would be deposited after the accumulation of the explosive pyroclastic material. According to these arguments, the age of the ash layers, found by our group in the Mtkvari valley, should be the same as the age of the Vardzia ignimbrite flow. If we share this idea, then the Miocene volcanic ash layers in the Eastern Caucasus intermountain depression are in full correlation with the Goderdzi formation volcanic ash layers according to their age, and also chemical and mineralogical composition. This indicates that the formation of the above-discussed volcanic layers was associated with a strong magmatic center, namely, the Niala megacaldera of the Gumbati Megavolcano, which was the source of the Goderdzi volcanic pyroclastic formation (Okrostsvaridze and Popkhadze, 2016).

Conclusion

Thus, if we take into account that the average distance from the Niala megacaldera to the volcanic ash layers located in the Eastern Caucasus intermountain depression (300–400 km), and also the thickness of these layers (from several decimeters up to several meters), then our view on the megacaldera explosion in Samtskhe-Javakheti volcanic province during Late Miocene becomes more reasonable.

Therefore, if we compare the results of the research, we should assume that the volcanic ash layers in the Eastern Caucasus intermountain depression were formed as the result of a caldera explosion that was the source of the Goderdzi formation. Analyzing the volcanic explosivity index—VEI (Newhall and Self, 1982)—of the this formation and considering the largest volcanic eruptions of the Earth (Bryan et al., 2010) prompts us to suggest that the volcanic ash layers in the Eastern Caucasus intermountain depression were formed as a result of the Niala megacaldera explosion.

References

Bryan, Scott E., Peate, Ingrid U., Peate, David W., Self, Stephen, Jerram, Dougal A., Mawby, Michael R., Marsh, J.S., and Miller, Jodie A., 2010. The largest volcanic eruptions on Earth. *Earth-Science Reviews* 102(3–4): 207–229.

Newhall, C.G., and Self, S., 1982. The Volcanic Explosivity Index (VEI): An estimate of explosive magnitude for historical volcanism. *Journal of Geophysical Research, Oceans* 87(C2): 1231–1238.

Okrostsvaridze, A.,and Popkhadze, N., 2016. Megavolcano in the Late Cenozoic Samtckhe-Javakheti Volcanic Province? Lesser Caucasus, Georgia-Turkish Border. *VI International Workshop on Collapse Calderas, Hokkaido, Japan, 4-10 September 2016.* International Association of Volcanology and Chemistry of the Earth's Interior, p. 42.

Okrostsvaridze, A., Popkhadze, N., Bluashvili, D., Chang, Y.H., and Skhirtladze, I., 2016. Pliocene-Quaternary Samtskhe-Javakheti Volcanic Highland, Lesser Caucasus—as a result of mantle plumes activity. In: A.S. Gilbert and V. Yanko-Hombach (Eds.), *Proceedings of the Fourth Plenary Conference of IGCP 610 "From the Caspian to Mediterranean: Environmental Change and Human Response during the Quaternary" (October 2-9, 2016; Tbilisi, Georgia)*, pp. 127–131. Georgian National Academy of Sciences, Tbilisi.

Skhirtladze, N.I., 1958. *Postpaleogenovyj effuzivnyj vulkanizm Gruzii* [*Post-Paleogene Effusive Volcanism of Georgia*]. Tbilisi, Akademiâ Nauk Gruzinskoj SSR. (In Russian)

Skhirtladze, N., 1964. On the use of volcanic ashes for dating volcanic formation. *XXII International Geological Congress, 14–22 December, 1964, New Delhi*, pp. 207–214.

Ustiev, E.K., and Jigauri, D.I., 1971. The velded tuffs from Vardzia formation (southern Georgia). *Izvestia AN SSSR* 4: 3–16. (In Russian)

HYDROGEOCHEMICAL EVOLUTION OF LIMANS OF THE NORTHWESTERN BLACK SEA REGION IN CONNECTION WITH THE PROBLEM OF THEIR USE AS SALT SOURCES

Pedan, G.[1], and Dragomyretska, O.[2]

[1] Department of Engineering Geology and Hydrogeology, Odessa I.I. Mechnikov National University, Odessa, Ukraine
pedangalina3@gmail.com
[2] State Institution "Hydroacoustic Branch of Institute of Geophysics by S.I. Subbotin name of National Academy of Sciences of Ukraine," Odessa, Ukraine
ol.dragomyretska@gmail.com

Keywords: Late Pleistocene, Holocene, transgression, regression, liman, salinity, pore water

Introduction

There are salt limans in the littoral area of the Northwestern Black Sea region within which a natural process of salt crystallization occurs due to climatic factors. As is known, salt used to have an exchange value in many regions of the world (Ivanova, 2014). The purpose of this study is to analyze the geological structure as well as the hydrogeochemical and paleoclimatic features of the region under investigation in order to substantiate the hypothesis of the use of limans as salt springs during the Middle and Late Holocene. The evidence consists of results from chemical analyses of pore waters within the bottom sediments of the Black Sea limans. Data from the Department of Engineering Geology and Hydrogeology of Odessa National University and the Black Sea Search and Survey Expedition "Krymgeologiya" were used.

Area and research targets

The subjects of our research are the limans of the Northwestern Black Sea region: Sasyk, Dzhanshey, Shaganyi, Alibey, Burnas, Budaki, Dnestrovskiy, Hadzhibey, Kuyalnik, Tiligul, Berezan, and Dnepro-Bugskiy.

Methodology

Using methods of paleogeographic reconstruction based on the study of patterns of variability in mineralization and pore water composition comes with certain difficulties. These paleoreconstructions have been criticized (Olshtyinskiy, 1977) due to the fact that biochemical, diagenetic, and other processes change the overall picture. Subsequent studies, however, have shown that these changes have been taking place throughout the centuries (Babinets and Sukhorebriy, 1981; Voskoboinikov et al., 1982, 1984; Konikov, 1993). Therefore, the use of these methods is fully justified for the paleoreconstruction of the recent geological past (Holocene).

Results

The liman deposits represent cyclically constructed strata (Konikov, 1993; Voskoboinikov et al., 1982). In lithological structure, these cycles represent alternations in strata of clayey mud, aleurolitic mud, and muddy shell. The average capacity of these strata is from 0.5–1.5 m up to 2.5 m. The cyclical structure of the Holocene deposits is also expressed in the variability of chemical structure and salinity of pore waters, as well as changes in the physical and mechanical properties of precipitation, and chemical composition. The rhythmic pattern in the distribution of these characteristics is caused by transgressive-regressive fluctuations in the level of the Black Sea basin (Konikov and Pedan, 2006).

When comparing the curves of sea-level fluctuations, the generalized values of the composition indexes, and the properties of muddy bottom sediments, one can approximately estimate the rate of accumulation of precipitation in the limans for the last 6.2 thousand years. These velocities are 1.5–2.5 mm/year (Konikov, 1983).

The pore solutions within the bottom sediments of the Black Sea limans are typically sedimentogenic waters, and they inherited the main features of the chemical composition of the waters of the limans (Voskoboinikov et al., 1984). Primarily, this applies to the general mineralization of pore solutions. The salt content of the Black Sea limans varies from 5 to 230 g/l in terms of both area and depth. The minimum mean value of mineralization is observed in the pore waters of the Berezan and Tiligul limans (16 g/l), although the range of salinity fluctuations is different (8.8–26.4 and 8.7–52.8 g/l, respectively). The average values of salt content in the pore waters of Lake Sasyk and Hadzhibey liman are 46 and 40 g/l, respectively, and the ranges of salinity changes in them are close (14.8–93.0 and 8.7–107.2 g/l). As it turns out, the greatest mineralization of pore waters is observed in the Tuzlovskaya group of lakes, where the average value is 112 g/l, and the difference between the extreme salinity values is 190 g/l. According to the data (Babinets and Sukhorebriy, 1981), mineralization of the pore waters within Dnestrovskiy liman ranges from 1 to 34 g/l, while in the Dnepro-Bugskiy liman, it ranges from 10 to 25 g/l. The salinity distribution of pore waters within bottom sediments in terms of the area and depth of the limans is characterized by a nonstationary regime of variability.

Stratification is clearly manifested in the sharp fluctuations of mineralization along the vertical. These fluctuations are accompanied by changes in the qualitative composition of the pore waters, primarily by a change in the content of sulfates and carbonates. As for the change in salinity of the pore waters within the bottom sediments of the limans, 2–4 peaks (maxima) of salinity (almost synchronous in time) are noted in depth. Their presence can be explained by the transgressive-regressive nature of the Black Sea level regime during the Holocene. For the closed limans (Hadzhibey, Budaki, Alibey), these peaks are more evident than for open limans (Tiligul, Berezan). Open limans are characterized by small fluctuations in the mineralization of the pore solution. The relationship between cyclicity in the salinity change of pore waters from limestone deposits with sea-level fluctuations in the limans is beyond doubt (Babinets and Sukhorebriy, 1981; Konikov, 1983).

Analysis of the dependence of the liman water-salt regime on the moisture content of the climate in the Northwestern Black Sea region identifies two groups of limans: (1) Tiligul, Hadzhibey, Shaganyi, Alibey, Burnas, and (2) Dnepro-Bugskiy, Dnestrovskiy, and Berezan. With regressive sea-level decline and inadequate moistening conditions, the runoff of "small" rivers could have been significantly reduced or completely stopped. At such a time, the limans turned into lakes in which the concentration of salts in the water was caused by evaporation. With sufficient climate humidification, when atmospheric precipitation exceeded evaporation (in cold and humid climate stages), freshwater runoff would increase and desalination of these limans could occur. However, the salinity of the pore waters of the sediments within the limans of this type indicates that the mineralization of their waters in the past was not lower than the salinity of the modern sea. Thus, it is possible to associate the high salinity of pore waters in the first group of limans with regressions—Phanagorian and Hadzhibey. The climate at this time in the Northwestern Black Sea region was relatively arid.

Large rivers flow into the limans of the second group. For this reason, the dependence of the water-salt regime of these limans on the degree of humidity in the climate of the study area is not manifested to the same extent as it is for the first group of limans. This is because run-off from the Dnepr, the Southern Bug, and the Dnestr rivers originates in a predominantly humid climate. Therefore, with regression of the sea, these limans were desalinated, and with transgressive increases in sea level, the salinity of their waters increased but did not exceed the salinity of the water of the modern sea. Repetition of these events, which were accompanied by a change in the hydrochemical conditions in basins receiving insignificant fresh water intake, are shown on the concave-convex diagrams of pore water salinity.

Conclusions

A rise in salinity of liman water during regressive cycles of the sea, as well as climatic conditions (climate aridization), give grounds to assume that, during the study period, there was a natural precipitation of salt due to saltiness of the Black Sea limans, especially in the limans fed by small rivers. Analysis of the geologic structure, and hydrogeochemical and paleoclimatic features of the Northwestern Black Sea region has shown the validity of the proposed hypothesis about hman use of limans as salt springs in the Middle and Late Holocene periods.

References

Babinets A.E., and Sukhorebriy A.A., 1981. O gidrogeokhimicheskikh osobennostyakh donnyikh otlozheniy limanov Severo-zapadnogo Prichernomorya. [On the hydrogeochemical features from bottom data of the limans of the Northwestern Black Sea region]. *Geologicheskiy zhurnal* 41(2): 104–111. (In Russian)

Ivanova, S.V., 2014. Dobyicha soli v Severnom Prichernomore i Kryimu (po arkheologichesrim i istoricheskim dannyim) [Mining of salt in the North Pontic and Crimea (by archaeological and ethnological sources)]. *Arkheolohiya i davnya istoria Ukrayiny* 2(13): 7–18. (In Russian)

Konikov, E.G., 1983. Sostav, stroenie, svoystva i porovyie vodyi golotsenovyikh otlozheniy severo-zapadnogo shel'fa Chernogo morya i Prichernomorskikh limanov [Composition, structure, properties and pore waters of the Holocene sediments of the northwestern shelf of the Black Sea and the Black Sea limans]. Avtoref. dis. kandid. geol-min. nauk. Odessa, 164 p.

Konikov, E.G., 1993. Gidgogeokhimicheskaya evolutsiya Azovo-Chernomorskogo basseyna v pozdnem pleistotsene i golotsene [Hydrochemical evolution of the Azovo-Black Sea basin in the Late Pleistocene and Holocene]. *Okeanologia* 33(2): 217–223. (In Russian)

Konikov, E., and Pedan, G., 2006. Geological-lithological structure of liman as a key to decoding late Neoeuxinian and Holocene history of the Black Sea. In: V. Yanko-Hombach, I. Buynevich, A. Chivas, A.S. Gilbert, R.E. Martin, and P. Mudie (eds.), *Extended Abstracts of the Second Plenary Meeting and Field Trip of IGCP 521 Project Black Sea-Mediterranean corridor during the last 30 ky: Sea-level change and human adaptation," (August 20-28, 2006, I.I. Mechnikov Odessa National University, Odessa, Ukraine)*, pp. 89–91. Astroprint, Odessa.

Olshtyinskiy, S.P., 1977. Paleogeograficheskie rekonstruktsii po himicheskomu sostavu interstitsialnyikh vod. [Paleogeographic reconstruction of the chemical composition of interstitial waters]. In Veklich, M.F., and Artiushenko, A.T. (eds.), *Paleogeograficheskie osnovy ratsional'nogo ispol'zovaniia estestvennykh resursov*, pp. 74–76. Naukova dumka, Kiev. (In Russian)

Voskoboinikov, V.M., Rotar', M.F., and Konikov, E.G., 1982. Svyaz ritmichnosti stroeniya tolsgh holocenovikh otlozheniy Prichernomorskikh limanov s kolebatelnim regimom urovnya Chornogo morya [Relationship between rythmic composition of thick Holocene layers of the Black Sea region lagoons and oscillatory level regime of the

Black Sea] In *Izmeneniya urovnya moray* [*Sea Level Fluctuations*]. Izdatel'stvo Moscovskogo universiteta, Moskva, pp 264–274. (In Russian)

Voskoboinikov, V.M., Konikov, E.G., and Rotar', M.F., 1984. Gidrogeologicheskie i gidrokhimicheskie osobennosti limanov. In Shnyukov, E.F. (ed.), *Geologiia shel'fa USSR. Limany* [*Geology of the Ukrainian Shelf. Limans*], pp. 81–102. Naukova dumka, Kiev. (In Russian)

VORTICES OF THE CRETAN STRAITS OF THE EASTERN MEDITERRANEAN AND THE BLACK SEA SHELF

Popov, Yu.I. [1], and Matygin, A.S. [2]

[1] Ukrainian Scientific Center of Ecology of the Sea, 89 Franzusky blvd, Odessa, Ukraine, 65009
ypopov50@mail.ru
[2] Black and Azov Seas Centre for Hydrometeorology, 89 Franzusky blvd, Odessa, Ukraine, 65009
acm32alex@mail.ru

Keywords: vortex, generation, development, structure, interaction, shelf water

Introduction

The Mediterranean and Black seas are an experimental polygon for research into the interaction of many dynamic processes that take place in the marine and atmospheric environments. The study of the vortices of the Cretan island arc (CrIA), and the vortex of the continental slope of the northwestern shelf of the Black Sea showed certain common features of their origin and development. Anticyclonic gyres that were discovered during a warm half-year 1986–1988 were located at the mouths of straits within the Cretan island arc. The Black Sea anticyclonic (Az) (so-called Sevastopol) vortices develop on the northwestern area of the mainland slope. They are one of the major mechanisms of transformation and utilization of eutrophic waters of the northwestern shelf (NWS) of the Black Sea.

Materials and methods

We investigated the features and spatio-temporal structure of vortices in the Eastern Mediterranean in the region the CrIA and on the mainland slope of the NWS using materials from seasonal expeditionary research on Ukrainian R/Vs from 1986 to 1999. We also used satellite information about surface conditions over the NWS during the interval 2005–2011.

Results

Data analysis has for the first time allowed us to define and describe the main mechanisms of generation and stages of development for vortices of the CrIA and NWS. The major pre-conditions for the generation of vortices are the local cooling of the sea surface during a fall-winter period. A subsequent convection forms the necessary large volume of dense salt water (Aegean Sea, NWS, and basic cyclonic gyres of the Black Sea). The source of generation of slope gyres in the CrIA district is the active creation during a spring-summer period of dense intermediate waters in the eastern Aegean Sea.

The entry into the southern regions of the circulation system of light and transformed Atlantic waters represents a second factor that assists in forming thermohalic and density fronts. The spatial instability of the Basic Black Sea Flow (BBF) is the generator of slope vortices in the Black Sea. The spring pumping of kinetic energy to the BBF from cyclonic Black Sea gyres and dense bottom waters of the NWS results in this intensification. The light and transformed waters of the Sea of Azov accumulate westward from Crimea in a topographically suitable district for the generation of vortices; here the heightened gradient is created in the density field.

The further development and formation of vortices supposes the inclusion of mechanisms of intensification of the maelstrom by the introduction into the cores of the Az rotations of light and transformed waters (shelf-derived for the NWS and Atlantic-Mediterranean for the CrIA vortices). These waters increase their radial density gradient and promote the development of vortices. Simultaneously, the influence of air flows can promote this mechanism of development for the circulation of local vortices. The dynamic influence of northwesterly winds and an orographic compression in the southeastern straits of the CrIA give a direct impulse for the development of circulation. The shelf waters (SW) are an active participant in forming the Sevastopol slope vortex, when they spread over the southeastern NWS during the protracted western winds (Fig. 1)

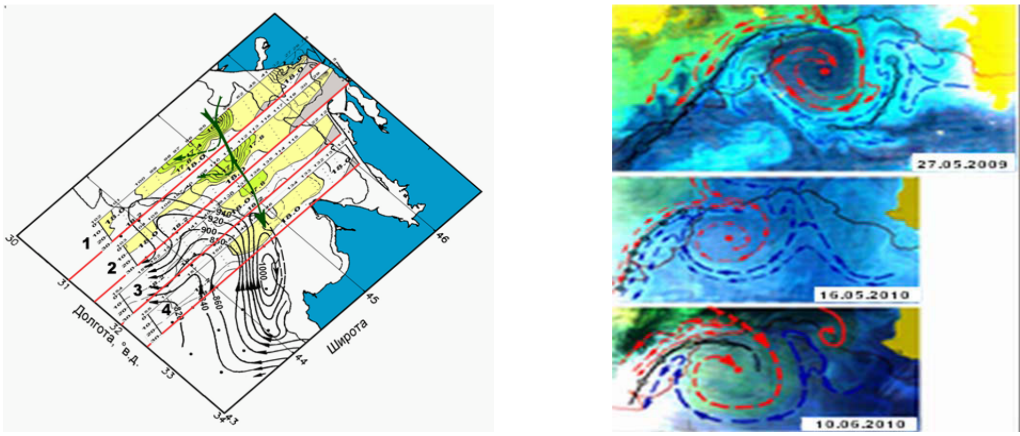


Figure 1. Interaction of the SW and the vortex structure on the continental slope of the NWS. Left: Vertical distribution of water salinity along 4 meridional tracks, combined with a map of the dynamic topography of the surface layer (from R/V "Vladimir Parshin" 01–19.09.1996). Right: The flow pattern and positions of divergence zones and fronts in three typical anticyclonic vortices of the northwestern slope of the Black Sea (AERONET, USA).

The circulation of the Eastern Mediterranean waters has a well-organized structure in the summer, if the activity of the described processes was high. The transport of dense waters from the straits of Otranto and the CrIA creates the primary chain of Az rotations (lying directly on borders areas of their distribution). These are: an Az meander in the north of the Ionian Sea, and anticyclones of Iera-Petra and Pelops (Fig. 2).

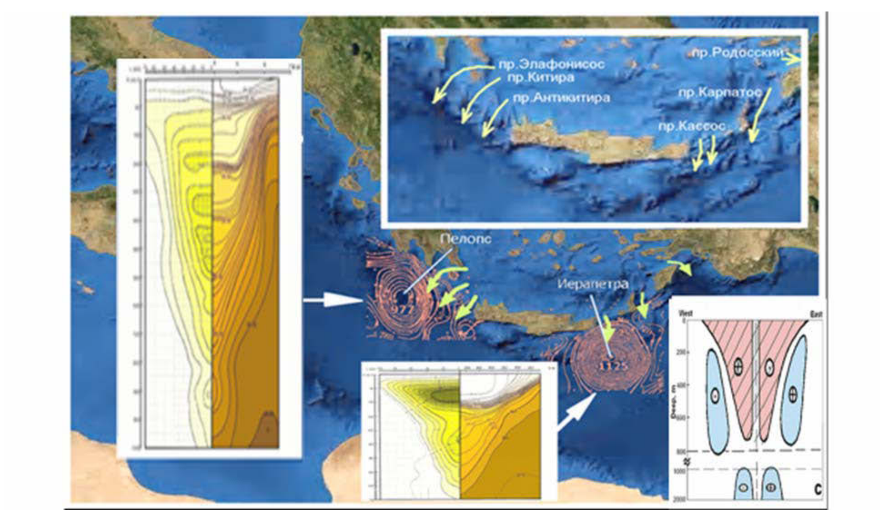


Figure 2. Scheme of the location of vortex structures of the CrIA. On the insets: the combined distribution of the density of potential energy and the conditional density of sea water in vertical sections through the central regions of the vortices of the CrIA. Left: Az-Pelops (from R/S "Passat", 30–31.05.1991); In the center: Az-Iera-Petra (from R/S "Jacob Gakkel" 06–07.10.1990); Right: the scheme of geostrophic circulation in the anticyclonic structure of Iera-Petra.

The Pelops vortex is a unique phenomenon in oceanography. It has five (from them three strongly expressed) underpycnoclinic cores that are distinctly visible on density distributions. The basic cone of the Az-vortex is determined mainly by the temperature changes of the environment. The vertical distribution of water salinity is the factor that creates internal local homogeneous zones in the vortex cone. In its generation, the Pelops gyre takes waters emerging from all three southwestern straits of the CrIA. The waters of the Aegean Sea are able to descend isopycnically to a depth corresponding to their density due to the complex orography of the southern slopes of the straits. This mechanism serves as a long-term support for the complex multi-core structure of the Pelops vortex.

The flow of water through the deep strait of Kasos produces the major influence on the development of the Iera-Petra vortex. Calculations of the geostrophic currents using data from the autumn surveys of the Iera-Petra vortex showed this important feature in the structure of its formation. This is the existence of the subsurface annular counterflow (toroidal form) with velocities of 6–8 cm/s, which is the cyclonic sheath of the Az-vortex (Fig. 2). The region of weak cyclonic vorticity was located under the Az-vortex of Iera-Petra in the deep layer at 1000–2000 m. It should be noted that there is also the Az-maelstrom, which is located under the extensive and quite powerful Rhodes cyclonic maelstrom in the layer at 1000–2000 m.

The process of development of the Sevastopol vortex is related both to the sharp changes in bottom orography and with the closeness of source of the light and freshened waters. On Fig. 1, it is shown as a stream of freshened waters spreads in the 20 meter layer of the NWS. As it moves east, it narrows, and the waters become saltier. The separation of the SW flow takes place before their interaction with the vortex (Fig. 1). The significant part of the SW is not involved in the vortex, but unfolds to the right and leaves in a southwestern direction along the active front between the SW and the water of the BBF. In rearward and front parts of the vortex, the narrow contour zone of water divergence is noticeable and is related to the differently directed motions of waters of the BBF in a cyclonic meander.

On the face of it, this zone hasn't the joint structure in the surface layer of the sea. The spatial structure of the currents of the Sevastopol vortex system indicates the existence of a dynamic compensation of the Az-rotation. The northwestern boundary of the divergence zone is the intense shelf front with high velocity of the flow. Frontal waters penetrate deeply on a spiral into the core of the Az-vortex and form vertical movements in the center of the Az.

The above-described system of counterflows in the Mediterranean vortices and elements of the structure of currents in the Black Sea vortices have one and the same nature: dynamic compensation for developing and energy vortices. Waters of the NWS undergo further transformation when they reach the areas of the mainland slope because they actively participate in the formation and development of sloping vortex formations. Conversely, large and stationary Sevastopol vortices play an important role in large-scale processes of water circulation and transformation throughout the southern half of the NWS.

The vortices in the straits of the Eastern Mediterranean are hardly a permanent feature (unlike the NWS vortices). They may be absent altogether or exist only in the spring-summer period and be at the same time sluggish and smaller in scale during years with little exchange through straits or runoff of less dense waters from the Aegean Sea.

SEDIMENTARY STRUCTURE AND LATE HOLOCENE EVOLUTION OF THE COASTAL EMBAYMENT ON THE SOUTHEASTERN COASTLINE OF THE CRIMEAN PENINSULA (BLACK SEA)

Porotov, A. [1]*, and Yanina, T.* [2]

[1,2] Faculty of Geography, Lomonosov Moscow State University, Moscow, Russia
alexey-porotov@ya.ru

Keywords: coastal geomorphology, sea-level changes, sedimentary structure, geochronology

Introduction

The coastal section of eastern Crimea includes several tectonic depressions, the low parts of which became shallow bays and limans during the Holocene transgression of Black Sea. The sedimentary infill of such environments holds great promise for paleogeographical reconstruction of coastal evolution and sea-level change under the climatic fluctuations of the Holocene.

In the present paper, we offer the results of a geologic study of the geomorphological patterns recognized in the five coastal embayments on the eastern coastline of Kerch peninsula, embayments that have been poorly researched to date. The study included continuous core-drilling and subsequent lithostratigraphic, sedimentologic, and malacofaunistic analyses, as well as radiocarbon determinations. We propose that recent neotectonic activity in the coastal depressions has contributed significantly to the sedimentary infilling during the Holocene and brought about local variation in the relative sea-level change.

As for Lake Tobechik, the low section of the Holocene sedimentary sequence consists of dark grey silty clay with shells and thin lenses of fine sands. The thickness of the layer reaches up to 15 m, and its top lies at a depth of 4.5 m bsl. The upper layer is represented by coarse sands with shell debris. The presence of the low layer of silty clay marks the prolonged phase of middle Holocene ingression of the sea into the coastal depression, thereby creating a semi-enclosed embayment. The upper age of this phase could not be evaluated reliably, but on the basis of the restricted ^{14}C dating, it could be dated to 4700–5200 cal BP. The upper sandy body reflects the evolving of the barrier and establishment of the environmental conditions of a closed liman. No clear evidence of the drop in sea level in the I millennium BC has been revealed in the sedimentary column, but based on the presence of traces of a low Holocene terrace on the mainland shore of Tobechik Lake (Geologiya Shelfa…, 1981), we don’t exclude such a possibility and require some future elaboration.

As for the former embayment in the Kamish-Burun Bay, research results have been previously published (Kaplin and Porotov, 2011). Below the subsurface cover of coarse sands with a thickness of about 4 m, the fine, well-sorted sands with shell extend within the inner part of the former semi-enclosed shallow embayment that reaches the eastern flank of a cliffed shore that surrounds the coastal lowland. The set of radiocarbon dates on shell from the fine sands has shown that the shallow embayment in the inner part of the coastal lowland existed between the end of the II millennium BC up until the end of the I millennium AD. The belt of silty clay in the outer part of the former embayment confirms the existence of a semi-enclosed embayment that was separated from the sea by a sandy barrier spit that was located eastward from the present-day Kamysh-Burun spit. The generation of this former barrier spit was related to the mid-Holocene highstand (4500–5000 cal BP). This barrier was destroyed during the accelerated sea-level rise of the last 1.5–1.0 thousand years.

During our research into a sediment structure of the coastal terrace south of the Nymphaion settlement, the sequence of the two generation of late Holocene marine sands has been revealed. Traces of the middle Holocene sea-level highstand are represented by coarse shelly sands at an elevation near the present-day sea level. The altitude and stratigraphic position of this layer allows us to relate its formation to the middle Holocene transgressive phase (4.5–5.0 ky BP) during which sea level for the first time reached its present position.

Overlying the coarse sands, a continental loamy soil can be related to the phase of lowering in relative sea level in the middle of the I century BC. The age of this layer is established on the basis of *in situ* cultural remnants of the III–II BC up to the I–II century AD, which contain foundations of walls, stone wreckage, and ceramics (Zinko, 2003).

The topography of underwater archaeological objects allows us to evaluate the position of relative sea level during the first millennium BC at no less than 4.5–5 m below the present; this was maintained until late antiquity-early medieval times. However, the scarcity of archaeological data from the underwater outskirts of Nymphaion has not provided an opportunity to estimate the possible changes in relative sea level during those millennia.

As for Kerch Bay, the coastal lowland within the bay head in Classical times was occupied by the lower town of Panticapaeum (modern Kerch) that was founded in the VI c. BC, and which subsequently became the capital of the Bosporus Kingdom. The constructional remnants of this lower town occupy the seaside part of the city. It is supposed (by Tolstikov, 1997) that the location of the central urban area (agora) was moved in the centuries I BC/I AD from the top of Metridat to the seaside part of the lower town in the vicinity of the present-day church of St. John the Baptist (VIII–IX AD). Over the centuries, there was a fortress on this place operated by Genoese, Turks, and Russians. The remains of the Genoese tower were still visible in the middle of the XIX century AD and were eventually destroyed during reconstruction of the city center.

The materials of archaeological research in the lower town reveal the presence of a cultural layer with a thickness up to 4.7 m in the immediate proximity of the present-day sea coast that contained artifacts from Classical up to medieval times.

Study of the sediment structure of the coastal lowland in the bay head has shown that the thickness of the cultural layer everywhere varies from 3.5 up to 7.5 m. The base of the cultural layer is located at a depth of –2 to –3 m bsl. The cultural layer in the vicinity of the present-day sea coast is underlain by fine to medium sands with a thickness of about 3.5–3.0 m. This confirms the existence of a sandy barrier (spit) inside the former sea border in Classical time that separated the shallow liman from the sea in the lower part of the river valley. The archaeological materials from the base of the cultural layers that overlie the ancient liman sediments allowed us to date these layers to the I–III centuries AD, or early medieval ages.

The submerged coastal barrier is underlain by silty clay with a thickness up to 10 m, the base of which lies at the depth of –16 to –17 m bsl. The lowermost part of the sedimentary column is represented by continental loamy soil of the Late Pleistocene.

Conclusion

The comparison of sedimentary structures of the typical coastal embayments on the eastern part of the Kerch peninsula allowed us to reveal the principal pattern of the Holocene sedimentary sequence, which reflects the impact of the slowing in sea-level rise on the coastal environments during the last 6.0 ky. An overlying small-amplitude fluctuation in the general trend of sea-level rise determined several stages in coastal evolution that are reflected both in coastal geomorphology and in the coastal sedimentary structure.

Observed differences in the timing and amplitude of the still stands or regressive phases could be explained by the role of local tectonics that essentially varied along the coastline. More significant, the impact of tectonic heterogeneity could be noted for the prominent sublatitudinal faulting zone (Kamich-Burun, Tobechik).

At the same time, the absence of the essential influx of river discharge into the coastal zone played an important role in coastal evolution and longshore sediment transport. This phase of sea-level rise was accompanied by drastic changes in coastline configuration: open stretches of seashore experienced a tendency for coastal erosion and retreat (up to 0.8–1.0 m/yr), while in the bays, advance of the coastline reached 2.0–2.5 km.

Acknowledgments

This research was conducted in the frame of the projects RFFI-RGS № 17-05-41041 and RGS 03/2017-R.

References

Geologiya Shelfa USSR. 1981. Kerchenskiy Proliv [Geology of the USSR. Kerch Strait]. 1981. Makarenko I.D. ed. Naukova Dumka, Kiev.

Kaplin, P., and Porotov, A., 2011. Late Holocene sea-level change in the northeastern Black Sea from archaeological and geomorphological indicators. In: A.S. Gilbert and V. Yanko-Hombach (Eds.), *Abstract Volume of the Seventh Plenary Meeting and Field Trip of INQUA 501 "Caspian-Black Sea-Mediterranean Corridor during the last 30 ky: Sea level change and human adaptive strategies" (August 21-28, 2011; Odessa, Ukraine)*, I.I. Mechnikov Odessa National University, pp. 111–113. Odessa, Astroprint, Ukraine,

Tolstikov, V.P., 1997. Descriptions of fortifications of the Classical cities in the region to the north of the Black Sea. *Ancient Civilizations from Scythia to Siberia* 4(3): 187–231.

Zinko V.N., 2003. *Chora bosporskogo goroda Nimfeja* [*The Chora of Nymphaion*]. Simpferopol, Krymskoe Otd. Inst. Vostokovedeniya Im. A.E. Krymskogo NAN Ukrainy, Centr Archeologiceskikh Issledovaniy.

REGIONAL DISTRIBUTION AND CLAY MINERALOGY OF THE MODERN SEDIMENTS IN THE NORTH-WESTERN ZONE OF THE BLACK SEA

Rădan, S.

National Institute of Marine Geology and Geoecology - GeoEcoMar,
23-25, D. Onciul St., 024053 Bucharest, Romania
radan@geoecomar.ro

Keywords: marine sediments, lithology, clay minerals, areal distribution

Following several cruises performed between 1995 and 2015, a vast amount of sediment was collected from the main depositional units outcropping within the northwestern zone of the Black Sea using a box corer and, in a few locations, a multicorer. Lithological observations carried out aboard the ship on the cores showed good correlation between the areal distribution pattern of the bottom sediments and the sedimentary evolution of the marine basin during the Holocene (Fig. 1).

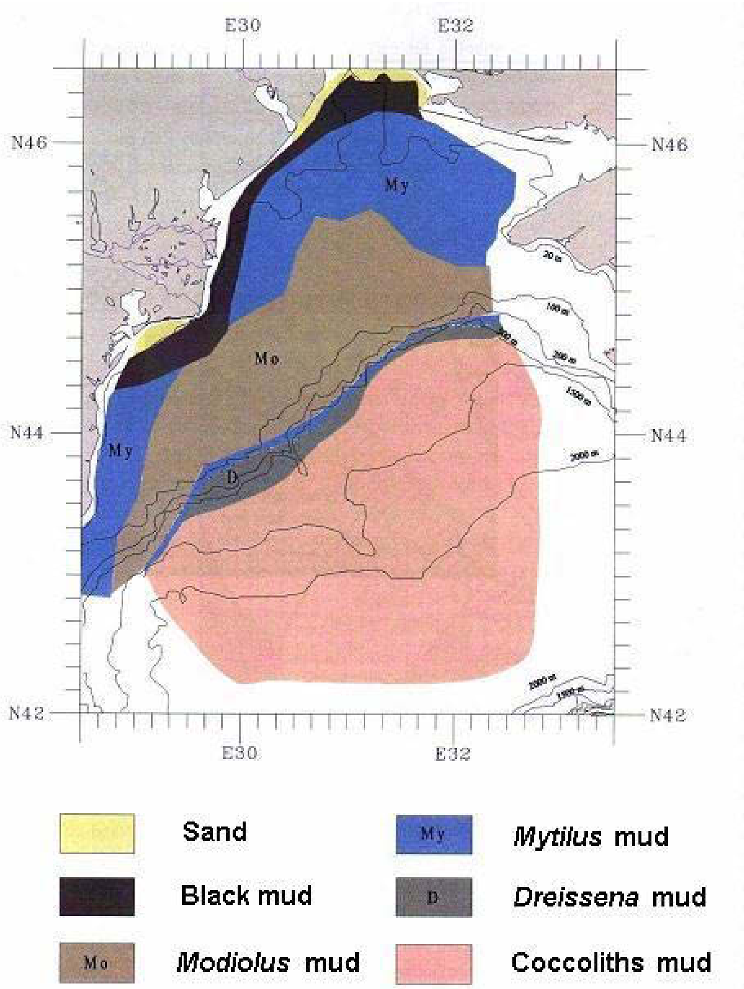


Figure 1. Areal distribution of lithological units in the northwestern Black Sea.

The Holocene sequence sampled on the shelf starts with *Dreissena* muds and/or sands, representing the transition from the lacustrine to marine environment within the Black Sea basin. This unit was found as superficial sediment at high water depths (130–150 m) along the continental shelf edge, or covered (hidden) by *Mytilus* and/or *Modiolus* (*phaseolinus*) muds at lower depths (50–70 m) on the continental shelf. The *Dreissena* sediment distribution pattern suggests the presence of an old gulf in the Viteaz canyon area.

The next overlying unit is represented by *Mytilus* muds, which spread over the largest area, from the Danube Prodelta zone to the continental shelf edge, at water depths ranging between 20–140 m. The major part of this unit, especially its basinward area (between 50–70 m), is covered by *Modiolus* muds (or *Phaseolinus* muds), the uppermost unit of the Holocene sequence on the continental shelf. The *Modiolus* mud occurrence area is located at varying depths (37–150 m), yet always covering the *Mytilus* unit.

The *Modiolus* mud occurrence area is located at varying depths (37–150 m), yet always covering the *Mytilus* unit.

Recent sediments, consisting mainly of black organic muds and subordinately of sands, are found at shallow depths (10–30 m) along the Danube Delta front zone, and within the Dniestr and Dniepr mouth zones.

Several samples were taken from the Danube and the Ukrainian rivers' deep-sea fan systems and from the deep-water zone of the Black Sea at depths ranging between 1200–2000 m. All the cores showed two distinct units, characteristic for the deep-water Holocene sequence: the uppermost unit (Unit I) is represented by the Coccoliths mud—a very fine laminated sediment, composed of an alternation of white-yellowish and black-brownish thin layers, and the underlying unit (Unit II), is represented by sapropelic mud, consisting of very fine laminated black-brownish sapropelic sediment with high fissility and jellylike texture. The thickness of Unit I varied between 30–40 cm, and the visible thickness of Unit II was 10–30 cm. Only the uppermost unit is cropping out, while Unit II is hidden under Unit I.

Along the coast, the recent sediments are represented by sands and black muds. Thus, the sands were found only in a few stations near the mouths of the Danube and Dniester rivers, in shallow waters (9–15 m). The black muds are characteristic of the delta and the delta front, and appear as a practically continuous strip from the mouth of the Dnieper River to the mouth of the Danube, and they are encountered at shallow depths (10–30 m).

Clay mineralogy studies carried out on the samples collected within the northwestern area of the Black Sea showed clear illite+smectite domination, similar to the composition of the clay fraction of the Danube River sediments. Kaolinite and chlorite display usually low contents, and irregular mixed layers of 10–14S type are ubiquitous, as in all Danubian sediments.

The distribution maps of the main clay minerals reveal the control of the main rivers, the areas of extension of their abyssal fans being underlined very well by practically all parameters. The distribution of kaolinite and chlorite highlights the same zoning, controlled by the contributions of the three rivers.

The map of smectite/illite ratio outlines better the Danube, Dniester and Dnieper areas of influence, showing some very significant additional details (Fig. 2).

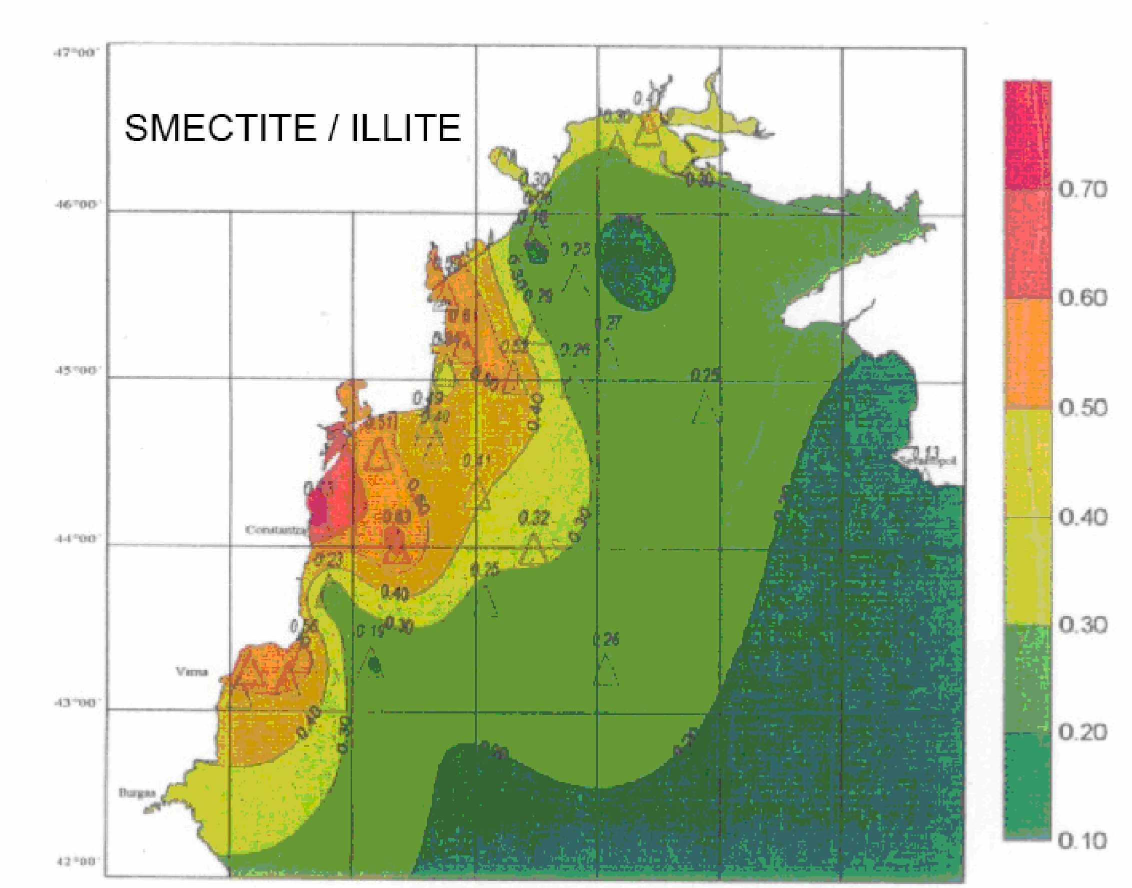


Figure 2. Distribution pattern of smectite/illite ratio within the northwestern area of the Black Sea.

It should be noted that the associations of clay minerals always contain predominantly illite; the trend of relative increase of the smectite contents at the mouth of the Danube reflects the decrease of the coarser and richer fractions after the building of the Iron Gates dams, as well as the differential transport and sedimentation of the clay minerals. Once the clay minerals reached the sea, a slight diagenetic change could be produced with increasing water depth and as a consequence of increasing burial depth below the water-sediment interface.

UNKNOWN MORPHOTYPES AS PERMANENT REPRESENTATIVES IN THE ANOXIC AND SULFIDIC BOTTOM SEDIMENTS OF THE BLACK SEA

Sergeeva, N.G.

Institute of Marine Biological Research of RAS, 2, Nakhimov ave., Sevastopol, 299011, Russia
nserg05@mail.ru

Keywords: unknown morphotypes, permanent hydrogen sulfide / anoxic environment

Introduction

For more than a century, the world of science has considered the anoxic zone of the Black Sea to be azoic, or lifeless. But modern data (Sergeeva, 2000, 2003, 2015; Korovchinsky and Sergeeva, 2004, Sergeeva et al., 2014) indicate that the deep-water bottom sediments of the Black Sea, which possesses permanent hydrogen sulfide pollution, are the natural habitats for some species of eukaryotic fauna (Protozoa and Metazoa). In connection with this, it has since been specially stressed that the term "azoic" or "lifeless" is not valid when applied to the anoxic zone of the Black Sea.

The above-mentioned research has made it clear that the extremely deep-water environment of the Black Sea is unexpectedly diverse: Ciliophora, Foraminifera, Nematoda, Copepoda, Cladocera, Tardigrada, and Acari are able to live in sulfidic bottom sediments. However, the environmental factors and specific physiological and biochemical processes of the benthic fauna that permit them to maintain their metabolic activity and facilitate survival are still unknown.

Along with representatives of unicellular and multicellular animals, the morphotypes of organisms, whose taxonomic status is unknown (Forms 3, 5, 6, 11), were isolated from samples of bathyal sediments. They have not been observed in the oxic coastal zone, even in sites with temporal hypoxia. These organisms have so peculiar a structure that it impedes their attribution to known types and classes in invertebrate systematics.

Based on the analysis of perennial collections of deep-sea bottom sediments received at more than 50 stations in the Black Sea, it has been shown that these forms are constant and numerous organisms not only in the surface (0–1 cm) layer of bottom sediments, but they penetrate into the column of sediment, up to a depth of 8.5–10 cm, the maximum investigated by us.

This work is a supplement to previously published material on the modern faunal anoxic zone of the Black Sea as a remnant of the ancient anoxic biosphere (Sergeeva, 2015). The purpose of this work is to give brief morphological information about some unknown (to us) morphotypes we observed only in the deep bottom sediments of the hydrogen sulfide zone; this is intended for scientists in the biological and geological fields, who study not only the Black Sea but also the Caspian and Mediterranean seas. Future detailed study of these organisms will reveal time of their origin and their ways of adaptation to this zone, thereby allowing us to determine their role in the extreme Black Sea ecosystem and, possibly, to assess them as a marker of the geological history of the basin.

Methodology

To previously cited materials (Sergeeva, 2015) we have added new data obtained in samples from the deep-water northwestern and northeastern parts of the sea in 2013–2016, during 72, 75, and 86 cruises of the R/V "Professor Vodyanitsky" (Russia), in 2004 onboard R/V "Poseidon," and 2007 R/V "Meteor" (Germany) in the field of active methane seeps in the northwestern part of the sea. The bottom sediments in total that were studied lay at depths from 182–2075 m.

The traditionally applied method of preparing bottom sediment samples in order to study deep-water meiobenthos was modified to avoid incidental contamination of them by organisms from higher water horizons. The sediments were washed with distilled water through sieves with a mesh size of 1 mm and 63 µm. The fraction retained on the sieves was stained with Rose Bengal solution. In the microscopic examination, temporary (glycerol) and permanent (glycerol-gelatin) preparations were used. Microdistribution and abundance of these organisms were studied along 5 or 10 cm into bottom sediment in each 1-cm layer. We studied the deep-water objects in detail under 100–1000x magnification using light microscope Olympus CX41 with equipped with a digital camera Olympus E-410. Micrographs and measurements of organisms carried out in the program QuickPhoto Micro 2.1.

Results

At deepwater stations, we recorded morphotypes, which we called Form 3, Form 5, Form 6, and Form 11. The last Form is the most numerous and widespread. These organisms have peculiar structures that make it difficult for us to assign them to known types and classes of invertebrates.

Form 3 (Fig. 1) is represented by three morphotypes differing in shape and size. Specimens of this form are round (180x180; 200x200 µm), bean-shaped (220x70 µm) and cigar-shaped (650x150 µm; 625x225 µm). However, regardless of the form and body size, they have common specific features: they are compact, frequently with finely dispersed bottom particles inside, and the body is covered completely by definitely directed hairs (or bristles?) of unknown nature and function.

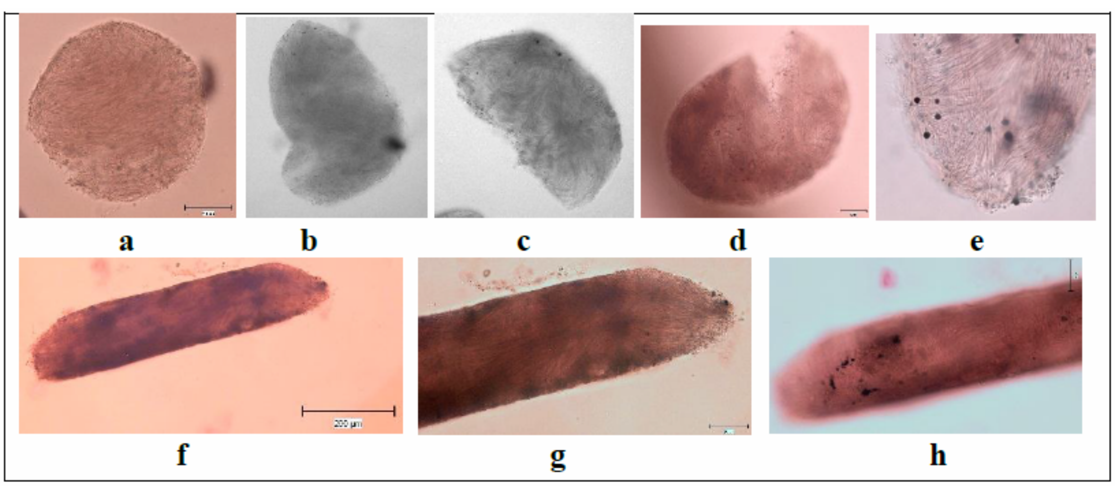


Figure 1. Form 3: a-c, f = variations in the shape of the body; d, e, g, h = the nature of the external pubescence and inclusions inside.

Despite some morphological likeness in a number of features, Forms 5, 6, and 11 differ among themselves. These are soft threadlike organisms in the size range from 160 to more than 1000 µm. Forms 5 and 6 are singular organisms, and Form 11 consists of even (2, 4) figures of long filamentous formations.

Form 5 (Fig. 2, a-d) comprises small organisms, nematode-like. The body is slender, tender, its anterior edge is rounded, and posterior end is conical. Sizes range between 160–500 µm. The covering is smooth, transparent, and inside the body, there is a clearly visible stem structure that is filled with olive-brown or intensely brown inclusions, creating homogeneity or heterogeneity of its inner contents.

Form 6 (Fig. 2, e-g) is bigger in size than Form 5 specimens, serpentine in form. The body is denser, slightly narrowed at both ends, completely filled with homogeneous olive-brown, more often intensely brown, contents; its anterior edge is rounded, posterior end is conical. The covering is smooth, transparent**.**

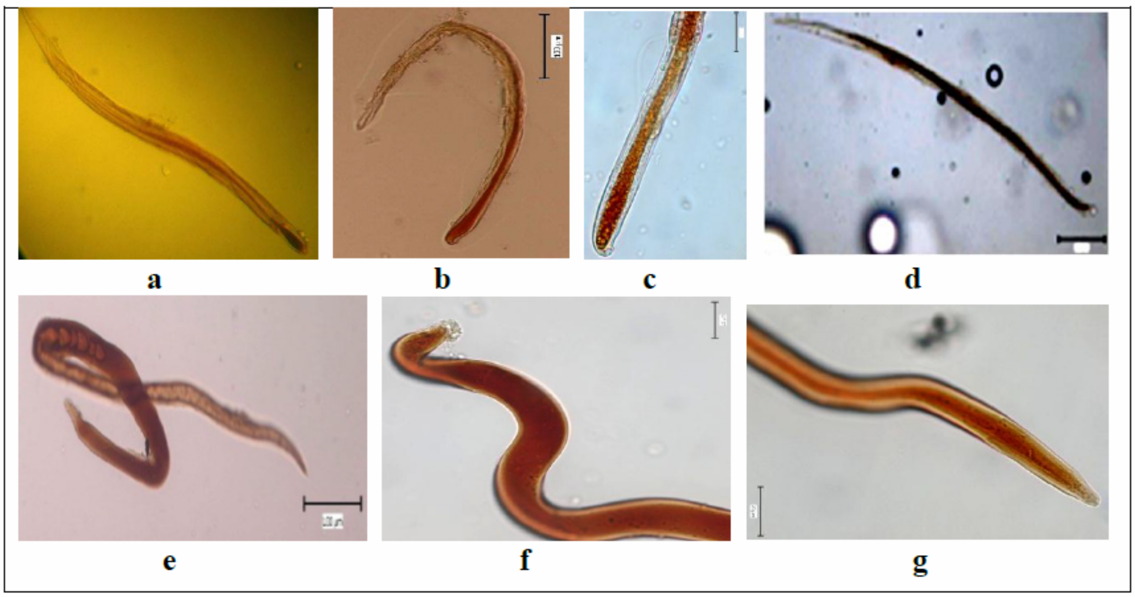


Figure 2. Form 5: a, b, d = general view, c = front edge; Form 6: e = general view, f = front edge, g = tail end.

Form 11 (Fig. 3**)** is the most widespread and numerous in the bottom sediments of the hydrogen sulfide zone. It is represented by organisms of two morphotypes that have an even number of filamentous formations (2 or 4), articulated together in the head zone. Sizes are 500–1000 µm. Covering is smooth, transparent**.** Inclusions in the head part and in the filamentous formations can be homogeneous and heterogeneous within the same specimen**.**

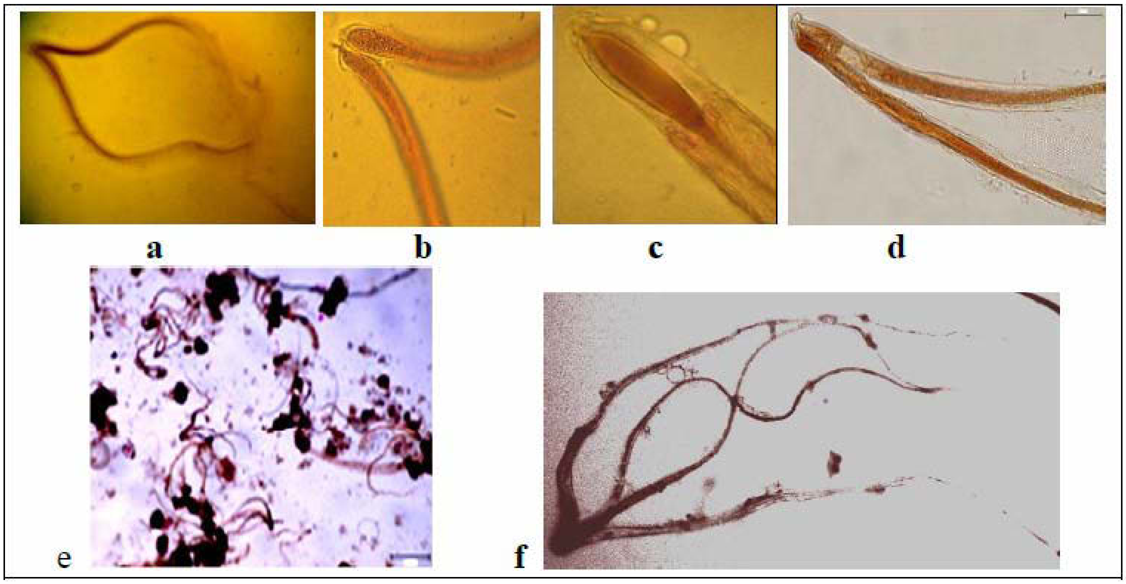


Figure 3. Form 11: a, f = general view of two-branched and four-branched specimens, b-d = structure of the inside; e = aggregation of Form 11 specimens.

Often observed, there is a penetration of unknown organisms (fungi?) into the covering of forms 5, 6, and 11. They are long, colorless tubular formations, which can be single or form bundles outside the body. The covering becomes turbid at the places of their penetration (Fig. 4).

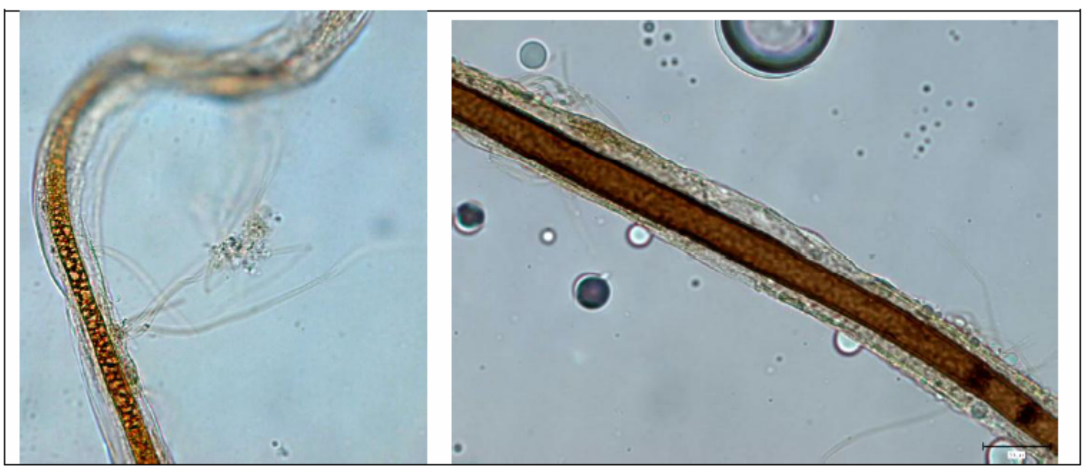


Figure 4. Parts of body with unknown organisms on covering of Form 11 and 6.

Conclusions

Considering the above mentioned, we conclude that we are dealing with an unknown life form specific to permanently extreme hydrogen sulfide conditions. The deep-sea ecosystem of the Black Sea has been studied quite incompletely; therefore, interdisciplinary research using the newest methods in field of biology and geology is needed. The described forms, having a definite shape and structure, retain these features at all deep-water stations and within the hydrogen sulfide zone bottom sediments, while researchers of the Black Sea have not found similar morphotypes for the oxygen zone.

References

Korovchinsky, N.M., and Sergeeva, N.G., 2008. A new family of the order Ctenopoda (Crustacea: Cladocera) from the depths of the Black Sea. *Zootaxa* 1795: 57–66.

Sergeeva, N.G., 2000. Meiobenthos of the Black Sea anaerobic zone. In Alexandrov, B.A., Kats, B.M., and Safranov, T.A., eds., *Collected Papers "The Black Sea Ecological Problems. Black Sea Strategic Action Plan Implementations (1996–2000)*. Odessa, SCSEO, pp. 258–262.

Sergeeva, N.G., 2003. Meiobenthos of deep-water anoxic hydrogen sulfide zone of the Black Sea. In Ayşen Yilmaz, ed., *Oceanography of the Eastern Mediterranean and Black Sea. Similarities and Differences of Two Interconnected Basins*. TÜBİTAK, Ankara, pp. 880-887.

Sergeeva, N.G., 2015. The modern faunal anoxic zone of the Black Sea as a remnant of the ancient anoxic biosphere. In Gilbert, A.S., and Yanko-Hombach, V., eds., *Proceedings of the Third Plenary Conference of IGCP 610 "From the Caspian to Mediterranean: Environmental change and Human Response during the Quaternary"* (September 22–30, 2015; Astrakhan, Russia), Moscow State University, Moscow, pp. 144–148.

PETROGRAPHIC DESCRIPTION OF CHOKRAK-SPIRIALIS MIOCENE DEPOSITS OF EASTERN AZERBAIJAN

Shiraliyeva, S.F.

ANAS, Geology and Geophysics Institute, H. Cavid Avenue 119, Baku, Azerbaijan, AZ 1143
shiraliyevas@gmail.com

Keywords: ***sand, siltstone, Saadan, pyrite, muscovite, light fraction, Orjandagh, disthen, analcime***

Introduction

Substantial interest has been shown by researchers in studying the Miocene deposits of Eastern Azerbaijan due to their rich oil-bearing potential. As a result of multi-year countrywide studies, great success has been achieved in finding new prospective oil fields. Nevertheless, there are still more efforts to be undertaken in the future to completely investigate and resolve all of the questions related to the oil potential of these Miocene deposits.

One of the most effective methods of research consists in the petrographic study of sedimentary formations. Today, this method is commonly used to solve various stratigraphic and paleogeographic tasks related to oil exploration. Based on the actual information that has so far been collected by other researchers, we propose to provide brief petrographic coverage of the Chokrak-Spirialis (lower parts of the Middle Miocene) layers in some of the oil-bearing regions of Eastern Azerbaijan (Fig. 1).

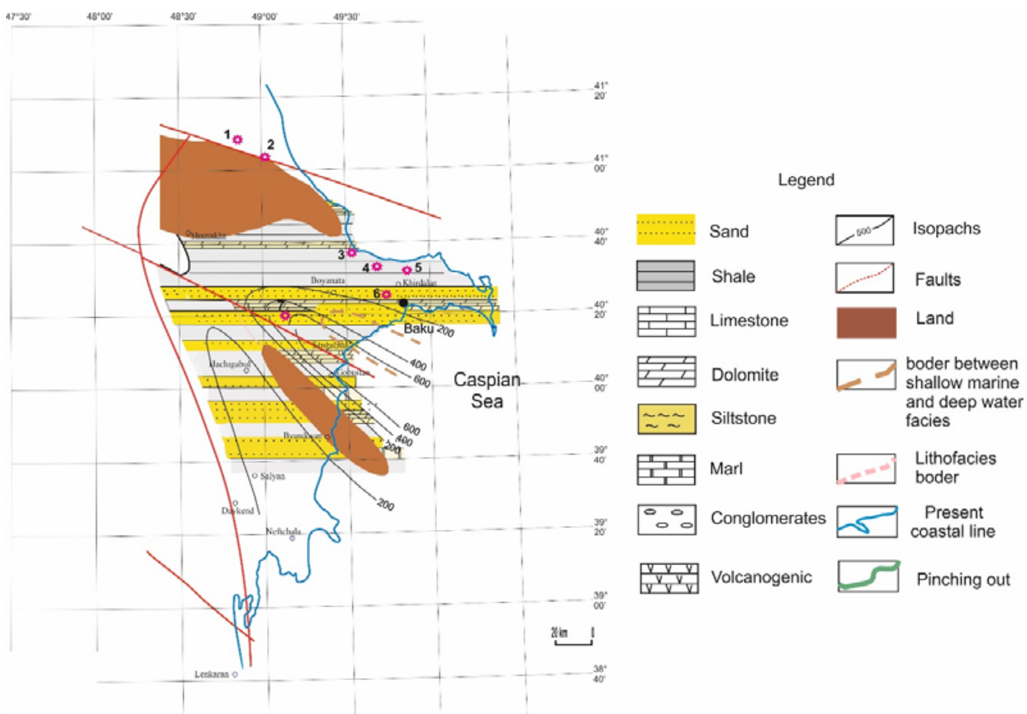


Figure 1. Paleogeographic map of Western Azerbaijan in the Tarkhan-Chokrak (developed by E.H. Aliyeva, in Ali-Zade, 2015) Sections: 1 – Amirkhanli; 2 – Saadan; 3 – Northwestern Absheron; 4 – Orjandagh; 5 – Kirmaki; 6 – Sulutapa; 7 – Cheyildagh.

Chokrak-Spirialis layers are mainly composed of dark brown, dark fulvous and dark grey clayey deposits. Clays are thinly bedded, schistose, and partly shelly, normally carbonate with a $CaCO_3$ content of 10–15% (Ali-Zade, 2015). Their mineral composition includes up to 27 minerals (Fig. 2).

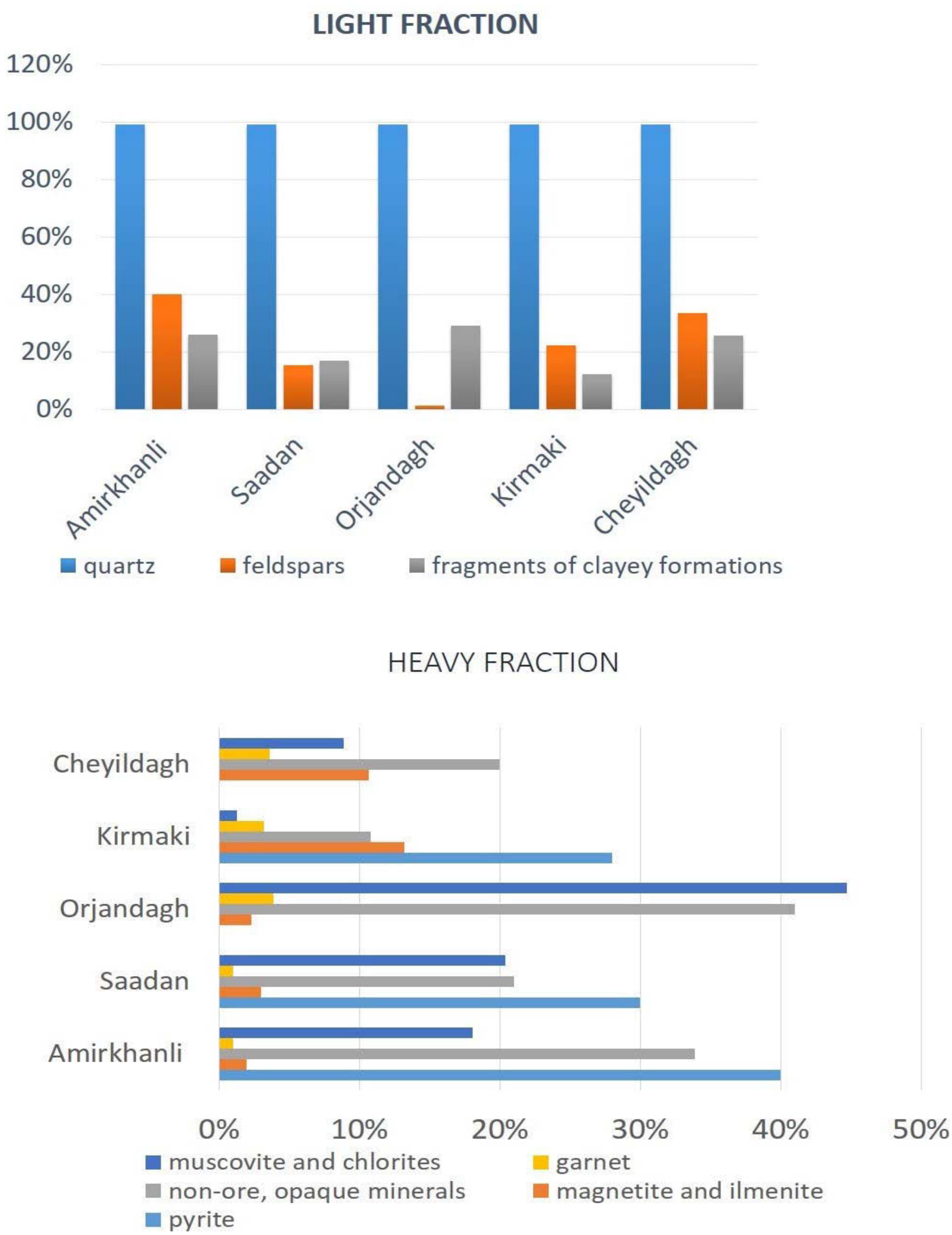
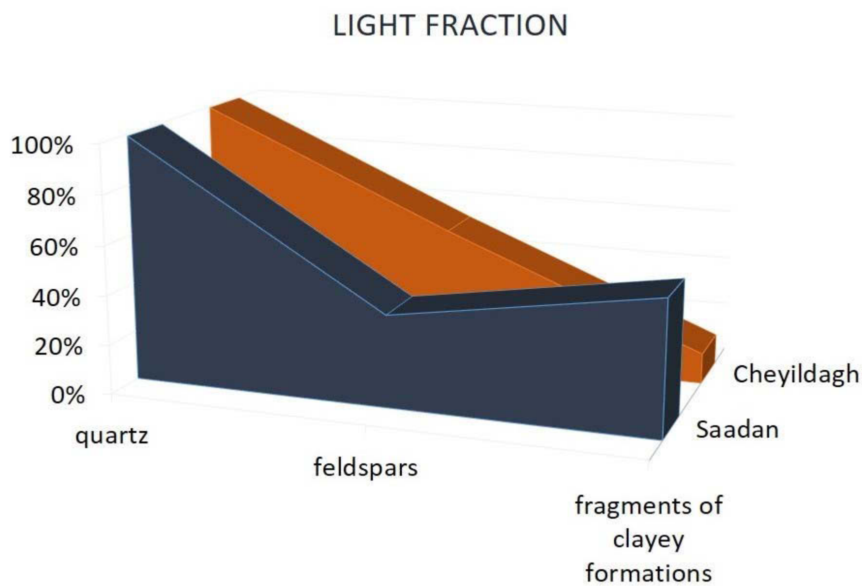


Figure 2. Mineral composition of clayey formations.

Sandy and aleurolitic formations often form oil-bearing interlayers or sheets. Clayey facies contain very rare interlayers of sands and siltstones, which make up only 0.5% of the suite's summary thickness. Sands and siltstones are grey, fulvous-grey, laminated, often flaglike. The carbonate content of sands and sandstones varies from 2 to 10% in Orjandagh (Fig. 3) (Aliyev, 1949).



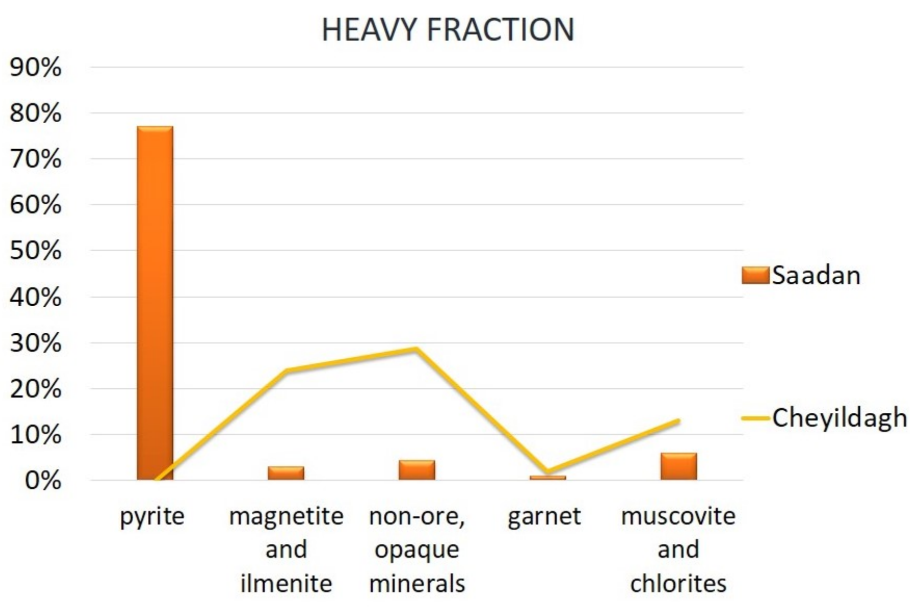


Figure 3. Mineral composition of sands and siltstones.

The chemical composition of the Chokrak-Spiriali formations is quite similar to a theoretical composition of normal dolomites. Indissoluble in HCl, remains are mainly represented by clayey particles; the share of aleurolitic and sandy fractions doesn't exceed 2%. The light fraction of indissoluble remains is represented by quartz, feldspars, and fragments of clayey formations. The heavy fraction contains magnetite and ilmenite, fulvous iron clay, and resistant minerals.

When tracing Chokrak-Spirialis layers from the northwest to the southeast, one may state that in Guba district (Jaghajig, Valvala, etc.), they are represented by the sand-clay facies.

In the Amirkhanli area (Fig. 1), these layers are represented by their clayey facies. According to granulometric analysis, clays are well elutriated. This conclusion is proven by the fact that 83% comprises fractions up to 0.01 mm. Mineral composition of the heavy fraction is dominated by pyrite (up to 40%), muscovite and chlorites (up to 18%), and kyanite. The light fraction contains quartz (33%), feldspars (40%), and analcime (<1%) (Avdusin, 1935; Azizbekov, 1947).

In the Saadan area (Fig. 1), located about 15–20 km to the southeast of Amirkhanli, the complex is represented by an alternation of clays with thin interlayers of dolomites and rarely siltstones. Its mineral composition contains up to 30% muscovite and chlorite, 6% of resistant minerals, and 85% of barite.

In northwestern Absheron (Fig. 1), in the Sumgayitchay area, clayey formations of Chokrak-Spirialis have higher levels of elutriation compared to the Caspian lowland, the light and heavy fractions of which include a mineral associations (except for siderite and barite) that are similar to those of Amirkhanli and Saadan.

In Orjandagh area (Fig. 1), the complex of Spirialis formations is quite different: its clayey formations become poorly elutriated as proven by the presence of large amounts of aleurolitic and sandy fractions (12.8 and 21.7%, respectively). Besides muscovite and chlorites, heavy fraction minerals are also represented by amphiboles, pyroxenes, and epidote (the same minerals are detected in the Kirmaki section as well). Resistant minerals are mainly represented by garnet. A similar composition is recorded in the Chokrak-Spirialis deposits of Sulutapa (Fig. 1). Their only difference is in the presence of individual granules of kyanite and staurolite (Kastryulin et al., 1991).

In Gobustan, the layers are represented by two types of facies: northern clayey and southern siltstone-clayey. Within the territory of Gobustan, petrographic data have been developed for the section of Cheyildagh (Fig. 1), which is part of the development area of the southern sand-aleurolitic-clayey facies. According to the mineral composition of the heavy fraction, 3 horizons can be distinguished (from the bottom to the top):

Lower horizon is represented by clays with siltstone and marl interlayers. Different types of horizon formations are distributed as follows: clays – 153 m (88.2%), siltstones – 20 m (10%), marls – 2 m (1.8%). The mineral composition of the rocks is quite typical. It stands out in the complete absence of staurolite, kyanite, and amphiboles, as well as low concentrations of epidote and tourmaline (1–2%). Non-transparent minerals are mainly represented by fulvous iron clay (40–50%).

Middle horizon (250 m) consists of clays with thick layers of partly cemented siltstones. At a depth of 210–254 m from the horizon's roof, a layer of oil-bearing bituminous siltstones is detected. Also detected are interlayers of dolomitized marls. The horizon consists of the following types of formations: clays – 195.5 m (78.4%), siltstones – 49 m (20.8%), marls – 2 m (0.8%). The horizon's mineral composition is different from that of the overlying horizons. It stands out for the presence of staurolite, kyanite, amphiboles, and epidote. It is also distinguished by the increase in resistant mineral content as well as the presence of barite, which amounts to 2% in the selected samples.

Upper horizon is represented by clays with siltstone and dolomitized marl interlayers. It includes the following types of rocks: clays – 49 m (70%), siltstones – 20.5 m (29.2), marls – 0.5 m (0.8%). There are no kyanite, staurolite, and amphiboles among the horizon's fragmentary minerals that are mainly represented by fulvous iron clay (80–90% in the individual tests). Other minerals are detected quite rarely (1–2%) or in the form of separate grains (Aliyev, 1949).

Conclusions

In contrast to other horizons of Miocene deposits, the arenosity percentage of the Chokrak-Spirialis layers reaches 50–55% (for example, the Chokrak horizon in the Jeyrankechmaz depression). Petrographic signs that distinguish Chokrak-Spirialis and its underlying Maikopian deposits include the carbonate content of the former as distinct from the weakly carbonate Upper Maikopian formations. Chokrak-Spirialis deposits do not contain such minerals as jarosite and volcanic glass, which are typical for Maikopian sediments.

The following minerals are distinguished as they bear a correlative importance for the current deposits of Azerbaijan: magnetite, ilmenite, garnet, resistant minerals, biotite, amphiboles, pyroxenes, epidote, kyanite, and staurolite among the clastic minerals, and pyrite, barite, and glaucolite among the synergetic minerals. A correlative sign of pyrite and siderite consists in their form. At the same time, it has to be stressed that the above-mentioned synergetic minerals are very important for comparing different sections that are located at great distances from each other.

References

Aliyev, A.G., 1949. *Petrografiya tretichnikh otlojeniy Azerbayjana* [*Petrology of Tertiary Deposits of Azerbaijan*]. Azerbaijan Oil Publishing House. (In Russian)

Ali-Zadeh, A., ed., 2015. *Geologiya Azerbaijana* [*Geology of Azerbaijan*]. Publishing house "Elm," Baku, vol. I, p. 290. (In Russian)

Avdusin, P.P., 1935. *Piroklasticheskie osadki v tretichnom komplekse porod severo-vostochnogo Azerbaijana* [*Pyroclastic precipitation in the tertiary complex of rocks of northeastern Azerbaijan*]. «NX» 10. (In Russian)

Azizbekov, Sh.A., 1947. Vulkanicheskie peply Azerbaijana [Volcanic ashes of Azerbaijan]. *Works of the Institute of Geology of the Academy of Sciences of the Azerbaijan SSR* XIII. (In Russian)

Kastryulin, N.S., Mamedov, S.B., and Efendiyev, A.A., 1991. Perspektivy neftegazonosnosti paleogen-miosenovikh otlojeniy Zapadnogo Apsherona i ocheredniye zadachi poiskovo-razvedochnogo bureniya [Prospects of oil and gas content of Paleogene-Miocene deposits of Western Absheron and regular tasks of exploratory drilling]. *Azerbaijan Oil Industry* 8: 1–7. (In Russian)

MUD VOLCANISM OF THE BLACK SEA REGION

Shnyukov, E.F. [1], *and Yanko-Hombach, V.* [2, 3]

[1] Department of Marine Geology and Mineral Resources of the Ukrainian Academy of Sciences, 55b Olesia Gonchara St., Kiev 10601, Ukraine
nikalmas@mail.ru
[2] Department of Physical and Marine Geology, 2 Shampansky Per., Odessa I.I. Mechnikov National University, Odessa 65058, Ukraine
valyan@onu.edu.ua
[3] Avalon Institute of Applied Science, 976 Elgin Ave, Winnipeg MB R3E 1B4, Canada
valyan@avalon-institute.org

Introduction

The Black Sea region encompasses the Black Sea, the Sea of Azov, and their coasts, and it has been inhabited by humans for at least the last 1.8 million years. The region is unique in its geological features and contains the largest meromictic basin in the world, with an area of 423,000 km^2. The region was formed in the Mesozoic era as a back-arc structure above the northward subducting Tethyan oceanic lithosphere. It is surrounded by Alpide fold belts and consists mainly of two large sub-basins (Western and Eastern) separated by the NW-SE trending Mid-Black Sea Ridge. The Black Sea basin holds great promise for providing new non-traditional energy sources to surrounding countries, along with most of Europe, due to the presence of huge methane resources stored in gas hydrates beneath the seafloor. These resources are estimated to be between 25 and 49 trillion m^3, which makes them several times greater than any other known gas reservoirs on Earth.

One of the most interesting features of the region is the extensive development of mud volcanism—a geological phenomenon that is widespread across the planet. The term "mud volcano" generally is applied to a more or less violent eruption or surface extrusion of watery mud or clay which is almost invariably accompanied by methane gas. The most ancient (Early Paleozoic) mud volcanoes are known from Decaturville, Missouri, in North America.

According to archaeological evidence, mud volcanoes of the Black Sea region have attracted the attention of humans since the Lower Paleolithic period. The history of investigation into mud volcanoes goes back to the X century AD when the Byzantine emperor Constantine VII Porphyrogenitus, also called Constantine VII Flavius, described some rocks spewing out oil near the town of Tamatarki on the Taman Peninsula. The first mud volcano described in the scientific literature was dubbed “Golubitsky” by Pallas in 1795; it was located in the Sea of Azov near Temryuk. Subsequently, the study of mud volcanoes was conducted mostly by Russian scientists (e.g., V.V. Belousov, A.D. Arkhangelsky). Research intensified in the second half of the XX century as the search for oil, gas, and other mineral resources accelerated.

Results and discussion

Since the 1990s, mud volcanism of the Black Sea region has been intensively studied by Ukrainian scientists over the course of dozens of research cruises using various research vessels (Shnyukov et al., 2013). Currently, the total number of mud volcanoes discovered within the Black Sea region is about 100 (Fig. 1).

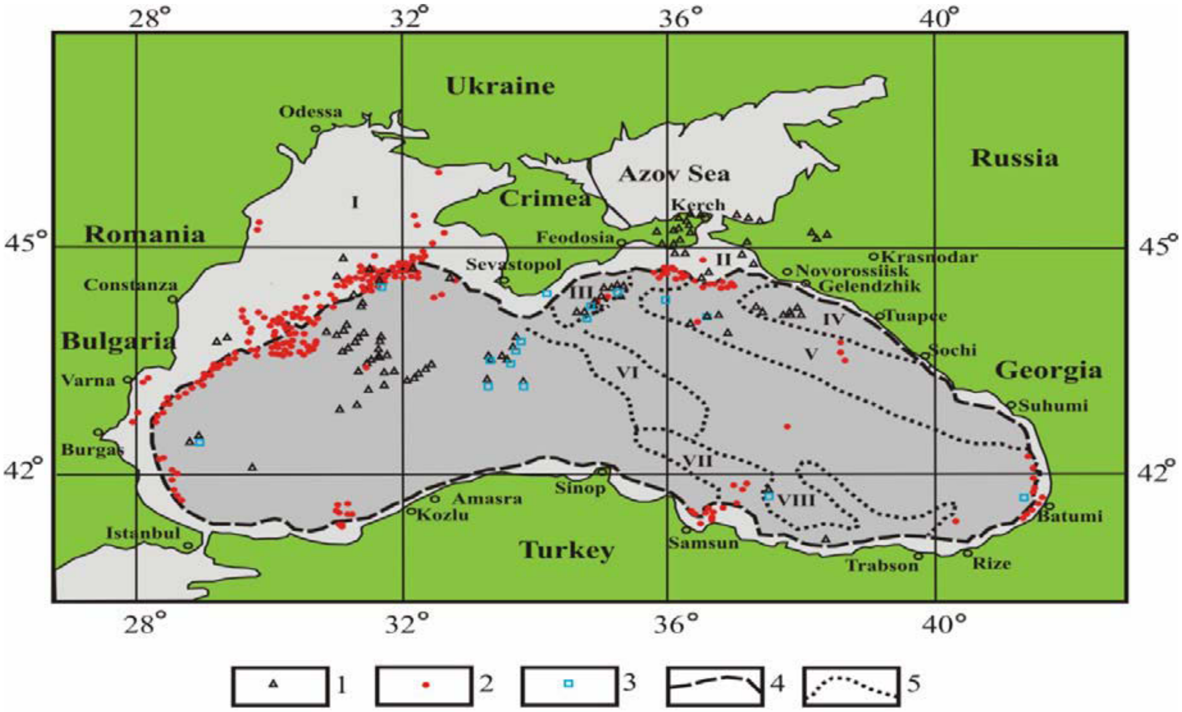


Figure 1. Mud volcanoes and gas flares in the Black Sea region. 1 – mud volcanoes, 2 – gas seeps, 3 – findings of gashydrates, 4 – shelf edge, 5 – contours of large Paleogene depressions and troughs.

They have been found on land (on the Kerch and Taman peninsulas, and in northwestern Caucasus) and off-shore (in the southeastern part of the Sea of Azov, in the northwest—including the Sorokin, Kerch-Taman, and Tuapse Troughs—and in the western part of the Black Sea depression). Multidisciplinary studies undertaken since 1990 enabled E.F. Shnyukov (the first author of this publication) to discover large fields of oolitic iron ores—including the Novoselovskoe field on the Kerch Peninsula, with a reserve of 150 million tons—that were formed by the activity of mud volcanoes. Shnyukov was also able to connect these ores to compensated or compressed geosynclines formed during the Cimmerian Orogeny cycle, as he had initially predicted based on scientific evidence (Shnyukov et al., 2013).

Mud volcanism is a multidimensional phenomenon, the study of which contributes significantly to improving the human condition, as it may aid in maintaining environmental integrity as well as providing a means for sustainable development of the region. Outbursts of submarine mud volcanoes located below the 600–700 m isobaths commonly contain ice-like aggregates of gas hydrates (largely methane) indicating their presence under the seafloor. The presence of both ore formations and gas hydrates is attributable to the compensated or compressed geosynclines. The compressed geosynclines can be used as reliable indicators in their search.

The dynamics of mud volcanoes represent a potential multidimensional risk to maritime activity and environmental security. Gas outbursts from offshore mud volcanoes affect the hydrochemical regime of the sea, producing currents and acoustics, and substantially affecting ecosystems, including especially routes of fish during seasonal migrations. The entire biota of the Black Sea is to a certain degree determined by the fluctuations of hydrogen-sulfide and methane exposure levels (Yanko-Hombach et al., 2009, 2017). Mud volcanoes can also cause great damage to the physical environment, as powerful eruptions create ground subsidence in adjacent areas, thereby presenting a serious threat to nearby urban agglomerations, for example, Kerch in Crimea and Temryuk in Krasnodar territory. Contamination of the air with mercury and other elements can also be hazardous to people. Mud volcanoes can pose a significant threat to maritime traffic, especially in narrow waterways. For instance, seven mud volcanoes have been found offshore within the Kerch Strait, and every year, nearly 10,000 ships cleave their way through the strait. There have been cases of ships running aground even though they were within the navigational channel (e.g., S/S "Caesar" in 1914, and some others). The shoals that grounded them proved to be mud-volcanic in nature. At times, mud volcanoes located within the strait have formed small islets. Some researchers have proposed that methane outbursts were the cause of ship loss in the Bermuda Triangle. Accidents of this kind are likely to happen in the Black Sea as well. The probability of such accidents has been shown experimentally. Mud volcanoes serve not just as regional signs for petrochemical prospection, but sometimes they can be used for precise localization of oil traps, as they are good indicators of oil- and gas-bearing provinces. This generality can be exploited in the future for the development of earthquake forecasting criteria.

In general, mud volcanism in the Black Sea region is an extremely interesting phenomenon of multidimensional importance, deserving in-depth study primarily as an indicator of the Earth's oil- and gas-bearing capacity. Today, mud volcano studies are largely focused on their scientific rather than applied aspects. To date, no surveys of mud volcanoes as markers for gas hydrates have been performed, and no calculations of their contribution to the total degassing of the seafloor have been made on a basin-wide scale. Likewise, no research on their hazardous role has been conducted. At the same time, mud volcanoes are the seafloor's expression of endogenic processes and a "cheap window" into the deep geosphere; they may be considered valuable tools for future industrial applications.

In the presentation, the following topics will be discussed: (1) the history of mud volcano studies with an overview of previous investigations that emphasize the main achievements as well as the present gaps in our knowledge; (2) modern ideas about mud volcanism; (3) the types of morphostructures related to mud volcanoes, including compensated or compressed geosynclines; (4) a regional overview of mud volcanoes and their origins, incorporating new and unpublished data; (5) other manifestations of Black Sea degassing phenomena, such as seeps and bogs of gases; (6) a description of minerals related to mud volcanoes, such as the iron ore deposits of the Kerch Peninsula, etc.; and (7) the influence of mud volcanoes on the environment, including the risks they pose for buildings, roads, on-shore and off-shore communications, and industrial equipment (cables, gas pipes, etc.) on the sea bottom, as well as their influence on fishing, and the stability of the ecosystem.

Conclusions

The main directions of future investigations on mud volcanoes in the Black Sea region, together with possible applications to other basins, will be discussed. It will be shown that mud volcanism is a complex and multidimensional phenomenon that requires a multidisciplinary and in-depth approach for their study. It appears that there is a clear interrelationship between mud volcanoes and methane gas hydrates, which allows mud volcanoes to be used as a "cheap window" in the search for the latter below isobaths 600–700 m.

Acknowledgments

This study is a contribution to the IGCP 610 project "From the Caspian to Mediterranean: Environmental change and human response during the Quaternary" and the project "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.

References

Shnyukov, E.F., Kobolev, V.P., and Pasynkov, A.A., 2013. *Gazovy vulkanizm Chernogo morya* [*Gas Volcanism of the Black Sea*]. Logos, Kiev. (In Russian)

Yanko-Hombach, V., Shnyukov, E., Konikov, E., Kravchuk, A., Kadurin, S., Kulakova, I., Likhodedova, O.G., Larchenkov, E., Ponomareva, L., Pedan, G., Gaponova, A., Smyntyna, O., Kovalishina, S., Pasynkov, A., and Bagriy, I., 2009. Response of biota to methane emissions in the Black Sea: Preliminary results from complex geological, geochemical, palaeontological, and biological study. In Gilbert, A. and Yanko-Hombach, V., eds. *Extended Abstracts of the Fifth Plenary Meeting and Field Trip of IGCP-521 "Black Sea - Mediterranean corridor during the last 30 ky: Sea level change and human adaptation" (2005–2010) - INQUA 0501 "Caspian-Black Sea-Mediterranean Corridor during last 30 ky: Sea level change and human adaptive strategies" (2005–2011). Izmir-Çanakkale (Turkey),* August 22-31, 2009, pp. 181–184.

Yanko-Hombach, V., Kadurin, S., Kravchuk, A., and Kulakova, I., 2017. Meiobentos kak indikator gazoobraznykh uglevodorodov v donnykh otlozheniyakh Chernogo morya [Meiobenthos as an indicator of gaseous hydrocarbon reservoirs in bottom sediments of the Black Sea]. *Geology and Mineral Resources of the World Ocean*, in press. (In Russian)

HOLOCENE ENVIRONMENTS OF THE VOLGA RIVER DELTA: INFERRED FROM DIATOM ASSEMBLAGES IN SEDIMENTS OF THE RYCHA RIVER CHANNEL

Shtyrkova, E.I. [1], *and Polyakova, E.I.* [2]

[1, 2] M.V. Lomonosov State University, Moscow, Russian Federation 119991
[1] lenobl1996@gmail.com
[2] ye.polyakova@mail.ru

Keywords: diatoms, paleogeography, aquatic conditions, sedimentation

Introduction

The Volga delta has been gently reacting to Caspian Sea level changes during the Holocene. This sedimentation area is of key importance for paleogeographical reconstructions of the Caspian Depression. Until the present, much data concerning the environmental changes in the avandelta region has been accumulated (Overeem et al., 2003; Bolikhovskaya and Kasimov, 2010; Richards et al., 2014). Nevertheless, the diatom flora of the region is still poorly understood. This paper reports on the diatom-inferred morphological, pH, salinity, and trophic development of part of the central delta during the Holocene time interval.

Methodology

Core Poy-2016 was obtained from the high floodplain of the Rycha River in the central part of the Volga delta, near the settlement of Poymenniy (Fig. 1).

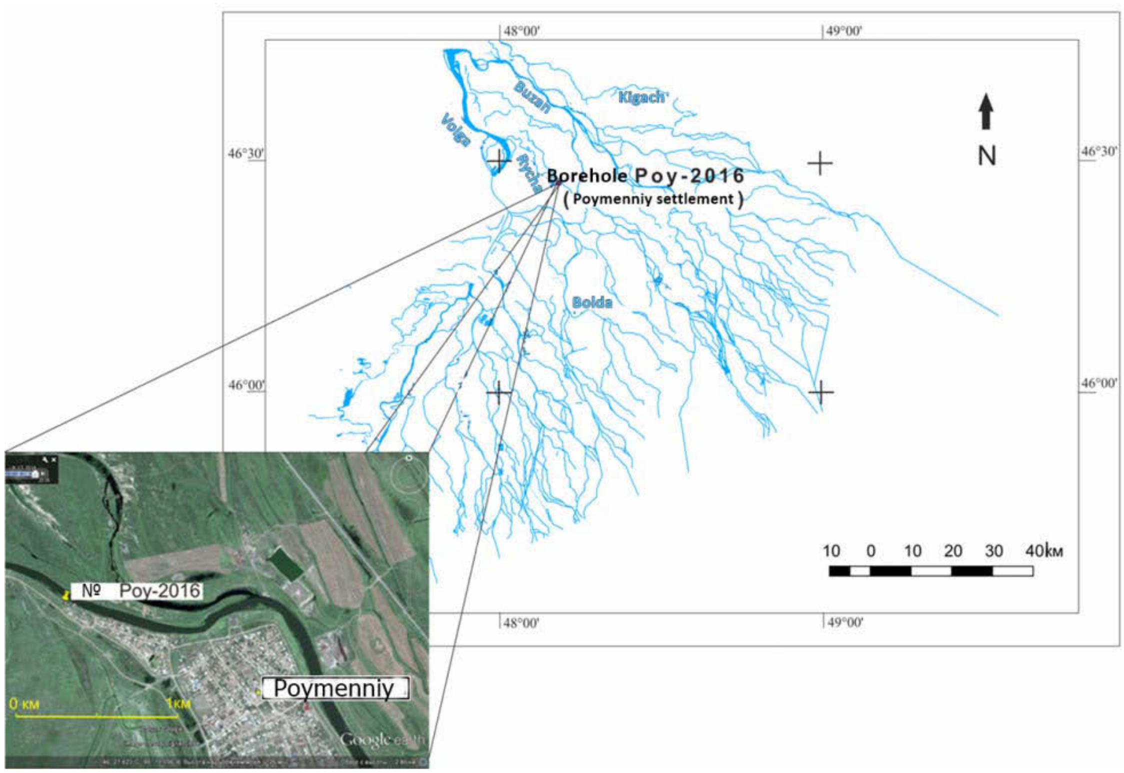


Figure 1. The location of the borehole Poy-2016 (Poymenniy settlement).

Core Poy-2016 is approximately 15 meters long and consists of four main lithological layers. The upper part (1–1.2 m) is represented by modern soil, passing downwards to a depth of 2.7 m into silt. The lower parts of the core until 15.0 m consist of minimally-variable sand layers. Unfortunately, samples from the intervals 3.2–3.7, 4.65–7.5, and 13.6–14.5 m were not selected due to the high water content.

Diatom samples were taken from all lithological layers, every 5 cm from the silt and every 50 cm from the sand (Fig. 2).

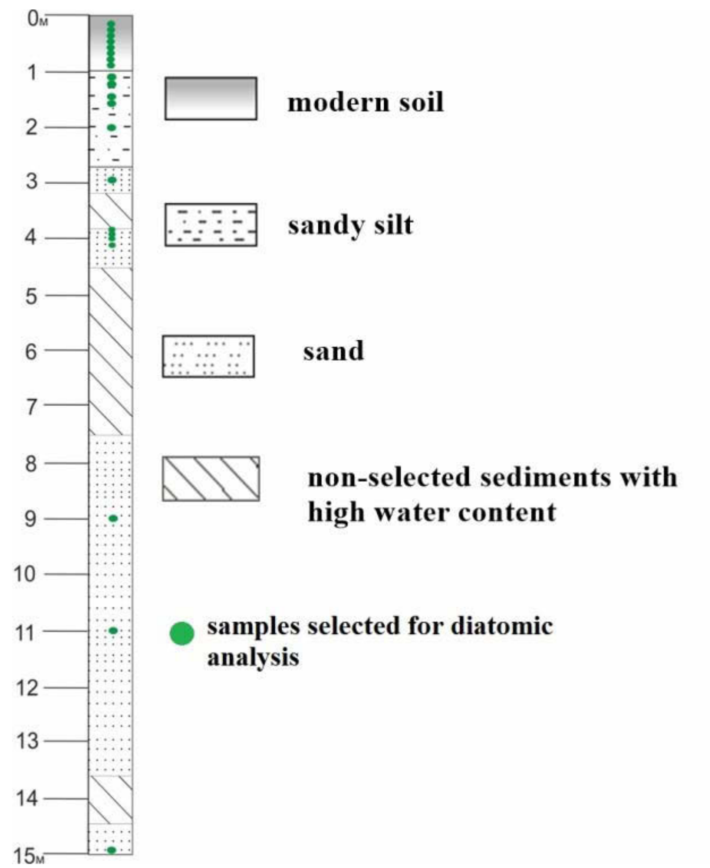


Figure 2. Log of the core Poy-2016.

After freeze-drying (by ALPHA 1-4 LDplus), bulk sediments were prepared for diatom analysis by treatment with 10% hydrogen peroxide solution for 1.5 hours. The residues were mounted on glass slides using the resin NAPHRAX and examined under a JENAVAL (Carl Zeiss) light microscope using ×1000 magnification. Approximately 200–300 specimens in each sample were counted and identified. Results are presented in percentages and concentrations (number of valves per gram of dry matter).

In order to improve the methodology of diatom analysis, modern diatoms from the bottom sediments and water samples from the current streams and reservoirs from different parts of the Volga delta were analyzed. The bottom sediments were selected with the dredger of the Ekman-Burge system (capture area 20 cm²). The water, containing planktonic diatoms, was selected with a 0.5 liter mug and fixed with a 40% formalin solution.

Results

Diatom assemblages were taxonomically diverse and yielded 93 species and varieties. The diatom analysis identifies five diatom assemblages (DA), which characterize several lithological and facies conditions of sedimentation (Fig. 3).

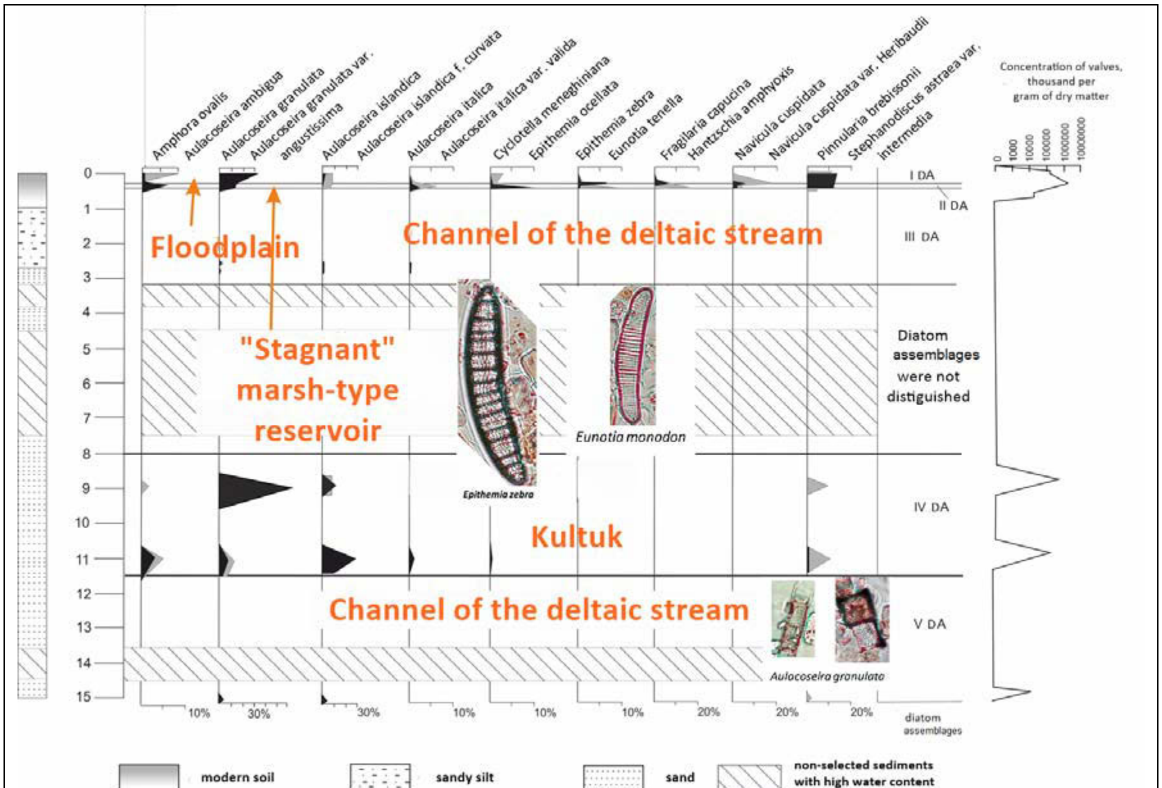


Figure 3. Results of diatom analysis of the core samples from Poy-2016.

V DA (12.0–15.0 m) is distinguished within the monotonous layer of sand by detritus in its upper part. It contains valves of riverine planktonic (*Aulacoseira granulata*, *Aulacoseira islandica*) and brackish taxa (*Stephanodiscus astraea* var. *intermedia*, *Melosira nummuloides*). Low concentration of valves (26.9×10^3/g of dry matter) is probably a result of the extremely high sedimentation rate. According to these facts, the sediments formed within the channel of the deltaic stream.

IV DA (8.0–11.5 m) differs in its relatively high concentration of valves (250×10^3/g dry matter in the lower part of the interval up to 773×10^3/g in the upper parts). In the assemblage planktonic cosmopolitan species of *Aulacoseira* predominate (more than 85% of the total number of valves). Mesogalobic species *Stephanodiscus astraea var. intermedia*, which prefers a salinity of 0.5‰, is subdominant in IV DA.

In the sample from 9.0 m depth, the planktonic riverine species *Aulacoseira granulata* predominates (60%). It is a typical inhabitant of freshwater eutrophic environments. The following galophilic and mesogalobic species are subdominants: *Aulacoseira islandica* (11.1%), *Aulacoseira islandica* f. *curvata* (9.7%), and *Stephanodiscus astraea* var. *intermedia* (9.7%). Relying on the absolute predominance of halophilic and mesogalobic species (90.5%), we can assume that salinity during sedimentation was not lower than 0.4‰.

In the sample from 11.0 m depth, around 50% of the total number of valves are represented by species of *Aulacoseira*, with dominants *Aulacoseira islandica* (26.3%), *Aulacoseira granulata*, and *Aulacoseira granulata* var. *angustissima* (11% each). The percentages of brackish *Stephanodiscus astraea* var. *intermedia* are up to 22.2%. The lower concentration of the halophilic and mesogalobic species in the lower part of the interval shows a gradual increase in salinity during the evolution of IV DA.

The highest relative abundance of planktonic diatoms (98%) in the assemblage is the result of low hydrodynamics, which was higher at the beginning of the sedimentation process (due to the higher content of benthic species in the sample from 11.0 m, approximately 12%). Concerning the pH of the aquatic environment, the absolute majority of species is indifferent – adapted to live in water with a wide range of pH values. The total relative abundance of valves of alkaliphiles reaches 5.7%. It is quite possible that the pH of the water was about 7–8 during the sedimentation process.

Probably, the sediments were laid down in water with low hydrodynamics, a salinity of about 0.4–0.5‰, and a pH not higher than 8. Due to the sand grain size of the sediments and diatom-inferred characteristics of the aquatic environment, the sediments formed in a shallow deltaic bay (kultuk). The rather high salinity could be the result of intensive evaporation.

III DA (1.5–3.2 m) is distinguished in the sand layer by an extremely small concentration of diatoms—18 × 10^3/g dry matter, which apparently takes place during a change in the diatom essential living conditions: increase in water turbidity or extremely high sedimentation rate, which prevents the formation of tafocenoses. In the species composition, freshwater planktonic taxa prevail: *Aulacoseira granulata*, *Aulacoseira italica*, *Stephanodiscus astraea* var. *intermedia*, and *Aulacoseira islandica*, typical for the Quaternary sediments of the Lower Volga (Genkal, 1992). Single valves of brackish diatoms *Navicula gastrum* and fragments of re-deposited marine diatoms, probably of Cretaceous age, were also identified. According to the sand grain size of the sediments and availability of the re-deposited marine diatoms, the sediments formed in a stream channel.

II DA (1.4 m) was identified in sandy silt with an admixture of organic matter due to the high rate of diatom valves (1.12 × 10^6/g dry matter) and composition of other prevailing species. The periphyton species of *Epithemia* (33.4%) are taxonomically diverse; riverine plankton species of *Aulacoseira* demonstrate a slightly smaller abundance up to 28.9%. Among the periphyton species (70% out of total), the most widespread species is the riverine (galophilic) diatom *Epithemia zebra*. Approximately equal content (10% each) were shown by the species *Aulacoseira granulata* and *Epithemia ocellata*. Among the other species, the highest percentages are revealed by the riverine (oligogalobic) *Amphora ovalis* (6.7%), *Hantzschia amphyoxis* (3.7%), and *Epithemia zebra* var. *saxonica* (3.7%). The predominance of boggy periphyton diatoms and the presence of organic matter in the early stages of peat formation indicate stagnant sedimentation conditions. Availability of the halophobic species *Amphora ovalis* excludes salinity values of more than 0.02‰. Along with the predominance of indifferent species (more than 53%), rather high abundance (13.7%) demonstrate the acidophilic *Epithemia ocellata* and *Epithemia zebra var. saxonica*, possibly confined to the interlayers of peeled material with oxidizing conditions.

Possibly, the accumulation of sediment occurred in a stagnant (with low hydrodynamics), shallow, fresh (salinity up to 0.02‰), boggy reservoir. The beginning of peat formation corresponds to the presence of an acidic environment. A large number of periphyton species indicates eutrophication of the reservoir.

I DA (1.0–1.3 m) is represented in silt with traces of soil formation in the upper part. This is demonstrated by reduced concentration of diatom valves (about 200 × 10^3/g dry matter), by low preservation, and the presence of the aerophilic species *Hantzschia amphioxys*.

The sample from the 1.0–1.2 m depth is characterized by a high abundance of planktonic diatoms (60%) that corresponds to low hydrodynamics. A significant number of benthic and periphyton species may indicate eutrophication of the aquatic environment during the sedimentation process. The list of species characterizes the sedimentation in the low-lying lands, which are episodically covered by river water that was eutrophic and slightly alkaline.

The sediments probably accumulated as the result of rare flooding of the high floodplain level.

In the lower part of I DA (1.3 m depth), the concentration of valves sharply increases to more than 2×10^6/g. This may indicate a more intensive influence of river water on the material during the sedimentation. Diatom assemblages in sediments are directly dependent on sediment grain size, since the predominant dimension of the diatoms corresponds to the fine aleurite fraction. The prevalence of benthic and periphyton forms (57.7%) also indicates a more active hydrodynamics. Diatom assemblages of the dominants are common to the upper layer: *Navicula cuspidata* (17.8%) prevails, subdominant species are *Aulacoseira granulata* and *Pinnularia brebissonii*, which account for 13.5% and 11.9%, respectively. Among the diatoms with percentages less than 10% appear: periphyton halophilic aerophilic species *Hantzschia amphyoxis* (7.5%) and planktonic brackish *Stephanodiscus astraea* var. *intermedia* (6.4%). In the sample, rare fragments of marine species of *Stephanopyxis* and *Triceratium* were identified.

In general, the sedimentation process corresponds to floodplain conditions. The predominance of species indifferent to pH and a significant proportion of alkaliphiles may indicate a neutral or slightly alkaline (pH 7–8) aquatic environment.

According to the diatom-inferred paleoenvironmental reconstructions, the formation of the deltaic sediments in the Rycha River area was influenced by both local factors and those common for the whole Volga delta territory, including the tendency for high sedimentation rate (Figures 4, 5, Overeem et al., 2003).

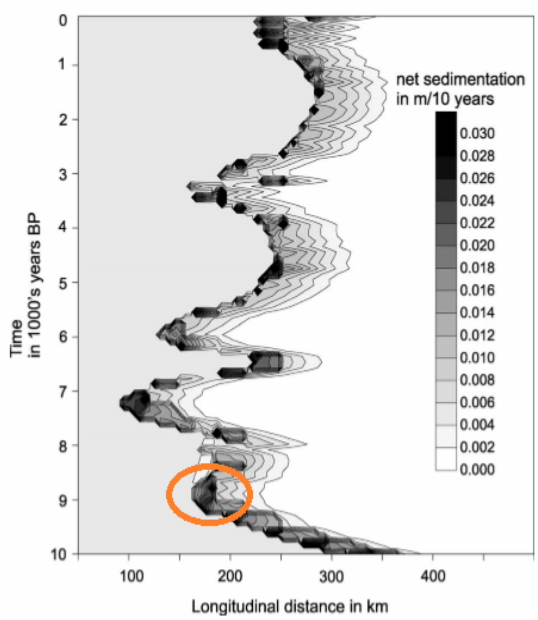


Figure 4. An approximate period and sedimentation rate during the V diatom assemblage formation (after Overeem et al., 2003).

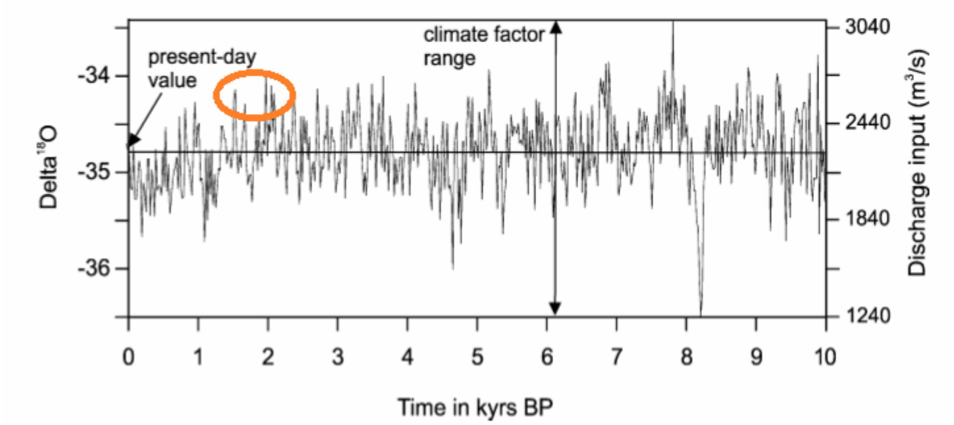


Figure 5. An approximate period and supposed cause of the high sedimentation rate during the III diatom assemblage formation (after Overeem et al., 2003).

For comparison with the results obtained, a complex of boreholes of the well-studied Damchik site of the Astrakhan Reserve was chosen. The comparison is rather complicated due to the interposition of the boreholes and different responses of the territories to Caspian Sea level changes.

Conclusions

Diatom assemblages I, II, and IV tend to have been formed mostly as the result of local factors (intensive evaporation, eutrophication, etc.), and, therefore, they are not very representative for comparison. At the same time, it is supposed that diatom assemblages III and V reflect average conditions for processes of intensive sedimentation throughout the whole Volga delta territory. Comparison is based on the annual sedimentation rate (Richards et al., 2014), which allows one to value the time interval of the sediments' formation. Thus, DA V could have been formed during the migration of the Volga delta to the modern position of the Rycha River borehole and the relatively stable level of the Caspian Sea (Fig. 4, Overeem et al., 2003). DA III could have been formed due to the increasing depletion of the Volga River (Fig. 5, Overeem et al., 2003).

Acknowledgments

This study is based on materials collected within the framework of the Russian Geographical Society project "River deltas of Southern Russia."

References

Bolikhovskaya, N.S., and Kasimov, N.S., 2010. The evolution of climate and landscapes of the Lower Volga Region during the Holocene. *Geography, Environment, Sustainability* 2(3): 78-97.

Genkal, S.I., 1992. *Atlas diatomovykh vodorosleĭ planktona reki Volgi* [*Atlas of Diatoms from the Volga River*]. "Gidrometeoizdat," St Petersburg.

Overeem, I., Veldkamp, A., Tebbens, L., and Kroonenberg, S.B., 2003. Modelling Holocene stratigraphy and depocentre migration of the Volga delta due to Caspian Sea-level change. *Sedimentary Geology* 159(3-4): 159-175.

Richards, K., Bolikhovskaya, N.S., Hoogendroon, R.M., Kroonenberg, S.B., Leroy S.A.G., and Athersuch, J., 2014. Reconstructions of deltaic environments from Holocene palynological records in the Volga delta, northern Caspian Sea. *The Holocene* 24(10): 1226-1252.

ADJUSTMENT THEORY IN THE STUDY OF HUMAN RESPONSES TO GLOBAL CLIMATE CHANGE IN THE NORTHWESTERN BLACK SEA REGION AT THE PLEISTOCENE-HOLOCENE BOUNDARY

Smyntyna, O.V.

Department of Archaeology and Ethnology of Ukraine, Faculty of History, Odessa I.I. Mechnikov National University, 12 Yelisavetynska St, Odesa, 65000
smyntyna_olena@onu.edu.ua

Keywords: Human adaptation, sea level change, adjustment

Introduction

Methodological plurality, which is inherent to recent studies of prehistoric populations, their lives, and subsistence strategies, has displayed itself also in the framework of interpretation of the relationship between hunter-gatherers and their natural environment. Interdisciplinary studies of the history of human population in the Northwestern Pontic region at the Pleistocene-Holocene boundary provide unique opportunities to evaluate perspectives of application of different approaches to the interpretation of human responses to global climate change.

Using the platform of IGCP 610, some of these approaches, particularly the theory of environmental crisis, the environmental stress concept, and resilience theory have already become subjects of our special analysis (Smyntyna and Goncharenko, 2013; Smyntyna, 2016). The aim of the current contribution is to highlight perspectives in the application of adjustment theory in studies of human response to global climate changes at the Pleistocene-Holocene boundary in the Northwestern Pontic region.

Adjustment theory: a view from the social and behavioral sciences

The roots of adjustment theory (which is sometimes also called 'theory of regulation') can be traced back as early as the 1960s, when it was put forward in sociology to describe a specific form of response by a society to environmental changes (Sonnerfeld, 1996: 70). At that time, adjustment was regarded as a certain opposition to the adaptation concept: in order to adjust, any transformation of behavior was not considered obligatory; survival of a society is possible as the result of a long chain of adjusting procedures which do not touch the inner essence of one's society and/or culture.

In the course of further discussion of this concept, it became possible to distinguish at least two basic versions of its understanding. In the framework of one of them, adjustment was interpreted as internal homeostatic changes taking place inside the society characterized by a certain adaptive level (Cohen 1974: 64). In such a way, adjustment was not possible without adaptation, which is its necessary prerequisite (or preliminary stage) and forms the fundamental background for adjustment procedures.

Proponents of another approach to this concept believe that adjustment involves dealing only with the correction of external stimuli, including the challenges of the natural environment. This correction envisages changes of mechanisms through which society realizes its relations with the environment (Bell et al., 1996: 125). These changes usually are regarded as permanent processes and could be realized on their own, i.e., they are possible even when the society is not well adapted to its environment and is searching for optimal ways of survival. In such a context, adjustment could be interpreted either as a behavioral strategy, an alternative to adaptation, or as a peculiar phase of behavior that could be realized with equal success before or after adaptive procedures, but not instead of them.

The crucial argument in favor of understanding adjustment as an alternative to adaptation is that the duration of the life-history of any society as well as the efficiency of its activity were determined by the effectiveness and success of its regulative measures (or adjustment), which this society has managed to establish in order to respond to environmental changes (Dincauze, 2000: 73).

In spite of obvious different understandings of the relationship between adaptation and adjustment, most researchers tend to agree that adjustment does not envisage a global transformation of culture, society, and group behavior; it is instead small-scale modifications of personal behavior, which in long-term perspective bring on changes in some aspects of livelihood and social (interpersonal) relations.

The recent decade of development in adjustment theory was marked by its broad application in psychology and other behavioral sciences for explanations as to how humans maintain equilibrium among their social, cultural, and biological needs, as well as how they balance all these needs with the challenges of their natural and social environment (Nilsson, 2007). The degree to which individual and environmental characteristics match the notion of person-environment fit was recently introduced (Kristof-Brown and Guay, 2011).

Discussion

Our vision of how humans responded to global climate changes taking place in the Northwestern Pontic region at the Pleistocene-Holocene boundary was elaborated in the course of the IGCP 521 project and was published (Yanko-Hombach et al., 2011). It was proven that changes in occupation system, mode of life, subsistence strategy, social relations and identity, ritual behavior, and many other aspects of human life during the final Paleolithic and Mesolithic were deeply connected with the transformation of the natural environment. Currently, our task is to verify which of these changes can be interpreted as displays of adjustment.

One should confess that changes connected with adjustment can hardly be traced in past cultures, especially on the basis of only archaeological and paleoenvironmental data, which are fragmentary on their own. Nevertheless, taking into account two basic characteristics of adjustment— modification (small-scale, non-transformative, non-revolutionary) and personal (i.e., could be not shared by other group members in current and in the next generation)—it is possible to delineate at least one indicator of adjustment: individual variability of flint artifacts.

Final Paleolithic and Mesolithic sites of Steppe Ukraine are extremely rich in non-typical artifacts, which represent all stages of the flint knapping process. Traditionally, this fact was explained either by unsatisfactory raw material (which is not true because 'typical' forms were made of the same flints) or by unsuccessful attempts to produce 'typical' artifacts by youngsters who were being trained through initiation. However, some of these primarily 'atypical' forms survived and later became an integral part of individual tool-kits. So, their primary origin could be interpreted as a display of adjustment strategy.

Moreover, one of the fundamental specific features of any tool industry is that every basic functional group (such as points, scrapers, or cutters) consists of artifacts with different morphology, which were produced with the help of different technology. Sometimes this fact is explained by the basic principles of social composition of any group, which, following the principle of exogamy, should consist of a representative of at least two kin groups. At the same time, diversity of morphology of every functional group of artifacts could reflect also personal attempts to improve personal tools which could very well correspond to adjustment behavior.

However, these hypotheses cannot be fully verified on the basis of the existing evidence base from the Northwestern Pontic region, because we are dealing with only fossil remains of different societies, while adjustment implies conscious actions and behaviors, and this fact needs to be confirmed by the personal statement of the subject of such an action—oral (declared in the course of an interview) or written (reflected in written historical sources). Nevertheless, the discussion of the adjustment theory in the framework of hunter-gatherers adapting to global climate changes can provide new insight into their everyday life, which can help make the picture of their society more comprehensive, and our understanding of the human-nature relationship more profound.

Acknowledgments

This study is a contribution to the IGCP 610 project “From the Caspian to Mediterranean: Environment change and human response during the Quaternary” and 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)

References

Bell. P.A., Green. T.C., Fisher. J.D., and Baum. A., 1996. *Environmental Psychology*, 4th edition. Harcourt Brace College Publishers, Fort Worth.

Cohen, Y.A., 1974. Culture as adaptation. In Y.A. Cohen (Ed.), *Man in Adaptation: The Cultural Present*, 2nd edition. Aldine, Chicago, pp. 45–68.

Dincauze, D.F., 2000. *Environmental Archaeology: Principles and Practice*. Cambridge University Press, Cambridge.

Kristof-Brown, A., and Guay, R.P., 2011. Person-environment fit. In S. Zedek, ed., *APA Handbook of Industrial and Organizational Psychology*. American Psychological Association, Washington, pp. 3–50.

Nilsson, D., 2007. Adapting coping theory to explain the concept of adjustment. *Social Work and Health Care* 45(2): 1–20.

Smyntyna, O.V., 2016. Cultural resilience theory as an instrument of modeling of human response to the global climate change. *Riparia* 2: 1–20.

Smyntyna, O.V., and Goncharenko, A.V., 2013. Human response to climate changes in northwestern Pontic region at Pleistocene-Holocene boundary: an application of environmental stress theory. In: A.S. Gilbert, and V. Yanko-Hombach (Eds.), *Proceedings of the First Plenary Conference of IGCP 610 “From the Caspian to Mediterranean: Environmental Change and Human Response during the Quaternary” (October 12-19, 2013; Tbilisi, Georgia)*, , pp. 133–136. “Sachino” Ltd., Tbilisi, Georgia.

Sonnerfeld, J., 1996. Variable values in space and landscape: an inquiry into the nature of environmental necessity. *Journal of Social Issues* 22(4): 71–82.

Yanko-Hombach, V.V., Smyntyna, O.V., Kadurin, S.V., Larchenkov, E.P., Motnenko, I.V., Kakaranza, S.V., and Kiosak, D.V., 2011. Kolebania urovnya Chernogo moria i adaptatsionnaya strategia drevnego cheloveka za poslednie 30 tysyach let [Oscillations of the Black Sea level and adaptive strategy of ancient man during last 30 thousand years]. *Geologia i poleznye iskopaemye mirovogo okeana* [*Geology and Mineral Resources of the World Ocean*] 2(24): 61–94. (In Russian)

CORRELATION OF THE LATE QUATERNARY SEDIMENTS OF THE EASTERN MEDITERRANEAN AND PONTO-CASPIAN BASINS

Sorokin, V., [1] *and Yanina, T.* [2]

[1] Geological Faculty, Lomonosov Moscow State University, 1 Leninskie Gory, Moscow, Russia, 119991
[1]sorokin@geol.msu.ru
[2] Faculty of Geography, Lomonosov Moscow State University, 1 Leninskie Gory, Moscow, Russia, 119991
[2]didacna@mail.ru

Keywords: Stratigraphy, paleogeography, marine deposits, radiocarbon dating

Introduction

For modern deep-sea basins with restricted connection to the World Ocean (Black, Caspian, Marmara, Aegean, and Mediterranean seas), there is the problem of stratigraphic correlation of shallow-water (shelf) and deep-water sections within seas and between them. It is accomplished using various paleontological groups from the residues of sediments from shelf and deep-sea basins (mollusks, foraminifera, coccolithophorids, diatoms, pollen, and spores, etc.) and lithostratigraphy. However, depending on the degree of isolation of the seas, which determines the salinity of water, the qualitative composition of fauna and flora in them can be radically different. Reliable correlation of the sections in these cases is based on very few definitions of absolute age.

There are different points of view on the age of the stratigraphic units of the Upper Quaternary deposits for the Mediterranean Sea, for the Black Sea, and especially for the Caspian Sea. Depending on the accepted points of view, a particular correlation of sections and their paleogeographic interpretation is carried out. The reliable determination of radioisotope age for the deposits holds crucial importance, allowing us to synchronize age boundaries, which are selected by biostratigraphic and lithological methods.

Stratigraphy

Upper Quaternary deposits are divided on the basis of alteration of residue complexes, reflecting climatic variations. The applicability of different paleontological remains for the different facies conditions within and between various seas is distinguished, then this is associated with substantial changes in the salinity of basin waters. Marking lithological horizons (sapropel, tephra, calcareous, and diatomaceous layers) is also used for correlation.

In accordance with the purpose of the IGCP 610 international project, we conducted a comparative stratigraphic analysis of the Upper Quaternary sediments of the above-mentioned intra-continental basins. The results of processing many tens of cores and boreholes from shelves, continental slopes, and deep-water basins of the Eastern Mediterranean, Black Sea, and North and Middle Caspian Sea are presented in our work.

The Eastern Mediterranean

We have identified the Riss-Würm, Würm, and Holocene horizons in sections of the Upper Quaternary deposits. Among the planktonic foraminifera in them are seen alternations of "warm" (with the dominance of *Globigerinoides ruber*, *G. succulifer*, *G. rubescens*, *Hastigerina aequilateralis*, *Orbulina universa*, and *Globoquadrina dutertrei*) and "cold-water" (*Globigerina pachyderma*, *G. quinqueloba*, *G. bulloides*, and *Globorotalia scitula*) complexes. The composition of benthic foraminifera is presented by two complexes, too, in accord with the "cold-water" and "warm-water" complexes of planktonic foraminifera. The "cold-water" one includes the following types: *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 rugosa subsp. conveza*, *Cibicidoides floridanus*, *Miliolinella circularis*, and *Hyalinea baltica*; and the "warm" complex 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*. In addition to species diversity of benthic foraminifera in sediments, differences were marked in their quantity. The "warm-water" complex is characterized by a minimum, and the "cold-water" by a maximum number. The composition of diatoms revealed fluctuations in the ratio of marine, brackish, and freshwater species belonging to the littoral, neritic, and oceanic ecological groups. "Warm" and "cold-water" forms are among them. In the composition of pollen spectra in the sedimentary section, there is a change of complexes with high content of arboreal pollen, indicating a moist climate, and with absolute dominance of herbaceous pollen, indicating an arid climate. Marking layers of sapropel and tephra are highlighted in the sediments.

Light gray calcareous silts *underlying the Riss-Wurm horizon* on the continental slope of the Gulf of Sirte contain 65% cold-water planktonic foraminifera, among which is noted the maximum number of *Globigerina quinqueloba* (up to 40%) and *G. bulloides* (15%). Among benthic foraminifera, the highest diversity and quantity is shown by *Gavelinopsis* sp. and *Bolivina albatrossi*. Pollen of herb-xerophytes (over 70%) dominate in the composition of the pollen spectrum, among which is defined *Ephedra*, Chenopodiaceae, and *Artemisia*. Arboreal pollen is represented by mostly pine.

The Riss-Wurm transgression horizon is represented in the Gulf of Sirte by green sapropel and in the Levantine basin by light gray, silt-clay, foraminiferal-coccolithus ooze with three sapropel layers (S3–S5). Warm-water species of planktonic foraminifera (60–80%) dominate, and in the sapropels are found the maximum number of *Globigerinoides sacculifer*, *G. rubescens*, *G. ruber*, and *Globoquadrina dutertrei*. Benthic foraminifers are absent or constitute non-significant amounts (not exceeding 50 individuals). In spore-pollen complexes, a high content of arboreal pollen (20–80%) is noted, and pine plays the main role. However, in the sapropel layers is observed a great number of species: pollen of broad-leaved trees: oak, ash, walnut, hornbeam, elm, beech, chestnut, pistachio, magnolia, and palm.

In the *Würm* horizon, which formed during regressive phases separated by a transgression, variations in the contents warm and cold-water planktonic foraminifera were marked. In the Lower Würm, the number of warm-water species is reduced to 5–47% compared with the Riss-Würm. In the sediments of the Middle Würm, it increases to 60–75%. In the ooze of the Upper Würm, it again drops to 10–30%. In the latter case, it is noted that the maximum number of cold-water species is 50–70%. Among the benthic foraminifera, representatives of the cold complex are the most abundant. Planktonic neritic species inhabited the coastal brackish areas and were dominated by diatoms in their composition. The brackish-water species reach their maximum here. *Coscinodiscus marginatus* prevails among marine species. In the Late Würm, the number and species diversity of diatoms are reduced. Intertidal species, such as *Paralia sulcata*, *Rhaphoneis surirella*, etc., are the most representative here. In the lower part of the horizon, the number of marine forms somewhat increased from the previous interval, but then it falls again, reaching its minimum. Apparently, this was an influence of the Late Würm glaciation, which led to the fall of sea level. Würm sediments contain little pollen and spores, and often they do not exist. At the bottom of the Würm, dominance of pollen of herb-xerophytes (60–80%) is observed; in the middle layer, the value of arboreal pollen increases up to 30–60%, mostly pine. In the upper layer, herbaceous pollen dominates, and in the group of arboreal pollen, pine is the most abundant with a small admixture of pollen from deciduous trees.

The Würm sediments are represented usually by calcareous silt-pelitic and politic muds in the Adriatic and Ionian seas and in the northern part of the Levantine Sea. Along the coast of Africa, siltstone-pelitic and calcareous silts are common and contain clay-limestone chemogenic concretions. On the Nile slope, a strong variability in sediment composition appears from pure clay type to calcareous silts. A characteristic feature of the structure of the sections is the presence of interbedded, coarse-grained sandy-silt and even gravel material. In conjunction with the facies variability in the Nile cone area, these features indicate an activation of slope processes at this time.

In eight columns of the Middle Würm sediments, an interlayer of ash lies in the area, spread as far as the coast of Africa. By chemical composition, it is characterized by high alkali content, with K_2O dominating over Na_2O. This interlayer of ash is well correlated between the cores and identified with ash interlayer Y-5, which was deposited about 35 thousand years ago.

The transgressive *Holocene* horizon is composed of calcareous sediments containing an interlayer of sapropel S1 and ash layers. Warm-water species (45–90%) dominate among the planktonic foraminifera in the sediments. Benthic foraminifers are few in number and also are represented by the "warm-water" complex. Pollen and spores are represented in significant quantities only in the sapropel. The arboreal pollen (50–80%) dominates here, and pollen of deciduous aqueous species reach up to 40% of the population with a rich species diversity. In the sapropel layer, there is a sharp jump in species diversity of diatoms, mainly of benthic forms. Most of them (genera *Grammatophora*, *Diploneis*, *Lyrella*) first appear in this interval. However, neritic species (*Thalassiosira deeipiens*, *Coscinodiscus marginatus*, *Chaetoceros* sp.) predominate, and a more prominent role relative to the underlying sediments is played by oceanic diatoms (*Thalassiosira oestrupii*, and *Coscinodiscus asteromphalus*), which are absent below. In general, marine diatoms dominate here. In the overlying sediments (middle-upper Holocene), the brackish-water species are completely absent, and among the marine species, oceanic forms (*Thalassiosira excentrica*, *Th. oestrupii*, and *Coscinodiscus madiatus*) are the most prevalent.

The Black Sea

In the sections of the Upper Quaternary sediments we identified the following horizons (from the bottom up): Karangatian, Postkarangatian, Surozh, Novoeuxinian, Oldchernomorian, Novochernomorian. On the shelf, they are determined by the change in complexes of Pelecypoda, reflecting the changing freshwater and marine conditions.

Karangatian transgressive sediments contain the most stenohaline and thermophilic mollusk shells (*Cardium tuberculatum*), planktonic foraminifera, etc. According A. Arslanov, their ages are defined in the range of 90–129 thousand years ago (^{230}Th). *Postkarangatian* regressive sediments opened on the Bulgarian shelf. They contain shells of *Dreissena* and *Monodacna* with redeposited marine Karangatian species. Discussing the *Surozh* transgressive strata defined on the northwest shelf under a mixed brackish and marine fauna. *ovoeuxinian* regressive-transgressive sediments conclude weakly brackish-water mollusks of the genera *Dreissena* and *Monodacna*. Their age is defined in the range from >30 to ~7 thousand ^{14}C years BP. *Oldchernomorian* transgressive sediments are distinguished by the predominance of shells of *Mytilus galloprovincialis*. Their radiocarbon age ranges from about 7–8 thousand years BP to 3–4 thousand years BP. Crowning the sections, *Novochernomorian* transgressive sediments contain the characteristic species *Modiola phaseolina*.

In the deep-sea depression, Karangatian sediments are represented by two types: sapropel and coccolith ooze. They contain a marine complex of diatoms and ocean coccolithophorida *Gephyrocapsa caribbeanica*. Between the Karangatian and Oldchernomorian deposits in deep-sea boreholes, powerful strata of clayey silts were discovered, in the upper part of which there are Novoeuxinian layers revealed also by numerous cores. They contain a complex of freshwater diatoms, predominantly *Stephanodiscus astraea*, and include diatoms and chemogenic limestone interlayers. AMS ^{14}C age revealed that the sediments vary from >25 to about 8 thousand years BP. Oldchernomorian deposits are of the Black Sea sapropel, which contains a marine complex of diatoms and coccolithophorida species *Braarudosphaera bigelowii*. In its lower part, there are many thin layers of aragonite mud. AMS ^{14}C ages of the sapropel lie in the range of 3–7 thousand years BP. Novochernomorian sediments are composed of thinly bedded, clayey-calcareous silts with *Emiliania huxleyi*.

The Caspian Sea

In the thickness of the Upper Quaternary deposits exposed within wells and cores, we subdivide: Hyrcanian, Atelian, Khvalynian, Enotaevian, Mangyshlakian, and Novocaspian horizons. The most complete sections are present on the shelf of the Northern Caspian, where their separation was carried out on the basis fauna of mollusks; the characteristics of the structure and distribution were identified according to seismo-acoustic profiling.

The *Girkanian* transgressive horizon is represented by layered sediments, mostly clay mud with inclusion of the characteristic species of mollusks: *Didacna subcatillus*, *D. cristata*. *D. parallella*. Their AMS ^{14}C age is greater than 60 kys, and U/Th is 100–122 k ys. The regressive *Atelian* horizon is represented by red-colored subaerial sediments containing rare freshwater mollusks: *Unio* sp., *Limnea stagnalis*, *Dreissena polymorpha polymorpha*, *Aninus eichwaldi*, *Valvata piscinalis*, and *Theodoxus pallasi*. They fill erosional incisions produced in the Gyrcanian layers. Deposits contain large amounts of plant residues from freshwater bodies. The calibrated ^{14}C age of the upper layers is 40–44 thousand years BP.

The transgressive *Khvalynian* horizon is represented by two sub-horizons, separated *Enotaevian* regressive layers. The Lower Khvalynian deposits at the base are composed of clay and sandy varieties with a large number of shells, which on seismo-acoustic records serve as a regional reflector. Above the layered clay strata lie interlayers of shells. Within its composition, we have defined *D. ebersini*, *D. protracta*, *D. zhukovi*, *D. parallella*, *D. subcatillus*, *D. cristata*, and *D. praetrigonoides*. AMS ^{14}C age of the subhorizon reaches 46–50 thousand years, and U/Th, about 62 thousand years BP. The Upper Khvalynian subhorizon is represented by two types of deposits. The upper part is a pack of deltaic sands, enriched with vegetable detritus, clay and silt-clay mud with different textures, formed in shallow-water conditions at the beginning of the regression of the sea. The lower part is silty sand, sometimes with interlayers of clay. The composition of shells is dominated by *Monodacna*, *Hipanis*, *Adacna*, and *Gastropoda*. *Didacna* is represented by *D. praetrigonoides*, small *D. parallella*, *D. cristata*, *D. subcatillus*, and *D. barbotdemarnyi*. Age of the lower boundary of the subhorizon is about 16–17 thousand years BP (more than 19 thousand calendar years).

The *Mangyshlakian* regressive horizon fills the incised-valley of lake and river types in Khvalynian sediments and is represented by sandy-clay and organic (peat, sapropel) muds. Deposits contain the remains of freshwater mollusks, grass pollen with a small admixture of arboreal pollen. ^{14}C age varies from 10 to 8.5 thousand years BP. The *Novocaspian* horizon has a variety of composition and genesis of sediments lying close to the modern fauna. According to seismo-acoustic data, they are contained within four horizontal-layered transgressive packs. There are 3 erosional incisions in the horizon, filled with lacustrine-alluvial, sandy-clayey mud with freshwater and slightly brackish-water mollusks. The lower boundary of the horizon is defined at the level of 7–8 thousand years BP.

In the deep basin of the Middle Caspian, cores discovered deposits of the Khvalynian, the Mangyshlakian, and the Novocaspian horizons. Their identification was made according to the diatom and spore-pollen analyses and lithological composition.

The Upper Khvalynian sediments are represented by blue, light brown, and grey mainly clayey muds with interbedded hydrotroilite. They contain a complex of marine brackish diatoms, dominated by marine brackish-water species. Freshwater-brackish species with marine species are in small quantity. A significant part of the complex consists of boreal species; a variety of endemic (central areas), cold-water species is identified in the northeastern part of Caspian Sea. Down the section, especially in the brown mud, diatom algae are not found. Among the pollen and spores, pollen of herbs and xerophytes dominate, but in the upper part of the horizon, there is an increase in the proportion of pollen from woody plants.

Mangyshlak sediments are represented by light gray, lime-clay silts with interbedded pure carbonate of chemical genesis. The diatom composition is dominated by *Actinocyclus ehrenbergi*. There are freshwater and brackish-water species. In the spore-pollen complex, the pollen of herbs dominates with a slight increase in arboreal pollen. Novocaspian sediments are enriched in organic matter up to the formation of the sapropel interlayer, they contain interlayers of diatom ooze, and are depleted in carbonate in comparison with the Mangyshlakian muds. Their characteristic feature is the domination of planktonic marine species among the diatoms, particularly *Coscinodiscus radiates*. In the composition of tree pollen, the number of which has its maximum in the sapropel (25–40%), there is a marked increase in the proportion of broad-leaved trees.

Correlation between shallow shelf and deep-sea sections of the Caspian sediments was conducted on the basis of diatom and pollen composition. In addition, in some deep-water cores, there were juvenile shells of some species of mollusk, corresponding to shallow complexes.

Conclusion

Our research allows us to correlate sections of the Upper Quaternary deposits of the studied seas and to make some paleogeographic conclusions.

The Riss-Würm and Karangatian sediments, based on the composition of fauna and flora, correspond to the last interglacial period (MIS-5), with high-standing seas and changing of waters, leading to maximum salinization of the Black Sea (up to 30‰). Their correlation is confirmed by the figures of absolute age. Girkanian deposits of the Caspian Sea, according radioisotopic age, are partially synchronized with the Karangatian Black Sea sediments. Their relationship in the Manych Strait suggests a formation during MIS-5 with a shift in time to the later stages and perhaps the beginning of the last glaciation. The lack of data on deep-sea sediments of this age, however, allows us to suppose that the basin could accumulate sapropel and diatoms analogous to the Novocaspian sediment.

The data obtained for the sediments of the Late Pleistocene interstadial allow us to draw a correlation between the Mediterranean Middle Würm, the Black Sea Surozh (?) (Middle Valdai), and the Caspian Sea Lower Khvalynian layers. The results of radioisotope (^{14}C AMS and U/Th) age provide the evidence to synchronize these sediments at the time of 25–50 thousand years ago (MIS-3). In this case, water of the extensive Early Khvalynian transgression may have flowed into the Surozh basin and maybe then into the Mediterranean Sea.

The time of the LGM (MIS-2) is marked by a major regression of the Mediterranean Sea and the Black Sea and less certain of the Caspian Sea. Their age is synchronized at the level of 15–17 thousand years BP.

Late- and postglacial sediments (MIS-2 to MIS-1) we identify with the last global transgression of the World Ocean. According to complex data and radiocarbon dating, that is the Holocene transgression of the Mediterranean Sea (from 17–18 thousand years BP), the Novoeuxine-Chernomorskaya transgression of the Black Sea (from 15–17 thousand years BP), and the late Khvalynian-Novocaspian (13–15 thousand years BP) transgression of the Caspian sea. The last was interrupted by a deep early Holocene Mangyshlakian regression in the range from 10 to 8.5 thousand years BP.

Despite a significant difference in depositional environment in the studied basins, the general trend of development of the natural environment in the Holocene interglacial period led to a similar result in the process of sedimentation. This was manifested in the accumulation of sapropel layers. The common cause of their formation is the dramatic increase in phytoplankton productivity due to increasing nutrient inflow into the seas during the Holocene climatic optimum. This is confirmed by the 2–4 fold increase in absolute mass of organic matter in the sapropels compared to the enclosing sediments. According to radiocarbon dating, the age of the sapropels was rejuvenated from the Eastern Mediterranean to the Caspian Sea, apparently after a time delay due to the occurrence of the optimum.

Acknowledgments

The authors are grateful to all colleagues who took part in this work. This study is a contribution to the IGCP 610 project “From the Caspian to Mediterranean: Environment change and human response during the Quaternary.”

PALEOGEOGRAPHIC STAGES IN THE DEVELOPMENT OF THE IRANIAN COAST OF THE CASPIAN SEA DURING THE HOLOCENE

Svitoch, A. [1], *Badyukova, E.* [2], *Makshaev, R.* [3], *Sheikhi, B.* [4], *and Yanina, T.* [5]

[1-5] Faculty of Geography, Lomonosov Moscow State University, 1 Leninskie Gory, Moscow, Russia, 119991
[1] a.svitoch@mail.ru
[2] badyukova@yandex.ru
[3] radikm1986@mail.ru
[4] bahriarsheihi@mail.ru
[5] didacna@mail.ru

Keywords: Caspian Sea, Iran, coastal zone, Holocene, environmental evolution

The Iranian coast of the Caspian Sea is a spacious, slightly seaward inclined lowland extending for over 600 km in the latitudinal direction and ranging from 1 to 60 km wide in its central part and in the Sefidrud and Gorgan river delta areas, respectively. The maritime part of this lowland represents a marine plain with altitudes of 27 to –20 m complicated by poorly expressed terraces and separated from the present day beach by a system of coastal bars that surround lagoons. In the west and east, these coastal bars form large nehrungs (spits), which separate Enzeli Lagoon and Gorgan Bay from the sea. In its central part, the lowland surface is characterized by altitudes ranging from 0 to –20 m. Its southern part is marked by a narrow band of low foothills with local relicts of poorly expressed terraces and cliffs. The maritime plain is covered by a young lithology of variable sediments. Our investigations were based on the complex analysis of available materials, including the stratigraphic position of sediments in the section, the general geomorphological and hypsometric situation, the composition of molluscan fossils, the lithological-facies features, and radiocarbon age estimates. The Holocene thickness includes the Mangyshlakian, Dagestanian, lower and upper Novocaspian, and Recent beds. The Mangyshlakian Beds, which reflect the significant Caspian Sea regression, are widespread on the Iranian coast, constituting the surficial part of the maritime plain section. With respect to their lithological-facies composition, these sediments are dominated by coarse-detrital alluvial and alluvial-proluvial varieties, which fill buried river valleys and form broad fans overlying the terraced surface of the late Khvalynian plain. Noteworthy are frequent finds of large, differently rounded boulders of Elburz bedrock. The subordinate role belongs to loess-like and eolian facies and buried soils.

The Dagestanian Beds of the section are conditionally defined proceeding from their occurrence at the base of marine Novocaspian sediments and the absence of *Cerastoderma glaucum*. They are represented by gray-lilac sands with whole *Didacna cristata* shells, which grade laterally into compact, caked plant remains overlying Mangyshlakian boulder gravel with pebbles. The lower Novocaspian Beds are developed at altitudes of –25 to –20 m. They are composed of lithologically variable terrigenous sediments with intercalations of organogenic mud containing plant remains and indications of insignificant hiatuses in the form of buried soils and eolian sediment reworking. These beds yielded several close radiocarbon dates of approximately 2.4 ka (Lahijani et al., 2010). The upper Novocaspian Beds were developed in the coastal part of the plain at altitudes of –25 to –26 m, where they constitute a low marine terrace and nehrungs that separate lagoons from the sea. These sediments yielded radiocarbon dates ranging from 0.3 to 1.0 ka (Svitoch and Yanina, 2007).

Recent sediments were deposited in the transitional shore-sea zone being represented by beach, abandoned cliff, river channel, and floodplain facies, eolian varieties, and soils.

As a whole, the Novocaspian section of the Iranian coast is characterized by a uniform lithological-facies composition, with dominant marine, fluvial, eolian, and pedogenic sediments. Marine facies are the most diverse, being represented by coastal marine (facies of shoals with calm, low-energy hydrodynamic environments and beach) and lagoonal sediments. The lagoonal sediments are recorded at different hypsometric levels, being most frequent at altitudes of –20 to –22 m and –25 to –26 m in basal parts of the lower and upper Novocaspian beds, respectively. The Novocaspian sediments are saturated with paleontological remains. They contain molluscan species of the Cardiidae family with representatives of the genus *Didacna* Eichw. and *Cerastoderma* Poll. being most abundant. The first genus is an endemic taxon for the Caspian Sea, which is characterized by rapid evolutionary development at the species and subspecies levels. The second genus is represented by immigrants from the Black Sea, which are characterized by a Mediterranean origin and which colonized the Caspian Sea during the Holocene Novocaspian epoch. The Novocaspian molluscan assemblages differ from their coeval counterparts populating other Caspian coasts by the dominant role of crassoid *Didacna* representatives, in addition to *Cerastoderma glaucum*, and the occurrence of species indicating slightly brackish water environments. The analysis of their bed-by-bed distribution through the section shows that they form three assemblages: Dagestanian, Novocaspian, and Recent. The Novocaspian assemblage is represented by two subassemblages that occupy different stratigraphic positions in the section. The defined fossil assemblages of differing composition and rank, combined with complex data on sediment lithology, provide the basis for paleogeographic reconstructions of the Iranian coast of the Caspian Sea.

The Mangyshlakian stage, lasting from c. 9.8 to 6.4 ^{14}C ka, was extremely important for the formation of the Iranian coastal topography. During this regressive epoch marked by a sea level falling by 100 m, practically the entire Caspian shelf became desiccated and subjected to intense erosion, which resulted in basin deepening and widening. When the regression terminated, the valleys were filled with coarse-detrital alluvial and proluvial material. After their filling, such coarse-detrital sediments formed fans from mountainous rivers, which prograded into watershed areas. This process resulted in the development of the continuous cover of coarse-grained fluvial sediments over the desiccated surface of the late Khvalynian plain up to altitudes of 0 m. The sole exception is the Astara area, which retained a partially water-filled lagoon. As was mentioned, the coarse-detrital Mangyshlakian sediments include many large boulders up to 1.0–1.5 m across. These relatively well rounded blocks are characterized by variable lithology (from metamorphosed rocks and granites to recrystallized limestones and sandstones of the Elburz) and are distributed from the low foothills to the sea shore. It is conceivable that these boulders resulted from a combination of two processes: gravitational landslide and mudflows. They both created rock blocks to channels of large rivers, which transported them through the maritime plain toward the seashore.

The Novocaspian stage lasting approximately 5 kyr corresponded to the terminal phase in development of the coast during the last Caspian transgression. The transgression was characterized by multistage patterns, which is reflected in the structure of marine sections and coastal topography. The section is composed of alternating terrigenous and coastal-marine sediments, which constitute two levels of the Novocaspian marine terrace separated by lagoonal mud deposited during the lower sea level. Lagoons became widely developed after the Mangyshlakian regression. The taxonomic composition of the molluscan assemblages from lagoonal sediments indicates that they represented desalinated, isolated or semi-isolated basins. With development of the Novocaspian transgression, depositional environments in the coastal zone were successively replaced by settings with more intense hydrodynamics and the accumulation of coarse pebbly and sandy-gravelly material, and subsequently calmer conditions with deposition of well-sorted sands on spacious shoals. Judging from abundant molluscan assemblages, the Novocaspian sea represented a brackish-water basin with salinity close to that in the present-day southern Caspian Sea.

The Novocaspian terrace occupies an extended band of the coast up to an altitude of –20 m. It is accretion-erosional in origin with the base represented by Mangyshlakian pebbly gravel in its back part and the accretion type composed of facies-variable sediments in the shore part. Its upper level (–20 to –24 m) is marked by mobile dunes and relicts of buried and recent soils. The Novocaspian terrace of the lower level (–25 to –26 m) is located in the coastal zone adjoining the abandoned cliff and representing a system of joint (overlapping) coastal bars separated by narrow lagoonal depressions. It was formed during the last significant sea-level rise. This epoch was marked by the final formation of the large Mordob and Miankal nehrungs, which separate the Enzeli Lagoon and Gorgan Bay from the sea. The complex structure of sections in these nehrungs (Svitoch and Yanina, 1997; Moghaddam, 2006) implies their formation to be a multistage process with deposition breaks and migrations of the main nehrung body. This was accompanied by the formation of the present-day Sefidrud River delta system, although the valley proper and its delta were formed considerably earlier. Their relicts are recognizable in space images at altitudes above 0 m on the early Khvalynian plain. The delta relicts reflecting the Mangyshlakian regression are established on shoals of the Caspian shelf. Large volumes of sedimentary material transported by the Sefidrud River are responsible for frequent migrations of creek and main river channels. For example, in the Holocene, the river changed its direction six times (Krasnozhon et al., 1999). The Recent stage reflects the present-day natural process on the Iranian coast of the Caspian Sea: primarily its dynamics and trend. The stable structure of the coast and its brief recent history allow the main features of the recent natural process to be extrapolated to past epochs. The present-day shoreline is slightly differentiated and consists of two arcuate northwestern and southeastern parts joining in the Sefidrud River mouth area. The shores are mainly represented by marine-deposition and eroded types. The offshore part of the low Novocaspian terrace is intensely eroded. The high sedimentation rates are recorded only in areas of large deltas, which prograde toward the shelf owing to intense sediment supply. The greater share of sedimentary material transported by the river to the offshore mouth area is quickly distributed over the underwater slope. This is also evident from the structure and composition of present-day bars that isolate lagoons from the sea and indicate the prevalent transverse transport of terrigenous sediments delivered by rivers into the sea. The recent epoch is marked by insignificant fluctuations of the Caspian Sea level accompanied by changes in coastal processes: the desiccation zone and beach became wider, and eolian reworking of sands in the coastal zone intensified during the period of the Caspian Sea level fall in 1950–1977, while its subsequent rise in 1978–1995 was marked by enhanced abrasion of the low marine terrace, onshore migration of the recent coastal bar, and reduction of the area occupied by the adjacent lagoonal depression.

The above-mentioned peculiar features in the geological-geomorphological structure and recent development history of the Iranian coast of the Caspian Sea were mainly determined by the position of this narrow zone at the transition between the Alpine Elburz mountain system and the southern Caspian basin, which is characterized by different-scale cyclicity and hydrodynamic activity. Such a situation was responsible for the intense supply of terrigenous material to the coastal zone and high rates of reworking and deposition to produce different forms of surface and underwater topography. These processes, complicated by various factors that rapidly changed in space and time, are well reflected in the development of river deltas, nehrungs, and the low terrace consisting of a system of beaches and coastal bars.

Acknowledgements

This work was supported by the Russian Foundation for Basic Research, Project 17-55-560012 and is a contribution to IGCP 610 project "From the Caspian to Mediterranean: Environment change and human response during the Quaternary."

References

Krasnozhon, G., Lahidjani, H., and Voropaev, G., 1999. Evolyutsiya delty r. Sefidrud po dannym kosmicheskih s'emok Iranskogo poberezhiya Kaspiyskogo morya [Evolution of the delta of the river Sefidrud according to space images of the Iranian coast of the Caspian Sea]. *Issledovaniya Zemli iz Kosmosa* [*Researches of Earth from Space*] 1: 105–111. (In Russian)

Lahijani, H.A.K., Leroy, S.A.G., Beni, A.N., Hagham, S., and Shahkarami, S., 2010. Controls on sediment distribution pattern in the South Caspian Sea, Iran. In T.A. Yanina, A. Kislov, S. Leroy, and S.A. Lukyanova, eds., *The Caspian Region: Environmental Consequences of the Climate Change. Proceedings of the International Conference. MSU*, Moscow, pp. 261–262.

Moghaddam, V., Vahabi-Asil, F., Lahijani, H.A.K., and Attarilar, A., 2006. South-Caspian sediments dating using 210Pb technique. In *4th International Conference of UNESCO Programme IGCP 481 "Dating Caspian Sea Level Change,"* 19–23 May, Aktau, Kazakhstan, p. 111.

Svitoch, A., and Yanina, T., 1997. Chetvertichnye otlozheniya poberezhiy Kaspiyskogo morya [*Quaternary Sediments of Caspian Sea Coasts*]. Rossel'khozakademiya, Moscow. (In Russian)

Svitoch, A., and Yanina, T., 2007. Marine Holocene of the Iranian coast of the Caspian Sea. *Doklady Earth Sciences* 401: 1166–1171.

ON THE OTHER SIDE OF THE CASPIAN SEA

Taumanova, G.E. [1,2]

[1] International Medical Geology Association (IMGA), Chapter NIS, ROSGEO, 2nd Roshchinskaya Str. 10, 115191, Moscow
[2] Association of Petroleum Geologists of Kazakhstan, 43A, Aiteke bi Str., Atyrau, Kazakhstan
[1,2] gulnara-t2007@yandex.ru

As is known, the Caspian Sea is the residual lake of the Caspian lowland. The origin of the Caspian Sea is associated with the geological fate of the ancient Tethys. The history of the Caspian Sea continues. The base of the Caspian depression is part of the hydrogeological megabasin, which has a heterogeneous structure. By deep faults, it is divided into blocks and megablocks. The geologic, tectonic, and hydrogeological features, and differences in the structure of the sub-Caspian artesian basin territory determine the origin of the hydrogeochemical conditions of the upper hydrodynamic zone of groundwater formation.

In 1948, the Institute of Geology and Geophysics of the Ministry of Geology of the USSR (Ural-Emba base of the Academy of Sciences of the Kazakh SSR) began the first systematic hydrogeological study using a special drilling technique for underground water prospecting. Due to these explorations, a powerful Lower Cretaceous (the upper Alburz) aquifer complex and an artesian basin, extending from the Mugodzhar to the Caspian Sea, was opened.

Moving toward the Caspian Sea, groundwater ramps up in pressure and temperature and changes its chemical properties. It regularly varies from fresh, slightly alkaline, hydrocarbonate-sodium to brackish, weakly-rigid, sulfate-sodium, and further to hard brines of chlorcalcic composition. In the transition, hydrocarbonate-sulphate-sodium groundwater rises in temperature up to 3000°C, and the hydrogen sulfide content in water is raised to 206 mg/l (Tugarakchan). They belong to the strong hydrogen sulfide waters of the Matsesta type (Dzhumagaliev, 1967). According to the results of analyses of control samples in 1957, it was established that groundwater has undoubted balneological significance and can be successfully used.

At present, it is known that in the territory of the city of Atyrau (Western Kazakhstan), there are seven deposits of mineral waters suitable for balneological application. All seven have almost the same chemical composition, and there is an opinion that they are a single whole mineral lake underlying the city. In 2002, the Research Institute of Cardiology and Internal Medicine of the Ministry of Health of the Republic of Kazakhstan conducted a study of the water of another salt lake (located in the Atyrau airport area) with a unique health-improving property, in particular, the presence of highly mineralized bromine brine.

Water with a high content of iodine was found in places rich in oil, including the coast of the Caspian Sea. It is interesting that the iodine-bromide waters typical for oil fields sometimes contain more than 100 mg/l iodine, and 300–400 mg/l bromine.

In the coastal zones of the northeastern part of the Caspian Sea, there are many salt lakes rich in medicinal properties. In the hot season, many people come here for treatment. The hydrographic regime of many lakes depends entirely on the state of the Caspian Sea. The chemical composition of the therapeutic hydro-mineral raw materials differs little from the composition of sea water. It is interesting that some lakes formed on the site of the destroyed salt dome (for example, Lake Shalkar in the West Kazakhstan region) (Fig. 1).

Figure 1. Shalkar lake

Figure 2. Karabatan lake.

There are not many places left on our planet with real curative muds. Therapeutic mud is a consistent substance born of the Earth, which can really provide help to the human body. The phenomenon of Lake Karabatan, which is 42 km east of Atyrau (Fig. 2), was known in the XIX century. In 1874 and 1884, it was described in the notes of Russian scientists Kirpichnikov and Garkem. This lake is visited by the local settlement in the third month of summer. From the 10th to the 25th of August, mud in the lake is considered most healing, or "ripe," as natives say.

In 2006, at the request of local hydrogeologists, the Institute of Cardiology and Internal Medicine of the Ministry of Health of the Republic of Kazakhstan carried out analyses of mud samples from the Karabatan salt lake (saline). It was found that the peloids of the Karabatan deposit are qualitative, saturated with medium sulfide silt, and recommended for mud treatment. "Atyrauhydrogeologiya" supplies Karabatan mud to the sanatorium "Atyrau" and some additional sanatoria outside the region.

On the eastern outskirts of the Atyrau region, the boundless steppe expanses have found their bounds, and the ideally flat horizon line has been replaced by sharp peaks of quaint chalky rocks (Fig. 3). From the plateau opens a beautiful view (Fig. 4).

Figure 3. Mangyshlak

Figure 4. Usturt' Chinks. Mangyshlak.

Here, "as in a reserved casket, the whole diverse manifestation of the nature of deserts is collected," wrote Professor B.A. Fedorovich. Long ago, the entire peninsula was the bottom of an ancient ocean where round concretions were formed (Fig. 5).

Figure 5. Round concretions of Mangyshlak.

Figure 6. Hot hydrogen-sulfide spring.

Shark teeth, fossil mollusks, and scales of huge unknown fish that lived here millions of years ago can still be found on the Cretaceous plateau. The bright, unique beauty of the plateau was formed in the Jurassic period when dinosaurs roamed the earth. There are places (Aktolagai) where paleontological monuments of the Mesozoic era —bones of dinosaurs—are literally scattered beneath one's feet.

There are many healing springs in Mangyshlak containing bromine, chloride, sodium, sulfur, etc. (Fig. 6). There are waters that not every specialist can distinguish from that of Matsesta. The peninsula has discovered a rich set of healing springs and thermal springs that approach the uniqueness of Kamchatka in temperature. The water from borehole no. 21 in the Cuyulus deposit, drilled during Soviet times, was examined, and it was recognized that it corresponds to the "Essentuki 17" in chemical composition. Mineral waters in this region have a favorable organoleptic effect. There are brackish springs with a salinity of 8.3 g/l, with a weak smell of hydrogen sulfide, alkaline, sulfate, which can be used to treat the digestive system, as well as for baths in the treatment of the musculoskeletal system, and chronic diseases of the nervous system. Everyone knows the radon source "Shevchenko."

Unfortunately, no one, except hydrogeologists, has any interest in this region nowadays. Lack of organized use of local mineral water resources has led to bringing mineral waters from afar, and workers are forced to go to hydrotherapy in remote resorts (Matsesta, Essentuki, etc.) or to engage in self-medication in springs.

References

Dzhumagaliev, T.N., 1967. *Ob* ispol'zovanii mineral'nykh vod Jembinskogo raiona [*About use of mineral water of the Lembinsky county*]. Kazakh Research Petroleum Geological Prospecting Institute

Drozdov, O.A.,Vasil'ev, V.A.and Kobysheva, N.V., 1989. *Klimatologiya* [*Climatology*]. Leningrad, Gidrometeoizdat.

Fedorovich, B.A., 1954. *Lik pustyni* [Image of Desert]. Moscow, Pulishing house "Molodaya gvardiya."

AGE OF THE PALEOLITHIC SITE SUKHAYA MECHETKA (LOWER VOLGA REGION)

Tkach, N.T. [1]*, and Sychev, N.V.* [2]

[1,2] Lomonosov Moscow State University, Faculty of Geography, Laboratory of Pleistocene paleogeography, Moscow, Russia, 119991
[1] tkachgeo@gmail.com
[2] nikita.sychev@gmail.com

Keywords: Mousterian, OSL, paleosol, Caspian sea, Würm

Introduction

Mousterian archaeological sites are widespread in Europe, North Africa, Central Asia, the Middle East, and south of Siberia. In addition to the many problems of correlation of *Homo* species and Paleolithic cultures, there is the problem of the lack of absolute dates for the Mousterian. According to most researchers, this culture developed during the epochs of the Moscovian (Riss, MIS-6) glaciation, the Mikulinian (Eemian, MIS-5e) interglacial up to the Bryansk (Middle Würm, MIS-3) interstadial. Until the development of radiometric methods (particularly optically stimulated luminescence) in the late 1990s, it was almost impossible to obtain absolute dates (because of the limits of the radiocarbon method). In many European (in contrast to Russian) archaeological sites, the problem of absolute age was already solved because of many dating laboratories.

The Sukhaya Mechetka Mousterian site (Volgograd, Russia) is in a unique geographical position. It was discovered in 1951 by M.N. Grischenko (Grishchenko, 1953; Moskvitin, 1962). It is located within the Caspian depression, which was repeatedly flooded by the Caspian Sea during the transgression epochs in Pleistocene history and buried under marine sediments of the Early Khvalynian transgression of the Caspian Sea. The aims of this research are (1) ascertaining the absolute age of the Sukhaya Mechetka site by correlating its stratigraphic position with the Srednaya Akhtuba section on the opposite side of the Volga-Akhtuba valley because of the presence there of reliable OSL dates, and (2) comparison with other Mousterian sites of the southern Russian plain.

Sukhaya Mechetka site

Since the discovery of the Sukhaya Mechetka site, notions of its age have varied. M.N. Grishchenko (1953) dates it within the Odintsovian (MIS-7) interstadial. N.K. Vereshchagin and A.D. Kolbutov (1957) classify the cultural layer as the end of the Khazarian cycle of sedimentation in the Caspian Sea (MIS-6 to MIS-5e). V.I. Gromov and E.V. Shanzer (1958) consider that the site is not younger than the Moscovian (Riss, MIS-6) glaciation. A.A. Chiguryayeva and N.Y. Khvalina (1961) relate the time of human habitation to one of the treeless phases of the Khazarian period (MIS-6). Yu.M. Vasil'ev (1961) relates the site to the paleosol in the upper part of the Lower Khazarian horizon (MIS-6). G.I. Goretsky (1966) considers that the deposits of the periglacial formation and the buried soil within the site formed at the end of the Dnieperian glaciation (Sozhian, Odintsovian, and Moscovian time, MIS-7 to MIS-6). A.I. Moskvitin (1962) believes that the site is located on the Mikulinian (Eemian, MIS-5e) soil and is covered by Akhtubian periglacial sands (MIS 4-3). Dolukhanov et al. (2009) consider that the age of the site is much younger, and they relate it to the Atelian (MIS-3 to MIS-2) regressive epoch of the Caspian Sea, which was in the LGM in their opinion. The bones of large mammals *Canis lupus* L., *Elephas* sp., *Cervus elaphus* L., *Saiga tatarica* L., *Bison priscus* Bif., and other species were found in the cultural layer (Vereshchagin and Kolbutov, 1957).

The upper part of the section is composed of Khvalynian "chocolate" clays with thin sandy interlayers filled with the shells of *Didacna ebersini*, *Hypanis plicatus*, *Monodacna caspia*, and *Dreissena polymorpha*. They are underlain by sandy-loam Atelian strata (5 m) with poorly expressed traces of soil formation in the middle part. Further, there is a dark brown-gray, poorly developed soil-horizon (S1) (which lies upon the cultural layer) with wedges penetrating into the underlying sediments. In the gullies near the site, there is a well-humified soil (S2) (15 cm) developed on the loam under S1. Under the soil, there are light-gray sands with horizontal interlayers of loam and sandy clay (total thickness of 2.2 m), containing numerous shells of trigonoid *Didacna* and slightly saline index-species of the freshened Khazarian basin. They are underlain by ferruginous sandy clays, including shells of similar species (3 m). A.I. Moskvitin (1962) defines the two developed soil-horizons as Mikulinian and Odintsovian, respectively, in his interpretation of the section. Thus, the time of site-formation he defines as a transition from the Mikulinian interglacial to the Early Valdayian (MIS-5e to MIS-4) cooling.

Srednaya Akhtuba section

The Srednaya Akhtuba site contains Early Khvalynian "chocolate" clays in the upper part. Underneath them there are Atelian strata represented by alluvial sands and loess. Below in the section, there are loess-like deposits with three soil horizons (S1: bluish-gray, broken by thick ice-wedges; S2: dark gray, broken by small ice-wedges; and S3: brownish, with carbonate nodules), developed over loess-like loams. A.I. Moskvitin (1962) defines the S1and S2 soil horizons as Mikulinian and Odintsovian, respectively, and apparently they correlate with the S1 and S2 soils in the Sukhaya Mechetka site.

In 2017, OSL dates were obtained for the first time for the Lower Volga sediments (Srednaya Akhtuba section) (Yanina et al., 2017). Sediment for dating was sampled at night in opaque plastic bags. Dating was conducted by the author in the Nordic Laboratory for Luminescence Dating, Aarhus University, under the guidance of professor A.S. Murray. Dates for the Khvalynian and Atelian strata were obtained by quartz and for loess-like loams and soil horizons by feldspar. As a result, the soil horizons are related to the warmings of the 5th isotopic stage (MIS-5e, -5c, -5a). The soil correlates with the soil of the cultural layer, and a date of 68,280±4170 was obtained (Yanina et al., 2017).

Comparsion with other sites

In the southern part of the Russian plain, there is only one more well-known Mousterian site—Rozhok (Veselo-Voznesenka, Rostov region). It is located on the left side of the large Bulnaya gully flowing into Taganrog Bay (Sea of Azov), 0.5 km east of the village Rozhok and 45 km west of Taganrog city. This site was opened by N.D. Praslov (1969). This site contains 6 cultural layers. It is located on the Beglitskaya marine terrace (MIS-7, unpublished data). The general geological structure is: loess strata lie on subaquatic limanic deposits, which lie on the indigenous limestones of Sarmatian time. The loess strata are cut by a series of paleogullies and filled with deluvial deposits. In the lower part of these strata, cultural layers are located (usually not more than 10–20 cm in thickness). There are different opinions about the absolute age of these deposits. M.D. Grishchenko (1965) believes that these sediments relate to the time of the retreat of the Dnieper glacier (MIS-7). N.D. Praslov (1969), and also A.A. Velichko (1968) believe that the sediments have a younger age—Mikulinian (MIS-5e) or Early Valdayian glaciation (MIS-5a-d to MIS-4). This can be judged on the basis that the cultural layers lie below the horizon of ephemeral soil formation, which most likely is the Bryansk soil (MIS-3) (S1). In the lower part, there is a strongly humified soil, which is most likely Mezin (MIS-5) (S2). This is indicated by the palynological data of V.P. Gritschuk, who revised the analysis data obtained by V.A. Vronsky, and came to the conclusion that the

Mikulinian (MIS-5e) age of sediments contained the cultural findings (Praslov, 1969). Also evidence of the age of this site is in the cultural layer found in the area of the famous, well-studied section—Beglitsa. In this context, I.K. Ivanova and Yu.M. Vasilyev found a Mousterian nucleus in sediments above the Mezin pedocomplex (MIS-5e) and under the Bryansk (MIS-3) interstadial soil.

Conclusions

It can be concluded that, apparently, there is a correlation between the S1 (Srednaya Akhtuba), S1 (Sukhaya Mechetka), and S2 (Rozhok) soils. Cultural layers in the Sukhaya Mechetka and Rozhok sites have the same stratigraphic position (exactly on strata that correspond to MIS-5e). Thus, the absolute age of the Sukhaya Mechetka cultural layers can be determined as 65–71 ka (based on OSL-dates from the Srednaya Akhtuba site) and related to the end of the warm stage of MIS-5a, which confirms the assumptions about its Early Valdayian age.

Acknowledgments

This work is supported by RSF № 16-17-10103. Also it is contribution to IGCP-610 project.

References

Chiguryayeva, A.A., and Khvalina, N.Y., 1961. O kharaktere rastitel'nosti v rayone Stalingrada v epohu srednego paleolita. *Kratkie soobshhenija Instituta arheologii*, Moskva. (In Russian)

Dolukhanov, P.M., Chepalyga, A.L., Shkatova, V.K., and Lavrentiev, N.V., 2009. Late Quaternary Caspian: Sea-levels, environments and human settlement. *The Open Geography Journal* 2: 1–15.

Goretsky, G.I., 1966. *Formirovanie doliny r. Volga v rannem i srednem antropogene*, Nauka, Moskva. (In Russian)

Grishchenko, M.N., 1953. Kratkoe soobshchenie o geologicheskikh usloviyakh zaleganiya novoy paleoliticheskoy stoyanki. *Bulleten po izucheniyu chetvertichnogo perioda 18*(In Russian)

Grishhenko, M.N., 1965. Geologiya Volgogradskoy stoyanki Suhaya Mechetka na Volge i stoyanki Rozhok 1 v Priazov'e. *Stratigrafiya i periodizatsiya paleolita Vostochnoy i Central'noy Evropy*. Nauka, Moskva, pp. 141–156. (In Russian)

Gromov, V.I., and Shanzer E.V., 1958. O geologicheskom vozraste paleolita v SSSR. *Izv. AN SSSR, seriya geol.* Izd-vo AN SSSR, Moscow. (In Russian)

Moskvitin, A.I., 1962. Plejstotsen Nizhnego Povolzh'ja. *Trudy Geologicheskogo instituta AN SSSR*. Izdatel'stvo AN SSSR, Moscow. (In Russian)

Praslov, N.D., 1969. Domust'erskie i must'erskie pamyatniki yuga Russkoy ravniny. *Priroda i razvitie pervobytnogo obshhestva na territorii Evropeyskoy chasti SSSR*. Nauka, Moskva. (In Russian)

Vasil'ev, Yu.M., 1961. *Antropogen Yuzhnogo Zavolzh'ya*, Izdatel'vo AN SSSR, Moskva. (In Russian)

Velichko, A.A., 1968. Glavnyj klimaticheskiy rubezh i etapy pleystocena. *Izvestiya AN SSSR. Seriya geograficheskaya.* 3: 5–17. (In Russian)

Vereshchagin, N.K., and Kolbutov, A.D., 1957. Ostatki zhivotnykh na must'erskoy stoyanke. *Trudy Zool. in-ta AN SSSR*. Izd-vo AN SSSR, Moscow. (In Russian)

Yanina, T.A., Svitoch, A.A., Kurbanov, R.N., Mjurrej, A.S., Tkach, N.T., and Sychev, N.V., 2017. Opyt datirovaniya pleystocenovykh otlozheniy Nizhnego Povolzh'ya metodom opticheski stimulirovannoy lyuminescencii. *Vestnik Moskovskogo Unviersiteta, Seriya Geografiya* 1: 21–29. (In Russian)

STONE AGE PEOPLE IN CRIMEA: AN ANTHROPOLOGICAL STUDY

Vasilyev, S. V. [1]*, and Borutskaya, S. B.* [2]

[1] Leninskiy prospekt 32a, Institute of Ethnology and Anthropology, Russian Academy of Science, Moscow 119361, Russia
[1,2] vasbor1@yandex.ru
[2] Leninskye Gory 1, Lomonosov Moscow State University, Moscow 119991, Russia,

Keywords: anthropology, craniology, osteology, Crimean peninsula, Paleolithic-Mesolithic period

Introduction

The Crimean Peninsula has yielded only a few finds relating to the Paleolithic-Mesolithic periods. The earliest known finds of Crimean hominins include fragmentary skeletons from Kiik-Koba, Zaskalnaya, Staroselie, and Prolom (apparently belonging to pre-Wurmian Neanderthals), a twin burial from Murzak-Koba (Figs. 1, 2 ,3) that dates to the Upper Paleolithic-Mesolithic, and a skeleton from Fatma-Koba (Figs. 4, 5) also belonging to the Upper Paleolithic-Mesolithic.

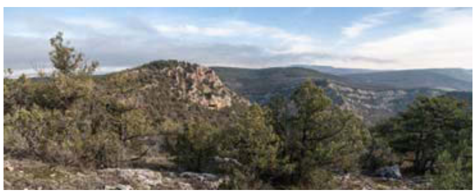


Figure 1. Cave Mursak-Koba.

Figure 2. Cave Mursak-Koba.

Figure 3. In the cave Mursak-Koba.

Figure 4. Grotto Fatma-Koba.

Figure 5. Grotto Fatma-Koba.

The skeleton of an adult from Kiik-Koba is very fragmented and essentially represented by only the hands and feet. A paleoanthropological study performed by G.A. Bonch-Osmolovsky showed considerable massiveness of the skeleton that is characteristic for known classic Neanderthal forms. Unfortunately, these remains do not give us any other information. At the same time, this find may be considered strange in that the burial contains complete skeletal hands and feet but lacks all other bones, including a skull.

We are mostly interested in finds belonging to slightly later ages: from Murzak-Koba and Fatma-Koba.

In 1927, during excavations in the cave of Fatma-Koba, G.A. Bonch-Osmolovsky recovered the skeleton of a male with an estimated age of about 40 years. The main characteristics of the skull included a low face, deep horizontal profiling, a high nose bridge, a sharp protrusion across the line of the face profile, and wide nasal bones slightly narrowed in the middle. The skull is characterized by a mesognathic profile—not alveolar, but a general one—which may be to an extent considered an archaic feature. However, in the opinion of G.F. Debets, a combination of the skull features demonstrates greater remoteness of the Fatma-Koba man from the Neanderthal type. According to Debets, this find may belong to "the early time of the Neolithic age" (Debets, 1948). Therefore, we may conclude that there could hardly be any evolutionary relationship between Neanderthals (represented in particular by the man from Kiik-Koba) and the people of Fatma-Koba type.

Stronger resemblance in skull morphology was observed between the Fatma-Koba skull and skulls from the grotto of Murzak-Koba. In 1935, while performing excavations in Murzak-Koba, S.N. Bibikov found a twin burial. The anthropological study was performed by E.V. Zhirov (Zhirov, 1940). The biological age of the buried individuals was estimated as 20-23 years (now there is a specific estimate of 23-26 years) and 45 years, respectively. It was concluded that the first skeleton belonged to a young female, and the second one to a male. This conclusion is still considered correct, though some authors suggested that the sexual identity of the first skeleton had been determined incorrectly. Thus, G.F. Debets wrote: "...The female skeleton turned out to be very similar to the one from Fatma-Koba. In this connection, I even had a suspicion concerning my determination of the latter's sex. Therefore, I inspected a left innominate bone from Fatma-Koba for the second time… After all, it has rather a male structure, though it is not very pronounced. Resemblance in the structure of both skulls saves us the trouble of more detailed characterization of the female skull from Murzak-Koba, which would be a repetition of the one given above for the Fatma-Koba skull" (Debets, 1948). Our study of skeletons from Fatma-Koba and Murzak-Koba, performed in 2004-2005, also raised doubts concerning the correctness of the conclusion that the young individual from Murzak-Koba was a female. Therefore, we provided a specimen for DNA sex determination, and it confirmed the correctness of its primary attribution. The female skull was large (skull cavity volume: 1534 cm^3), mesocranic, low-faced, moderately prognatic, high, with straight forehead and low orbits. The male skull was dolichocranic, high, with a very wide, high, orthognathic face, a low, inclined forehead, very developed superciliary arches, and very low orbits. The skulls resemble the late Cro-Magnon type (Brno-Předmostí) (Debets, 1948). The postcranial skeletons were previously studied according to a minimal program, mainly with a view to calculate intravital body length.

Materials and methods

The materials for our study were represented by three skeletons from Murzak-Koba I, Murzak-Koba II, and Fatma-Koba, respectively. They are kept in the Museum of Anthropology and Ethnography of the Russian Academy of Sciences (Kunstkamera) in Saint-Petersburg.

Measuring of postcranial skeleton bones was performed according to the standard osteometric program with several additions. Descriptions of bone features were based on schemes proposed in V.P. Alekseev's *Osteometriya* (Alekseev, 1966), and methods used for particular measurements of skeletal bones was based on rules described in the same source. In order to describe muscular relief, we used a scheme introduced by V.N. Fedosova (Fedosova, 1986) with our own additions.

Within the framework of craniological processing, we used the standard procedures for determination of individual sex and age in accordance with methodological recommendations of Russian anthropologists. Sex and age were determined on the basis of special scales for obliteration of skull sutures and degree of dental attrition (Alekseev and Debets, 1964). We applied a standard technique of craniometric measurement and recording of descriptive features (Alekseev and Debets, 1964). A categorical estimation of feature values was taken from rubrics contained in the same guide.

Results and discussion

Osteological investigation

We present measurement results of the postcranial skeletons from the Murzak-Koba individuals in Table 1. Now, the collection lacks long bones of the skeleton from Fatma-Koba. Therefore, we calculated some indices of extremity proportions on the basis of bone length data cited in the work of G.F. Debets (1948). Then, we calculated indices of extremity proportions and bone robusticity (except for Fatma-Koba). Some results are shown in Tables 1 and 2.

Table 1. Indices of extremity proportions.

Index/burial		Fatma-Koba	Murzak-Koba I	Murzak-Koba II
Intermembral	right	-	-	-
	left	68.07*	70.80	-
Brachial-femoral	right	-	69.16	72.28
	left	72.29*	71.44	-
Radio-tibial	right	-	-	-
	left	63.10*	69.97	-
Radio-brachial	right	-	78.185	78.41
	left	74.25*	76.83	-
Pedidian-femoral	right	-	-	-
	left	85.07*	78.44	-
Clavicular-brachial	right	-	46.62	44.57 ??
	left	-	45.57	-
Shoulder width (cm)		-	35.38 cm	39.04 ??
Pelvis width (cm)		29.40 cm	28.60 cm	-
Pelvic index		79.25	69.93	-
Body length (according to Dupertuis and Hadden formulas)		173.2* cm	167.8 cm	182.8

* Data according to G.F. Debets or calculated based on some long bone sizes according to Debets (1948).

?? = approximate measurement; the result is not lower than the actual one (i.e., shoulder width could be *a little bit* more).

Thus, intermembral indices of individuals from Murzak-Koba I and Fatma-Koba are very close to each other and fall within medium values for modern man, which suggests an average correlation of extremity length. For the individual from Fatma-Koba, this index is a little lower than average, i.e., we can speak about quite elongated legs. Brachial-femoral indices were obtained for all three individuals. For the individual from Murzak-Koba I, this index suggests a comparatively medium-long or quite increased femoral section as compared to shoulder size. For the other skeletons, this correlation reflects a considerably elongated shoulder compared to the femur. The correlation of forearm and shoulder of both individuals from Murzak-Koba is very similar and indicative of a medium or slightly elongated forearm.

The individual from Fatma-Koba has a different correlation indicating a shortened forearm. At the same time, we may recognize a very elongated shin as compared to the femur. This result also corresponds to the value of the radio-tibial index. In contrast, the individual from Murzak-Koba I reveals a shortened shin (or elongated femur).

The supposed shoulder width of the male from Murzak-Koba II is quite wide, while that of the first individual is medium (within the range for females but quite allowable for a young male). In terms of the pelvic width, the individuals from Murzak-Koba I and Fatma-Koba are very similar, but the pelvic width of the male from Fatma-Koba is a little wider (by almost 1 cm). However, the first of the above-mentioned individuals has a very low pelvis, the ilium wings are more folded, and the iliac and ischial bones are short. In this context, the pelvis of the male from Murzak-Koba II is more 'masculine'. The height of the right hip (including iliac and ischial bones separately) is greater. We should note that the male from Fatma-Koba has much longer pubic bones and wider ilium wings than the 'female' from Murzak-Koba I. At the same time, 'she' has a larger coxal cavity, and 'her' pubic symphysis is 49.5 cm, i.e., higher than that of the 'male'.

Thus, according to extremity proportion indices, we may suppose that all three individuals belong to the mid-continent adaptive type. Also, the male from Fatma-Koba is distinguished by an elongated medial section of the leg (the shin), which is more characteristic for people of tropical adaptive type. However, the radio-brachial index of the man from Fatma-Koba does not correspond to this type.

The intravital body length was determined for femoral bones (according to the Dupertuis and Hadden formulae) (Alekseev, 1966). The male from Murzak-Koba turned out to be high—almost 183 cm. The intravital body length of the male from Fatma-Koba may be estimated as average or just above the average—173.2 cm. The intravital body length of the female from Murzak-Koba I was 167.8 cm, which is quite high for women.

Table 2. Massiveness indices of extremity bones.

Index/burial		Murzak-Koba I	Murzak-Koba II
Clavicula	right	24.14	-
	left	24.14 ?	-
Humerus	right	19.11	21.10
	left	18.66	19.46
Radius	right	16.70	15.03
	left	17.00	-
Ulna	right	16.45	16.73
	left	16.31	-
Femur	right	19.60	21.19
	left	19.78	-
Tibia	right	-	-
	left	20.40	-

Unfortunately, it was impossible to estimate bone robusticity of the skeleton from Fatma-Koba, and so the analysis was performed only for those from Murzak-Koba. Almost all the bones of the individual from Murzak-Koba I are of medium massiveness. The humeral bone is slightly more gracile, and the radii are a little more massive than the human average. Moreover, we should note that the left shin bone is aciniform (the right one is absent). The humerus and cubitus of the second individual are of medium massiveness, the available right radius is gracile, the only femur (right) is massive and better fastened in the upper part of the diaphysis.

In general, muscular relief of both individuals is developed moderately and almost equally. Differences mainly concern femoral bones. The male from Murzak-Koba II has more pronounced femoral relief, especially the *linea aspera*, an intertrochanteric crest, and epicondyles. However, it is probably connected with a difference in their age. The first individual (female) was 23-26, and the second one (male) was about 45 years old. We should note that the humeral bone of the young woman from Murzak-Koba I possesses a much more developed deltoid roughness, while on the male's humerus, it is almost invisible.

It is hard to imagine rough labor of Mesolithic people in the low-hill terrain. Most probably, they subsisted on hunting, fishing, and gathering. Much energy was apparently expended in travelling across hills and mountains, crossing of cold mountain rivers, and transportation of spoils, tools, and weapons. Probably, loads on the shoulder joints account for quite good development of collar-bone relief in both individuals, as well as crests of the greater and lesser tubercles of the humerus, i.e., relief of muscles ensuring force movements and static loads on the shoulder joints. Perhaps, this is also implied by the considerable deformation of the lumbar vertebrae of the adult male from Murzak-Koba.

Craniological study (Figs. 6, 7)

Figure 6. Fig.6. Skulls Fatma-Koba, Mursak-Koba I, Mursak-Koba II.

Figure 7. Skulptural reconstraction Mursak-Koba II (man) and Mursak-Koba I (woman) (by M.M.Gerassimov)

Measurement results and indices are presented in Tables 3 and 4.

Table 3. Craniological characteristics.

No.	Features	**MURZAK-KOBA I**	**MURZAK-KOBA II**	**FATMA-KOBA**
1	Length	191	198	189
8	Breadth	145	140	137
17	Height	145	-	151
5	Skull base length	100	-	109
9	Breadth frontal minimum	105	97	94
10	Breadth frontal maximum	119	113	110
11	Skull base width	131	-	126
12	Nape width	113	-	111
29	Forehead horde	119	122	112
30	Cranial horde	117	123	127

31	Nape horde	103	103	108
26	Forhead arch	138	138	125
27	Cranial arch	130	140	142
28	Nape arch	123	122	127
7	Cranial openning lenghth	39	-	35
16	Cranial openning width	32	-	30
45	Cheekbone diameter	142	142 (?)	142
40	Face base length	101	107(?)	112
48	Upper face height	67	77	68
43	Upper facial breadth	112	113	112
46	Middle facial breadth	104	107	102
60	Alveolar arch length	56	58	53
61	Alveolar arch width	63	67	67
55	Nose height	50	54	49
54	Nose width	25	28	26
51	Orbit breadth	45	47	45
52	Orbit height	30	28	30
77	Nose-mollar angle	144°	138°	143°
<zm	Zygomaxillar angle	128°	125°	134°
SC	Symotic width	8	11	11
SS	Symotic height	2.6	5	5.5
MC	Maxillofrontal width	-	-	22
MS	Maxillofrontal height	-	-	9
	Canine fossa depth (on the right)	-	2	2.5
	Jugal bone bend height (according to Wu) (on the right)	-	15	59
	Jugal bone width (according to Wu) (on the right)	-	14	64

Table 4. Indices of craniofacial characteristics.

	Index	Murzak-Koba I	Murzak-Koba II	Fatma-Koba
8/1	Skull index	75.9	70.7	72.5
17/1	Height-Length Index	75.9	-	79.9
17/8	Height-Breadth Index	100	-	110.2
29/26	Forehead curvature index	86.2	88.4	89.6
30/27	Cranial curvature index	90.0	87.8	89.4
31/28	Nape curvature index	83.7	84.4	85.0
9/8	Cross forehead index	72.4	69.3	68.6
12/8	Cross nape index	77.9	-	81.0
48/17	Vertical cranial facial index	46.2	-	45.0
45/8	Cross cranial facial index	97.9	101.4	103.6
9/45	Frontomolar index	73.9	68.3	66.2
40/5	Face profile index	101.0	-	102.7
48/45	Upper facial index	47.2	54.2	47.9
48/46	Upper middle-facial index	64.4	72.0	66.7
54/55	Nose index	50.0	51.9	53.1
52/51	Orbit index	66.7	59.6	66.7

Ss/Sc	Symotic index	31.3	45.5	50.0

Neurocranium description

When looking from above, the neurocranium has a pentagonal shape, and the greatest width of the skull is shifted backwards, falling within the back third. Frontal and especially parietal protuberances are quite developed. It is their development that determines the pentagonal shape of the neurocranium. The male skulls may be described as elongated and comparatively narrow—dolichocranial. The female skull from Murzak-Koba is mesocranial. The longitudinal height index is high and testifies to hypsicrania (a high skull index). According to the transversal height index, it falls within the category of acrocranial skulls. Both indices suggest that the skulls are comparatively high.

The forehead of the female skull from Murzak-Koba is straight and (visually) quite wide; those of the male skulls are backward-sloping and medium-wide. Absolute dimensions of the minimal and maximal forehead width belong within the medium and large categories. According to the transverse frontal index, the skull from Murzak-Koba I is megasemic (possessing a wide forehead), and the male skulls from Murzak-Koba II and Fatma-Koba are mesosemic (having a medium-wide forehead). The frontomolar index of the female skull is medium and that of the males is small. Based on the comparatively low frontal bone curve index, we can conclude that it is quite curved. The parietal protuberances are high. The comparatively low parietal bone curve index suggests a small radius of curvature. The nape is wide.

Facial skeleton description

According to the upper facial index, the facial part of the Murzak-Koba I and Fatma-Koba skulls is wide, comparatively low, and eurienic (low face index), while that of the Murzak-Koba II skull is mesenic. Horizontal profiling angles are medium and small, i.e., the face is quite well profiled, especially in the area of maxilla alveolar ridge. Facial prognathism is also confirmed by the face protrusion index (Flower index). The craniocephalic vertical index is close to the minimum for *Homo sapiens*, i.e., there is a tendency for a combination of low face and medium-high brainpan. On the other hand, the craniocephalic transverse index is very high, which testifies to a combination of wide face and comparatively narrow brainpan.

The orbits are low and comparatively wide (chameconic). In absolute dimensions, the nose is not high but comparatively wide (chamerinic), which is also confirmed by the nasal index. The symotic index is high, which suggests a considerable height for the nasal bridge. The zygomaxillar area is of medium massiveness. The lower edge of the piriform aperture reveals a Forma anthropina, i.e., its lateral edges pass into the lower edge having a sharp shape.

We also performed a comparative analysis of a number of metric features using the multidimensional method of principal components. For this analysis, we used the following features: longitudinal (1) and transversal (8) diameters; minimal forehead width (9); frontal (29), parietal (30) and occipital (31) chords; cheekbone diameter (45); upper height (48) and width (43) of the facial skeleton; nose height (55) and width (54). The comparative analysis included only the male skulls from Murzak-Koba II, Fatma-Koba, and Upper-Paleolithic *Homo sapiens* from Europe. Two main components describe about 45 percent of the variation. Results of the analysis may be seen in Fig. 8.

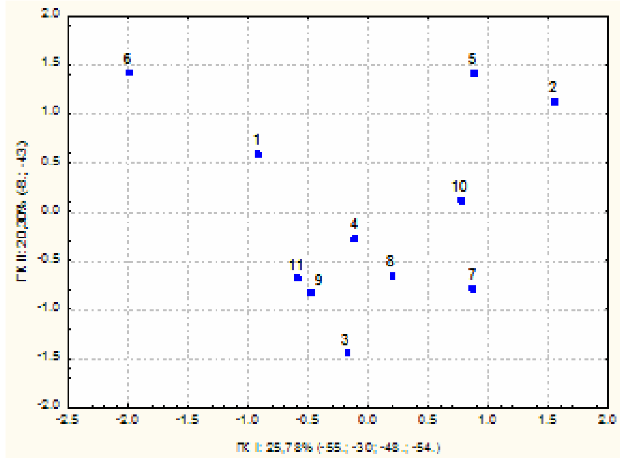


Figure 8. Spatial arrangement of skulls based on principal components (ГК) I and II. 1 – Murzak-Koba II; 2 – Fatma-Koba; 3 – Cro-Magnon I; 4 – Solutré II; 5 – Solutré IV; 6 – Combe-Cappelle; 7 – Oberkassel; 8 – Předmostí III; 9 – Předmostí IX; 10 – Mladeč I; 11 – Sungir I.

The first principal component comprises an increase in upper facial width and decrease in parietal chord, upper facial height, and nose width and height. The second component is indicative of an increase in occipital chord and a decrease in transverse diameter and upper facial width. The figure shows that the Murzak-Koba II skull is distinguished by a comparatively narrow, but high face, high and wide nose, large occipital chord, and small transverse diameter. Close to these characteristics is the skull from Combe-Cappelle. The skull from Fatma-Koba represents the complete contrast, according to the first component, i.e., it has a comparatively wide and low face with a small transverse diameter. It is evident that both males from Crimea have different craniotypes. While the first is more similar to the Combe-Cappelle type, the second is closer to the specimen from Solutré IV.

Paleopathological study

In 2004, the authors of this work had a chance to visit the grotto of Murzak-Koba, to range through the hills and mountains and cross an "icy" river near the grotto, which is now much shallower than it was in ancient times. Almost the same conditions were observed near Fatma-Koba. The analysis of pathologies revealed by the skeletons from Murzak-Koba include, first, porosities of various structures in the end sections of long bones, sometimes vertebrae, and some areas of hip bones. This could have been caused by poor diet, lack of some substances (maybe vitamins), and infections. Another noticeable manifestation of disease was some periostitis on various bones (including some sections of collar bones, humeri, cubiti, and radii); the periostitis was expressed more prominently on leg bones. Infections and frequent trauma, plus a necessity to cross very cold water may have provoked *inter alia* inflammatory processes in the periosteum.

The main skull pathologies are: fine-meshed porosis (of the *cribra* type) of the superciliary arches, tympanal parts of temporal bones, malar bones, and sometimes parietal bones, occipital squama, and some other structures. The male from Murzak-Koba II shows porosis and tumor of the tympanal plates of the temporal bones and size reduction of the external auditory canals. This implies some ear infection and a decrease in this man's hearing. The disease could have been caused by the necessity to dive in cold water, as well as winter winds, etc. We may be seeing here the consequences of adaptation to occasional cold stress.

We should also note that the individual from Murzak-Koba II shows periodontosis with a cavern from a probable cyst above the left upper first premolar. The male from Fatma-Koba has very worn teeth and small enamel hypoplasias on cutting and canine teeth.

And, finally, we have to describe the after-effects of a trauma or, perhaps, some ritual actions on the skeleton of the young woman from Murzak-Koba. It seems that distal phalanges of the fifth fingers of both her hands were cut off during her life. Adhesion was accompanied by an inflammatory process. As a result, the distal articular surface of the second phalanges show some porous hyperostosis. This trauma was described in detail by D.G. Rokhlin (Rokhlin, 1965).

Conclusions

Based on the indices of extremity proportions, we may suppose that all three individuals belonged to the mid-continent adaptive type. Intravital stature of the individuals was quite high.

In general, muscular relief in both individuals from Murzak-Koba is moderately developed and almost equally.

In terms of craniology, the Mesolithic males from Crimea are heterogeneous. While the man from Murzak-Koba is similar to the Combe-Cappelle variant, the Fatma-Koba variant is closer to the finds from Solutré.

The analysis of pathologies in the skeletons from Murzak-Koba revealed porosities in various structures and end sections of long bones, sometimes vertebrae, and some areas of the hip bones. It seems that the woman from Murzak-Koba had her distal phalanges of the fifth fingers on both hands cut off during her life.

Acknowledgments

The authors of this study would like to thank the employees of the anthropology section of the Museum of Anthropology and Ethnography of the Russian Academy of Sciences (Kunstkamera) in Saint-Petersburg and, personally, V.I. Seleznyova.

Acknowledgments

This research was made possible by the financial support of the fundamental research Program of OHPS RAS "Historical heritage of Eurasia and its modern meanings." Direction 1. The historical heritage of Eurasia from antiquity to the middle ages: steps, materials, and concepts. The project "Regularities of the formation of the anthropological composition of paleopopulations of Northern Eurasia."

References

Alekseev, V.P., 1966. *Osteometria*. Moscow, Nauka. (In Russian)

Alekseev, V.P., and Debets, G.F. 1964. *Kraniometriya*. Moscow, Nauka. (In Russian)

Debets, G.F., 1948. *Paleoantropologiya SSSR*. Moscow and Leningrad, Izdatelstvo Akademii nauk SSSR. (In Russian)

Fedosova, V.N., 1986. Obshchaya otsenka razvitiya komponenta mezomorfii po osteologicheskim dannym (osteologicheskaya metodika). *Voprosy antropologii* 76: 104-116. (In Russian)

Rokhlin, D.G., 1965. *Bolezni drevnikh liudei* [*Diseases of Ancient Men*]. Moscow, Nauka.(In Russian)

Zhirov, E.V., 1940. Kostyaki iz grota Murzak-koba. *Sovetskaya Arkheologia* 5: 179-186. (In Russian)

POSSIBLE SOCIAL-CLIMATIC CONSEQUENCES OF CIRCULATION CHANGES IN HADLEY'S CELL

Yakovleva, N. [1], *and Matygin, A.* [2]

[1]Association "Center for Industrial Waste Management," 4 Svobody sq., Kharkov, Ukraine, 61022
nat_yakovleva@mail.ru
[2] Black and Azov Seas Centre for Hydrometeorology, 89 Franzusky blvd, Odessa, Ukraine, 65009
acm32alex@mail.ru

Keywords: widening Hadley belt, climate change, precipitation, air temperature

Questions about the dependence between climate and migrations address an extremely relevant problem for today. Under these conditions, humankind must confront poorly studied, but always existing, phenomena that will apparently have an avalanche character: the increasing depletion of natural resources, risks that will bring us droughts and floods, and also the inevitable increase in global sea level. They can force many millions of people to migrate, therefore creating "climatic refugees or migrants" (Stern, 2007). Presently, research into the influence of climate on migration is, in a sense, limited and separated for a variety of reasons: indeterminacy about the real mechanisms of population migration, and an insufficiency of data and empirical research on this subject. The following approach is represented as optimum: the single historical event that involves migration can initially be interpreted by taking into account ecological factors, and later, it can be reinterpreted from an economic or political point of view. The fact of resettlement says that previously habitable territories offered living conditions that did not suit these people. Therefore, they were forced to migrate. Permanent droughts or floods could be reasons for the organized migration of people.

The dramatic events of the 12–14th centuries happening in territories of the entire Eurasian continent are well-known: an invasion of tribes led by Tatars and Mongols. Sources (Gumilev, 2004) show that the death of Khazaria is explained by a number of factors, among which feature political reasons, military defeats, and social factors. Also, climatic changes of that time became one of the essential reasons for the disappearance of the state. Humidification of the East European Plain in the second half of the 13th century led to the fact that the Volga became swollen with water, and the level of the Caspian Sea rose by 12 meters to an absolute elevation of –20 meters. Natural disasters and transgression of the Caspian Sea caused flooding of Khazarian settlements. The population, escaping from floods, huddled on Baer's mounds. Eventually, the semi-flooded country was completely crushed. It should be noted that greater or lesser humidification always influenced environmental conditions, and with that the economy of the people inhabiting the forest-steppe zone of Eurasia. At the same time, the nomadic tribes living a subsistence economy were most sensitively affected by the climatic changes. Climatic decrease in rainfall forced them to leave familiar spots and to move in search of other places suitable for their lifeways.

We should reconsider habitual explanations that invoke climatic changes, which are most sharply expressed in ideas of drought/overwetting of the Mediterranean-Black Sea-Caspian Sea corridor. The main feature of climate on Earth is the difference between the tropical and subtropical modes. Seasonal and intra-daily temperature in the tropics changes much less in comparison with subtropical climate. Another important feature of the tropics is its high moisture, unlike the dry conditions in subtropical regions. Such a pattern of temperature and rainfall is substantially defined by the large-scale atmospheric wind circulation known as the

Hadley cell. This meridional circulation cell covers half of the area of the Earth, and variability in this structure influences the life of billions of people.

Results of research (Frierson et al., 2007; Seidel et al., 2008) show that the tropical zone expanded within the last several decades. This expansion can continue, especially in the future in connection with global warming. Analyzing variability in the values of the parameters defining the spatial extent of the Hadley cell, Hu et al. (2007) estimated them at 2–4.5 degrees of latitude, and Seidel et al. (2007) reported an expansion from 5 to 8 degrees of latitude during 1979–2005.

The average annual map (http://www.mit.edu/~pog/12.003//pdf_slides/Topic12.pdf) of evaporation minus precipitation is provided in Fig. 1.

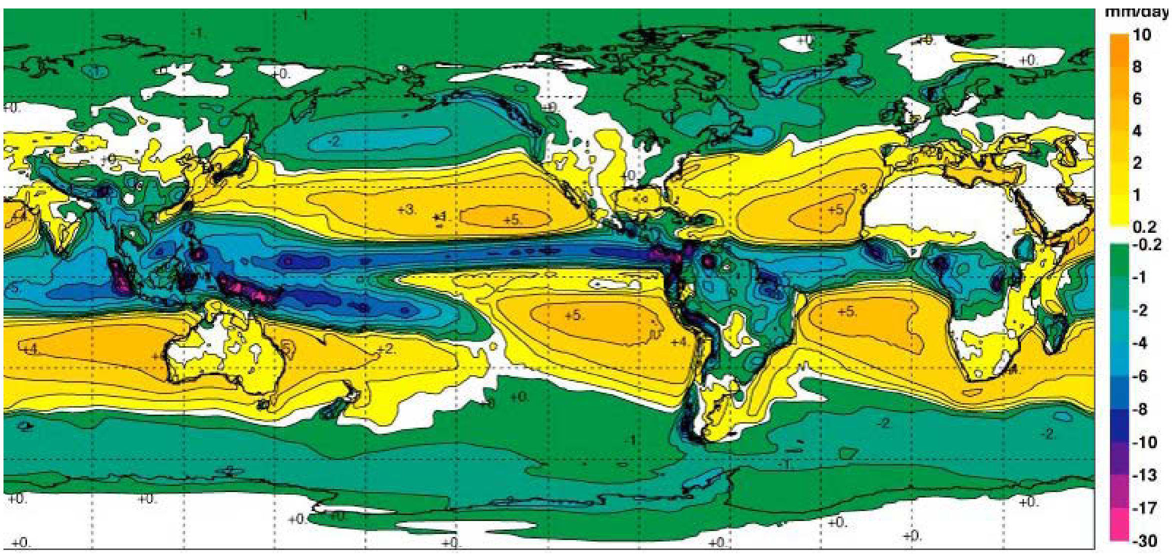


Figure 1. Evaporation minus precipitation (mm/day). Annual mean (ERA40 atlas).

Positive values indicate insufficient moisture content within the yellow and orange colored regions. We see belts of such areas at the northern and southern extremes of Hadley's cell. Within the 21st century, global warming will displace these boundaries of circulation within the Hadley cell, and the subtropical dry zone will extend toward the poles; this will reduce the amount of precipitation and humidity of the soil in the subtropics (Lu et al., 2007) and can lead to fundamental shifts in ecosystems and, concomitantly, in settlements.

Shifts in the pattern of precipitation will have apparent consequences for agriculture and water resources and can present serious difficulties in certain subtropical districts. Special concern is caused by the semi-drought-prone regions located to the north of the subtropical belts, including the Mediterranean basin. Expansion of the tropics poleward, most likely, will lead to even more severe conditions in these densely populated areas. But in other areas, the expansion can increase humidity. Expansion of the tropics also will probably drive the subtropical climatic zones toward the poles (Kushner et al., 2001), and also the storm tracks (Bengtsson et al., 2006), as well as the average position of the centers of action of the atmosphere and corresponding modes of rainfall. Increase in the width of the tropics can lead to an increase in the territories affected by tropical storms. Also, changes in the circulation of the Hadley cell (or its regional manifestation, such as the monsoons) can cause changes in the structure of ocean currents.

Therefore, a more detailed study and modeling of the variability of the spatio-temporal structure of the Hadley cell is one of the important elements in accurate forecasting of future climate, especially for the boundary of the tropical and subtropical belts.

References

Bengtsson, L., Hodges, K.I., and Roeckner, E., 2006. Storm tracks and climate change. *Journal of Climate* 19(15): 3518–3543.

Frierson, D.V.W., Lu, J., and Chen, G., 2007. Width of the Hadley cell in simple and comprehensive general circulation models. *Geophysical Research Letters* 34(18), L18804.

Gumilev, L.N., 2004. *Otkrytie Khazarii* [*Opening of Khazaria*]. Airis-press, Moscow. (In Russian)

Hu, Y., and Fu, Q., 2007. Observed poleward expansion of the Hadley circulation since 1979. *Atmospheric Chemistry and Physics* **7**: 5229–5236.

Kushner, P.J., Held, I.M., and Delworth, T.L., 2001. Southern Hemisphere atmospheric circulation response to global warming. *Journal of Climate* 14(10): 2238–2249.

Lu, J., Vecchi, G.A., and Reichler, T., 2007. Expansion of the Hadley cell under global warming. *Geophysical Research Letters* 34, L06805.

Seidel, D.J., and Randel, W.J., 2007. Recent widening of the tropical belt: Evidence from tropopause observations. *Journal of Geophysical Research, Atmospheres* 112, D20113.

Seidel, D.J., Fu, Q., Randel, W.J., and Reichler, T.J., 2008. Widening of the tropical belt in a changing climate. *Nature Geoscience* 1: 21–24.

Stern, N., 2007. *The Economics of Climate Change*. Cambridge University Press, Cambridge.

THE NORTHERN CASPIAN SEA: ENVIRONMENTAL CONSEQUENCES OF THE CLIMATE CHANGE DURING THE KHVALYNIAN EPOCH (EVIDENCE FROM THE BOREHOLES)

Yanina, T. [1], Sorokin, V. [2], Bezrodnykh, Yu. [3], and Romanyuk, B. [4]

[1] Faculty of Geography, Lomonosov Moscow State University, 1 Leninskie Gory,
Moscow, Russia, 119991
didacna@mail.ru
[2] Geological Faculty, Lomonosov Moscow State University, 1 Leninskie Gory,
Moscow, Russia, 119991
vsorok@geol.msu.ru
[3,4] Morinzhgeologiya Company, Riga, LV-1019, Latvia
[3,4] paleo@inbox.ru

Keywords: Caspian Sea, drilling data, radiocarbon dating, transgressions, regressions, correlations, global climatic changes

Introduction

In the North Caspian region, the Upper Pleistocene sedimentary series has been studied mostly within the limits of oil-producing fields during the course of prospecting work. This paper is based on the processing of high and low frequency seismic-acoustic profiles, as well as on cone penetration tests. The results have provided a basis for sequence stratification, and the identified lithological and stratigraphic units being traced all over the region and beyond it.

Taking into account the above-mentioned data, an exploratory boring to a depth of 80 m was carried out in four areas (Fig. 1).

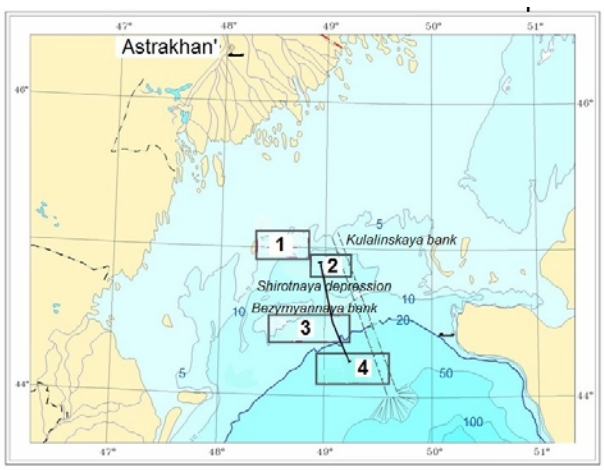


Fig. 1. Northern Caspian Sea. Area of research.

As is evident from the data of the seismic-acoustic survey, the Upper Pleistocene series of the Northern Caspian deposits includes several seismic-stratigraphic units separated by distinct reflecting interfaces; the inner structure of some units permits us to distinguish subunits within them. The identified units and subunits, as well as reflecting horizons, are easily correlatable over the entire surveyed area, and they are in good agreement with sequences penetrated by drilling.

Results

The Khvalynian sequence occurs on top of a series of older Caspian sediments of complicated structure up to 30 m thick (Fig. 2).

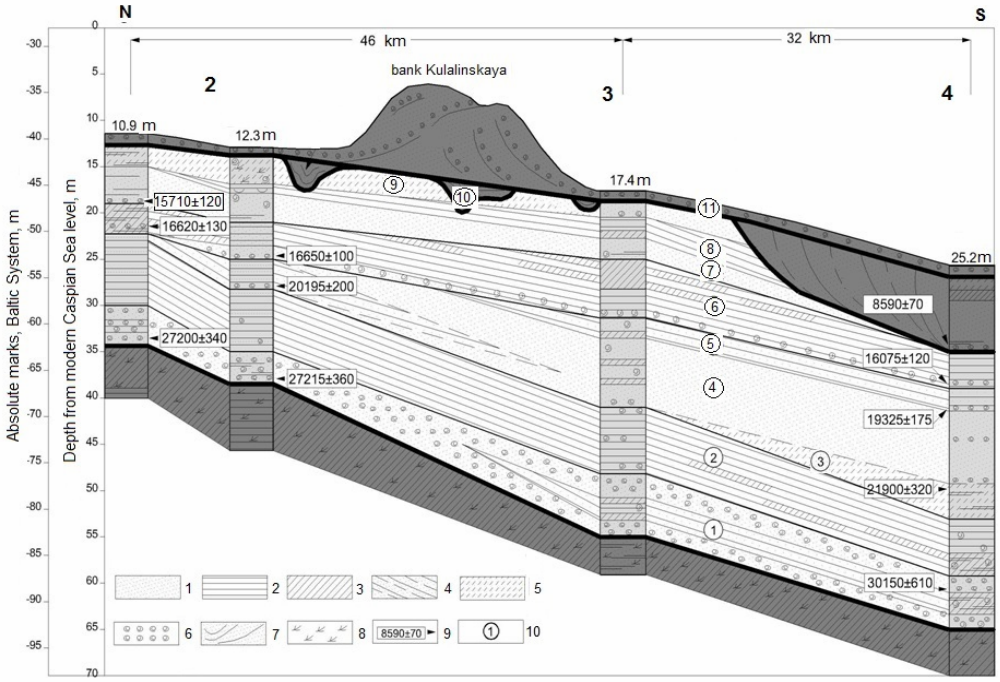


Figure 2. Structure of the deposits along transect profile (see Fig. 1) between areas 2 – 3 – 4. 1 = sand, 2 = clay, 3 = loam, 4 = layers of clay and sandy deposits, 5 = sandy loam, 6 = shells and debris, 7 = a complex filling of the paleo-depressions and paleo-valley of the Volga river, 8 = inclusions of vegetal remains, 9 = radiocarbon dates, 10 = number of layers, reflecting paleogeographical events.

It is separated from the Upper Khazarian deposits by the well-pronounced Atelian regressive sediments. The regression is readily recognizable in the seismic-acoustic profiles by a number of distinct erosional incisions under the base of the Khvalynian sediments. The series is variable in lithology, with alternating layers of clay loams, sandy loams, and clays; they contain iron monoxide in the form of hydrotroilite. The deposits include plant detritus arranged along the layers. They contain freshwater mollusks *Dreissena polymorpha polymorpha*, *Valvata piscinalis*, *Theodoxus pallasi*, *Limnea stagnalis*, as well as terrestrial gastropods.

The Atelian formations are overlain by a Khvalynian series of complicated structure. There is a layer of shell and sandy deposits 2.5 to 5.0 m thick at its base (Fig. 2, layer 1). The fauna is dominated by *Didacna subcatillus*, occasionally found are *Didacna zhukovi*, *D. parallella*, *Monodacna caspia*, *Micromelania caspia*, *Clessiniola variabilis*, and *Theodoxus pallasi*; *Dreissena* shells are numerous. The shells recovered from that layer were dated by the scintillation radiocarbon method and yielded a ^{14}C age within the interval of 27,200±340 to 31,600±420 yr BP (33,860±1490 to 36,580±340 cal yr BP). The deposits suggest a shallow-water basin—the initial stage of the Khvalynian transgression. Judging from the shell appearance (medium to large size, with thick valves), the water temperature was moderately warm.

On top of the above-described shallow-water deposits, there are marine clays 8 to 10 m thick with sand interbeds varying in thickness (layer 2). That part of the sequence may be interpreted as indicative of a continuing transgression. The series contains Early Khvalynian shells *Didacna protracta protracta*, *D. protracta submedia*, *D. subcatillus*, *Dreissena rostriformis distincta*, and *Dreissena rostriformis compressa*. In the mollusk assemblage, there are numerous subspecies known as dwellers of relatively deep water (*D. protracta submedia*, *Dreissena rostriformis compressa*); along with the sediment composition, their presence implies a deep-water stage of the Khvalynian transgression. The clays are overlain by a predominantly sandy layer up to 8 m thick that suggests a drop in the Khvalynian basin level. In the southern part of the area under study (No. 4), the faunal material includes *Didacna parallella*, *D. subcatillus*, *D. protracta*, *D. zhukovi*, *Monodacna caspia*, *Hypanis plicatus*, *Adacna laeviuscula*, *Dreissena polymorpha*, *Clessiniola variabilis*, *Micromelania caspia*, and *Theodoxus pallasi*. The lower boundary of the series is dated by radiocarbon to the interval of 22 to 20 ka BP (layers 3–4). At area No. 4 and in its vicinity, the sands are covered by a layer of sandy loam up to 2 m thick (layer 5). Among the shells occurring at its base, there have been identified *Didacna protracta protracta*, *D. subcatillus*, *Hypanis plicatus*, and *Dreissena rostriformis distincta*. A sample from the layer's base was dated by ^{14}C at 19,325±75 yr BP. The deposition of this layer was related to a short-term rise in the Khvalynian sea level.

Clays about 5 m thick (layer 6) overlying the eroded surface of that layer contain some shells of Khvalynian mollusks (*Didacna protracta*, *D. parallella*, *D. ebersini*, and *Monodacna caspia*), as well as various *Dreissena*. Both lithology and composition of the mollusk fauna suggest that the clays were deposited in a deep-water basin corresponding to a transgressive stage of the Khvalynian Sea. Mollusk shells recovered from the base of the layer were ^{14}C dated to the interval of 16,650±100 to 16,075±120 yr BP. The clay member is overlain by a 3–4 m layer (layer 7) of predominantly sandy composition. Quite common are inclusions of small-size *Didacna parallella*, fragments of *D. praetrigonoides*, *Hypanis plicatus*, and *Micromelania caspia*. There is a single radiocarbon date (15,710±120 yr BP). This layer is covered by a layer of sandy loam and clay deposits (layer 8) with rare Caspian gastropods and fragments of *Didacna praetrigonoides* and *Monodacna caspia.* The overlying sedimentary complex (layer 9) is noted for its chaotic arrangement of discontinuous reflecting horizons. The sediments are mostly deltaic sands and clayey silts deposited in shallow water during the Caspian regression. The total thickness of the member varies from 1–2 m to 10 m. The sediments include small-size shells of *Didacna parallella*, *D. praetrigonoides*, *Hypanis plicatus*, and *Micromelania caspia*, as well as numerous fragments of indeterminable shells. The radiocarbon dates lie in the range between 12,870±100 and 11,220±100 yr BP.

The complex of deltaic deposits is overlain by a series attributed to the Mangyshlakian regression of the Caspian Sea (layer 10). Their occurrence is clearly seen in seismic-acoustic profiles as paleo-depressions; the drilling cores display poorly consolidated clay, peat, sapropels, silts, and sands. Various organic materials are present in abundance. They are mostly mollusk shells varying in the degree of preservation and locally arranged in clusters along the layers. The malacofauna includes inhabitants of both low salinity basins (*Dreissena*, *Monodacna*, *Adacna*, and *Hypanis*), and fresh-water ones (*Unio*, *Viviparus*, *Valvata*, *Lymnaea*, and *Planorbis*). The radiocarbon age of the sediments infilling the paleo-depressions falls in the range of 9860–6350 yr BP; that makes them attributable to the initial stages of the Holocene. The mantle of Novocaspian deposits (layer 11) with its Holocene mollusk fauna lies at the top of the sequence.

Discussion and conclusions

It seems from the above that most of the transgressive and regressive events in the Khvalynian Caspian history have been recorded in the Upper Pleistocene sequence of the Northern Caspian basin. The records permit us to perform a comprehensive reconstruction of the Caspian against the background of global climate changes. We correlate the Atelian regression with the first maximum of the Valday glaciation (MIS 4) and with the beginning of the MIS 3 interglacial warming (Bezrodnykh et al., 2017). The onset of the global warming of interstadial rank resulted in a certain increase in the positive constituent of the Caspian water balance both due to increasing runoff from the drainage basin (Panin et al., 2017) and to changes in the rainfall-evaporation regime over the water area. Those changes brought about the first stage of the Khvalynian transgression recorded in the borehole sequences as deposits of a shallow and relatively warm (Fig. 2, layer 1) and those of a deeper and relatively cold (layer 2) marine basin. Radiocarbon dates support the attribution of that event to the MIS 3 interval.

The Last Glacial Maximum (MIS 2) was marked by exceedingly cold and dry environments even in the south of the East European Plain (Velichko, 2012), hardly favorable for a transgressive regime of the Caspian. Lowering of its level may be inferred from the presence of sandy layers in the Khvalynian series (layers 3–4). Radiocarbon dates obtained for deposits adjoining Khvalynian ones provide support for their attribution to MIS 2. The ice sheet decay, together with permafrost thawing, both resulting from the global climate warming, induced the rise of the Khvalynian Sea level. The first phase of the transgressive changes in the sea level is evidently recorded in the predominantly clayey unit (layer 5), the lower boundary of the latter being dated at about 19 ka BP. A transition to an active transgressive regime after a short-term fall of sea level was marked by erosion that is clearly seen at the base of the overlying clayey series. The sea-level fall seemingly corresponds to a sharp cooling and increase in the climate continentality known as the Oldest Dryas; according to reconstructions, the time was marked by a decrease in runoff from the Caspian catchment area (Thom, 2010).

The warmer intervals of Bølling and Allerød were noted for an increased runoff (Thom, 2010; Panin and Matlakhova, 2015) and corresponded to the next transgressive stage in the Khvalynian Sea history. In the sedimentary sequence, the stage corresponds to the clay series (layer 6), as is confirmed by numerous radiocarbon dates obtained on mollusk shells. A series of so-called "chocolate" clays was accumulating in the Volga estuary and in depressions of pre-Khvalynian relief, presumably due to active thawing of permafrost and a great mass of fine material transported by rivers. A high rate of accumulation together with a considerable concentration of suspended materials account for the absence of mollusk fauna in the clays. The deposits of that transgressive stage are widely distributed in the coastal zone. The dates obtained using radiocarbon and thorium–uranium (Arslanov et al., 2016), and optically stimulated luminescence (Tkach et al., 2016) methods are close to each other.

A remarkable climatic event of the Late Pleistocene was the Younger Dryas, when vegetation in Europe was dominated by periglacial formations, not unlike those of glacial time (Grichuk, 1982). In the Khvalynian history, it corresponds to a regressive stage, presumably due to considerably reduced river discharge (Thom, 2010). In the Upper Pleistocene sequences in the Northern Caspian, the sea-level drop was marked by the deposition of a sandy layer (layer 7). The very first dramatic warming of climate (generally taken as indicator of the Pleistocene-Holocene boundary) resulted in a high stand of the Caspian level—the last stage of the Khvalynian transgression (layer 8). The presence of mollusks in abundance, and their larger and more massive shells, resulted probably from more favorable environments, in particular, higher water temperature as compared with that of the Early Khvalynian basin.

The regressive trend began to develop against the background of increasingly dry climate in the region, as is apparent from the pollen assemblages (Bolikhovskaya and Kasimov, 2010) distinctly showing the transition from diversified tree species to xerophytic grasses and herbs. In the borehole cores, the climatic changes are recorded by deposition of deltaic sediments (layer 9) and later by formation of depressions intruding into Khvalynian deposits and filled with freshwater sediments. This stage is known as the Mangyshlakian regression, dated to the interval of 9860 to 6350 ^{14}C yr BP (Bezrodnykh et al., 2016). Such was the Caspian response to increasing continentality of the climate in the Boreal period of the Holocene.

Acknowledgements

The authors are thankful to our colleagues from the geochronological laboratories of the Moscow and St.-Petersburg state universities, the Institute of Geography RAS (Moscow), and specialists from the Lawrence Livermore National Laboratory (USA), for performing radiocarbon dating of core samples. The work was financially supported by the Russian Science Foundation (Project № 16-17-10103).

References

Arslanov, Kh.A., Yanina, T.A., Chepalyga, A.L., Svitoch, A.A., Makshaev, R.R., Maksimov, F.E., Chernov, S.B., Tertychnyi, N.I., and Starikova, A.A., 2016. On the age of the Khvalynian deposits of the Caspian Sea coasts according to ^{14}C and ^{230}Th/^{234}U methods. *Quaternary International* 409A: 81–87.

Bezrodnykh, Yu.P., Romanyuk, B.F., Sorokin, V.M., and Yanina, T.A., 2017. First data on the radiocarbon age of the Atelian deposits in the North Caspian region. *Doklady Earth Sciences* 473(1): 277–280.

Bezrodnikh Y.P., Sorokin V.M., 2016. On the age of the Mangyshlakian deposits of the Northern Caspian Sea. *Quaternary Research* 85(2): 245–254.

Bolikhovskaya, N.S., and Kasimov, N.S., 2010. The evolution of climate and landscapes of the lower Volga region during the Holocene. *Geography. Environment. Sustainability* 3(2), 78–97.

Grichuk, V.P., 1982. Rastitelnost Evropy v pozdnem pleistotsene [Vegetation of Europe in the late Pleistocene]. In I.P. Gerasimov and A.A. Velichko, eds., *Paleogeografiya Evropy za poslednie sto tysyach let* [*Paleogeography of Europe for the Last Hundred Thousand Years*], Nauka, Moscow, pp. 79–85. (In Russian)

Panin, A., and Matlakhova, E., 2015. Fluvial chronology in the East European plain over the last 20 ka and its palaeohydrological implications. *Catena* 130: 46–61.

Panin, A., Adamiec, G., Buylaert, J.-P., Matlakhova, E., Moska, P., and Novenko, E., 2017. Two Late Pleistocene climate-driven incision/aggradation rhythms in the middle Dnieper River basin, west-central Russian Plain. *Quaternary Science Reviews* 166: 266–288.

Thom, N., 2010. A hydrological model of the Black and Caspian Seas in the late Pleistocene and early-middle Holocene. *Quaternary Science Reviews* 29(23–24): 2989–2995.

Tkach, N., Murray, A., Kurbanov, R., Yanina, T., Svitoch, A., and Sychev, N., 2016. First optically stimulated luminescence dating results of Lower Volga sediments (Srednaya Akhtuba). In: A.S. Gilbert and V. Yanko-Hombach, eds., *Proceedings of the Fourth Plenary Conference IGCP 610 "From the Caspian to Mediterranean: Environmental Change and Human Response during the Quaternary."* Tbilisi, Georgian National Academy of Sciences, p. 180–184.

Velichko, A.A., 2012. *Evolutsionnaya geografiya: problem i resheniya* [*Evolutionary Geography: Problems and Decisions*]. GEOS, Moscow. (In Russian)

BIODIVERSITY OF THE VOLGA RIVER DELTA MOLLUSKS IN THE HOLOCENE

Yanina, T. [1], *and Svitoch, A.* [2]

[1, 2] Faculty of Geography, Lomonosov Moscow State University, 1 Leninskie Gory, Moscow, Russia, 119991
[1] didacna@mail.ru
[2] a.svitoch@mail.ru

Keywords: Holocene, Volga delta, water basins, Caspian Sea level, mollusks, biodiversity

The characteristic feature of the Caspian Sea is its unstable sea level. During the Holocene, it has been fluctuating within a range of almost 50 meters from the Mangyshlak regression to the maximal stage of the Novocaspian transgression. The existing material on sea-level fluctuations allows us to conclude that the main reason for Caspian instability is the climate. At present, the role of human impact has increased greatly. The modern biodiversity of the Caspian Sea and the Volga delta simply reflects a complicated history of paleo-Caspian transgressions and regressions and, recently, human activity. The Holocene Caspian history includes the Mangyshlak regression and several stages of the Novocaspian transgression. The Mangyshlak basin formed about 9.8–6.15 ky ago. The level of this lake was –80 m (Mayev, 2006). Its waters used to cover only depressions of the Middle and Southern Caspian. The Novocaspian transgression maximum emerged approximately 5–6 thousand years ago. The sea level was –19 to –20 m. In the 20th century, it has been fluctuating within the range of almost four meters, approximately from –25 m in the beginning of the century to –29 m in 1977. At the end of the 20th century, sea level soared, and in the beginning of the 21st century, it began to drop again. The Caspian Sea level fluctuations have influenced the development of the Volga delta and the biodiversity of its water basins.

In spite of its geological youth, the Volga delta is a territory with a complex development and very dynamic hydrological and lithodynamic processes. The dominating regime is active accumulation of diverse deltaic deposits. These processes are especially active within the avandelta and the seaward part of the delta. The seaward delta is the youngest land formation of the Volga mouth. It is represented by a low, partly flooded kultuk-delta plain, split by numerous river arms and separated from the avandelta, located to the south, by a migrating marginal sea-land zone. The low plain was recently the bottom of the kultuks, separated by erosional troughs. Its surface is composed of modern kultuk and deltaic sediments that overlie more ancient deltaic and avandeltaic formations. The avandelta is the most dynamic and actively re-forming river-mouth structure of the Volga. It has a southward sloping surface and is composed of deltaic deposits that change facies into shallow-water deposits of the North Caspian Sea. The shoal of the avandelta is characterized by a wide distribution of hygrophyte plants that are closely connected to the silt, silty sand, and siltstone lithofacies. At the depth of 1.5–2 m, the plants disappear, and the sediments become sandier and sorted.

The water salinity is not stable; it changes from 0.5 to 3–5‰ due to Volga runoffs. Many unique Caspian species rarely occur in this part of the Caspian because of low water salinity. Almost all the waters of northern part can be regarded as an oligohaline ecosystem. Factors defining the geographic distribution of mollusks include: salinity, ground and related gas regime of the benthic layer, and distribution and population of the major benthos consumers. Deltaic water bodies of different size and configuration, with diverse hydrological and hydrochemical regimes, and possessing various bottom sediments, are inhabited by different mollusks. The predeltaic part of the Volga is characterized by sandy grounds, relatively deep environments, and current activity. In the psammophilic biocoenosis that inhabits it, there are rare *Dreissena* among the mollusks. Active branches, pits ("yamas"), and reaches are characterized by silty, sandy grounds with pelo-reophilic biocoenoses of *Sphaerium*, *Viviparus*, *Dreissena*, and *Unio*. Former branches, bays, inlets with a stagnant environment and muddy grounds are inhabited by pelophilic biocoenoses with *Sphaerium*, *Viviparus*, *Anodonta*, and *Unio*.

Grounds covered with macrophytes are occupied by phytophilic biocoenoses. Shallow-water swamps and bogs are characterized by mixed pelophilic-phytophilic molluscan assemblages. Long and narrow ilmens between Baer knolls with muddy lifeless grounds are occupied by single *Unio* and *Anodonta*. Rushy shore fronts are inhabited by abundant terrestrial forms; *Planorbis*, *Physa*. *Dreissena polymorpha*, *Anodonta complanata*, *Sphaerium corneum*, *Pisidium*, *Viviparus viviparus*, and *Valvata piscinalis* are on muddy grounds of bigger ilmens; rare small *Unio pictorum* are on sandy grounds. In shallow-water rushy ilmens with mud and plant remnants, the mollusks *Planorbis* and *Lymnea* occur only in nearshore rushy areas. The poloi zone with plants, hosts a nearshore assemblage with *Lymnea* and *Planorbis*. The lower part of the delta branches with silty, sandy grounds covered with macrophytes is habited by freshwater mollusks: *Dreisena polymorpha*, *Dr. bugensis*, *Theodoxus*, *Viviparus*, *Hydrobia*, *Valvata*, and *Lithoglyphus*; rare Caspian euryhaline species: *Monodacna edentula*, *Adacna laeviuscula*, and *Hypanis plicatus*.

All Caspian species inhabiting the Volga delta are strongly euryhaline (tolerate salinities between 0.3–12‰) and oxiphilic; they prefer silty, sandy grounds and weak currents. *Monodacna colorata* migrated to the Volga delta from Volga reservoirs where it had been previously acclimatized. Kultuks with sandy, silty grounds are characterized by the freshwater mollusks *Unio pictorum*, *Anodonta complanata*, *Viviparus viviparus*, *Valvata piscinalis*, *Sphaerium corneum*, *Pisidium*, *Dreissena polymorpha*, and the euryhaline Caspian mollusks *Monodacna edentula* and *Adacna laeviuscula*. The freshwater prodeltaic area is habited by the freshwater species *Unio pictorum*, *Anodonta complanata*, *Viviparus viviparus*, *Valvata piscinalis*, *Sphaerium corneum*, *Pisidium*, *Dreissena polymorpha*, and euryhaline Caspian mollusks. The slightly brackish-water zone with silty, sandy sediments is characterized by abundant *Dreissena polymorpha*, far less abundant *Monodacna edentula* and *Adacna laeviuscula*. Sandy ground with detritus is characterized by the same molluscan composition but lower abundances. *M. edentula* and *Ad. laeviuscula* predominate in the brackish-water zone.

Comprehensive research of the Damchik section (Astrakhan' Biosphere Reserve) conducted by the authors allowed us to obtain interesting data on the recent history of the modern seaward part of the delta and avandelta of the river Volga. The Holocene malacofauna of the delta includes all modern species except for those that penetrated from the Azov and Black Sea basins by anthropogenic means. The distribution of mollusks in Holocene water bodies of the Delta was similar to that of the modern one. This is the basis for paleoenvironmental reconstructions. The malacofaunistic analysis revealed that the fauna forms specific combinations that characterize different hydrological and eco-facies environments of sedimentation.

During the Mangyshlak regression, the Volga River delta was located at the latitude of the Agrakhan spit. This resulted in active erosion. Two wide channels were formed in the central and eastern parts of the Volga-Akhtuba valley that served as pathways for river discharge. The sequence of deposits with different types of mollusk characterized the water basin changes during the Holocene. The sequence of deposits reflects three large stages of delta development in accordance with Caspian Sea level changes. The small-scale deposit gradation reflects the unstable sea-level condition during each stage (Yanina et al., 2011).

The modern Caspian ecosystem is the result of long-term biological evolution. For a long time, all levels of biodiversity formed and interacted naturally without human influence. The development of human civilization resulted in a strong anthropogenic impact, which interferes with the natural course of events. Humankind has become a powerful external factor destabilizing the processes of the Caspian ecosystem.

The paper is a contribution to the Russian Geographical Society Project "Complex expedition Deltas of rivers of the south of Russia" and IGCP 610 Project "From the Caspian to Mediterranean: Environment change and human response during the Quaternary."

References

Mayev, E.G., 2006. Extremalnaya regressiya Kaspiyskogo morya v rannem golotsene [Extreme regression of the Caspian Sea in the Early Holocene]. In *Extremalnye gidrologicheskie sobytiya v Aralo-Kaspiyskom regione* [*Extreme Hydrological Events in the Aral-Caspian Region*]. Moscow, Rosselkhozakademia, pp. 62–66. (In Russian)

Yanina, T.A., Svitoch, A.A., and Wesselingh, F.P., 2011. Bioraznoobrazie malakofauny Kaspiyskogo morya v golotsene [Biodiversity of the Caspian Sea mollusks in the Holocene]. *Vestnik Moskovskogo Unviersiteta, Seriya Geografiya* 2: 38–48. (In Russian)

MEIOBENTHOS AS AN INDICATOR OF GASEOUS HYDROCARBON RESERVOIRS UNDER FLOOR OF THE BLACK SEA

Yanko-Hombach, V. [1, 2], *Kadurin, S.V.* [3], *Kravchuk, A.O.* [4], *Kulakova, I.I.* [5]

[1, 4] Department of Physical and Marine Geology, 2 Shampansky Per., Odessa I.I. Mechnikov National University, Odessa 65058, Ukraine
[1] valyan@onu.edu.ua
[4] aokravchuk@gmail.com
[2] Avalon Institute of Applied Science, 976 Elgin Ave, Winnipeg MB R3E 1B4, Canada
valyan@avalon-institute.org
[3] Department of Engineering Geology and Hydrogeology, 2 Shampansky Per., Odessa I.I. Mechnikov National University, Odessa 65058, Ukraine
kadurinsergey@yandex.ru
[5] Institute of Marine Biology of the National Academy of Sciences of Ukraine, 37 Pushkinskaya Str., Odessa 65011, Ukraine
kulakovaira@list.ru

Keywords: Foraminifera, Nematoda, Ostracoda, tectonic settings, monitoring

Introduction

In the water of the Black Sea, about 80 billion m^3 of methane are dissolved, and this condition persists despite a full cycle of water renewal every 400–2000 years. This indicates a powerful continuous flow of hydrocarbon gases (HG), and hence the presence of their reservoirs beneath the seabed (Sozansky, 2013). Vertical migration of HG occurs through tectonic ruptures (e.g., faults, cracks) that form within weakened zones in the sedimentary cover (Tari et al., 2000) that act as "chimneys" for upwardly migrating fluids, such as HG, H_2S, and CO_2 that saturate the bottom sediments (Shnyukov et al., 2013). Gasometric surveys of HG have enabled to establish promising on the HG tectonic structures represented by Cretaceous-Paleogene anticlines (Tkachenko et al., 1974). One of them is the Golitsyn Uplift, where in 1975 the first gas deposit on the northwestern shelf of the Black Sea was explored. Under the supervision of G.G. Tkachenko, the basics of the survey were developed in the 1970s at the Department of Physical and Marine Geology and the Research Laboratory of Marine Geology and Geochemistry of Odessa I.I. Mechnikov National University. Based on thousands of samples of bottom sediments and water, the survey demonstrated the complete absence of any interrelationship between the distribution of HG and the lithology of the bottom sediments. But it clearly showed that increased concentrations of HG relate to tectonic structures, and this connection enabled the conclusion about the epigenetic deep origin of HG (Tkachenko et al., 1974).

Methane in the Black Sea has a double nature. On one hand, it contains the so-called fossil (deep) methane, emerging from the depths of the Earth, but on the other, it contains also biogenic methane produced by bacteria (Sovga and Lyubartseva, 2006). These two types of methane have a number of characteristic differences, for example, the lack of homologues in biogenic methane (Lein and Ivanov, 2005).

Long-term emission of methane in the marine environment acts upon taxonomic and quantitative characteristics of biota. Rapid penetration of methane into fish bodies disrupts vital functions adversely affecting breathing, nervous, and hematopoietic systems, as well as enzymatic activity up to the death of the organism in a relatively short period of time (Patin, 2004). The influence of methane on benthic organisms is still poorly understood (Yanko-Hombach et al., 2017).

The main goal of this paper to identify the influence of HG on meiobenthic organisms that possess hard shells (foraminifera, ostracoda) and those that do not (nematodes) by conjugative gasometric, geochemical, and meiobenthic survey of the Black Sea seabed with consideration of its tectonic features. Such a survey is characterized by the simplicity of the technique, high productivity, and low cost.

To achieve this goal, we determined (1) tectonic features of the seabed, (2) physico-chemical parameters of the bottom water, (3) lithological and geochemical characteristics of the bottom sediments, (4) composition and concentrations of HG and CO2 in the bottom sediments, (5) quantitative and qualitative (taxonomic) distribution of foraminifers, ostracods, and nematodes in the bottom sediments, and (6) correlated abiotic and biotic parameters listed in points 1–5. This enabled us to integrate the results, determine general patterns of biotic distribution, and compare results with other marine basins.

The present research is a continuation of the previous one (Tkachenko et al., 1974), but conducted at a new level using modern equipment and methods. It has a fundamental and an applied significance. First, it promotes a better understanding of biota behavior and survival under extreme environmental conditions, and second, it can serve as an important search criterion for HG accumulations stored under the sea bottom.

Study area

The study area is located in the center of the northwestern part of the Western Black Sea depression within a depth range of 70–905 m (Fig. 1).

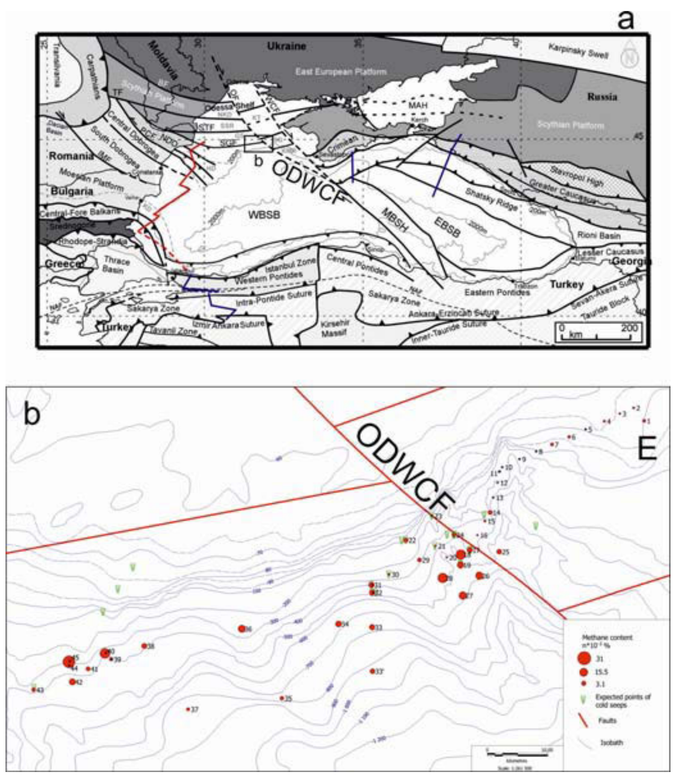


Figure 1. a. Tectonic map of the Black Sea and adjacent coast (Mureşan, 2014); Study area is divided into western (W) and eastern (E) parts by the ODWCF (Odessa Western Crimea Fault).

The Western Black Sea depression (with its sub-oceanic and oceanic crust) is separated from the Eastern Black Sea basin (with its sub-oceanic and oceanic crust surrounded by a refined continental crust) by the Andrusov Ridge (with its continental crust). The Andrusov Ridge is complicated by a system of faults with inclinations both to the west and to the east at angles of 30°–45° (Ermakov, 2005). The western boundary separating the Andrusov Ridge from the Western Black Sea depression passes through a deep-seated Odessa Fault that continues from the shelf to the continental slope and then to the deep-water basin, where it is transformed into the West Crimean fault. Therefore, the ODWCF (Odessa Western Crimea Fault) abbreviation is adopted for this tectonic structure (Fig. 1a, b).

A series of sublatitudal smaller faults that determine the transition from the shelf to the continental slope adjoin the ODWCF on the western side. They originated due to tectonic stretching of the Western Black Sea depression and serve as "chimneys" for HG migrating upwards and forming gas flares (Yanko-Hombach et al., 2017).

The ODWCF divides the study area into eastern and western parts (Fig. 1b). The eastern part lies in the outer shelf area, while the western part, in addition to the outer shelf, also includes the continental slope. Both parts are considered separately and compared with each other.

Materials and methods

The direction of sailing and the position of the sampling stations were laid out in full accordance with distributional patterns and coordinates of the cold seeps provided in Egorov et al. (2003), and they were planned to capture the response of biota to different environmental conditions. The material was obtained in the course of the FR6 EU funded HERMES-BS-ONU 01-2008 cruise performed on 19–27 September, 2008, in the northwestern part of the Western Black Sea basin using the Ukrainian Research Vessel "Vladimir Parshin."

To reach this goal, the echo-sounder mapping of bottom relief was carried out in conjunction with water and sediment observations. Forty-six stations at water depths of 71–905 m were sampled by grab and gravity core (Fig. 1b). At the majority of the stations, the salinity and temperature of bottom water were measured. Water and sediment samples for hydrochemical, lithological, geomechanical, mineralogical, gasgeochemical, organic carbon, liquid hydrocarbons, as well as meiobenthos (e.g., Foraminifera, Ostracoda, Nematoda) were collected and investigated in the laboratory by respective methods for further statistical treatment (Yanko-Hombach et al., 2017

Results and discussion

Environmental parameters

There is no significant difference in all measured physico-chemical, grain-size, geochemical, and lithological parameters of the water and bottom sediments on either side of the ODWCF. The only significant difference is the content of HG and CO2, which are much higher in the western part.

Meiobenthic parameters

In the study area, ten groups of meiobenthos have been recorded: Foraminifera, Nematoda, Harpacticoida, Ostracoda, Halacaridae, Turbellaria, Oligochaeta, Polychaeta, Bivalvia and Gastropoda (Fig. 2, 3), among which organisms stained by Bengal Rose were present in all groups, ie, were alive at the time of sample collection.

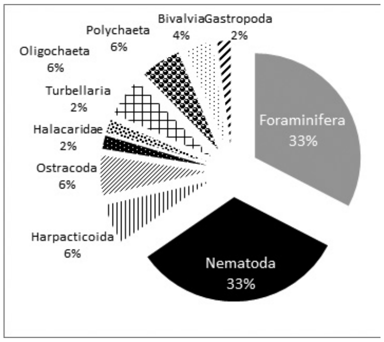


Figure 2. The proportion of meiobenthos groups in the total collection.

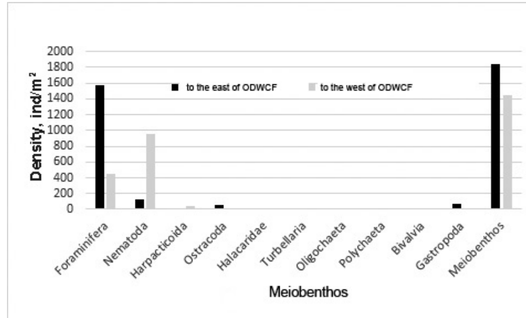


Figure 3. The average population density of individual groups of meiobenthos collected to the east and west of the ODWCF.

Foraminifera

A total of 29 species of benthic foraminifera (one of them in the open nomenclature) from 20 genera, 10 families, and 5 orders were identified. The greatest and least numbers of foraminifera were found at the stations located to the east and west from the ODWCF, respectively. The average abundance and species diversity of foraminifera is significantly higher to the east than to the west of the ODWCF. On both sides of the ODWCF, polyhaline species predominate, while holeuryhaline species with the widest ecological spectrum prevail on west of the ODWCF. This is quite natural, since such species adapt more easily to the variable environmental conditions, including stress. To the east of the ODWCF, the epibenthic polyhaline epifaunal species *Ammonia compacta* dominates. To the west, polyhaline infaunal species *Lagena vulgaris*, *Fissurina fragilis*, and *Parafissurina lateralis* prevail. This shows a significant difference in environmental living conditions on both sides of the ODWCF; such conditions are more stressful on the west. The presence of sulfides (mostly pyrite) in foraminiferal tests from the stations located to the west of the ODWCF is in a full agreement with this assumption.

Nematods

Nematodes are represented by 44 free-living benthic species (9 of them in the open nomenclature) from 26 genera, 17 families, and 6 orders. Most species are marine, some of them can withstand brackish water conditions. Of these, 16 species are adapted to oxygen deficiency (Sergeeva et al., 2014). In contrast to foraminifera, their average density and diversity are significantly higher to the west than to the east of the ODWCF. To the east of the ODWCF, only six species were found, while to the west, 39 species were present.

In the east, four species of nematodes are adapted to oxygen deficiency, and in the west the number of such species is twice as large. The highest density of nematodes was present at Station 40 (13,900 ind./m2), where the methane content in the bottom sediments was the highest among all other stations. The Nematoda assemblage is dominated by Sabatieria abyssalis, which is well adapted to hypoxic-anoxic conditions. At the same time, the abundance and diversity of foraminifers and ostracods here is very low. In general, the correlation of abiotic and biotic parameters shows a negative response of biota to the increase in HG in bottom sediments.

Conclusions

Three main problems will be discussed in the presentation: (1) the origin of HG in the bottom sediments of the study area and their relationship to tectonics, (2) the impact of HG on the quantitative and qualitative (taxonomic) distribution of meiobenthos and comparison of such impacts to other basins, and (3) the possibility of using distributional patterns of meiobenthos for contouring the HG clusters under the seabed.

The results here obtained are new for the scientific exploration of the area and require further study to be better understood. This work should be considered pilot research..

Acknowledgements

We thank the staff of the R/V "Vladimir Parshin" for their help in obtaining sediment material. Prof. E.G. Konikov is thanked for the grain-size analysis. Academician of the National Academy of Sciences of Ukraine E.F. Shnyukov is thanked for the ongoing discussion and critical remarks that helped to improve the manuscript. We are much obliged to Prof. N.S. Sergeeva for her help in discussing the environmental characteristics of nematodes.

The work was executed with the financial support of the EU-FP6 project HERMES "Hotspot Ecosystems Research on the Margins of European Seas" (2006–2010) and the State Budget Theme #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" financed by the Ministry of Education and Science of Ukraine. This study is a contribution to IGCP 610 project "From the Caspian to Mediterranean: Environmental change and human response during the Quaternary."

References

Egorov, V.N., Polikarpov, G.G., Gulin, S.B., Artemov, Yu.G., Stokozov, N.A., and Kostova S.K., 2003. Sovremennye predstavleniya o sredoobrazuyuschey i ekologicheskoy roli snruynykh metanovykh gazovydeleniy so dna Chernogo morya [Recent understanding of the environmental formation and ecological role of gas seeps from the Black Sea bottom]. *Marine Ecological Journal* 2(3): 5–26. (In Russian)

Ermakov, A.P., 2005. Glubinnoe stroenie chernomorskoy vpadiny po rezultatam novoy interpretatsii seismichnykh dannykh [*Deep Structure of the Black Sea Depression Based on Results of New Interpretation of the Seismic Data*]. PhD Thesis, Moscow. (In Russian)

Lein, A.Yu., and Ivanov, M.V., 2005. Krupneishy na Zemle metanovy vodoem [The largest methane basin on Earth]. *Priroda* 2:19–26. (In Russian)

Mureşan, M., 2014. Diversity and distribution of free-living nematodes within periazoic level on the Romanian shelf of the Black Sea. Geo-Eco-Marina 20: 19–28.

Patin, S.A., 2004. Assessment of anthropogenic impact on marine ecosystems and biological resources in the process of oil and gas field development in the shelf area. *Water Resources* 31(4): 413–422.

Sergeeva, N.G., Mazlumyan, S.A., Lichtschlag, A., and Holtappels, M., 2014. Benthic Protozoa and Metazoa living in deep anoxic and hydrogen sulfide conditions of the Black Sea: Direct observations of actively moving Ciliophora and Nematoda. *International Journal of Marine Science* 4(49): 1–11.

Shnyukov, E.F., Kobolev, V.P., and Pasynkov, A.A., 2013. Gazovy vulkanizm Chernogo morya [*Gas Volcanism of the Black Sea*]. Logos, Kiev. (In Russian)

Sovga, E.E., and Lyubartseva, S.P., 2006. Istochniki, stoki i perenos metana v Chernom more [Sources, drains and methane transport in the Black Sea]. *Ekologichna bezpeka poberezhzhya na shelfovykh zon ta kompleks vykorustuvannya resursiv shelfu* 14: 530–545. (In Ukrainian)

Sozansky, V.I., 2013. Відновлення світових запасів нафти і газу як стратегічна проблема сучасності Vidnovlennya svitovykh zapasiv nafty i gazu yak strategichna problema suchasnosti [Renewal of world oil and gas reserves as a strategic problem of the modernity]. *Geologichny zhurna*l 2: 68–74. (In Ukrainian)

Tari, E., Sahin, M., Barka, A., Reilinger, R., King, R.W., McClusky, S., and Prilepin, M., 2000. Active tectonics of the Black Sea with GPS. *Earth, Planets and Space* 52(10): 747–751.

Tkachenko, G.G., Derkach, Yu.I., Eifa, M.M., and Sokolovskaya G.M., 1974. Hazopodibni vuhlevodni donnykh vidkladiv zakhidnoyi chastyny pidnyattya Golitsyna ta oznaky yikh epihenetychnosti (Chorne more) [Gaseous hydrocarbon sediments of the western part of the Golitsyn Rise and signs of their epigeneticity (Black Sea)]. Mezhvedomstvenny respublikansky naukovy sbornik "Geologiya uzberezhzhia i dna Chernogo ta Azovs'kogo moriv u mezhakh Ukrainskoi RSR" [Interdepartmental Republican Scientific Miscellanea *"Geology of the Coast and Bottom of the Black Sea and Sea of Azov within the Ukrainian SSR*"] 7: 106–108. (In Ukrainian)

Yanko-Hombach, V., Kadurin, S., Kravchuk, A., and Kulakova, I., 2017. Meiobentos kak indikator gazoobraznykh uglevodorodov v donnykh otloxheniyakh Chernogo morya [Meiobenthos as an indicator of gaseous hydrocarbon reservoirs in bottom sediments of the Black Sea]. *Geology and Mineral Resources of the World Ocean*, in press. (In Russian)

PALEOGEOGRAPHY OF THE ATELIAN PERIOD IN THE LOWER VOLGA REGION

Yarovaya, S.K. [1], Kurbanov, R.N. [2], Stevens, T. [3], and Költringer, C. [4]

[1,2,4] Faculty of Geography, Lomonosov Moscow State University, 1 Leninskie Gory, Moscow, Russia, 119991
[1] sofya.yarovaya@gmail.com
[2] roger.kurbanov@gmail.com
[4] Uppsala University, Geocentrum, Villavägen 16, Uppsala, Sweden, 752 36
[3] thomas.stevens@geo.uu.se
[4] chiara.koltringer@geo.uu.se

Keywords: Caspian Sea, Late Pleistocene loess, paleosols, magnetic susceptibility

Paleogeographic development of the Caspian Sea in the Late Pleistocene is characterized by the alternation of transgressive and regressive stages. The paleogeographic environment during regressive periods is less understood than that of transgressive ones. The main reason is the lack of paleontological and paleobotanical remains (including malacofauna and pollen) in continental deposits of various genesis.

The longest period of low Caspian Sea level in the Late Pleistocene was the Atelian regression. During this period, a thick sequence of continental deposits was formed. This formation is widely spread within the Caspian Depression and presents both subaqueous and subaerial deposits, including alluvial and aeolian deposits (Yanina, 2012).

The main goal of this research is the paleogeographic reconstruction of the environment of the Lower Volga region during the Atel regression. To achieve this goal, we have chosen the Raigorod section, which is located in the northern part of the Lower Volga region, 50 km downstream from Volgograd. The main feature of this section is that it contains the greatest observed thickness of Atelian deposits (around 7 m) in a natural outcrop underlying the Khvalynian “chocolate” clays. The upper part of the Atelian thickness is represented by a monochromatic, pale-yellow, silty-loam (aleurite) unit. It is a homogeneous, thick, “loess-like,” barren formation with plant residues and carbonate nodules. The main characteristics of this thickness are: its silty (aleuritic) grain size, high carbonate content, porosity, significant thickness, and columnar structure. Additionally, the outcrop maintains a very stable vertical position. All of the above mentioned points match the definition of a typical loess. The description of this thickness preliminarily divided it into several units based upon weak differences in color and concentration of carbonate nodules. At its base there are alluvial sandy deposits (Akhtuba sands) that penetrate the underlying layer through 25-30 cm deep fissures. These traces of the cryogenic process are the most important characteristic of the marking horizon in sections of the Lower Volga region.

To obtain an improved subdivision of this homogeneous unit, we carried out a survey using the magnetic susceptibility method. For this kind of deposit (“loess-like”, supposedly of aeolian genesis), the value of magnetic susceptibility (χ) reflects the presence of pedogenesis (Heller, 1995). Since it is considered that regressions of the Caspian Sea corresponded to glacial periods on the Russian Plain, traces of pedogenesis would attest to periods of climatic mitigation. Magnetic susceptibility in deposits depends on three characteristics: type of magnetic minerals, their concentration, and grain size. During the process of pedogenesis, the value of χ increases.

During fieldwork, we performed high-resolution sampling (every 2 cm). Laboratory research included the measurements of χ for every second sample (every 4 cm depth). In the field, the value of χ for every sample was measured with ZHinstruments SM-30. In the laboratory, the χ

for every second sample was measured in three types of magnetic fields (Low Field – LF, Medium Field – MF, and High Field – HF) on the MFK1-FA Kappabridge. Then, the frequency dependent susceptibility (χ_{FD}) was calculated using the formula $\left(\frac{\chi LF - \chi MF}{\chi MF}\right) \cdot 100$. Frequency dependent χ represents the contribution of magnetic minerals of different sizes (viz. superparamagnetic grains, which are 0.001 to 0.5 µm for magnetite). Fig.1 shows the research results in the form of three curves.

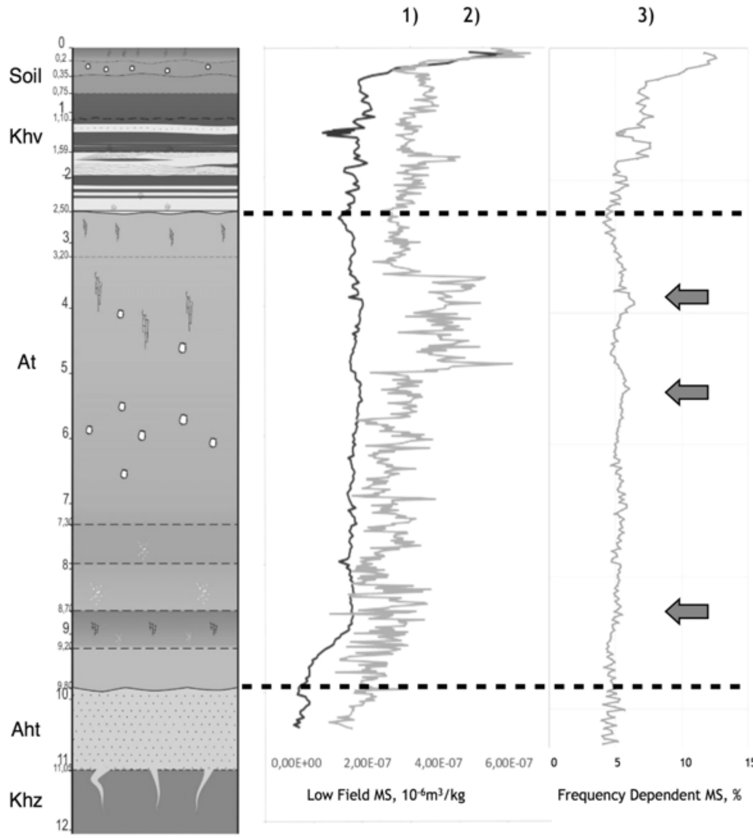


Figure 1. Scheme of the Raigorod section showing curves plotted on (1) the laboratory data, (2) the data from field measurements, and (3) calculated for frequency dependent MS. Dotted lines mark the Atelian loess-like thickness, and arrows indicate anomalies in MS.

The first curve reflects the laboratory measurements in a low-frequency magnetic field. The second one shows the value of χ_{LF}, measured during fieldwork. The third graph illustrates the calculated χ_{FD}. Dotted lines mark the Atelian "loess-like" thickness, and arrows indicate anomalies in χ_{FD} and χ_{LF}. As we can see, the homogeneous "loess-like" Atelian thickness is indeed different in magnetic properties. Reviewing the entire section, we can also notice the maximum peaks in the modern soil and in the Early Khvalynian "chocolate" clay horizon (MIS-2). We assume that these peaks in the Atelian thickness attest to the development of paleosols.

The definition of the Atelian thickness in the Raigorod section as loess (according to the complex of typical loess features, traces of cryogenesis at the lower boundary, and existence of paleosols) confirms the hypothesis of a cold periglacial depositional environment. The signs of pedogenesis, especially in the top part of the thickness, attest to inhomogeneity of the climate, including phases of warming at the final stage of the regression epoch. This research is the first step toward an improved paleogeographic reconstruction of the environment in the Lower Volga region and Caspian Plain during the Atel regression.

Acknowelegments

This work is supported by RSF, Project 16-17-10103.

References

Heller, F., and Evans, M.E., 1995. Loess magnetism. *Reviews of Geophysics* 33(2): 211- 240.

Yanina T.A., 2012. Correlation of the Late Pleistocene paleogeographical events of the Caspian Sea and Russian Plain. *Quaternary International* 271: 120 - 129.

APSHERON DEPOSITS (LATE EARLY PLEISTOCENE) OF THE LOWER VOLGA (ASTRAKHAN ARCH)

Zastrozhnov, A. [1], Danukalova, G. [2], and Ushakova, D. [3]

[1,3] A.P. Karpinsky Russian Geological research Institute (FSBI «VSEGEI»), 74 Sredny prospect, 199106, St. Petersburg, Russia
[1] zast@vsegei.ru
[3] Darja_Ushakova@vsegei.ru
[2] Institute of Geology USC RAS, 16/2, K. Marx str, 450077, Ufa, Russia, Kazan Federal University, 18, Kremlyovskaya Str, 420008, Kazan, Russia
danukalova@ufaras.ru

Keywords: Apsheron, biostratigraphy, palynology, molluscs, ostracods

Introduction

Apsheron (Apsheronian) deposits were described first by Barbot de Marny and Simonovich in 1891. Later, Andrusov (1923) studied these deposits in detail and established them as a Stage of the Upper Pliocene of the Caspian basin. This stage was named after the Apsheron peninsula (Azerbai-jan). Nowadays, this stage is known as a Horizon of the Lower Volga Regional Scheme and is cor-related with the Eopleistocene of the Russian Stratigraphic Chart.

The Apsheron Horizon of the Lower Volga area is correlated with the Calabrian stage of the Italian Marine Stages (Mediterranean Sea) and with the upper part of the Early Pleistocene of the Quater-nary International Chart (Cohen and Gibbard, 2016) (Fig. 1).

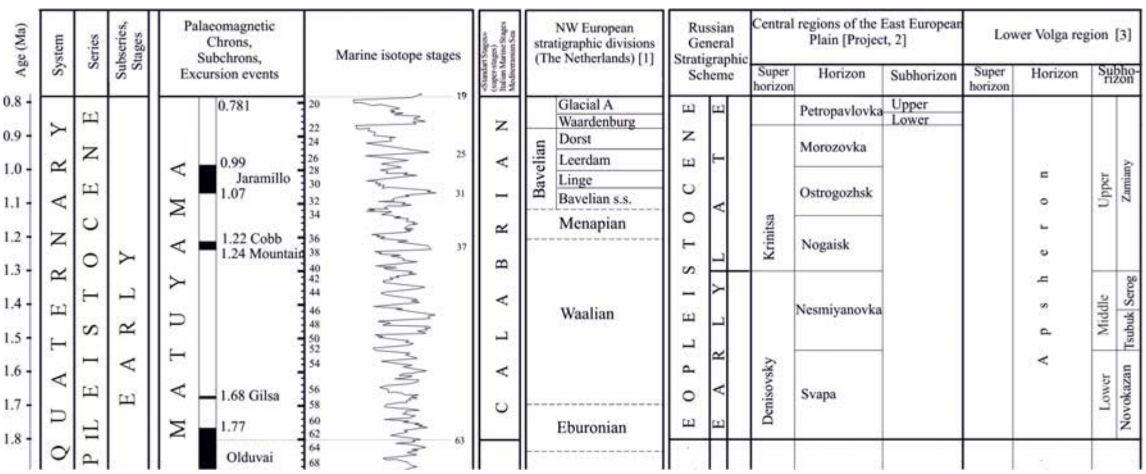


Figure 1. Correlation of Apsheron Horizon (Lower Volga) with units of the regional stratigraphic chart of Central European Russia, the General Stratigraphic Scale of Russia, and the International Chart. Legend: Serog = Seroglazovka; Novokazan = Novokazanka; [1] see Urban, 1995; Zagwijn, 1985; Turner, 1998; [2] see Schick et al., 2015a,b, Project; [3] = Zastrozhnov in Provisions, 1999. International Chart, Palaeomagnetic chart, Marine isotope Stages, and Italian marine stages are given according to Cohen and Gibbard (2016).

The area of our investigations from the tectonic point of view is located on the Astrakhan arch in the southwestern part of the Fore-Caspian Depression (Russian Plate) close to the Karpinsky Edge and Manych through zone (Scythian Plate) (by Strelnikov in Geological Map, 2012).

The main aim of our investigations was to characterize the Apsheron deposits of the Lower Volga area in the light of new data.

Methodology

Our considerations are based on fieldwork conducted from 2008–2017 when the Apsheron sedi-ments of numerous boreholes were described and sampled for biostratigraphic and paleomagnetic investigations in the framework of 200,000 scale mapping. Additionally, we used multi-proxy data from the Geological Survey, including mapping and research archives of oil and mineral resource companies.

Results

Apsheron horizon which is divided into three subhorizons on the base of fauna of molluscs, ostracods and spore and pollen complexes is represented mainly by marine formations.

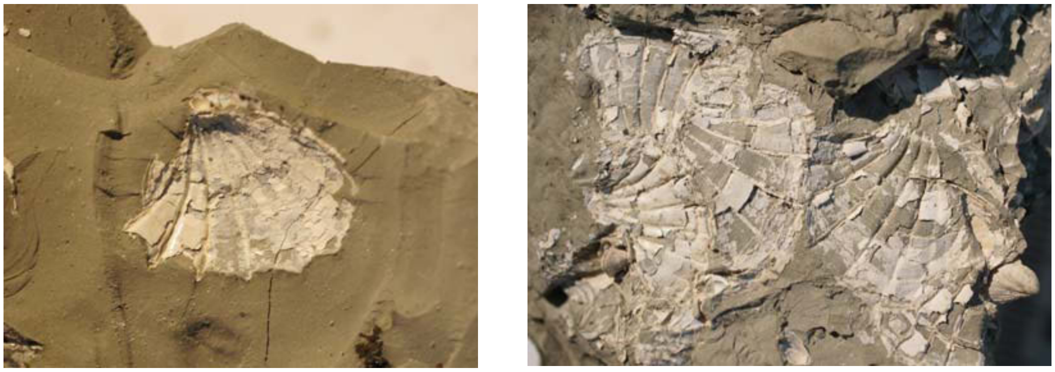
Marine deposits are common throughout the Fore-Caspian Depression and in the Eastern Fore-Caucasia (thickness is up to 400 m). Thickness is up to 2,000 m in the compensation troughs (Zastrozhnov et al., 2009; Lavrishchev et al., 2011a, b). On the Astrakhan arch Apsheron Horizon occurs without visible traces of erosion above the Akchagyl deposits and is wide distributed. Apsheron deposits can be reached be drilling at depths ranging from 36 m to 251.4 m. Its average thickness is about 250 m.

1. Marine deposits of the **Lower Apsheron** (Novokazanka Subhorizon) (thickness is up to 170 m) are characterized by brackish water mollusc fauna with *Dreissena* dominance and depleted assemblage of brackish water and marine ostracods. At this time, land was dominated by vegetation represented by coniferous-deciduous forests. Species correspond to the r-Matuyama orthozone. Zone of normal polarity in the subhorizon foot may belong to the top of the Olduvai subzone. A zone with normal polarity (probably Giles microzone) was also recorded in the roof (Zastrozhnov et al., 2009).

On the Astrakhan arch Lower Subhorizon was established only in the borehole 515, where it is constituted by gray micaceous sandy clays with layer of gray micaceous aleurite and with iron oxides at its base. Above there are layers and lenses of dark gray fine-grained sand (thickness is up to 5-7 m). Sediments contain poorly represented macrofauna complex: *Dreissena carinatocurvata* and *Micromelania* sp. were met in borehole 515 (interval 314-324 m). Thickness is 61 m.

2. Marine Middle Apsheron deposits (Tsubuk and Seroglazovka Subhorizons) (to 130 m) are the most widespread. In the lower part (thickness is up to 90 m), they contain a rich faunal assemblage of the Apsheron transgression maximum: numerous brackish water molluscs, marine and brackish water ostracods. Spore-pollen spectra here have the forest-steppe composition. A depleted assemblage of brackish water and freshwater molluscs and ostracods, spore and pollen complexes of steppe type are registered in the overlying deposits (thickness is up to 100 m). A normal polarity zone, the potential Jaramillo analogue, was registered in the roof (Zastrozhnov et al., 2009).

On the Astrakhan arch Middle Subhorizon is underlined by Lower Subhorizone or by Middle Akchagylian with erosional boundary. The section is represented by gray silty micaceous calcareous clay. Interlayers of gray thin-grained sand and aleurite (thickness 10-15 cm) exist in clay. Brackish water molluscs *Parapscheronia raricostata*, *P. eurydesma*, *Pseudocatillus bakuanus*, *Ps. dubius*, *Monodacna minor* etc. (interval 462-146 m, borehole 123; 175.8-147.9 m borehole 5E; 233.2-166.8 m, borehole 3E; 175.8-133.2 m, borehole 8E; 251.4-245 m, borehole 5S) indicate the age of the deposits and attribute them to the maximal Apsheron transgression (Fig. 2).



a b

Figure 2. *Parapsheronia raricostata* (Sjoegren) (Andrussov, 1923): a – borehole 5 Seroglazovka, 245 m; b – borehole 5 E, 171 m.

The Middle Apsheron ostracod complex is represented by species of the Caspiolla, Caspiocypris, Cypris, Cryptocyprideis, Leptocythere, and Loxoconcha genera. A rich complex of marine, brack-ish- and freshwater Apsheronian diatoms was found in these deposits. According to palynological data, the deposits are characterized by mixed complexes with equal amounts of boreal and aboreal pollen and sporophytes. Deposits are characterized by reverse polarity and correlated with ortho-zone Matuyama with episode Jaramillo at their upper boundary (borehole 123). Thickness of the deposits is from 169 m (borehole515) to 319 m (borehole 123).

3. An assemblage of brackish water, marine ostracods and mollusks, and spore-pollen complexes of semi-desert type characterize the Upper Apsheronian marine deposits (Zamiany Subhorizon) (thickness is 100 m). A normal polarity zone, the Kamikatsura microzone analogue (850 Ka), was registered (Zastrozhnov et al., 2009).

On the Astrakhan arch, the Upper Subhorizon is widespread and is underlain by the Middle Sub-horizon with a gradual transition. The Subhorizon is represented by marine gray, thin-layered clay with sandy interlayers and rare brackish water mollusks Monodacna sjoegreni, M. laevigata, M. cf. minor, Pseudocatillus isseli, P. bacuanus, Apsheronia propinqua, Dreissena carinatocurvata, D. bacuana, D. cf. eichwaldi, Hyrcania cf. intermedia, and brackish- and freshwater ostracods (bore-hole 123) Caspiolla acronasuta, Mediocytherideis apatoica, Leptocythera martha, and Cyprideis torosa, etc. Total thickness of the Upper Subhorizon ranges between 32 m (borehole 123) to 82 m (borehole 515).

Discussion and conclusion

A unified regional stratigraphic chart of the territory (Lower Volga region) was adopted in 1986 (supervisors: A.A. Romanov, G.I. Karmishina, and V.K. Shkatova). In 1998, the chart was verified (Zastrozhnov in Provisions, 1999) (Fig. 1).

Stratigraphic units reflect general characteristics of the deposits for the entire Lower Volga area. New data we obtained show differences in the deposits' characteristics, which are as follows:

1. Because of the attribution of the studied area to the Astrakhan arch, Lower Apsheron deposits were sometimes eroded;

2. In the periphery of the sea, close to the Apsheron shoreline, several transgressive and regressive episodes were recorded. Because the studied area was covered by marine waters during all the pe-riod of the Apsheron Sea's evolution, clear boundaries between subhorizons

are absent, and it is hard to divide the deposits into subunits. Sections show a continuous development of the Apsheron Sea during the 1.8–0.8 interval.

References

Andrusov, N.I., 1923. *Apsheronsky Yarus* [*Apsheron Stage*]. St. Petersburg. (In Russian)

Cohen, K.M., and Gibbard, P., 2016. *G1obal Chronostratigraphical Correlation Table for the Last 2.7 Million Years.* Subcommission on Quatemary Stratigraphy (Intenational Commission on Stratigraphy, Cambridge, http://www.quaternary.stratigraphy.org.uk/charts.

Geological Map of Russia and Adjoining Water Areas, 2012. Petrov, O.V., Morozov, A.F., and Strelnikov, S.I., eds. Scale 1: 2 500 000. All-Russian Geological Institute (VSEGEI) Press, St. Petersburg. http://www.vsegei.com/ru/info/gk-2500/jpeg/ggk2500-1.jpg

Lavrishchev, V.A., Sheikov, A.A., Andreev, V.M., et al., 2011a. *Gosudarstvennaya geologicheskaya karta Rossyiskoi Federatcii. Masshtab 1:1000000 (tretye pokolenie). Seriya Skifskaya. List K-37 – Sochi, K-38 - Makhachkala, K-39. Ob'yasnitelnaya zapiska* [*State Geological Map of the Russian Federation. Scale 1:1000000 (third generation). Scythian series. Sheet K-37 – Sochi, K-38 - Makhachkala, K-39. Explanatory notes*]. All-Russian Geological Institute (VSEGEI) Press, St. Petersburg. (In Russian)

Lavrishchev, V.A Grekov, I.I., Semenov, V.M., et al., 2011b. *Gosudarstvennaya geologicheskaya karta Rossyiskoi Federatcii. Masshtab 1:1000000 (tretye pokolenie). Seriya Skifskaya. List L-38 - Pyatigorsk. Ob'yasnitelnaya zapiska* [*State Geological Map of the Russian Federation. Scale 1:1000000 (third generation). Scythian series. Sheet L-38 - Pyatigorsk. Explanatory notes*]. All-Russian Geological Institute (VSEGEI) Press, St. Petersburg. (In Russian)

Provisions of the Interdepartmental Stratigraphic Committee and its permanent Commissions [*Postanovleniya Mezhvedomstvennogo stratigraphicheskogo komiteta i ego postoyannykh komissyi*], 1999. Issue 31. All-Russian Geological Institute (VSEGEI) Press, St. Petersburg, pp. 26–29. (In Russian)

Shick, S.M., Agadjanian, A.K., Iosifova, Yu.I., Markova, A.K., Pisareva, V.V., Semenov, V.V., and Tesakov, A.S., 2015a. Proekt regionalnoi stratigraphicheskoi shkaly eopleistotcena centra i yugo-vostoka Vostochno-Evropeiskoi platform [Project of the regional stratigraphic scheme of the Eopleistocene of the center and south-east of the Eastern-European platform]. In: Fundamental problems of Quaternary, results and main trends of further studies. Proceedings of the IX All-Russian conference on Quaternary Research. Institute of geography of the Siberian branch of the Russian academy of sciences press, Irkutsk, pp. 505–507 (in Russian).

Shick, S.M., Agadjanian, A.K., Iosifova, Yu.I., Pisareva, V.V., Semenov, V.V., and Tesakov, A.S., 2015b. Proekt regionalnoi stratigraphicheskoi shkaly gelaziya centra i yugo-vostoka Vostochno-Evropeiskoi platform [Project of the regional stratigraphic scheme of the Gelazian of the center and south-east of the Eastern-European platform]. In: Fundamental problems of Quaternary, results and main trends of further studies. Proceedings of the IX All-Russian conference on Quaternary Research. Institute of geography of the Siberian branch of the Russian academy of sciences press, Irkutsk, pp. 507–508 (in Russian).

Turner, Ch., 1998. Volcanic maars, long Quaternary sequences and the work of the INQUA subcomission on European Quaternary stratigraphy. Quaternary International 47/48, 41-49.

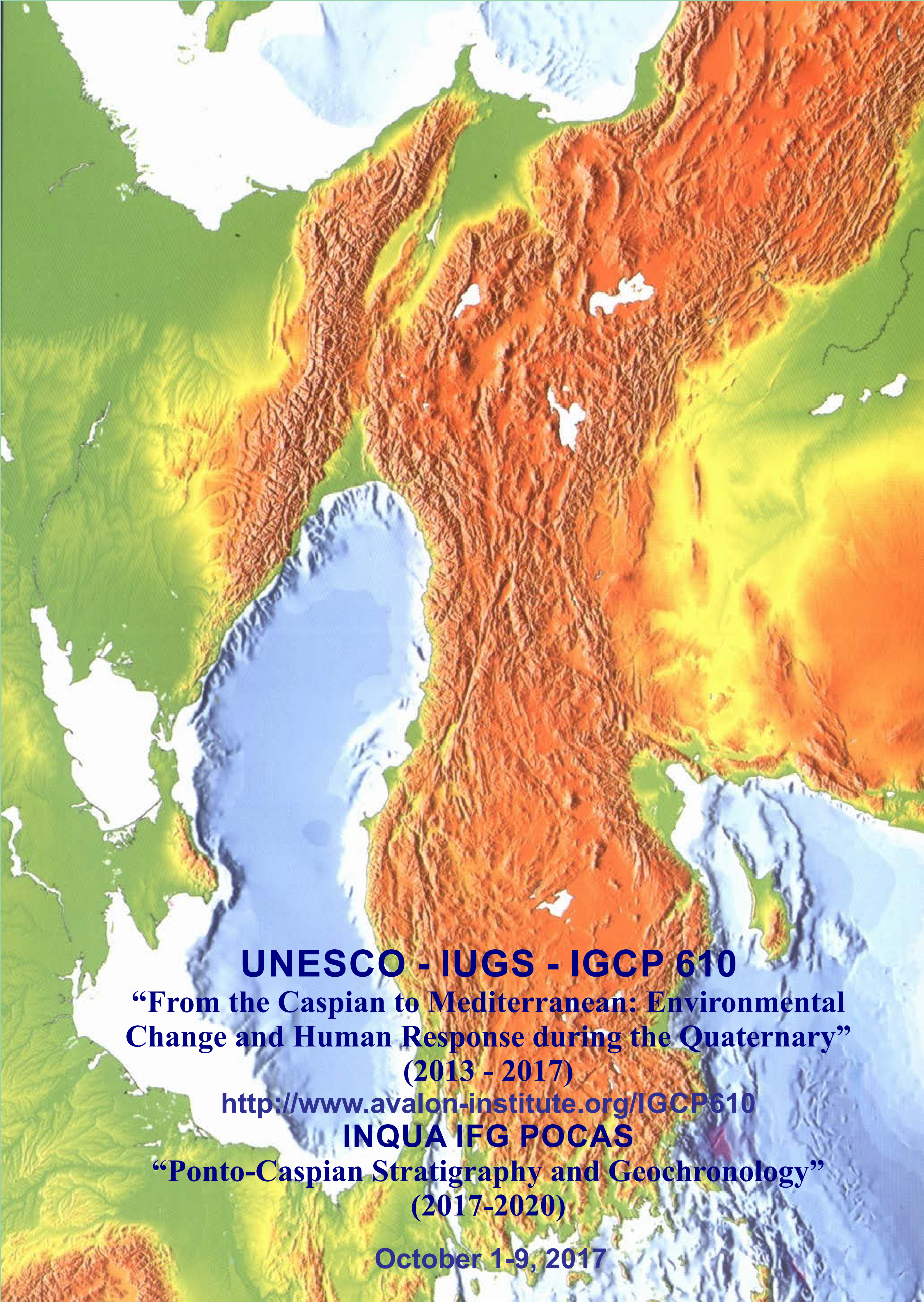
Urban, B., 1995. Palynological evidence of younger Middle Pleistocene Interglacials (Holsteinian, Reinsdorf and Schoningen) in the Schoningen open cast lignite mine (eastern Lower Saxony, Germany). Mededelingen Rijks Geological Dienst 52, 175-186.

Zagwijn, W.H., 1985. An outline of the Quaternary stratigraphy of the Netherlands). Geologic en Mijnbouw 64, 17-24.

Zastrozhnov, S.I. (Ed.), Zastrozhnova, O.I., Zastrozhnov, A.S., Gagin, A.M., Shkatova, V.K., Savin, V.V., Pisarenko, Yu.A., Zhuravleva, O.Yu., Fomenko, A.K., Rogachev, V.N., Tikhonov, V.I., Kluev, N.K., Valieva, A.I., Chuyko, M.A., et al., 2009. *Gosudarstvennaya geologicheskaya kartf Rossyiskoi Federatcii masshtaba 1:1000000 (tretye pokolenie). Central'no-evropeiskaya seria. List M-38-Volgograd. Ob'yasnitelnaya zapiska* [*State Geological Map of the Russian Federation. Scale 1:1000000 (third generation). Central-European Series. Sheet M-38-Volgograd. Explanatory notes*]. All-Russian Geological Institute (VSEGEI) Press, St. Petersburg. (In Russian)

INDEX

Finito di stampare mese di Settembre 2017
presso la ditta Fotograph s.r.l-Palermo (Italy)



UNESCO - IUGS - IGCP 610

“From the Caspian to Mediterranean: Environmental Change and Human Response during the Quaternary”

(2013 - 2017)

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

INQUA IFG POCAS

“Ponto-Caspian Stratigraphy and Geochronology”

(2017-2020)

October 1-9, 2017