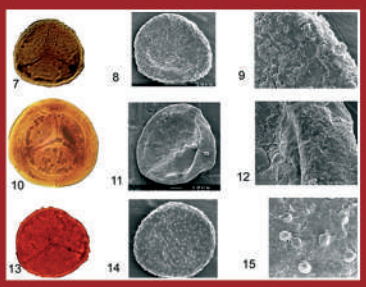
ISSN 2617– 2909 (print)
ISSN 2617– 2119 (online)

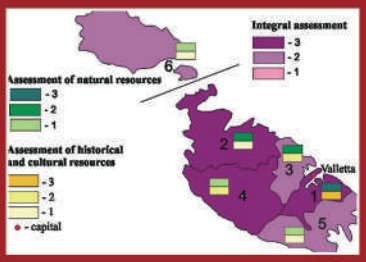
Journal of Geology, Geography and Geoecology

http://geology-dnu.dp.ua

2021 /30(4)



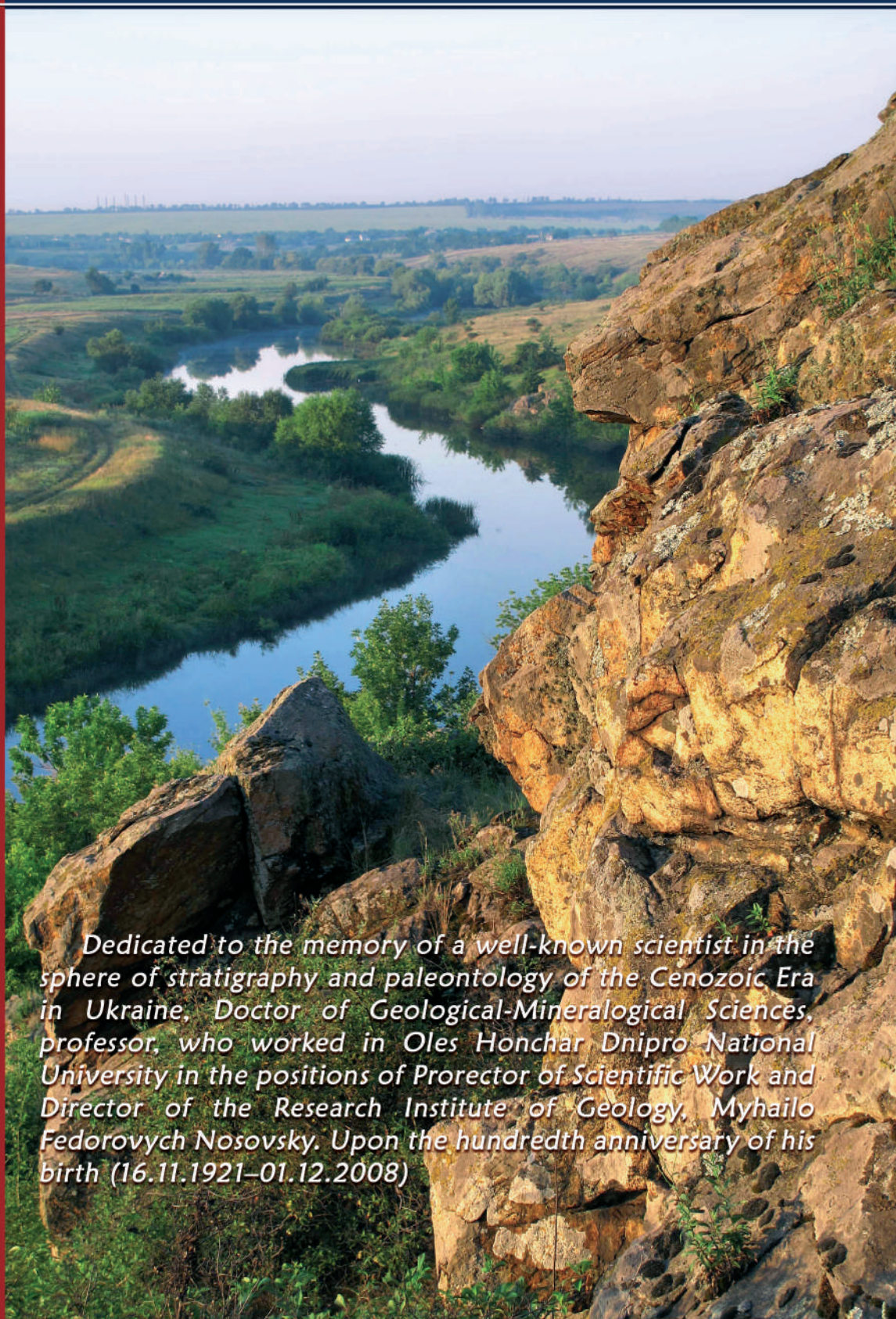
Palynology of Devonian



Malta tourist resources

German Cultural Heritage

Geological Museum



Dedicated to the memory of a well-known scientist in the sphere of stratigraphy and paleontology of the Cenozoic Era in Ukraine, Doctor of Geological-Mineralogical Sciences, professor, who worked in Oles Honchar Dnipro National University in the positions of Prorector of Scientific Work and Director of the Research Institute of Geology, Myhailo Fedorovych Nosovsky. Upon the hundredth anniversary of his birth (16.11.1921–01.12.2008)

doi:10.15421/11217301

Journal of Geology, Geography and Geoecology

http://geology-dnu.dp.ua 2021 / 30(4)

The main aim of the Journal of Geology, Geography and Geoecology is to publish high quality research works and provide Open Access to the articles using this platform. Collection of scientific works publishes refereed original research articles and reviews on various aspects in the field of geological, geographical and geoecological sciences. Journal materials designed for teachers, researchers and students specializing in the relevant or related fields of science. Journal included in the list of professional publications, you can publish the main results of dissertations for the degree of doctor and candidate of geological sciences. The scope of distribution: international scientific journal. All published articles will be assigned DOI provided by Cross Ref.

EDITORIAL BOARD

Editor-in-Chief:
Associate professor, Ph.D., **Manyuk Volodymyr**, Assoc. Prof. of Department of Earth Sciences, Oles Honchar Dnipro National University, Dnipro, Ukraine;
E-mail: vgeoman@gmail.com;
tel.: +067 947 45 04; +095 824 61 77.

Deputy Editors:
Professor, Dr. hab., **Andrzej Tomasz Solecki**, Scientific Head of the team of WS Atkins-Polska Sp. z o.o. experts preparing the report on uranium metallogeny, Institute of Geological Sciences University of Wrocław, Wrocław University, market and prospects in Poland for the Polish Ministry of the Environment, Poland; E-mail: andrzej.solecki@ing.uni.wroc.pl; tel. +48 600 96 63 61.
Professor **Şaşmaz Ahmet**, Dr. Sc. in environmental geochemistry and mining deposits, Head of Geology Department, Firat University, Elazığ, Turkey;
E-mail: sasmaz@gmail.com; tel. +90 424-2370000.

Executive Editor:
Professor, Dr. Sc., **Sherstyuk Natalya Petrivna**, Oles Honchar Dnipro National University, Head of Department of Earth Sciences, Faculty of Chemistry, Dnipro, Ukraine;
E-mail: sherstuknp@gmail.com; tel.+38-096-124-15-35.

Members of the editorial board:

Professor (mult.), Dr. hab., **Harald G. Dill,** Dr.h.c in economic geology (additional focal disciplines: applied sedimentology/ geomorphology, technical mineralogy), Gottfried-Wilhelm-Leibniz University, Mineralogical Department, Hannover, Germany.
E-mail: h.geo.dill@gmx.de; tel. +49-(0) 511 643 2361.
Professor in Biostratigraphy-Micropaleontology, D.Sc., **Karoui** – **Yaakoub Narjess**, Carthage University, Faculty of Science of Bizerte (Departament of Earth Science), Jarzoura, Bizerte,Tunisia
E-mail: narjess.elkarouiyaakoub@fsb.rnu.tn.
Research Fellow **William A.P. Wimbledon**, Dept. of Earth Sciences, University of Bristol; Member Geological Society of London's Conservation Committee, Member of Berriasian (Jurassic-Cretaceous) Working Group (International Subcommission on Cretaceous Stratigraphy);
E-mail: williamwimbledon@gmail.com
Professor in Geology, Dr.Sc., **José Bernardo Rodrigues Brilha**, University of Minho, Department of Earth Science, Braga, Portugal, E-mail: jose.brilha@gmail.com; tel. +351-25-3604306.
Ph.D., MSc., **Afsoon Moatari-Kazerouni**, Geology Lecturer Geology Department - Rhodes
University Grahamstown, Eastern Cape, South Africane,
E-mail: afsoon.moatari@gmail.com;
tel: +27 (0)46-603-8618

Professor in Geology, Dr.Sc., **Abderrazak El Albani**, Université de Poitiers, Laboratory IC2MP, Poitiers, France, E-mail: abder.albani@univ-poitiers.fr; tel. +33 (0)5.49.45 39 26

Associate Professor, **Ilya V. Buynevich**, Temple University, College of Science and Technology Department of Earth and Environmental Science, Philadelphia, USA, E-mail: coast@temple.edu, tel: 215-204-3635

Prof., Dr. Sc., **Mokritskaya Tatiana**, Oles Honchar Dnipro National University, Ukraine; Faculty of Chemistry, E-mail: mokritska@i.ua; tel.: 098 257 70 19.

Prof., Dr. Sc., **Yevhrashkina Galina Petrivna**, Oles Honchar Dnipro National University, Faculty of Chemistry, Ukraine;
E-mail: galina.evgrashkina@gmail.com;
tel.: 067 565 51 13

Prof., Dr. Sc., **Reynard Emmanuel**, Prof. of physical geography at the University of Lausanne, Faculty of geosciences, Switzerland;
E-mail: emmanuel.reynard@unil.ch;

Associate Prof., Dr.Sc., **Afroz Ahmad Shan**, Assoc. Prof. of Structural Geology with the Faculty of Science, Department of Petroleum Geology University of Brunei Darussalam, Brunei; E-mail: afroz.shah@gmail.com;

Prof., Dr. Sc., **Gerasimenko Natalia**, Department of Earth Sciences and Geomorphology Taras Schevchenko National University of Kyiv, Kyiv, Ukraine;
E-mail: n.garnet2@gmail.com

Ajin R.S., M. Sc. Hazard analyst, Idukki District Emergency Operations Centre (Idukki-DEOC), Idukki District Disaster Management Authority (Idukki DDMA), Department of Disaster Management, Government of Kerala, Painavu, Idukki, Kerala (State), INDIA,
tel. +91-9061762170,
E-mail: ajinares@gmail.com, ajinares@hotmail.com

Associate professor, PhD **Anatoliy Melnychuk**, Assoc. Prof. of Department of Economic and Social Geography Taras Shevchenko Kyiv National University, Kyiv, Ukraine; E-mail: melan97@ukr.net

Prof., Dr. Sc., **Baranov Volodymyr**, Head of Lab. Invest. Structural changes in rock, Senior Researcher Institute of Geotechnical Mechanics of NAS of Ukraine, Department of Geology and exploration of mineral deposits SHEI "National Mining University," Ukraine;
E-mail: baranov-va@rambler.ru; tel.: +38 097 506 43 73.

Prof., Dr. Sc. **Berezovsky Anatolii**, Dean of Mining - Processing Faculty, Krivyi Rig Technical University, Ukraine; E-mail: berez@mail.ru: tel.: +38 098236 84 27.

Associate professor, Ph.D., **Maniuk Vadym**, Assoc. Prof. of Department of Geography Oles Honchar Dnipro National University, Dnipro, Ukraine;
E-mail: zapovidna.sich@gmail.com;
tel.: +38 098 290 80 69; +38 066 270 14 48.

Professor, Dr. Sc., **Kroik Anna Arkadyevna**, Oles Honchar Dnipro National University, Dnipro, Ukraine;
E -mail: no-name2001@yandex.ru;
tel.: +38 095 149 65 50.

Professor, Dr. Sc., **Prikhodchenko Vasiliy Fedorovich**, Dean of the Faculty of exploration, Head. Department of Geology and mineral exploration National TU Dnipro Polytechnic; Dnipro, Ukraine;
E-mail: pvfpvf@meta.ua; tel.: +38 056 24 7 33 52.

Professor, Dr. Sc., **Lurie Anatolii**, V.N. Karazin Kharkiv National University, Ukraine;
E-mail: hydrogeology@karazin.ua;
tel.: +38 067 579 89 41.

Prof., Dr. Sc., **Zelenska Lyubov Ivanivna**, Oles Honchar Dnipro National University, Head of Department of geography, Dnipro, Ukraine;
E-mail: lubov.zelenska@gmail.com; tel.:067 56067 02

Prof., Dr. Sc., **Shevchyuk Viktor Vasylievych**, Taras Shevchenko National University of Kyiv, Ukraine;
E-mail: kzg@univ.kiev.ua; tel.: +38 050 656 33 20.

Prof., Dr. Sc., **Baranov Petro M.**, Oles Honchar Dnipro National University, Ukraine; Faculty of Chemistry,
E-mail: baranov_pn@bk.ru; tel.: +38 097 291 68 13.

Literary editors: P.V. Bradbeer, M.O. Tikhomyrov.
Cover design: Vadym V. Manyuk.
Text Layout: Vadym V. Manyuk.

Information about publication: Journal of Geology, Geography and Geoecology. (ISSN 2617-2909 (print), ISSN2617-2119 (online). Complete information on the requirements for the publication of copyright articles in the collection can be found on the website of the journal www.geology-dnu.dp.ua or by addressing the **Editor-in-Chief** Volodymyr Manyuk at vgeoman@gmail.com.

In accordance with the Order of the Ministry of Education and Science of January 15, 2018, №32 «Journal of Geology, Geography and Geoecology» December 18, 2018 is included in category A «List of professional publications of Ukraine» by specialties 103 (Earth Sciences) and 106 (Geography)

Approved by the Decision of the Scientific Council of the Oles Honchar Dnipro National University, 72 Gagarin ave., Dnipro, 49010, Ukraine.

© Oles Honchar Dnipro National University, 2021

Journal of Geology, Geography and Geoecology

Journal home page: geology-dnu.dp.ua

ISSN 2617-2909 (print)
ISSN 2617-2119 (online)

Journ. Geol. Geograph. Geology, 30(4), 613–420.
doi: 10.15421/112156

Socio-geographic analysis of the demographic situation in Vinnytsia Oblast: current condition and peculiarities of development

Lyudmila V. Ataman, Inna M. Voyna, Leonid M. Kirilyuk, Olga P. Chyzh, Yuriy V. Yatsentiuk

Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University, Vinnytsia, Ukraine, ataman2412@gmail.com

Received: 01.03.2021
Received in revised form: 18.04.2021
Accepted: 08.05.2021

Abstract. The article contains analysis of the current demographic situation in Vinnytsia Oblast. We determined causes and factors influencing the development of the demographic situation in Vinnytsia Oblast. The paper reveals the specifics of development of the demographic processes in Vinnytsia Oblast according to the data of the Main Statistic Service in Vinnytsia Oblast for the period from 1959 to January 1, 2020. We determined how the totals of the urban and rural populations have changed. Based on the analysis of statistical and literature sources, we researched the specifics of natural movement of population, its sex and age structure, migration, distribution of the employed population and unemployment rate. We provide characteristics of specifics of the territorial differentiation of parameters of birth, death rates, natural increment (decline), migration, sex and age structure in Vinnytsia Oblast. We analyzed the specifics of employment of population in Vinnytsia Oblast, levels of economic activity and unemployment. We eterminded modern tendencies of natural movement of the population, its impact on the prospects of further changes. We found out the problems of current demographic development in Vinnytsia Oblast based on determining modern specifics of the demographic parameters of the population in the researched area. The paper suggests ways to improve the demographic situation in Vinnytsia Oblast in the immediate future. As a result of the research, the demographic situation in Vinnytsia oblast was found to be negative. We observed a number of negative tendencies and patterns, including decrease in the rural population; decrease in the birth rate in the period from 1995 to 2020; high death rates due to diseases of blood circulation and malignant tumors; high parameters of aging of the population, especially in rural areas; decrease in the number of the employable population in the Oblast, etc.

Keywords: demographic situation, Vinnytsia oblast, natural increment, migration, sex and age structure.

Суспільно-географічний аналіз демографічної ситуації у Вінницькій області: сучасний стан та особливості розвитку

Л.В. Атаман, І.М. Война, Л.М. Кирилюк, О.П. Чиж, Ю.В. Яцентюк

Вінницький державний педагогічний університет імені Михайла Коцюбинського, м. Вінниця, Україна
ataman2412@gmail.com

Анотація. У статті проаналізовано сучасну демографічну ситуацію у Вінницькій області. Визначено причини та чинники, що впливають на розвиток демографічної ситуації у Вінницькій області. Розкрито особливості розвитку демографічних процесів у Вінницькій області за даними Головного управління статистики у Вінницькій області, статистичних збірників України та результатів власних досліджень. Вивчено динаміку чисельності населення у Вінницькій області за період з 1959 року до 1 січня 2020 року. З'ясовано, як змінилась чисельність міського і сільського населення. На основі аналізу статистичних та літературних джерел досліджено особливості природного руху населення, його статево-вікову структуру, міграції, розподіл зайнятого населення та рівень безробіття. Охарактеризовано особливості територіальної диференціації показників народжуваності, смертності, природного приросту (зменшення), міграцій, статево-вікової структури у Вінницькій області. Розглянуто особливості зайнятості населення у Вінницькій області, рівня економічної активності та безробіття. Визначено сучасні тенденції природного руху населення, їх вплив на перспективи його подальших змін. З'ясовано проблеми сучасного демографічного розвитку Вінницької області на основі виявлення сучасних особливостей у демографічній ситуації, що склалися в області, для подальшого проведення дослідження за основними демографічними показниками населення досліджуваної території. Запропоновано шляхи покращення демографічної ситуації у Вінницькій області впродовж найближчого періоду. В результаті дослідження з'ясовано, що демографічна ситуація у Вінницькій області є негативною. Виявлено ряд негативних тенденцій та закономірностей, серед яких зменшення чисельності сільського населення; зниження показників народжуваності у період з 1995 по 2020 роки; високі показники смертності у зв'язку з хворобами системи кровообігу та злоякісними новоутвореннями; високі показники старіння населення, особливо у сільській місцевості; зменшенням кількості осіб працездатного віку в області тощо.

Ключові слова: демографічна ситуація, Вінницька область, природний приріст, міграція, статево-вікова структура.

Introduction.

Over the past decades, one of the most acute problems in Ukraine has been the demographic crisis, accompanied by decrease in birth rate and life expectancy of the population, increase in the death rate (first of all, among employable men), outflow migration of highly-qualified workers, mostly young, deterioration of the health of citizens, etc. The main parameters of the natural movement of the population, its sex and age structure, migration flows significantly influence the economic and political environments in Ukraine in general, and in regions. Therefore, research on the demographic specifics of some oblasts, particularly Vinnytsia Oblast, with the purpose of developing a strategy and effective implementation of regional demographic policies has become a priority.

Study of the demographic situation in Vinnytsia Oblast is especially important for rational use and recreation of the labour potential in the Oblast, regulation of migratory processes, stimulation of the birth rate and decreasing the death rate, increasing natural growth of the population and preventing depopulation, providing employment, reducing unemployment and improving the social security of the population.

Objective of the study was the analysis of demographic situation in Vinnytsia Oblast, characteristics of modern condition and assessment of the peculiarities of its development.

Materials and methods.

It is expedient to study the current condition and specifics of the development of demographic situation in Vinnytsia Oblast based on an algorithm comprising 4 stages: theoretic-methodological, analytical, stating and summarizing. At the first (theoretical-methodological) stage, one should analyze theoretical material, determine the object, subject and key notions of the research, substantiate the relevance and methods of the research, and also analyze sources (literature, statistical, normative-legal bases, etc). At this stage, it is useful to use such general scientific methods as comparisons and analogues, analysis and synthesis, deduction and induction, abstract-logical method, historical method, systematization, generalization, etc. At the second (analytical) stage, the main parameters (population, number of newborn, death rate, natural growth of population, net migration rate, division of the population by sex and age, etc) are determined and the primary data analysis is conducted and the main factors influencing them are identified. The main methods of the research at this stage are systemic analysis, statistical, comparative-geographic, grouping, ordering by type, dialectics, monitoring. The third (stating) stage involves analysis of data of research, identification of socio-geographic specifics of demographic situation of the studied region, substantiation of results of the research. At this stage, it is best to use methods of the systematization and classification, graphic, comparative-geographic and comparative-historic methods. The fourth (summarizing) stage involves developing recommendations on management of demographic situation of the Oblast, identification of ways to improve it and formulation of the main conclusions of the research. It implies systematization, generalization methods, etc.

Results and discussion.

The demographic situation in Vinnytsia Oblast is determined by internal and external factors, including economic, social, psychological, ecological (low birth rate and high mortality; work migration; deterioration in age structure; marriage and divorce; revenue per family member; level of education among women and change in the social status of women; life conditions of the population and living conditions; aggravation of the problem of functioning of the family as a center of reproduction of the population, decrease in its demographic potential; employment-to-population, especially women's employment, i. e. increase in education and employment levels; ecological problems).

Birth rate and mortality are determined by a complex of social, economic, natural and other conditions, including level of income of the population, living conditions, ecological situation, working conditions, development of services, employment, etc (Zastaveczka, Zastaveczkyj & Tkach, 2003).

Birth rates across Vinnytsia Oblast depend first of all on socio-economic factors. The main one is income per family member, level of women's education and living conditions. The unfavourable demographic situation in Vinnytsia Oblast and the drastic drop in the birth rate are related to exacerbation in the problems of family functioning, decrease in demographic potential. Employment of population significantly affects birth rate, especially women's employment. An important socio-economic factor is also the level of medical service.

One of the factors determining the number of the population and birth rate is nature-biological, which manifests in the ability of women and men to reproduce. In this context, in Vinnytsia Oblast, there is a high level of infertility, which is directly associated with low birth rates.

The demographic situation in Vinnytsia Oblast is characterized by a tendency toward a gradual steady decrease of population in most administrative districts. The decrease in the overall number of population in the

Oblast over the recent 10 years (2010–2020) is 6.37% (Fig.1). Since 1959, the population in the Oblast is observed to have shown a continuous tendency toward decrease, especially in rural areas. Over the period from 1959 to 2019 (as of January 1 2020), Vinnytsia Oblast lost 587.2 thou people of its population. The declines in urban and rural populations were not even. An especially significant decrease over the last 60 years occurred in the number of rural citizens (by 1.023.3 thou people). Thus, between 1970 and 1990, the population was decreasing by 10.0 thou people per year on average, and between 1990 and 2020 – by 13.0 thou people annually.

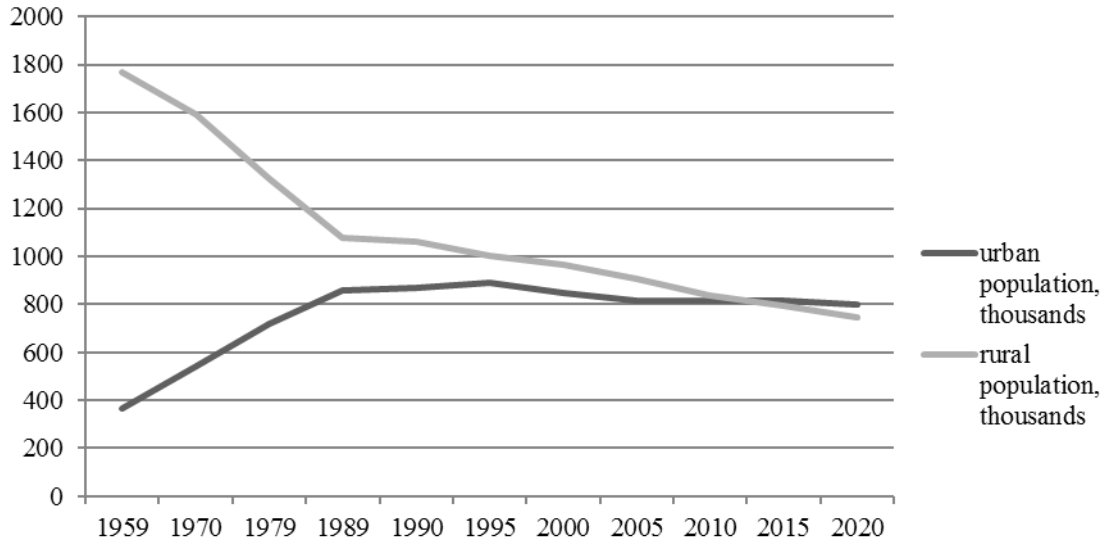


Fig. 1. Population Dynamics in Vinnytsia Oblast (1959–1 January, 2020.)

The population has decreased in the towns Zhmerinka, Koziatyni, Mohyliv-Podilsky, Khmilnyk, and also all the districts of the Oblast, except Vinnytsia district. The greatest decrease was in Zhmerynka, Bar, Nemyriv, Tulchyn, Bershad, Kalynivka, Sharhorod districts. Some of the main reasons are aging of the population and high death rate coefficient, and also the outflow of active employable population to cities (Statistical Yearbook, 2019).

The population across the Oblast has also declined as a result of migration processes, which exhibit a negative net migration rate. Particularly, during the period of 2014–2018, the population in the Oblast decreased by 42.5 thou people, including a 9.0 thou decrease in the urban population and 33.5 thou decline in the rural population.

According to the general parameters, the population in Vinnytsia Oblast is decreasing by 0.68% every year on average. The urban population is decreasing by 0.07% every year on average (data for the last 10 years), and rural – by 1.15% annually (data of the last 10 years), indicating significant loss of population in the Oblast's villages.

The population of Vinnytsia Oblast as of January 1, 2020 accounted for 1,545.4 thou people (ninth in Ukraine). In 2019, the population of the Oblast was 1,547.5 thou people, indicating a significant decrease over the year.

Negative demographic processes occurring over the recent years also manifest in unfavourable parameters of demographic load on the employable population. Especially negative variables are seen among rural citizens (Zastavnyj, 1993). In the proportion of urban and rural populations in Vinnytsia Oblast as of 2015, the urban population prevailed. In 2020, 51.7% (799.4 thou people) of the population of Vinnytsia Oblast lived in cities and 48.3% in rural areas (746 thou people).

It should be noted that up to 1995, while the population in the Oblast in general was decreasing, the urban population was increasing. Overall, from 1970 to 1995, the urban population increased by 1.5 times. Nonetheless, since 1995 the urban population has also started to decrease.

In almost all districts of Vinnytsia Oblast, throughout this period, the urban population was decreasing, while its parameters somewhat grew in most administrative districts, except Vinnytsia, Sharhorod and Pishchanka districts.

The rural population dominates in the following districts: Vinnytsia (63.0 thou people), Sharhorod (48.4 thou people), Bershad (44.1 thou people), Kalynivka (37.7 thou people), Khmilnyk, Bar and Koziatyn districts. The only district in the Oblast where the urban population prevails over the rural population is Tyvriv, respectively 22.1 thou urban population and 18.8 thou rural population.

The districts with largest populations are as follows: Vinnytsia (81.3 thou people), Bershad (56.8 thou), Kalynivka (56.3 thou), Sharhorod (55.4 thou), Haisyn (55.3 thou), Tulchyn (53.4 thou), Bar (50.0 thou).

The least populated districts are Orativ (19.8 thou), Pishchanka (20.0 thou), Chechelnyk (21.1 thou) and Chernivtsi (20. 2 thou) districts (Statistical Yearbook, 2019).

The Oblast is characterized by low density of population – around 60 thou/km^2 of the territory. The highest density of population is in Vinnytsky district – 90 thou/km^2, which is related to closeness to the Oblast administrative center. Parameters of density are also high in Bar, Haisyn, Kalynivka, Tyvriv, Tulchyn, Sharhorod and Yampil districts (50 thou/km^2). The lowest densities of population are in the peripheral districts – Orativ and Pohrebyshche (20 thou/km^2).

One of the main parameters of the demographic situation in the region is the birth rate, which in the demographic context is the process of giving birth among people that comprise a generation, or among the totality of the generations – population (Prybytkova, 2002). The simplest parameter of birth rate is the total fertility rate which indicates the average number of newborns per 1,000 people of the entire population of a certain territory (Gudzelyak, 2008). Total fertility rate indicates how many children may be born on average from one woman in the conditions of a certain intensity of fertility over life and the condition that her childbearing period would be lived through in comfort (Stecenko, 2005).

Vinnytsia Oblast has low birth rates, high mortality rates (especially among employable men) and negative natural growth (natural decline). In general, natural movement of the population within the Oblast has internal differences. The birth rate varies 9.4 % (Pohrebyshche and Chernivtsi districts) to 13.0 ‰ (Tyvriv and Vinnytsia districts). Among cities of Vinnytsia Oblast, the highest birth rates are in Zhmerynka and Koziatyn. It has to be noted that reflection of differentiation of the parameters of birth rate is significantly affected by historical-political events that took place in the country and their socio-economic consequences (Nyemecz L., Segida & Nyemecz K., 2012).

Another important variable of demographic situation is mortality. It is measured by ratio of the number of deaths to the number of the entire population or its certain groups differentiated by sex, age, social status, territory (Prybytkova, 2002). Death rates are observed to have sharp fluctuations, particularly the lowest values are in Vinnytsia district (around 9 ‰), and the highest in Pohrebyshche district (almost 21 ‰). High mortality among the population is also observed in Orativ, Zhmerynka, Chechelnyk districts. In general, mortality in the Oblast is 80 % higher in rural areas than in cities.

All districts of the Oblast, including Zhmerynka, Koziatyn, Ladyzhyn and Khmilnyk, have negative increment of population. Lowest natural increments (decline) of population are in Vinnytsia and Kalynivka districts, the highest being in Pohrebyshche, Orativ, Murovani Kurylivtsi and Chernivtsi districts (Statistical Yearbook, 2019). In terms of natural decline in rural population, the Oblast is the first among the oblasts of Ukraine. Such a situation is not favourable for job offers, especially in rural areas.

Natural movement of the population of Vinnytsia Oblast is the main factor of the decline in the Oblast population. For the studied period, decrease has been recorded in the number of newborns in the region – from 19,987 people in 1995 to 11,878 people in 2019. In total, indicators of births and deaths have decreased all across the Oblast.

Furthermore, the Oblast is observed to have a negative tendency in differences in depopulation

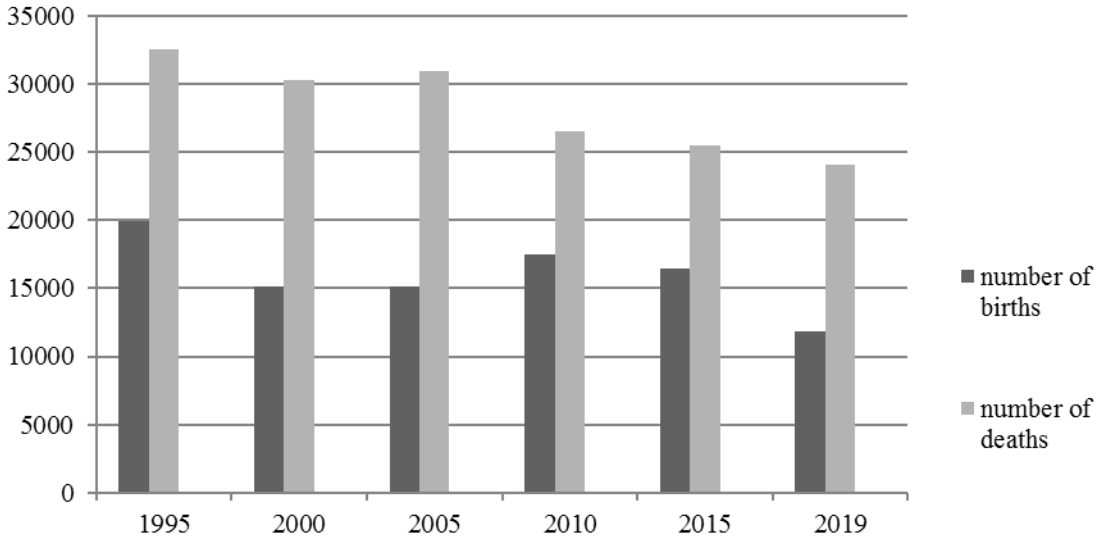


Fig. 2. Numbers of newborns and deaths (1995–2019)

processes among populations of urban and rural areas. Mortality in villages remains significantly higher than in urban settlements.

The main factor of population loss in 2019 (as of January 1, 2020), as in the previous years, was natural decline resulting from a death rate that exceeds the number of newborns (–11,572 people). Compared with 2010, the natural decline of population increased by 1.9%.

The greatest natural decrease was observed in Khmilnyk district, and the lowest in Mohyliv-Podilskyi. In Vinnytsia, the natural increment was the highest – 0.4 people per 1,000 existing population.

Among the causes of death among the population, the number one cause comprises diseases of blood circulation (72.9% of the total number of diseased), the second one – tumors (12.7%), third – external causes of death (about 5%). In the previous 10 years, the rate of death from disorders of blood circulating systems among the Oblast population has somewhat decreased.

The population of Vinnytsia Oblast is influenced to a large degree by migration processes occurring in its territory. Since 1995, the net migration rate in the Oblast has been negative. The statistics section contains the data for 10 months (January-October) of 2019, migration-caused decrease accounted for 2,623 people. For the previous year – 2018, there are more detailed data, particularly changing residence registration, indicating that 22,387 people came to the Oblast that year, while 26,229 people left. As of 2018, migration also decreased, equaling 3,842 people.

Therefore, since 1995, Vinnytsia Oblast has been characterized by a negative net migration rate. Nonetheless, over the period of 2009–2015, the number of migrating population significantly decreased. For several consecutive years (2014, 2015), the net migration rate was positive. Most of relocations were made within the Oblast and between regions of Ukraine. However, since 2018, the rates of migrating population were quite high, leading to negative net migration rate in Vinnytsia Oblast (from –2,505 to –3,842 people every year).

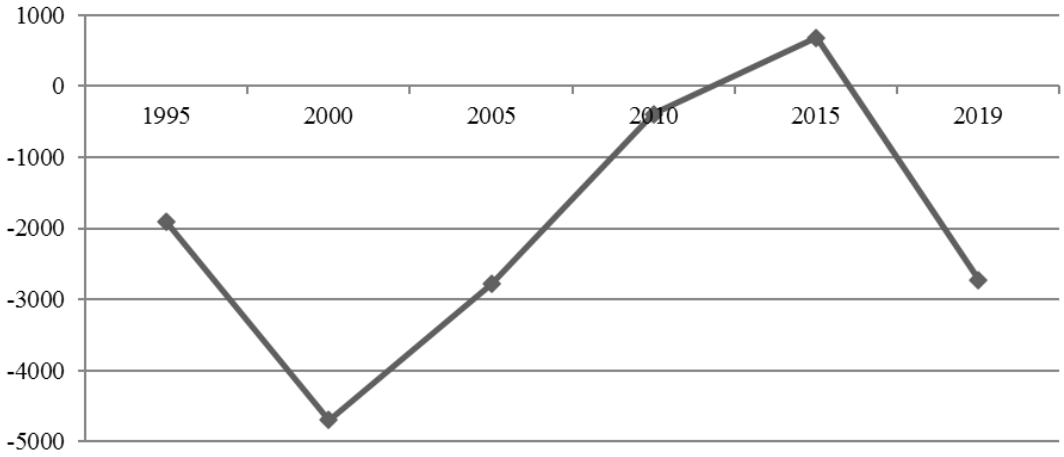


Fig. 3. Migration increment (decline) in Vinnytsia Oblast (1995–2019)

In general, the Oblast is experiencing a migration-caused decrease in population, though some districts and cities are observed to have a positive net migration rate – Vinnytsia (1,397 people), Zhmerynka (85 people), Vinnytsia district (747 people), Haisyn district (38 people).

The number of incoming people was the highest in city of Vinnytsia (7,206 people), Vinnytsia district (1,836), Haisyn (1,061 people), Kalynivka (700 people), Bershad (598 people) districts. The lowest number of people arrived in Orativ (134 people), Chernivtsi (137 people), Chechelnyk (170 people) districts. The numbers of incoming people are highest in the city of Vinnytsia, and Vinnytsia, Haisyn, Kalynivka, Bar, Tulchyn districts.

As for the net international migration, it was positive in the cities of Vinnytsia and Khmilnyk, and in districts of the Oblast with a sufficiently high level of economic development – Vinnytsia, Kalynivka, Koziatyn, Nemyriv and Tulchyn districts. The remaining towns and districts of the Oblast had a negative net migration rate for the last five years, especially in poorly developed periphery districts – Murovani Kurylivtsi, Bershad, Orativ and Teplyk. The most powerful migration flows between the neighboring oblasts are in Kyiv, Odesa, Khmelnytsk, Zhytomyr, Cherkasy Oblasts. This has negative effects on the development of th labour market in the Oblast.

Sex composition of the population of Vinnytsia Oblast is characterized by continuous excess of women over the number of men. The same tendency persists in Ukraine in general. Since 1995, there has been observed a tendency toward decrease in the number of both men and women (Fig. 4).

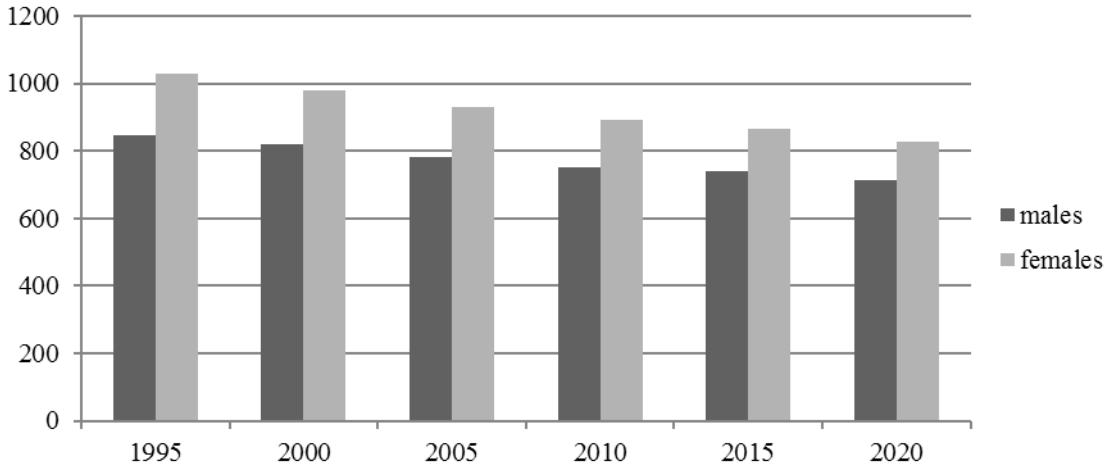


Fig. 4. Population Dynamics by Gender, thou people (1995–1 January, 2020)

In general, over the period between 1995 and 2020, the number of women decreased by 202.4 thou, and men by 134.9. This indicates a significant decrease in female population, which may be associated with high disproportion in 1995. As of now, this situation has significantly decreased and the difference between women and men is 112.9 thou people, suggesting an increase in the male population in the Oblast.

As of January 1, 2020, women account for 53.7 % of the Oblast population, and men make up 46.3 % (by the way, the same proportion was in 2018). In the Oblast, the population aged over 60 equals 23.6 %, including 35.6 % men and 64.4 % women. Women do not prevail in all age groups, specifically, in the age group of 0–34 the number of males exceeds the number of females, but begins to decrease in the 35–39 age group. In the 65–69 age group, the share of men is 39.4 %, while women significantly prevailed, accounting for 60.6 %. The number of men decreases with age, as indicated in the data that women comprise 70 % in the group of 70 and older.

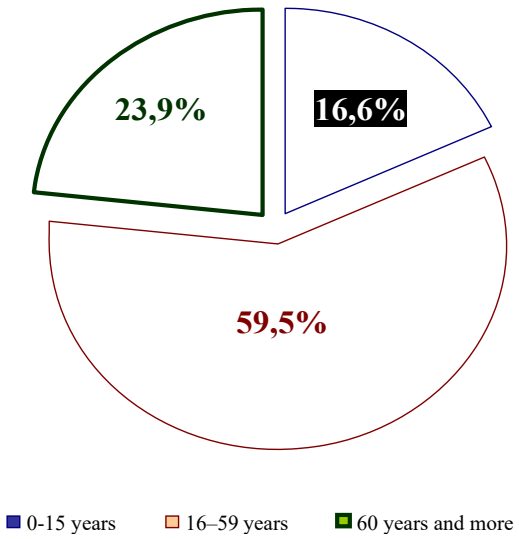


Fig. 5. Age composition of the population of Vinnytsia Oblast in 2019

There is also another tendency in settlements of Vinnytsia Oblast which is that the number of men is becoming lower than that of women starting from the age of 25 and 35 in rural areas. In the group of 70 years and older, women make up 67.3 % in urban settlements, 71.3 % in rural settlements, which indicates significant decrease in the number of men in the age group of 60 and older in rural areas.

Vinnytsia Oblast is characterized by the unfavourable age structure of the population. It belongs to oblasts with high share of 60+ age population. A negative tendency is also the decrease in the share of children in the overall population along with significant increase in share of people above the employable age.

Therefore, we may state that the age structure of the population in the Oblast has developed having a high specific share of older people and low number of young people, and which is leading to further aging of the population. In Vinnytsia Oblast, the regressive type of reproduction of population remains, as well as high rate of demographic aging (share of people older than 60 years is 23.9 %). Furthermore, population older than 60 is observed to have progressive chronic illnesses, malignant tumors, endocrine diseases, etc, which promotes the decline of the population of the Oblast.

Demographic load is a generalized quantitative characteristic of age structure of the population which indicates the load of unproductive population on the society and is determined by various ratios of number of generalized age groups: children, senior citizens

and those of employable age (Prybytkova, 2002). Demographic load on people of socially active age in Vinnytsia Oblast is characterized by a high level. In 2019, there were 234 people aged 0–15 years and 262 people aged 65 years and older per 1,000 people aged 16–64 years. In rural areas, these parameters were higher (235 and 321 people) than in urban settlements (233 and 208 people). Compared to 2014, the total coefficient of demographic load per 1,000 people aged 16–64 years increased from 470 to 496 people (Distribution of permanent population, 2020).

Significant change occurred in the sex and age structure of the population in the period from 1989 to 2020. At the same time, it should be noted that the share of employable population is increasing (1989–52.5%, in 1999–54.4%, and in 2020–59.5). This indicates positive tendency of development of job vacancies in the Oblast.

As for the number of pre-employable, employable and retired citizens, the following tendencies take place: the share of population of pre-employable age in the Oblast on average equals 16.6%, though it significantly fluctuates territorially, particularly Mohyliv-Podilskyi district – 12.8%, and Sharhorod district – 17.4%.

The largest share of employable population is in the cities of Vinnytsia and Mohyliv-Podilskyi, and Vinnytsia district. The rate of employable population in the rest of the districts is below the average, especially in Chernivtsi, Orativ, Pohrebyshche, which negatively affects the functioning of the labour market. The share of retirement-age population is higher than the average in the rural areas in villages of Chernivtsi, Pohrebyshche, Orativ, Murovani Kurylivtsi districts, which is determined by peripheral location and low socio-economic development of the districts.

As of January 1, 2020, the mean age of women and men has undergone no significant changes over the previous years and relative to type of settlement. However, mean life expectancy according to sex has increased. The difference in the average life expectancy is classic for Ukraine, equaling around 10 years (in cities and villages) and as of January 1, 2020 was 67.75 years for men and 77.47 years for women. In previous year of 2019, it was 67.58 years for men and 77.69 years for women. Overall, over the period between 1995 to 2020, the average life expectancy in the Oblast has increased by 5 years. In cities, women and men live longer: men by 3 and women by almost 2 years.

The level of economic activity is higher among men, equaling 67.5%, while being 56.8% among women. The economically active 15–70 year-old population of Vinnytsia Oblast in 2018 was 724.3 thou people, including 652.7 thou people – or 90.1% – who were engaged in economic activity. The level of economic activity of the population aged 15–70 years during the years 2014–2018 increased from 62.9% in 2014 to 63.0% in 2018, which is higher than the average level in Ukraine (62.6%) (Regions of Ukraine, 2019).

Distribution of employed population aged 15–70 according to types of economic activity has the following structure: agriculture, forestry and fisheries at the first place, wholesale and retail trade, vehicle repair at the second place, and industry at the third (Regions of Ukraine, 2019).

The number of unemployed people aged 15 and over is 68.7 thou (9.4%) and people aged 15–70 years – 68.7 thou people (9.4%). In 2018, unemployment was 9.9%; in 2017–10.7%, indicating a positive tendency toward decrease in unemployment in Vinnytsia Oblast. The percentages of unemployed women and men are almost the same, equaling about 10%. However, in 2014, unemployment was 4% higher among men (8.6% among women; 12.2% among men). The highest unemployment rate among women is in the age group of 15–24 years (around 17%) and the age group of 25–29 years (around 16%). Unemployment rates in the age group of 30–34 years are almost the same for both men and women (around 12%). In general, unemployment (according to methodology of ILO) in percentage of economically active population aged 15–70 years tends to decrease (by almost 1%).

The current demographic situation affects the development of the labour potential of the Oblast and territorial concentration of employable population in cities and districts of the Oblast. Territorial concentration of employable population is the greatest in cities of Vinnytsia and Ladyzhyn, and also in districts of Vinnytsia, Mohyliv-Podilskyi, Trostianets and Zhmerynka. These are the districts where the level of economic development is high.

Taking into account the aforesaid, we should note that the labour force should be involved more actively through commuting, development of productive and market infrastructures and social sphere, stimulation of the development of professional and technical education, etc.

The population of Vinnytsia Oblast is characterized by the same negative processes and problems which are relevant for most of other Oblasts of Ukraine, though in some aspects there is a certain regional specific. One of the distinctive tendencies of development of the demographic situation in Vinnytsia Oblast is the prevalence of women over men in all age groups and especially the elderly group where the number of women is significantly higher than men. One of such negative tendencies of contemporary demographic processes is aging of the population caused by decline in the birth rate and decrease in the number of children, which is especially noticeable in rural areas.

The main measures that need to be taken in Vinnytsia Oblast to improve demographic situation and development of positive demographic processes are:

– Improvement of the medical service and social protection of the population, especially in rural areas. This would be achieved due to the fact that, apart from unique natural-recreation resources (sources of mineral water and clay), the Oblast has an advanced network of sanatoriums and resorts, recreation facilities, tertiary care institutions and an advanced scientific-medical education institution – National Pirogov Memorial Medical University, Vinnytsya. An important element of the system of high-quality and available medical service in Vinnytsia Oblast is the development of the emergency system that must be available to both urban and rural populations, including those living in the remotest communities (Strategiya zbalansovanogo regionalnogo rozvytku, 2020);

– Decrease in the unemployment rate and regulation of migration outflow of the population from the Oblast by organizing effective employment of the population and increase in salaries. Over the recent years, large-scale projects of developing modern infrastructure have been implemented in the Oblast – elevators, fruit and vegetable storage facilities, staging posts, etc. In Vinnytsia Oblast, there has already been developed a powerful sector of enterprises in the spheres of producing and processing agricultural goods which have a sufficient level of financial and institutional capacities for implementing investment projects and training specialists (Strategiya zbalansovanogo regionalnogo rozvytku, 2020);

– Increase in the birth rate due to active governmental and regional demographic policies;

– development of social infrastructure. Therefore, in Vinnytsia Oblast, the infrastructure of providing various social services to the population continues to develop, for example: in the system of social protection of the population, there are operating 36 territorial centers of social services (provision of social services), 26 district centers of social services for families, children, youth, etc.

Conclusions.

The results of the analysis of demographic situation in Vinnytsia Oblast indicate the need to develop a program of development and management of reproduction of the population as a result of an active demographic policy. The overall parameters indicate that demographics in Vinnytsia Oblast are negative. The research revealed a number of tendencies and patterns of change in the numbers of both urban and rural populations. Birth rates have significantly decreased compared with 1995. In the region, a high death rate has been observed, though over the recent 25 years the annual number of deaths has been much lower. The main causes of death among the population of Vinnytsia Oblast are diseases of system of blood circulation, malignant tumors and external impact.

The demographic situation in the Oblast is characterized by high parameters of aging of the population, especially in rural areas and also decrease in the number of employable people in the Oblast (share of people older than 60 is 23.9%). Mechanical movement of the population in Vinnytsia Oblast is first of all determined by economic factors, and the net migration rate in the Oblast for the analyzed period from 1995 to 2019 was negative.

The analysis of the sex and age structure of the population in Vinnytsia Oblast indicates a regressive type of reproduction of population, high degree of aging, which negatively affect the processes of reproduction of the Oblast's population in general. Therefore, the demographic situation that has developed in Vinnytsia Oblast is unfavourable for development of the labour market. Nonetheless, over the recent years, there has been seen a tendency toward decrease in unemployment in the region. Districts of Vinnytsia Oblast which have low population increment need measures that would improve socio-economic conditions, promote development of entrepreneurship and create new jobs. The Oblast needs active demographic policy, development of social infrastructure and improvement of healthcare.

References

Dzhaman, V. O., Krul, V. P., Chernyux, G. Ya.,2002. Demogeografiya: Navchalnyj posibnyk [Demogeography: Textbook]. Chernivtsi: Ruta. 159 (In Ukrainian).

Gudzelyak, I. I., 2008. Geografiya naselennya: Navchalnyj posibnyk [Geography of the population: Textbook]. Lviv: Publishing Center of Ivan Franko Lviv National University. 232 (In Ukrainian).

Nyemecz, L. M., Segida, K. Yu., Nyemecz, K. A., 2012. Demografichnyj rozvytok Xarkivskogo regionu: monografiya [Demographic development of Kharkiv region]. Kharkiv: KhNU. 200 (In Ukrainian).

Prybytkova, I., 2002. Demografichna sytuaciya v Ukrayini u dzerkali Vseukrayinskogo perepysu naselennya 2001 roku [Demographic situation in Ukraine in the mirror of the All-Ukrainian census of 2001]. Sociology: theory, methods, marketing, 3, 133–142 (In Ukrainian).

Shablij, O. I., 2003. Osnovy zagalnoyi suspilnoyi geografiyi: Pidruchnyk [Fundamentals of general social geography]. Lviv: LNU. 444 (In Ukrainian).

Statystychnyj shhorichnyk Vinnyczkoyi oblasti za 2019 rik., 2019. [Statistical Yearbook of Vinnytsia region for 2019]. Vinnytsia: Main Department of Statistics in Vinnytsia Region. Retrieved from: https://www.vn.ukrstat.gov.ua/index.php/statistical-information.html (In Ukrainian).

Statystychnyj zbirnyk «Chyselnist nayavnogo naselennya Ukrayiny na 1 sichnya 2020 roku»., 2020. [Statistical collection «The number of the current population of Ukraine on January 1, 2020»]. Kyiv (In Ukrainian).

Statystychnyj zbirnyk «Regiony Ukrayiny 2019»., 2019. [Statistical collection «Regions of Ukraine 2019»]. Kyiv (In Ukrainian).

Statystychnyj zbirnyk «Rozpodil postijnogo naselennya za stattyu ta vikom na 1 sichnya 2020 roku., 2020. [Statistical collection «Distribution of permanent population by sex and age on January 1, 2020»]. Kyiv (In Ukrainian).

Stecenko, S. G., 2005. Demografichna statystyka: Pidruchnyk [Demographic statistics]. Kyiv: High school. 415 (In Ukrainian).

Strategiya zbalansovanogo regionalnogo rozvytku Vinnyczkoyi oblasti na period do 2027 roku. Vinnycya., 2020. [Strategy of balanced regional development of Vinnytsia region for the period up to 2027] Retrieved from: https://vinrada.gov.ua/proekt-strategii-2027.htm (In Ukrainian).

Yavorska, V. V., 2013. Regionalni geodemografichni procesy v Ukrayini: monografiya [Regional geodemographic processes in Ukraine]. Kamyanets-Podilsky: Axiom. 384 (In Ukrainian).

Zastaveczka, O. V., Zastaveczkyj, B. I., Tkach, D. V., 2003. Geografiya naselennya Ukrayiny. [Geography of the population of Ukraine]. Ternopil. 149 (In Ukrainian).

Zastavnyj, F. D., 1993. Naselennya Ukrayiny. [The population of Ukraine]. Lviv: Krai, Prosvita. 348 (In Ukrainian).

Journal of Geology, Geography and Geoecology

Journal home page: geology-dnu.dp.ua

ISSN 2617-2909 (print)
ISSN 2617-2119 (online)

Journ. Geol. Geograph. Geology, 30(4), 622–431.
doi: 10.15421/112157

Regarding the choice of composite indicators of ecological safety of water in the basin of the Siversky Donets

Vitalii L. Bezsonnyi[1,2], Roman V. Ponomarenko[3], Oleg V. Tretyakov[4], Vitalii V. Asotskyi[3], Andrii Y. Kalynovskyi[3]

[1]*V. N. Karazin Kharkiv National University, Kharkiv, Ukraine,* bezsonny@gmail.com
[2]*Simon Kuznets Kharkiv National University of Economics, Kharkiv, Ukraine,* bezsonny@gmail.com
[3]*National University of Civil Defence of Ukraine, Kharkiv, Ukraine,* asotskiy@nuczu.edu.ua
[4]*IPRIS-PROFIL LTD, Kharkiv, Ukraine,* mega_ovtr@ukr.net

Received: 14.01.2021
Received in revised form: 07.02.2021
Accepted: 11.02.2021

Abstract. The lack of effective mechanisms of the methods of basin management, control of and responsibility for the ecological state of surface sources of drinking water leads to the fact that the main man-made objects that determine the ecological state of surface water sources are most often located in one oblast, while the production and consumption of the drinking water from those sources occur in the territory of other oblasts, which complicates the effective management of environmental safety of surface water sources. This is especially true for the regions of Ukraine which are poor in surface water resources, located in the basin of the Siversky Donets River, the water bodies of which are the main sources of water supply in the eastern regions of the country. The main consumer of water is Donetsk Oblast (over 50% of the annual volume), and Kharkiv and Luhansk Oblasts together consume approximately the same volume of water per year (up to 50% of the annual volume). Therefore, it is important to substantiate the integrated indicators of the ecological status of the water body to improve the environmental safety of surface water sources. The paper shows that oxygen indicators play an important role in the ecology of a water body. They are associated with the assimilative ability of water, the ability of water to decompose organic matter. Therefore, the content of dissolved oxygen and biochemical oxygen consumption in water is of great interest not only in terms of life development, but also as a composite measure of the ecological status of the aquatic environment. The relationship between the value of the combined index of water pollution and the value of biochemical oxygen consumption makes the indicator of biochemical oxygen consumption important for the integrated assessment of water contamination with various organic substances. For the tasks for which we justify the choice of composite measures of the ecological condition of surface waters, it is more important to identify the effects of contamination not directly at the site of contamination, but at some distance from it and after some time. Therefore, the use of the amount of dissolved oxygen and biochemical oxygen consumption as indicators that characterize the oxidation of pollutants present in water is the most appropriate for the tasks of timely monitoring of water bodies. Therefore, as a composite indicator for characterizing the condition of the watercourse and conducting timely monitoring, we chose oxygen indicators.

Keywords: ecological safety of surface waters, composite water quality indicator, complex water quality index

До питання вибору інтегральних показників екологічної безпеки стану вод басейну Сіверського Дінця

В.Л. Безсонний [1,2], Р.В. Пономаренко[3], О.В. Третьяков[4], В.В. Асоцький[3], А.Я. Калиновський[3]

[1]*Харківський національний університет імені В.Н. Каразіна, Харків, Україна,* bezsonny@gmail.com
[2]*Харківський національний економічний університет імені Семена Кузнеця, Харків, Україна,* bezsonny@gmail.com
[3]*Національний університет цивільного захисту України, Харків, Україна,* asotskiy@nuczu.edu.ua
[4]*ТОВ»Іпріс-профіль», Харків, Україна,* mega_ovtr@ukr.net

Анотація. Відсутність діючих механізмів басейнового принципу управління, контролю і відповідальності за екологічний стан поверхневих джерел питного водопостачання призводить до того, що частіше за все основні техногенно-небезпечні об'єкти, які обумовлюють екологічний стан поверхневого джерела води, розташовані на території одних областей, а виготовлення і споживання питної води з цього джерела відбувається на території інших, що ускладнює ефективне управління екологічною безпекою поверхневих джерел водопостачання. Особливо це характерно для малозабезпечених поверхневими водними ресурсами регіонів України, розташованих у басейні р. Сіверський Донець, водні об'єкти якого є головними джерелами водопостачання східних областей держави. При цьому основним споживачем води є Донецька область (понад 50% річного обсягу), а Харківська і Луганська області споживають приблизно однаковий об'єм води на рік (до 50% річного обсягу). Тому є актуальним обґрунтування інтегральних показників екологічного стану водного об'єкта для підвищення екологічної безпеки

поверхневих джерел водопостачання. В роботі показано, що, кисневі показники відіграють важливу роль в екології водного об'єкта. З ними пов'язана асимілююча здатність вод, тобто здатність вод до розкладання органічної речовини. Тому вміст розчиненого кисню та біохімічного споживання кисню у воді становить великий інтерес не тільки з погляду розвитку життя, але і як інтегральний показник екологічного стану водного середовища. Зв'язок, що існує між величиною комбінаторного індексу забрудненості води і величиною біохімічного споживання кисню, робить показник біохімічного споживання кисню важливим для інтегральної оцінки забруднення вод різними органічними речовинами. Для задач, щодо яких ми обґрунтовуємо вибір інтегрального показники екологічного стану поверхневих вод, більш важливим є виявлення наслідків забруднення не безпосередньо в місці забруднення, а на деякій відстані від нього і через деякий час. Тому використання саме величини розчиненого кисню та біохімічного споживання кисню, як показників, що характеризують процес окислення уже наявних забруднювачів у воді, є найбільш доцільним для задач оперативного моніторингу водних об'єктів. Тому в якості інтегрального показника для характеристики стану водотоку та проведення оперативного моніторингу, обрано показники кисневої характеристики.

Ключові слова: екологічна безпека поверхневих вод, інтегральний показник якості води, комплексний індекс якості води

Introduction.

Almost 80% of drinking water in the country is provided from surface sources. Therefore, quality and condition of water in surface water objects are significant factors of sanitary and epidemic safety of the population (Bezsonnyi, Tretyakov, Khalmuradov, Ponomarenko, 2017).

Over the recent years, the problem of ecological safety of surface water has been exacerbated as a result of the unsatisfactory condition of water resources. Among the reasons for this, we should underscore absence of effective mechanisms of managing water resources, control and responsibility. This situation is conditioned by the historical development and location of industrial objects. The main polluters of the surface sources of drinking water are located in one territory (oblast), while the water is processed and consumed in another territory.

The Siversky Donets is the largest river and the most important source of freshwater in eastern Ukraine. The basin of the river is located in the territories of Kharkiv, Donetsk and Luhansk Oblasts of Ukraine and is an urbanized region with highly developed industry and agriculture. The structure of water use which has developed in the basin of the Siversky Donets is represented by all the types of water use, including those with large amounts of water consumption and ecologically harmful productions.

Problems of ecological conditions of the Siversky Donets have been described in a number of studies; particularly, according to the results of the studies (Grischenko, Vasenko, Kolysnyk, 2011), the condition of water in the upper part of the river within Kharkiv Oblast is assessed as "good" in terms of ecological condition and "quite clean" by the level of purity; water appropriate to be used for providing drinking water is only found in the region of the Siversky Donets, in the upper current (approximately 850 km higher) in the conditions of applying intense methods of water purification.

Studies of the influence of large cities of the region on the development of oxygen water regime in the basin of the Siversky Donets have revealed the ability of the ecosystem of the basin to self-purify. On some sites, the process of self-purification are slowed. The oxygen content in the drain below the city of Kharkiv is lower by 30% due to powerful technogenic pressure (Ukhan, Osadcha, 2010).

As an approach to integrated assessment and timely prediction of technogenic pressure, an article (Ponomarenko, Plyatsuk, Hurets, Polkovnychenko, Grigorenko, Sherstiuk, Miakaiev, 2020) proposed using the approximate required level of decrease in harmful effect of inflow of polluting substances on the area of a surface water object. Based on retrospective analysis, composite measures of ecological condition of the Dnipro were modeled mathematically.

Researchers (Zadniprovskii, Maximenko, 2003) note that water that flows from Belgorod Oblast (according to the data for the borderline drain in Staraia Tavolzhanka village of Belgorod Oblast) during recent years was characterized as moderately polluted: copper content equaled 2.83 TLV, nitrites – 1.75 TLV, total iron – 1.78 TLV, phosphorus – 1.39 TLV, and the value of BOD_5–1.2 TLV. A study (Ukhan, Osadchiy, Osadcha, Manchenko, 2002) revealed that the development of the chemical composition of the surface waters in the north part of the basin (the River Siversky Donets in the region from Ohirtseve village to the city of Izium and the Uda, Lopan, Vovcha, Oskil rivers) is dominated by natural factors. Physical-geographic conditions of the basin and hydrological regime of the rivers are determined as seasonal, as well as multi-dynamic overall mineralization and separate elements of chemical composition of surface waters.

It has been established (Bezsonnyi, Tretyakov, Khalmuradov, Ponomarenko, 2017) that technogenic factors play a significant role in development of chemical composition of surface waters in the central and southern parts of the basin (the Siversky Donets in the section from the city of Izium to Kruzhylivka village, left-bank tributaries – the Chervona, Borova rivers and right-bank tributaries – the Suhy Torets, Kazenny Torets, Luhan, Bahmut, Mokra Plotva, Bilenka rivers).

Drawing on the conducted assessments, the studies (Buts, Asotskyi, Kraynyuk, Ponomarenko, Kovalev, 2019) developed mathematical models for the influence of heavy metals on the development of composite indicators of the condition of water bodies, determining the conditions of migration and concentration of compounds of heavy metals, and composing an equation for calculating concentration of mobile forms of heavy metal compounds.

Integrated assessments of the ecological condition of a water environment may be based on absolute measurements of the monitoring system, indicators of degree of change in the condition of water objects in space and time, identified level of influence on recipients, effect and anthropogenic pressure on aquatic environment, criteria of the condition of aquatic ecosystem. Aquatic objects are identified to classes or categories of quality according to the values of excess of the actual level of the concentration of substances, their threshold limit values (TLV) or ecological norms, ratio of actual level to background level, mean or absolute differences between those levels (Kuzin, 1996).

We shall analyze the main approaches to integrated assessment of the quality of the environment, including aquatic objects: hygienic and ecological. The fundamental difference between those approaches is that the hygienic regulations are aimed at protecting the health of a population, while the ecological regulations aim at protecting the life environment for maintaining stability of the natural ecosystems. This fundamental difference makes it impossible to use the methods of hygienic regulations in ecological regulations. Both ecological and sanitary-hygienic regulations are based on knowledge of factors that cause various effects on living organisms. However, a scientifically-substantiated hygienic regulation can be used anywhere, for the adaptive abilities of certain individuals may vary depending on socio-economic and other factors, but generally speaking the protective abilities of the human organism are practically the same. Ecosystems have unique properties, having abiotic and biotic characteristics, different resistance to anthropogenic pressure, and therefore ecological regulations should be developed in a territorially differentiated way taking into account adaptive reserves based on the relationship between the conditions of biota in ecosystems and the environment (Vasenko, Ribalova, Artemyev, Gorban, Korobkova, Polozentseva, Kozlovskaya, Matsak, Savichev, 2015).

In Ukraine and other countries, there is currently a fairly large amount of criteria for integrated assessment of ecological condition of aquatic objects. Some classifications (Shitikov, Rosenberg, Zinchenko, 2003) are based on the assessment of bacteriological and physiological-chemical parameters, while others are based on hydrobiological assessment of water pollution. Each of the criteria provides important information, and using them all together helps in assessing aquatic environment from ecological perspectives.

Integrated assessment of indicators of ecological safety of surface water according to chemical criteria is considered quite a laborious task, for it is based on comparing mean concentrations that are observed at the water control points and the established norms of threshold limit values for each substance. Most of the currently proposed composite parameters (Zhuk, Korobkova, 2015) have been obtained by uniting and generalizing numerous complex indicators in one composite indicator that may characterize various conditions of aquatic objects.

As of now, there is a number of methods to characterize the degree of contamination of water using one generalized indicator (contamination index I_c), which equals mean arithmetic ratio (Losev, Milka, 2011):

$$I_э = \frac{1}{n}\sum_{i=1}^{n}\frac{C_i}{TLV_i}, \quad (1)$$

for substances with values of $C_i/\mathrm{TLV}_i > 1$,
where C_i – actual concentration of i chemical indicator, mg/m^3;
TLV_i – threshold limit concentration of i chemical component, mg/m^3;
n – amount of substances.

The main threat is manifestation of synergism, when presence of one substance increases toxicity of another substance or when two toxic compounds form a compound with much higher toxicity than the initial ones had (for example, compounds of ions of heavy metals and other organic acids). Studies (Shitikov, Rosenberg, Zinchenko, 2003) suggest identifying the complex ecological index of the condition of river ecosystem I depending on values of various parameters:

$$I = \sum_{i=1}^{n}\frac{C_{i_{факт}} \Big/ C_{i_{норм}}}{n}, \quad (2)$$

де $C_{i\ actual}$ – actual concentration of i hydrochemical or trophosaprobiological factor, mg/m^3;
$C_{i\ standard}$ – regulation-established concentration of i hydrochemical factor, mg/m^3.

Moreover, the qualitative condition of natural water is assessed using complex indicators: water contamination index (WCI) (Baranovsky, Bardov, Omelchuk, 2000) and contamination coefficient (CC). Comparing those two complex parameters revealed

superiority of CC. The Ministry of Ecological Resources adopted the method (Zhuk Korobkova, 2015) of assessing CC of natural water. CC is a generalized indicator that characterizes the degree of contamination overall according to water quality parameters that had been numerously measured at several points (drains) of monitoring of aquatic objects. Furthermore, ecological assessment of quality of surface water is performed using corresponding criteria. It allows one to perform comparative assessment of ecological condition of surface waters in various aquatic objects (regardless of the content of contaminating compounds), identification of tendency of its quality over years, facilitating and significantly improving the form of presenting the information, including in the form of maps.

The problem of selecting indicators that are used for ecological assessment of surface water was described in-detail in the study (Shitikov, Rosenberg, Zinchenko, 2003). The solutions for this issue were classified by the authors into three groups:

– using all parameters for which TLVs are determined;

– using a small amount of regulation-established parameters;

– account of some regulation-established parameters and also compounds that characterize processes affecting the water quality.

Implementing the parameters of the first group would be the best variant, but this is practically impossible.

Suggestions from the second group are reflected in research and regulations. In general, the circle of obligatory parameters is limited within the range from ten to twenty.

Parameters of the third group are based not only on the necessity of assessing but also the necessity of predicting changes of ecological condition of surface waters. At the same time, such parameters are taken into account, the change in concentrations which due to physical, chemical and biological reasons automatically affect the values of other indicators.

Combined index of water contamination, which is calculated according to (RD, 2002) and is currently recommended (Zhuk, Korobkova, 2015), allows one to obtain integrated assessment of the ecological condition of surface water based on the extent of excesses of TLVs of individual compounds and will be analyzed below.

Practice and regulatory activity related to monitoring surface waters indicate the necessity to minimize the resources to obtain integrated assessment of the ecological safety of a water body. Therefore, the necessity arises of selecting one or two parameters that would provide integrated assessment of the ecological condition of an aquatic object in general, without the necessity of performing numerous analyses.

Therefore, the objective of this study was substantiation of choosing the biochemical consumption of oxygen as an integrated indicator of ecological safety of water in the Siversky Donets. For this purpose, we needed to characterize the ecological condition in the studied area using combined index of water contamination (CIWC) and determine the relationship between this index and biochemical consumption of oxygen.

Materials and methods.

The study draws from the materials of multi-year monitoring of the ecological condition of surface waters above the place of discharge, at the place of discharge and below the place of discharge of wastewater into the River Siversky Donets from the cleaning stations in the city of Izium. The data are given in Table 1.

Table 1. Values of differences of mean annual values of the parameters of ecological condition of the River Siversky Donets in the area affected by wastewater.

Months	January	Febrary	March	April	May	June
Ammonium salt	0.13575	0.0455	0.026	0.0055	-0.0215	0.0035
BOD_5	0.505	0.4125	0.3075	0.31	0.235	0.3125
Overall iron	0.00,125	0.00525	0.011	0.0135	0.01125	0.009
Oil products	0	0	0	0	0	0
Nitrates	0.97	0.6025	-0.3725	0.7675	0.8475	0.7525
Nitrites	0.00375	0.02	0.00775	0.006	-0.002	0.00025
Surfactants	0.00775	0.0075	0.01475	0.0065	0.00775	0.0055
Sulfates	-2.835	-10.85	-9.835	9.17	-4.0075	-2.75
Dry residue	-10.29	-3.3325	-22.4175	-13.847	-60.46	-14.002
Phosphates	0.185	0.1725	0.145	0.0955	0.1055	0.1325
Chlorides	4.38	5.1925	1.15	1.6075	2.9275	2.7075
COD	0.7675	1.5925	0.795	1.4975	1	1.1275
Dissolved oxygen	0.0025	0.0175	0.0975	-0.0225	-0.1875	-0.1475
Ammonium salt	0	0.01275	0.0175	0.0115	-0.00425	0.02025
BOD_5	0.2875	0.48	0.2975	0.5025	0.28	0.475
Overall iron	0.01	0.009	0.00925	0.005	0.011	0.00975

Continuation of Table 1

Months	January	Febrary	March	April	May	June
Oil products	0	0	0	0	0	0
Nitrates	0.4725	0.9375	1.045	0.7075	0.9525	0.6775
Nitrites	0.002	0.0045	0.00325	0.00225	0.00175	-0.001
Surfactants	0.00725	0.006625	0.00475	0.007875	0.007	0.00575
Sulfates	-3.085	-2.62625	-3.4825	-5.3825	-5.04	-3.2475
Dry residue	-14.275	-10.4275	-11.3425	-17.65	-18.875	-11.8775
Phosphates	0.18075	0.185375	0.15	0.0975	0.115	0.1425
Chlorides	3.3075	3.54875	4.0875	3.7925	3.555	3.725
COD	1.1675	1.34375	1.235	1.08	0.825	0.69
Dissolved oxygen	-0.1575	-0.18375	-0.1725	-0.1975	-0.1725	-0.14

The methods of integrated assessment of contamination of surface water which exist today are divided into two basic groups: the first comprises methods that allow assessment of the quality of water using the general hydrochemical, hydrophysical, hydrobiological, microbiological parameters; the second one – methods related to the calculation of complex indices of water contamination.

Let us perform a more detailed analysis of one of the commonest indicators – combined index of water contamination according to (Zhuk Korobkova, 2015), which is currently recommended (RD, 2002). This index provides an integral assessment of the ecological condition of surface water, based on degree of excess of TLVs for individual substances.

Combined index of water contamination is used to determine the extent of the pollution according to the complex of contaminating compounds. The index may be calculated for any drain or point of monitoring of surface water condition, for an area or entire aquatic object. The informativeness and representativeness of the index in conditions of sufficient amount of information is quite high.

Prior to calculations, the period for which the generalization is made is chosen, depending on the purposes and sufficiency of the amount of initial data. Combined index of water contamination may be calculated for any period of time: day, decade, month, quarter, half a year, year, or multi-year period if there is a sufficient amount of samples.

Calculation of the combined index of water contamination and relative assessment of ecological condition of the surface waters were performed in two stages: first according to each studied substance and parameter of ecological condition of surface water, then we analyzed the entire complex of contaminating compounds simultaneously, calculating the resulting value.

According to each substance, for the period of assessment of the selected object, we determined the following characteristics:

1) repetition of cases of pollution α_{ij}, i.e. frequency of identification of concentrations that exceed TLVs (RD, 2002):

$$\alpha_{ij} = \frac{n'_{ij}}{n_{ij}} \cdot 100\%, \quad (3)$$

where n'_{ij} is the amount of results of the chemical analysis according to i substance in j drain for the analyzed period of time, in which their content or value exceeded the allowable TLVs;

n_{ij} – total amount of results of the chemical analysis for the analyzed period of time according to i compound in j drain.

By the values of repetition, the pattern of water pollution was determined according to the stability of pollution in correspondence to Table 2.

2) Mean value of multiplicity of TLV excess of $\overline{\beta}'_{ij}$ was calculated using the results of the analysis of samples where such an excess was seen. Results of the analysis of samples in which the concentration of contaminant was below TLV were not included in the calculation. The calculation was carried out using the formula

$$\overline{\beta}'_{ij} = \frac{\sum_{f=1}^{n''_{ij}} \beta_{ifj}}{n'_{ij}}, \quad (4)$$

where $\beta_{ifj} = C_{ifj}/TLV_i$ is multiplicity of TLV excess according to i compound in f result of chemical analysis for j drain;

C_{ifj} – concentration of i compound in f result of chemical analysis for j drain, mg/dm^3.

Multiplicity of excess of the normative for dissolved oxygen was determined using the formula

$$\beta_{O_2fi} = \frac{ГДК_{O_2}}{C_{O_2fi}}, \quad (5)$$

According to excesses of TLVs, we determined the level of water contamination, as indicated in Table 2.

Table 2. Classification of water in water object according to repetition of pollutions

Repetition,%	Characteristic of water pollution	Partial assessing point according to repetition, $S_{\alpha ij}$	Share of partial assessing point per 1 % of repetition
[1*; 10)	Singular	[1; 2)	0.11
[10; 30)	Irregular	[2; 3)	0.05
[30; 50)	Characteristic	[3; 4)	0.05
[50; 100)	Regular	4	–

* In values of repetition less than one, we consider Sαij = 0.

Note. Intervals are indicated as follows: number on the right – beginning of the interval; number on the left – end of the interval; parentheses indicate that the number near it is not in the interval; square bracket –the value is included in the interval

According to mean multiplicity of TLV excess of $\overline{\beta}'_{ij}$ and data in Table 3, we assessed partial assessing point for excess of $S_{\beta ij}$. The points were determined using linear interpolation.

Table 3. Classification of water objects according to multiplicity of LTV

Multiplicity of TLV excess	Characteristic of pollution level	Partial assessing point according to multiplicity of TLV excess, $S_{\beta ij}$	Share of partial assessing point per unit of multiplicity of TLV excess
(1; 2)	Low	[1; 2)	1.00
[2; 10)	Average	[2; 3)	0.125
[10; 50)	High	[3; 4)	0.025
[50; ∞]	Extremely high	4	–

Note: Intervals are indicated as follows: number on the right – beginning of the interval; number on the left – the end of the interval; parenthesis indicates that the number near it is not in the interval; square bracket – values is in the interval. For dissolved oxygen, the following conditional gradations of multiplicity of the pollution level are used: (1; 1,5] – low; (1,5; 2] – mean; (2; 3] – high; (3; ∞] – extremely high. If the concentration of dissolved oxygen in a sample equals 0, we consider it to equal 0.01 mg/dm^3 for calculation.

3) Generalized assessment point S_{ij} for each compound was calculated as product of assessment points according to repetition of pollutions and mean multiplicity of excess of TLV:

$$S_{ij} = S_{\alpha ij} \cdot S_{\beta ij}, \quad (6)$$

where $S_{\alpha ij}$ – partial point according to repetition of pollutions with *ith* substance in *jth* drain for the period of time which is analyzed;
$S_{\beta ij}$ – partial point according to multiplicity of excess of TLV of *ith* compound in *jth* drain for the analyzed period of time.

Generalized assessment point allows calculation of values of the studied concentrations and frequency of detecting the cases of TLV excesses for each compound at the same time.

The value of generalized assessment point for each substance individually may vary 1 to 16 for different waters. Its higher value corresponds to higher degree of water contamination.

Further, we determined the combined index of water pollution using the following formula:

$$S_j = \sum_{i=1}^{N_i} S_{ij} \cdot w_i, \quad (7)$$

where S_j – combined index of water pollution in *j* drain;
N_j – amounts of compounds taken into account in the assessment,
w_i – weight coefficients that take into account the significance of *i* compound, w_i in this calculation = 1/*N*.

Results and their analysis.

According to the data of multi-years monitoring, we researched seasonal changes in CICP for three points of monitoring: place of discharge of wastewater from water-cleaning structures, 1,000 m above and 500 m below the place of discharge. As seen from the provided graphs, graphs (Fig. 1), wastewater from cleaning structures worsens the condition of water in the Siversky Donets, for the CICP values 300 m below the outfall are greater than the CICP above the outfall.

The analysis of annual seasonal dynamics of difference between CICP 500 m lower and 1,000 m higher than the outfall of wastewater indicates constant positive difference between the values, except for some cases where wastewater that had run through treatment constructions dissolved polluted river water, as revealed by comparison to the initial data.

The presented graphs also indicate seasonal fluctuations of the difference between CICP values, which may be associated with increase in the surface

runoff as a result of snow melting in spring and rains in autumn, and therefore increase in the amount of polluted wastewater from the treatment constructions.

Let us determine the presence of interrelation between CICP and BOD.

Water quality in the basin of the Siversky Donets was monitored through more than thirty hydrochemical parameters. The results of the monitoring allows us only to state that the water quality currently corresponds to the requirements, i.e. there are no excesses of TLVs (Bezsonnyi, Tretyakov, Khalmuradov, Ponomarenko, 2017). In such a case, it is impossible to perform the complex assessment of the ecological condition of surface water according to hydrochemical indicators. Also, it is impossible to make judgements about the changes that take place in water under the impact of anthropogenic factors. Therefore, the parameters of the third group, which are not mentioned in the literature as much as they deserve, are worthy of attention and research (Bezsonnyi, Tretyakov, Kravchuk, Statsenko, 2016).

Optimum conditions for the development of most microorganisms, plants and animals depend not only on the presence of food, but also combination of abiotic factors of aquatic environment: temperature, pH-environment, salinity, water turbidity, illumination, aerobic conditions.

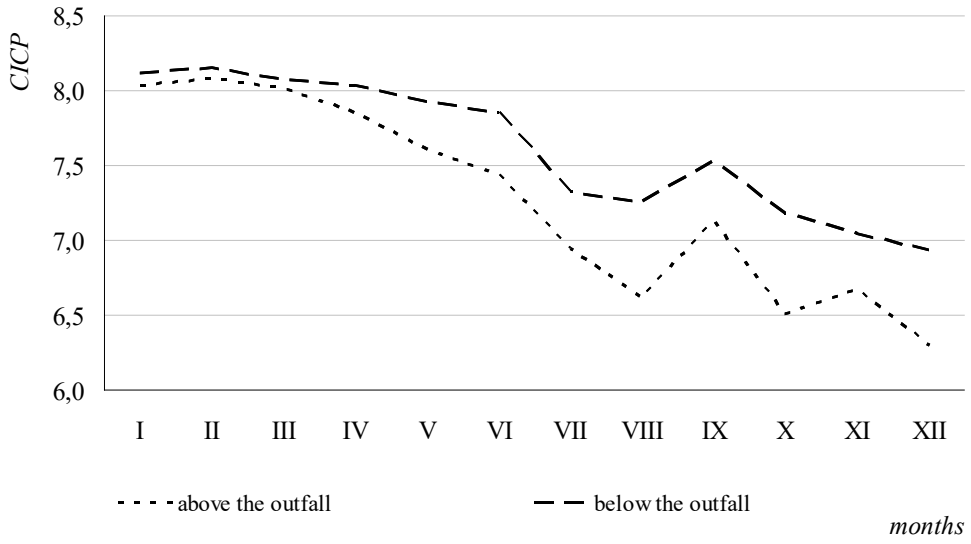


Fig. 1. Seasonal mean annual dynamics of CICP above and below the outfall of wastewater

Vitality of aquatic organisms is to a large degree determined by the content of dissolved oxygen in water. For example, minimum content of DO, which provides the normal development of fish, equals about 5 mg/dm^3. Its decrease down to 2 mg/dm^3 causes mass death of fish. Oversaturation (over 120%) of water with oxygen also has an unfavourable effect on their condition. It should be also mentioned that assessment of the ecological wellbeing of aan quatic environment rarely takes into account the relative content of oxygen. However, oversaturation of water with oxygen usually occurs in cases of concentrations that are far from critical, for example 11 mg/dm^3 in the water temperature of 15 °C or 10 mg/dm^3 in the water temperature of 22 °C.

Concentration of oxygen in water depends on its physical characteristics (temperature and salinity), and also biochemical factors (photosynthesis and oxygen consumption in the conditions of aerobic oxidation of organic compounds). Intensity of photosynthesis depends on light and temperature, and oxidation – on the amount of organic matter, microorganisms and, again, temperature. Other than the considered mechanisms, the concentration of oxygen in water may change under the influence of hydrodynamic factors – transfer (advection) by currents, vertical wavy mixing, etc.

Ingress of oxygen into an aquatic object may be limited by its solubility in water. At a certain water temperature and pressure, a strictly limited amount of oxygen can be dissolved.

Concentration of DO in water also depends on its consumption during oxidation of organic matter, i.e. biochemical factors. In aerobic environments, biochemical oxidation of organic compounds takes place under the effect of bacteria according to the following pattern: organic compounds + oxygen →water + carbon dioxide + other compounds. Decomposition of organic compounds may be considered an equivalent to the oxidation reaction, which reduces DO in water and causes ecological imbalance.

The criterion that characterizes the overall content of organic compounds in water is the indicator of oxygen consumption, which expresses the amount of oxygen

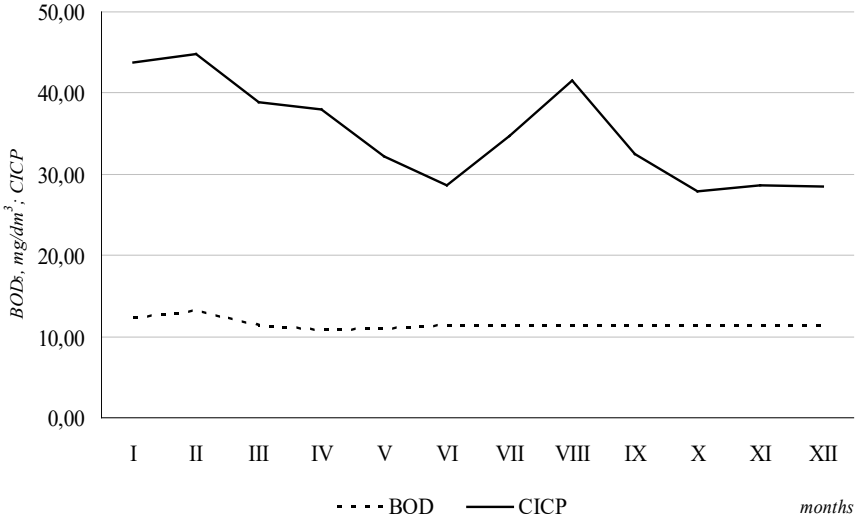


Fig. 2. Seasonal dynamics of mean annual parameters of BOD_5 and CICP at the outfall

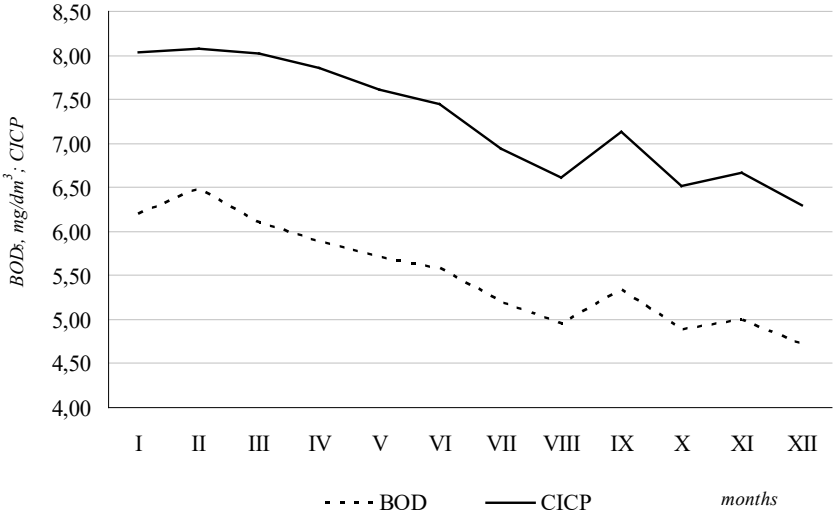


Fig. 3. Seasonal dynamics of mean annual parameters of BOD_5 and CICP above the outfall

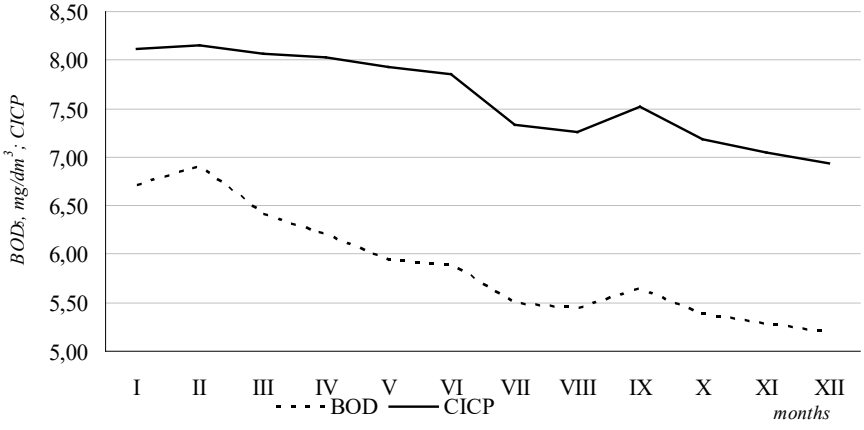


Fig. 4. Seasonal dynamics of mean annual parameters of BOD_5 and CICP below the outfall

(mg) needed for biochemical oxidation of organic compounds held in water, for a certain interval of time. The norm indicator of BOD_5 is the amount of oxygen consumed in five days in the process of oxidation of organic compounds present in analyzed water. Values of BOD_5 (mg/dm^3) are calculated as difference between oxygen content at the moment when sample was taken and 5 days after.

Therefore, there are reasons for selecting oxygen indicators in a watercourse, namely BOD_5 and dissolved oxygen, which is related to it, as indicative (signaling) of ecological condition of surface waters. To confirm this assumption, we checked for presence of correlation between CICP and BOD_5.

We compared three points of control – the outfall of wastewater and places above and below it.

The graphs (Fig. 2) present the seasonal dynamics of mean annual parameters of BOD_5 and CICP in the place of discharge of wastewaters. Correlation coefficient between the indicated values equals 0.57.

The graphs (Fig. 3) demonstrate seasonal dynamics of mean annual of parameters of BOD_5 and CICP above the place where wastewater is discharged. Correlation coefficient between the said parameters equals 0.98.

The graphs (Fig. 4) show the seasonal dynamics of mean annual of parameters of BOD_5 and CICP below the outfall of wastewater. Correlation coefficient between those parameters equals 0.94.

The analysis of seasonal dynamics of parameters and the relationship between these values suggests that determining factor of CICP development below the contamination source is particularly the BOD_5 parameter, as confirmed by correlation coefficient. Right at the place of wastewater discharge, excesses of TLVs of several contaminants caused CICP to various extents.

Conclusions.

Thus, oxygen indicators play an important role in the ecology of aquatic object. They are associated with the assimilating ability of water, i.e. ability of water to decompose organic matter. Therefore, the content of dissolved oxygen and biochemical consumption of oxygen in water is of great interest not only from the perspective of development of life, but also as composite indicators of the ecological condition of an aquatic environment. The relationship that exists between CICP and BOD_5 makes BOD_5 important for indicative assessment of water pollution with various organic compounds. Therefore, as a composite indicator of the condition of watercourse and for carrying out timely monitoring, we selected parameters of oxygen characteristics.

Detecting consequences of contamination at some distances from it and after a certain time, and directly in the place of pollution is the main goal for substantiation of choosing composite indicators of ecological condition of surface water. Therefore, we consider it most expedient to select such indicators for purposes of timely monitoring of aquatic objects, which characterize intensity of processes of water contamination.

References

Baranovskiy, V.A., Bardov, V.G., Omelchuk, S.T., 2000. Ukrayina. Ekolohichni problemy pryrodnykh vod [Ukraine. Ecological problems of natural waters]. K.: Center for Eco-awareness and Information. (In Ukrainian).

Bezsonny, V.L., Tretyakov, O.V., Kravchuk, A.M., Statsenko, Yu.F., 2016. Prohnozuvannya kysnevoho rezhymu richky Sivers′kyy Donets′ metodamy matematychnoho modelyuvannya [Predicting the oxygen regime of the River Siversky Donets by the methods of mathematical modeling]. Business, material knowledge, machine-arypy!building: zb. sciences. good. Vip. 93. DVNZ "Pridnipr. holding academy of bud-va and architecture «Seriya: Bezpeka zhittєdiyalnosti. Dnipro. 113–119. (In Ukrainian).

Bezsonnyi, V., Tretyakov, O., Khalmuradov, B., Ponomarenko, R., 2017. Examining the dynamics and modeling of oxygen regime of Chervonooskil water reservoir. Eastern-European Journal of Enterprise Technologies, 5/10 (89), 32–38.

Buts, Y., Asotskyi, V., Kraynyuk, O., Ponomarenko, R., Kovalev, P., 2019. Dynamics of migration property of some heavy metals in soils in Kharkiv region under the influence of the pyrogenic factor. Journal of Geology, Geography and Geoecology, 28(3), 409–416. https://doi.org/https://doi.org/10.15421/111938 (In Ukrainian).

Gritsenko, A.V., Vasenko, O.G., Kolisnik, A.V., 2011. Suchasnyy ekolohichnyy stan ukrayinskoyi chastyny richky Siverskyy Donets (ekspedytsiyni doslidzhennya) [The current ecological condition of the Ukrainian part of the River Siversky Donets (expedition study)]. Kharkiv: Runway «Contrast». 340 p. (In Ukrainian).

Kuzin, A.K., 1996. Kontseptsyya okhrany vod. Problemy okhrany okruzhayushchey pryrodnoy sredy: sbornyk nauchnykh trudov [The concept of water protection. Problems of environmental protection: collection of scientific works], UkrNTSOV. Kharkov, 23–29. (In Russian).

Losev, M. Yu., Milka, I.V., 2011. Otsinka yakosti poverkhnevykh vod baseynu richky Salhyr [Estimation of surface water quality in the Salgir river basin]. Information processing systems. 3 (93), 199–202. (In Ukrainian).

Ponomarenko, R., Plyatsuk, L., Hurets, L., Polkovnychenko, D., Grigorenko, N., Sherstiuk, M., Miakaiev, O., 2020. Determining the effect of anthropogenic loading on the environmental state of a surface source of water supply. Eastern-European Journal of Enterprise Technologies, Vol 3, 10 (105), 54–62. doi: https://doi.org/10.15587/1729–4061.2020.206125.

RD 52.24.643–2002., 2002. Metod kompleksnoy otsenky stepeny zahryaznennosty poverkhnostnykh vod po hydrokhymycheskym pokazatelyam [Method for a comprehensive assessment of the degree of contamination of surface waters using hydrochemical indicators]. Retrieved from: http://meganorm.ru/ Index2 / 1/4293831 / 4293831806.htm (In Russian).

Rekomendatsyy po provedenyyu obobshchennoho pokazatelya dlya otset urovnya zahryaznennosty pryrodnykh vod [Recommendations for the generalized indicator for assessing the level of contamination of natural waters], 1984. Collection of scientific works of VNIIVO. Kharkiv. 76–79. (In Russian).

Shitikov, V.K. Rosenberg, G.S., Zinchenko, T.D., 2003. Kolychestvennaya hydroékolohyya: metody systemnoy ydentyfykatsyy [Quantitative Hydroecology: Methods for Systemic Identification]. Togliatti: IEVBRAN, 463 p. (In Ukrainian).

Vasenko, O.G., Ribalova, O.V., Artemev, S.R., Gorban, N.S., Korobkova, G.V., Polozentsva, V.O., Kozlovska, O.V., Matsak, A.O.,. Savichev, A.A., 2015. Intehralni ta kompleksni otsinky stanu navkolyshnoho pryrodnoho seredovyshcha: monohrafiya [Integral and complex assessments of the future of the natural environment: monograph]. X: NUGZU. 419 p. (In Ukrainian).

Ukhan, O.O., Osadcha, N.M., 2010. Kharakterystyka kysnevoho rezhymu poverkhnevykh vod baseynu r. Siverskyy Donets [Characteristics of the oxygen regime of surface waters in the basin of the Siverskiy Donets River]. Naukovi pratsi UkrNDGMI. Vip. 259, 199–216. (In Ukrainian).

Ukuhan, O.O., Osadchiy, V.I., N.M. Osadcha, N.M., Manchenko, A.P., 2002. Osoblyvosti formuvannya khimichnoho skladu poverkhnevykh vod baseynu r. Sivers′kyy Donets [Features of the development of chemical composition of the surface waters in the basin of the River Siverskiy Donets]. Naukovi pratsi UkrNDGMI. Vip. 250, 262–279. (In Ukrainian).

Zadniprovsky, V.V., Maksimenko, N.V., 2003. Problemy i dynamika ekolohichnoho stanu baseynu r. Siverskyy Donets na Kharkivshchyni. [Problems and dynamics of the ecological condition of the Siverski Donets River in Kharkivshchyna]. Naukovi pratsi UkrNDGMI. Vip. 252, 150–153. (In Ukrainian).

Zhuk, V.M., Korobkova, G.V., 2015. Intehralna otsinka suchasnoho yakisnoho stanu r. Sivers′kyy Donets u mezhakh Kharkivskoyi oblasti [Integral assessment of the current qualitative condition of the Siversky Donets in Kharkiv Oblast]. Lyudina and Dovkilla. Problems of neoecology. 1–2, 103–109. (In Ukrainian).

Journal of Geology, Geography and Geoecology

Journal home page: geology-dnu.dp.ua

ISSN 2617-2909 (print)
ISSN 2617-2119 (online)

Journ. Geol. Geograph. Geology, 30(4), 632–441.
doi: 10.15421/112158

Tourism potential of Ukraine in the context of geography and current state of German cultural heritage

Nataliia I. Dnistrianska, Mariana I. Senkiv, Halyna Ya. Ilnytska-Hykavchuk, Myroslava I. Haba, Oksana P. Makar

Lviv Polytechnic National University, Lviv, Ukraine, mariana.i.senkiv@lpnu.ua

Received: 20.02.2021
Received in revised form: 06.03.2021
Accepted: 27.03.2021

Abstract. The article describes theoretical foundations of the study of tourism potential of the regions of Ukraine in the context of geography and current state of German cultural heritage. The historical preconditions for the formation and development of cultural heritage of German ethnic minority on the territory of the modern Ukraine are studied. Geography of German ethnic minority of the early XX century within the modern territory of Ukraine and geography of ethnic Germans and German cultural heritage in the modern Ukraine are developed. On the basis of a cluster analysis of indicators of the number of preserved objects and the number of former German settlements, groups of regions with high, medium and low potential for the development of ethnic tourism are identified. Odesa, Lviv, Zaporizhzhia, Kyiv and Zhytomyr are the leaders by the number of objects of German cultural heritage among all regions of Ukraine. The group of regions with a medium level of potential for ethnic tourism includes the Autonomous Republic of Crimea, Volyn, Kherson, Ivano-Frankivsk, Mykolaiv, Poltava, Chernivtsi, and Khmelnytskyi regions. Seven main types of preserved objects of German cultural heritage in Ukraine are identified. Sacred objects and public buildings and structures are best represented. The objects of German cultural heritage preserved to this day in the context of the regions of Ukraine are described. It was found that the main obstacles to the development of German ethnic tourism in Ukraine are the destruction of many cultural heritage objects, lack of funding for restoration of these objects, insufficient involvement of objects to tourist routes and low level of their promotion. The main ways to overcome these obstacles are identified: allocation of budget funds for the restoration of objects, attracting private investors, international organizations and German community; development of new tourist routes; marking places with information stands, publishing information materials about objects; digitalization of objects; organization of international conferences, round tables, festivals, etc.

Keywords: Germans, ethnicity, cultural heritage, tourism, tourism potential, tourism resource, church, cluster analysis.

Туристичний потенціал України у контексті географії і сучасного стану німецької культурної спадщини

Н.І. Дністрянська, М.І. Сеньків, Г.Я. Ільницька-Гикавчук, М.І. Габа, О.П. Макар

Національний університет «Львівська політехніка», Львів, Україна, mariana.i.senkiv@lpnu.ua

Анотація. У статті охарактеризовано теоретичні основи дослідження туристичного потенціалу областей України у контексті географії і сучасного стану німецької культурної спадщини. Вивчено історичні передумови формування та розвитку культурної спадщини німецької етнічної меншини на території сучасної України. Розроблено картосхеми географії німецької етнічної меншини початку XX ст. в межах сучасної території України та географії етнічних німців та німецької культурної спадщини в сучасній Україні. На основі кластерного аналізу показників кількості збережених об'єктів і кількості колишніх німецьких поселень виділено групи областей з високим, середнім та низьким потенціалом для розвитку етнічного туризму. Лідерами серед регіонів України за кількістю об'єктів німецької культурної спадщини є Одеська, Львівська, Запорізька, Київська та Житомирська області. До групи областей із середнім рівнем потенціалу етнічного туризму належать АР Крим, Волинська, Херсонська, Івано-Франківська, Миколаївська, Полтавська, Чернівецька, Хмельницька. Виокремлено сім основних типів збережених об'єктів німецької культурної спадщини в Україні. Найкраще представлені сакральні об'єкти та громадські будівлі і споруди. Охарактеризовано збережені до сьогодні об'єкти німецької культурної спадщини в розрізі областей України. З'ясовано, що основними перешкодами розвитку німецького етнічного туризму в Україні є зруйнованість багатьох об'єктів культурної спадщини, відсутність фінансування для відновлення та реставрації цих об'єктів, недостатнє залучення об'єктів у туристичні маршрути та низький рівень їхньої популяризації. Визначено основні способи подолання цих перешкод: виділення бюджетних коштів для реставрації об'єктів, залучення приватних інвесторів, міжнародних організацій та німецьких спільнот; розроблення нових туристичних маршрутів; ознакування місць інформаційними стендами, видання інформаційних матеріалів про об'єкти; діджиталізація об'єктів; організація міжнародних конференцій, круглих столів, фестивалів тощо.

Ключові слова: німці, етнос, культурна спадщина, туризм, туристичний потенціал, туристичний ресурс, кірха, кластерний аналіз.

Introduction.

The cultural heritage of each country, as a set of material and spiritual values and monuments, is directly related to the history of ethnic communities and groups living on its territory, and, therefore, is distinguished by diversity and regional differences. Knowledge of all ethnic components of the country's cultural heritage performs the functions of socio-cultural mutual enrichment, understanding and cooperation. At the same time, the study of cultural heritage is also important in practice, as it can be used in educational and local history work and tourism (Polyvach, 2012). Taking into account the growing interest in the diverse achievements of diasporas and nostalgic motives of people from ancient settlements of national minorities, their cultural heritage can be of great attraction significance and become a factor in intensifying the development of inbound tourism in Ukraine, overcoming the depression of modern socio-economic development of various settlements and areas.

One of the first definitions of cultural heritage is given by UNESCO in the Mexico Declaration on Cultural Policy: the cultural heritage of people includes works by artists, musicians, architects, writers, scientists, expressions of people's spirituality and a set of values that give meaning to life (UNESCO, 1982). It includes both tangible and intangible products, due to which the creativity of the people finds its expression: rituals, historical objects, monuments, literature, works of art, archives, etc.

Cultural heritage is a prerequisite for the development of tourism. These areas are interconnected. Tourism helps to attract public attention to historical and cultural objects, their preservation. We can talk about the cultural heritage of tourism, that is, elements of the human past as a resource, which include various reasons for the arrival of tourists: the desire to improve personal culture, learn something new, spend time with friends or family (Timothy, 2011). The relationship between cultural heritage and tourism is based on three concepts that combine as the main drivers of tourism interest: physical heritage, cultural diversity, and intangible heritage (Brooks, 2011).

The use of cultural heritage as a special tourism resource is effective only if this resource is combined and interacted with other necessary factors (entrepreneurial initiative, human labor and investment), which ensures the formation of tourism potential, the ability of destination to implement tourism services (Terebukh, 2016).

Historical and cultural heritage especially intensifies the development of nostalgic tourism, which includes trips to visit relatives; visiting places with which important events in a person's private life are connected; the history of the ethnic community which a person belongs to, or important moments in the life of the family, ancestors (Dorosh, 2020). There are two types of nostalgic tourists: real and historical. The first ones seek to revise their past cultural environment, to relive past events, last ones – to visit a specific environment that they have learned about from various sources (books, movies, stories) (Stern, 1992).

The development of ethnic cultural, cognitive and nostalgic tourism has every reason to be effectively combined with ecological, sports and health tourism, providing favorable conditions for the creation of multidisciplinary tourism and recreational clusters.

The purpose of the article is to reveal the peculiarities of the formation, distribution and current state of the cultural heritage of the German national minority in Ukraine in the context of the prospects of its use in tourism. Tasks: 1) to characterize the main stages and features of the settlement of ethnic Germans in Ukraine; 2) to reveal and cartographically reflect the modern geography of the German national minority; 3) substantiate the methodology for assessing the German cultural heritage in Ukraine as a tourism resource; 4) describe the current state of German cultural heritage objects in Ukraine and substantiate the possibilities of their use in tourism; 5) to reveal the problems of development of German ethnic tourism in Ukraine and to suggest ways of their solution.

Materials and methods.

The study is based on the use of two main sources of information: observations and analysis of secondary sources. The observations included visits to and descriptions of major cultural monuments and areas related to German cultural heritage in Ukraine. The works of national and foreign scholars on German cultural heritage, ethnic tourism, geography, history, management and marketing are analyzed. A number of secondary sources is also analyzed, in particular, statistics on the share of the German national minority in Ukraine in different years (population censuses), materials directly or indirectly related to German history, heritage and tourism (the number of cultural heritage objects preserved to the present day and the number of former German settlements), maps and webobjects.

During the processing of the collected data, as well as to illustrate the results of the study, the following methods were used: historical (to describe the historical preconditions for the formation of the cultural heritage of the German ethnic minority in modern regions of Ukraine); typological (for identifying types of preserved objects); cartographic (to analyze the share of Germans

within the former provinces and modern regions of Ukraine); analytical and problematic (to identify problems of development of German ethnic tourism in Ukraine), etc. Cluster analysis (Excel software) was also used to group the regions according to the main criteria – the share of preserved objects of German cultural heritage and the share of former German settlements in the context of regions of Ukraine.

Results of the research and their analysis.

Historical preconditions for the formation and development of the cultural heritage of German ethnic minority on the territory of modern Ukraine

Migration of the ethnic German population to the territory of Ukraine, having passed several stages and directions of settlement, relating to different periods of history and associated with the demographic and socio-political situation in both German and Ukrainian lands. The first information about Germans in Ukrainian lands dates back to the princely period of Ukrainian history and dates back to the XIII–XIV centuries. It is known that at that time Germans came from Regeneburg, Mainz, Vienna, Lubeck, where there was an excess of workers in the field of handicrafts, construction, trade, forming small communities in Kyiv, Volodymyr-Volynskyi, Lutsk, Lviv. The presence of the German ethnic group of that period immediately affected the architecture of cities and their appearance in general, as the German population predominantly settled compactly in individual neighborhoods, reproducing German residential traditions. Subsequently, this influence became even more significant, as German communities from the XIII century began to grant Magdeburg (German) law, which later extended to all settlements. This meant that the development of such settlements had to take place taking into account certain urban planning standards (the presence of the town hall in the center of the settlement, the central market square, etc.). The first to receive the Magdeburg right were Sianok (1339), Lviv (1356), Kamianets-Podilskyi (1374), Terebovlia (1389), and Sambir (1390). Later, already in the XIV–XVI centuries, during the belonging of Ukrainian lands to the Kingdom of Poland and the Grand Duchy of Lithuania, Magdeburg law spread to other cities of the Right Bank and Left Bank of Ukraine, also contributing to the creation of new urban settlements (Kobyletskyi, 2008). That is, the spread of German legal relations has become an important factor in accelerating the urbanization of Ukraine, linking the development of events in the Ukrainian lands with European processes. At the same time, the granting of the Magdeburg right to the cities became one of the reasons for the growth of foreign ethnic colonization of Ukrainian lands, including German one.

German communities of that time arose not only in cities, but also in rural areas, primarily in the western and eastern parts of Galicia. According to the research of the Austrian historian-ethnographer R.F. Kaindl, which was analyzed by I.S. Monolatii, in this period there were 650 localities, the structure of which was based on German law. In particular, in terms of counties: Old Town (16), Turka (27), Stryi (5), Drohobych (17), Sambir (14), Rudky (9), Mostyska (12), Yavoriv (15), Zhovkva), Gorodok (22), Lviv (38), Bibrka (3), Zhydachiv (4), Dolyna (1), Kalush (2), Stanislaviv (5), Peremyshlyany (4), Sokal (2), Brody (4), Zolochiv (6), Berezhany (4), Pidhaytsi (3), Tovmach (5), Kolomyia (1), Sniatyn (1), Buchach (3), Terebovlia (1), Ternopil (1). The German settlers were mostly peasants, artisans, and merchants from Silesia, the Saar, and the Rhineland (Monolatii, 2002).

In the second half of the XVIII–XIX century a new wave of colonization of the territory of Ukraine by the German people begins, which covered both Ukrainian lands as part of the Russian and Austrian empires. The main centers of German settlement within the Russian Empire were the Lower Dnipro (from the second half of the XVIII century) and Southern Ukraine (from the beginning of the XIX century). The German colonists were mostly peasants from Baden, Württemberg, Hesse and the Palatinate, who settled in southern Bessarabia (Ackerman County), Kherson Province (Odesa, Tiraspol and Kherson Counties), Katerynoslav and Tavriia Provinces. These resettlements were the result of the encouraging policy of the tsarist regime, interested in the rapid socio-economic development of sparsely populated areas, which until recently were the part of the Crimean Khanate. The resettlement of Germans to the territory of Volyn also intensified. According to the 1897 census, 345,000 Germans lived in south of Ukraine, accounting for 4.2% of the total population of Ukraine, and 171,000 (5.73%) in Volyn.

After the entry of Bukovyna and Galicia into the Austrian monarchy in the late XVIII century the government of this country also purposefully pursued a policy of resettlement of the German population. These were mostly agricultural workers from Baden, Württemberg, Hesse and the Palatinate and other regions, who settled in Stryi, Dolyna, Drohobych, Kolomyia, Lviv, Stanislav, Rava-Ruska and some other counties (Encyclopedia of Ukrainian Studies, 1996). The process of settlement of Galicia was carried out in two directions: 1) Dobromyl – Stryi – Stanislav (Ivano-Frankivsk); 2) Sambir – Liubachiv – Sokal – Radekhiv –Brody – Berezhany. German colonies formed small rural settlements, the number of inhabitants of which ranged from 25 to 100 people. The largest colonies were Josefeberg (573 people) and Brigidau (607 people) in the Sambir district, as well as Landestroy (327 people) and Ugartstal (329 people) in the Stryi district.

A number of German colonies were created even earlier in the Transcarpathian Ukraine, and the total

German population reached 20 thousand people. Thus, at that time, up to 150 German autonomous settlements emerged on ethnic Ukrainian territory as part of the Austrian Empire. The Austrian government sought to establish new German settlements separately for Protestants and Catholics in order to make it easier and faster to provide religious buildings and educational institutions (Monolatii, 2002).

Although, most German colonies were formed on the plains, German colonization brought some changes to the settlement network of mountainous areas. These were mostly small settlements in the immediate vicinity of Ukrainian villages. While most German colonies in the mountainous Carpathian region of Galicia were mostly agricultural, in Transcarpathia and Bukovyna the establishment of such settlements was due to the needs of forestry and extraction of some mineral resources (Dnistrianskyi, 2019).

Thus, from the end of the XVIII to the beginning of the XIX century the number of the German ethnic minority in the Ukrainian lands increased significantly and according to the censuses of 1897 (in the Russian Empire) and 1900 (in the Austro-Hungarian Empire) totalized 431 thousand people. However, the settlement of ethnic Germans in some regions was significantly differentiated (Fig. 1): its largest concentration (over 10%) was in Volyn, Southern Bessarabia and Northern Crimea, the smallest (less than 1%) – in Podillia and the Left Bank of Ukraine.

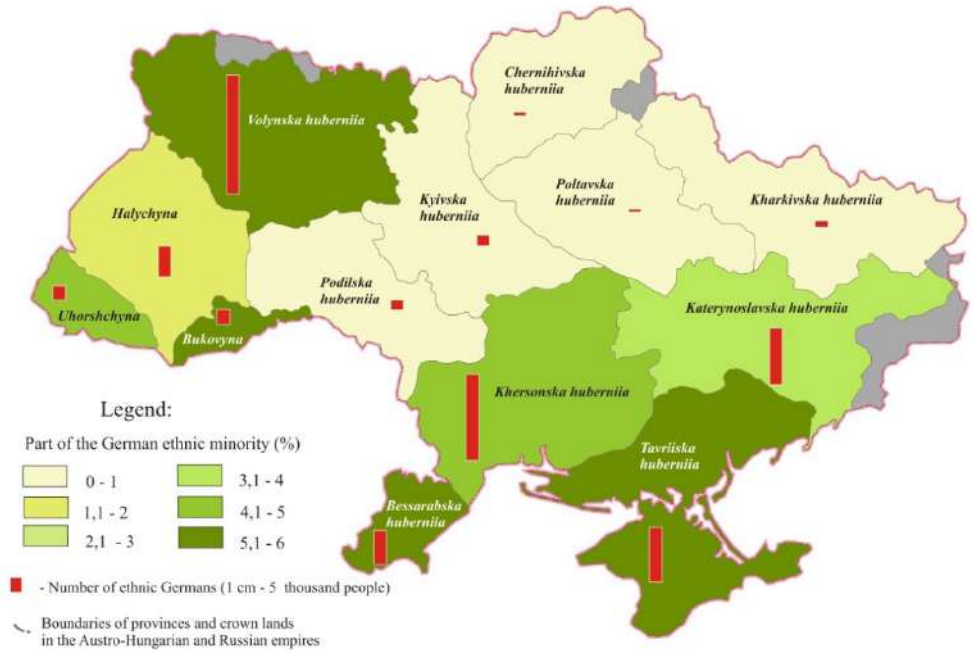


Fig. 1. Geography of the German ethnic minority at the beginning of the XX century within the modern territory of Ukraine (developed by the authors)

In 1939, the German population of Western Ukraine was resettled to Germany in accordance with Soviet-German agreements, and the settlements founded by the Germans were either liquidated or underwent ethnocultural transformation. The fate of the German population was even more tragic, which became the part of the USSR: with the beginning of the German-Soviet war, in 1941, ethnic Germans were deported to Kazakhstan and Central Asia, suffering huge human losses. Despite the limited number of German settlements, their spread to Ukrainian lands to some extent affected the complexity of construction and planning structure of neighboring Ukrainian villages, some aspects of agricultural production and the formation of cultural landscapes in general.

According to the 2001 census, there were 33.3 thousand Germans in Ukraine: the largest number was in Donetsk (4.6 thousand people), Dnipropetrovsk (3.8 thousand people), Zakarpattia (3.5 thousand people), and Odesa (2.9 thousand people) regions and in the Crimea (2.5 thousand people) (Fig. 2).

Assessment of tourism potential of the regions in the context of the current state of German cultural heritage

We will conduct a cluster analysis based on the grouping of regions of Ukraine according to such indicators as the share of preserved objects of German cultural heritage and the number of settlements founded by ethnic Germans. According to obtained results, we can distinguish three groups of areas. The first group includes areas where the share of preserved objects is less than 2%; to the second – from 2 to 5%; to the third – more than 5% (table 1).

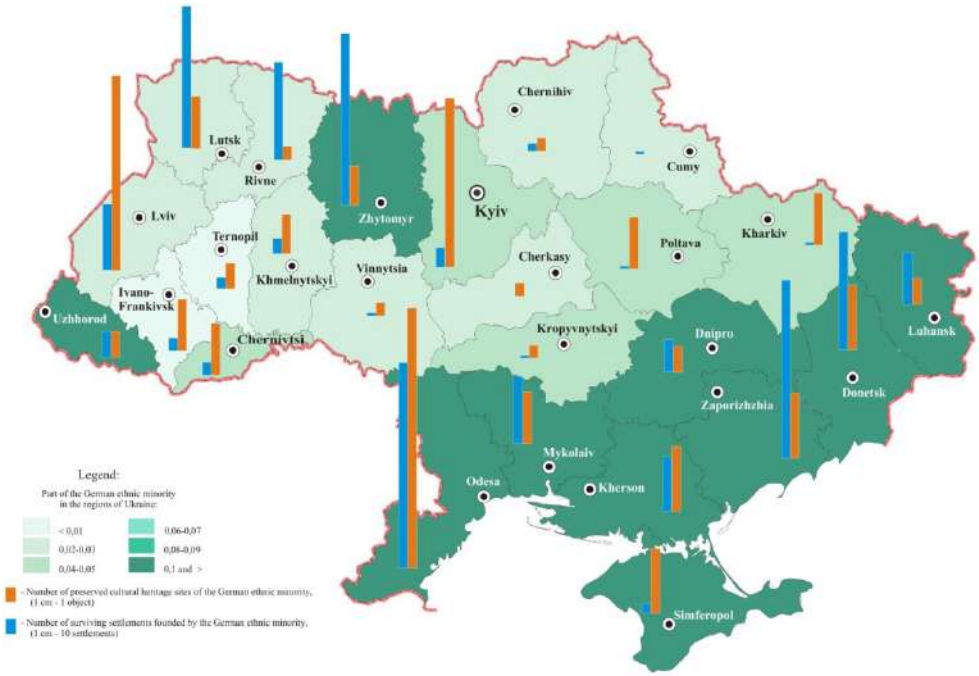


Fig. 2. Geography of ethnic Germans and German cultural heritage in the modern Ukraine (developed by the authors)

Table 1. Cluster analysis of German cultural heritage of the regions of Ukraine (developed by the authors)

Group	Region (Oblast)	Share of preserved objects,%	Share of settlements founded by ethnic Germans,%
1	Dnipropetrovska	1.5	2.5
	Rivnenska	0.7	7.4
	Sumska	0	0.2
	Vinnytska	0.7	0.2
	Zakarpatska	1.5	2
	Kirovohradska	0.7	0.2
	Luhanska	1.5	4
	Donetska	1.5	9
	Ternopilska	1.5	0.8
	Kharkivska	1.5	0.2
	Cherkaska	0.7	0
	Chernihivska	0.7	0.6
Total		**12.5**	**27.1**
2	AR Krym	3.7	0.6
	Volynska	3.7	10.8
	Ivano-Frankivska	3	1
	Mykolaivska	3	5.1
	Poltavska	3	0.2
	Khersonska	3.7	4.2
	Khmelnytska	2.2	1.2
	Chernivetska	3	1
Total		**25.3**	**24.1**
3	Kyivska	9.7	1.5
	Lvivska	15	5
	Zaporizka	10.4	13.6
	Zhytomyrska	6	13.1
	Odeska	21.1	15.6
Total		**62.2**	**48.8**

developed by the authors

According to the results of cluster analysis, the leaders among the regions of Ukraine by the number of objects of German cultural heritage are Odesa, Lviv, Zaporizhzhia, Kyiv and Zhytomyr regions. They are characterized by a high number of preserved objects (62.2%) and a significant number of settlements (48.8% of the total number in Ukraine). These areas have the greatest potential for the development of German ethnic tourism. The second group of regions is characterized by the medium number of preserved objects (25.3%) and the number of settlements (24.1% of the total number in Ukraine). They also have sufficient potential for the development of ethnic tourism. The first group of region has the lowest share of preserved objects (12.5%), although it has a slightly higher share of settlements than in the regions of the second group (27.1%).

Among the regions of Ukraine, the largest number of German settlements was in Odesa (158 units or 15.6% of the total number in Ukraine), Zaporizhzhia (137 units or 13.6%), Zhytomyr (132 units or 13.1%) and Volyn regions (109 units or 10.8%). The smallest number of German colonies was in Cherkasy, Poltava, Kirovohrad, Vinnytsia, Kharkiv and Sumy regions. Few objects of German cultural heritage have been preserved in these areas. There are areas where the number of former German settlements is high, but few objects of German cultural heritage have been preserved, in particular, Rivne, Donetsk and Volyn regions.

Based on this analysis, seven main types of preserved objects of German cultural heritage in Ukraine were identified (Fig. 3). Sacred objects, in particular Lutheran churches, and public buildings and structures, in particular, schools and gymnasiums, are best represented in Ukraine.

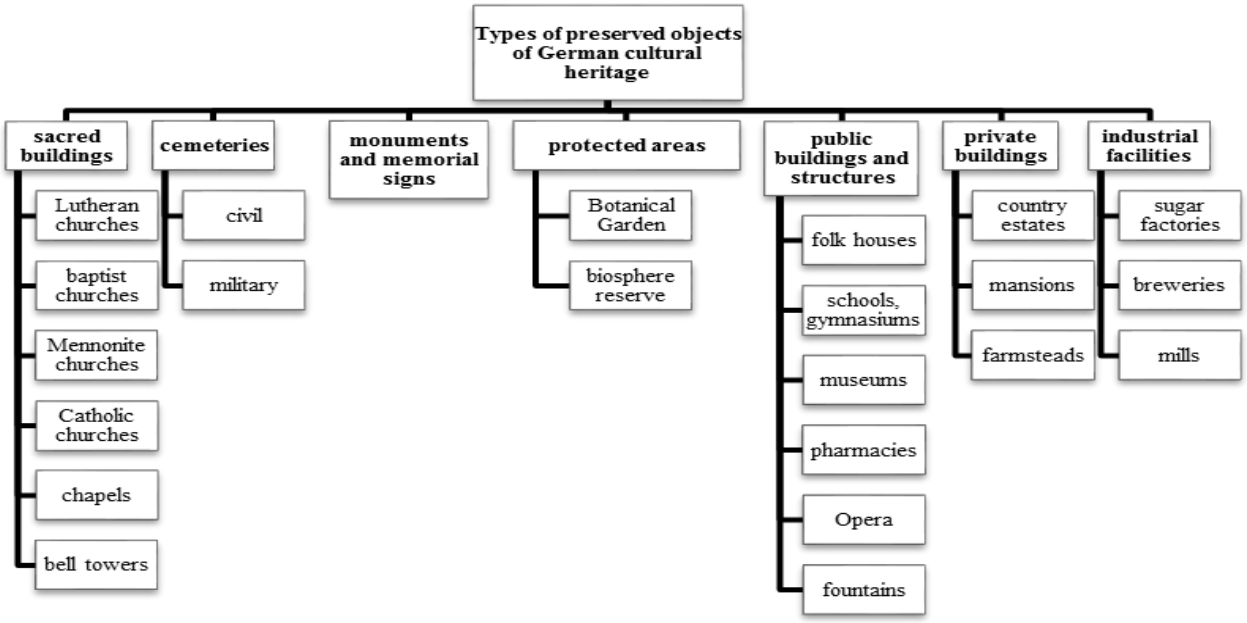


Fig. 3. Types of preserved objects of German cultural heritage in Ukraine (developed by the authors)

To assess the tourism potential of the cultural heritage objects of the German ethnic minority, the geography of their distribution is important. Thus, *Odesa region* has a strong potential for the development of ethnic tourism due to the largest number of preserved objects of cultural heritage of ethnic Germans in Ukraine, in particular, churches, cemeteries, monuments, farmsteads, museums. The contribution of German colonists to the development of villages and towns in the region is especially significant and is evident even now. For example, a unique water supply system built by the Germans is still used in the village Tarutyne. Some temples impress with their style and decoration. Once the largest Catholic cathedral in southern Ukraine – the Cathedral of the Assumption of the Blessed Virgin Mary – was built by the Germans in the village Lymanske (former German settlement of Zelts) on the model of the cathedral in Zaltsburz (Austria). Now the monument needs to be restored. The town also has a museum of German colonists.

A large number of interesting objects of German cultural heritage are located in the *Lviv region*, in particular: the Church of the Nativity of St. Ivana Khrestytelia, the former Lutheran church and the German cemetery in Vynnyky; Church of St. Ursula and the Greek Catholic Church of St. Clement the Pope in Lviv, which was designed in the late nineteenth century by german architect Frans Shtats; Evangelical Church in Pidhaichyky, built in 1910.

The largest military memorial complex of German burials in the Lviv region and a church in the village Potelychi deserve the attention of tourists (Dorosh, Y.,

2020); a German chapel, a former German school and a German cemetery in village Piatnychany; churches in the villages of Yosypivka, Ushkovychi, Sapizhanka; ethnographic museum of Galician Germans in the village of Nyzhni Gaii. In the former German colony of Dornfeld (now the village of Ternopillia) a church, a former German people's house, a school, a mill and a parish have been preserved.

Among the eastern regions of Ukraine, *Zaporizhia region* has the largest number of German cultural heritage objects. In particular, it is the church of Christ the Savior in Berdiansk, as well as churches in the villages of Kutuzivka and Tersyanka. A house-museum of German colonists in the village of Ruchaivka has been preserved, the founder of which is considered to be Victor Dick. Many objects have been preserved in the former German colony of Verkhnia Khortytsia (Zaporizhzhya): mennonite church (now the House of culture), school for girls, hospital complex, Valman Castle. The oldest preserved cemetery in Zaporozhzhia with German burials is located on the island of Khortytsia. There are a large number of historical heritage objects in the former colony of Halbshtadt (now city Molochansk), including the Wilms House, a school for girls, a Mennonite school for boys, the Wilms Mill, and the Shreder House. In the village Mirske (former colony of Mirau) there is a church built in the second half of the XIX century, which is located on the outskirts of the settlement and is half-destroyed. The ruins of the Catholic church in the village Sviatotroitsk have been preserved (former colony of Eikhvald), built in 1871.

There are a number of interesting objects of German cultural heritage in the *Kyiv region*. In particular, the oldest botanical garden in Kyiv (named after Academician O.V. Fomin), which was founded by the German botanist Ernst Rudolf von Trautfetter in 1839. The first German private museum-pharmacy has also been preserved in Kyiv. There are a number of notable buildings and structures built by German architects, including Baron Steingel's house, the Southwestern Railway Administration building, the Weeping Widow's House, the Kyiv Opera House, the bell towers of the Kyiv-Pechersk Lavra and St. Sophia Cathedral (Sait Goethe-Institut v Ukraini).in Ukraine). The German mountain, which is also called the Lutheran mountain is an attractive tourist destination. This is the historical name of a small district of Kyiv, where the Church of St. Catherine has been preserved, in front of which a memorial "Sorrowful Angel" was built in memory of the deportation of Germans from Ukraine during the Second World War.

The following sacred objects of German origin have been preserved in *Zhytomyr region*: the Lutheran Church in Zhytomyr, the churches in the villages of Zazdrivka and Viazovets. Noteworthy is Himmler's headquarters called "Hegewald", built in 1941–1942 in the forest (Sulimenko, 2009).

The group of regions with a medium level of potential of German ethnic tourism includes: Crimea, Volyn region, Kherson region, Ivano-Frankivsk region, Mykolaiiv region, Poltava region, Chernivtsi region and Khmelnytskyi region.

The potential of the *Crimean peninsula* in the context of the development of ethnic tourism, unfortunately, is limited due to the Russian occupation and the uncertain state of the cultural heritage objects themselves, including the German one. Among the preserved objects are: Kessler-Fersman Castle in Lozove, Milhausen estate and the current church in Simferopol, the current church of St. Mary in Yalta and the former Lutheran church in Sudak.

In the *Volyn region* there are three well-preserved churches – Lutheran churches in Lutsk, in the village Oleshkovychi and in the city of Volodymyr-Volynskyi. Another church in the town of Rozhysche is in ruined state (Shovchko; Nadolska, 2004).

Kherson region has a relatively small number of preserved objects. The Askania-Nova Nature Reserve, founded in 1898 by the German naturalist Friedrich Falz-Fein, is unique. The festival of German culture "Kronau Fest" in the village Vysokopillya (former German colony of Kronau) is famous in the region, where the old German gymnasium, the building of the former church and the German cemetery have also been preserved.

Regarding *Ivano-Frankivsk region*, it is also referred to the group of regions with a medium level of ethnic tourism potential. Important objects of German cultural heritage are: the buildings of the former German gymnasium in Ivano-Frankivsk, the orphanage "Bethlehem", the German school, the former German People's House. The Lutheran Church in Kolomyia is also known in the region, which was built in 1873–1875; now it is the Church of St. Nicholas of the Ukrainian Greek Catholic Church.

Among the cultural heritage objects of the German ethnic minority in the *Mykolaiiv region* are the ruins of former churches, in particular, the Church of St. George in the village of Krasnopillya and the Church of St. Antoine of Padua in the village of Novoselivka. However, in Mykolaiiv there is a functioning Lutheran church of Christ the Savior.

Preserved German cultural objects located in the *Chernivtsi region* are Lutheran churches in the village Hlyboka and Chernivtsi. The German People's House in Chernivtsi, built in the early XX century, which was the center of German cultural and social life in Chernivtsi and Bukovyna.

As for the *Poltava region*, it should be noted that the houses of ancient architecture, built by German

colonists are preserved to this day in Poltava, on the streets of Skovoroda, Balakin and Morgun.

In the *Khmelnytskyi region*, German cultural heritage is represented by the Lutheran Church in Dunaiivtsi and the Lutheran Church in Kamianets-Podilskyi, which is now replaced by a children's and youth sports school (Hradun, E. Iu., & Tomilevych L.V., 2016). There are industrial facilities built by the Germans in the region: one of the oldest sugar factories in Ukraine in Gorodok, Khmelnytskyi region, as well as a brewery in Proskuriv (today the company is called "Khmelpivo").

Let us consider the regions that according to the cluster analysis are classified as regions with a low number of preserved objects and settlements.

In the *Ternopil region*, objects of German cultural heritage are represented by a church in the village of Novosilky, but now the building is in a ruined state and needs reconstruction. In 1821, Jan von Konopka opened a boarding house near Mykulyntsi on the basis of hydrogen sulfide mineral springs. Now it is a sanatorium "Medobory" in the village Konopkivka near the town of Mykulyntsi (Volovyk, Yatsiuk, 2017).

In the *Cherkasy region*, the only object that remains to this day is the former Lutheran church in Uman, which is owned by the community of the Evangelical Baptist Church.

In the *Vinnytsia region*, one of the centers of German settlements was the town of Nemyriv, which had a functioning Lutheran church, which was converted into a fire station during the Soviet era. The German cemetery has also survived to this day.

It is worth paying attention to *Zakarpattia region*. The most attractive preserved object in the region is the former residence and hunting lodge of the Counts of Schönborn in the village of Chynadiievo. Schönborn Castle is now a sanatorium "Carpathians", an architectural monument of national importance. There is also a German house in the village that unites ethnic Germans. Worth noting is the village of Nimetska Mokra, which was founded by colonists from Upper Austria in 1775. The church of St. John of Nepomuk, built in 1780, is still preserved in this village. It is the only preserved wooden church of the Germans of Zakarpattia.

An interesting object is the Evangelical Lutheran Church of St. Catherine in *Dnipro*. A mural was created in *Kharkiv* for part of the 25th anniversary of Ukrainian-German diplomatic relations. The German military cemetery is also preserved here.

Problems and prospects of development of German ethnic tourism in Ukraine

Analyzing the existing objects of German cultural heritage in Ukraine, we can note that many of them are destroyed or half-destroyed, so it is necessary to restore and promote them. A partial solution to the problem of lack of public funding may be the transfer of facilities in need of restoration to the ownership of private investors. They will invest in historic objects rather than ordinary ones. The uniqueness and value of historic real estate will help fill local budgets. Historic public spaces (squares, streets) can become a venue for fairs, festivals and more. Some churches can be transferred to other denominations, thanks to which they would be restored (this is how a wooden church in the village of Nova Lypivka in Ivano-Frankivsk region was restored).

In the European countries, particularly, in Germany, owners who restore cultural objects, tax rebates, soft loans, etc. are encouraged. It is expedient to introduce such a practice in Ukraine as well. In recent years, grant programs, most often funded by European organizations, have become popular. In view of this, it is advisable to attract grant funds for the restoration of German cultural heritage.

Legislation needs to be improved to ensure the protection and preservation of historical and cultural heritage by state and local authorities, as well as to oblige owners to keep their facilities in good condition. To date, Ukraine has not developed a sustainable model for the preservation of historical and architectural heritage. Budget expenditures for cultural heritage activities are constantly declining. The state policy of cultural heritage protection is based on the Law "On Protection and Preservation of Immovable Cultural Heritage of Ukraine", but the current system of state control over cultural heritage preservation is not effective, a significant amount of functions is transferred to places, but they are unable to perform financial ones. Ukraine lacks the successful experience of private initiative or public-private partnership to preserve historical and cultural heritage.

Another important task is to involve the public in the preservation of cultural heritage. Public involvement and participation will contribute to the sustainable development and preservation of cultural and historical heritage. The public-private partnership will focus public and private initiatives on the development and maintenance of historic objects for the benefit of communities, including employment, education, tourism and general awareness of cultural value. The descendants of German colonists who went abroad are most interested in the German historical and cultural heritage. They often come to their native lands and finance various projects. That is why it is important to promote German cultural heritage objects. One of the popularization ways can be the organization of a virtual museum or virtual exhibitions, as well as certification and inclusion in the national electronic information resource of cultural heritage, conferences, round tables and more.

Conclusions.

Ukraine has a rich cultural heritage, including German. As the state seeks to integrate into the world cultural space, the study of cultural heritage, its preservation is an important task of national importance. Historic objects are the key to sustainable development of the country. The protection of cultural heritage is an international legal obligation of our state to the world community. This encourages the analysis of the state of historical objects, the directions of activation of all components of their potential. Their recovery will contribute to the development of the country's economy, tourism and improve living standards. The main centers of development of German ethnic tourism can be Odesa, Lviv, Zaporizhzhia, Kyiv and Zhytomyr regions. In addition, a number of regions oblsthave a slightly lower but sufficient tourism potential that needs to be developed (Crimea, Volyn, Kherson, Ivano-Frankivsk, Mykolaiiv, Poltava, Chernivtsi and Khmelnytskyi regions). Many German cultural heritage objects in Ukraine are abandoned and in need of restoration, so a serious problem is the insufficient state funding for appropriate measures for their preservation and restoration. To develop German ethnic tourism and improve the state of German cultural heritage in Ukraine, it is advisable to promote, study and implement foreign experience, in particular, in financing, management, legislative regulation of heritage, develop tourist routes with different types of objects, attract sponsors (in particular, among German descendants), participate in grant programs, etc. An important role here is given not only to the state, but also to the local governments and the public.

References

Baitsar, A., 2013. Heohrafiia nimetskykh poselen u Vynnykakh (v konteksti rozvytku etnokulturnoho turyzmu) [Geography of German settlements in Vynnyky (in the context of ethnocultural tourism development)]. Visnyk Lvivskoho universytetu. Seriia heohrafichna.– Visnyk of the Lviv University. Series of geography, 43, 11–16 Retrieved form: http://old.geography.lnu.edu.ua/Publik/Period/visn/43(1)/index43(1).html (In Ukrainian).

Bidenko, N., 2012. Staryu dancing – pershe nimecke poselennia na terytorii Kirovogradskoi oblasti [Old Danzig is the first German settlement in the Kirovohrad region]. Naykovi zapysy Kirovogradskoho derzavnoho pedahohichnoho universytetu V. Vynnychenka, 16, 63–69. Retrieved from: http://nbuv.gov.ua/UJRN/Nz_i_2012_16_11 (In Ukrainian).

Dnistrianskyi, M. S., 2019. Rol riznospriamovanykh kolonizatsiinykh rukhiv u zaselenni Ukrainskykh Karpat uprodovzh XIII – pershoi polovyny XIX st [The role of multidirectional colonization movements in the settlement of the Ukrainian Carpathians during the XIII – first half of the XIX century]. Lviv: LNU imeni Ivana Franka. Retrieved from: https://geography.lnu.edu.ua/wp-content/uploads/2020/02/Maket-Dnistrianskyy-1–116.pdf (In Ukrainan).

Dorosh, Y., 2020. Nimetska istoryko-kulturna spadshchyna yak resurs dlia rozvytku nostalhiinoho turyzmu u Lvivskii oblasti [German historical and cultural heritage as a resource for the development of nostalgic tourism in the Lviv region]. Visnyk Kyivskoho natsionalnoho universytetu kultury i mystetstv. Seriia: Turyzm. Bulletin of Kyiv National University of Culture and Arts. Series in Tourism, 1, 115–127 Retrieved from: https://doi.org/10.31866/2616–7603.3.1.2020.207515 (In Ukrainian).

Graham Brooks, 2011. Heritage as a driver for development Its contribution to sustainable tourism in contemporary society, 497–505. Retrieved from: https://openarchive.icomos.org/id/eprint/1207/1/III-1-Article1_Brooks.pdf.

Hnes, L.B., 2004. Nimetski kolonii Halychyny v riznykh sotsialno-ekonomichnykh formatsiiakh [German colonies of Galicia in various socio-economic formations]. Visnyk Natsionalnoho universytetu "Lvivska politekhnika" – Bulletin of the National University "Lviv Polytechnic", 505, 174–178. Retrieved from: http://ena.lp.edu.ua:8080/bitstream/ntb/9609/1/23.pdf (In Ukrainan).

Hradun, E. Iu., & Tomilevych L. V., 2016. Problemy ta perspektyvy doslidzhennia kulturnoi spadshchyny m. Dunaivtsi Khmelnytskoi oblasti [Problems and prospects of research of cultural heritage of Dunaivtsi, Khmelnytsky region]. Sivershchyna v istorii Ukrainy: Zb. nauk. pr.– Severshchyna in the history of Ukraine: Coll. Science. ave., 9, 33–39. Retrieved from: http://nz-hlukhiv.com.ua/wp-ontent/uploads/sivershuna/sivershuna_2016.pdf (In Ukrainian).

Kobyletskyi, M.M., 2008. Mahdeburzke pravo v Ukraini: XIV – poch. XIX st. Istoryko-pravove doslidzhennia [Magdeburg law in Ukraine: XIV – beg. XIX century Historical and legal research]. Lviv: PAIS (In Ukrainan).

Monolatii, I., 2000. Nimetski kolonii Halychyny v tablytsiakh. Dovidnyk [German colonies of Galicia in the tables. directory]. Kolomyia. Retrieved from: https://kalusz.io.ua/s120978/nimecki_kolonie_galichini (In Ukrainan).

Monolatii, I.S. 2002. Vid kontaktiv do spivpratsi: sotsialno-ekonomichne stanovlennia ta kulturnyi rozvytok nimtsiv u Halychyni [From contacts to cooperation: socio-economic formation and cultural development of Germans in Galicia]. Kolomyia: Vydavnytstva-polihrafichne tovarystvo "Vik" (In Ukrainan).

Nadolska, V., 2004. Nimtsi na Volyni: etapy rozvytku diaspory i suchasne natsionalno-kulturne vidrodzhennia [Germans in Volhynia: stages of diaspora development and modern national and cultural revival]. Etnichna istoriia narodiv Yevropy – Ethnic history of the peoples of Europe, 16, 114–119. Retrieved from: https://evnuir.

vnu.edu.ua/bitstream/123456789/935/3/16_19.pdf (In Ukrainan).

Nimci u Xersonskiy oblasti [Germans in the Kherson region]. Retrieved from: https://lib.kherson.ua/n-i-n_nimtsi.htm (In Ukrainian)

Nimetski slidy v Ukraini [German traces in Ukraine]. Sait Goethe-Institut v Ukraini – Goethe-Institut website in Ukraine. Retrieved from: https://www.goethe.de/ins/ua/uk/kul/sup/dsu/art.html (In Ukrainan).

Nimtsi na Ukraini. Entsyklopediia Ukrainoznavstva [Germans in Ukraine. Encyclopedia of Ukrainian Studies]. 1996, Lviv, Vol.5, 1768–1774. Retrieved from: http://izbornyk.org.ua/encycl/euii133.htm (In Ukrainan).

Polyvach, K.A., 2012. Kulturna spadshchyna ta yii vplyv na rozvytok rehioniv Ukrainy [Cultural heritage and its impact on the development of the regions of Ukraine]. Kyiv: Instytut heohrafii NAN Ukrainy. Retrieved from: https://igu.org.ua/objects/default/files/pdf-text/PolyvachK_Heritage.pdf (In Ukrainian).

Shovchko, V. Liuteranska kirkha Volodymyr-Volynskoho [Lutheran Church of Volodymyr-Volynsky] Retrieved from: https://zabytki.in.ua/uk/2236/lyuteranska-kirkha-volodimir-volinskogo (In Ukrainan).

Silberberg, T., 1995. Cultural tourism and business opportunities for museums and heritage places. Tourism Management, 16(5), 361–365.

State Statistics Committee of Ukraine: All-Ukrainian Census 2001. Retrieved from: http://2001.ukrcensus.gov.ua/

Stern, B.,1992. Historical and personal nostalgia in advertising text: The fin de sie'cle effect. Journal of Advertising, 21(4), 11–22.

Sulimenko, O., 2009. Nimetska kolonizatsiia volynskoi hubernii v kintsi XVIII – 70-Kh rr. XIX st [German colonization of the Volyn province in the late XVIII – 70's of the XIX century]. Retrieved from: http://eprints.zu.edu.ua/4862/1/Sulimenko_2.pdf (In Ukrainan).

Terebukh, A.A., Moroz, O.I., 2016. Otsiniuvannia turystychnoho potentsialu destynatsii [Estimation of tourism potential of destinations]. Aktualni problemy ekonomiky – Current problems of the economy, 7(181), 335–343 (In Ukrainian).

Timothy, D.F., 2011. Cultural Heritage and Tourism: An Introduction; Chanel View Publications: Bristol, UK.

UNESCO. Mexico City Declaration on Cultural Policies World Conference on Cultural Policies Mexico City, 26 July-6 August 1982. Retrieved from: https://culturalrights.net/descargas/drets_culturals401.pdf.

Volovyk, V. & Yatsiuk, V., 2017. Nimetski silski etnokulturni landshafty Podillia XIX – pochatku XX storichchia [German rural ethnocultural landscapes of the 19th – early 20th centuries]. Visnyk Kyivskoho natsionalnoho universytetu imeni Tarasa Shevchenka – Bulletin of Taras Shevchenko National University of Kyiv, 3–4 (68–69), 103–107 (In Ukrainan).

Volovyk, V. & Yatsiuk, V., 2017. Nimetski silski etnokulturni landshafty Podillia XIX – pochatku XX storichchia [German rural ethnocultural landscapes of the 19th – early 20th centuries]. Visnyk Kyivskoho natsionalnoho universytetu imeni Tarasa Shevchenka, Geografiya – Bulletin of Taras Shevchenko National University of Kyiv, Geography, 3–4 (68–69), 103–107. Retrieved from: http://doi.org/10.17721/1728–2721.2017.68.19 (In Ukrainian).

Journal of Geology, Geography and Geoecology

Journal home page: geology-dnu.dp.ua

ISSN 2617-2909 (print)
ISSN 2617-2119 (online)

Journ. Geol. Geograph. Geology, 30(4), 642–652.
doi: 10.15421/112159

Malta's tourism potential

Viktor V. Hrushka[1], Nataliya A. Horozhankina[2], Alla P. Girman[2], Serhii V. Shulyak[2], G.V. Shcholokova[2]

[1]*Oles Honchar Dnipro National University, Dnipro, Ukraine,* grush_vv@ua.fm
[2]*University of Customs and Finance, Dnipro, Ukraine,* nataliagorozhankina@gmail.com, girmanap77@gmail.com, sergiishuliak@gmail.com, a.shcholokova@gmail.com

Received: 20.02.2021
Received in revised form: 06.03.2021
Accepted: 27.03.2021

Abstract. Methods of estimation of tourist and recreational resources are traced; the analysis of natural tourist and recreational resources of the Republic of Malta is carried out; the analysis of historical and cultural tourist and recreational resources of the country is carried out; a point assessment of the country's provision of tourist and recreational resources; the place of the Republic of Malta on the tourist market of Ukraine is revealed. The Republic of Malta is one of the few countries in the world with such a large and diverse historical and cultural site. The lands of the country have experienced centuries of historical events, after which there are memories in the form of cathedrals, palaces, museums, fortifications, etc. Malta has been established as a country with an ancient history. It has a large number of unique cultural monuments, as there were Carthaginians and Phoenicians, Roman and Byzantine empires, Arabs, knights of the Order of St. John, Napoleon, the British Empire. The country's historical and cultural tourist resources make it interesting for tourists to visit. Malta has a great historical past, which has left a great legacy in the form of ancient fortresses, churches, cathedrals, majestic palaces. The UNESCO World Heritage Site is no exception for the country; there are 3 of them in the list. There are 7 sites in the country that are also currently candidates for inclusion in the World Heritage List. The country is rich in fortifications; there are 35 units in the country, which are of particular interest for tourists. Most of the fortifications were built during the Order of Malta to fortify the country from invaders. The natural conditions of Malta, which are the basis for tourism development, are analyzed. Methods for estimating the tourist potential of the country have been studied, in particular: normative-index, balance, graphic, cartographic, expert, statistical and mathematical methods, scoring. Integrated indicators for each region of Malta were determined using a score. Three categories of regions have been identified according to the assessment of the tourist potential of the territory.

Keywords: Republic of Malta, score estimation, climate, relief, tourist and recreational resources, tourism development

Туристичний потенціал Мальти

В.В. Грушка[1], Н.А. Горожанкіна[2], А.П. Гірман[2], С.В. Шуляк[2], Г.В. Щолокова[2]

[1]*Дніпровський національний університет імені Олеся Гончара, Дніпро, Україна,* grush_vv@ua.fm
[2]*Університет митної справи та фінансів, Дніпро, Україна,* nataliagorozhankina@gmail.com, girmanap77@gmail.com, sergiishuliak@gmail.com, a.shcholokova@gmail.com

Анотація. Простежено методики оцінки туристсько-рекреаційних ресурсів; проведений аналіз природних туристсько-рекреаційних ресурсів Республіки Мальта; проведений аналіз історико-культурних туристсько-рекреаційних ресурсів країни; здійснена бальна оцінка забезпеченості країни туристсько-рекреаційними ресурсами; виявлено місце Республіки Мальта на туристичному ринку України. Республіка Мальта є однією з небагатьох країн світу, що має таку кількість і різноманіття історико-культурних об'єктів. Землі країни пережили багатовікові історичні події, після яких залишилися згадки у вигляді соборів, палаців, музеїв, фортифікаційних споруд, тощо. Встановлено, що Мальта є країною зі стародавньою історією. На її території зосереджена велика кількість унікальних культурних пам'яток, адже тут були і карфагеняни, і фінікійці, Римська і Візантійська імперії, араби, лицарі Ордена Святого Іоанна, Наполеон, Британська імперія. Забезпеченість країни історико-культурними туристичними ресурсами робить її цікавою для відвідування туристами. Мальта має велике історичне минуле, яке залишило по собі велику спадщину у вигляді стародавніх фортець, церков, соборів, величних палаців. Не винятком для країни є об'єкти, що увійшли до Всесвітньої спадщини ЮНЕСКО, їх у списку 3 одиниці. Та об'єкти, що є на даний час кандидатами до внесення до списку Всесвітньої спадщини, таких в країні 7 одиниць. Країна багата на фортифікаційні споруди, їх в країні налічується 35 одиниць, що представляють особливу зацікавленість серед туристів. Основна кількість фортифікаційних укріплень будувалася за часів Мальтійського ордену для укріплення країни від нападників. Проаналізовано природні умови Мальти, що є підгрунтям розвитку туризму. Вивчено методи для оцінки туристичного потенціалу країни, зокрема: нормативно-індексний, балансовий, графічний, картографічний, експертний, статистичні та математичні методи,

бальної оцінки. Із застосуванням бальної оцінки визначено інтегральні показники для кожного регіону Мальти. Виявлено три категорії регіонів за оцінкою туристичного потенціалу території.

Ключові слова: Республіка Мальта, бальна оцінка, клімат, рельєф, туристсько-рекреаційні ресурси, розвиток туризму

Introduction.

Recreation, tourism and health are the highest social values in the modern world. Therefore, over the past few decades, the importance of tourism and recreation in the world is gradually growing. The tourist and recreational potential of any country depends on the resources and suitability for tourism. International recreation covered almost all European countries, but very unevenly. The nature of the participation of particular countries in recreational activities also differs significantly (Barabanova, Bohatyryova, Gorina, 2021). Among the countries with the most powerful developed recreation – France, Great Britain, Spain, Italy, Greece, etc. However, a region that wants to become a popular tourist destination must have unique natural and cultural complexes and offer them to the tourist market. Malta belongs to this one.

The Republic of Malta is a country that entered the history of independent Ukraine by the fact that during its presidency in the European Union we received the long-awaited visa-free regime with the countries of the European Union. Now Ukrainians can visit a country where tourism development is considered by scientists to be success stories.

The purpose of the work is to analyze and estimate a score of tourist and recreational resources of the Republic of Malta, to determine the most suitable for recreation and tourism districts of the country.

Research methods.

The study used literary, analytical, comparative, mathematical and statistical methods and the method of scientific systematization, the method of scoring.

Results and their analysis.

Identification and assessment of natural and recreational resources is one of the main tasks of recreational nature management. It is possible to establish the natural and recreational potential of the territory (water area) only after the implementation of these studies. Based on it, plans for the development of recreation and management of natural and recreational resources are developed.

There are different methods and approaches to assessing recreational resources. For example, the method of assessing the aesthetic properties of objects (Topchiev, Kolomiets, Sych, Yavorskaya, 2020). Excursion objects carry two types of information: a) semantic, which has a logical character and is directed to the human subconscious; b) aesthetic. Of these, the least studied Aesthetic information is least studied among them all. However, not only the cognitive information of the object is important to obtain a certain recreational effect, but also its attractive properties.

When assessing recreational resources, it is necessary to take into account the so-called "geographical recreational area", which reflects the features of the settlement system, environmental and climatic conditions and the needs of the population in recreation not far from their place of residence.

According to the methods of Zorin I. and Birzhakov M., it is possible to use the following methods to assess and analyze recreational resources:

– Normative-index method, which lies in the study of the actual state of a certain type of recreational resources in comparison with the normative level adopted as a standard. With the help of this method it is possible to study the provision of the population and those who rest with the main types of recreational resources, meeting their needs in different types of recreational activities, etc.;

– Balance sheet method, which involves comparing the availability of resources and their use. This method is successfully used for drawing up balances of land, beach, labor resources, etc., in studies of the needs of different groups of the population in certain types of recreation;

– Graphical method, which is based on the representation of the structural and dynamic composition of indicators in the form of diagrams, line graphs;

– Cartographic method, which involves modeling recreational activities using recreational research maps. This method opens up great opportunities in obtaining qualitatively new data on the patterns of formation, development and dynamics of territorial recreational systems;

– Expert method used to obtain information about the potential of various areas in which recreation is organized;

– Statistical and mathematical methods that are widely used in the processing and analysis of recreational resources;

– A scoring method used to identify and characterize natural recreational resources that cannot be estimated using absolute quantities. This method can also be used to assess the suitability of areas for the organization of recreational zoning (Yavkin, Rudenko, Korol', 2006).

In our study, the analysis and scoring of tourism and recreational resources of the Republic of Malta based on the proposed approaches.

Malta is a country with an ancient history. It has a large number of unique cultural monuments, as

there were Carthaginians and Phoenicians, Roman and Byzantine empires, Arabs, knights of the Order of St. John, Napoleon, the British Empire (Caruana, Farrugia, 2018).

The sites included in the international list of UNESCO World Heritage Sites are of the greatest importance in the historical and architectural potential of Malta.

There are three UNESCO cultural heritage sites in the country (Table 1). As for such a rich country, there are few attractions, and it should be borne in mind that one of them is the entire capital city of the country (City of Valletta).

Table 1. UNESCO World Heritage Sites (National Statistics Office Malta, 2020, OECD Tourism Trends and Policies, 2020)

Historical and cultural monument	Location	Object creation time	Year of inclusion of objects in the UNESCO list	Characteristics of a historical and cultural monument
Hal-Saflieni Sanctuary	City of Paola	2.5–3 thousand years BC	1980	Megalithic underground sanctuary (hypogeum). It represents 34 rooms hollowed out in the limestone layer.
Valletta	City of Valletta	The middle of the XVI century	1980	The whole city is a cultural heritage of mankind and a UNESCO monument.
Megalithic temples of Malta: – Jgantia – Mnajdra – Sorrow – Tarshien – Ta 'Hajrat – Hajar-Kim	Municipalities: Shaara, Candy, Mjarr, Tarshien	3.6–3 thousand years BC	1980	This is a group of prehistoric megalithic temples. They include eleven prehistoric monuments, seven of which are a UNESCO World Heritage Site.

Malta is called “a unique open-air museum”. An increasing number of tourists come to the archipelago to get acquainted with the rich historical heritage, architectural and artistic monuments. Many of the historical and cultural sites are located in Valletta. The city itself is a UNESCO World Heritage Site, because it has a large number of sites with centuries-old history (Grima, 2017).

The Maltese archipelago has a great cultural and historical heritage (Fig. 1). Each object is unique in its history of creation, majesty and is quite interesting in tourist and recreational activities (Jones, Navarro, 2018).

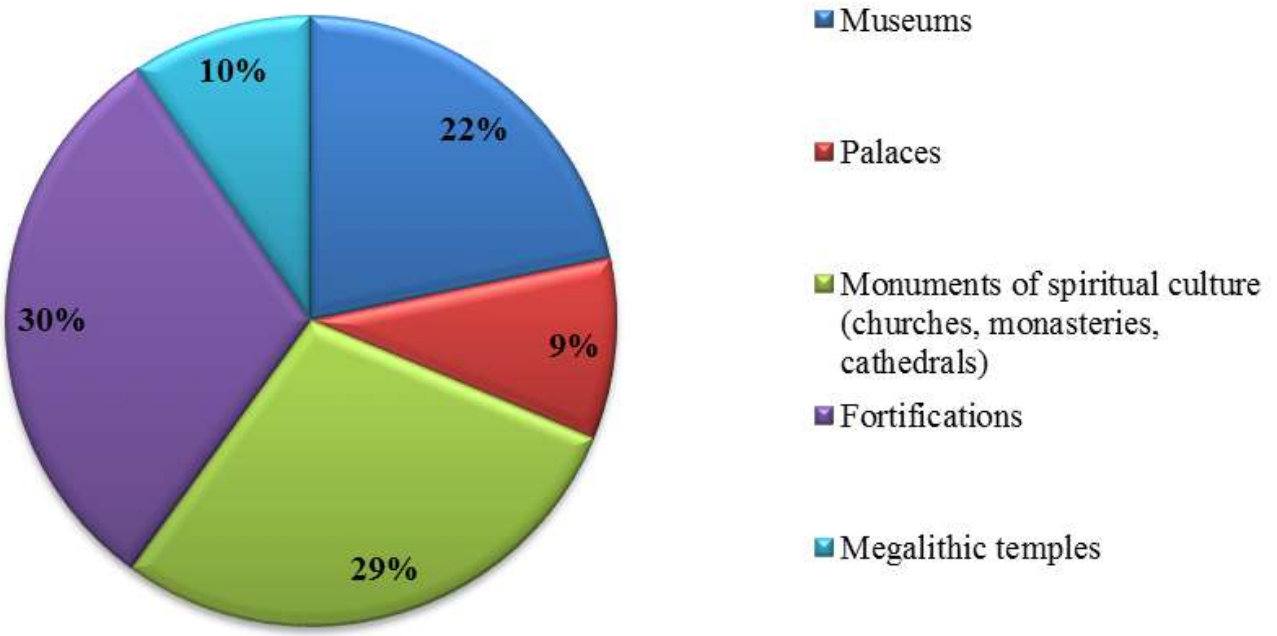


Fig. 1. The main cultural and historical monumen0ts of Malta

The country is rich in fortifications; there are 35 units in the country, which are of particular interest of tourists. Most of the fortifications were built during the Order of Malta to fortify the country from invaders. The country also has a large heritage of spiritual monuments, churches, monasteries, cathedrals fill the streets of Maltese cities (Ebejer, 2019).

Museums are an important tourist attraction for the country. They are interesting archaeological finds and compositions made in the present, reproducing the past (Museum of Torture) (Croes, Ridderstaat, Niekerk, 2018).

The Republic of Malta is one of the few countries in the world with such a large and diverse historical and cultural site. The lands of the country have experienced centuries of historical events, after which there are mentions in the form of cathedrals, palaces, museums, fortifications, etc. (Ebejer, 2019, Attard, S., 2019).

According to the administrative-territorial structure, the Republic of Malta is divided into six districts (Table 2).

Table 2. Districts of Malta

No	Districts	Administrative center	Area, km^2
1	Inner Harbor	Valletta	26.2
2	Northern District	Mosta	73.7
3	Outer Harbor	Birkirkara	24.0
4	Western District	Rabat	72.5
5	Southeastern District	Zeytun	50.2
6	Gozo and Comino	Gozo and Comino Islands	68.7

Assessment of orographic resources of the country, namely the relief, is made basing on a three-point scale relative to the heights of the country, which is divided into districts (Fig. 2, Table 3).

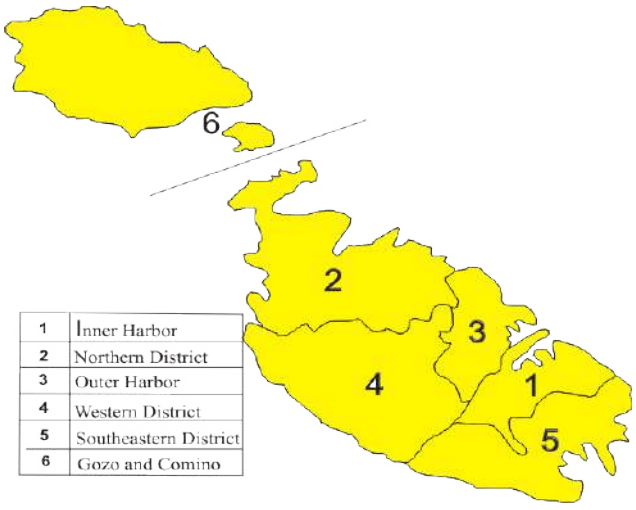


Fig. 2. Map of the districts of the Republic of Malta

Table 3. Scorecard of the relief of the Republic of Malta

Score	Height above sea level, m
3	More than 251
2	151–250
1	100–150
0	–

Orographic resources are determined by the relief of the territory and its suitability for tourist and recreational activities, namely for which types of tourism the terrain is suitable.

The highest elevations are in the Western District, where the highest point in the archipelago is Mount Ta' Dmejrek (253 m) (Malta's travel and tourism, 2019).

Altitudes with a maximal above sea level of 151–250 m prevail throughout the country; they cover the Northern, Southeastern and Gozo and Comino Districts. Two districts received 1 point, where the heights are 100–150 m, they cover the districts of Inner Harbor and Outer Harbor (Table 4).

Table 4. Score assessment of the maximal height above the sea level in the districts of the Republic of Malta

No	Districts	Maximal height above sea level, m	Score
1	Inner Harbor	100–150	1
2	Northern District	151–250	2
3	Outer Harbor	100–150	1
4	Western District	More than 251	3
5	Southeastern District	151–250	2
6	Gozo and Comino	151–250	2

The climate creates the general conditions for tourist and recreational activities in the country and the ability of tourism in its territory.

The Republic of Malta is located within the subtropical climate zone, the temperature is evenly distributed throughout the country, with small differences of 1–2 °C in any season of the year (Tables 5, 6).

Table 5. Estimation of the average annual temperature in the Republic of Malta

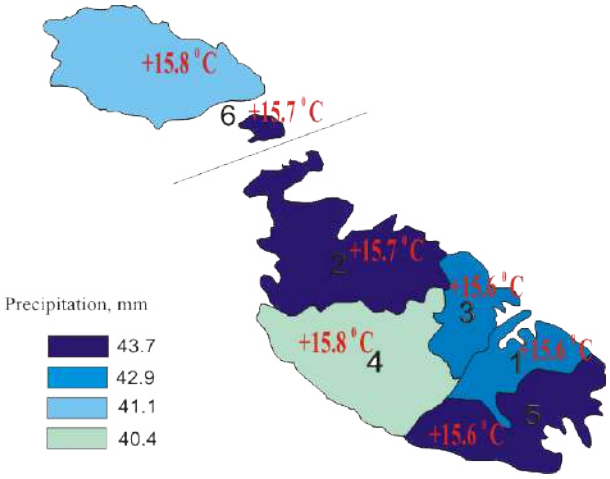
Score	Average annual temperature, °C
3	22.1–23.0
2	21.1–22.0
1	20.1–21.0
0	Under 20.0

The temperature in the country during the year is warm and favorable for recreational activities, in winter the figures do not fall below + 10 °C and can reach a maximum of + 15…16 °C. From May to November the bathing season begins, with a minimum of +15…17 °C, and the maximum falls on the middle of summer + 29…32 °C (Fig. 3).

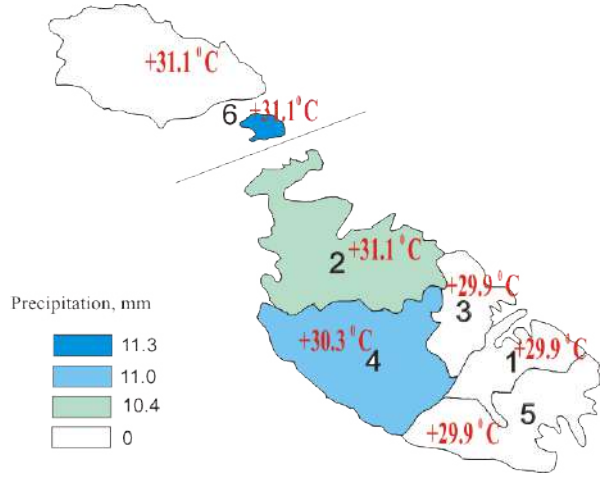
The highest scores were received by the districts: Northern, Gozo and Comino.

Table 6. Score of the average annual temperature of the Republic of Malta by districts

No	Districts	Score
1	Inner Harbor	1
2	Northern District	3
3	Outer Harbor	1
4	Western District	2
5	Southeastern District	1
6	Gozo and Comino	3



a) January temperatures



b) August temperatures

Fig. 3. The temperature of the warmest and coolest months of the Republic of Malta

The Republic of Malta is poor in hydrological resources, several rivers flow through the country, but in the hot period they dry up. There are no fresh water sources. The main hydrological resource is the sea; it washes the country from all sides.

The assessment of marine resources can be carried out by the rank of the coastal position (Tables 7, 8).

Thus, the Table 8 shows that the security of the sea is estimated at 3 points, that is, each district is coastal, which is a good indicator for tourism. Due to this indicator, the country has developed beach tourism and diving.

Table 7. Assessment of the rank of the coastal position of the Republic of Malta

Score	Rank of coastal position
3	Seaside
2	Neighbor of the first order
1	Neighbor of the second order
0	Neighbor of the third order

Table 8. Score assessment of the coastal situation of the Republic of Malta by districts

No	Districts	Score
1	Inner Harbor	3
2	Northern District	3
3	Outer Harbor	3
4	Western District	3
5	Southeastern District	3
6	Gozo and Comino	3

The biological tourist resources of the country include national parks, reserves, gardens and nature parks. There are many gardens in the country, these are the so-called parks of landscape art and the largest numbers of them are located in the Inner Harbor district.

Due to the fact that the Republic of Malta is small in area and not sufficiently provided with flora and fauna, a large part is covered with agricultural land or not suitable for landscaping, the country has few natural reserves, natural parks (Fig. 4; Tables 9, 10).

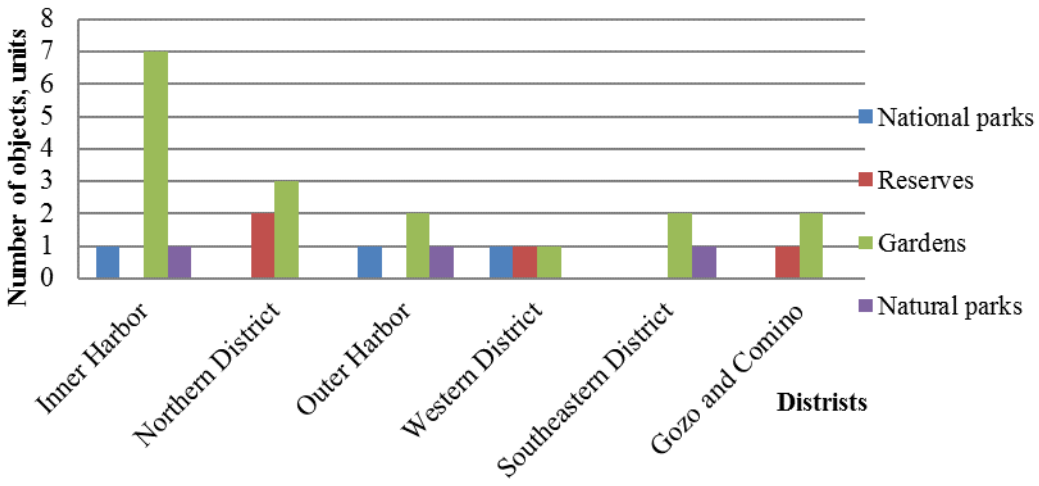


Fig. 4. Distribution of objects of the nature reserve fund of the Republic of Malta by districts

Table 9. Indicator of the score assessment of the provision of objects of the nature reserve fund

Score	Number of objects, units
3	7–9
2	4–6
1	1–3
0	0

Table 10. Score assessment of the provision of the Republic of Malta with objects of the nature reserve fund by districts

No	Districts	Score
1	Inner Harbor	3
2	Northern District	2
3	Outer Harbor	2
4	Western District	1
5	Southeastern District	1
6	Gozo and Comino	1

The lowest number of points was awarded to the districts of Western, Southeastern and Gozo and Comino, with the lowest number of nature reserves in their territory.

After assessing of the natural tourist and recreational resources, we can conclude that the Republic of Malta is provided with them and suitable for various types of tourism (Fig. 5).

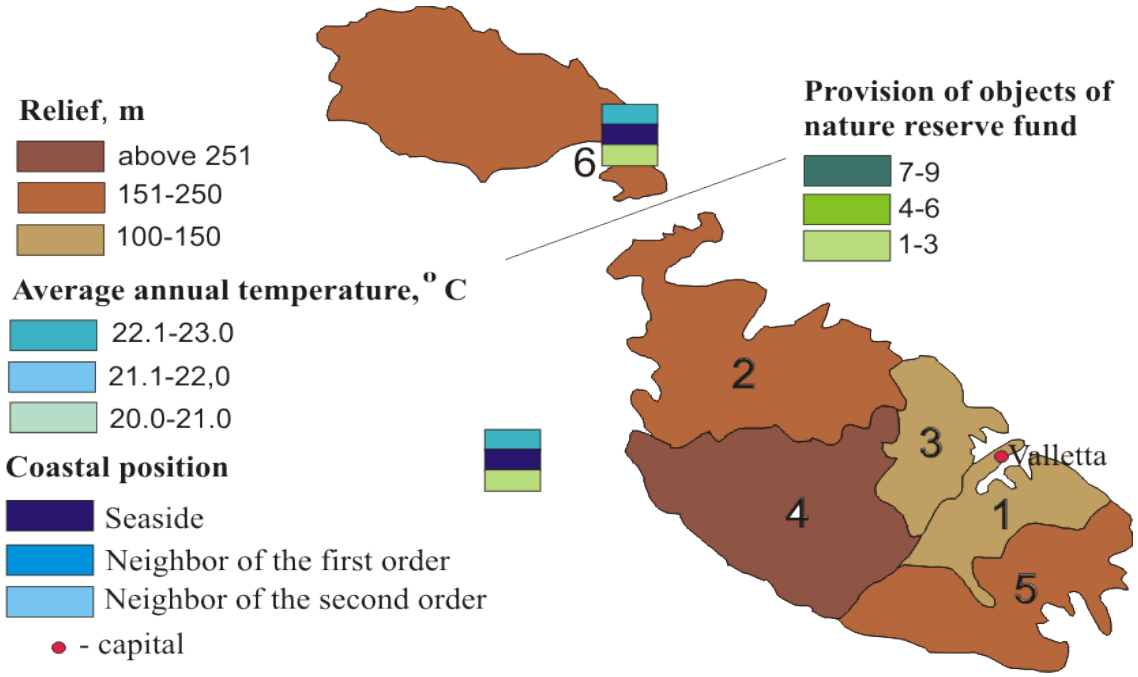


Fig. 5. Assessment of natural tourist and recreational resources of the Republic of Malta

When conducting a score assessment of orographic resources, we note that the biggest heights, which received the highest score of 3 points, are inherent in the Western District of the country, on the territory of which is the highest point of the republic.

Orographic resources of the country are not suitable for ski tourism.

Climatic resources are favorable for tourism throughout the whole, because summers are hot and winters are warm and mild. Precipitation generally falls in winter, but in small quantities. The temperature is evenly distributed throughout the country with a slight difference of 1–2 degrees.

Due to the fact that the Republic of Malta is the only country in Europe that does not have its own rivers and sources of fresh water, the potential of the coastal situation was assessed. All six counties received the highest score of 3 because they all have access to the sea.

The country's nature reserve fund includes national parks, nature reserves, nature parks and gardens. Inner Harbor County received the highest number of points, with a large number of parks of landscape art, which provided the highest score. The Western, Southeastern and Gozo and Comino Districts of the country have the lowest supply of nature reserves.

Next, consider the assessment of historical, cultural, tourist and recreational resources of the Republic of Malta.

The country's historical and cultural tourist resources make it interesting for tourists to visit. Malta has a great historical past, which has left a great legacy in the form of ancient fortresses, churches, cathedrals, majestic palaces.

The UNESCO World Heritage Site is no exception for the country, there are 3 of them in the list. There are 7 sites in the country that are currently candidates for inclusion in the World Heritage List.

The highest rating was given to the Inner Harbor district, there are 3 monuments in its territory, in the Northern and South-Eastern districts there are 2 UNESCO heritage sites. Outer Harbor and Western Districts received 0 points, as there are no UNESCO World Heritage Sites in their territory (Table 11).

Table 11. Indicator of the number of UNESCO-listed sites and potential candidates

Score	UNESCO sites, units	Score	Potential candidates, units
3	3	3	3
2	2	2	2
1	1	1	1
0	0	0	0

According to the number of potential candidates for the UNESCO list, 3 points were awarded to Gozo and Comino districts (Maltese coastal cliffs, Victoria Citadel, Azure Eye).

Western District (Mdina, Coastal Rocks) received 2 points.

Other districts received 1 point each (Inner Harbor – Knights fortifications around the harbors of Malta, North – Catacombs of Malta, Outer Harbor – Lines of Victoria fortifications) (Table 12).

Table 12. Score of the number of UNESCO-listed sites and potential candidates in the Republic of Malta by districts

UNESCO sites			Potential candidates		
No	Districts	Score	No	Districts	Score
1	Inner Harbor	**3**	1	Inner Harbor	**1**
2	Northern District	**2**	2	Northern District	**1**
3	Outer Harbor	**0**	3	Outer Harbor	**1**
4	Western District	**0**	4	Western District	**2**
5	Southeastern District	**2**	5	Southeastern District	**0**
6	Gozo and Comino	**1**	6	Gozo and Comino	**3**

The assessment of the provision of historical and cultural sites by districts is calculated as follows (Tables 13, 14).

Table 13. Indicator of assessment of historical and cultural sites of the Republic of Malta

Score	Number of objects, units
3	31–40
2	21–30
1	10–20
0	0

Table 14. Score assessment of the availability of historical and cultural sites of the Republic of Malta by districts

№	Districts	Score
1	Inner Harbor	3
2	Northern District	1
3	Outer Harbor	2
4	Western District	2
5	Southeastern District	1
6	Gozo and Comino	1

The highest score was awarded to the Inner Harbor District; the largest number of attractions is concentrated in it. This is not surprising, because here is the city of Valletta, which is a UNESCO World Heritage Site.

Two points were awarded to the districts of Outer Harbor and Western District. The Western district is rich in attractions, because there is the city of Mdina, the former capital of the Republic of Malta, it is the historical and cultural center of the country (Fig. 6).

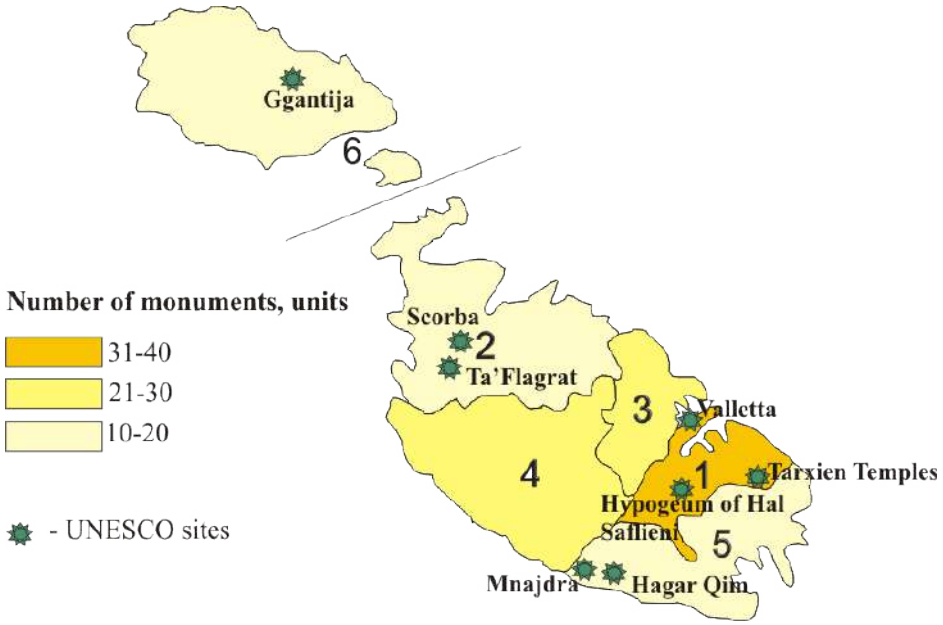


Fig. 6. Assessment of historical and cultural tourist and recreational resources of the Republic of Malta

Let's move on to a comprehensive assessment of tourist and recreational resources of the country.

The suitability of the Republic of Malta for tourist and recreational activities is determined by its provision of natural, and cultural tourist resources.

Among the natural tourist and recreational resources of the country, orographic, climatic, hydrological and biological resources were assessed.

Among the historical, cultural, tourist and recreational resources, indicators on the availability and number of museums, palaces, cathedrals, monasteries, churches and fortifications were assessed.

The score of tourist and recreational potential was defined as the sum of scores of assessment of orographic, climatic, hydrographic, biological and historical and cultural resources.

Comprehensive assessment is carried out according to the following indicators (Tables 15, 16).

Table 15. Indicator of comprehensive assessment of tourist and recreational resources of the Republic of Malta

Score	Estimation
3	11–15
2	6–10
1	1–5
0	–

Table 16. Comprehensive assessment of tourist and recreational resources of the Republic of Malta by districts

No	Districts	Relief	Climate	Seaside position	Nature reserve fund	Historical and cultural monuments	Total score	Estimation
1	Inner Harbor	1	1	3	3	3	11	**3**
2	Northern District	2	3	3	2	1	11	**3**
3	Outer Harbor	1	1	3	2	2	9	**2**
4	Western District	3	2	3	1	2	11	**3**
5	Southeastern District	2	1	3	1	1	8	**2**
6	Gozo and Comino	2	3	3	1	1	8	**2**

When conducting a comprehensive assessment of the country on the natural and historical-cultural tourist and recreational resources of the country, it was found that the resource potential is high.

Districts such as Inner Harbor, Northern and Western Districts received the highest score of 3, i.e. these districts have the highest provision of resources, which contributes to the direct development of tourism.

The other three districts, Outer Harbor, Southeastern, Gozo and Comino, each of them received 2 points, which is also a qualitative indicator of the availability of resources for tourism development.

We can say that the districts that received the highest scores are the most favorable for tourism, because they are provided with both natural, historical and cultural resources, they complement each other and make these areas of the country interesting for tourists.

The warm climate, the provision of resources for beach tourism complements the provision of various attractions, so the vacationer can simultaneously engage in several types of tourism.

Visual display of indicators of integrated assessment of tourist and recreational resources of the country is shown in the Fig. 7.

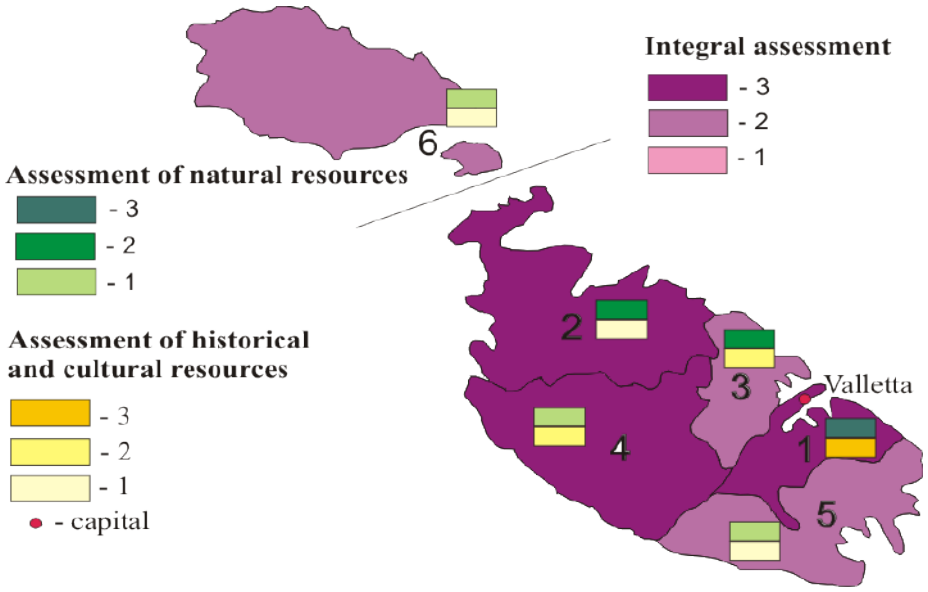


Fig. 7. Integrated assessment of tourist and recreational resources of the Republic of Malta

Conclusions.

Recreational resources are a basic component of the tourism business. Like industries (industry, agriculture and others), the organization of mass recreation requires certain resources for its existence. Its potential for recreation and tourism largely depends on the provision of the territory with recreational resources.

The islands of the Maltese archipelago are characterized by low mountains and plains based on a small limestone plateau.

Malta's orographic resources are not suitable for ski tourism.

It is established that the greatest importance in the historical and architectural potential of Malta is occupied by the objects included in the international list of monuments of human heritage of UNESCO.

When conducting a point evaluation of orographic resources, we note that the highest heights, which received the highest score of 3 points, are inherent to the Western District of the country, which is the highest point (253 m) of the republic.

Climatic resources are favorable for tourism throughout the year, because summers are hot and winters are warm and mild. Precipitation generally falls in winter, but in small quantities. The temperature is evenly distributed throughout the country with a slight difference of 1–2 degrees.

Due to the fact that the Republic of Malta is the only country in Europe that does not have its own rivers and sources of fresh water, the potential of the coastal situation was assessed. All 6 counties received the highest score of 3 because they all have access to the sea.

The country's nature reserve fund includes national parks, nature reserves, nature parks and gardens. The highest number of points was received by 1 district (Inner Harbor), on its territory there is a large number of parks of monuments of landscape art, which provided the highest score. The Western, Southeastern, and Gozo and Comino Districts have the lowest provision of nature reserves.

After assessing the natural tourist and recreational resources, we can conclude that the Republic of Malta is provided with them and suitable for various types of tourism.

A point assessment of the historical, cultural, tourist and recreational resources of the Republic of Malta was conducted.

The highest rating was given to the Inner Harbor district, on its territory there are 3 monuments, in the Northern and South-Eastern districts there are 2

UNESCO heritage sites. Outer Harbor and Western Districts received 0 points, as there are no UNESCO World Heritage Sites in their territory.

According to the number of potential candidates for the UNESCO list, 3 points were awarded to Gozo and Comino District (Maltese coastal cliffs, Victoria Citadel, Azure Eye). Western District (Mdina, Coastal Rocks) received 2 points. Other districts received 1 point each (Inner Harbor – Knights fortifications around the harbors of Malta, Northern – Catacombs of Malta, Outer Harbor – Lines of Victoria fortifications)

According to the assessment of the provision of historical and cultural sites by districts, it was found that the highest security is characterized by the Inner Harbor District.

Outer Harbor and Western Districts received 2 points. The Western District is rich in attractions, because there is the city of Mdina, the former capital of the Republic of Malta, it is the historical and cultural center of the country.

When conducting a comprehensive assessment of tourist and recreational resources of the country, the score of tourist and recreational potential was defined as the sum of scores of assessment of orographic, climatic, hydrographic, biological, historical and cultural resources.

Having conducted a comprehensive assessment of the natural and historical-cultural tourist and recreational resources of the country, it can be seen that the resource potential is high.

Districts such as Inner Harbor, Northern and Western received the highest score of 3, i.e. these districts have the highest provision of resources, which contributes to the direct development of tourism.

The other three districts, Outer Harbor, Southeast, Gozo and Comino, received 2 points each, which is also a good indicator of the availability of resources for tourism development.

References

Attard, S., 2019. The Evolution of Malta's Tourism Sector. Xjenza Online – Science Journal of the Malta Chamber of Scientists. No.7. P. 37–48. Retrieved from: https://www.xjenza.org/JOURNAL/OLD/7–1–2019/02.pdf

Barabanova V., Bohatyryova G.. Gorina G., 2020. Marketing mechanisms of tourist industry development in an unstable environment Journal of Geology, Geography and Geoecology. Vol. 29 (4), 625–636.

Caruana, S., Farrugia G., 2018. The Impact of Social Media on the Lodging Performance of Five Star Hotels in Malta. In: Katsoni V., Velander K. (eds) Innovative Approaches to Tourism and Leisure. Springer Proceedings in Business and Economics. Springer, Cham. https://doi.org/10.1007/978–3–319–67603–6_17

Croes, R., Ridderstaat, J., van Niekerk, M., 2018. Connecting quality of life, tourism specialization, and economic growth in small island destinations: The case of Malta. Tourism Management. Vol. 65, 212–223. DOI:10.1016/j.tourman.

Ebejer, J., 2019. Urban heritage and cultural tourism development: a case study of Valletta's role in Malta's tourism. Journal of Tourism and Cultural Change. Vol. 17, 3, 306–320. DOI: 10.1080/14766825.2018.1447950

Grima, R., 2017. Heritage Management, Tourism, and World Heritage on Malta. American Anthropologist. Vol. 119, Issue 1. P. 125–127. https://doi.org/10.1111/aman.12808

Jones, A., Navarro, C., 2018. "Events and the blue economy: Sailing events as alternative pathways for tourism futures – the case of Malta", International Journal of Event and Festival Management. Vol. 9, 2. 204–222. https://doi.org/10.1108/IJEFM-09–2017–0055

Malta's travel and tourism sector review. 14 Feb 2019. Retrieved from: https://www.grantthornton.com.mt/globalassets/tourism-review-2019.pdf

National Statistics Office Malta, 2020. Retrieved from: https://nso.gov.mt/en/Pages/NSO-Home.aspx

OECD Tourism Trends and Policies, Malta. Retrieved from: https://www.oecd-ilibrary.org/sites/ade41547-en/index.html?itemId=/content/component/ade41547-en#chapter-d1e126923

Topchiev O., Kolomiets K., Sych V., Yavorskaya V., 2020. Structuring of recreational and tourist potential on the basis of geographical environment: Monograph. Kamianets-Podilskyi. 332 p.

Yavkin, V.G., Rudenko, V.P., Korol', O.D., 2006. Problemy' geografiyi ta menedzhmentu tury'zmu [Problems of geography and tourism management]. Chernivci: Ruta, 260 (In Ukrainian).

Journal of Geology, Geography and Geoecology

Journal home page: geology-dnu.dp.ua

ISSN 2617-2909 (print)
ISSN 2617-2119 (online)

Journ. Geol. Geograph. Geology, 30(4), 652–665.
doi: 10.15421/112160

The main directions of sustainable socio-economic development of the Caspian littoral areas of the Republic of Azerbaijan and the existing environmental problems

Zaur T. Imrani[1], Shakar İ. Mammadova[2], Nasiba N. Hadjiyeva[3], Oleksandr Y. Vysotskyi[4]

[1]*Institute of Geography named after acad. H.A. Aliyev of National Academy of Sciences of Azerbaijan, Baku, Azerbaijan*
[2]*Baku State University, Baku, Azerbaijan*
[3]*Ganja State University. Ganja, Azerbaijan*
[4]*Oles Honchar Dnipro National University, Dnipro, Ukraine,* vysalek@gmail.com

Received: 31.08.2021
Received in revised form: 07.10.2021
Accepted: 20.11.2021

Abstract. In Azerbaijan, since the earliest times, the Caspian Sea has contributed to the settlement of population and structure of the economy. The favourable natural geographical conditions of the coasts, exploitation of offshore oil and gas fields and rich tourist-recreational potential favoured the economy of Azerbaijan significantly. However, sea-level fluctuations and environmental damage observed due to exploitation of natural resources served as curbing factor in the development. In modern times, planning of residential areas in the coastal areas, improvement of industrial, agricultural and tourism infrastructure, and successful management of the ecological situation are achievable through effective use of the natural resources and human potential of the Caspian Sea. The coastal region of the Caspian Sea, composed of three zones, is favourable for the development of Azerbaijan's economy. The attractiveness of coastal areas is related mainly to preferences of natural conditions and resources and the advantages of their transport-geographical location. As a result, the development level of the economy of the Pre-Caspian region is higher compared to other regions of the country. The region accounts for 88.7% of the total industrial output in the country. The main part of it, i.e. 95.7% is shared by the city of Baku. The cause of significant difference in development level between the regions and the capital Baku is associated with the use of oil and gas resources of the Caspian. Thus, offshore oil and gas reserves in the Caspian have played a notable role in the development of coastal areas, and of the country's whole economy. This has led to inequality in terms of regional development. This factor prompted the need to study the role of the use of resources of the Caspian Sea in the sustainable development of Azerbaijan's economy. In order to achieve the goal, a comparative analysis of the leading economic branches in the Pre-Caspian regions was carried out from a historical point of view. The obtained information was systematized, and the socio-economic aspects of sustainable development were identified based on statistical-mathematical materials. Aerospace data were used as well.

Keywords: sustainable development; socio-economic development; resettlement of the population; industry; investment; ecological problem; Caspian Sea.

Основні напрямки сталого соціально-економічного розвитку прикаспійських прибережних районів Азербайджанської Республіки та існуючі екологічні проблеми

З. Т. Імрані[1], Ш. І. Маммадова[2], Н. Н. Хаджієва[3], О. Ю. Висоцький[4]

[1]*Інститут географії імені академіка Х.А. Алієва Національної академії наук Азербайджану, Баку, Азербайджан*
[2] *Бакинський державний університет, Баку, Азербайджан*
[3] *Гянджинський державний університет, Гянджа, Азербайджан*
[4] *Дніпровський національний університет імені Олеся Гончара, м. Дніпро, Україна,* vysalek@gmail.com

Анотація. В Азербайджані з найдавніших часів Каспійське море сприяє розселенню населення і визначає структуру економіки. Сприятливі природно-географічні умови узбережжя, а також експлуатація морських нафтових і газових родовищ і багатий туристично-рекреаційний потенціал значно сприяли розвитку економіки Азербайджану. Однак коливання рівня моря, а також збиток навколишньому середовищу, що спостерігається в результаті використання природних ресурсів, послужили стримуючим фактором в економічному розвитку. У теперішній час планування житлових районів в прибережних районах, поліпшення промислової, сільськогосподарської та туристичної інфраструктури, а також успішне управління екологічною ситуацією досяжні за рахунок ефективного використання природних ресурсів і людського потенціалу Каспійського моря. Прибережний Регіон Каспійського моря, що складається з трьох зон, сприятливий для розвитку економіки Азербайджану. Привабливість прибережних районів пов'язана в основному з перевагами природних умов і ресурсів, а також перевагами їх транспортно-географічного положення. Рівень розвитку економіки Прикаспійського регіону вищий порівняно з іншими регіонами країни. На частку регіону припадає 88,7% від загального обсягу промислового виробництва в країні. Основна його частина, тобто 95,7%,

припадає на місто Баку. Причина значної різниці в рівні розвитку між регіонами і столицею Баку пов'язана з використанням нафтогазових ресурсів Каспію. Таким чином, морські запаси нафти і газу на Каспії зіграли виняткову роль не тільки в розвитку прибережних районів, але і всієї економіки країни. Це призвело до нерівності з точки зору регіонального розвитку. Саме цей фактор викликав необхідність вивчення ролі використання ресурсів Каспійського моря в сталому розвитку економіки Азербайджану. Для досягнення поставленої мети був проведений порівняльний аналіз провідних галузей економіки прикаспійських регіонів з історичної точки зору. Отримана інформація була систематизована, і на основі статистико-математичних матеріалів були виявлені соціально-економічні аспекти сталого розвитку. Також використовувалися аерокосмічні дані.

Ключові слова: сталий розвиток; соціально-економічний розвиток; розселення населення; промисловість; інвестиції; екологічна проблема; Каспійське море.

Introduction.

Population transformation is a complex process that depends on socio-economic changes. This process is directly influenced by the economic and geographical position of the region (capital, border, etc.) (Nelipa, 2017). At the same time, natural conditions, demographic situation, socio-economic development, location of production areas, etc., in turn, participate in this process (VyatkinandVyatkin, 2018). However, in this case, we must not forget about the environment and environmental factors. Because the consideration of environmental values in economic decisions, unlike the previous principle, enhances the role of ecology, offers a new strategic approach to achieving socio-economic equality in relations between society and nature (Zagorsky et al., 2015). In determining the main directions of sustainable socio-economic development, we have tried to study the existing environmental problems and the natural conditions of the area, the location of settlements and production areas.

During the collapse of the USSR, Azerbaijan had the most immense and most explored resource potential in the Caspian Sea. The region has been extracting hydrocarbon resources industrially for about two centuries (Zavyalova, 2017). Although the increase in oil production is of great importance for economic development and employment, it has led to an increase in environmental risk. Therefore, the Caspian Sea must be seriously studied, and its potential must be used and preserved for future generations.

Object of study.

The Caspian Sea Basin is an ancient structural element, covered with-thick sediments of the Quaternary Period and of the modern period. The sea is located in the splice of the two main tectonic regions – the Turan platform and the Caspian geosyncline.

Studies conducted over many years show that many complex and diverse geological processes heavily influence the Caspian Sea. Together with the Black Sea, the Caspian Sea was a part of the ancient Sarmatian Sea for a long time, covering a large water area where the World Ocean combined with the Tethys. Only in the Piacenzian Pleocene (2–3 million years ago), which was one of the critical phases of Caucasus Mountain system formation, did the outlines of the Caspian Sea began to take shape. In the Akchagil period, the formation of the Caspian Sea's depression was completed.

In modern times, the physical parameters of the Caspian Sea vary depending on its level. Currently, the total area of the Caspian Sea, which is 28 meters below the ocean level, is 380 thousand km^2, and the length of its coastline is about 4,800 km. It is located between five states – the Republic of Azerbaijan (825 km), the Russian Federation (747 km), the Republic of Kazakhstan (1422 km), the Republic of Turkmenistan (1035 km) and the Islamic Republic of Iran (728 km). The Caspian Sea extends over 1,200 km along the meridian. Its maximum width is 435 km, while the narrowest width is 196 km. Lankaran trench (1025 m) is the deepest area in the Caspian.

The Caspian Sea is considered to be one of the wealthiest water basins in the world. The valuable fish, its black caviar, oil, gas, and salt reserves, and recreation resources of the sea play an essential role in all national economies present on the Caspian coast.

Within the boundaries of Azerbaijan, the Caspian Sea extends 825 km from the Samur River in the north to Astarachay in the south. In terms of natural-geographical conditions and socio-economic development, the Pre-Caspian regions of Azerbaijan can be divided formally into three zones: the Northern region that includes Khachmaz, Shabran, Siyazan and Khizi administrative districts; the Central region, which includes Absheron administrative district, as well as the cities of Baku and Sumgait; and the South, where Saylan, Neftchala, Masalli, Lankaran and Astara districts are located.

The primary purpose of the research is to determine the role of the Caspian Sea in the sustainable development of the Azerbaijani economy and to eliminate future environmental problems by exploring ways to use its natural resource potential effectively.

Material and Methods.

The information base of the study consists of journals published by the Ministry of Economy of the Republic of Azerbaijan, the Ministry of Ecology and Natural Resources of the Republic of Azerbaijan, and the State Statistics Committee of Azerbaijan, the fund materials of the Institutes of Geography and Economics of the Azerbaijan National Academy of Sciences, current legislation of the Republic of Azerbaijan, scientific works of scientists who have researched in this field,

methodological instructions, as well as the results of scientific research carried out by the authors.

Historical-geographical approach, mathematical-statistical, comparative, and systematic analysis, Geographic Information Systems (GIS), field observations, and other methods were used in carrying out the research work.

Sea level fluctuations in the Caspian. One of the most important elements of the hydrological regime of the Caspian Sea is fluctuations in its level. Since the level fluctuation in the Caspian Sea is very disputable issue, different approaches to this question have been observed up to the present. P.S. Pallas, E.I. Eikhvald, K.M. Ber, E.H. Lenz, A. Voyeykov, G.S. Karelin, G.K. Gul, R.M. Mammadov and other scientists were engaged in this. Level fluctuation has been explained by geomorphological, geological, climatic, hydrological and human factors. It should be added that there is still no commonly accepted idea about sea level variation in the Caspian.

The level of the Caspian Sea is affected by various economic branches that are present on its shores. Fall of sea level leads to the increase of needs for hydro-technical installations, including seaports. It also entails the reduction of the shelf zone where marine creatures are primarily concentrated. The process impedes fishes in their regularly migration to the rivers for spawning. The hydrometeorological regime of the coastal areas changes unfavourably as well. Rise in sea level may considerably damage the socioeconomic condition of the coastal regions, leading to deterioration of the environmental conditions and the formation of swamps. Moreover, rise in groundwater level may result in inundation of houses and vulnerable lands.

According to the data obtained, the level of the Caspian Sea in the last century equaled 3.2 m. The lowest level during this period was recorded in 1977, when it reached a critical level (–29 m). Since 1978 the water level up to 2.5 m in the sea has seriously damaged the low-inclined areas of the coastal zone. From 1978 to 1995, the average annual rainfall in the region increased by 40–60 mm, and the volume of water of rivers flowing into the Caspian Sea increased by 10–11%. There has been a slight decrease in water level since 1996. In 1996–2000, the decline of the sea level was observed. Since 2001 the level rose as much as about 30 cm. Although in 2006 the water level dropped by 3–5 cm compared to the previous year, the level has remained relatively stable in recent years (Imrani, 2009).

The level change in the Caspian Sea had a severe impact on the coastal areas' economy. For example, the fall of the level in 1930s in the Zarat-Gilachi area resulted in accumulation processes, and later, beginning from 1977, the beach areas were partially washed off. Because the Nabran coastal area faced accumulation, the sea level rise later caused inundation in the low-inclined areas. The south-eastern Shirvan and Salyan plains can be mentioned as well, where groundwater levels have risen. As a result, the marsh and grass-covered ecological landscapes were replaced by the aquatic landscapes around the Kizilaghaj Gulf. In Baku seaport, the rise in the level resulted in damage costing about 1 million USD. The above mentioned issues show that all construction and installation works must be conducted by taking into account the level of the Caspian Sea to prevent related adverse events in the future.

From 1978 to 1998, 80.72 hectares of Azerbaijani territory was inundated by sea water, while the damage directly caused to the coastal zone made up about 2 billion USD. Of this amount, 89.1% was shared by Neftchala and Lankaran districts. In these areas, seawaters inundated areas 300–500 m in length, and communication systems (highways, railways and electric lines) were destroyed. In addition, fisheries faced considerable damage as well (Imrani, 2014).

The changes in level cause changes in the volume of water, coastline configuration, bathymetry and the all morphometric parameters of the Caspian Sea. From this point of view, it is essential to carry out comprehensive research on the change of the level of the Caspian Sea. This can relate to the identification of critical factors responsible for level changes in terms of their quality and quantity, limits of water balance and perennial forecast of them, the contribution of anthropogenic factors in the level change, socio-economic and geographical aspects, use of Azersky satellite images, development of relevant scenarios.

Population settlement in the coastal areas of the Caspian Sea. Archaeological excavations carried out in the coastal areas discovered settlements in the region's plains the age of which is assumed to be 3–4 thousand B.C. Historical sources prove that ancient settlements dated to the period of Manna, Media, Albania, Atropatena – the ancient states in the territory of Azerbaijan existed here in the past. One of them was the town of Shabran. Founded in the mid-I millennium and located on the Great Silk Road, this city was a big economic, commercial and cultural center and existed until the middle of the eighteenth century. The ruins of the city were discovered near Shahnazarli village during the archaeological excavations carried out in the mid-1930s. The area of the Historical Reserve of "Shabran city" was established as a worldwide archaeological monument upon Order No. 1343 dated September 27, 2003, signed by the President of the Republic of Azerbaijan.

The total area of the Pre-Caspian region is 14.65 thousand km^2, accounting for 16.9% of the country's territory. The population was 3,858.4 thousand or 39.3% of the country's population in 2016 (Table 1). However,

the conducted studies show that 59.7 % (5,858.4 thousand) of the country's population is concentrated in the Caspian region (mainly Baku city). The unregistered people are those migrating from different regions of the country to Baku and Sumgait cities because of employment factors. This process has led to an increase in the urbanization rate.

Table 1. Demographic and settlement indicators of the Pre-Caspian region of Azerbaijan

Territory	Territory, sq. km^2	Population number, thousand persons	Population density per 1 sq. km	Number		
				City	Urban settlement	Village
Khacmaz administrative district	1.06	174.8	165	2	12	137
Shabran administrative district	1.09	58.0	53	1	-	68
Siyazan administrative district	0.70	41.4	59	1	1	32
Khizi administrative district	1.67	16.6	10	1	3	25
Absheron administrative district	1.97	207.5	105	1	8	8
Sumgait city	0.09	339.0	3767	1	2	-
Baku city	2.14	2245.8	1049	1	59	-
Salyan administrative district	1.60	135.6	85	1	2	48
Neftchala administrative district	1.45	86.5	60	1	3	48
Masalli administrative district	0.72	221,5	308	1	2	100
Lankaran administrative district	1.54	225.2	146	2	8	83
Astara administrative district	0.62	106.5	172	1	2	89
Total:	*14.65*	*3858.4*	*263*	*14*	*102*	*638*
Republic of Azerbaijan	86.6	9810.0	113	78	262	4255

Source: Administrative and territorial units. Library of Affairs Department of the President of the Republic of Azerbaijan. Baku, 2017

In this region, represented by 14 cities, 102 urban settlements and 638 rural settlements, population density data varies for its different parts. The population density for the overall territory of the region is 263 per km^2. The last is higher than the average figure. Sumgait (3,767 persons per km^2) and Baku (1,049 persons per km^2) cities are the most populous areas. The development of these cities was affected significantly by such factors as the use of natural resources of the Caspian Sea, transport and geographical position, and the function of the capital city borne by Baku. Population density in other cities and administrative districts ranges from 105 to 308 per km^2. The areas with low density are Shabran, Siyazan, Neftchala and Salyan districts. The most sparsely populated area is the territory of Khizi administrative district (10 persons per 1 km^2).

The Northern Zone of the Pre-Caspian territories includes five cities, 16 settlements and 262 villages. The region accounts for 30.8 % of the territory and 7.5 % of the population of all coastal regions.

In the Northern Zone, the Khachmaz administrative district is the largest in population (174.8 thousand persons) and population density (165 people / km^2). The fact that Khachmaz borders Russia has a positive impact on the economic development of this district. The large settlements of the administrative district include Khachmaz, Khudat, Yeni Hayat, Mugtadir, Mushkur, Gusarchay, Narajan and others. Guneshli (25 persons), Tourist (45) and Samurchay (49) are the smallest settlements. These settlements have fully exhausted their potential capabilities, and the population of them typically migrates to other areas in search of employment.

The second most populous administrative district in the Northern Zone is Shabran (58.0 thousand people). Most of its territory is mountainous. The territory of Shabran district is washed by the Caspian Sea to the East, and the length of the coastline is 40 km. The population density is 53 persons/km^2. The largest settlements in the administrative district are Shabran city, and also Gandov, Aghalig, and Davachi villages. The population is settled almost evenly across the territory.

Siyazan – the third most populous administrative district of the Northern Zone is inhabited by 41,500 people. Most of them (65.6 %) live in Siyazan city. Siyazan district is located in the Samur-Davachi lowland, and it has a more favourable natural-geographical position in terms of settlement. In the east this district borders the Caspian Sea. The largest settlements here are Gilgilchay settlement, Yenikand, Hemye, Mashrif, and Zarat.

The administrative district with the lowest population in the Northern Zone is Khizi. Population density in the administrative district is 10 people person/km^2 only. This is the lowest figure throughout the country. Khizi district mainly covers the north-eastern slope of the Greater Caucasus and the Samur-Davachi plain, and is bordered by the Caspian Sea in the east. Its territory consists of low mountains and plains.

Although the area has a favourable natural condition for settlement, the villages of Angilan, Yukhari Angilan and Gars are depopulated due to migration. Each of the villages of Gızılgazma, Tudar and Guney Qishlag has about ten inhabitants.

The Central Zone is characterized by intensive land development, high population density, presence of different industrial and service facilities, and limited land resources. In Baku and Sumgait cities, relatively high population growth has created severe demographic, socio-economic and environmental problems in the region, and this process continues. 2,792,300 people live here, accounting for 72.4 % of the total population of the Pre-Caspian region. In addition, this zone holds three towns, 69 urban settlements and eight rural settlements.

The largest city in the Central Zone is Baku. The history of the city of Baku dates back to the 3rd century. As authors of ancient antiquity have reported, Baku maintained trade relations with neighboring countries by caravan and sea ways. There are descriptions of oil wells drilled in and around Baku in the late ninth century and the transportation of oil to the Middle Eastern countries and India in the late 9th century. The economic upheaval of the city was related mainly to the development of the oil industry. Economic relations between Baku and other areas expanded due to the oil factor as well. Among the most significant events, the construction of the Sabunchu and Surakhani oil fields (26 km long) in 1880, the construction of the Baku–Tbilisi railway in 1883 (520 km long), as well as the launch of the Baku-Batumi oil pipeline (885 km long) in 1907 should be noted in particular.

Since the 1930s, the migration of the population to the Absheron peninsula, mainly to Baku has been exacerbated due to the increase in oil production and demand for labour. As a result, urban-type settlements with a new status have been created around Baku (Figure 1). The status of urban-type settlement firstly was acquired by Alat in 1935. In 1936, 25 settlements more were given the same status. According to the 1939 census, there were 40 such settlements in the Baku agglomeration (including Sumgait), and 32 urban settlements in surroundings of Baku (Eminov, 2005). At present, 59 settlements are included in the administrative unit of Baku city. The city accounts for 58.2 % of the population dwelling in the Pre-Caspian area, while the population density is 1,049 persons/km^2.

Fig.1. Distribution of population in the coastal area of the Caspian Sea (within the territory of Baku city)

The higher pace of development of Baku compared to the Pre-Caspian regions and other regions of the country was related to its natural resource (oil and gas) potential. Meanwhile, regional differences in living standards associated with the higher development of Baku will lead to the job-driven migration of the population from other regions, resulting in more severe demographic problems in the future. Since 2004 state programs on socio-economic development of the regions have been continuously adopted and implemented to overcome the problem. However, the complete solution to the problems has not been achieved yet. Nevertheless, in recent times serious projects have been developed in this direction, and since 2016 the implementation of "The Strategic road map for the national economy and main economic sectors" has been underway.

The second-largest settlement in the Central Zone is Sumgait. It is located on the western coast of the Caspian Sea and the bank of Sumgait River. Haji Zeynalabdin and Jorat settlements are subordinated to Sumgait city. The population density of Sumgait is the highest in the Caspian region (3,767 persons/km^2). In the city, industrial and social infrastructure facilities are more developed than that of other regions.

The most sparsely populated area of the Central zone is Absheron district. Here the population density is 105 persons/km^2. In Absheron, most of the population (82.9 %) is settled in cities. Absheron's administrative center is Khirdalan city, which received the status of city on 29th November 2006.

The Southern Zone accounts for 40.5 % of the territory and 39.3 % of the population of the entire Pre-Caspian region. The lesser density of population

is in Salyan (85 persons) and Neftchala (60 persons) districts. Salyan is located in the Southeastern Shirvan and Salyan plains, bordered by the Caspian Sea in the East. Here most of the population lives in rural areas (66.5%). On the other hand, the population of Neftchala administrative district is 86.5 thousand persons, the lowest in the south. The territory of this administrative district is situated in the eastern part of the Kura-Aras lowland, the plains of Southeastern Shirvan and Salyan, and partly in the Mughan Plain, while washed by the Caspian Sea in the east.

Masalli administrative district has the highest density (308 persons/km^2) in the Southern Zone since its geographical location, and the natural condition is favourable for settlement. The territory of Masalli district is mainly plain (Lankaran lowland) and partly mountainous (Burovar Ridge) and borders the Caspian Sea in the east. Masalli district is mainly an agro-industrial region, while 84.3% of its population lives in villages. It is the second district in the Pre-Caspian region behind Khachmaz for the number of villages (100 villages).

The Kura-Aras lowland surrounds the Lankaran administrative district in the north and the Caspian Sea in the east and south-east. The relief of its territory is mainly plain and in small part composed of foothills. Lankaran is one of the oldest settled areas in Azerbaijan. Currently, it is an agro-industrial region. Here the shares of the urban (40.3%) and rural population (59.7%) are almost equal.

Astara administrative district borders the Talish mountain ranges in the west, Lankaran lowland in the north-east, and the Caspian Sea in the east. It borders the Islamic Republic of Iran in the southwest and southeast. Though Astara's population is lowr, population density here is the second in the South Zone (172 persons/km2). Most of the population (77.0%) is composed of inhabitants of villages.

The study found that the demographic pressure in the Pre-Caspian region is much more complicated than that of other regions of the Republic of Azerbaijan. While social infrastructure facilities have been increased, zones of environmental tension have been grown, and high risk areas are formed. It has also affected the efficient organization of productive forces throughout the country.

Modern development level of industry in the coastal areas of the Caspian Sea. The first offshore well on the coasts of Azerbaijan was drilled in shallow waters. Oil and gas production on an industrial scale in the Caspian Sea began in 1949. Although solid industrial potential was formed in Azerbaijan during the former USSR, the economy's structure was completely adapted to the requirements of the Union. The country's industrial production funds, namely 67%, were composed of the oil-related primary industries and ready-made products. However, after gaining independence, the Republic of Azerbaijan succeeded in attracting foreign investments to the country's economy associated with rich oil and gas deposits. An agreement called "Contract of the Century", aiming at the exploitation of oilfields of "Azeri", "Chirag" and Deep-water "Gunashli" was signed in 1994. According to this contract, it was planned to produce 510 million tons of oil, while the volume of investments was planned to make up 7.4 billion US dollars.

Many countries regard investment policy as an essential component of their economic development strategy in the modern world. This is because investments positively affect production and employment and lead to capital increase. From this view, investments should be used fully and more efficiently in the condition of the market economy to provide successful development of economic sectors.

The share of investment in the state budget is an indicator of the priority feature of economic growth in the country's economic policy. Deepening the international distribution of labour allows the specialization level of national economies to be raised, thereby increasing production volume due to more efficient use of economic resources available. As a result of the development of foreign economic relations, countries can earn additional profits as they specialize in relatively productive products and these products are relatively efficient. In addition, the development of foreign economic relations enables countries to specialize in more efficient production and earn from the import of products which are less-efficient to produce domestically.

In 2016, 9.3 billion dollars was invested in the economy of the country. However, a major part (74.5%) of investments were directed towards Baku and 92.4% to the Pre-Caspian region as a whole, which was due to the fact that most investments deal with the exploitation of oil and gas resources. This has led to inequalities in the socio-economic development of the country's regions. At present, the Azerbaijan government is taking serious measures in this direction.

According to statistical data of 2016, 1153 industrial enterprises operate in Baku, accounting for 73.8% of all industrial enterprises operating in the Pre-Caspian region. The share of the private sector in industrial production is 81.7%. The total number of employees working in these facilities is 94,722 people. The products of the industrial facilities of Baku city include industrial gasoline, kerosene, diesel, black oil, cement, construction gypsum, etc., as well as light and food industry products.

In terms of industry, Sumgait city and Absheron administrative district are the most developed regions

in the Pre-Caspian region after Baku. They together account for 3.4% of the total industrial output. In Sumgait, 59.9% of industrial production is a portion of the non-state sector, and the figure is 71.1% in Absheron district. The industrial products of Sumgait city and Absheron district enterprises are nitrogen, chlorine acid, ethylene, polyethylene, construction brick and gypsum, limestone, and food products.

As for the resort districts of the Pre-Caspian region, they lag significantly in terms of industrial products and the average employed labour force. In these districts there are 181 industrial enterprises, which account for 0.9% of the total production. The number of employees is less than 2.700 people. The lowest corresponding figure is in Khizi administrative district, represented by seven industrial enterprises. Here, the total number of employees is 219 people only. The low level of indicators is related to the fact that those administrative districts are mainly agrarian-industrial ones. Among their products, oil, gas, iodine, construction sand, concrete, carpets, flour, canned fruits and vegetables, meat and meat products, dairy products, tea, cotton, etc. products can be mentioned.

The main place in the economic structure of the Northern Zone is occupied by the oil-extracting industry (based on the Chongar-Zarat, Siyazan-Zarat, and Sadan-Amirkhanli fields etc.), production of fruits and vegetables, and canning industry. The critical industrial branches in the zone are oil and gas extraction and production of the brick plants, gravel workshops, carpet factories, grain processing plants, and others.

The Central Zone has grown economically better than other zones. Its leading economic areas are the oil and gas industry, oil-processing, and chemical and petrochemical industries. Ferrous and non-ferrous metallurgy, heat power industry, machinery, raw materials and products of construction importance, light and food industries are developed here.

The economic structure of the Southern Zone is represented by the oil and gas industries, iodine-bromide production, machinery industry, brick production, wood processing, production of furniture, carpet production, food industry, etc. The Iodine-bromine plant in Neftchala produces approximately 25,000 m^3 of iodine and brominated water a day converted into crystalline iodine. At present, the plant produces about 400 tons of iodine a year.

Development of industrial fields and involvement of investments in the region have a positive influence on trade turnover. Thus, the volume of trade turnover in the country has grown, reaching 17 billion USD in 2016. As a result, trade turnover in the Caspian region in total was as much as 64.9% of the overall trade by the country, the major part of which, i.e. the facilities of Baku, contributed 84.6%.

The branch structure of the Caspian region's industry reflects the social division of labour and the level of differentiation and specialization of the various fields. The volume of industrial production here describes the socio-economic development of the region and the country and the employment and living conditions of the population. However, the present situation is not advantageous in terms of the country's territorial distribution of business activities. To eliminate the problem, there is a need to create strategically more appropriate new industries in other regions of the country (Figure 2)

Touristic and recreational importance of coastal areas of the Caspian Sea. The expansion of the system of international economic relations, the growth of people's standard of living, the development of industry and services, etc. are factors which positively affect the development of tourism. The tourism industry, in turn, contributes to employment, conduction of social and cultural events, and improvement of the ecological situation.

Tourism is one of the fastest-growing industries with an annual average growth rate of about 5%, and international travel numbers might nearly double until 2020 compared to 2006. Having experienced a growth of 25% between 1995 and 2005, tourism today accounts for 10% of the world's economic activity and is one of the leading employment generators. Tourism is also a significant source of foreign exchange earnings for many developing countries (Sustainable Tourism Development., 2008).

Tourism can improve the quality of life in an area by increasing the number of attractions, recreational opportunities, and services. Tourism offers opportunities to meet interesting people, form friendships, learn about the world, and expose oneself to new perspectives. Experiencing different cultural practices enriches experiences, broadens horizons, and increases insight and appreciation for different approaches to living (Glenn Krieg, 2001).

2.2 million foreigners visited Azerbaijan in 2016, of whom 90.9% visited with the purpose of rest (Tourism in Azerbaijan, 2017). Out of all foreign tourists, 697.1 thousand people enjoyed rest and entertainment, 691.7 thousand represented business tourism, 562.0 thousand visited their relatives and friends, 41.5 thousand visited for treatment purposes, 12.6 thousand visited sacred places, and the remaining 39.8 thousand visitors were motivated by other reasons. The fact that 96.4% of those tourists spent time in the Pre-Caspian regions indicates a significant regional imbalance in terms of tourism development.

The question of why people travel is both obvious and fundamental to any understanding of the practice of tourism and its consequences, including the geography

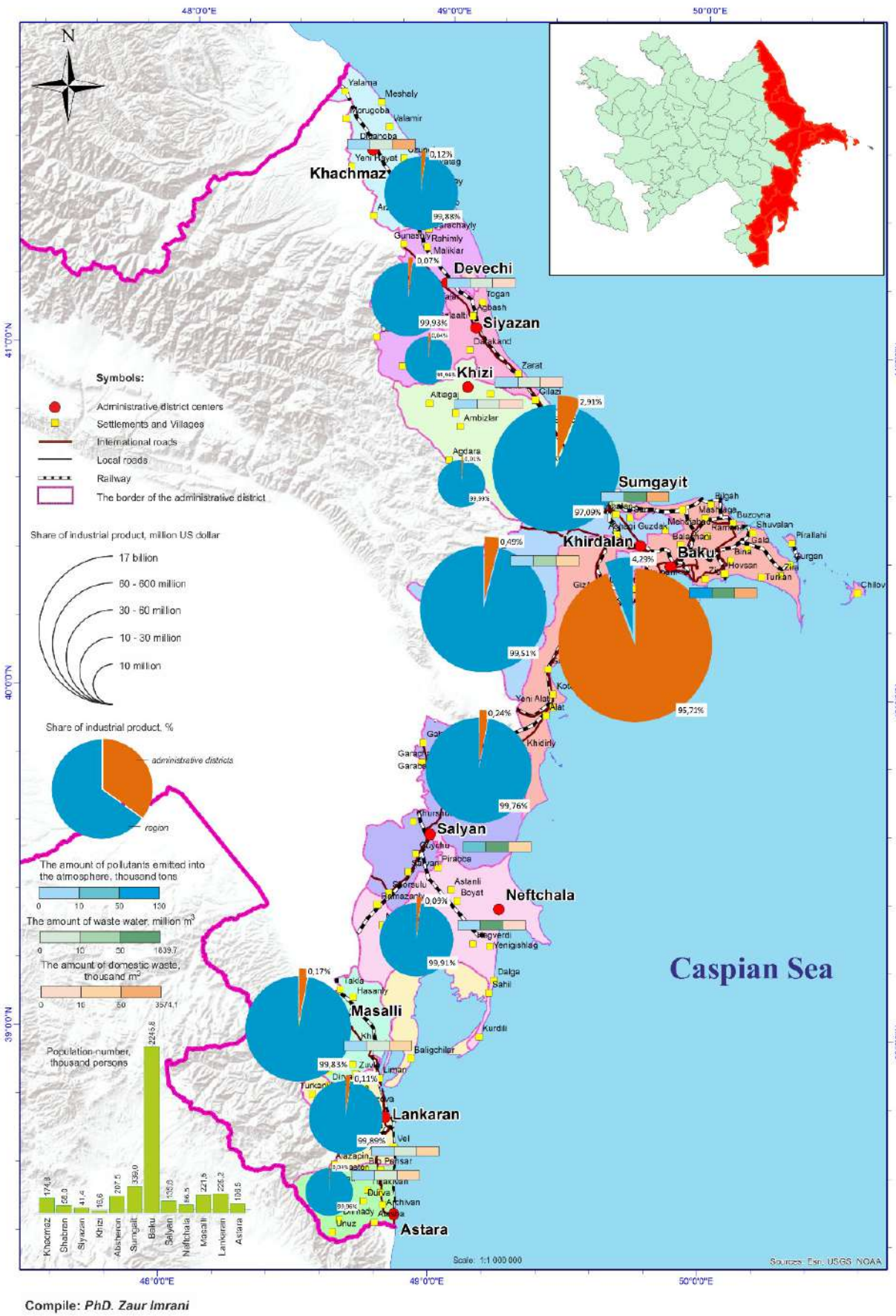


Fig. 2. Socio-economic indicators of coastal areas of the Caspian Sea

of tourism. However, although there is general (though not universal) agreement that the primary motive for pleasure tourism is a real or perceived need to escape temporarily from the routine situations of the home, the workplace and the familiarity of their physical and social environments, the many theories of tourist motivation may differ quite substantially in their interpretation and explanations of resulting tourist patterns and behaviours (Stephen Williams, 1998).

There are natural and economic conditions and factors necessary for developing the tourism industry on the coast of the Caspian Sea. They include the beaches, clean marine air, boat trips, fishing, medicinal mud, thermal and mineral water sources, forests, rivers, islands, national parks, nature reserves, historical monuments, museums, the favourable transport position of the region and others.

The comfortably warm temperatures characteristic of the Pre-Caspian region enables the wide use of natural and recreational resources. The abundance of solar energy in the summer months favours the development of beach tourism in the country's coastal regions. Beach tourism, organized in the Pirshaghi, Bilgah, Buzovna, Mardakan, Shuvalan and Shikh areas of the Absheron peninsula, provides rest opportunities for both domestic and foreign tourists during summer. A network of rest centers, sanatoriums and tourist bases is created in these areas.

Most of the tourism and recreation complexes are located close to the beach areas, most of which are on the Absheron Peninsula and in the Yalama-Nabran area. According to statistical data of 2016, the majority (80.7%) of 272 travel agencies and tour operators operating in the country are concentrated in Baku. 1,472 out of 1,838 persons working in these facilities are directly dealing with tourism activities. In 2016, the incomes of travel agencies and tour operators made up 21.6 mln. US dollars, most of which were gained in the summer (Tourism in Azerbaijan, 2017).

Here the adoption of the Action Plan for the development of beach tourism in the Republic of Azerbaijan for the years 2017–2020 should be mentioned. The document envisages improving access to beaches, creating new beaches, providing relevant favourable conditions, and establishing related infrastructure (roads, water provision, sewerage, electricity, communications and other services).

Accommodation related businesses significantly contribute to the development of the tourism industry in the coastal areas. As an integral part of the tourism industry, the hotel business provides guests with temporary accommodation and offers relevant services. There are 548 hotels and hotel-type facilities in Azerbaijan, of which 50.9% are in the Pre-Caspian region. This region accounts for 61.7% of the country's hotel rooms, 60.1% of its capacity and 64.9% of people accommodated (Table 2).

In general, the Pre-Caspian areas are different for their recreational resources in the tourism industry.

The Northern Zone covers mainly the Yalama-Nabran, Samur-Davachi and Shollar plains. The Yalama-Nabran forest strip is 24 km in length and 7–9 km in width. This forest strip stretches up to the sandy beaches on the terrace in some parts, creating beautiful landscapes. In terms of tourism, it is the second main area after the Central Zone.

The territory has plenty of solar energy and is covered with coastal plain forests and sandy beaches. Thermal springs and natural sources of mineral waters

Table 2. The main data of tourism facilities in the Pre-Caspian region

Territory	Total number of hotels and hotel types of enterprises, unit	in those		
		Number of rooms, unit	Capacity, bed places	Number of accommodated persons total
Khacmaz administrative district	50	2,282	6,220	15,851
Shabran administrative district	4	21	50	1,115
Siyazan administrative district	-	-	-	-
Khizi administrative district	4	53	148	790
Absheron administrative district	5	180	283	4,213
Sumgait city	13	183	390	2,348
Baku city	143	8,692	14,020	686,793
Salyan administrative district	2	88	142	363
Neftchala administrative district	1	32	60	-
Masalli administrative district	29	441	1,148	6,474
Lankaran administrative district	18	466	1322	8,681
Astara administrative district	10	103	263	1,445
Total:	279	12,541	24,046	728,073
Republic of Azerbaijan	548	20,330	40,042	1,122,068

Source: Tourism in Azerbaijan. Statistical yearbook. Baku, 2017

are widespread as well. The absolute altitude of these areas varies from –28 m to 100 m, and the inclination ranges from 0.5 to 3.5o. The duration of beach season when the seawater is above 18 °C, lasts up to 140 days in this territory. The presence of a variety of broadleaf trees in the coastal areas adds to the comfort offered by the vegetation cover. However, the current eco-geographical conditions of the forests are not good since the construction of numerous tourism and recreational centers have led to the decline in the area of forest.

In contrast, the wastes from those tourist facilities have the worsened ecological and sanitary conditions in the Pre-Caspian territories in general. Consequently, the degradation of the forests and the deterioration of the ecological situation in the coastal zone is observed (Geography of the Republic of Azerbaijan, 2014). The carbonate and hydrocarbonated mineral water resources of treatment importance are spread mainly in the Samur-Devechi lowland. The total flow of mineral water springs is over 5,000 litres per day. Although the natural potential is high, the horticultural sector is poorly developed in the zone. This harms the tourism industry.

The coastline of the Khachmaz administrative district is used mainly for tourism. Tourism facilities in the area are numerous; among them, there are 50 hotels and hotel-type facilities. Galaalti, the naftusya type water, located at 700 m of altitude in the territory of Shabran administrative district, has excellent healing importance. Based on the Galaalti water, "Galaalti Hotel & Spa" therapeutic and rehabilitation resort complex has been established. Besides this, the hunting farm of "Liman" operates on the coast of the Caspian Sea. The Beshbarmag parallel fortification (6–7th centuries) is of world importance; the Gilgilchay defence fortifications complex (5th century) and other historical and cultural monuments allow development of cultural and religious tourism. However, there is no hotel or hotel-type accommodation in the Siyazan administrative district.

The Central Zone is a suitable area for tourism due to its climatic conditions, being rich in mineral and thermal waters, healing muds, unique natural environment, and historical monuments. Most of the tourists arriving in Azerbaijan stay in this area since the capital city Baku has luxurious and modern hotels and improved infrastructure.

On the Absheron Peninsula, hydrogen-sulfide thermal waters are used to treat cardiovascular, gynecological and rheumatic diseases. The healing muds of the Masazir and Big Shor lakes are also in use. Such muds are also present in the Shikhov, Surakhani and Gobustan areas. However, the reserves of the last are small and are not used widely by resort facilities. (Ismailov, 2004).

The city of Baku, with its historical and architectural monuments (Maiden Tower, Shirvanshahs Palace, Juma Mosque, etc.) and beaches, attract a much larger number of tourists. Sumgait, the second-largest city in Absheron, is far behind Baku for the number of visitors. Though the number of tourists visiting Sumgait and its tourism facilities is smaller, the new parks and beaches recently opened for use are of great interest to tourists.

The Southern Zone is one of the areas less-used for tourism. However, this zone has favourable natural conditions and economic potential, suitable for the establishment of tourism businesses. There are possibilities for developing medical tourism near the mineral springs of Ag korpu, Istisu, Sim, Bi, Toradi, Sheikh Nasrallah and others. The seafront is mainly composed of sand and river stones. As a result of the rise in the level of seawater, the width of beach areas in some places has been reduced as 5–10 m as less.

The temperature of sodium-chlorine mineral water reserves of tourism-recreational importance may reach up to 45ºC. This kind of thermal water are found in the Lankaran lowland, based on which the Istisu sanatorium operates. The last is the only operating facility of medical tourism that uses thermal water in the Southern Zone.

The main historical monuments in the Lankaran administrative district are Lankaran fortress, the Mayak building, the circular fortress called Zindan, the Ballabur fortress, the German church, the Jewish synagogue, etc., which attracts foreign tourists. The kurgans in the Astara administrative district, such as Dash gutu, Kholobin, Miki dolmen necklaces, and Baba Jabbar, Tangarud, Seyidjamal, Vago and others, dated to the Bronze Age, have cultural tourism importance. The Yanardagh and Istisu forests, composed of rare tree species and various springs, are found in the Masalli administrative district. Istisu water is used to treat muscles, the nervous system; skin, gastrointestinal and gynecological diseases. The Salyan and Neftchala districts territories are rich in historical and architectural monuments but less-developed in terms of tourism. There are only two hotels in Salyan, and only one hotel-type accommodation in Neftchala, not enough for the attraction of tourists in mass.

Considering the aforementioned, interregional differences must be eliminated to develop tourism in the Pre-Caspian zone as a complex. New tourism facilities should be created taking into account the natural environment and economic potential of each region.

Environmental problems of the Caspian Sea and ways of their solution. The ecological problems of the Caspian Sea and its surrounding zone are linked to the features of the historical development of the region's economy. In these circumstances, long-term natural changes (centuries-old change in the sea level, climate change) and the serious socio-economic problems of the modern era (transitional period, economic crisis, conflicts,

interference of international companies, etc.) have been responsible for the deterioration of the ecological situation. The great interest taken in the hydrocarbon reserves of the Caspian Sea, the development of oil production, population growth and industrialization in the coastal zone, application of new synthetic substances in households, the use of agricultural chemicals, etc., have adversely affected the ecological situation of the Caspian Sea.(Mammadov, 2013).

Azerbaijan is much more closely interfaced with the Caspian Sea than other Pre-Caspian countries, considering its geographical location, the settlement of its population, and the development of the economy. In addition, the fact that most critical industrial facilities and the majority of the population in Azerbaijan are concentrated here has adverse ecological effects.

The development of forest and meadow landscapes in the northern zone is associated with the spread of groundwater in the conic-shaped plains near the lower flows of the Samur, Gusarchay, Gudyalchay and other rivers. During the historical period, anthropogenic impacts related to settlements and agricultural activities have led to partial deforestation in this territory. Currently, these areas are widely used in the irrigated plantations and horticulture. This harms the local environmental situation.

The environmental situation of the Central Zone is considered to be the most difficult. This is because large cities (Baku and Sumgait), petroleum, petrochemical, ferrous metallurgy, and other industrial facilities are located here. Moreover, the lack of sewerage systems in the enlarged and newly founded settlements have caused the direct discharge of wastewater into the Caspian Sea.

Although the Southern Zone is less polluted, the amount of household wastes in Lankaran and Masalli regions is higher. Therefore, works on the improvement of sewage systems are needed.

The rise of the Caspian and abrasion process often may result in subsidence, observed in the coastal areas and places where accumulation happens. This adverse process typically occurs when carbonate and sandy-clay rocks are located horizontally in coastline areas, including the north-eastern coasts of the Absheron peninsula and Sangachal, Alat Pirsaat, Bandovan areas. Land subsidence is most common in the Nabran-Khachmaz, Alat-Bandovan and Lankaran-Astara coasts of the Caspian and in various river valleys.

As a result of the regression in the Caspian, erosion processes in the coastal areas are intensified. This condition may entail aeolian-type desertification as well when lands uncovered due to regression become salinized. Factors contributing to the desertification process in coastal areas are also global climate change and economic activities.

Factors entailing the desertification process in recent years also include the unregulated destruction of forest areas by humans. For example, the disappearance of forests in the coastal areas from Beshbarmag Mountain to Pirsaat River can be shown. This deforestation happened because of planting and grazing of livestock which has persisted here for decades.

Currently, the solution of environmental problems is the most urgent among other problems related to the Caspian Sea. The Caspian is considered to be one of the most polluted water basins in the world.

The primary pollution sources in the Caspian Sea are rivers, oil extraction, transportation and processing, and wastes of residential and industrial facilities located in the coastal zone.

The rivers flowing into the Caspian Sea are considered the key sources of pollution since according to experts, the wastes contaminating the Caspian Sea mainly (90%) enter via river waters. The largest rivers flowing into the sea are Volga, Ural, Terek, Samur, Kura and Safidrud. Among them, the largest one is the Volga River, the annual flow of 250 km3 or 81.2% of the total river flow. 2.5 km3 of untreated and 7 m3 of insufficiently treated sewage enter the sea via the Volga River in a year (Mammadov et. al., 2000). Pollutants include oil products, iron and copper compounds, rapidly oxidizing organic compounds, etc. (Gul, 1956).

Another key source of pollution in the Caspian Sea is the technical accidents occurring during oil extraction and transportation. These accidents cause oil spills, which in some cases are 20 times more than the allowed limit. The most polluted areas in the Azerbaijani sector of the Caspian are “Neft Dashlari”, “Bibiheybatoil”, “Absheronoil”, “28th May”, “Gum adasi”, etc.

The fires in the offshore fields also contribute to the pollution of the Caspian Sea. For example, the fire that happened in May 1989 on the “28th May” caused an oil slick to form on the sea 12 km in length and 4 km in width, which remained there for 15 days.

Sea pollution in the Caspian may also happen because of the discharge of industrial and domestic wastes along the coasts. These wastes are discharged in all settlements throughout the Caspian. Over 60 million m3 of pollutants are concentrated in the Baku Bay, of which 40% are oil compounds. While the oxygen content in the waters of the Baku Bay must equal at least 10 mg/litre, the current figures vary between 1.8 and 3 mg/litre.

The fact that wastes containing hazardous chemical compounds are continuously discharged into the Caspian serves as an additional source of pollution for the sea. These chemicals include hydrocarbons, carbonuclides, chlorinated organic compounds, and heavy metals. The volume of phenol and heavy metals spilt into the sea is 3 times as much as the norm.

In terms of the heaviness of pollution, the Northern Zone is less polluted than the Central and Southern zones. Currently, work on the construction of treatment facilities with 70,000 m3/day capacity is underway in the Khachmaz district. Similar works are planned in Shabran, Siyazan and Khizi districts as well.

The composition of samples taken from the bottom of the seabed includes oil products, phenols, and even mercury. The amount of phenol in Baku Bay is 0.2–1 g/kg, the amount of mercury is 5–14 g/kg. Near Sumgait, sea bottom sediments with 1–2 g/kg of hydrocarbons, 0.5–1 g/kg of phenols and 0.1–0.6 g/kg of mercury were found. Such a situation has led to the contamination and the decline and even extinction of marine species of fauna in some areas.

In 2016, the total amount of gaseous wastes emitted from various sources in the Pre-Caspian region was 146.5 thousand tons. In the densely populated Baku area, where numerous industrial and infrastructure facilities and also motor vehicles are present, the figure equaled 130 thousand tons. Wastes emitted in the region's other cities and administrative districts amounted to 16,500 tons, out of which 1.9 thousand tons were from to sources present in Sumgait city, 11,500 tons from Salyan district and 1.2 thousand tons from Siazan district.

The amount of sewage and domestic wastes are significantly different from those emitted into the air both for residential and industrial facilities of the region. The amount of sewage discharged from the facilities of Baku and Sumgait cities and Salyan and Neftchala districts together amounts to 3,371 million m3, accounting for 99.1 % of the total sewage water discharged in the pre-Caspian region. The major part of wastewater is discharged by facilities located in Salyan (1839.7 million m3) district (Regions of Azerbaijan, 2017).

Most of the domestic wastes are discharged from Baku (3,574.1 thousand m3) and Sumgait (626.0 thousand m3) cities. In 2009, the French company CNIM S.A. launched the construction of a modern Balakhani Garbage Recycling Plant in Baku to manage domestic wastes. The plant was put into operation in 2012. Two garbage burning lines with a capacity of 500,000 tons operate. Moreover, turbines capable of producing 230 megawatts/year of electricity are installed in the plant. The sludge formed due to the burning of garbage will be used for road construction (table 3).

Table 3. The main sources of pollution in the Pre-Caspian coasts of Azerbaijan

Territory	The amount of pollutants emitted into the atmosphere, thousand tons	The amount of waste water, million m^3	The amount of domestic waste, thousand m^3
Khacmaz administrative district	0.6	0.6	69.1
Shabran administrative district	0.01	0.9	9.0
Siyazan administrative district	1.2	0.8	3.3
Khizi administrative district	0.005	0.03	0.1
Absheron administrative district	0.1	25.8	48.0
Sumgait city	1.9	247.7	626.0
Baku city	130.0	842.7	3574.1
Salyan administrative district	11.5	1839.7	19.4
Neftchala administrative district	0.1	440.9	5.9
Masalli administrative district	0.02	0.1	23.1
Lankaran administrative district	0.009	1.1	43.1
Astara administrative district	1.1	0.08	10.4
Total:	*146.5*	*3400*	*4431.1*

Source: Regions of Azerbaijan. Baku, 2017

At present, one of the most critical issues related to the Caspian Sea is to predict the proliferation of pollution, depending on the specific conditions. This would enable effective anti-crisis measures to be carried out upon defining the extent of pollution in the seas.

Results.

The directions of development or nature-use of territories are determined taking into consideration the special differentiation of natural conditions and pattern of division of natural-resource potential (Hudzevich, et. at.2020). Socio-economic development is a complex and multifaceted concept that characterizes the activity of the national economy in two main areas (economic and social) (Grabowski, 2012). Along with the growth of a country's power, economic growth also stimulates the development of the social sphere, improves the living standards and material well-being of the country's population, and meets their needs.

Therefore, economic development is essentially an integral part of the goals of "sustainable development"

(environmental, economic and social) and ensures the sustainable development of the economy. Sustainable development in the economy depends on the establishment of socio-economic relations, economy, economic relations and economic management.

This, in turn, creates favourable conditions for the establishment of free-market relations, development of socio-economic infrastructure and elimination of environmental problems.

1. In places of settlement and socioeconomic activities where the demographic pressure is very high, social infrastructure facilities have increased, and, as a result, some environmental zones and risk areas have emerged.

2. The coastal areas, exposed to technogenic impact, have been changed and transformed much dramatically. This is due to the growth in the population as well as an increase in production.

3. Though healing mineral and thermal waters are widespread in the Pre-Caspian areas, these resources are markedly underutilised. To solve this problem, reconstruction of the existing resort centers should involve investments into this region. In addition, new treatment and recreation centers should be established based on the present resources as well.

Discussion.

The development of the regional economy is carried out through the trends, priorities and factors that determine the state of the national economy. Therefore, to effectively study such trends and factors, it is necessary to consider the socioeconomic priorities that shape and determine the current state of the domestic, regional economy. (Nazarova, 2011).When examining the place and position of the Caspian Sea in the Azerbaijani economy as an object of discussion, it becomes clear that environmental problems should first be investigated and prevented, because the surrounding areas of large settlements and industrial centres in the study area are severely polluted. Most coastal regions of the world face this problem. These include: urbanisation along the coastline of the Caspian Sea has amplified in recent years, with ever-increasing pressure on the land-based and marine environment. Population densities along the Caspian Sea coastline are uneven, and most of the population is concentrated in major urban centres in Azerbaijan, the Russian Federation and Iran. At the same time, the metropolitan area of Baku in Azerbaijan represents the most significant urban agglomeration (Project. Urbanisation and Climate Change Adaptation in the Caspian Sea Region, 2019).

– Sea-level changes pose considerable problems in biological and economic activities, both socio-economic and ecological, especially in shipping and fishing, both in the coastal zone and estuaries of rivers and on the high seas (Kenzhegaliev et. at., 2021).

– In the suburbs of Baku, there are very few cases in which the rise in sea level has directly affected houses. Instead, most concern stems from the economic and environmental effects of the rise in sea level, such as the blockage of sewerage lines and the deterioration of production enterprises (Kudat et. at., 1999).

– In the case of hazardous waste management, despite a proliferation of efforts to address problems of multiple contaminations of the Absheron Peninsula, no overall strategy of dealing with it exists that would involve optimum sequencing of activities, corresponding zoning, the role of financial instruments in assisting the process, environmental liability rules, and others (Country environmental analysis Azerbaijan. 2005).

– High population growth and the weakening of the health care system pose health problems to many people living around the Caspian Sea. This was due to socio-political and economic changes in the former Soviet republics (Caspian in maps and diagrams, France).

Conclusion.

1. Over the past ten years, demographic pressure (e.g., land acquisition by population increase) has become acute in the areas of the Caspian Basin, and the number of infrastructure facilities has increased, and as a result, some environmentally damaged zones and risk areas have emerged. Ecological tension zones and hazardous areas include Baku and Sumgait's seacoasts and Lankaran, Masalli and Khachmaz administrative districts because household wastes in these settlements are directly discharged into the sea and are a threat to the population's health.

2. Coastal areas exposed to technogenic pressure have been subjected to much faster change and transformation. This is due to the increase in the population and production volumes. At present, 88.7% of the country's total industrial output comes from the researched region. Carbon and other heat-generating gases emitted into the atmosphere through these facilities can increase the average annual temperatures in the region. To prevent this, climate change mitigation and adaptation are required.

3. Though mineral and thermal waters are widely used in the coastal areas of the Caspian Sea (Absheron Peninsula, Khachmaz and Lankaran administrative districts), they are used at a deficient level. These areas, which are the resort zone, are rich in fresh air, sea views, sandy beaches, and are more populated than many other areas. In order to solve the problem, investments in tourism and recreational firms are needed, reconstruction of resort centers should be carried out, and new treatment and recreation centers created (mainly in Baku city).

4. Absence of sewerage systems in newly built settlements in Baku and Sumgayit and direct discharge of wastewater, intensive destruction of forest massifs in Khachmaz, Lankaran and Astara administrative regions, development of agriculture and horticulture in their territories, reduction of the level of the Caspian Sea, strengthening of erosion processes in coastal areas and aeolian-type desertification processes have exacerbated the ecological situation. For example, the amount of phenol in Baku Bay was determined to be 0.2–1 g/kg, and the mercury content was 5–14 g/kg. This has led to a decrease in marine organisms and, in some cases, deep sea fauna.

References

Country environmental analysis Azerbaijanm, 2005. Asian Development Bank.Philippines.

Eminov, Z.N., 2005. Naselenie Azerbajdzhana [Population of Azerbaijan]. Baku (in Azerbaijani).

Geografiya Azerbajdzhanskoj Respubliki [Geography of the Republic of Azerbaijan], 2014. Vol.1: Physical Geography. Baku: Europe. (In Azerbaijani).

Glenn, K., 2001. The Impacts of Tourism. Minnesota.

Gul, G.K., 1956. Kaspiyskoye more [The Caspian Sea]. Baku. (In Russian).

Hudzevich, A.V., Nikitchenko, L.O., Baiurko, N.V. et al., 2020. Geoecological approach to organization of naturalized anthropogenically-modified territory. Journal of Geology, Geography and Geoecology, 29(3). Dnipro, 520–529. doi:10.15421/112047.

Imrani, Z.T., 2009. Vliyanie kolebanij urovnya Kaspijskogo morya na pribrezhnye rajony Azerbajdzhana [Impact of the fluctuation of the Caspian Sea level on Azerbaijan's coastal areas] Transactions of fellow researchers, 2. Baku, 110–116. (In Azerbaijani).

Imrani, Z.T., Zeynalova, K.Z., 2014. Ekonomiko-geograficheskie osobennosti territorial'noj organizacii ekonomiki Azerbajdzhana [Economic and geographical features of territorial organization of the Azerbaijan economy]. Baku. (In Azerbaijani).

Ismailov, Ch., 2004. Prirodnye resursy Kaspijskogo morya [Natural resources of the Caspian Sea]. Baku. (In Azerbaijani).

Kaspij v kartah i diagrammah, 2011. [The Caspian in maps and diagrams]. Zoï environment network, France, 38 p. (In Russian).

Kenzhegaliev, A., Kanbetov, A., Kulbatyrov, D., et. at., 2021. Fluctuation in the level of the Caspian sea and its consequences. E3S Web Conf., Volume 288. France, 1–4. https://doi.org/10.1051/e3sconf/202128801064.

Kudat, A., Musayev, A., Ozbilgin B., 1999. Social Assessment of the Azerbaijan National Environmental Action Plan: A Focus on Community Responses to the Caspian Sea Environmental Disaster. Washington.

Mammadov, R.M., 2013. Gidrometeorologiya Kaspiyskogo morya [Hydrometeorology of the Caspian Sea]. Baku. (In Russian).

Mammadov, R.M., Humbatov, A.I., Mammadov, G.M., 2000. Izuchenie vetrovogo dvizheniya vody na zapadnyh beregah Kaspijskogo morya [Investigation of wind-driven water movement in the western shores of the Caspian Sea]. Proceedings of Azerbaijan National Academy of Sciences (series of Earth sciences). Baku, 35–38. (In Azerbaijani).

Nazarova, M.I., 2011. Stimuli social'no ekonomichnogo rozvitku regionu [Stimuli of social and economic development of the region] Economy and state, 11, Kiev, 88–90. (In Ukrainian)

Nelipa, K.G., 2017. Ponyattya transformaciï regional'nih sistem rozselennya [The concept of transformation of regional settlement systems] Proceedings of the Scientific and Practical Internet Conference Problems of Regional Studies: Past, Present, Future. Kiev, 26–29. (In Ukrainian)

Project, 2019. Urbanisation and Climate Change Adaptation in the Caspian Sea Region. Azerbaijan and Iran.

Qrabovski, O., 2015. Teoretichni osnovi social'no-ekonomichnogo rozvitku v konteksti Evropejs'koi integracii [Theoretical fundamentals of socio-economic development in the context of European integration] Collection of scientific works, efficacy public administration, Issue 45, Lviv, 94–100. (In Ukrainian)

Regiony Azerbajdzhana, statisticheskij ezhegodnik, 2017. [Regions of Azerbaijan, Statistical yearbook]. Baku. (In Azerbaijani)

Stephen, W., 1998. Tourism Geography. London.

Sustainable Tourism Development in UNESCO Designated Sites in South-Eastern Europe. 2008. Ecological Tourism in Europe – ETE. Bonn.

Turizm v Azerbajdzhane. Statisticheskij godovoj [Tourism in Azerbaijan. Statistical yearbook]. 2017. Baku. (In Azerbaijani)

Vyatkin, K.I., Vyatkin, R.S., 2018. Sistema rozselennya naselennya v Ukraïni[Population resettlement system in Ukraine] Municipal utilities, Issue 142. Kharkiv, 199–204. (In Ukraine)

Zagorsky, V., Borshchuk, E., Zholobchuk, I., 2015. Zabezpechennya stalogo rozvitku nacional'noï ekonomiki: social'ni ta ekologichni aspekti [Ensuring the stable development of national economies: social and environmental aspects] Collection of scientific works Efficacy public administration, Issue 44. Lviv, 9–17. (In Ukraine).

Zavyalova, E.B., 2017. Kaspijskaya mechta i geopoliticheskaya [Caspian dream and geopolitical reality] Economic policy, 5, 1., 41–48. (In Russian).

Journal of Geology, Geography and Geoecology

Journal home page: geology-dnu.dp.ua

ISSN 2617-2909 (print)
ISSN 2617-2119 (online)

Journ. Geol. Geograph. Geology, 30(4), 667–674.
doi: 10.15421/112161

Givetian trilete spores of *Geminospora* from the Volyn–Podillya (Western Ukraine)

Antonina V. Ivanina[1], Anastasiia O. Myronova[2]

[1] *Ivan Franko National University of Lviv, Ukraine,* antonina.ivanina@lnu.edu.ua
[2] *National University of Kyiv-Mohyla Academy,* anastasiia.myronova@ukma.edu.ua

Received: 03.10.2021
Received in revised form: 18.10.2021
Accepted: 27.11.2021

Abstract. Givetian sediments are widely distributed within the Volyn-Podillia margin of the East-European platform (VPO EEP)**.** These are terrigenous-carbonate cyclically constructed formations with a thickness of 102 to 165 m, the stratification of which is complicated due to the facial variability of rocks. Therefore, when studying this stratum, palynology and the implementation of palynostratigraphic delimitation are of great importance. The initial stage of palynological research of Devonian VPO EEP deposits is clear identification of miospores and their monographic study, the main components of which are morphological and morphometric research, taxonomic determination of genera and species by morphological-comparative method, elucidation of their stratigraphic and geographical distribution. The object of research is dispersed miospores. During their taxonomic study, M.V. Oshurkova's artificial, or formal, taxonomy was used, which modernized the morphological classification of R. Potonier and G. Kremp, clarified palynological terminology, detailed diagnostics of taxa, and gave unified diagnoses of genus forms. For the first time, a monographic description of five species is given according to this classification. They are *Geminospora extensa* (Naumova) Gao (from 36 to 51%); up to 10%: *G. decora* (Naumova) Archangelskaja, *G. tuberculata* (Kedo) Allen, *G. micromanifesta* (Naumova) Archangelskaja, *G. notata* (Naumova) Obukhovskaja. belonging to the genus *Geminospora* (Balme) Owens of infraturma Pseudosacciti, subturma Zonocavatitriletes, suprasubturma Cavatitriletes turma Triletes. These are trilete radial zonate cavate hilate spores with ornamented exine. They are main indicators, key and characteristic species of palyzone **E** of the Givetian of the Middle Devonian.

Keywords: palynology, spores, Givetian, Devonian, Volyn-Podillya, the Eastern European platform.

Живетські трілетні спори *Geminospora* (Balme) Owens Волино-Поділля (Західна Україна)

А.В. Іваніна[1], А.О. Миронова[2]

[1] *Львівський національний університет імені Івана Франка, Львів, Україна,* antonina.ivanina@lnu.edu.ua
[2] *Національний університет «Києво-Могилянська академія»Київ, Україна,* anastasiia.myronova@ukma.edu.ua

Анотація. Відклади живетського ярусу поширені повсюдно в межах Волино-Подільської окраїни Східноєвропейської платформи (ВПО СЕП). Це теригенно-карбонатні циклічно побудовані утворення товщиною від 102 до 165 м, стратифікація яких ускладнена внаслідок фаціальної мінливості порід. Під час вивчення цієї товщі велике значення має палінологія і виконання паліностратиграфічного розмежування. Початковим етапом палінологічних досліджень девонських відкладів ВПО СЄП є чітка ідентифікація міоспор та їхнє монографічне вивчення, головними складовими якого є морфологічне і морфометричне дослідження, таксономічне визначення родів і видів морфолого-порівняльним методом, з'ясуванням їхнього стратиграфічного і географічного поширення. Об'єктом досліджень є дисперсні міоспори. Під час їхнього таксономічного вивчення застосовували штучну, або формальну, систематику М.В. Ошуркової, яка модернізувала морфологічну класифікацію Р. Потонье і Г. Кремпа, уточнила палінологічну термінологію, деталізувала діагностику таксонів, навела уніфіковані діагнози форма-родів. За цією систематикою вперше для палінології девону ВПО СЄП наведено монографічний опис чотирьох видів *Geminospora extensa* (Naumova) G a o (від 36 до 51%); до 10%: *G. decora* (Naumova) Archangelskaja, *G. tuberculata* (Kedo) Allen, *G. micromanifesta* (Naumova) Archangelskaja, *G. notata* (Naumova) Obukhovskaja, які належать форма-роду *Geminospora* (Balme) Owens інфратурми Pseudosacciti, субтурми Zonocavatitriletes, супрасубтурми Cavatitriletes турми Triletes. Це трипроменеві радіальні зонатні каватні монопсевдосакатні спори з орнаментованою екзиною. Вони є чіткими індикаторами і керівними видами відкладів палінозони **E** живетського ярусу середнього відділу девонської системи.

Ключові слова: палінологія, спори, живетський ярус, Волино-Поділля, Східноєвропейська платформа.

Introduction.

This publication is one of the works that follow (Ivanina, 2004, 2018, 2019) devoted to the palynological characteristics of the Devonian sediments of the Volyn-Podillya margin of the East-European platform (VPM EEP).

The purpose of the palynological study is to improve the biostratigraphic substantiation of local stratons and stratigraphic schemes in general, which is impossible without the initial stage of any paleontological research, namely the study of the structure and taxonomic definition of genera and species of dispersed spores and its spreading.

The most important stage of palynological research is morphological investigations and identification of spores. The reliability of scientific elaboration and practical application of palynological data depends on the quality of the initial data the accuracy of the taxonomic definition. Morphological (artificial or formal) classifications are used in the study of Paleozoic spores and pollen. Today there are many modifications of morphological classification systems of Paleozoic spores, which differ in the principles of typification, volumes, and diagnoses of taxa, differences in the hierarchical sequence of systematic units, and so on. M. V. Oshurkova (Oshurkova, 2003) revised the existing taxonomies and, choosing the classification of R. Potonie and G. Kremp (Potonie, Kremp, 1955, 1956) as the base, clarified palynological terminology, detailed the diagnosis of taxa, gave unified diagnoses of form-genera and streamlined the taxonomy of Paleozoic spores by the restoring the rule of priority and returning to its composition valid taxa. Such modernization of the classification of Paleozoic spores by M. V. Oshurkova is a significant step forward, as it corresponds to the current state of the study of palynomorphs, is the best-generalized summary of unified genus diagnoses in their taxonomic and hierarchical subordination. According to this classification system, the study of Paleozoic spores was not performed in Ukraine.

Givetian sediments of the VPM EEP are terrigenous-carbonate with a thickness of 102 to 165 m, characterized by a cyclic structure with alternating of chemogenic and terrigenous rocks with different thicknesses. The main types of rocks – limestones, dolomites, anhydrite, argillites, sandstones, siltstones, form complicated paragenetic associations (Ivanina, Havrylets, Stokhmanska, 2000; Stratyhrafiia URSR, 1974; Stratyhrafiia verkhnoho proterozoiu, paleozoiu ta mezozoiu Ukrainy, 2013). Stratification of them is difficult because of the facial variability of rocks (Konstantynenko, Ivanina, 2004), low content of macrofossils and it is possible only by micropaleontological and spore-pollen data.

Palynological studies of the Devonian of the VPM EEP were initiated in the middle of the last century by G. I. Kedo, O. V. Chibrikova, I. I. Partyka (only manuscript), continued by A. V. Ivanina (Ivanina, 2004, 2018, 2019), who isolated and characterized the palynozone **Geminospora extensa** (**E**) and gave its generalized (Ivanina, 2004) and standardized (Ivanina, 2018) palynological characteristics.

Palynological zone **E** is the biozone – *Geminospora extensa* (Naum.) Gao index-species spreading zone. It is widespread in the VPM EEP. It occurs on the deposits of the palynozone **TL** (Middle Devonian, Eiffel) and is covered by Frasnian sediments (Ivanina, 2018). It corresponds to the palyzone **EX** (**Geminospora extensa**) of the East-European platform (Avkhimovitch, Tchibrikova, Obukhovskaja, Nazarenko, Umnova, Raskatova, Mantsurova, Loboziak, Streel, 1993; Atlas spor i pyltsy neftehazonosnykh tolshch fanerozoia Russkoi i Turanskoi plyt, 1985), Ural (Chibrikova, 1977), Pripyat depression (Kedo, Obukhovskaya, 1981.), upper part of zone **AD** (**acathomammillatus**–**devonicus**) and spore zone **TA** (**triangulatus**–**ancyrea**) the Ardenne-Rhenich regions (Streel, Higgs, Loboziak, Riegel, Steelmans, 1987).

The most important signs of this zone are:

- 65 taxa are recorded – 28 transit, 24 key and 13 characteristic (or typical) species (table 1);
- significant content (from 36 to 81 %) of spores of the genus *Geminospora* (Balme) Owens has been established among key taxa, and especially of index-species *Geminospora extensa* (Naum.) Gao (36–51 %);
- only in the sediments of the zone there are four species of the genus *Geminospora* – *Geminospora extensa* (Naum.) Gao, *G. decora* (Naum.) Archangelskaja, *G. tuberculata* (Kedo) Allen, *G. micromanifesta* (Naum.) Archangelskaja.
- one species – *Geminospora notata* (Naum.) Obukhovskaja is typical, because it has a wider range of existence; it appears in zone **E**; within its limits occurs in significant quantities, disappears in the Late Devonian.

The genus *Geminospora* (Balme) Owens was first described by Balme B. E. from the Upper Devonian sediments of Western Australia (Balme, 1962). Its diagnos was modernized by Owens W. during the study of Middle and Upper Devonian sediments in Canada (Owens, 1971).

Spores of the genus *Geminospora* (Balme) Owens from Givetian of the VPM EEP are trilete radial zonate cavate monopseudosaccate spores with ornamented exine and are similar in structure. Common morphological features are trilete suture, the presence of stratified layers of exine, and the growth of exoexina in the form of a pseudosaccus. They are distinguished by the ornamentation of the exine.

Table 1. Miospores' composition of the **Geminospora extensa (E)** Zone

Taxa	Dominant and subdominant	Accessory
Key	*Geminospora extensa*, *G. decora*, *G. tuberculata*, *Acanthozonotri-letes spinutissimus*	*Geminospora micromanifesta*, *Calyptosporites krestovnikovii*, *Aneurospora heterodonta*, *Hymenozonotriletes spinosus*, *H. argutus*, *H. polyacanthus*, *Speciososporites novus*, *Calyptosporites proteus*, *C. velatus*, *Sinuosisporis sinuosus*, *Rhabdosporites langii*, *Grandispora torezi*, *G. naumovae*, *Corystisporites multispinosus*, *Cymbosporites magnificus*, *Chelinospora timanica*, *Retusotriletes radiosus*, *Monilospora latemarginatus*, *Tuberculiretusispora subgibberosa*
Typical	*Geminospora notata*, *Lophozonotriletes curvatus*	*Acanthotriletes parvispinus*, *Trachytriletes*? *devonicus*, *Leiotriletes furcatus*, *Retusotriletes concinnus*, *Lophozonotriletes scurrus*, *L. curvatus*, *Auroraspora varia*, *Ancyrospora honesta*, *Retusotriletes simplex*, *Diaphanospora rugosa*
Transit	–	*Calamospora*, *Punctatisporites*, *Granulatisporites*, *Brochotriletes*, *Acanthotriletes*, *Trachytriletes*? *trivialis*, *Leiotriletes laevis*, *L. simplex*, *Retusotriletes minor*, *R. triangulatus*, *Foveolatisporites*, *Stenozonotriletes conformis*, *S. laevigatus*, *Ambitisporites pumilis*, *A. simplex*, *Lophotriletes*, *Verrucosisporites*, *Converrucosisporites*, *Reticulatisporites*, *Camptotriletes*, *Periplecotriletes*, *Spinozonotriletes*, *Apiculiretusispora*, *Anapiculatisporites*

Monographically from Devonian deposits of the VPM EEP they are not described.

Material and methods of the research.

The material for research is 270 samples of rocks with different lithology. Givetian sediments containing species of genus *Geminospora* (Balme) Owens are widespread within the VPM EEP.

During palynological studies of Devonian sediments of the VPM EEP taxonomic determination was performed by morphological-comparative method, the main purpose of which is to clarify the systematic position and determine taxa by their structure (Uziiuk, Ivanina, Hotsaniuk, Shainoha, Tuziak, 2007; Hotsaniuk, Ivanina, 2017). This method involves such operations: analysis of the spore's preservation; morphological description; morphometric observations (measuring the size of spores in general and their individual elements); taxonomic definition; detection of geographical and stratigraphic spreading.

The morphology of spores was studied on biological microscopes "Nicon-eclipse" and "Axiolab" and was accompanied by photographing spores with a digital camera "Optiphot-2". The external structure of the exina of five species of the genus *Geminospora* (Balme, 1962) Owens, 1971 from Givetian of the VPM EEP, selected by the method of V.K. Teteriuk (Teteriuk, 1964), was first studied and photographed on a scanning microscope "Geol" JSM-6400.

Results and their analysis.

The monographic description of species is given according to classical canons, in compliance with the International Code of Botanical Nomenclature (1974) and the procedure for describing species of fossil spores (Instructions for the description of fossil plant and animal organisms in paleontological works, 1971). The optimal set of morphological features was selected for the species characteristic, first of all, which can be recognized on the fossil material; secondly, they are necessary and sufficient to determine the species. For each species the full name, author, year of definition, synonymy, material, morphological characteristics (type of spore, outlines, the structure of aperture, exines, the character of sculpture, etc.), sizes, stratigraphic and geographical spreading are given.

Morphological descriptions of species of the genus *Geminospora* are based on the genus characteristics given in (Oshurkova, 2003). At the same time, reliable diagnostic features were found for each species, which serve as criteria for species identification.

This morphological description is the first generalized summary of unified diagnoses of the main spore's species of the genus *Geminospora* (Balme, 1962) Owens, 1971 from Givetian (palynological zone **E**) of the VPM EEP. It will help to correctly identify fossil species.

Anteturma **PROXIMEGERMINANTES** Potonie, 1970 (**Sporites** H. Potonie, 1893)

Turma**TRILETES** (Reinch, 1881) Potonie et Kremp, 1954

Suprasubturma **Cavatitriletes** Oshurkova et Pashkevich, 1990

Subturma **Zonocavatitriletes** Oshurkova et Pashkevich, 1990

Infraturma **Pseudosacciti** Oshurkova et Pashkevich, 1990

Genus *Geminospora* (Balme, 1962) Owens, 1971

Geminospora extensa (Naumova, 1953) Gao, 1981

Plate 1, fig. *1–3*

Archaeozonotriletes extensus Naumova: Naumova, 1953, p. 33, 86, pl. 3, fig. 5; pl. 13, fig. 20; Кедо, 1955, pl. 5, fig. 16, 17; Tchibrikova, 1962, pl. 17, fig. 25; Raskatova, 1969, pl. 14, fig. 48; Tchibrikova, 1977,

pl. 17, fig. 7; Stratigraficheskie i paleontologicheskie issledovaniya v Belorussii, 1978, pl. 30, fig. 2, 23, 39; Kedo, Obukhovskaja, 1981, pl. 18, fig. 1, pl. 19, fig. 4, 21.

Geminospora extensa (Naumova) Gao: Gao, 1981, pl. 3, fig. 6; Archangelskaja, 1985, p. 46, pl. 5, fig. 2; Avkhimovitch, Tchibrikova, Obukhovskaja, Nazarenko, Umnova, Raskatova, Mantsurova, Loboziak, Streel, 1993, p. 108, pl. 7, fig. 1; p. 110, pl. 8, fig. 4; p. 112, pl. 9, fig. 4; Oshurkova, 2003, p. 207; Ivanina, 2004, p. 118, 150, pl. 1, fig. 1–3.

Palynological material. 37 well-preserved specimens.

Description. Small and medium-sized radial trilete zonate cavate mono-pseudo saccate spores with rounded-triangular amb. The exine is with separated layers. The central body is triangular-rounded, with convex sides and rounded corners and a moderately thick verrucate intexine on the distal side. Exoexina of the pseudosaccus of medium thickness, with verrucate ornamentation; at the equator of spores has the form of a very narrow zone. The surface of the pseudosaccus is densely covered with small, densely spaced verrucae – low growths of irregularly rounded or irregularly oval shape with flat or slightly rounded tips.

The edge of the spores is irregular, slightly wavy, due to the protrusion of sculptural elements along the equator of the spores.

The trilete suture is simple, the rays are straight, the length is equal to the radius of the spores.

Dimensions, μm. (19 measured specimens). Equatorial diameter: the spore body – 24–43, central body – 18–31; width of equatorial zone – 4–6; verrucae: width – 0,5–2,0; height – 1,0–1,5.

Localities. Boreholes: Gorochiv 6, 1 070–1 180 m, Gorochiv 2, 875–970 m, Ludyn 1, 1 412–1 553 m, Lokachi 9, 883–986 m, Lokachi 27, 830–930 m, Markovychi 1, 922–1 013 m, Reniv 24 c, 100–210 m, Tychotyn 1, 430–567 m, Tychotyn 3, 668–782 m and others.

Occurrence. Middle Devonian; Givetian of the East-European platform (zone **EX** of the general East-Europian palynostratigraphic scales) (Naumova, 1953; Avkhimovitch, Tchibrikova, Obukhovskaja, Nazarenko, Umnova, Raskatova, Mantsurova, Loboziak, Streel, 1993; Atlas spor i pyltsy neftehazonosnykh tolshch fanerozoia Russkoi i Turanskoi plyt, 1985), Upper Givetian and Lower Frasnian of Pripyat depression (Stratigraficheskie i paleontologicheskie issledovaniya v Belorussii, 1978), Givetian of the VPM EEP (palynological zone **E**).

Geminospora micromanifesta
(Naumova, 1953) Owens, 1971
Plate 1, fig. *4–6*

Archaeozonotriletes micromanifestus Naumova: Naumova, 1953, p. 31, 79, 128, pl. 2, fig. 18; pl. 12, fig. 2–4; pl. 19, fig. 5; Tchibrikova, 1959, pl. 15, fig. 23; 1962, pl. 17, fig. 19; Nazarenko, 1964, pl. 1, fig. 8, 51, 64; Tchibrikova, 1977, pl. 16, fig. 9; pl. 19, fig. 12; Stratigraficheskie i paleontologicheskie issledovaniya v Belorussii, 1978, pl. 30, fig. 9, 26; Kedo, Obukhovskaja, 1981, pl. 19, fig. 5, 22, pl. 21, fig. 9.

Geminospora lemurata Balme: Balme, 1962, p. 4, pl. 1, fig. 5, 7, 8.

Archaeozonotriletes micromanifestus Naumova var. *microtuberculatus* Tschibrikova: Tchibrikova, 1962, p. 414, pl. 7, fig. 5.

Archaeozonotriletes antaxios Tschibrikova: McGregor, Camfield, 1982, pl. 3, fig. 7.

Archaeozonotriletes cf. *antaxios* Tschibrikova: Bar, Riegel, 1974, pl. 1, fig. 10.

Geminospora micromanifesta (Naumova) Archangelskaja: Archangelskaja, 1985, p. 46, pl. 5, fig. 1; Avkhimovitch, Tchibrikova, Obukhovskaja, Nazarenko, Umnova, Raskatova, Mantsurova, Loboziak, Streel, 1993, p. 110, pl. 8, fig. 13; p. 112, pl. 9, fig. 8; p. 114, pl. 10, fig. 2; Ivanina, 2004, p. 118, 150, pl. 1, fig. 10.

Geminospora micromanifesta (Naumova) Owens: Owens, 1971, pl. 3, fig. 6; Oshurkova, 2003, p. 207.

Palynological material. 19 well-preserved specimens.

Description. Medium-sized trilete radial zonate cavate triangular-rounded spores with a triangular-rounded central body, which is sometimes shifted to the side. The exina is stratified around the equator and the distal side of the spores. The exoexina is thick, forming a pseudosaccus around the central body, which at the equator has the appearance of a medium-width zone. The surface of the pseudosaccus with verrucate ornamentation is densely covered with weakly expressed flat, very small, densely placed verrucae. The Interradial area is without sculptural elements, smooth.

The edge of the spores is uneven, weakly and slightly wavy.

The laesura is trilete, the rays are straight, its' length is equal to the radius of the spores.

Dimensions, μm. (based on 11 specimens). Equatorial diameter: the spore body – 43–72, central body – 31–51; width of equatorial zone – 9–14.

Localities. Boreholes: Gorochiv 6, 1 070–1 180 m, Gorochiv 2, 875–970 m, Ludyn 1, 1 412–1 553 m, Lokachi 9, 883–986 m, Lokachi 27, 830–930 m, Markovychi 1, 922–1 013 m, Reniv 24 c, 100–210 m, Tychotyn 1, 430–567 m, Tychotyn 3, 668–782 m and others.

Occurrence. Middle Devonian, Givetian of the East-European platform (zone **EX** of the general East-

Europian palynostratigraphic scales) (Naumova, 1953; Avkhimovitch, Tchibrikova, Obukhovskaja, Nazarenko, Umnova, Raskatova, Mantsurova, Loboziak, Streel, 1993; Atlas spor i pyltsy neftehazonosnykh tolshch fanerozoia Russkoi i Turanskoi plyt, 1985), Upper Givetian and Lower Frasnian of Pripyat depression (Stratigraficheskie i paleontologicheskie issledovaniya v Belorussii, 1978), Givetian (palynological zone **E**) of the VPM EEP.

Geminospora decora (Naumova, 1953) Archangelskaja, 1980

Plate 1, fig. *7–9*

Archaeozonotriletes decorus Naumova: Naumova, 1953, p. 35, pl. 3, fig. 11, 12; Kedo, 1955, p. 39, pl. 5, fig. 20; Tchibrikova, 1959, pl. 15, fig. 28; Raskatova, 1969, pl. 14, fig. 24, 30; Kedo, Obukhovskaja, 1981, pl. 18, fig. 4.

Archaeozonotriletes pustulatus Naumova: Naumova, 1953, p. 35, pl. 3, fig. 10; Kedo, 1955, p. 38, pl. 5, fig. 19; Tchibrikova, 1959, pl. 15, fig. 27; Raskatova, 1969, pl. 14, fig. 22; Tchibrikova, 1977, pl. 15, fig. 5; pl. 16, fig. 10; pl. 17, fig. 9; Kedo, Obukhovskaja, 1981, pl. 18, fig. 3; pl. 20, fig. 8.

Geminospora decora Archangelskaja: Archangelskaja, 1985, p. 48, pl. 5, fig. 6. 7; Avkhimovitch, Tchibrikova, Obukhovskaja, Nazarenko, Umnova, Raskatova, Mantsurova, Loboziak, Streel, 1993, p. 110, pl. 8, fig. 11; p. 112, pl. 9, fig. 14; Oshurkova, 2003, p. 207; Ivanina, 2004, p. 118, 150, pl. 1, fig. 4.

Palynological material. 35 well-preserved specimens.

Description. Small and medium-sized trilete radial zonate cavate triangular-rounded spores with a pseudosaccus, which at the equator has the form of a narrow zone. The central body is triangular and rounded, with convex sides and rounded corners. Exina is fine-grained, thick, layered around the equator and the distal side of the spores, with conate ornamentation. Sculptural elements in the form of low coni with a rounded base and rounded tip, placed on the distal

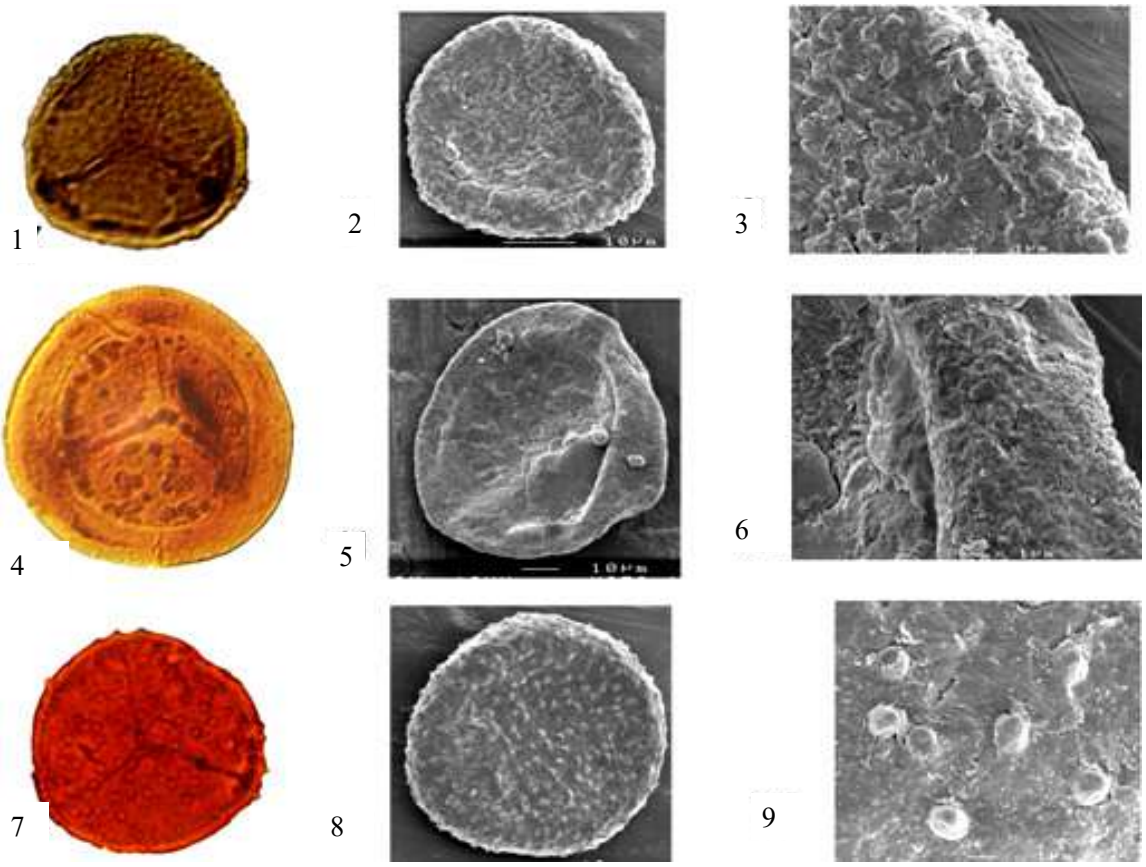


Plate 1. Key species of genus *Geminospora* (palynozone **E**, borehole Reniv 24 c, 100–210 m), Givetian, Middle Devonian of the VPM EEP. All figures in transmitted light x400. Magnification under the electronic microscope is on images.
1–3. *Geminospora extensa* (Naum.) Gao: *1* – view in transmitted light; *2*, *3* – view under the electronic microscope: *2* – from distal side; *3* – fragment of distal side with verrucate ornamentation; *4–6. Geminospora micromanifesta* (Naum.) Owens: *4* – view in transmitted light; *5*, *6* – view under the electronic microscope: *5* – from distal side; *6* – fragment of distal side with ornamentation from small verrucae; *7–9*. *Geminospora decora* (Naum.) Arkh.: *7* – view in transmitted light; *8*, *9* – view under the electronic microscope: *8* – from distal side; *9* – fragment of distal side with tuberculate sculpture.

side and along the equator of the spores evenly and at almost the same distance from each other. Intexin forms the central body, exoexina saccus.

The edge of the spores is uneven, finely conate due to the protrusion of sculptural elements along the equator of the spores.

The suture is trilete, the rays are straight, the length is equal to the radius of the spores.

Dimensions, μm. (29 measured specimens). Equatorial diameter: the spore body – 34–43, central body – 30–34; width of equatorial zone –2–4; coni: width – до 2,5, height – 1,5–2,0, distance between coni – 5–10.

Comparison. In the descriptions given in the works (Naumova, 1953; Stratigraficheskie i paleontologicheskie issledovaniya v Belorussii, 1978; Atlas spor i pyltsy neftehazonosnykh tolshch fanerozoia Russkoi i Turanskoi plyt, 1985) sculptural elements in the form of rounded tubercula. Electron microscopic studies have shown that the sculptural elements of this species are coni (narrowed upwards) with sharp but rounded tops, rounded bases, the diameter of which is equal to or slightly larger than the height.

Localities. Boreholes: Gorochiv 6, 1 070–1 180 m, Gorochiv 2, 875–970 m, Ludyn 1, 1 412–1 553 m, Lokachi 9, 883–986 m, Lokachi 27, 830–930 m, Markovychi 1, 922–1 013 m, Reniv 24 c, 100–210 m, Tychotyn 1, 430–567 m, Tychotyn 3, 668–782 m and others.

Occurrence. Middle Devonian; Givetian of the East-European platform (zone **EX** of the general East-Europian palynostratigraphic scales) (Naumova, 1953; Avkhimovitch, Tchibrikova, Obukhovskaja, Nazarenko, Umnova, Raskatova, Mantsurova, Loboziak, Streel, 1993; Atlas spor i pyltsy neftehazonosnykh tolshch fanerozoia Russkoi i Turanskoi plyt, 1985), Upper Givetian and Lower Frasnian of Pripyat depression (Stratigraficheskie i paleontologicheskie issledovaniya v Belorussii, 1978), Givetian (palynological zone **E**) of the VPM EEP.

Geminospora tuberculata (Kedo, 1955) Allen, 1965

Plate 2, fig. *1–3*

Archaeozonotriletes meonacanthus Naumova: Naumova, 1953, pl. 22, fig. 100; Tchibrikova, 1959, p. 58, pl. 7, fig. 4; Nazarenko, 1964, pl. 1, fig. 32–34.

Archaeozonotriletes tuberculatus Kedo: Kedo, 1955, p. 35, pl. 5, fig. 6,7; Raskatova, 1969, pl. 14, fig. 28; Kedo, Obukhovskaja, 1981, pl. 18, fig. 9.

Geminospora tuberculata (Kedo) Allen: Allen, 1965, p. 696, pl. 94, fig. 10; Archangelskaja, 1985, p. 47, pl. 5, fig. 5; Avkhimovitch, Tchibrikova, Obukhovskaja, Nazarenko, Umnova, Raskatova, Mantsurova, Loboziak, Streel, 1993, p. 108, pl. 7, fig. 3; p. 110, pl. 8, fig. 5; p. 112, pl. 9, fig. 12; Oshurkova, p. 207; Ivanina, 2004, p. 118, 150, pl. 1, fig. 7–9.

Geminospora tuberculata (Kedo) Allen var. *tuberculata* McGregor: McGregor, Camfield, 1982, p. 110, pl. 8, fig. 5.

Palynological material. 17 well-preserved specimens.

Description. Medium-sized trilete radial zonate cavate triangular-rounded spores. The triangular-rounded central body, which has convex sides and rounded corners, is sometimes offset from the center. The exina is moderately thick, sometimes with single folds, stratified around the equator and the distal side of the spores. Exoexina with tuberculate ornamentation forms around the body a pseudosaccus, which at the equator looks as a medium-width, sometimes asymmetric zone. The surface of the saccus is covered with small, evenly, and occasionally placed, low tubercula, which are narrowed upwards, have a rounded base and rounded tops. The diameter of the base and the height of the tubercula are approximately the same.

The edge of the spores is uneven, tuberculate due to the protrusion of sculptural elements along the equator of the spores.

The suture is trilete, the rays are straight, with thin lips, equal in length to the radius of the spores.

Dimensions, μm. (based on 10 specimens). Equatorial diameter: the spore body – 52–63, central body – 32–41; width of equatorial zone – 10–15; coni: width – 0,5–2,0; height – 1,0–1,5.

Localities. Boreholes: Gorochiv 6, 1 070–1 180 m, Gorochiv 2, 875–970 m, Ludyn 1, 1 412–1 553 m, Lokachi 9, 883–986 m, Lokachi 27, 830–930 m, Markovychi 1, 922–1 013 m, Reniv 24 c, 100–210 m, Tychotyn 1, 430–567 m, Tychotyn 3, 668–782 m and others.

Occurrence. Middle Devonian; Givetian of the East-European platform (zone **EX** of the general East-Europian palynostratigraphic scales) (Naumova, 1953; Avkhimovitch, Tchibrikova, Obukhovskaja, Nazarenko, Umnova, Raskatova, Mantsurova, Loboziak, Streel, 1993; Atlas spor i pyltsy neftehazonosnykh tolshch fanerozoia Russkoi i Turanskoi plyt, 1985), Upper Givetian and Lower Frasnian of Pripyat depression (Stratigraficheskie i paleontologicheskie issledovaniya v Belorussii, 1978), Givetian (palynological zone **E**) of the VPM EEP.

Geminospora notata (Naumova, 1953) Obukhovskaja, 1981

Plate 2, fig. *4–6*

1953 *Archaeozonotriletes notatus* Naumova: Naumova, p. 84, pl. 13, fig. 12; p. 116, pl. 17, fig. 25.

1978 *Archaeozonotriletes notatus* Naumova: Stratigraficheskie i paleontologicheskie issledovaniya v Belorussii, p. 220, pl. 31, fig. 20, 29.

1981 *Geminospora notata* (Naumova) Obukhovskaja: Obukhovskaja, p. 46, pl. 5, fig. 2.

1993 *Geminospora notata* (Naumova) Obukhovskaja: Avkhimovitch, Tchibrikova, Obukhovskaja, Nazarenko, Umnova, Raskatova, Mantsurova, Loboziak, Streel, 1993, p. 112, pl. 9, fig. 15; p. 114, pl. 10, fig. 10; p. 116, pl. 11, fig. 11; p. 122, pl. 14, fig. 14.

2003 *Geminospora notata* (Naumova) Obukhovskaja: Oshurkova, p. 207.

Palynological material. 29 well-preserved specimens.

Description. Small and medium-sized radial trilete zonate cavate mono-pseudosaccate triangular-rounded spores. The exina is stratified around the equator and the distal side of the spores. The exoexina is thin, sometimes crumpled into folds, forming a pseudosaccus around the body. A pseudosaccus look as a narrow zone along the equator and is densely covered with small, densely spaced, verrucae (irregularly rounded outgrowths with flat tips). Ornamentation is verucate.

The edge of the spores is uneven, slightly wavy, due to the protrusion of sculptural elements along the equator of the spores.

The suture is trilete, the rays are straight, the length is equal to the radius of the spores.

Dimensions, μm. (21 measured specimens). Equatorial diameter: the spore body – 34–53, width of equatorial zone – 7–9.

Stratigraphic distribution. Characteristic in Middle and Upper Devonian: subdominant in Zone **E** (Givetian), rare in zones **HM, V** (Famenian) of VPM EEP (Ivanina, 2018).

Localities. Boreholes: Oglyadiv 1, 681–1 332 m, Oglyadiv 3, 460–1 020 m, Volytsa 1, 1 075–1 195 m, Vazhev 2, 1 124–1 340 m, Rajmysto 42, 128–180 m, Torchyn 201, 262–289 m, Gorochiv 1, 396–900 m, Gorochiv 2, 543–970 m, Gorochiv 6, 490–1 180 m, Lokachi 9, 883–986 m and others.

Occurrence. Middle, Upper Devonian; Givetian, Frasnian of the East-European platform (zones **EX–OG** of the general East-Europian palynostratigraphic scales) (Naumova, 1953; Avkhimovitch, Tchibrikova, Obukhovskaja, Nazarenko, Umnova, Raskatova, Mantsurova, Loboziak, Streel, 1993); Upper Devonian, Frasnian of Pripyat depression (Stratigraficheskie

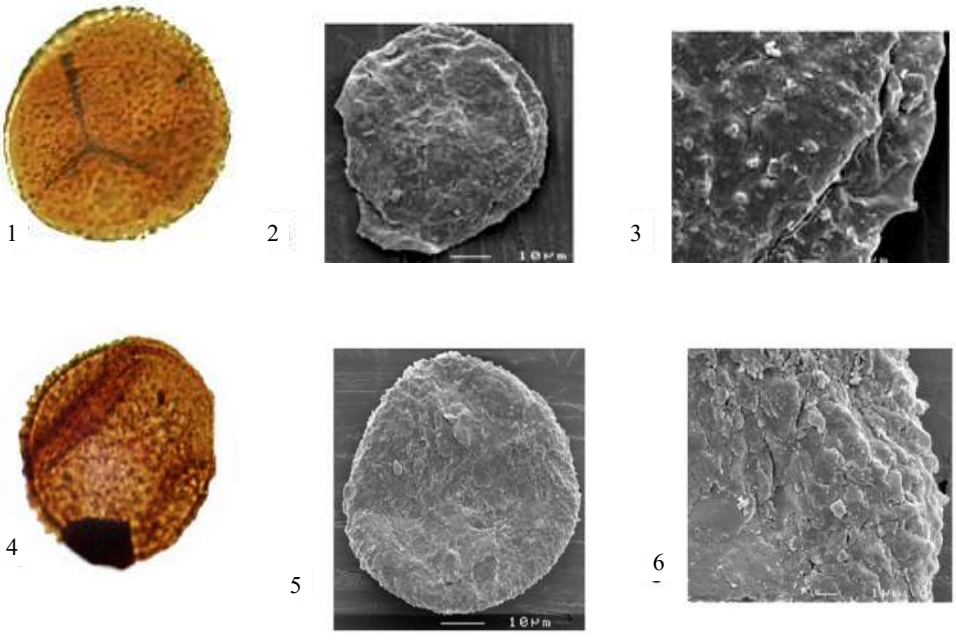


Plate 2. Some species of genus *Geminospora* (Balme, 1962) Owens. All figures in transmitted light x400. Magnification under the electronic microscope is on images.

1–3. Geminospora tuberculata (Kedo) Allen, borehole Reniv 24 c, 100–210 m; palynozone **E**; Givetian, Middle Devonian of the VPM EEP: *10* – view in transmitted light; *11*, *12* – view under the electronic microscope: *11* – from distal side; *12* – fragment of distal side with spinate ornamentation. *4–6. Geminospora notata* (Naumova) Obukhovskaja, Tychotyn 5 447, 188–214 m; palynozone **E**; Givetian, Middle Devonian of the VPM EEP: *4* – view in transmitted light; *5*, *6* – view under the electronic microscope: *4* – from distal side; *5* – fragment of distal side with verrucate ornamentation.

i paleontologicheskie issledovaniya v Belorussii, 1978), Givatian – lower part of Famenian (palynological zones **E–V**) of the VPM EEP.

Conclusions.

During palynological research of Devonian of the Volyn-Podillia margin of the East-European platform (VPM EEP):

– the systematic composition of the spores key species of the genus *Geminospora* (Balme, 1962) Owens, 1971 from Givetian, Middle Devonian (palynological zone **E**) of the VPM EEP was determined;

– according to the updated taxonomy of M. V. Oshurkova (2003) for the first time the ultrastructure of five species was described and studied monographically. These species are *Geminospora extensa* (Naum.) Gao, *G. decora* (Naum.) Arkh., *G. tuberculata* (Kedo) Allen, *G. micromanifesta* (Naum.) Arkh., *G. notata* (Naum.) Obukh.;

– diagnos of all spores species of the genus *Geminospora* (Balme, 1962) Owens, 1971 from Givetian of the VPM EEP are detailed and specified.

References

Allen, K. C., 1965. Lower and Middle Devonian spores of North and Central Vestspitsbergen. Palaeontology. 8, 687–748.

Atlas spor i pyltsy neftehazonosnykh tolshch fanerozoia Russkoi i Turanskoi plyt, 1985. [Atlas of spores and pollen of oil and gas bearing strata of the Phanerozoic of the Russian and Turan plates]. VNIHNI. 253. (In Russian).

Arkhangel'skaya, A. D., 1980. Spory' rastenij iz nekotory'kh razrezov nizhnego devona zapadny'kh regionov Russkoj plity'[Plant spores from some Lower Devonian sections of the western regions of the Russian Plate]. VNIHNI. 217, 26–46. (In Russian).

Avkhimovitch, V. I., Tchibrikova, E. V., Obukhovskaja, T. G., Nazarenko, A. M., Umnova, V. T., Raskatova, L. G., Mantsurova, V. N., Loboziak, S., Streel, M., 1993. Middle and Upper Devonian miospore zonation of Eastern Europe. Bull. Centres Research. Explor. Prod. Elf Aquitaine. 17, 79–147.

Balme, B. E., Hassel, C. W., 1962. Upper Devonian spores from the Canniug Basin, Western Australia. Micropaleontol. 8, 1, 1–28.

Balme, B. E., 1962. Upper Devonian (Fransian) spores from the Carnarvon Basin, Western Australia. Palaeobotanist. 9, 1–2.

Chibrikova, E. V, 1959. Spory' iz devonskikh i bolee drevnikh otlozhenij Bashkirii [Spores from Devonian and older deposits of Bashkiria]. Materialy' po paleontologii i stratigrafii devonskikh i bolee drevnikh otlozhenij Bashkirii. Moskva, 3–116. (In Russian).

Chibrikova, E. V., 1962. Spory' terrigennoj tolshhi devona Zapadnoj Bashkirii i zapadnogo sklona Yuzhnogo Urala [Spores of the Devonian terrigenous strata of Western Bashkiria and the western slope of the Southern Urals]. Brakhiopody', ostrakody' i spory' srednego i verkhnego devona Bashkirii. M.: Izd-vo AN SSSR. 351–476. (In Russian).

Chibrikova, E. V., 1972. Rastitel'ny'e mikrofossilii Yuzhnogo Urala i Priural'ya [Plant microfossils of the Southern Urals and the Urals]. Moskva: Nauka. (In Russian).

Chibrikova, E. V., 1977. Stratigrafiya devona i bolee drevnikh paleozojskikh otlozhenij Yuzhnogo Urala i sosednikh ploshhadej [Stratigraphy of the Devonian and older Paleozoic deposits of the South Urals and neighboring areas]. Moskva: Nauka. (In Russian).

Gao, L., 1981. Devonian spore assemblages of China. Review of Palaeobotany and Palynology. Elsevier. 34. 1. 11–23. https://doi.org/10.1016/0034–6667(81)90063–4

Hotsaniuk, H. I., Ivanina, A. V., 2017. Istorychna heolohiia z osnovamy paleontolohii. Chastyna 1 Paleontolohiia (u skhemakh, rysunkakh i tablytsiakh). [Historical geology with the basics of paleontology. Part 1. Paleontology (in diagrams, figures and tables)]. Lviv: Vydavn. tsentr LNU im. I. Franka. (In Ukrainian).

Ivanina, A. V., Havrylets L. V., Stokhmanska O. H., 2000. Budova ta osoblyvosti vidkladiv serednoho devonu pivnichnoi chastyny Volyno-Podilskoi naftohazonosnoi oblasti [Structure and features of Middle Devonian deposits of the northern part of Volyn-Podilsky oil and gas region]. Heolohiia i heokhimiia horiuchykh kopalyn. 1, 17–25 (In Ukrainian).

Ivanina, A. V., 2004. Miospory z zhyvetskykh (serednii devon) vidkladiv Volyno-Podillia [Miospores from Givetian (Middle Devonian) deposits of the Volyn–Podillya]. Paleontol. Zb. 36. 117–123.

Ivanina, A., 2018. Famenian palynostratigraphy of the Volyn–Podillya margin of the East–Europian platform. Dniprop. Univer. Bulletin. Geology, geography. 26 (1), 71–78. Doi: 10.15421/111808

Ivanina, A., 2019. Metodolohichni zasady zastosuvannia palinolohii u stratyhrafii [Methodological bases of application of palynology in stratigraphy]. Visnyk Lvivskoho universytetu. Ser. heol. 32, 30–53. (In Ukrainian).

Ivanina, A., 2019. Palinolohichna kharakterystyka serednopaleozoiskykh vidkladiv Volyno-Podillia [Palynological characteristics of Middle Paleozoic sediments of Volyn-Podillya]. Visnyk Lvivskoho universytetu. Ser. heol. 33, 47–59. (In Ukrainian).

Ivanina, A., 2018. Standartyzovana kharakterystyka palinozon devonu Volyno-Podilskoi okrainy Skhidnoievropeiskoi platformy [Standardized characteristics of Devonian palynozones of the Volyn-Podilsky margin of the Eastern European platform]. Visnyk Lvivskoho universytetu. Ser. heol. 32, 30–53. (In Ukrainian).

Instrukcziya po opisaniyu iskopaemy'kh rastitel'ny'kh i zhivotny'kh organizmov v paleontologicheskikh rabotakh [Instructions for the description of fossil plant and animal organisms in paleontological works]. Moskva, 1971. (In Russian).

Kedo, G. I., Obukhovskaya, T. G., 1981. Srednij devon Baltijskogo regiona i severo-vostoka Belorussii [Middle Devonian of the Baltic region and northeastern of Belarus]. Devon i karbon Baltijskogo regiona. Riga: Zinatne. 419–436. (In Russian).

Kedo, G. I., 1955. Spory' srednego devona severo-vostoka Belorusskoj SSR [Spores of the Middle Devonian of the northeast of the Byelorussian SSR]. Paleontologiya i stratigrafiya BSSR. Minsk. 3–43 (In Russian).

Konstantynenko, L.H., Ivanina, A.V., 2004. Aktualni problemy stratyhrafii nyzhnoho ta serednoho devonu Volyno-Podillia [Current problems of stratigraphy of the Lower and Middle Devonian of Volyn-Podillya]. Heol. zhurn. 1, 76–81. (In Ukrainian).

McGregor, D. C., Camfield, M., 1982. Middle Devonian miospores from the Cape De Bray, Weatherall and Hecla Bay formations of northern Melville Island, Canadian Arctic. Geol. Surv. Can. Bull. 348, 1–105.

Mezhdunarodnyi kodeks botanycheskoi nomenklatury, pryniatyi 11 Mezhdunarodnym botanycheskym konhressom, Syetl, 1969. 1974. Ed. by F.A. Stafleu. [International Code of Botanical Nomenclature, adopted by the 11th International Botanical Congress, Seattle, 1969]. Moskva: Nauka. (In Russian).

Naumova, S. N., 1953. Sporovo-pylcevye kompleksy verhnego devona, Rysskoj platfopmy i ih znachenie dlya stratigrafii [Spore and pollen assemblages in Upper Devonian of the Russian Platform and their stratigraphic significance]. Moskow: IGN AN SSSR. 60. (In Russian).

Oshurkova, M.V., Pashkevich, N.G., 1990. Morfologicheskaya klassifikaciya iskopaemyh dispersnyh spor [Morphological classification of fossil dispersed spores]. Prakticheskaya palinostratigrafiya. Leningrad: Nedra. 5–15.

Oshyrkova, M. V., 2003, Morfologiya, klasifikaciya i opisaniya forma-podov miospor pozdnego paleozoya. [Morphology, classification and description of form-genera of Late Paleozoic miospores]. St. Petersburg: VSEGEI. 377 p. (In Russian).

Potonie, H., 1893. Die flora des Rotliegenden von Thuringen. Kgl. Preuss. Geol. L-A. Berlin. 9. 2. 298p.

Potonie, R., 1970. Die fossilen Sporen, ihre morphologische (phylogenetische) neben morphographischen Ordnung. Forsch.-Ber. Land Nordrh.-Westf. 2108.

Potonie, R., Kremp, G., 1955, 1956. Die Sporae dispersae des Ruhrkarbons. Palaeontogr. Stuttgart. I. 98. 1–136; II. 99. 86–191.

Owens, B., 1971. Miospores from me Middle and Early Upper Devonian rocks of the Western Queen Elizabeth Islands, Arctic Archipelago. Geol. Surv. Canada. 70–38.

Raskatova, L.G., 1969. Sporovo-py'l'czevy'e kompleksy' srednego i verkhnego devona yugo-vostochnoj chasti Czentral'nogo devonskogo polya [Spore-pollen complexes of the Middle and Upper Devonian of the southeastern part of the Central Devonian field]. Voronezh: izd-vo VGU. (In Russian).

Reinsch, P. F., 1884. Neue untersuchungen uber de mikrostruktur der steinkohle des Carbons, der Dyas und Trias. Leipzig. 1881.

Stratyhrafiia URSR. T. IV. Devon. 1974. Holovnyi redaktor P.L. Schulga. [Stratigraphy of the URSR. T. IV. Devon] K.: Nauk. dumka. (In Ukrainian).

Stratyhrafiia verkhnoho proterozoiu, paleozoiu ta mezozoiu Ukrainy, 2013. Holovnyi redaktor P. F. Hozhyk. [Stratigraphy of upper proterozoic, paleozoic and mesozoic of Ukraine]. K.: IHN NAN Ukrainy. Lohos. (In Ukrainian).

Stratigraficheskie i paleontologicheskie issledovaniya v Belorussii, 1978. Pod red. Golubcova V.K. [Stratigraphic and paleontological research in Belarus]. Minsk: Nauka i tekhnika. (In Russian).

Streel, M., Higgs, K., Loboziak, S., Riegel, W., Steelmans, P., 1987. Spore stratigraphy and correlation with faunas and floras in the type marine Devonian of the Ardenne-Rhenich regions. Review of Palaeobotany and Palynology. 50, 211–229.

Teteriuk, V. K., 1964. Metodyka poshtuchnoho vidboru vykopnykh mikrospor [Methods of piece selection of fossil microspores] Heol. zhurn. 24, 6, 17–27. (In Ukrainian).

Uziiuk, V. I., Ivanina, A. V., Hotsaniuk, H. I., Shainoha, I. V., Tuziak, Ya. M., 2007. Vyznachnyk reshtok paleoorhanizmiv. Navchalno-metodychnyi posibnyk [Determinant of the remains of paleoorganisms]. Lviv: Vydavnychyi tsentr LNU im. I. Franka. (in Ukrainian).

Journal of Geology, Geography and Geoecology

ISSN 2617-2909 (print)
ISSN 2617-2119 (online)

Journ. Geol. Geograph. Geology, 30(4), 675–682.

Journal home page: geology-dnu.dp.ua

doi: 10.15421/112162

Impact of anthropogenic activity on the chemical regime of underground waters

Jale V. Jafarli

Baku State University, Azerbaijan Republic, Baku, j.gzade@hotmail.com

Received: 24.05.2021
Received in revised form: 20.07.2021
Accepted: 08.09.2021

Abstract. The article is dedicated to definition of the tendency to change and pattern of formation of the chemical regime of underground waters in the Turyanchay-Girdimanchay interfluve in the Shirvan steppe, Azerbaijan as a result of anthropogenic activity. The subsoil waters studied are spread in the zone between the Turyanchay and Girdimanchay rivers. From 1930 to 2019 based on analysis of the observation of the chemical regime of subsoil waters, the natural regime of the groundwaters in the studied area strongly changed as a result of irrigation and construction works. In 1930 the average mineralization degree of subsoil waters was 26.8 gram/liter in the zone. The level of subsoil waters approaches the surface and is exposed to strong evaporation as a result of irrigation and filtration of waters from irrigation channels. Consequently, the mineralization rate of subsoil waters increased and mass secondary salinization process occurred in the irrigated lands. The average mineralization degree of subsoil waters was 33.6–34.5 gram/liter in the research zone in the 1960s-1970s. Collector-drainage networks were built and basic washing of soils is carried out in order the prevent secondary salinization and regulate the level of subsoil waters. After the 1970s the mineralization rate of subsoil waters began to decrease due to basic washing, intensive irrigation and the activity of the collector-drainage network.The average mineralization degree decreased to 15.1 gram/liter. The mineralization degree of the water in the Main Shirvan Collector which takes subsoil waters formed in the zone with 253,000 hectares and which discaharges them into the Caspian Sea decreased more than 3 times in comparison with 1995. At present the mineralization degree of collector water is 1.8–2.5 gram/liter while its mineralization degree was 8.81 gram/liter in 1995. Formation of the process in a favourable direction enchances the potential of using collector water for irrigation, technical and other purposes and creates a basis for elimination of water deficiency in drought years. The research shows that anthropogenic activity mainly plays an important role in formation of the chemical regime of subsoil waters.

Keywords: anthropogenic activity, underground waters, chemical regime, reduction, tendency, formation, mineralization rate.

Вплив антропогенної діяльності на хімічний режим ґрунтових вод

Жаля В. Джафарлі

Бакинський Державний Університет Азербайджанська Республіка, Баку, j.gzade@hotmail.com

Анотація. Стаття присвячена питанню встановлення тенденції зміни та закономірності формування хімічного режиму ґрунтових вод, що залягають на території Туріанчай – Гирдиманчайського межиріччя Ширванського степу Азербайджану. На основі аналізу спостережень за хімічним режимом ґрунтових вод, проведених у 1930–2018 р.р. встановлено, що в результаті здійснення широкомасштабних іригаційно-будівельних робіт докорінно змінився природний режим ґрунтових вод на досліджуваній території. Так, у 1930 р. середня мінералізація ґрунтових вод становила 26,8 г/л, а глибина їх залягання – понад 5–10 м. Однак за рахунок інтенсивного зрошення та фільтрації з зрошувальних каналів, побудованих у земляному руслі, сприяли підйому рівня ґрунтових до денної поверхні та в результаті якого сталося сильне випаровування з їхньої поверхні. Це у 1960–1970 р.р. призвело до підвищення мінералізації ґрунтових вод до 33,6–34,5 г/л та до масового вторинного засолення земель. Для боротьби з вторинним засоленням земель та запобігання цьому явищу здійснено будівництво колекторно-дренажної мережі та проведено капітальне промивання засолених ґрунтів. За рахунок капітального промивання, інтенсивного зрошення та завдяки діям колекторно-дренажної мережі, після 1970 року відбувалося поступове зниження мінералізації ґрунтових вод. Встановлено, що під впливом господарської діяльності відбувається поступове опріснення води Головного Ширванського колектора, в який впадають стоки 29 первинних колекторно-дренажних мереж, що дренують ґрунтові води на площі 253 тис. га. Якщо мінералізація води Головного Ширванського каналу 1995 р. становила 8,81 г/л, то до кінця 2018 року вона стала 1,8–2,5 г/л. Формування сприятливого хімічного режиму стоку колектора, ґрунтових вод створюють умови використання їх з метою зрошення, технічних та інших потреб під час посухи та в умовах дефіциту поверхневих вод. Дослідження показують, що хімічний режим грунтових вод даної території загалом формується переважно під впливом антропогенних чинників, тобто. господарської діяльності людини.

Ключові слова: антропогенна діяльність, ґрунтова вода, хімічний режим, зниження, тенденція, формування, мінералізація.

Introduction.

Serious disruption of the ecological balance as a result of anthropoghenic and natural impacts on the environment is observed in recent times. Unplanned and unscientific interventions on the earth's surface, for example, an example, an excessive expoitation of the underground resources (underground water sources), large-scale construction works works of various purposes, deforestation, destruction of natural landcapes, climate changes and other similar situations have led to creation of some disturbances, including changes of the hydrogeological conditions.

Research indicates that excessive use of underground waters in Ganja-Gazakh and Garabagh regions has caused depletion of their reserves while in other regions, such as the Shirvan Mughan and Mil plains, the construction of large-scale irrigation-melioration systems have caused change in the level and chemical regime of underground waters. Identification of tendencies to change in the chemical regime in subsoil waters and formation regularities under such condition is of particular importance in the context of developing preventive measures.

Aim of the research.

The aim of the research consists of definition of tendency to change and patterns of formation of the chemical regime in subsoil waters under anthropoghenic impacts in the zone between the Turyanchay and Girdimanchay rivers of the Shirvan region.

Research object.

The object is subsoil water which developed in the Quaternary sediments in the zone between the Turyanchay and Girdimanchay.

Materials and method.

The studies are based on the chemical analysis and results of analysis of water samples taken from fixed observation wells located in a chequer form every 2.5–5.0 km in the zone where the chemical regime of underground waters is investigated.

The factors affecting the change and formation of the chemical regime in underground waters have been determined on the basis of investigation of the melioration-irrigation works and farming activity carried out in the zone.

We used the account archive and fund materials (Abbasov, 2009; Abbasov, 2013; Namazov and Allahverdiyeva 2014; Aliyev et al., 1990) of the National Geological Expert Service of the Ministry of Environment and Natural Resources, Hydrogeological-Meliorative Service Department of the Open Joint Stock Company of Water Resources and Melioration-Irrigation in references dedicated to the problem of these materials (Aliyev et al., 1990; Israfilov, 1999) and the result of the observation and experiments.

The chemical regime of underground waters in the research zone was studied on the basis of chemical regime of flow in the Main Shirvan Collector, which takes waters of the initial collector-drainage networks built for regulation of their level and sheds them into the Caspian Sea. In 2010–2018 the mineralization degree and ion composition $(HCO_3^-, Cl^-, SO_4^{2-}, Ca^{2+}, Mg^{2+}, Na^+ + K^+)$ of water was fixed by subjecting the water samples taken from the Main Shirvan Collector in every season to the full chemical analysis.

So, the chemical regime of subsoil waters was studied on the basis of chemical analysis of the water samples taken from the Main Shirvan Collector which takes subsoil waters from the zone and observation wells located in the horizon carrying the subsoil waters from two sources.

Analysis and discussions.

The area of 320 000 hectares is located in the central part of the Shirvan plain is 860 000 h. (Fig.1). The research zone is bordered by the Great Caucasus Mountains to the North, by the Kur River to the south, by the Aghsu-Girdmanchay River to the West. The inclination of the surface changes from North to South. The absolute height of the plain part of the zone is 408m in the North, but it is 26m below sea level in the South. The annual quantity of rainfalls is 250–400mm, but the amount of evaporation is 800–1400mm. The average perennial temperature is 13–16ºC.

Recently, the amount of precipitation in the area has decreased by 27, the value of the annual temperature increased by –1,1–17ºC (Mahmudov, 2017). Subsoil waters are spread everywhere in the zone. The river-bed depth of underground waters changes from 0.5m to 5.0m according to hydroisogypsum map and observation materials of 2019 (Gulmamedov and Jafarli, 2019) The river-bed depth of subsoil waters is 1–3m in the areas with irrigation and drainage.

Change in the level and chemical regimes of underground waters in the research zone in the years 1930–1962 was investigated by H.Y. Israfilov (Israfilov, 1972; Israfilov 1965) and for 1950–1995 by A.K (AK is The High Attestation Commision) the regular observations on level and chemical regimes of subsoil waters were performed in the Republic, the generalization and systematization have not been performed in recent times. The information about the chemical regime of subsoil waters based on accounts of the previous materials and accounts of the Department of Hydrogeological-Meliorative Service in 1990–2018 was systematized and presented in Table 1.

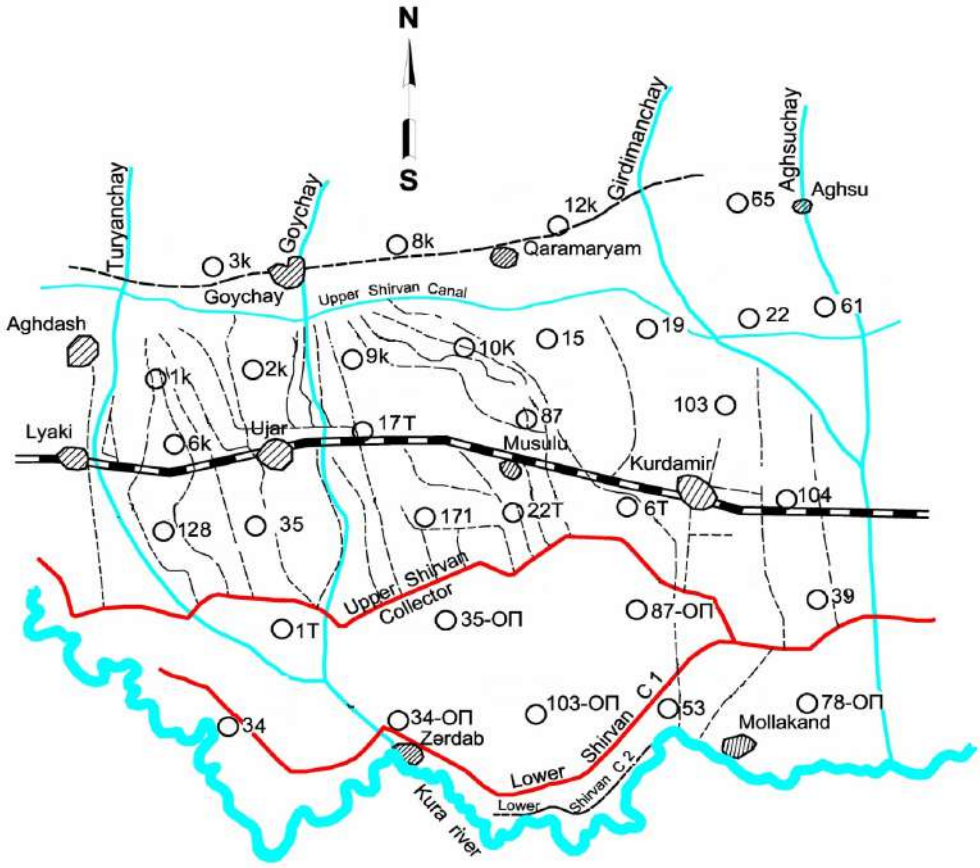


Fig. 1. Schematic Map of Turyanchay-Girdimanchay Interriver Area: 1-Collector drainage network; 2-River and irrigational system; 3-Observation wells and their number; 4-Residential settlement;5-Railway.

Groundwater is ubiquitous in Quaternary sediments in the Turyanchay-Girdimanchay interfluve area, but is not found in some foothill areas of interconal depressions. The depth of a deposit of subsoil waters varies from 0.5 m to 73 m. The depth of a deposit of subsoil waters in the eastern part of the Girdimanchay river, in the upper part of the Agsu River is 30–40 m. The depth of groundwater in the Upper Shirvan channel and in areas with intensive irrigation varies between 1–3 m. Their depth decreases toward the south-west of the area and the Kura River and is drained by the river.

In the upper part of the area, a single layer of water is divided into several layers in the direction of subsoil water flow. However, this division is of local character and the groundwater in the area is represented by a single aquifer horizon. The slope of the subsoil waters flow varies between 0.03–0.0007 cms and decreases from the foothills toward the plains. Due to the widespread distribution of alluvial-proluvial sediments in the areas where the alluvial (debris) cones are located, the aeration zone has a high water permeability. The thickness of the subsoil aquifer horizon varies from 5 to 178 m. Its thickness in the foothills is 110–178 m, and 5–10 m – in the plain areas.

The leakage coefficient of soils in the detrital cone of the Turyanchay River is higher than in the sediments of other rivers. Here, the value of the filtration coefficient of permeable rocks reaches to 4 m/day and mainly ranges between 1–3 m/day. In the peripheral parts of the alluvial cones and in the interconal depressions, the value of the filtration coefficient is confined to 0.2–0.5 m/day. The filtration coefficient of aquifers varies from 0.1 m/day to 64.1 m/day and decreases successively from the beginning of the alluvial cones to the periphery. The said lithological differences have a permanent impact on the groundwater regime in the area.

Changes in groundwater water levels and chemical regimes in the study area occur under the influence of natural and anthropogenic factors. In general, various sources are involved in the formation of subsoil waters. These sources are divided into two parts, in turn- natural and artificial sources.

Natural sources include atmospheric sediments, water vapor condensation, pressurized water, floods, kariz (underground water supply system), springs, rivers, and parent rocks. Atmospheric sediments and condensation from these waters, which feed groundwater, are regional and local sources of supply.

Artificial groundwater sources include water losses from all types of channels and reservoirs, as well as infiltration from irrigational water. At the same time, the natural evaporation factor plays an important role in

the formation of quantitative and qualitative indicators of groundwater sources. General evaporation includes evaporation from groundwater and water transpirated by vegetation.

Evaporation is one of the balancing elements of groundwater and plays a substantial role in the formation of their chemical regime, which is mainly a negative factor that leads to an increase in the degree of mineralization of groundwater and re-salinization of soils. Evaporation is also a key factor directly affecting the reduction of groundwater resources and reserves.

The analysis shows that there is a close relationship between the groundwater level regime (depth of deposition) and the hydrochemical regime (degree of salinity, chemical composition and type of water). In areas with low groundwater depth, the water mineralization rate increases, and in the case of deep groundwater levels, on the contrary, the mineralization rate decreases.

The chemical composition and type of groundwater distributed in the area varies drastically depending on the depth of their deposition and location (position). Here, the degree of mineralization of groundwater varies from fresh to saline and is subject to a certain regularity. In the upper parts of the supply cones of the Turyanchay, Goychay and Girdimanchay rivers, in the zone of groundwater formation, the mineralization rate of groundwater does not exceed 1 g/l. The salinity of groundwater begins to increase in the direction of the wings of the interconal depression and in the direction of the periphery of the alluvial cones, and in some cases the mineralization reaches 130 g/l. In this case, groundwater has different chemical types.

If the groundwater deposition level is deep, its type is sodium bicarbonate, and if it is close to the surface – chlorine-sulphate and sulphate-chlorine. In groundwater with a salinity up to 1 g/l, hydrocarbonate holds a leading position among anions, and sodium and calcium among cations. Rarely, magnesium predominates among cations. In groundwater with a salinity level 10–15 g/l, the amount of hydrocarbons decreases, the amount of chlorine and sulphate increases. These waters contain more sodium and magnesium than calcium. In groundwater with a salinity level 50–100 g/l and more, a decrease in sulphate is accompanied by an increase in chlorine, and in some cases, a decrease in chlorine and an increase in sulphate.

As a result of reclamation and irrigation measures carried out in the study area, there have been many and seasonal changes in groundwater level and hydrochemical regimes, and the process is currently underway. First of all, let's have a look at the regularity of the formation of the multi-level regime of groundwater.

The outcomes of analysis of the materials show that at the beginning of the last century, the irrigation capacity did not cover the greater area in Azerbaijan as compared to today. In the 1930s, irrigation and land reclamation works in Azerbaijan were less developed than at present, and irrigation channels and collector drainage networks in irrigated areas were rarely found in Azerbaijan. During these years, the depth of groundwater deposition in the Kura-Araz lowland of the republic, including the Shirvan Plain, ranged between 5–10 m (Israfilov, 1972).

The groundwater level gradually begins to rise in the plains where irrigation is carried out. Yet in 1951, the area occupied by groundwater with a depth of 5–10 m and 10 m in all irrigated areas decreased from 33 % to 20 %. In the Shirvan plain, the areas occupied by groundwater with a depth of 5–10 m and more than 10 m decreased by 1.5 times, while the areas covered by groundwater with a depth of 0–3 m increased by 2.6 times (Israfilov, 1972).

Starting from the 1950s, a new stage of development of land irrigation began in Azerbaijan, and by 1960, the area of irrigated lands had reached up to 950,000 hectares. Currently, the area of irrigated lands occupies 1.428m hectares.

Construction of hydraulic structures, irrigation systems and expansion of irrigated areas gave rise to fundamental changes in the natural regime of groundwater. Within a short period of time, the leakage losses from irrigation channels and the widespread use of intensive surface irrigation have caused the rise of groundwater levels closer to the surface. In 1962, areas covered by groundwater with a depth above 10m were almost completely erased from the map. Groundwater with a depth of 0–5 m covered above 84 % of the Shirvan Plain. With the exception of the foothills of the Shirvan Plain, the groundwater with a depth below 5–10 m was not found. Yet in 1970–1980, groundwater with a depth of 0–3 m in the Shirvan Plain covered 90 % of the overall area.

The analysis of observational study materials carried out with regard to the groundwater level regime shows that the groundwater level rise continued at different intensities till 1995 and stabilized in the following years. The analysis shows that the stabilization of the groundwater level regime is dependent on two factors:

Construction of collector-drainage networks in irrigated areas;

Increase in the expenditure part of the water balance with the increase of non-productive evaporation from groundwater close to the surface.

The groundwater level regime in the study area – the depth of deposition differs not only over many years, but also throughout the year. The groundwater levels rise up and fall down throughout the year, depending on

the factors forming the regime – irrigation, atmospheric precipitation and the operation of irrigation channels (seepage losses). The groundwater level rises and falls faster near irrigation channels. The water level in the channel rises and falls synchronously with the groundwater level. The groundwater level is relatively stable in the strips close to the drainage line, but as it moves away from the drainage line, the groundwater level rises in line with the irrigation process, mainly due to infiltration of irrigation water in the inter-drainage strips, and gradually decreases after irrigation is suspended.

Observations show that the groundwater level regime is dependent insignificantly on atmospheric precipitation. The groundwater deposition level is deeper at different times of the year, mainly when the rainfall occurs in autumn-winter. As a rule, the groundwater level begins to rise gradually from April, and the maximum amplitudes of the level are observed in July-August. From October to January, the level drops. In areas with a groundwater depth exceeding 3 m, the level does not rise significantly. The value of the rise and fall amplitude very rarely varies between 0.3–0.6 m. However, in areas irrigated and close to irrigation channels, the amplitude of groundwater level change comprises 0.7–1.0 m, and in some cases even more.

Due to water losses from irrigation channels and infiltration from irrigation, the hydrogeological conditions of the area have changed and the automorphic regime of groundwater has been replaced by hydromorphic and semi-automorphic regimes. The balance of groundwater has been formed to determine the impact of anthropogenic activity and natural factors on the level and hydrochemical regime of groundwater, as well as the regularities of their formation (Jafarli 2020).

According to the water balance compiled, it was determined that 10% of the balance income refers to irrigation water, 7% – atmospheric sediments, 35% – pressurized water, 26% – condensation water, and 22% – seepage losses from irrigation channels.

Total evaporation comprises 63% of the balance output, and 37% comprises water discharged through collector-drainage networks.

63% of the water inflowing to the area is used for physical evaporation and transpiration by plants, and 37% is discharged from the area through collector-drainage networks. The groundwater level regime is determined according to these factors. That is, in general, the water entering the area is compensated by evaporation and artificial flow.

One important point to note is that the experience of irrigated agriculture shows that re-salinization of soils occurs due to rising groundwater levels and increased physical evaporation from the soil. Therefore, there is a need to establish a collector-drainage network in irrigated areas.

The compiled balance also indicates that the operation of the collector-drainage network operating in the area is unsatisfactory. Physical evaporation against the background of drainage should be kept to a minimum. But we see otherwise in practice. Therefore, it is necessary to increase the efficiency of existing collector-drainage networks in Shirvan Plain.

Although the amount of condensate water is high in mountainous areas and low in lowland areas, they play a key role in forming the groundwater level and its chemical regime.

In line with the above-mentioned, it was determined that the groundwater is fed by pressurized water throughout the year, which plays an important role in raising the groundwater level, as well as the formation of the hydrochemical regime. Despite rising groundwater levels, their degree of mineralization and chemical composition vary depending on available supply sources. For example, irrigation and condensation water, seepage losses from channels, along with raising the level of groundwater, lead to a gradual decrease in their salinity.

The information on the groundwater chemical regime is systematized and reflected in Table 1 according to the literature sources, research work we conducted and the reports of Azerbaijan Hydrogeological and Melioration Service for the period 1990–2018 (Aliyev et l., 1990).

Table 1. Distribution of the areas according to mineralization degree of subsoil waters (by % from total area)

Years	Mineralization degree of subsoil waters								Average Mineralization degree, *q/l*
	< 1	1–3	3–5	5–10	10–25	25–50	50–75	> 75	
1930	6.3	8.6	13.1	16.0	15.3	15.9	13.9	12.9	26.8
1950	4.2	6.3	9.4	14.9	17.3	18.1	15.2	14.6	31.5
1960	6.7	8.5	9.7	15.1	17.1	15.9	14.8	12.2	34.5
1970	8.8	9.9	11.3	15.3	16.3	15.4	13.2	9.8	33.6
1980	10.5	12.5	12.6	15.6	15.5	14.7	10.4	8.2	22.9
1990	12.6	15.7	13.3	15.8	14.8	11.6	9.8	5.4	19.8
2000	14.7	16.9	14.8	16.1	14.6	11.2	5.9	4.8	17.2
2010	18.4	17.5	15.6	16.2	13.3	11.4	6.6	3.9	16.1
2018	14.3	18.6	15.0	16.7	14.4	11.5	6.3	4.2	15.1

As seen from Table 1 the average mineralization degree of subsoil waters was 26,8 g/l in the zone in 1930. But the mineralization rate of subsoil waters began to increase beginning from 1950 and this growth continued till 1970. In 1960–1970 the subsoil waters with 33,6–34,5 g/l mineralization degree occupied about 70 % of the whole zone. But then the mineralization degree began to decrease gradually and in 2000 it passed to a stage of relative stabilization. The subsoil waters with mineralization rate less than 5g/l occupied 28 % of the zone in 1930, but in 2018 the waters with mineralization degree less than 5g/l occupied 48 % of the zone (Table 1).

Increase-decrease of mineralization degree of subsoil waters was directly related to anthropogenic activity. Beginning from 1950 irrigation agriculture quickly developed in Azerbaijan. In 1953 the Mingachevir Water Reservoir with 80m height, 60,5 000 h of surface area, 16 billion m^3 of total water capacity and dozens of reservoirs of water of water capacity of more than 1–10 billion m^3 were built for the purpose of irrigation and energetics (Ahmedzade and Hashimov 2019). At the same time, construction of large irrigation systems was carried out to provide the sown areas with irrigative water. In 1958 the Upper Shirvan Channel with 122km length, capacity of 78 m^3 and taking its beginning from Mingachevir Water Reservoir, the Upper Garabagh canal with capacity of 113m^3, 172km length were built and put into operation (Ahmedzade and Hashimov 2006). These canals are able to provide 190 000h of cultivated ground with irrigation water. The irrigation water taken from the main channels is distributed to the sown areas by inter-farm and on-farm canals the length of which is more than 10,000km. As both main and other distribution channels are built in the soil, the leaching from these canals can lead to a change in their level regime, including groundwater in irrigated areas. According to the groundwater level regime, groundwater levels of reach more than 5–10 meters depth and closer to the earth's surface. In 70 % of all irrigated areas the groundwater depth is 0–3m (Israfilov, 1972). The subsoil water near the earth's surface is subjected to severe evaporation. Consequently, increase in the groundwater mineralization process occurs in irrigated soil.

In 1950–1970 in order to prevent secondary salinization in the Shirvan Plain and to fight against it, 29 Shirvan drainage networks in an area of 209,000 ha and the Main Shirvan Collector which sheds drainage water into the Caspian Sea were built (Ahmedzade and Hashimov 2006). As a result, salts leached from the topsoil enter groundwater and increase their salinity. However, in the following years, as a result of thorough washing of soils, which lasted for about 20 years, the operation of collector-drainage networks and intensive irrigation, the mineralization rate of groundwater began to gradually decrease. We should note that the plants in this zone are watered by the strip, burial, furrow techniques. This leads to increase of water losses.

In order to define a change tendency of the chemical regime and formation of regularities of subsoil water, the changes in the chemical composition and mineralization of water in the Main Shirvan Collector have been studied. Change in the chemical regime of water in the Main Shirvan Collector taking subsoil water from 253,000 ha permits us to obtain more substantial information about change and formation of the chemical regime in grounwater.

The study of this problem is also of practical importance in terms of determining accessibility of collector water for irrigation, technical and other purposes in times of water defficiency. We note for information that systematic and consistent observation on chemical regime of the Main Shirvan Collector water has been carried out beginning from 2010. Only in 1995 was the chemical composition and mineralization of waste water was studied for the Main Shirvan and other collectors to determine the possibility of collector water use, (Alimov et al., 1997). Therefore the infomation was adopted.

The dynamics of chemical composition and mineralization rate in water of the Main Shirvan Collector are presented in Table 2.

As seen from Table 2 the mineralization rate of the collector water decreased about 3 times during 23 years. But the water type doesn't change. Both in 1995 and in 2018 the collector water is characterized by sulphate-chlorine, natrium-magnesium type.

But the mineralization rate of the Main Collector water is 2–2.5 times less than the mineralization degree of groundwater (water taken from observation wells).

This difference is explained by the fact that during the vegetation period one part of the drinkable water that flows though the irrigation channels enters the bottom of the soil. The drinkable water layer is formed on upper horizons of subsoil water. This drinkable water is filtered into the first drains, from there it flows into the water collectors. At the same time the water having the highest mineralization degree enters the collector drainage network from low layers of groundwater. Consequently, the chemical regime of the collector-drainage water is formed from irrigation and subsoil water.

1. The anthropogenic activity plays an important role in formation of the chemical regime in groundwater.
2. The chemical regime of groundwater in the relative stabilization phase. The mineralization rate decreased more than 2 times in comparison with the 1930s-70s.

Table 2. Mineralization rate (*qr/l*) and and chemical composition, *mq/l* / *mq-ekv*,%-*ekv*

Years	Mineralization rate (dry resiidue), *mq/l*	Anions			Cations		
		HCO_3^-	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	$Na^+ + K^+$
2010	4.85	427 7.00 9.24	1012 28.50 37.64	1931 40.22 53.12	230 11.50 15.18	252 21.00 27.74	994 43.22 57.08
2011	3.80	397 6.50 19.72	888 25.01 41.71	1366 28.45 47.47	170 8.50 14.18	222 18.50 30.85	758 32.96 54.97
2012	2.95	366 6.00 12.57	888 25.00 52.37	804 16.74 35.06	190 9.50 19.90	198 16.50 34.56	500 21.74 45.54
2013	3.09	336 5.51 11.33	728 20.51 42.16	1086 22.63 46.51	180 9.00 18.50	168 14.00 28.78	590 25.65 52.72
2014	2.51	275 4.50 11.21	657 18.50 46.08	823 17.15 42.71	60 3.00 7.47	174 14.50 36.11	521 22.65 56.42
2015	2.01	275 4.51 13.70	497 14.00 42.54	691 14.40 43.76	100 5.00 15.19	216 18.00 54.70	228 9.91 30.11
2016	1.85	282 4.63 16.58	257 7.24 25.92	771 16.06 57.50	105 5.25 18.80	99 8.25 29.54	332 14.43 51.66
2017	2.15	305 5.00 15.29	284 8.00 24.46	946 19.71 60.25	110 5.50 16.80	138 11.50 35.16	362 15.71 48.03
2018	2.51	336 5.50 14.55	337 9.49 25.11	1095 22.81 60.34	170 8.50 22.49	108 9.00 23.81	467 20.30 53.70

3. The chemical regime of groundwater is formed as a result of the collector-drainage network and water losses in irrigation canals including anthropogenic activity in the arid zone (in the regions where evaporation is 3–5 times more than rainfall). Therefore regulation of these factors and management in a good condition is one of the important terms.

4. The mineralization rate of the Main Shirvan Collector water which is taken from the research zone and available collector-drainage networks and flows into the Caspian Sea decreased more than 3 times and this reduction tendency weakly develops. Formation of a suitable chemical regime creates an opportunity to use from collector water for irrigation, technical and other aims in drought years and under conditions of the water defficiency.

References

Abbasov, F.M., 2009. Azərbaycan Respublikası Ekologiya və Təbii Sərvətlər Nazirliyinin Milli Geoloi Kəşfiyyat Xidmətinin Kompleks Hidrogeologiya və Mühəndis Geologiya Ekspedisiyasının «2004–2008-ci illərdə Girdimançay-Göyçayarası sahəsində içməli yeraltı şirin su ehtiyatlarının ilkin qiymətləndirilməsi işlərinin nəticələri haqqında Hesabat».[Report on the results of the preliminary assessment of drinking groundwater resources in the Girdimanchay-Goychayarasi area of the Complex Hydrogeology and Engineering Geology Expedition of the National Geological Survey of the Ministry of Ecology and Natural Resources of the Republic of Azerbaijan in 2004–2008] Baku. (In Azerbaijani).

Abbasov, F.M., 2013. Azərbaycan Respublikası Ekologiya və Təbii Sərvətlər Nazirliyinin Milli Geoloi Kəşfiyyat Xidmətinin Kompleks Hidrogeologiya və Mühəndis Geologiya Ekspedisiyasının «2009–2012-ci illərdə Türyançay gətirmə konusunda yeraltı şirin su qaynaqlarının axtarışı işlərinin nəticələri haqqında Hesabat» [Report on the results of the search of groundwater sources in the Turyanchay delivery area of the Complex Hydrogeology and Engineering Geology Expedition of the National Geological Survey of the Ministry of Ecology and Natural Resources of the Republic of Azerbaijan in 2009–2012.] (In Azerbaijani).

Ahmedzade, A.C., Sadigov. S.T, Amishov. Sh.M. Pambıqçılığın inkişafı ilə əlaqədar Kür-Araz ovalığının hidrigeoloji-meliorativ vəziyyətinin qiymətləndirilməsi və tənzimlənməsi [Assessment and regulation of hydro-ameliorative condition of Kur-

Araz lowland in connection with development of cotton growing] Baku (In Azerbaijani).

Ahmedzade, A.J., Hashimov, A.J., 2019. Ensiklopediya: Azərbaycan meliorasiya və su təsərrüfatı [Encyclopedia: Azerbaijan amelioration and water economy. Baku. (In Azerbaijani).

Ahmedzade, A.J., Hashimov, A.J., 2006. Meliorasiya və su təsərrüfatı sistemlərinin kadastrı [Cadastre of amelioration and water management systems]. Baku (In Azerbaijani).

Alimovm, A.K., 1997. Baku Ocenka i prognoz kachestva kollektorno-drenazhnyh vod i vozmozhnosti ispolzovaniya ih v narodnom hozyajstve. [Assessment and forecast of the quality of collector-drainage waters and the possibility of using them in the national economy.] (In Russian).

Alimov, A.K., Magomedov, A.M., Mailov, Y.Q., 1995. Gidrogeologicheskie osnovy regulirovaniya vodno-solevogo rezhima oroshaemyh zemel aridnoj zony. [Hydrogeological bases of regulation of water-salt regime of irrigated lands in arid zone.]. Baku (In Russian).

Aliyev, A.Q., Shabanov, A.I., Qovrilov, V.M., Informaciya o gidrogeologo-meliorativnom sostayaniie oroshaemyh zemel Azerbajdzhanskoj SSR [Information on the hydrogeological-reclamation state of the irrigated lands of the Azerbaijan SSR] (In Russian).

Behbudov, A.K., Jafarov, X.F., 1980. Melioraciya zasolyonyh zemel. [Reclamation of saline soils.] (In Russian).

Behbudov, A. K., 1977. Eksperimentalnye osnovy provedeniya melioracii zasolennyh zemel Kura-Araksinskoj nizmennosti. [Experimental basis for reclamation of saline lands in the Kura-Araks lowland.] (in Russian).

Gulmamedov Ch.D., Jafarli J.V. 2019 Rezhim podzemnyh vod Shirvanskoj stepi Azerbajdzhanskoj Respubliki // Nauka i Mir. [Groundwater regime of the Shirvan steppe of the Azerbaijan Republic. Science and World (In Russian).

Israfilov, Y.Q., 1999. Konceptual'naya model' formirovaniya podzemnyh vod Azerbajdzhanskoj Respubliki. V kn.: Materialy nauchno-prakticheskoj konfrencii. AzNII VP «Voda: problemy, poiski». [Conceptual model of the formation of groundwater in the Azerbaijan Republic. In the book: Materials of scientific-practical conference. ARI «Water: problems, searches».] Baku (In Russian).

Israfilov, Y.Q., 1972. Gruntovye vody Kura-Araksinikij nizmennosti. [Ground waters of the Kura-Araksinikiy lowland] Baku. (In Russian).

Israfilov, Y.Q., 1965. Baku. Izmenenie himicheskogo sostava i mineralizacii poverhnostnogo sloya gruntovyh vod Kura-Araksinskoj nizmennosti. Uchenye zapiski Azgosuniversiteta. [Changes in the chemical composition and mineralization of the surface layer of groundwater in the Kura-Araz lowland. Scientific notes of the Azerbaijan State University].(In Russian).

Jafarli, J.V., 2020. Türyançay-Girdimançay çaylararası ərazinin qrunt sualrı və onların formalaşma qanunauyğunluqları. AzETHvəMİ EİB-nin elmi əsərlər toplusu. [Soil question of Turyanchay-Girdimanchay inter-river area and regularities of their formation. Collection of scientific works] (In Azerbaijani).

Namazov, I. Sh., Allahverdiyeva, F.F. 2014. Azərbaycan Respublikasının su təsərrüfatı sahələri üzrə suların keyfiyyətinə dair çoxillik məlumatlar.[Multiple information on water quality in the water resources of the Republic of Azerbaijan.] Baku. (In Azerbaijani).

Azərbaycan Geologiya İdarəsinin fond materialları. Bakı: 1981–1989-cu illər [Fund materials of the Azerbaijan Geological Department. Baku: 1981–1989]. (In Azerbaijani).

Azərbaycan Meliorasiya Su Təsərrüfatı ASC-nin Hidrogeoloji-Meliorativ Xidmət İdarəsinin hesabatları. [Reports of Hydrogeological-Ameliorative Service Department of Azerbaijan Melioration Water Management OJSC] Baku 2010–2018. (In Azerbaijani).

Journal of Geology, Geography and Geoecology

Journal home page: geology-dnu.dp.ua

ISSN 2617-2909 (print)
ISSN 2617-2119 (online)

Journ. Geol. Geograph. Geology, 30(4), 683–691.
doi: 10.15421/112163

Geospatial Technology for Landslide Susceptibility Mapping along the Vathalmalai Ghat road section, South India

G. Kavitha[1], S. Anbazhagan[1], S. Mani[2]

[1]*Centre for Geoinformatics and Planetary Studies, Periyar University, Salem, India,* anbu02@gmail.com
[2]*School of Civil Engineering, SASTRA Deemed University, Thanjavur, India*

Received: 04.02.2021
Received in revised form: 14.04.2021
Accepted: 09.08.2021

Abstract. Landslides are among the most prevalent and harmful hazards. Assessment of landslide susceptibility zonation is an important task in reducing the losses of life and properties. The present study aims to demarcate the landslide prone areas along the Vathalmalai Ghat road section (VGR) using remote sensing and GIS techniques. In the first step, the landslide causative factors such as geology, geomorphology, slope, slope aspect, land use / land cover, drainage density, lineament density, road buffer and relative relief were assessed. All the factors were assigned to rank and weight based on the slope stability of the landslide susceptibility zones. Then the thematic maps were integrated using ArcGIS tool and landslide susceptibility zonation was obtained and classified into five categories ; very low, low, moderate, high and very high. The landslide susceptibility map is validated with R-index and landslide inventory data collected from the field using GPS measurement. The distribution of susceptibility zones is ; 16.5% located in very low, 28.70% in low, 24.70% in moderate, 19.90% in high and 10.20% in very high zones. The R-index indicated that about 64% landslide occurences correlated with high to very high landslide susceptiblity zones. The model validation indicated that the method adopted in this study is suitable for landslide disaster mapping and planning.

Keywords: Landslides, Remote sensing and GIS, Causative factors, Susceptibility.

Геопросторова технологія картографування зсувонебезпечної ділянки уздовж дороги у гірському пасмі Ваталмалай, Південна Індія

Г. Кавіта[1], С. Анбажаган,[1] С. Мані[2]

[1]*Центр геоінформатики та планетарних досліджень, Університет Періяр, Салем, Індія,* anbu02@gmail.com
[2]*Школа будівництва, Академія мистецтв, науки, технологій та досліджень Шанмуги (SASTRA), Тханджавур, Індія*

Анотація. Зсув ґрунту є однією з поширених та шкідливих небезпек у порівнянні з іншими катастрофами. Оцінка зональності сприйнятливості до зсувів є важливим завданням щодо зменшення людських втрат та майна. Дане дослідження має на меті розмежування зсувних територій уздовж ділянки дороги Ватхалмайлай Гат (VGR) з використанням методів дистанційного зондування та ГІС. На першому етапі були встановлені чинники, що спричиняють зсув, такі як геологія, геоморфологія, схил, схиловий аспект, використання землі / покрив землі, щільність дренажу, щільність перекриття, буфер дороги та відносний рельєф. Усі фактори були оцінені за рангом та вагомістю виходячи зі стійкості схилів до зсуву. Потім тематичні карти були інтегровані за допомогою інструменту ArcGIS, і було отримано зонування сприйнятливості до зсувів та класифіковано у п'ять категорій, таких як дуже низькі, низькі, помірні, високі та дуже високі. Карта сприйнятливості до зсувів валідується за допомогою R-індексу та даних інвентаризації зсувів, зібраних у польових умовах за допомогою вимірювання GPS. Розподіл зон сприйнятливості становить 16,5% у дуже низьких, 28,70% у низьких, 24,70% у помірних, 19,90% у високих і 10,20% у дуже високих зонах. R-індекс вказує, що близько 64% випадків зсувів корелюються із високими та дуже високими зонами сприйнятливості до зсувів. Валідація моделі показала, що метод, прийнятий у цьому дослідженні, підходить для картографування та планування зсувів.

Ключові слова: зсуви, дистанційне зондування та ГІС, причинні фактори, сприйнятливість.

Introduction

Landslides affect a significant impact on people's life and their property. They are among the costliest and most damaging geological hazards in many parts of the world. In landslide mass movement terrain, the loam or debris material along with the inclined sloping terrain causes major natural disasters, loss of lives, damage to infrastructure and properties throughout

the world (Varnes 1978; Aleotti and Chowdhury 1999; Dai et.al., 2002; Wang et.al 2015). In general, landslide susceptibility mapping is defined as qualitative methods which are direct hazard mapping techniques or quantitative methods which are indirect mapping techniques (Jaupaj et al 2014). Landslide occurrences are mainly controlled by various geo environmental parameters of the terrain (Anbazhagan and Ramesh 2014). In most mountainous terrain, geomorphology plays a significant role in the occurrence of landslides, so necessary importance has to be given to appraisal of geomorphology in landslide studies. (Sajinkumar and Anbazhagan,2014). At some locations, the development of fractures and land subsidence provide early warning for slope failure (Anbazhagan et al 2008) and one has to seriously look for such evidences in ghat road sections. Geospatial technology is widely utilized for landslide inventory, hazard zonation mapping through integration of causative factors, risk assessment and mitigation (Sajinkumar et al 2013; Anbazhagan et al 2017; Ramesh et al 2017; Amit et.al 2019). GIS based multi criteria analysis has been effectively implemented to create landslide susceptibility zonation mapping on CNG-37 ghat road section (Saranaathan and Mani 2016). In this study, several factors such as geology, geomorphology, aspect, land use /land cover, drainage density, lineament density, road buffer, slope angle, relative relief and rainfall density were considered. Similarly, GIS technique has been adopted for multi criteria analysis of Bodimettu ghat section (Kannan et.al 2011). Many researchers have used different methods for landslide susceptibility zonation mapping (Sarkar and Kanungo 2004); Arnous 2011; Ahmed 2015; Mahdadi et.al 2018, Amit et.al 2019; Sharma and Mehta 2012; Maheep et.al 2018; Lee et.al 2004; Meng et.al 2011; Hong et.al 2007). Overall, the GIS based multi criteria decision analysis is simple and it provides convincing results for zones of landslide hazards. Vathalmalai was comparatively little known prior to 2012 when the hilly terrain attracted attention through being announced by the Government of Tamil Nadu as a tourist spot in Dharmapuri district. In consequence of new road construction along the Ghat section leading to slope failure at several locations , Kavitha et al 2020a have carried out preliminary studies on landslide inventory and volume estimation. Several causative parameters in the hilly terrain were integrated for preparation of a landslide hazard zonation map though the Landslide Hazard Evaluation Factor method (Kavitha et al 2020b). The main objective of the present study is to assess the landslide susceptibility zones along the Vathalmalai Ghat road using multi-criteria analysis.

Study area

The study area Vathalmalai is a fast-growing tourist spot located in Dharmapuri district, Tamil Nadu state, India. The geographical area is located between 12°02’18”-12°04’15” N latitudes and longitudes of 78°10’30” -78 °13’15” E. Vathalmalai Periyur is a small village located at 1140m above mean sea level (msl) and 25km away from Dharmapuri town. Until 2010 there was no proper road connectivity and transport facility available for the people who lived in this hilly terrain. They couldn’t cultivate any cash crops. The majority of the people living in the Vathalmalai Hills belong to the tribal community. They have to walk at least 12 km to access transport facilities in the foot hills. They are also forced to sell their cultivated products for their livelihood at a lowest cost. In the year 2012, the Government of Tamil Nadu announced Vathalmalai as a tourist spot and proposed several development plans. At present, a ghat road connects the Dhinnahalli village in the foothills to Periyur Potlangadu located on the hilltop in Vathalmalai (Fig.1). The ghat road was constructed and maintained by the District Forest Department. Geologically, the road is covered by weathered gneiss and charnockite formation. The elevation of hill ranges between 500m and 1180m above msl. A series of landslides occurred during November 2015 and May 2016, which were triggered by heavy rainfall. The transport was totally cut off for several days and people located on the hill suffered numerous difficulties.

Methodology

The Weighted Linear Combination (WLC) method applying weight values of each thematic factor is applied for landslide susceptibility mapping. It consists of a process of thematic layer, database generation, assignment of weightage to each factor and validation of the landslide model. In this study, nine landslide causative factors were considered; geology, geomorphology, land use/ land cover, slope, slope aspect, drainage density, lineament density, road buffer and relative relief. A Survey of India (SOI) toposheet was used for preparation of the drainage map and contour map with 20 m intervals on the scale 1:50,000. Slope and slope aspect were derived from the SRTM DEM data and spatial analysis tools using ArcGIS 10.4.1 software. The Geology map was prepared from the Geology and Mineral map of Tamil Nadu and Pondicherry (1995). The geomorphology, land use and land cover, lineament and road maps were derived from IRS P6 LISS –III satellite imagery.

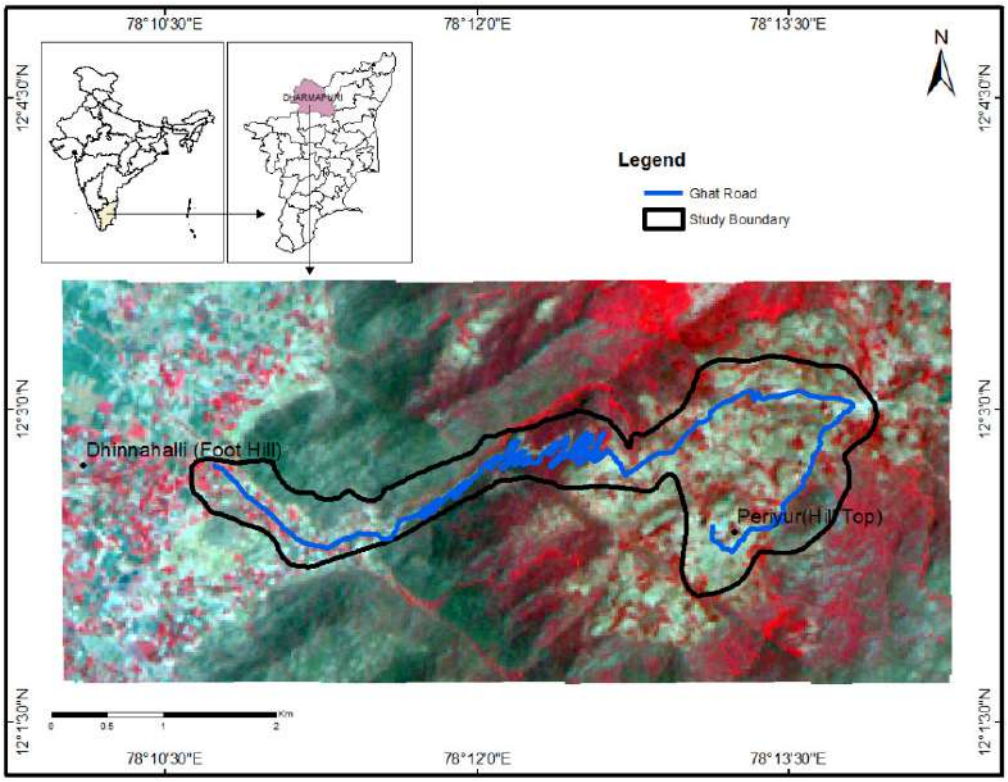


Fig.1. Location map of Vathalmalai Hills in the state of Tamil Nadu, India

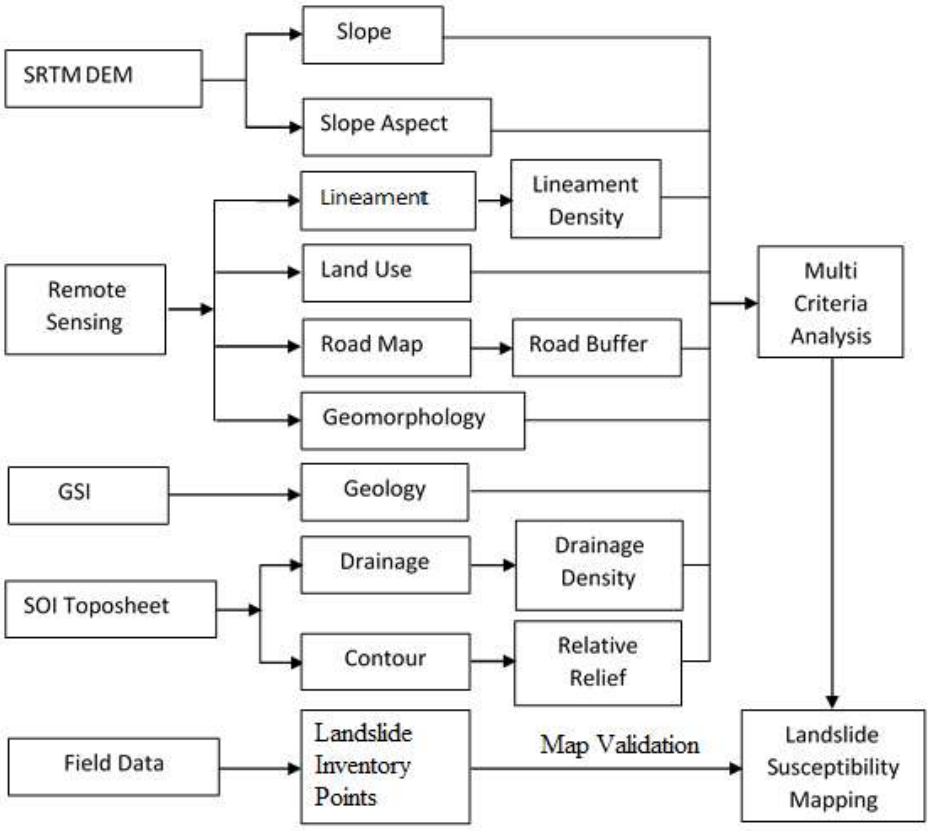


Fig. 2. Flow Chart shows the Methodology adopted in the study

Landslide Causative Factors

Geology

Geology is one of the main factors have a direct influence on the occurrence of landslides (Wang et al 2009). In the study area, there is not much variation in lithology. The major rock types in the study area are charnockites and basic alkaline dykes (Fig.3). The rock prone to weathering has the greatest influence on occurrence of landslides Accordingly , ranking and weights were assigned.

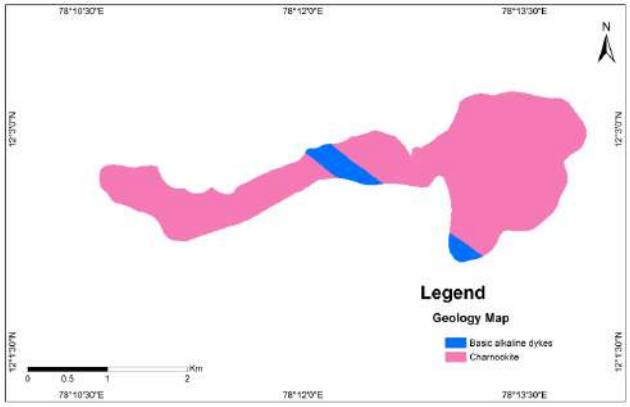


Fig. 3. Geology of the study area mostly covered by Charnockite rocks

Geomorphology

Geomorphology is one of the important parameters active in occurrence of landslides. In the present study, IRS P6 LISS III satellite imagery was interpreted to delineate different geomorphological features in the study area. The interpreted features were verified during field investigation. The structural hill system, pediment and fracture valley are the important geomorphological features in the study area (Fig.4).

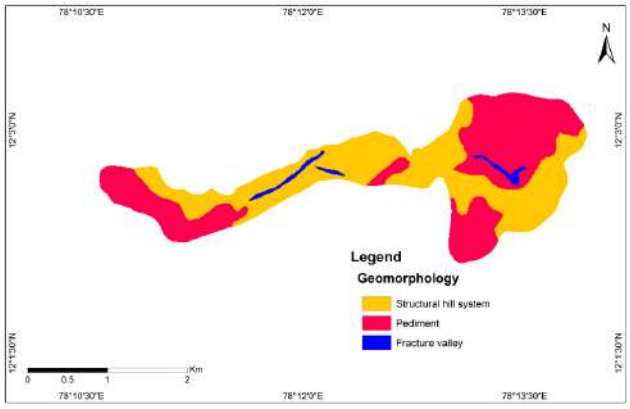


Fig. 4. Geomorphological features in the study area

Land use and land cover

Land use / land cover is one of the most sensitive parameters in the study and it is easily affected by changes resulting from the environment and human activities (Begueria, 2006). The type of vegetation is affected by the soil hydrology during increased rainfall interception, infiltration and evapotranspiration. The land use / land cover in the Vathalmalai Hill region was prepared from IRS P6 LISS III satellite image and toposheet. The major types of land use and land cover in the study area are fairly dense scrub, flat land, moderately vegetated areas, plantations and settlements. Out of these, dense scrub and vegetation occupy the major portion of the hills (Fig.5). Though different land cover occupied the entire hill system, the forest cover is degrading at a faster rate due to frequent landslide occurrences.

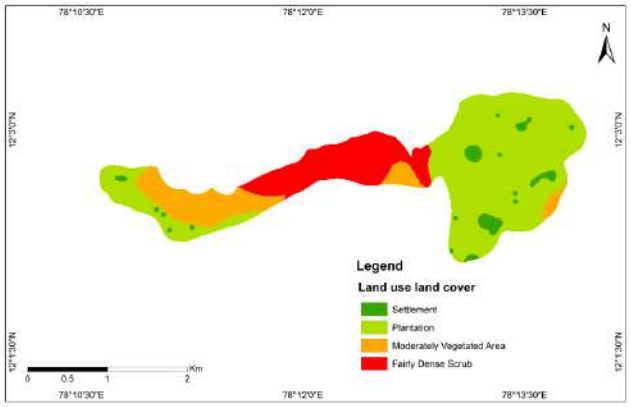


Fig. 5. Land use / land cover in the study area

Slope

The nature of slope in a terrain controls the stability or failure of slope. Slope inclination is one of the mandatory parameters required for occurrence of landslides. Plains and gentle slopes are always free from landslide occurrences. Slope in degree is the form between any part of the surface of the earth and a horizontal datum (Ayalew et al 2004). SRTM DEM data was utilized to obtain a slope map for the study area. In the present study, the slope map was categorized into five classes ; 0°-11°, 11°-19°, 19°-27°,27°-31° and 31°-38° respectively (Fig.6).

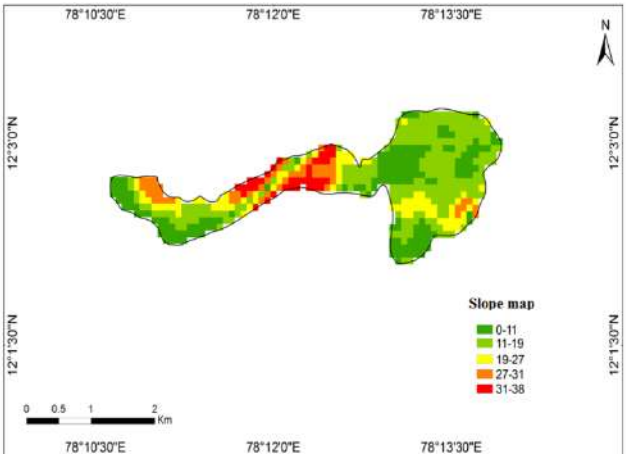


Fig.6. Slope (degree) categories of the study area

Slope aspect

Slope aspect is another important parameter, which denotes the direction of maximum slope of a terrain. It is an indirect factor which affects slope instability. In the study area, the aspect map is classified into flat, north, northeast, east, southeast, south, southwest, west and northwest directions. The slope aspect map is useful to understand the impact of sunlight and local microlevel climate of the area. The aspect map was derived from SRTM DEM data (Fig.7).

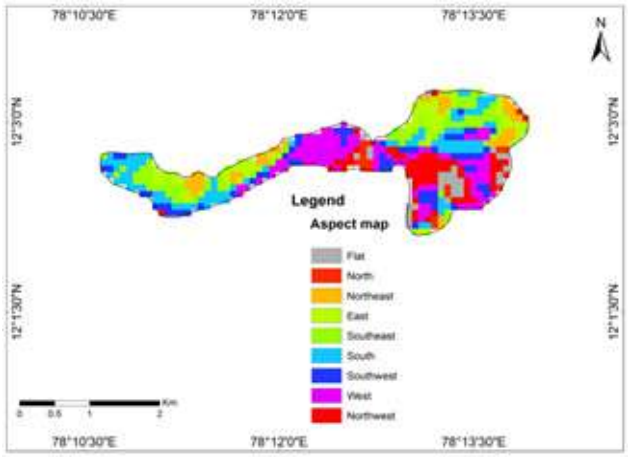


Fig. 7. Slope aspects map of Vathalmmalai Ghat road section

Drainage density

Besides soil type and geotechnical properties , drainage and drainage density are the causative factors which control occurrence of landslides . Drainage density is the total length of all streams and rivers in a drainage basin divided by the total area of the drainage basin. Sarkar and Karungo (2004) stated that there is an adverse relationship between landslides and drainage density. The drainage density map was generated from drainages extracted from the Survey of India toposheet using ArcGIS tool. Further, the drainage density in the study area is grouped into three classes ; low, medium and high (Fig.8).

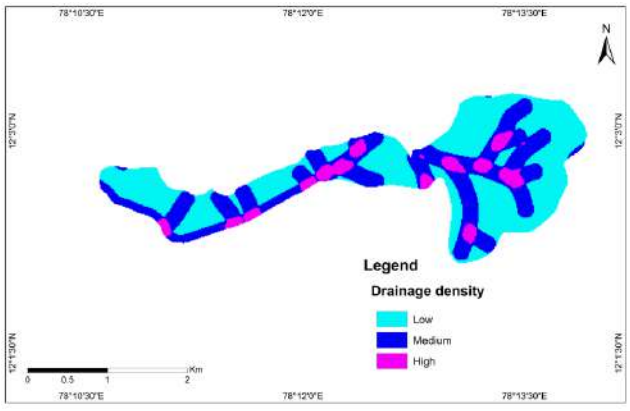


Fig. 8. Drainage density map for the study area

Lineament density

Lineament in general defined as any straight-line features in the satellite image, controlled by structural features like fault, fold axis, dyke, joints, fractures, etc., Lineament density is considered one of the important parameters in landslide studies. The IRS P6 LISS III Satellite image was used to interpret the lineaments in the study area. The major lineaments were identified in the northern and southern part of this study area and few landslide occurrences were noticed in the north-west and south-east directions. The lineament density map was derived from the lineament map and reclassified into three categories ; low, medium and high (Fig.9).

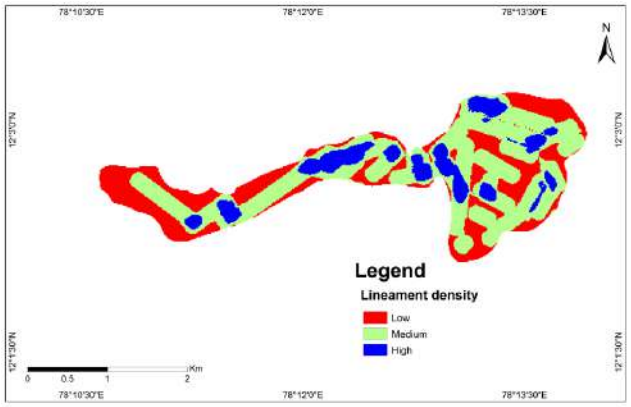


Fig. 9. Lineament density map of Vathalmalai Ghat road section

Road buffer

Road cutting is one key factor that affects the modification of natural slope into cut slope. Road construction is a significant factor which causes slope instability in a terrain. In this study, a buffer zone with 50m distance on both side of the road was generated using Arc GIS software. The road buffer zone was classified into three categories 25m, 50,100m (Fig.10).

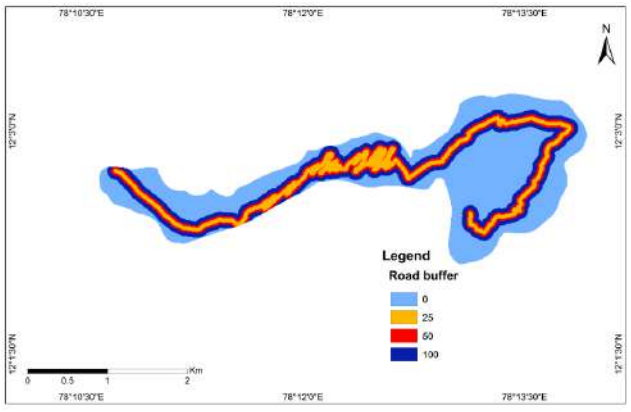


Fig.10. Road buffer zone along the Ghat road section of the Vathalmalai Hills

Relative relief

Relative relief denotes the maximum and minimum height in the study area. Relative relief is one of the important terrain parameters which control the occurrence of landslides. In this study area, the relative relief ranges from 500 to 1180 m. It was classified into two classes , low and medium relative relief zones (Fig.11).

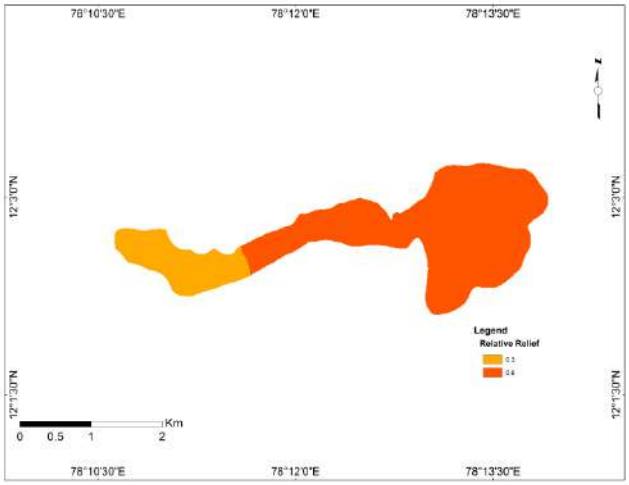


Fig. 11. Relative relief in the study area

Weighted linear combination (WLC)

Weighted linear combination (WLC) function aggregates all criteria and produce a single score. WLC is a function used to standardize the factor maps, ensuring the sum of the set of factors weights. The weightage and scores were assigned to all causative parameters according to its contribution to susceptibility of landslide occurrence. Landslide susceptibility index formula is given in the equation 1.

$$\text{Susceptibility index} = \sum_{i=1}^{n} (W_i \times R_i) \quad (1)$$

Where W_i is the weight for factor i,
R_i is the score of class of factor i and
n is the total number of factors
(Muheep et.al 2018).

The weightage from 0 to 100 and scores from 0 to10 were assigned each causative factor in the study (Table 1). The landslide inventory details were collected through field investigation and validated the distribution of landslide susceptibility classes.

Table 1. Ranking and weights assignment to causative factors

S. No	Factors	Classes	Weights	Rank
1	Geology	Charnockite	15	7
		Basic alkaline dykes		5
2		Structural hill system	10	9
		Pediment		8
		Fracture valley		4
3	Land Use / Land Cover	Settlement	15	7
		Plantation		6
		Moderately Vegetated area		6
		Fairly Dense Scrub		9
4	Slope	0-11	10	3
		11-19		3
		19-27		7
		27-31		5
		31-38		8
5	Slope Aspect	Flat	20	0
		North		1
		Northeast		2
		East		3
		Southeast		4
		South		5
		Southwest		7
		West		8
		Northwest		9
6	Drainage Density	Low	10	9
		Medium		8
		High		5
7	Lineament Density	Low	5	9
		Medium		7
		High		6
8	Road Buffer	0	10	9
		25		8
		50		6
		100		4
9	Relative Relief	0.3	5	7
		0.6		9

Results and Discussion

In the present study, weighted linear combination analysis was adopted for the purpose of the calculation of the landslide susceptibility index (LSI). All the causative factors processed and converted the vector based layers into raster format with a 10m grid size of IRS P6 LISS III satellite imagery with help of spatial analysis tool for ArcGIS 10.4.1 software. The landslide influencing factors were integrated and converted into raster format through calculation of values and scores. The integrated landslide susceptibility zonation map of the study area contains five cluster zones ; very low, low, moderate, high and very high . The percentage

distribution of susceptibility zones is 16.5% in very low, 28.70% in low, 24.70% in moderate, 19.90% in high and 10.20% in very high zones (Fig.12). Out of the five classes, the high and very high landslide susceptibility zone occupied a limited part of the area. The integrated resultant landslide susceptibility map shows that the middle part of the Ghat road section is more prone to occurrence of future landslides.

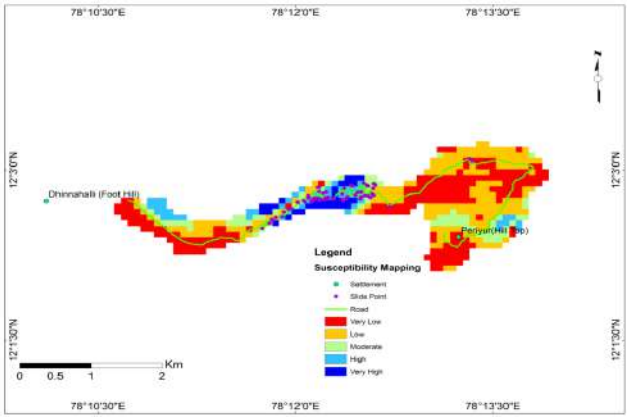


Fig.12. Landslide Susceptibility Map of Vathalmalai Ghat road section

The landslide inventory details were collected during field investigation and used in validation of landslide susceptibility mapping analysis. In the susceptibility zone, several types of landslide activities were identified as debris flow mixed with mud and water in flowing condition, rockfall on the steep slopes, weathered charnockite rock formation and piping phenomena in the soil profile. Landslide occurrences were noticed along 3, 6, 7, 11, 12, 15, 16, 17 and 21 hairpin bends. The landslide locations were captured through GPS measurements during field investigations. Most of the landslides consist of debris , where water acts as lubricant with highly weathered soil. In almost all the landslide locations, the parent rock is not visible and the entre slope section is in weathered conditions. Altogether 62 landslide locations were delineated in different sizes during the landslide inventory. The landslide inventory locations were compared with the landslide susceptibility map and validate the accuracy of the mapping. There are five susceptibility zones in the map ; very low, low, moderate, high and very high. In the correlation, 22 landslides fall within very high zones, 17 within high zones, 13 within moderate zones, 7 within low zones and 3 within very low zones. In comparison, 35.50%, and 27.40% of landslide occurrences respectively fall within very high and high landslide susceptibility zones. About 64% of previous landslides were closely associated with high to very high category and the multicriteria and WLC method were found to be suitable for landslide susceptibility mapping.

The potential map was verified using distribution of landslide locations. For the verification, the R-index method was used. The R-index method is used to evaluate the association between location of landslide points and the LSI map. The aim of validation is to evaluate performance of the landslide density of the study area. An index of relative landslide density (R) has been used to validate the results. The index is defined as follows (Baeza and Corominas, 2001);

$$R = (n_i / N_i) / \sum(n_i / N_i) \times 100 \quad (2)$$

Where, n_i is the number of landslides in susceptibility level 'i' and
N_i is the area occupied by the cells of susceptibility level 'i'.

The R-index for each landslide class is represented in Table 2, and the graphical representation (Fig.13) points out the distribution of landslide locations observed in the classes, indicating the consistency of landslide density classes. It may be expected that slope failures will appear in cells which have higher discriminant scores.

Table 2. R-index in the landslide susceptibility in the study area

Susceptibility Classes	Area Pixels	Area %	Landslide point	Landslide %	R Index
Very low	3894	16.50%	3	4.80%	4.59
Low	6796	28.70%	7	11.30%	6.13
Moderate	5839	24.70%	13	21.00%	13.27
High	4694	19.90%	17	27.40%	21.58
Very high	2410	10.20%	22	35.50%	54.41

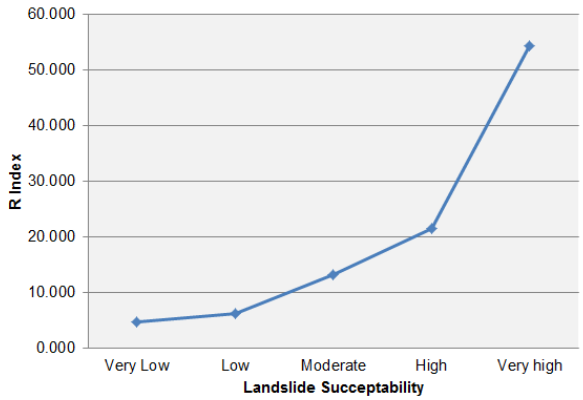


Fig. 13. Graphical representation of R-index of landslide susceptibility

Conclusion

The Vathalmalai Ghat road section is susceptible to frequent landslide occurrences and the most common triggering factor for landslide occurrence is heavy rainfall. In the present study, landslide susceptibility mapping has been carried out using multi criteria analysis with help of remote sensing and Geographical Information System (GIS) techniques. In this study, nine causative factors, namely geology, geomorphology, slope aspect, land use land cover, drainage density,

lineament density, road buffer, slope angle, and relative relief were considered for generation of a landslide susceptibility map. The results indicated that the high and very high susceptible zones include steep slope and unconsolidated materials in cut slope areas. The R-index method was used to validate the results of landslide susceptible mapping and it indicated that the procedure adopted in this study is appropriate and valid. Careful planning and suitable mitigation measures are required in moderate, high and very high landslide susceptibility zones. In the landslide inventory study, it was inferred that soil erosion, piping and saturation of highly weathered soil profile lead to slope failure. Hence, a proper drainage mechanism should be provided for the entire Ghat road section so that soil erosion and soaking of slope can be avoided. Suitable low-profile plants can be planted to prevent soil erosion. The landslide susceptibility map will assist planners and decision makers in taking appropriate measures to reduce risk in the future.

Acknowledgment

The first author acknowledges the Department of Science and Technology, New Delhi for providing the INSPIRE Fellowship (2015/IF150252) for the research work. The authors thank the District collectorate, Dharmapuri and District Forest Department for respectively providing necessary data and information.

References

Anbalagan, R., 1992. Landslide Hazard Evaluation and Zonation Mapping in Mountainous Terrain, Engineering Geology, 32:269–277

Anbazhagan, S., Neelakantan, R., Arivazhagan, S., Vanaraju, G., 2008. Developments of fractures and land subsidence at Kolli Hills, Tamil Nadu, India. Journal of Geological Society of India, Vol.42, September, 348–352

Anbazhagan, S., Ramesh, V., 2014. Landslide hazard zonation mapping in ghat road section of Kolli hills, India. J Mt Sci 11(5):1308–1325

Anbazhagan, S., Ramesh, V., Saranaathan, S. E., 2017. Cut slope stability assessment along ghat road section of Kolli hills, India. Natural Hazards. DOI 10.1007/ s11069–016–2731–0

Amit, Bera, Bhabani Prasad Mukhopadhyay and Debasish, Das, 2019. Landslide hazard zonation mapping using multi criteria analysis with the help of GIS techniques: a case study from Eastern Himalayas, Namchi, South Sikkim. Natural Hazards, pp: 935–959, doi.org/10.1007/ s11069–019–03580

Ayalew, L., Yamagishi, H., Ugawa, N., 2004. Landslide susceptibility mapping using GISbased weighted linear combination, the case in Tsugawa area of Agano River, Niigata Prefecture, Japan. Landslides 1(1):73–81

Arnous, M., 2011. Integrated remote sensing and GIS techniques for landslide hazard zonation: a case study Wadi Watier area, South Sinai, Egypt. J Coast Conserv 15(4):477–497

Ahmed, B., 2015. Landslide susceptibility mapping using multi-criteria evaluation techniques in Chittagong Metropolitan Area, Bangladesh. Landslides 12(6):1077–1095. https://doi.org/10.1007/ s1034 6–014–0521-x

Aleotti, P. and Chowdhury, R., 1999. Landslide hazard assessment: summary review and new perspectives. Bulletin of Engineering Geology and the Environment 58. 21–44. DOI: 10.1007/s100640050066

Begueria, S., 2006. Changes in land cover and shallow landslide activity: a case study in the Spanish Pyrenees. Geomorphology 74(1–4):196–206

Baeza, C. and Corominas, J.: 2001. Assessment of shallow landslide susceptibility by means of multivariate statistical techniques, Earth Surface Processes and Landforms 26: 1251–1263.

Dai, F.C., Lee, C.F. and Ngai, Y.Y., 2002. Landslide risk assessment and management: an overview. Engineering. Geology 64 (1), 65–87

Jaupaj, O., Lateltin, O., Lamaj, M., 2014. Landslide Susceptibility of Kavaja, Albania. In Landslide Science for a Safer Geoenvironment. 351–356

Hong, Y., Adler, R., Huffman, G., 2007. Use of satellite remote sensing data in the mapping of global landslide susceptibility. Nat Hazards 43:245–256. https://doi.org/10.1007/s1106 9–006–9104-z

Kannan, M., Saranathan, E., Anbalagan, R., 2011. Macro Landslide Hazard Zonation Mapping – Case study from Bodi – Bodimettu Ghat section, Theni District, Tamil Nadu – India. Journal of Indian Society of Remote Sensing, 39(4):485–496.

Kavitha, G., Anbazhagan, S., Mani, S., 2020a. Spatial Integration of Landslide Hazard Evaluation Factors and Assessment of Landslide prone areas in Vathalmalai hills, India. Disaster Advances Vol 13(7) July 2020, pp 58–68 (E-ISSN: 2278–4543 Print ISSN: 0974–262X,

Kavitha, G., Anbazhagan, S., Mani, S., 2020b. Landslide Inventory along newly Constructed Ghat road section at Vathalmalai Hills, Tamil Nadu, India. Journal of Science and Technology Vol. 5, Issue 2, March – April 2020, 90–98, ISSN: 2456–5660

Lee, S, Choi, J., Min, K., 2004. Probabilistic landslide hazard mapping using GIS and remote sensing data at Boun, Korea. Int J Remote Sens 25(11):2037–2052. https://doi.org/10.1080/01431 16031 00016 18734

Meng, Y., Malczewski, J, Boroushaki, S., 2011. A GIS-Based multicriteria decision analysis approach for mapping accessibility patterns of housing development sites: a case study in Canmore, Alberta. J Geogr Inform Syst 3:50–61

Muheeb, M. Awawdeh, Mohammad, A. El Mughrabi, and Mohammad, Y. Atallah., 2018. Landslide susceptibility mapping using GIS and weighted overlay method: a case study from North Jordan, Environmental Earth Sciences 77:732;1–15

Mahdadi, F., Boumezbeur, A., Hadji, R., Kanungo, DP, Zahri, F., 2018. GIS-based landslide susceptibility assessment using statistical models: a case study from Souk Ahras province, NE Algeria. Arab J Geosci 11:476. https://doi.org/10.1007/s1251 7–018–3770–5

Ramesh, V. and Anbazhagan, S., 2014. Landslide susceptibility mapping along Kolli hills Ghat road section (India) using frequency ratio, relative effect and fuzzy logic models, Environmental Earth Science, 73, June 2015, 8009–8021 (Impact Factor – 1.572)

Ramesh, V., Mani, S., Baskar, M., Kavitha. G., Anbazhagan, S., 2017. Landslide hazard zonation mapping and cut slope stability analyses along Yercaud ghat road (Kuppanur–Yercaud) section, Tamil Nadu, India. International Journal of Geo-Engineering 8:2. DOI 10.1186/s40703–017–0039-x

Sajinkumar, K.S., Anbazhagan S., 2014. Geomorphic appraisal of landslides on the windward slope of Western Ghats, southern India, Natural Hazards, Springer, Vol.75, Issue 1 (2015), 953–973 (Impact Factor – 1.958)

Sajinkumar, K.S., Anbazhagan, S., Rani, V.R. & Muraleedharan, C., 2013. A paradigm quantitative approach for a regional risk Assessment and management in a few landslide prone hamlets along the windward slope of Western Ghats, India, Elsevier-International Journal of Disaster Risk Reduction, (http://dx.doi.org/10.1016/j.ijdrr, 2013.10.004)

Saranaathan and Mani, 2016. Landslide Susceptibility Zonation mapping using Multi-criterion Analysis–CNG 37 Ghat section, Nadugani, Gudalur Taluk, The Nilgiris–Using Geological Factors, International Journal of Earth Science and Engineering. 09(04).

Sarkar, S., Kanungo, D., 2004. An integrated approach for landslide susceptibility mapping using remote sensing and GIS. Photogramm Eng Remote Sens 70(5):617–625

Sharma, R.K., Mehta, B.S., 2012. Macro-zonation of landslide susceptibility in Garamaura-Swarghat-Gambhar section of national highway 21, Bilaspur District, Himachal Pradesh (India). Natural Hazards, 60:671–688. DOI:10.1007/s11069–011–0041–0.

Varnes, D., 1978. Slope movements, type and processes. In: Schuster RL, Krizek R J (eds) Landslide analysis and control. Washington Transportation Research Board, Special Report 176. NAS, Washington

Wang, W.D,, Xie, C.M,, Du, X.G., 2009. Landslides susceptibility mapping based on geographical information system, GuiZhou, south-west China. Environ Geol 58(1):33–43

Wang, Q., Li, W., Chen, W., Bai, H., 2015. GIS-based assessment of landslide susceptibility using certainty factor and index of entropy models for the Qianyang County of Baoji city, China. J Earth SystSci 124(7):1399–1415

Journal of Geology, Geography and Geoecology

Journal home page: geology-dnu.dp.ua

ISSN 2617-2909 (print)
ISSN 2617-2119 (online)

Journ. Geol. Geograph. Geology, 30(4), 692–705.
doi: 10.15421/112164

Petrogenetic peculiarities of Fe-Ti oxide minerals in the processes of crystallization and evolution of late Cretaceous volcanic complexes of the Lesser Caucasus

Musa Nasib ogly Mammadov, Gultekin Javad gizi Babayeva

Institute of Geology and Geophysics of the National Academy of Sciences of Azerbaijan, Baku, Azerbaijan Republic, gultekin56@rambler.ru

Received: 05.03.2021
Received in revised form: 19.07.2021
Accepted: 10.08.2021

Abstract. Drawing from the determined differences between iron-titanium oxide minerals, we analyzed the conditions of crystallization and evolution of late-Cretaceous magmatic complexes of the Lesser Caucasus. It was found that the rocks of basalt-andesibasalt complex, which correspond to the early substage (upper Coniacian-lower Santonian) of late-Cretaceous volcanism in the Qazakh, Agjakand, Agdara depressions, have crystallized in the conditions of relatively highly-thermobaric crystallization of titanomagnetite, poorly differentiated and evolutionized according to the Fenner trend. In the second substage of volcanism, due to decrease in permeability of the Earth's crust, the elevation of the remaining magma to the upper horizons was hindered. Therefore, within the Qazakh depression, shallow intermediate sites of crystallization developed where moderately titaniferous magnetite crystallized with the participation of oxidized fluids earlier than hornblende, pyroxene and plagioclase. Thus, the remaining magma evolutionized its composition through Bowen's reaction series. In the Agjakand and Agdara depressions, change of previous expansion to compaction was the cause of hindering of partly fractioned portion of the magma. The latter thermally interacted with the above-embedded maghemite, hematite and in a number of cases magnetite. In the Khojavand depression, rocks of trachibasalt-trachiodolerite complex, which characterize the late substage of the Santonian volcanism, contain moderately titanium magnetites and maghemites. In the second substage of volcano-plutonism, rocks of tephrite-teshenite complex developed. There, accompanied by oxidized fluids, highly-clayey titanomagnetite crystallized before chrome-diopside and salite. However, the ulvospinel titanomagnetite in teshenites, having associated with barkevikite and kaersutite, crystallized at a relatively higher temperature. Within the Senonian volcanites of the Azykh depression, along with the moderately-titanium magnetite, chromic titanomagnetite and rarely chromite was determined. Similar mineralogical diversities are also characteristic for the Gochas depression.

Keywords: Lesser Caucasus, Fe-Ti oxide minerals, magnetite-ilmenite thermometer, Curie point, crystallization differentiation

Петрогенетичні особливості Fe-Ti оксидних мінералів у процесі кристалізації та еволюції пізньокрейдових вулканічних комплексів Малого Кавказу

М.Н. Мамедов, Г.Д. Бабаєва

Інститут геології та геофізики НАН Азербайджану, Азербайджанська республіка, м. Баку, gultekin56@rambler.ru

Анотація. У статті, на підставі встановлених відмінностей залізо-титан оксидних мінералів, аналізуються умови кристалізації та еволюційного перетворення пізньокрейдових магматичних комплексів Малого Кавказу. Виявлено, що породи базальт-андезібазальтового комплексу, що відповідають ранньому підетапу (верхній коньяк-нижній сантон) пізньокрейдового вулканізму Газахського, Агджакендського і Агдеринського прогинів, кристалізувалися при порівняно високотермобаричної кристалізації титаномагнетиту, слабодиференційований і еволюціонований Феннерівським шляхом. У другому підетапі вулканізму, у зв'язку з зменшенням проникності земної кори, відбувалося утруднення підйому залишкового розплаву у верхні горизонти. Тому в межах Газахського прогину формувалися малоглибинні проміжні вогнища, де при супроводі окислених флюїдів відбувалася кристалізація помірно-титаністого магнетиту раніше рогової обманки, піроксену і плагіоклазу. У цьому залишковий розплав еволюціонував свій склад Боуеновским шляхом. У Агджакендском і Агдеринском прогинах зміна попереднього розтягнення на стиск стала причиною затримки частково відфракціонованої порції розплаву. Останній термічно взаємодіяв з лежачими аркозовими пісковиками, у результаті формувалися корові дацити і риодацити, у складі яких беруть участь маггеміт, гематит та іноді магнетит. У Ходжавендскому прогині породи трахибазальт-трахидолеритового комплексу, що характеризують ранній підетап сантонського вулканізму, містять помірно-титанисті магнетити і маггеміти. У другому підетапі вулкано-плутонізму відбувалося формування порід тефрит-тешенитового комплексу. Тут, при супроводі окислених флюїдів, високоглиноземистий титаномагнетит кристалізувався раніше хромдіопсіду і саліту. Однак у складі тешенітів ульвошпінелевий титаномагнетит, тісно асоціюючи з баркевікітом і керсутитом, кристалізувався при порівняно більш високій

температурі. У складі сенонських вулканітів Азихського прогину поряд з помірно-титаністим магнетитом встановлено хромистий титаномагнетит і рідко хроміт. Подібні мінералогічні розмаїття характерні й у Гочасського прогині.

Ключові слова: Малий Кавказ, Fe-Ti оксидні мінерали, магнетит-ільменітовий термометр, точка Кюрі, кристалізаційна диференціація.

Introduction.

Iron-titanium oxide minerals that crystallized at different-depth intermediate sites and intrusive chambers bear a certain petrogenetic data, particularly location of deposits in series of crystallization, structural-optical types, chemical and mineral compositions, and petromagnetic peculiarities of iron-titanium oxide minerals.

The abovementioned peculiarities of these minerals can be used for clarifying physical-chemical (P, T, fo_2) and geodynamic conditions (compression, expansion) of crystallization of magmatic rocks.

To determine the temperature and partial pressure of oxygen of crystallization of iron-titanium oxide minerals as a geological thermometer, the following methods are used: Buddington-Lindsley (Buddington, Lindsley, 1964), Carmichael (Carmichael,1965), Anderson (Anderson, 1968), Lindsley et al. (Lindsley, Spencer, 1982), Stormer (Stormer, 1983), Genshaft et al. (Genshaft et al., 1999, 2003), and to determine depths of crystallization – methods of Kawai (Kawai, 1956), Osborn (Osborn, 1983), Pechetskij (Pecherskij, 1975, 1985), Zubov et al. (Zubov i dr., 2015).

Based on the interpretation of thermomagnetic and chemical analyses of titanomagnetites and ilmenites, Creek and Ibbetson (Creek, Ibbetson, 1970), and D.M. Pecherskij (Pecherskij, 1975) propose using experimental and calculated values of Curie points.

Along with them, the location of titanomagnetite crystallization, according to Osborn (Osborn, 1983), is an indicator of oxidative and reduction conditions of the evolutionary conversion of magmatic melts.

In this article, we attempted to determine the physical-chemical and geological conditions of crystallization of rocks of late Cretaceous magmatic complexes of the Lesser Caucasus according to the noted peculiarities of iron-titanium oxidative minerals.

Methods of studies.

With the purpose of determining significance of the presented analyses of iron-titanium oxide minerals, we used microprobe, chemical, X-ray diffractometer and thermomagnetic methods.

Microprobe analyses of impregnations with Fe-Ti oxide minerals, chrome-spinels and olivines were carried out in a electron-microprobe analyzer (JEOL, JSM-6610 LV, Oxford Instruments, X–MAX) with internal standard. All the microprobe, X-ray diffraction-metric and chemical analyses of iron-titanium oxide minerals were performed at the Analytical Center of the Institute of Geology and Geophysics of the National Academy of Sciences of Azerbaijan.

Monomineral fractions of rocks (weighing 20 kg) were divided at the Institute of Geology and Geophysics of the Siberian Branch of the Russian Academy of Sciences (SB RAS), under the leadership of T.S. Yusupova. For the chemical analysis, we used fractions sized 0.25 mm and purity was tested with binocular magnifying glass.

During the calculation of Curie points, we used chemical and microprobe analyses of TiO_2 (Nagata, 1965; Pecherskij, 1975).

Crystal chemical formulae of minerals and evaluations of the conditions of their development (T, fo_2) were calculated in ILMAT software (Lepage, 2003).

Geological and petrogenetic peculiarities of the Late Cretaceous magmatic complexes of the Lesser Caucasus. For the purpose of clarifying the depths of localization, and therefore the conditions of crystallization of the rocks, the most expedient objects were considered to be the Late Cretaceous magmatic complexes of the Lok-Garabagh (Gazakh, Agjakand, Agdara depressions), Goycha-Akeri (Khojavand, Azykh depressions) and Miskhan-Kafan (Gochas depression) structural-formation zones of the Lesser Caucasus (Shikhalibejli, 1994) (Fig.1).

The Lok-Garabagh structural-formation zone. This zone, starting from the Lok crystalline structure, in parallel to the southern side of the Kura depression, runs eastward from the west in the general-Caucasian direction to the Murovdagh thrust fault. From the southwest contour of the indicated thrust fault, it changes its strike toward the southeast and is seen to the middle reach of the Khachinchay River.

The Late Cretaceous volcanic complexes of the analyzed zone within Azerbaijan are developed in the Gazakh, Agjakand, Agdara depressions.

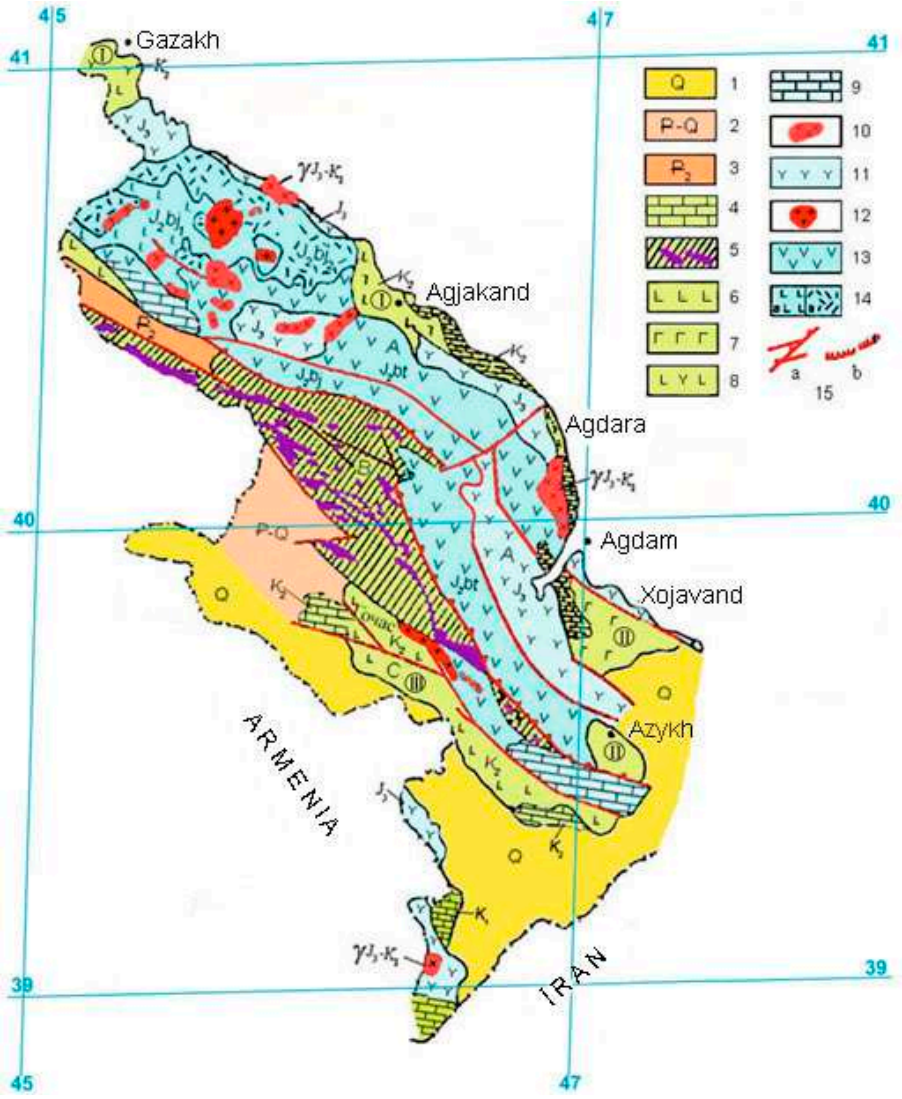


Fig. 1. Schematic geological map of the Lesser Caucasus (Shikhalibejli, 1994).

I–Lok-Garabagh structural-formation zone (Gazakh, Agjakand, Agdara depressions); II – Goycha-Akeri structural-formation zone (Azykh and Khojavand depressions), III–Miskhan-Kafan structural-formation zone (Gochas depression)

1 – Contemporary sediments; 2 – Paleogene-Neogene volcanogenic sedimentary deposits; 3 – Paleogene volcanogenic sedimentary deposits; 4 – Upper Cretaceous limestones; 5 – ophiolite complexes; 6 – Late Senonian basalt-andesibasalt and trachybasalt-trachyandesibasalt complexes (Gochas depression); 7 – Santonian basalt-andesibasalt and trachybasalt-trachyandesibasalt complexes (Azykh depression), trachybasalt-trachydolerite and tephrite-teschenite (Khojavand depression) complexes; 8 – Late Coniacian-Early Santonian basalt-andesibasalt and Late Santonian-Early Campanian rhyolite-rhyodacite complexes (Gazakh depression), Coniacian- Santonian basalt-andesibasalt and rhyolite-rhyodacite complexes (Agjakand and Agdara depressions); 9 – Upper Jurassic limestones; 10 – Late Jura-Early Cretaceous gabbro-diorite-granite complex; 11 – late Jurassic-early Cretaceous dacite complex; 12 – Bathonian plagiogranite complex; 13 – Bathonian basalt-andesite-dacite-rhyoilte complex; 14 – a) Early Bajocian basalt complex, б) late Bajocian rhyolite complex; 15 – deep faults (a), flexures (b).

Based on the petrographic composition and time of emergence of volcanism, in correspondence with the stage of volcanic activity, the Late Cretaceous volcanites of the Gazakh depression are divided into two following complexes: 1) basalt-andesibasalt; 2) rhyolite-rhyodacite (Mamedov, 1999) (Table 1).

The first complex that characterizes the substage of volcanism (the Upper Coniacian-Lower Santonian), is mainly composed of volcanic breccias, currents, thin sill and dykes of dolerites, basalts, andesibasalts and also a subordinate number of andesites.

The second complex corresponds to the Late Cretaceous substage (the Upper Santonian-Early Campanian) of volcanism and is represented by rhyolite, rhyodacite extrusive rocks and zeolitic tuff.

In the central part of the Gazakh depression, the composition of the first complex is noticeably dominated by lava flows, lava breccias of olivine, olivine-clinopyroxene and clinopyroxene-plagioclase basalts. In the southwest outskirts of the depression, there are thin flows of olivine-chrome-spinel picrites and olivine-clinopyroxene picrobasalts. Within the

Table 1. Chemical compositions of the rocks of Late Cretaceous volcanic complexes of the Azerbaijanian part of the Lesser Caucasus

depressions	Gazakh depression					Agjakand depression					Khojavand depression				Azykh depression		Gochas depression	
rocks / components	dolerites		basalts		rhyolite	dolerites		basalts		rhyolite	teshenite	tephrite	trachybasalt	trachydolerite	basalt	trachyandesite	basalt	trachyandesite
SiO_2	46.00	46.50	49.72	49.66	70.47	46.30	46.50	45.0	48.50	68.73	44.52	44.41	44.15	44.63	50.66	56.32	47.74	59.20
TiO_2	1.03	0.98	0.67	1.00	0.21	0.98	1.03	0.85	0.98	n.d.	1.36	1.03	0.56	0.90	1.40	1.16	1.70	1.45
Al_2O_3	17.35	17.29	19.04	20.89	13.26	16.05	13.90	14.45	15.52	15.78	17.32	13.1	15.70	14.14	19.26	16.54	17.78	16.51
Fe_2O_3	5.35	4.59	5.93	5.51	1.64	4.36	4.07	5.06	3.22	2.26	2.00	6.77	10.75	7.22	3.66	6.62	3.91	3.11
FeO	6.78	9.21	5.37	3.42	1.44	7.38	9.39	9.15	5.24	0.65	5.39	5.33	2.44	3.61	4.22	1.79	5.34	1.89
MnO	0.17	0.10	0.09	0.08	0.08	0.27	0.14	0.16	0.16	0.04	0.13	0.19	0.12	0.20	0.19	0.21	0.16	0.08
MgO	7.64	6.44	4.90	3.17	0.58	6.46	6.91	2.05	4.47	0.45	6.87	8.3	6.18	7.65	4.27	1.56	5.62	2.16
CaO	11.45	11.41	11.29	11.56	3.11	12.08	11.40	15.47	15.32	4.60	13.37	12.06	11.25	12.23	9.25	4.34	10.13	5.19
Na_2O	2.92	2.16	2.22	2.54	4.93	3.34	3.64	3.71	4.47	3.93	3.17	4.08	4.12	4.32	2.80	6.40	3.67	5.30
K_2O	0.58	0.98	0.14	0.36	3.41	1.01	1.62	1.32	0.45	1.20	0.42	0.81	1.80	1.49	0.80	2.27	0.97	2.57
P_2O_5	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.08	0.34	0.64	n.d.	0.69	0.32	0.17	0.37	0.21
ппп	n.d.	n.d.	0.84	1.71	0.75	1.23	1.34	2.05	1.12	2.17	3.73	2.64	2.23	2.69	2.78	2.15	2.39	1.96
∑	99.27	99.66	100.21	99.9	99.88	99.46	99.94	99.27	99.45	99.89	98.62	99.36	99.3	99.77	99.61	99.53	99.78	99.63

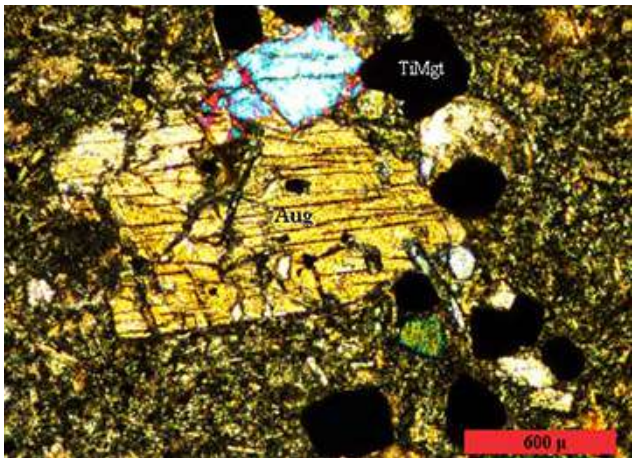


Fig. 2. Intergrowth of titanomagnetite (TiMgt) with highly-calcium augite (Aug) in clinopyroxene basalt.

picrites, olivine and chrome spinel as idiomorphic deposits form interrelated grains, whereas chrome spinel in picrobasalt is replaced by chrome titanomagnetite. Labradorite-bytownite plagioclase and high-calcium augite impregnations continue to undergo the process of crystallization.

In the subsequent differentiates, distinctly cut grains of titanomagnetite grow together with high-calcium augite (Fig. 2). In relation to porphyry generations of mineral parageneses, the early stage of crystallization is characterized by olivine-chrome spinel balance. The temperature of crystallization of those impregnations, calculated according to Fabries' thermometer (Fabries, 1979), equaled 1,050–1,100 °C (Table 2).

Table 2. Chemical compositions of olivines and chrome-spinelides of olivine-chrome-spinel picrites of the Gazakh depression

Rocks	olivine			chrome-spinel		
sample / component	1	2	3	1	2	3
SiO_2	39.40	38.44	39.14	n.d.	n.d.	n.d.
TiO_2	0.24	0.30	0.34	0.06	0.06	0.06
Al_2O_3	n.d.	n.d.	n.d.	14.28	14.64	12.24
Cr_2O_3	n.d.	n.d.	n.d.	46.75	47.33	50.30
Fe_2O_3	0.37	0.37	0.42	7.36	8.36	6.38
FeO	16.12	18.60	15.86	18.75	18.86	16.60
MnO	0.23	0.29	0.26	0.18	0.21	0.33
MgO	42.38	41.58	43.86	12.36	10.15	13.64
∑	98.74	99.58	99.88	99.74	99.61	99.55

In all types of basalts and dolerites, titanomagnetite is characterized by comparatively high content of titanium and homogenous structure. According to microprobe, chemical (Table 3, 4), X-ray diffraction (α=8.484–8.516Å) analyses, the content of ulvospinel molecules ranges 50% to 64%.

According to the magnetite-ilmenite thermometer, crystallization of porphyry generations of minerals of basalts and dolerites most likely took place in somewhat heightened thermobaric conditions (t=1030–1100 °C, fo_2= –9.7–9.2) (Table 3), and the crystallization depth ranges 18–21 km (Fig. 3).

Presence of inclusions of moderately titanium magnetite in the pyroxene and hornblende phenocrysts that the andesite-basalt melt was crystallized in comparatively more oxidative conditions. Therefore, the depth (4–11 km) (Fig. 3) and temperature (t=750–850ºC) of crystallization respectively decrease.

Phenocrysts of titanomagnetite in basalts and dolerites of the basalt-andesibasalt complex of the Agjakand and Agdara depressions developed in several relatively heightened thermobaric conditions (Table 1). Therefore, the calculated Curie points (Tc=140–250) and accordingly the depth of crystallization at the intermediate site increase (20–22 km) (Table 3, Fig. 3).

In the Upper Santonian-lower Campanian periods, change of the previous regime and decrease in permeability of the Earth crust in Agjakand and Agdara depressions hindered the elevation of fractioned portion of the melt. Therefore, highly heated basalt melt has been thermally interacting with above-embedded arkose sandstones, which developed during destruction of the Lower Jurassic quartzitic-plagioporphyry volcanites, causing those sandstones to melt. Thus, from the rhyolite melt that was developing, crust dacites and rhyodacites formed (Table 1).

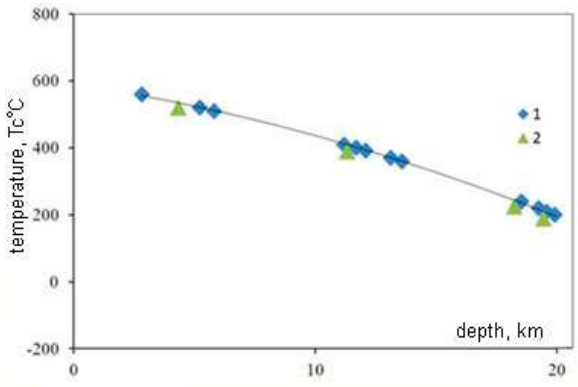


Fig. 3. Dependence of Curie temperature of iron-titanium minerals on depth of Late Cretaceous volcanic complexes of the Gazakh (1) and Agjakand (2) depressions (Kawai, 1956).

Table 3. Chemical, crystal-chemical and minal compositions of titanomagnetites of the Gazakh and Agjakand depressions

Gazakh depression																	
Comnplexes	Basalt-andesibasalt														Rhyolite-rhyodacite		
Rocks	Dolerites				Basalts				Andesibasalts				Andesites		Rhyolite		Obsidian
№ samples / component	300	301	303	307	324	326	328	332	310	316	331	333	312	315	322a	322	323
TiO_2	17.55	18.77	19.97	22.87	19.98	20.42	18.91	19.40	9.48	7.73	9.00	9.11	1.36	3.58	4.23	4.76	10.67
Al_2O_3	0.65	1.08	0.92	0.86	0.58	0.66	0.92	1.33	4.57	3.21	4.36	4.26	3.36	2.73	2.21	2.36	3.21
V_2O_3	0.36	1.21	0.74	0.20	0.73	0.82	0.81	1.24	0.01	0.22	0.32	0.36	0.13	0.11	0.26	0.17	0.20
Cr_2O_3	0.23	0.17	0.16	0.07	0.07	0.19	0.26	0.17	0.01	0.01	0.004	0.09	0.03	0.23	0.01	0.01	0.08
Fe_2O_3	33.95	30.50	29.0	24.02	29.15	28.75	29.25	30.20	48.50	55.36	52.66	50.36	66.40	59.50	63.26	62.18	56.40
FeO	46.85	46.85	48.89	51.89	47.93	47.83	48.66	46.60	34.75	32.20	31.20	33.48	26.28	31.86	29.42	29.34	27.75
MnO	0.20	0.47	0.63	0.16	0.60	0.61	0.36	0.39	0.20	0.57	0.46	0.43	0.50	0.50	0.38	0.52	0.75
MgO	0.29	0.42	0.36	0.34	0.42	0.28	0.52	0.30	1.80	0.56	1.72	1.84	1.34	1.20	0.45	0.66	1.33
∑	100.08	99.47	100.67	100.41	99.46	99.56	99.70	99.63	99.32	99.86	99.76	99.93	99.40	99.71	100.22	100	100.39
Tc°C	250	240	230	140	180	200	240	238	400	450	370	370	570	520	530	540	360
Ti	0.496	0.530	0.560	0.641	0.566	0.577	0.535	0.545	0.262	0.215	0.247	0.250	0.038	0.089	0.118	0.133	0.288
Al	0.029	0.048	0.040	0.038	0.026	0.029	0.041	0.058	0.198	0.140	0.188	0.184	0.148	0.121	0.097	0.104	0.136
V	0.011	0.037	0.022	0.006	0.022	0.025	0.024	0.037	0.000	0.007	0.009	0.011	0.004	0.003	0.008	0.005	0.006
Cr	0.007	0.005	0.014	0.002	0.002	0.005	0.008	0.005	0.000	0.000	0.001	0.003	0.000	0.07	0.000	0.000	0.000
Fe^{+3}	0.961	0.863	0.814	0.673	0.827	0.813	0.855	0.849	1.340	1.539	1.447	1.381	1.858	1.690	1.770	1.78	1.523
Fe^{+2}	1.473	1.472	1.525	1.616	1.510	1.502	1.496	1.456	1.067	0.995	0.952	1.025	0.820	1.006	0.915	0.911	0.838
Mn	0.006	0.015	0.020	0.005	0.002	0.019	0.012	0.012	0.006	0.018	0.014	0.013	0.016	0.016	0.012	0.016	0.023
Mg	0.016	0.023	0.020	0.019	0.023	0.016	0.029	0.017	0.098	0.031	0.094	0.100	0.074	0.067	0.025	0.037	0.071
Mgt	48.8	44.9	41.5	34.1	42.4	41.6	44.3	44.9	65.1	75.5	67.3	67.1	76.5	84.9	76.6	76.4	51.0
Usp	49.5	50.1	54.6	64.0	54.6	51.7	53.6	47.2	13.7	n.d.	n.d.	9.1	n.d.	8.9	n.d.	n.d.	n.d.
Il	0.2	2.6	n.d.	n.d.	1.7	5.2	n.d.	6.2	11.7	20.3	23.1	14.9	3.6	0.1	11.2	12.6	25.7
Hm	n.d.	n.d.	1.9*	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	1.3	0.8	n.d.	12.8	n.d.	9.8	7.5	17.3
Sp	1.6	2.4	21.0	1.9	1.3	1.5	2.0	1.6	9.5	2.9	8.8	8.8	7.1	6.1	2.4	3.5	6.1

* Wüstite is involved in the subordinate amount.

Continuation of Table 3

Agjakand depression									
Complexes	Basalt-andesibasalt								Rhyolite-rhyodacite
Rocks	Dolerites		Basalts				Andesibasalts		Dacite
№ samples / component	359	360	346	350	358	363	334	347	338
TiO_2	22.75	23.0	18.04	20.53	22.92	19.60	9.28	3.45	3.43
Al_2O_3	2.16	2.06	1.24	1.16	1.31	1.40	1.75	4.60	3.26
V_2O_3	0.36	0.43	0.38	0.32	0.36	0.33	0.16	0.15	0.10
Cr_2O_3	0.75	0.86	0.43	0.42	0.42	0.41	0.12	0.12	0.08
Fe_2O_3	21.69	28.80	33.29	31.93	25.23	32.10	49.03	63.80	64.25
FeO	50.20	49.30	42.80	44.77	48.75	45.30	32.60	25.60	26.74
MnO	1.36	1.40	3.21	0.35	0.26	0.55	0.34	0.20	0.36
MgO	0.64	0.52	0.43	0.52	0.43	0.48	2.52	1.82	1.31
∑	99.91	99.99	99.82	100.2	99.68	100.17	99.40	99.74	99.53
Tc°C	150	150	160	200	150	240	400	530	530
Ti	0.634	0.639	0.508	0.565	0.639	0.545	0.255	0.094	0.095
Al	0.094	0.090	0.054	0.050	0.027	0.051	0.204	0.197	0.142
V	0.011	0.013	0.011	0.015	0.011	0.010	0.005	0.004	0.003
Cr	0.022	0.025	0.012	0.012	0.012	0.022	0.003	0.003	0.002
Fe^{+3}	0.605	0.623	0.937	0.880	0.704	0.893	1.358	1.747	1.786
Fe^{+2}	1.556	1.523	1.339	1.393	1.512	1.401	0.991	0.719	0.826
Mn	0.042	0.044	0.102	0.011	0.008	0.017	0.010	0.006	0.011
Mg	0.035	0.029	0.024	0.028	0.024	0.026	0.137	0.099	0.072
Mgt	33.1	34.2	47.6	43.5	35.7	43.9	65.8	75.5	80.0
Usp	63.4	57.2	44.3	37.1	49.7	41.2	9.6	n.d.	n.d.
Il	n.d.	5.8	5.7	17	12.13	11.9	14.8	8.1	5.1
Hm	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	7.9	8.5
Sp	3.5	2.8	2.4	2.4	2.3	3.0	9.8	8.5	6.3

Indexes of minerals: Mgt – magnetites; Usp – ulvospinel; Il – ilmenite; Sp – spinel; Hm – hematite; Tc – calculated value of Curie points

Table 4. Chemical, crystal-chemical and mineral compositions of ilmenites of the Gazakh and Agjakand depressions

Gazakh depression								Agjakand depression				
Complexes	Basalt-andesibasalts											
№ samples / components	300	307	324	328	310	315	322	№ samples / component	359	360	346	334
TiO_2	48.66	47.2	48.64	48.38	49.16	48.3	46.63	TiO_2	49.16	48.60	47.63	48.50
Al_2O_3	0.64	0.93	0.34	0.16	0.75	1.15	1.34	Al_2O_3	0.36	0.23	0.36	1.18
V_2O_3	0.28	0.2	0.27	0.38	0.18	0.04	0.21	V_2O_3	0.28	0.25	0.66	0.42
Cr_2O_3	0.26	0.18	0.1	0.16	0.34	0.09	0.14	Cr_2O_3	0.18	0.19	0.16	0.04
Fe_2O_3	6.5	9.17	7.42	7.52	5.2	6.8	9.68	Fe_2O_3	6.21	6.98	9.25	6.53
FeO	42.99	40.11	42.13	41.93	42.2	41.74	41.09	FeO	42.72	41.97	40.78	41.38
MnO	0.56	0.94	0.66	0.58	1.36	1.18	0.78	MnO	1.34	1.60	1.36	1.58
Mgo	0.24	0.73	0.54	0.66	0.34	0.36	0.23	MgO	0.06	0.07	0.34	0.36
∑	100.13	99.46	100.1	99.77	99.53	99.66	100.1	∑	100.31	99.89	100.54	99.99
t°C	1030	1080	1050	1100	850	750	760	t°C	1120	1100	1150	780
$lgfo_2$	-9.7	-9.8	-10	-9.2	-12.5	-11	-12.5	$lgfo_2$	-9.8	-9.6	-8.6	-12.5
Ti	0.922	0.896	0.921	0.919	0.934	0.916	0.882	Ti	0.931	0.926	0.899	0.916
Al	0.019	0.028	0.01	0.005	0.022	0.034	0.039	Al	0.011	0.007	0.011	0.035
V	0.006	0.004	0.005	0.008	0.004	0.001	0.004	V	0.006	0.005	0.013	0.008
Cr	0.005	0.003	0.002	0.003	0.007	0.002	0.003	Cr	0.003	0.004	0.004	0.001
Fe^{+3}	0.123	0.174	0.141	0.143	0.099	0.129	0.183	Fe^{+3}	0.118	0.133	0.175	0.123
Fe^{+2}	0.904	0.847	0.887	0.885	0.892	0.88	0.865	Fe^{+2}	0.900	0.889	0.857	0.869
Mn	0.012	0.02	0.014	0.012	0.029	0.025	0.016	Mn	0.029	0.034	0.029	0.034
Mg	0.009	0.028	0.02	0.025	0.013	0.013	0.008	Mg	0.002	0.003	0.013	0.013
$MnTiO_3$	1.1	2.00	1.9	2.3	2.7	2.3	1.42	$MnTiO_3$	2.7	3.2	2.6	3.2
$MgTiO_3$	0.8	2.8	1.3	1	1.2	1.2	0.7	$MgTiO_3$	0.2	0.3	1.2	1.2
$FeTiO_3$	83.6	84.7	82.2	81.7	83.7	81	76.4	$FeTiO_3$	84.2	82.7	77.8	80.1
Fe_2O_3	14.5	10.5	14.6	14.9	12.7	15.5	21.2	Fe_2O_3	12.9	13.8	18.4	15.5

Indexes of minerals: $FeTiO_3$ – ilmenite, $MgTiO_3$ – geikielite, $MnTiO_3$ – pyrophanite.

The latter are different from the similar dacites and rhyodacites of the Gazakh depression because of the somewhat increased content of large-ion alkaline (K, Rb) and alkaline-earth (Ba) elements, discreetness, and also presence of arkose sandstones in the distribution range of those rocks.

Based on the analyses of the presented materials, we may conclude that in the compound of picrobasalts and picrodolerites, in relatively more high-baric conditions, crystallization was undergone by olivine-chrome spinel paragenesis (t=1,080–1,100ºC). In the composition of the subsequent differentiates, over the process of evolution of the olivine-basalt melt, due to crystallization differentiation, chrome spinel has been excluded from the paragenesis and therefore the content of olivine partly decreases. The following paragenesis is accompanied by bytownite plagioclase, augite clinopyroxene, chrome-impoverished titanomagnetite. Increase in the content of ulvospinel molecules and decrease in the calculated and experimental Curie points (150–240 °C) indicate that titanomagnetites in basalts and dolerites of the Agjakand and Agdara depressions, compared with the similar petrographic types of rocks of the Gazakh depression, have crystallized in high thermobaric conditions (Table 3, Fig. 4).

Due to palligenic transformation of partly hydrated arkose sandstones in dacites and rhyodacites, in the oxidative setting, crystallization of hematite, goethite and maghemite occurred.

The Goycha-Akeri structural-formation zone (the Khojavand and Azykh depressions), starting from the eastern bank of Goycha Lake, can be seen in the southeast direction to the Araz River and is located between the Lok-Garabagh and Miskhan-Kafan structural-formation zones.

Iron-titanium oxide minerals in the composition of the rocks of Late Cretaceous formations of tephrite-teshenite and trachybasalt-trachydolerite complexes of Khojavand, and also trachybasalt-trachyandesite complex of the Azykh depressions of the Goycha-Akeri structural-formation zone of the Lesser Caucasus are represented by moderately titanium and high alumina titanomagnetite, ilmenite, maghemite, hematite and others.

Geological structure and also petrological-mineralogic peculiarities of the trachybasalt-trachydolerite and tephrite-teshenite complexes of the Khojavand depression were analyzed in previous articles (Akhundov, 2003, Avdeev i dr, 1989, Mamedov i dr., 2012, 2013, 2015).

The trachybasalt-trachydolerite complex that characterizes the early substage of the Santonian volcanism is composed of olivine, clinopyroxene-plagioclase and plagioclase trachybasalts and trachydolerites (Table 1).

The rocks of tephrite-teshenite complex correspond to the late substage of the Santonian volcanism. The effusive-pyroclastic facies consist of picrotephrite, melano- and leukotephrite. The mentioned rocks often contain several rolled inclusions of subalkaline picrite, and also singular large megacrystals of clinopyroxene and phlogopite plates (0.5x2.5 cm). As inclusions, chrome spinel and titanomagnetite are in most cases confined to clinopyroxene phenocrysts. This indicates that the process of crystallization of tephrite melt at the intermediate site occurred in the oxidative setting. Therefore, crystallization of the main plagioclase was hindered, leading to enrichment of titanomagnetite with specifically spinel, and clinopyroxene – with calcium tschermakite molecules.

Early stage of crystallization of the subalkaline picrite melt took place according to olivine-chrome spinel Fabries' geothermometer (Fabries, 1979) in the temperature of 980–1,100 °C (Table. 5, 6).

Table 5. Chemical, crystal-chemical and minal compositions of chrome-spinels and titanomagnetite rocks of tephrite-teshenite, trachybasalt-trachydolerite complexes of the Khojavand depression.

Complex	Tephrite-teshenite								Trachybasalt-trachydolerite				
№ samples / Components	372v	372a	372b	376	375	381	399	399a	379	380	388	392	370
TiO_2	2.12	3.47	2.93	9.79	2.6	10.93	16.59	18.2	10.2	9.36	9.16	0.81	12.14
Al_2O_3	18.05	12.38	13.87	10.99	16.82	3.24	2.07	1.46	4.6	3.31	5.38	0.59	4.89
V_2O_3	0.15	0.23	0.23	n.d.	0.26	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Cr_2O_3	33.50	34.13	31.40	13.04	34.42	0.01	0.09	0.1	1.19	0.01	0.01	n.d.	0.23
Fe_2O_3	16.80	16.31	17.68	25.83	14.47	44.66	34.51	32.24	43.68	48.00	47.43	67.09	41.4
FeO	14.47	23.85	25.99	31.02	16.31	38.81	44.37	46.8	39.05	37.24	33.44	21.36	36.43
NiO	0.88	0.12	0.12	n.d.	0.78	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
MnO	0.24	0.14	0.53	0.36	0.28	0.54	0.98	0.68	0.04	0.03	0.04	0.31	0.61
MgO	13.71	8.59	7.24	8.44	12.6	1.5	0.84	0.46	1.52	1.96	4.56	0.21	3.91
∑	99.92	99.22	99.99	99.47	98.54	99.69	99.45	99.94	100.3	99.91	100	90.37	99.61
Tc°C	n.d.	n.d.	n.d.	n.d.	n.d.	360	250	230	377	395	380	350	360
t,°C	1040	1200	1150	1180	995	980	1020	1030	758	n.d.	n.d.	n.d.	960
$lgfo_2$	-5.90	-7.2	-5.39	-6.32	-5.68	-10	-11	-10	-14,2	n.d.	n.d.	n.d.	-10,2

Continuation of Table 5

Complex	Tephrite-teshenite								Trachybasalt-trachydolerite				
№ samples / Components	372v	372a	372b	376	375	381	399	399a	379	380	388	392	370
Ti	0.050	0.087	0.073	0.248	0.062	0.305	0.467	0.51	0.281	0.26	0.247	0.023	0.33
Al	0.669	0.487	0.547	0.437	0.634	0.142	0.091	0.064	0.199	0.144	0.227	0.027	0.208
V	0.004	0.006	0.006	0.000	0.006	0.000	0.003	0.003	0.000	0.000	0.000	0.000	0.000
Cr	0.833	0.913	0.831	0.348	0.870	0.000	0.000	0.000	0.034	0.001	0.002	0.000	0.007
Fe^{+3}	0.398	0.410	0.445	0.718	0.348	1.248	0.972	0.908	1.204	1.335	1.279	1.927	1.126
Fe^{+2}	0.380	0.665	0.727	0.813	0.436	1.205	1.389	1.465	1.197	1.151	1.002	1.001	1.1
Mn	0.006	0.004	0.003	0.010	0.007	0.002	0.031	0.022	0.001	0.001	0.001	0.01	0.018
Mg	0.642	0.428	0.361	0.424	0.601	0.083	0.047	0.026	0.083	0.108	0.243	0.012	0.21
Ni	0.022	0.004	0.003	0.000	0.020	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sp	29.4	24.0	23.2	21.1	27.0								
$MgCr_2O_4$	32.2	18.1	7.4	17.0	24.2								
$FeCr_2O_4$	7.6	26.3	27.8	-	12.9								
Mgt	21.3	22.9*	31.6*	37.8	30.6*								
Usp	9.6	8.6	10.0	24.1	5.31								
Sp						7.1	4.6	2.6	6.7	7.2	11.2	1.2	10.4
Mgt						62.3	48.7	46.2	70.7	66.8	63.8	96.5	56.6
Usp						30.5	46.7	51.2	3.0	25.9	24.4	2.3	33.0
Il						n.d.	n.d.	n.d.	19.6	0.1	0.5	n.d.	n.d.

*- Wüstite is involved in the subordinate amount.

372v – subalkaline picrite, 372a – subalkaline picrotephrite, 372b, 376 – melano-tephrite, 375 – megacrystal of chrome spinel, 381 – leucocratic tephrite, 399 – melano-teshenite, 399a – leucoteshenite, 379, 380 – analcime-clinopyroxene trachybasalt, 388 – clinopyroxene trachybasalt, 392 – plagioclase trachybasalt, 370 – trachydolerite.

Table 6. Chemical compositions of olivine of rocks of tephrite-teshenite complex of the Khojavand depression

№ samples / components	372a	372b	382b
SiO_2	38.30	37.20	38.20
FeO	21.36	25.70	20.40
MgO	40.22	36.80	41.70
∑	99.88	99.70	100.30

In the composition of melano- and leucocratic tephrites, the share of phenocrysts of olivine, chrome-diopside, chrome spinel gradually decreases, whereas in the phenocrysts, the content of fayalite, ferrosilite and ulvospinel minerals notably increases. This indicates that melano- and leucocratic tephrites are differentiates of sub-alkaline picrite melt.

In the composition of tephrites, there is a small amount of phenocrysts of kaersutite-barkevikite amphibole, and mainly the late magmatic analcimes, indicating oxidative conditions of crystallization. Therefore, crystallization of the main plagioclase was slowed, and therefore a certain share of alumina dissolves in the compound of moderately titanium titanomagnetite, causing the latter to crystallize before the clinopyroxene impregnations. This is indicated by the presence of inclusions of distinctly cut depressions of titanomagnetite in clinopyroxene (Fig. 4). Therefore the temperature of crystallization of porphyry generations of the minerals of tephrite melt somewhat decreases (760–820 °C), while the partial pressure of oxygen increases ($lgfo_2$= –9.2–10). According to the calculated (Table 5, 7) and experimental values of Curie points, the depth of crystallization of tephrite melt at intermediate site somewhat decreases (6–12 km) (Fig. 5).

Table 7. Chemical, crystal-chemical and minal composition of ilmenites of tephrite-teshenite and trachybasalt-trachydolerite complexes of the Khojavand depression

Complexes	tephrite-teshenite			trachybasalt-trachydolerite	
№ samples / components	381	399	399a	370	379
TiO_2	46.74	48.31	48.36	47.68	48.50
Al_2O_3	0.75	0.23	0.32	0.52	0.56
V_2O_3	0.28	n.d.	n.d.	n.d.	n.d.
Cr_2O_3	0.36	n.d.	n.d.	0.48	0.36
Fe_2O_3	10.05	7.39	7.67	8.06	4.06
FeO	40.81	42.19	42.06	42.06	42.66
MnO	0.58	0.56	0.75	0.58	0.63
MgO	0.42	0.66	0.38	0.26	0.33
∑	99.99	99.63	99.54	99.64	97.1
Ti	0.886	0.924	0.922	0.891	0.924
Al	0.022	0.007	0.009	0.016	0.016
V	0.006	0.000	0.000	0.000	0.000
Cr	0.007	0.000	0.000	0.010	0.007
Fe^{+3}	0.191	0.141	0.146	0.186	0.123
Fe^{+2}	0.860	0.892	0.892	0.839	0.904
Mn	0.012	0.012	0.016	0.055	0.013
Mg	0.016	0.025	0.014	0.001	0.012
$MnTiO_3$	1.1	1.1	1.5	1.1	1.1
$MgTiO_3$	1.4	2.3	1.3	0.9	1.2
$FeTiO_3$	77	82.2	82.8	81.3	83.6
Fe_2O_3	20.5	14.4	14.4	16.7	14.1

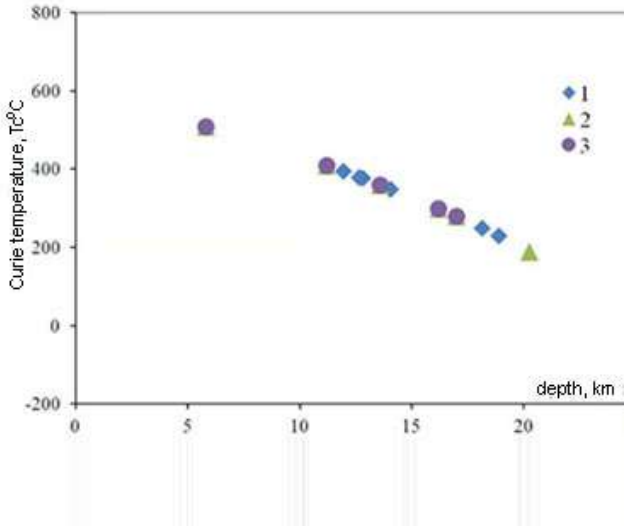


Fig. 4. Inclusions of moderately titanium and alumina titanomagnetites (TiMgt) in salite pyroxene (Sal).

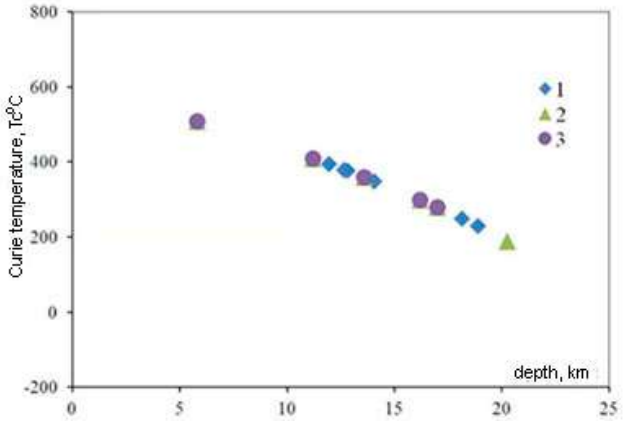


Fig. 5. Dependence of the temperature of Curie ferromagnetic minerals on the depth of Late Cretaceous volcanic complexes of Khojavand (1), Azykh (2) and Gochas (3) depressions of the Lesser Caucasus (Kawai, 1956).

Teshenites, present as thin plate injection, which are vertically composed of picroteshenite, melano-, meso- and leucocratic teshenites, teshenite-syenite, are to a sufficient degree differentiated. Those differentiates are cut by light grey and whitish grey veins of analcime syenites.

Iron-titan oxide minerals in the rocks of the complex of the Azykh depression of the Goycha-Akeri zone are represented by moderately and highly titanous magnetite and singular ilmenites (Tables 8, 9).

In the rocks of basalt-andesibasalt complex, moderately titanium magnetites crystallized almost at the same time with the clinopyroxene phenocrysts (Table 8, samp. 1, 2). In a number of cases, they are concentrated around amphibole as drops. Along with them, there are also seen shapeless, secondary maghemite and bloody-red hematite. Content of ulvospinel component varies 28% to 33%.

In the rocks of subalkaline of trachybasalt-trachyandesibasalt complex, the content of titan in the titanomagnetite significantly increases (Table 8,

samp. 3, 4). Unlike the rocks of basalt-andesibasalt complex, titanomagnetite in the rocks of this complex is present as inclusions in clinopyroxenes, which leads to the conclusion that titanomagnetite crystallizes before clinopyroxene.

All determined peculiarities of titanomagnetites indicate development of their impregnations within the differentiates of basalt-andesibasalt complex in moderately thermobaric conditions. However, comparatively earlier crystallization of the phenocrysts of titanomagnetite within the rocks of subalkaline of trachybasalt-trachyandesibasalt complex suggests that the development process took place in relatively deeper and oxidative conditions.

The Miskhan-Kafan structural-formation zone. This structural-formation zone, located in the northeast outskirts of the Goycha-Garabagh zone, is limited by the Lachin-Bashlybel faults in the northwest, and the Girratagh fault in the east.

Structurally, the Gochas depression is confined to the Miskhan-Kafan structural-formation zone. The Late Cretaceous volcanites comprise differentiates of the volcanic complexes confined to the axis zone of this depression.

Unlike the Azykh depression, iron-titan oxide minerals in the rocks of the Gochas depression consist of chrome spinel, picotite, titanomagnetite, maghemite, ilmenite and hematite.

Late Cretaceous volcanic complexes of the Gochas depression fill the narrow long flat-bed structure that strikes northwest. Most scientists (Ostroumova et al.., 1988, Karjakin, 1989) consider that the volcanism and accumulation of sediments came about in the Late Senonian period.

There, similarly to the Azykh depression, the rocks of the basalt-andesibasalt complex were developing during the early substage of volcanism in the Late Senonian period. They are composed of highly titanium olivine-plagioclases, olivine-plagioclase-pyroxene basalts (Table 1). In those poorly differentiated basalts, titanomagnetite in many phenocrysts is involved in singular grains, and is somewhat enriched with titanium (Table 8, samp. 4, 5). Moreover, melanobasalts were determined to contain picotite (Ostroumova et al., 1988). The rocks of trachybasalt-trachyandesibasalt complex, which characterize the late substage of Late Senonian volcanism, are composed of subalkaline trachybasalts, trachyandesibasalts, even trachyandesibasalts, which contain magnetite that is relatively more enriched with titanium (Table 1).

In the most high-temperature conditions, there occurred crystallization of olivine-pyroxene-plagioclase basalts (1,050 °C), while for olivine-plagioclase varieties of basalts, the temperature was calculated as 820–920 °C (Table 7). The temperature of chrome spinel-olivine equilibrium (SiO_2=39.16, FeO=22.30, MgO=38.43; d_{hkl130}=2.780–2.784Å; $Fo_{73–76\%}$), present in melanobasalts, was calculated as 1,100–1,150 °C. Presence of homegenity, and also high content of *ulvospinel molecule* involved in the composition of titanomagnetites indicates that porphyry-like phenocrysts of olivine dolerites and basalts crystallized at the deepest intermediate sites (14–19 km) (Fig. 5).

Table 8. Chemical, crystal-chemical and minal analyses of magnetites of basalt-andesibasalt and trachybasalt-trachyandesibasalt complexes of the Gochas and Azykh depressions.

	Gochas depression						Azykh depression			
Complexes	Basalt-andesibasalt						Basalt-andesibasalt		Trachybasalt-trachyandesibasalt	
Rocks	basalts						basalts		trachyandesites	
№ sample / components	1	2	3	4	5	6	1	2	3	4
TiO_2	0.60	4.16	12.16	15.36	14.21	7.88	0.41	2.16	12.20	12.14
Al_2O_3	19.31	18.24	1.16	3.21	3.75	4.36	0.79	1.23	4.94	4.89
Cr_2O_3	9.34	21.00	0.38	n.d.	0.42	0.75	n.d.	0.21	0.43	0.28
Fe_2O_3	48.76	31.38	45.21	43.39	43.55	36.42	67.36	63.20	41.38	41.21
FeO	7.84	13.25	38.24	36.90	36.42	47.65	30.80	32.21	36.46	36.51
MnO	0.38	0.56	1.30	0.63	0.63	0.82	0.31	0.38	0.75	0.61
MgO	13.30	10.40	1.24	0.42	1.10	1.78	0.33	0.61	3.48	3.91
CaO	0.10	0.06	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
∑	99.63	99.05	99.69	99.91	100.08	99.66	100	100	99.64	99.55
Tc	n.d.	510	360	280	300	410	580	530	350	350
Ti	0.013	0.010	0.343	0.428	0.388	0.219	0.012	0.061	0.332	0.330
Al	1.603	0.713	0.051	0.140	0.163	0.190	0.035	0.055	0.211	0.210
Cr	0.206	0.550	0.011	0.000	0.016	0.004	0.000	0.006	0.012	0.008
Fe^{+3}	0.165	0.331	1.275	1.346	1.189	1.327	1.939	1.809	1.126	1.120
Fe^{+2}	0.450	0.870	1.198	1.030	1.105	1.127	0.984	1.024	1.103	1.103
Mn	0.009	0.016	0.041	0.020	0.019	0.025	0.010	0.012	0.023	0.019

Continuation of Table 5

	Gochas depression						Azykh depression			
Complexes	Basalt-andesibasalt						Basalt-andesibasalt		Trachybasalt-trachyandesibasalt	
Rocks	basalts						basalts		trachyandesites	
№ sample / components	1	2	3	4	5	6	1	2	3	4
Mg	0.553	0.514	0.069	0.023	0.059	0.098	0.019	0.034	0.186	0.211
Ca	0.003	0.002	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Usp	n.d.	0.6	17.3	37.0	40.7	n.d.	1.2	6.1	27.7	32.9
Mgt	8.1	41.0	70.9	5.55	49.9	62.7	96.7	90.0	56.5	56.3
Il	1.2	6.2	9.8	5.2	3.7*	22.2	n.d.	n.d.	8.3	n.d.
Sp	54.5	29.4	2.0	2.3	5.2	9.6	1.8	2.7	10.5	10.3
Hm	n.d.	n.d.	n.d.	n.d.	n.d.	5.6	0.3	n.d.	n.d.	0.5

Table 9. Chemical, crystal-chemical and minal compositions of the ilmenites of the basalt-andesibaslt complexes of the Gochas and the Azykh depressions

	Gochas depression			Azykh depression	
№ samples / components.	3	4	5	1	2
TiO_2	49.36	48.68	48.72	48.82	48.80
Al_2O_3	1.10	0.64	0.73	0.46	0.58
V_2O_3	0.18	0.44	0.38	0.82	0.94
Cr_2O_3	0.16	0.23	0.24	1.75	1.64
Fe_2O_3	5.28	6.51	6.53	4.05	3.74
FeO	41.97	40.50	40.48	42.71	42.35
MnO	1.38	2.63	2.71	0.64	0.68
MgO	0.52	0.33	0.43	0.43	0.66
∑	99.95	99.96	100.22	99.68	99.43
t°C	820	920	1050	870	900
fo_2	-12	-11.3	-9.2	-12.5	-11.8
Ti	0.931	0.922	0.920	0.928	0.927
Al	0.033	0.019	0.021	0.014	0.017
V	0.003	0.009	0.008	0.017	0.019
Cr	0.003	0.004	0.005	0.035	0.033
Fe^{+3}	0.100	0.124	0.123	0.077	0.071
Fe^{+2}	0.880	0.853	0.851	0.903	0.895
Mn	0.029	0.056	0.057	0.010	0.015
Mg	0.019	0.012	0.016	0.016	0.024
$MnTiO_3$	2.1	5.2	5.3	0.9	1.4
$MgTiO_3$	1.8	1.1	1.5	1.5	2.2
Fe TiO_3	82.5	79.2	76.3	84.1	82.7
Fe_2O_3	13.0	14.5	14.9	13.4	13.7

Therefore, iron-titanium oxide minerals in the compound of highly titanium differentiates of the Khojavand, Azykh and Gochas depression have in general crystallized in an oxidative environment. Thus, crystallization of moderately titanium magnetite occurred before or at the same time with clinopyroxene.

Unlike the intrusive teshenites, the rocks of trachybasalt-trachydolerite complex crystallized in a comparatively reductive environment. At the same time, impregnations of the main plagioclase underwente crystallization either together or later than titanomagnetite.

The calculated Curie points (Tc=230, 250) and therefore ulvospinel molecules ($Usp_{48–53}$) in the composition of the titanomagnetite indicate that intrusive teshenites crystallized in relatively deeper conditions, because of which the relatively titanium magnetites are less enriched with alumina.

Phenocrysts of moderately titanium magnetites in andesibasalts and andesites developed at deeper intermediate sites.

Conclusions:

1. Based on calculated and experimental Curie points and physical-chemical parameters (t, fo_2, H и др.), and also the determined variations of compositions, we may state that crystallization of iron-titanium oxide minerals occurred at intermediate sites of various

depths. At the same time, during the Late Coniacian and Early Santonian periods, in the Gazakh, Agjakand and Agdara depressions, there continued stable depression, which caused poorly differentiated portions of olivine basalt melt to localize at deeper intermediate sites, from which the highly titanous magnetite crystallized. At the boundary of the Upper Santonian-Lower Campanian periods, the activity of magma-providing faults within the Gazakh Depression significantly weakened. Therefore, within this fault, near-the-surface intermediate sites formed, the presence of which may be indicated by spatial division of volcanic centers, composed of rhyodacites, perlite, andesite and dacite.

2. Unlike the Gazakh depression, within the Agjakand and Agdara depressions, the process of compression manifested more intensely, causing thermal impact of hot basalt melt with above embedded arkose containing sandstones. This caused those sandstones to melt and led to generation of pallingenic rhyodacites and dacites.

3. Within the Khojavand and Azykh depressions, in the conditions of depression during the Early Santonian Age, a poorly differentiated trachybasalt-trachydolerite complex formed. The differentiates of this complex include moderately titanous titanomagnetite. In relatively oxidative conditions during the Late Santonian Age, the differentiates of the tephrite-teshenite complex crystallized. In the same place, due to slowing of the crystallization of plagioclase, moderately titanium magnetite in the tephrites was significantly enriched with alumina. In the composition of intrusive teshenites, crystallization was undergone by ulvospinel titanomagnetite.

4. In the Gochas depression, crystallization in the basalts and andesibasalts was first undergone by clinopyroxene. In the compound of rocks of subalkaline series, more titanium magnetite crystallized together with clinopyroxene.

5. During the crystallization of the Late Cretaceous volcanic complexes at intermediate sites of various depths, the most melanocratic components of magmatic melts formed at relatively higher temperatures and restorative conditions (t= 1030–1080ºC, fo_2= –9,2–10). Sedimentary melts, which by composition correspond to andesitess, dacites and rhyolites, were developed in comparatively low thermodynamic conditions (t=758–980 ºC, fo_2= –5.9–7.2), accompanied by oxidized volatile components.

References

Akhundov, F.A., 2003. Pozdnemelovye vulkanicheskie formacii Malogo Kavkaza. [Late Cretaceous volcanic formations of the Lesser Caucasus].Baku, 232.

Anderson, A.T., 1968. Oxidation of the La Blanche Lake titaniferrous magnetite deposit, Quebec. Journal of Geology, 76, 5, 528–547.

Avdeev, A.G., Ostroumova, A.S., Center, I. Ja., Shafiev, H.I., 1989. Epilejcitovye tefrity verhnemelovogo vulkanicheskogo kompleksa Martuninskogo sinklinorija (Juzhnyj Karabah). [Epileucite tephrites of the Upper Cretaceous volcanic complex of the Martuni Sinclinorium (Southern Caucasus)] Bulletin of the Moscow Society of Naturalists. Geological Department, 64, 3, 86–96. (In Russian)

Buddington, A.F., Lindsley, D.H., 1964. Iron-titanium oxide minerals and synthetic equivalents. Journal of Petrology, 5, 310–357.

Carmichael, I.S.E., 1967. The iron-titanium oxides of salic volcanic rocks and their associated ferromagnesian silicates. Contributions to Mineralogy and Petrology, 14 (1), 36–64.

Creer, K.M. and Ibbetson, J.D., 1970. Electron microprobe analyses and magnetic properties of non-stoichiometric titanomagnetites in basaltic rocks. Geophys. J. R. astr. Soc., 21, 485–511.

Fabries, J., 1979. Spinel-olivine geothermometry in peridotites form ultramafic complexes. Contributions to Mineralogy and Petrology, 69, 329–336.

Genshaft, Ju.S., Celmovich, V.A., Gapeev, A.K., Solodovnikov, G.M. 1999. Znachenie Fe-Ti oksidnyh mineralov v naukah o Zemle. Vestnik OGGGG RAN, 1(7), 3–12. (In Russian)

Genshaft, Ju.S, Celmovich, V.A, Gapeev, A.K. 2003. Kristallizacija vysokotitanistoj ferroshpineli v P-T uslovijah verhnej mantii [Crystallization of highly titanous ferrospinel in P-T conditions of the upper mantle]. Fizika Zemli, 3, 71–75. (In Russian)

Geologija Azerbajdzhana. 2005. Magmatizm. V. III.

Karpova, O.V., 1974. Titanomagnetitovye rudy Juzhnogo Urala [Titanomagnetite ores of the Southern Ural]. Moskva: Nauka, 152 c. (In Russian)

Karjakin, Ju.V., 1989. Geodinamika formirovanija vulkanicheskih kompleksov Malogo Kavkaza [Geodynamics of the development of the volcanic complexes of the Lesser Caucasus] Moskva: Nauka, 150. (In Russian)

Kawai, N., 1956. Exsolution of titanomagnetites and its effect on rock-magnetism. Proceedings of the Jap.Acad., 32, 464–468.

Lepage, L.D., 2003. ILMAT: an excel worksheet for ilmenite – magnetite geothermometry and geobarometry. Comput. Geosci. 29 (5), 673–678.

Lindsley, D. H. & Spencer, K.J., 1982. Fe-Ti oxide geothermometry: Reducing analyses of coexisting Ti-magnetite (Mt) and ilmenite (Ilm) abstract AGU 1982 Spring Meeting Eos Transactions. American Geophysical Union, 63, 18, 471.

Osborn, E.F., 1983. On the significance of the spinel phase in subalkaline volcanic magmas. Memoir of the geological society of China. 5, 1–12.

Ostroumova, A.S., Center, I. Ja., Avdeev, A.T., Bugrova, J.M. 1991. Pozdnemelovye vulkanicheskie serii Gochasskogo progiba (Malyj Kavkaz) [Late Creataceous volcanic series of the Gochas depression (Lesser Caucasus)]. Sovetskaja geologija, 7, 65–72. (In Russian)

Sack, R.O., Carmicahael, I.S., Rivers, S.E., Ghiorso, M.S., 1980. Ferric-ferous equilibria in natural silicate liquids at 1 bar. Contributions to Mineralogy and Petrology, 75, 369–376.

Stormer, J.C., 1983. The effects of recalculation on estimates of temperature and oxygen fugacity from analyses of multicomponent iron-titanium oxides. American Mineralogist, 68, 5–6, 586–594.

Mamedov, M.N., 1999. Petrologija i geohimija pozdnemelovyh i jeocenovyh magmaticheskih for-macij Malogo Kavkaza i Talysha [Petrology and geochemistry of the Late Cretaceous and Eocene magnetic formations of the Lesser Caucasus and Talysh]. Baku: Nafta-press, 400. (In Russian)

Mamedov, M.N., Babaeva, G.D., Sadygov, N.M., 2012. Klinopirokseny trahibazalt-trahidoleritovogo i tefrit-teshenitovogo kompleksov Hodzhavendskogo progiba. [Clinopyroxene trachybasalt-trachydolerite and tephrite-teshenite complexes of the Khojavand depression] Otechestvennaja geologija, 6, 48–55. (In Russian)

Mamedov, M.N., Babaeva, G.D., Panahi, K.A., Sadygov, N.M., Kerimov, V.M., 2013. Indikatornye znachenija zhelezo-titan oksidnyh mineralov v processe kristallizacii porod trahibazalt-trahidoleritovogo i tefrit-teshenitovogo kompleksov Hodzhavendskogo progiba Malogo Kavkaza. [Indicative values of the iron titanium oxide minerals in the process of crystallization of rocks of trachybasalt-trachydolerite and tephrite-teshenite complexes of the Khojavand depression of the Lesser Caucasus] News of Baku University, series of natural sciences, 3, 76–85.

Mamedov, M.N., Panahi, K.A., Babaeva, G.D., Sadygov, N.M., 2015. Petrogeneticheskie znachenija shpinelidov v processe kristallizacii porod trahibazalt-trahidoleritovogo i tefrit-teshenitovogo kompleksov Hodzhavendskogo progiba Malogo Kavkaza. [Petrogenetic values of spinelides in the processes of crystallization of rocks of trachybasalt-trachydolerite and tephrite-teshenite complexes of the Khojavand depression of the Lesser Caucasus] News of Baku University, series of natural sciences, 3, 82–96. (In Russian)

Nagata, T., 1965. Magnetizm gornyh porod [Magnetism of rocks]. Moscow: Mir, 347. (In Russian)

Pecherskij, D.M. 1975. Magnetizm i uslovija obrazovanija izverzhennyh gornyh porod. [Magnetism and node formations of eruptive rocks] Moscow: Nauka, 1975, 288. (In Russian)

Pecherskij, D.M. 1985. Petromagnetizm i paleomagnetizm. [Petromagnetis and paeomagnetism] Moscow: Nauka, 128. (In Russian)

Shikhalibejli, H. Sh., 1994. Geologija i poleznye iskopaemye Nagornogo Karabaha Azerbajdzhana [Geology and fossils of the Nagorno-Karabakh of Azerbaijan]. Baku: Elm, 281. (In Russian)

Zubov, A.G., Bazanova, L.I., Ananev, V.V., Ovsjannikov, A.A., Zhidkov, G.V., 2015. O primenenii titanomagnetitovogo metoda dlja opredelenija glubiny magmaticheskogo ochaga na primere nekotoryh kamchatskih vulkanov [On use of titanomagnetite method of determining depth of magmetite sites on the example of some Kamchatka volcanoes]. Material of annual conference Volcanism and Processes Related To It, dedicated to Day of Volcanologist,, 138–147. (In Russian)

Journal of Geology, Geography and Geoecology

ISSN 2617-2909 (print)
ISSN 2617-2119 (online)

Journal home page: geology-dnu.dp.ua

Journ. Geol. Geograph. Geology, 30(4), 706–717.
doi: 10.15421/112165

Appraisal of the Quality Parameters of the Groundwater used for Domestic and Irrigation Purposes in the Hard Rock Aquifer System of the Vasishta sub- basin of the Vellar River, Tamil Nadu

Poongodi R ., Venkateswaran S., Suresh R., Vimala R.

Periyar University, Salem, Tamil Nadu, India Govt. Arts College for Women, Salem, Tamil Nadu, India, poovijigeo@gmail.com, geosvenkat@gmail.com

Received: 02.12.2020
Received in revised form: 15.07.2021
Accepted: 25.10.2021

Abstract. This article presents an appraisal of the quality of groundwater in the hard rock aquifer system of the Vasishta sub basin, of the Vellar River Basin. Seventy nine representative groundwater samples were collected from dug and bore wells which are intensively used for domestic and irrigational purposes. The physical parameters viz. P^H, EC and TDS were estimated in the field using a portable multiparameter meter. The groundwater samples were transported to the laboratory for measuring major ionic concentrations viz, Ca, Mg, Na, K, CO_3, HCO_3, Cl, SO4, F and NO_3. The hydrochemical data were graphically projected and spatial temporal thematic maps generated with reference to the World Health Organization (WHO) and Bureau of Indian (BIS) Standards. The peoples living in the sub basin engage in agricultural activities where the groundwater availability is sufficient. The groundwater is a major source for meeting their basic needs, such as for domestic, irrigational and industrial purposes. Good correlation is exhibited between EC and TDS Cl, SO_4.Cl exhibits good correlation with Mg and Ca (0.817), (0.751) indicating leaching of secondary salts. TDS and EC showed strong correlation with Cl, SO_4. Clustering groundwater samples based on their similarity is known as Q-mode type clustering method. Spatial and temporal maps of the water quality index reveal that the majority of the groundwater samples fall under the categories excellent to good.

Keywords: groundwater quality, Vasishta sub basin, domestic and irrigational purposes, multiparameter, major ionic concentration, WHO and BIS Standard, Correlation matrix.

Оцінка параметрів якості підземних вод для побутових та іригаційних цілей у системі водоносних горизонтів твердих порід (Хард рок) суббасейну Васишта, річка Веллар Таміл Наду

Пунгоді Р., Венкатесваран С., Сюреш Р., Вімала Р.

Періярський університет, Салем, Таміл Наду, Індія, poovijigeo@gmail.com, geosvenkat@gmail.com

Анотація. Для даного дослідження було розглянуто оцінку якості підземних вод у системі водоносного шару твердих порід суббасейну Васишта, річка Веллар. Сімдесят дев'ять проб підземних вод були зібрані з викопаних і бурових свердловин, які інтенсивно використовуються для побутових і іригаційних цілей. Фізичні параметри: PH, EC та TDS, оцінені в польових умовах за допомогою портативного мультипараметра. Зразки підземних вод транспортували до лабораторії для оцінки основних концентрацій іонів, зокрема Ca, Mg, Na, K, CO_3, HCO_3, Cl, SO_4, F та NO_3. Результати гідрохімічних досліджень графічно спроектовані та просторово-часові тематичні карти, сформовані з посиланням на Світову організацію охорони здоров'я (ВООЗ) та Бюро індійських стандартів (BIS). Люди, які живуть у підбасейні, займаються сільським господарством там, де достатньо підземних вод, підземні води є основним джерелом для задоволення основних потреб, таких як побутові, зрошувальні та промислові. Хороша кореляція виявляється між EC та TDS, Cl, SO_4. Cl демонструє хорошу кореляцію з Mg та Ca (0,817), (0,751), що свідчить про вимивання вторинних солей. TDS та EC показали сильну кореляцію з Cl, SO_4. Кластеризація зразків підземних вод на основі їх подібності відома як метод кластеризації типу Q-mode. Просторові часові карти індексу якості води показують, що більшість проб підземних вод підпадають під категорії від відмінної до хорошої.

Ключові слова: якість підземних вод, суббасейн Васишта, побутові та іригаційні цілі, мульти параметр, основна іонна концентрація, стандарт ВООЗ та Бюро індійських стандартів, кореляційна матриця.

Introduction.

Water is often considered to be one of the most important resources of our planet. It is the most abundant physical substance and transparent liquid on the earth. Groundwater is the largest obtainable resource for fresh water. Ground water is commonly referred as water which lies below the surface of the earth occupying the interstices and voids in various formations (*Todd,*

1980).It is the major readily available source of fresh water on our earth (*Ragunath, 1987*). Nowadays ground water resources are being continuously exploited from the aquifers to meet industrial, agricultural and domestic needs. Rapid urbanization, industrialization, frequent failures in the monsoon and reduced surface water resources have created a major threat to the groundwater resource in terms of quantity and quality.Groundwater is always an underwater movement and the flow takes place from the higher potentiometric surface to the lower potentiometric surface. Groundwater geochemistry is a forensic tool which helps to understand the possible processes that control groundwater chemistry as well as helping with planning for efficient water management (*Subramani et al. 2010*).Therefore chemical fluxes in groundwater environment indicate the dynamic movement and prolonged hydrochemical interactions (*Bernard et al. 2006*). *Sreedevi et al. (2001)* have used the remote sensing and GIS techniques to understand the occurrence of groundwater in various geomorphological units of the study area. Water resources play a vital role in the growth and development of human civilization on the surface of the earth and play a key role in the economy of any country. Ground water resources in the Vasishta sub-basin, Tamil Nadu, India are being continuously exploited to meet the demand for the water supply and irrigation because the water available in surface water bodies such as wells, tanks and reservoirs is not sufficient, and thus the resulting rapid decline in the ground water head in many areas. Groundwater quality is also affected in many places of the sub-basin due to anthropogenic activities. In hard rock terrain with arid and semi-arid climatic conditions, all the water requirements are met by sub-surface water due to reduction in surface water resources. Changing climatic conditions, growing population, industrialization, and intensive agricultural and urbanization activities have led to a high demand for groundwater especially in countries experiencing economic growth like India (*Srinivasamoorthy et al. 2011*). However, no systematic work has been carried out in this sub-basin to understand the ground water regime. Thus, it is essential to assess the ground water quality for extraction and management of the water resources, which is emerging as a great public concern in this region.

Study Area. The Vasishta sub- basin of the Vellar River Basin, in Tamilnadu covers in total an area of 1770.78 km^2. The Vasishta is a major stream river originating from the southern slope of the Kalrayan Hills and flows through Kurichi, Belur, Pethanaikenpalaiyam, Attur, Thalaivasal and Aragalur, habitations of Salem and Perambalur districts of Tamilnadu. Major and minor artificial recharge structures, constructed across the streams significantly contribute to groundwater recharge in the sub basin. Irrigation mainly depends upon the groundwater resources from dug and bore wells. Groundwater is the main source of water for agricultural activities and is pumped through dug and bore wells. (Poongodi and Venkateswarn 2018). The important plants cultivated are finger millet, jasmine, cucumbers, maize, groundnuts, celosia, betel trees, tapioca tubers, cotton grass, sugar cane, turmeric, coconuts, bananas and areca nut.The base map of the study area is given in Fig.1

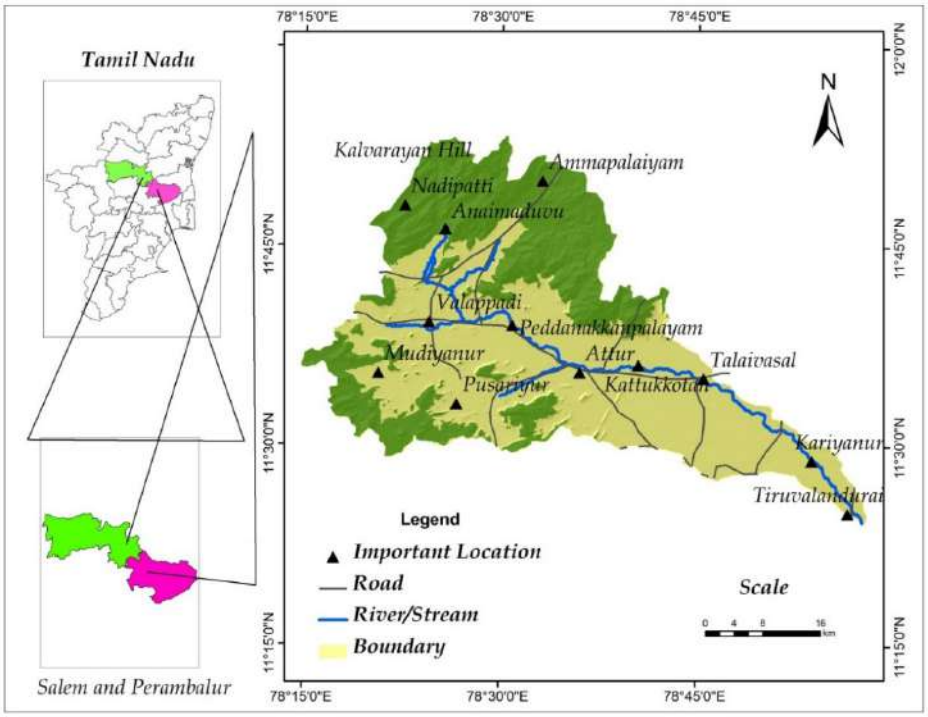


Fig.1. Base map of the Vasishta sub basin

Geology and hydrogeological settings. The Vasistha sub- basin is mainly underlain by crystalline rocks of Archean age, of gneissic rocks, charnockite, pyroxenite, amphibole pyroxene granulite and mylonite respectively. The geomorphological units are structural hills and pediplain denudation hillspediments and floodplain. The structural hill is located in the northwestern parts of the study area whereas the southwestern and eastern parts of the study area are occupied by gently undulating and dotted relic isolated hillocks underlain by a hard rock crystalline aquifers system and groundwater phreatic condition. The occurrence and movements of groundwater through weathered zones is followed by occurrence of fissures, joints and fractures, The availability of groundwater in the sub- basin is greater in the river courses of paleochannels, foothills of the Kalrayan Hills, Bothumalai, and Sitheri Hills.

Materials and Methods.

A total of 79 groundwater samples was systematically collected from sources intensively utilized by farmers. Physical parameters such as colour, odour, taste, turbidity, P^H and EC were estimated in the field itself. The samples were sent to the laboratory for further ionic concentration analysis. The ionic concentration was estimated using titration method, spectrophotometer and flame photometer. Shown in Fig.2.

Standardization of analytical data. The hydochemical data were standardized graphically as shown in Fig. 3. It shows the total sum of cations versus the total sum of anions for groundwater samples, it also indicates all the samples on or near the aquiline in the graph. The quality of the analysis was documented by standardization using blank, spike, and duplicate water samples.

The hydrochemical data have been projected graphically using Piper's, Wilcox's, Donnen's and Gibb's plots for understanding the suitability of water for domestic irrigation and industrial purposes. A set up of spatio- temporal maps have been generated in the GIS platform with reference to the WHO and BIS Standards.

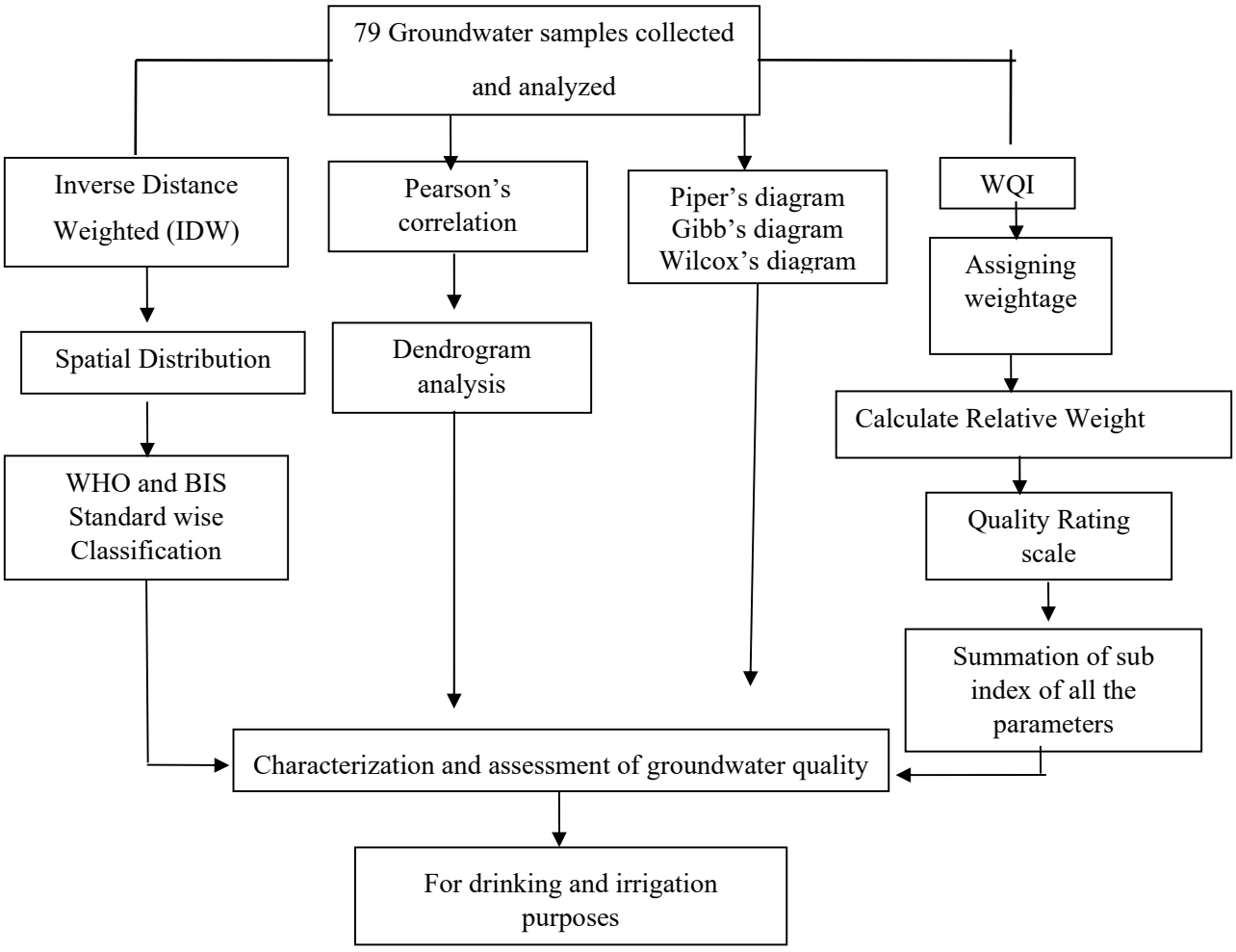


Fig. 2. Flow chart for the Methodology

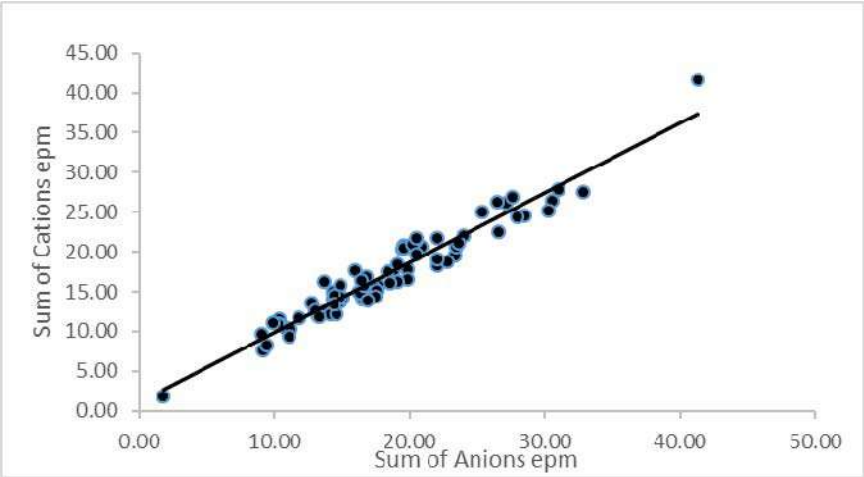


Fig. 3. Correlation co-efficient between total concentration of Cation epm and total concentration of Anion epm

Result and Discussion.

Water quality appraisal. The WHO standard was followed for the physical and chemical parameters for the groundwater samples of the study area. It was found that P^H limit varies from 6.74 to 8.41, which indicates that groundwater is acidic, alkaline, and 5% to 95% of the groundwater sample is of potable category, the P^H value within the maximum falls within the permissible category. *The groundwater through the quantity of transmitting electrical current*. WHO limit in EC 1500 µs/cm^2, The values varied from 190 µs/cm^2, to 5130 µs/cm^2. The high values of indicators of a huge quantity of salt occur in groundwater. 22 samples show a low amount of salt. Other samples covered high electric conductivity. TDS ranges between 373.52 mg/l to 4669 mg/l. The TDS varied from 124 to 3335 mg/l, which indicates rock water interaction in relation to groundwater, the TDS depending upon variation process such as domestic sewage and agricultural activities, The most common source of calcium and magnesium in groundwater concentration of Ca value varied from16 to 281 mg/l. 96% of the sample was of allowable category, 4% of the sample only was not of potable category, Mg content value varied from 7 to 153 mg/l, 94% of the sample was of potable category,6% of the sample was not of potable category. The Na values varied from 10 mg/l to 360 mg/l. It values Most of the samples (96%) were of potable category, 4% of the samples were not potable, K value varied from 0.5 to 43.9 mg/l .57% of the samples were of allowable category, 32% of the groundwater samples were not of potable category. WHO limit 200 mg/l of CO_3 HCO_3, The values varied from 50 mg/l to 622.4 mg/l. The chloride range was 25 mg/l to 1110. The most desirable was 250 mg/l. This is explained by the drainage system and polluting environments of the study area. The sulfate range was from 10 mg/l to 380 mg/l. All samples were within the WHO allowable limit. Nitrogen ions contaminating subsurface endogenic activities originated in agricultural sources. The values varied from 1.5 mg/l to 18 mg/l. This groundwater samples of this study area all within desirable limits. Major ions were as follows in abundance; Ca >K >Mg>Na and CO_3>Cl>SO_4> HCO_3>NO_3 respectively. Multivariate statistical analyses display good correlation. Quality of groundwater for drinking purposes based on WHO and BIS standards are given in Table.2.

Water quality Index (WQI) for domestic purposes. Water Quality Index (WQI) has been utilized as a tool to assess the spatial and temporal changes in the quality of groundwater and its appropriateness for drinking purposes, Ketata et al.(2012) and is a method using individual water quality parameters on the overall quality of the water. This calculation based on WHO standards 2011 and BIS 1991. (Vasanthivigar et al 2010,) Shown in Table 1. Its computing followed the physico- chemical parameters analysis of each of the 12 parameters, for major cations and anions

$$W_i = w_i / \sum_{i=1}^{n} w_i \quad (1)$$

Where, W_i is the relative weight,w_i is the weight of the each parameter and n is the number of parameter. In the second step a quality rating scale q_i for the each parameter is assigned by dividing its concentration in each water sample (WHO 2011).Shown in Table 2.

$$q_i = C_i / S_i \times 100 \quad (2)$$

Where q_i quality rating, C_i is the concentration of each chemical parameter in mg/l, according to WHO guidelines (2011).For computing the WQI, the sub index of its parameter (SI) is first determined for each physic- chemical parameter WQI as per the equation, Shown in Table 4.

$$SIi = W_i \times q_i \quad (3)$$

$$WQI = \sum SIi \quad (4)$$

Where, *SIi* is the sub index of its parameter, q_i the rating based on concentration i th parameter, n number of the parameter.

Categorization of groundwater quality according to water quality index is as follows; <50 % Excellent water, 50 %-100 % good water, 100 %-200 % poor water, 200 %-300 % very poor water,> 300 % water unsuitable for domestic purposes. The relative weight shown in Table, 1 quality rating, a total of seventy nine samples of groundwater samples was taken for water quality index in the sub- basin. Spatial distribution maps for water quality index showed 27.85 % of the sample as belonging to the Excellent water category, 59.50 % of the sample as belonging to the Good category and 12.65 % of the sample as belonging to the Poor water category for domestic purposes respectively in the sub-basin. The Water Quality Index spatial map is presented in Fig.4

Table 1. Percentage of groundwater samples exceeding limits for drinking purposes based on WHO and BIS standard

Sl.No	Parameters	Minimum	Maximum	Mean	WHO (2011)	BIS (1991)	Desirable (%)	Allowable (%)	Not potable (%)
1	P^H	6.74	8.41	7.41	6.5–8.5	6.5–8.5	100	-	-
2	EC (µS/cm)	190	5130	2151.01	1500	-	2	60	38
3	TDS (mg/l)	124	3335	1398.42	500	500	2	64	34
4	Ca (mg/l)	16	281	110.53	75	75	18	78	4
5	Mg (mg/l)	7	153	64.76	50	30	38	56	6
6	Na (mg/l)	10	360	166.36	200	-	4	-	96
7	K (mg/l)	0.5	43.9	10.40	12	-	62	6	32
8	HCO_3 (mg/l)	50	622.404	336.1	500	-	11	89	-
9	Cl (mg/l)	25	1110	298.74	250	250	66	32	2
10	F (mg/l)	0.2	1.9	0.89	1.5	1.5	61	30	9
11	SO_4 (mg/l)	10	380	132.44	250	200	87.34	12.66	-
12	NO_3 (mg/l)	1.5	18	9.93	45	45	100	-	-

Table 2. Relative weightage of the chemical parameter for water quality index

Sl.No	Physico- chemical parameter	WHO Standers (2011)	Weightage (w_i)	Relative weightage $W_i = w_i / \sum_{i=1}^{n} w_i$
1	pH	6.5–8.5	4	0.117647059
2	EC (µS/cm)	1500	3	0.147058824
3	TDS (mg/l)	500	4	0.117647059
4	Ca (mg/l)	75	2	0.058823529
5	Mg (mg/l)	50	1	0.029411765
6	Na (mg/l)	200	2	0.058823529
7	K (mg/l)	12	2	0.058823529
8	HCO_3 (mg/l)	500	3	0.088235294
9	Cl (mg/l)	250	3	0.088235294
10	F (mg/l)	1.5	2	0.058823529
11	SO_4 (mg/l)	250	3	0.088235294
12	NO_3 (mg/l)	45	5	0.088235294
			$\sum wi$ =34	$\sum Wi$ =1.00

Table 3. Water Quality Index is the groundwater sample in the Vasishta su-b basin

Sl.No	Water Quality types	Groundwater sample No
1	Excellent water	2,4,8,10,13,16,22,23,24,26,35,43,47,51,53,57,58,63, 74,77,78 and 79
2	Good water	1,3,5,6,7,9,11,12,14,15,17,18,19,20,21,25,29,30,31, 32,33,34,36,38,39,41,44,46,48,49,52,54,55,56,59,61, 62,64,65,67,68,69,70,72,73,75 and 76
3	Poor water	27,28,37,40,42,45,50,60,66 and 71

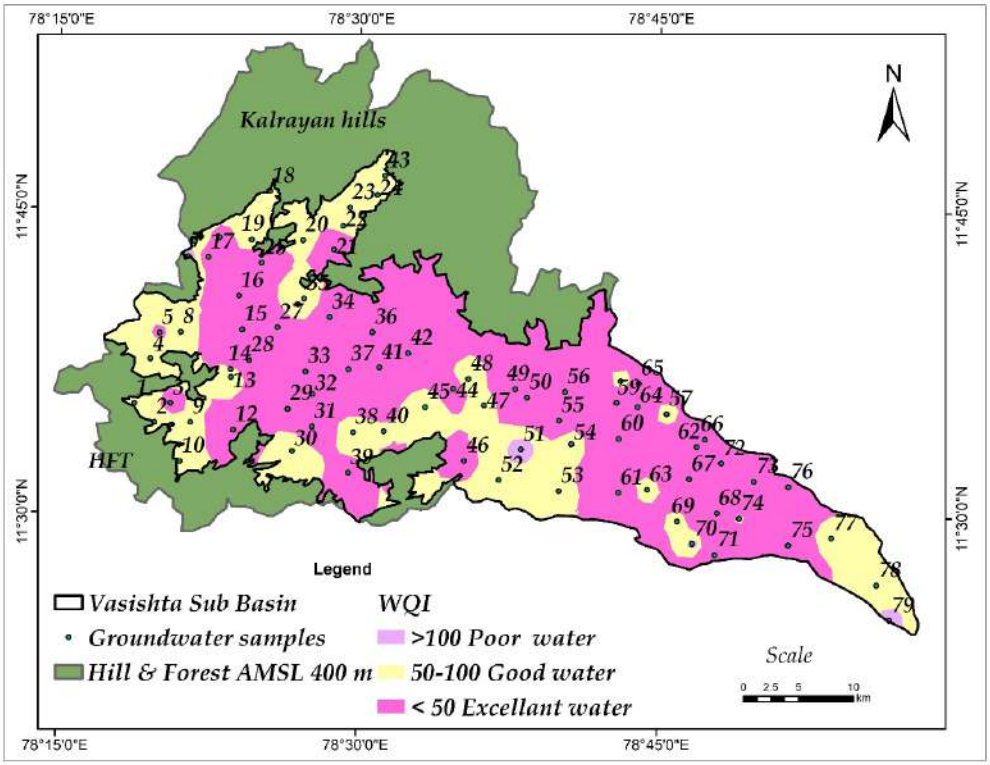


Fig. 4. Water Quality Index spatial map of the Vasishta sub- basin

Hydrogeochemical Facie. Piper's diagram (1944) includes two triangles, one for plotting cations and the other for plotting anions. The cation and anion fields are combined to show a single point in a diamond shaped field from which inferences drawn on the basis of hydrogeochemical facies concept are useful in bringing out the chemical relationship among groundwater samples in more definite terms rather than with other possible plotting methods.

The following groundwater facies have been identified in the sub basin; Na-K-Cl-SO4 facies and Ca-Mg-HCO3 type, cation ions fall under domain C-sodium and potassium facies, domain A-Magnesium type, anion such as, domain E-sulphate type, F-bicarbonate type. The majority of the groundwater samples fall under Ca-Mg-HCO3 groundwater facies presented in Fig.5

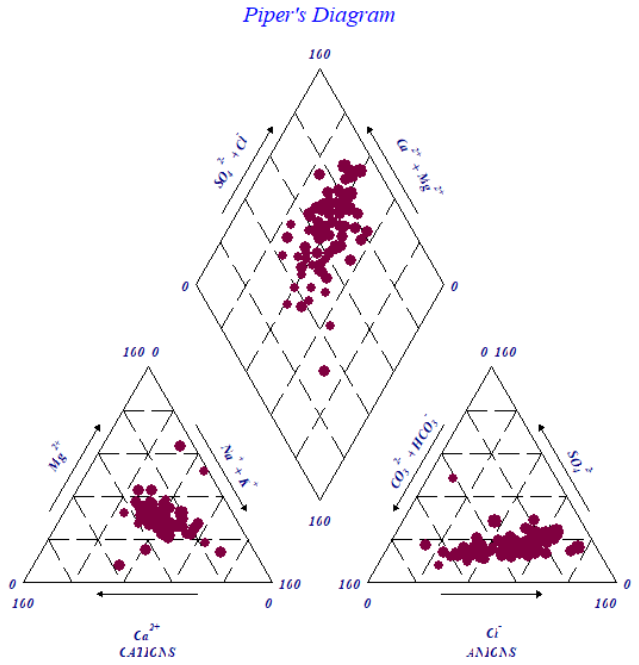


Fig. 5 Piper's hydrogeochemical facies of the Vasishta sub basin

Groundwater and Soil relationships. The Wilcox's diagram plotted against specific conductance is used in evaluating the irrigation waters Wilcox's (1955). Sodium is one of the important ions for irrigation and agriculture purposes. Sodium is computed to relative proportions of cations present in water. Percentage of Sodium greater than 60% may result in sodium accumulations that will cause a breakdown in the soil's physical properties. Excess Na combining with carbonate leads to formation of alkali soils, whereas with chloride, saline soils are formed, and soil will not support plant growth Rao (2005). The ions' (Na%) values were obtained by the following equation:

$$Na\% = \frac{(Na+K)}{Ca+Mg+Na+k} \times 100$$

Wilcox's Diagram is used to classify the water for irrigation, where EC plotted against Na% shows that 96.21% of the groundwater samples are good to permissible and 3.79% are in the not potable category. Sodium concentration disperses soil and increasing salinity flocculates soil (Hanson et al 1999). Wilcox's plot and groundwater classifications are presented in Fig.6 and Table 4. It is clearly stated that the water from the following villages is not of potable category; Iddaiyapatti, Vellaiyur and Thiruvalanthurai villages.

Table 4. Wilcox's groundwater classifications

Sl.No	Water class	Groundwater sample No
1	Excellent to Good	48
2	Good to Permissible	1,2,4,6,8,10,11,17,13,16,19,20,21,27,28,30,33,35,37,39, 41,44,45,46,49,50,54,55,56,75 and 78
3	Permissible to Unsuitable	68 and79
4	Doubtful to unsuitable	7,9,12,23,29,31,32,34,36,42,47,51,52,53,59,60,62,65, 66,67,70,71,73,74,76 and 77
5	Unsuitable	43,38,64,58,15,25,2,69,35,57 and 40

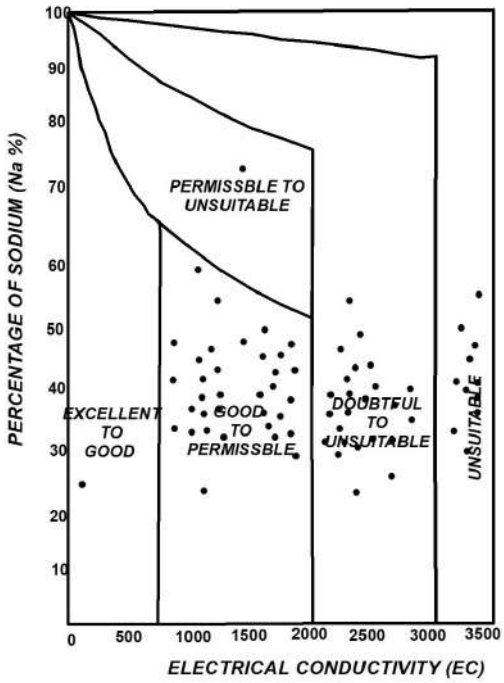


Fig.6. Wilcox diagram of the Vasishta sub- basin

Gibb's diagram. Gibbs diagram is mainly used to begin the affiliation of groundwater alignment and aquifer lithological characters. There are three domain fields, viz. precipitation dominance, evaporation dominance and rock–water interaction dominance domains in the Gibbs diagram (Gibbs, 1970). The maximum number of groundwater samples fall within the rock–water interaction domain and evaporation domain.The rock–water interaction domain clearly shows that the groundwater chemistry is controlled by aquifer materials. Gibbs diagram is presented in Fig. 7(a), (b)

Gibb's ratio for cations = Na+K/Na+K+Ca

Gibb's ratio for anions = Cl/Cl+HCO_3

All values of ion concentration are stated in meq/l.

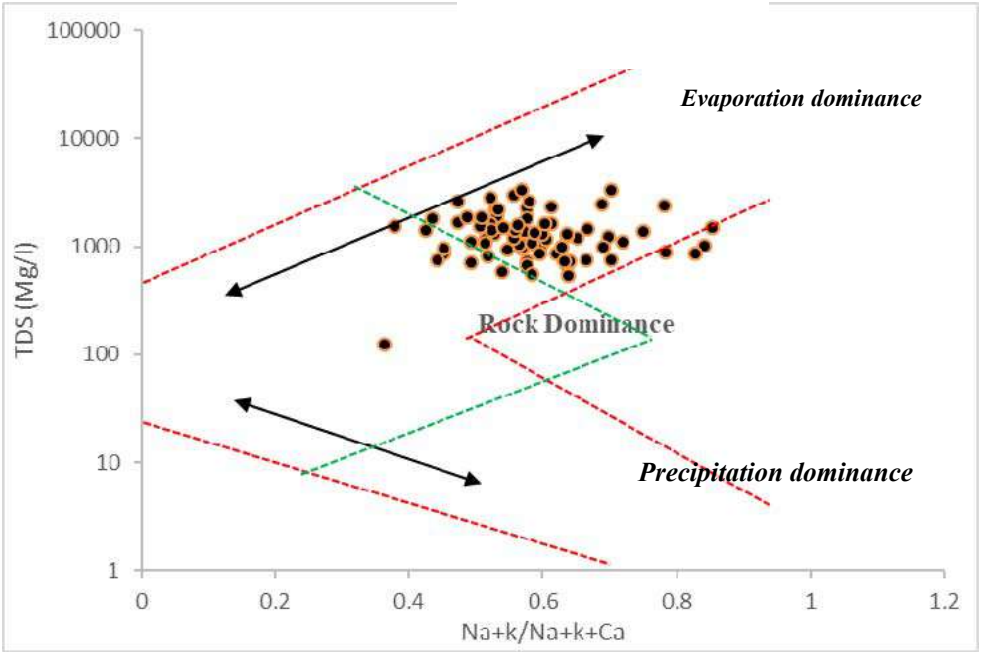


Fig.7. (a) Groundwater and rock interaction mechanism of Gibb's plot -cations

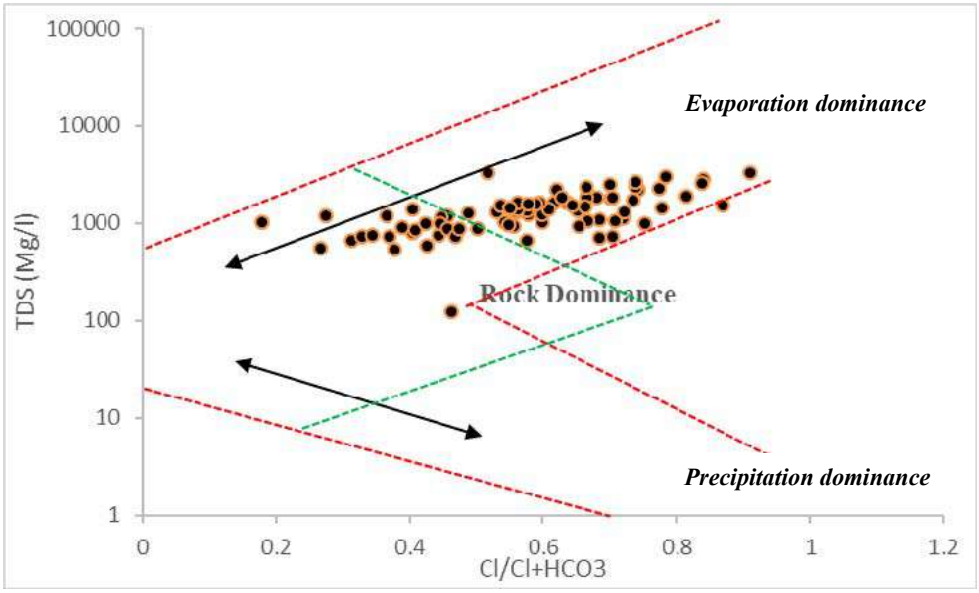


Fig.7. (b) Groundwater and rock interaction mechanism of Gibb's plot -anions

Results of the Correlation Matrix. The correlation analysis matrix involving statistical calculations was devised by Pearson (1896). It is commonly used to examine the degree of correlation between the different chemical parameters which affect the quality of groundwater. It is a simple measure to exhibit how well one variable predicts the other (Kurumbein and Greybill (1965).The Pearson correlation matrices (Swan and Sandilands 1995) are used to find the relationships between two or more variables. Coefficients (r=>0.7) are considered to be strongly correlated where (r) values between 0.5 and 0.7 show moderated correlation at a significance level p=0.05 while r <0.3 is weak. It also illustrates that EC and TDS show high positive correlation with Cl, SO_4, HCO_3, Ca, Cl show very high positive correlation with Ca (r=0.817). Good correlation is exhibited between EC and TDS Cl, SO_4. Cl exhibits good correlation with Mg and Ca (0.817), (0.751) indicating leaching of secondary salts. TDS and EC showed strong correlation with Cl, SO_4 moderate correlation with Ca, Mg, K, F and Hardness indicating that most of the ions are involved in physicochemical reactions such as oxidation reduction and ion exchange and also indicating that they are from the same source Subba Rao, (2002). Difference in variation of major cations and anions correlation is shown in Table 5.

Table 5. Correlation analysis of the physico-chemical parameters

	pH	*EC*	*TDS*	*Ca*	*Mg*	*Na*	*K*	*HCO_3*	*Cl*	*F*	*SO_4*	*NO_3*
pH	1.000											
EC	0.102295	1.000										
TDS	0.101158	**0.999999**	1.000									
Ca	0.19725	-0.0184	-0.01873	1.000								
Mg	0.09596	0.012054	0.012061	0.604636	1.000							
Na	0.111688	-0.00992	-0.01003	**0.591661**	**0.557501**	1.000						
K	0.09227	0.064575	0.064409	**0.61203**	0.415096	**0.559415**	1.000					
HCO_3	0.100417	0.141909	0.141609	0.204394	0.127654	0.256821	-0.05897	1.000				
Cl	0.260742	-0.03523	-0.03553	**0.825324**	**0.729007**	0.696992	**0.669742**	-0.10684	1.000			
F	-0.77812	-0.23406	-0.23279	-0.14767	0.140104	0.030309	-0.04876	-0.22396	-0.08438	1.000		
SO_4	0.192453	0.003892	0.003762	**0.656203**	**0.718156**	**0.720919**	**0.734585**	-0.03408	**0.794821**	0.060281	1.000	
NO_3	0.207007	0.193818	0.193591	**0.656602**	**0.556943**	**0.552107**	**0.601085**	0.179881	0.620028	-0.10462	**0.706081**	1.000

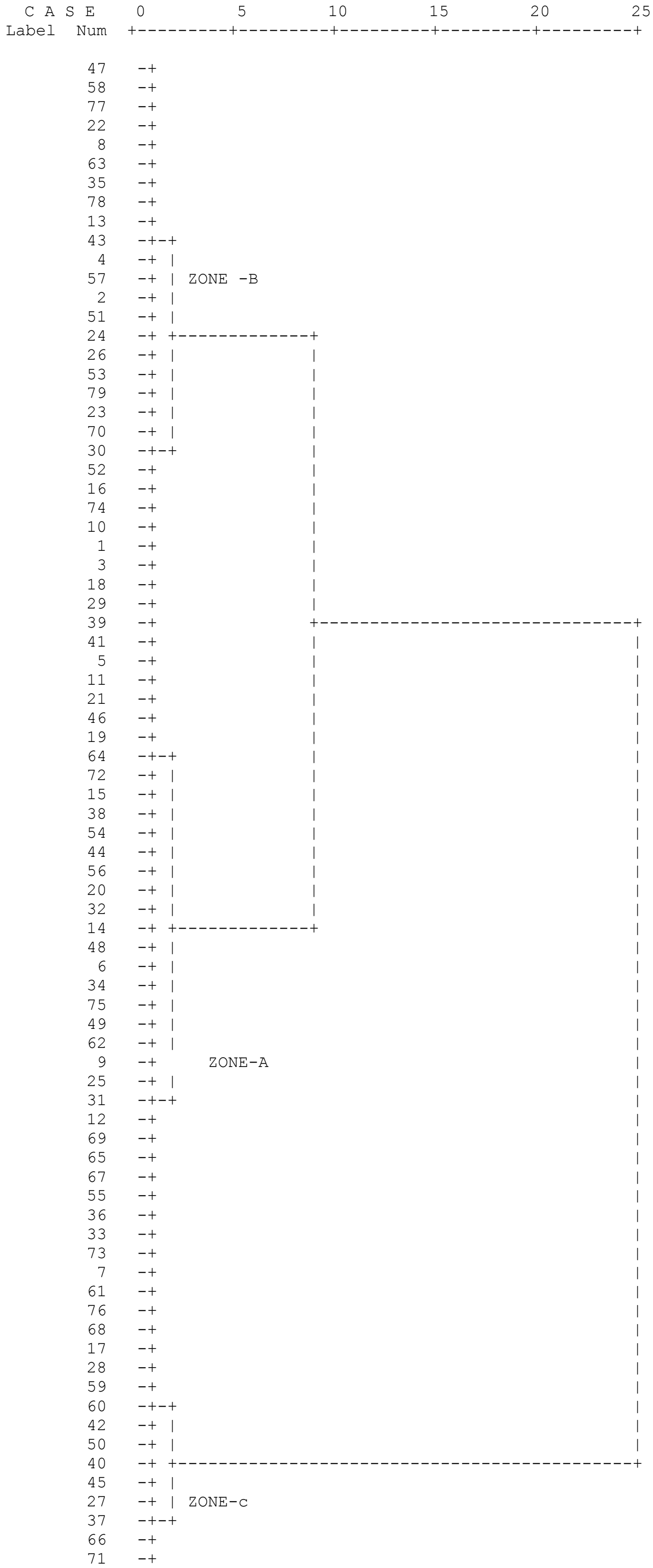


Fig.8. Cluster analysis in the dendrogram

Zone A grouped with the following groundwater samples (43, 4, 57, 2, 51, 24, 26, 53, 79, 23), Zone-B (64, 72, 15, 38, 54, 44, 56, 20, 32,14,48,6,34,75,49,62,9,25,31) and one C (60,42,50, 0,45,27,37,66,71). TDS seems to be a major influencing factor in the following the order of dominance ; Zone C > Zone B > Zone A. The zone A comprises samples (32, 54,74,55,66,9,8,64,72,52,53,28,10,31,35,5). The result is presented as a dendrogram shown in Figure.8.

Cluster analyses.

Cluster analysis is a method for grouping individuals or objects according to their distinct characters. This method is used to group the groundwater chemical data. Each cluster indicates a particular groundwater character similarity. Clustering groundwater samples based on their similarity is known as Q-mode type clustering method. For the present study Q-mode clustering has been attempted to group the samples in terms of chemical characteristics. Ward's linkage uses the Pearson correlation method to produce the most distinctive groups where each member within the group is more similar to its fellow member than outside groups. All the 14 hydro chemical variables such as Electrical Conductivity (EC), Total Dissolved Solids (TDS), P^H, Ca, Mg, Na, K, Cl, SO_4, NO_3, HCO_3 and F were utilized in this analysis.

Conclusions.

The sub- basin is mainly comprised of Archean crystalline rocks such as gneisses, charnockite, pyroxinite, amphibole granulite and myolinite. Groundwater chemistry in the sub- basin is highly variable in nature. Groundwater occurs and movements in the sub basin are mainly in the weathered rocks, fissures, fractures and joints. The TDS values varied from 124 to 3335 mg/l. TDS depends upon the groundwater interaction with different aquifer materials, and anthropogenic activities such as application of fertilizer, domestic sewage, and industrial effluent. The groundwater ionic concentration sequences are Ca >K >Mg>Na and CO_3>Cl>SO_4> HCO_3>NO_3. Groundwater categories are fresh to brackish in nature, Ca and Mg are mostly within the allowable category, NO_3 and SO_4 are also within the allowable limit for domestic purposes, The dominant water quality index falls into the excellent to good categories based on WHO and BIS standards. According to Piper's trilinear diagram the groundwater facies are Ca -Mg and SO4 type.In Wilcox's diagram it is clearly shown that most of the groundwater samples are suitable for irrigation purposes, however 3.79 % of groundwater samples (from the villages Iddaiyapatti, Vellaiyur and Thiruvalanthurai) are not suitable for irrigation purposes, which may be due to geogenic and anthoropogenic activities. In Gibb's diagram it is clearly revealed that groundwater chemistry is mainly controlled by rock water interaction domain and evaporation domain. In the hydrochemical correlation matrix, high positive correlation is exhibited between EC-TDS (r=0.9), Ca-Cl (r=0.82), and moderate correlation between Na-Cl, K-Ca, NO3-Ca, Na-Mg, Cl-Mg, SO4-Mg, SO4-Cl, NO3-SO4, with correlation value of 0.5 to 0.7, weak correlation exists between Ca-EC (r= –0.0184), F-K (r= –0.04). The correlation results projected in the dendrogram show that three groups were classified based on visual interpretation the dendrogram. Total dissolved solids seems to be a major influencing factor in the following order of dominance; Zone C > Zone B > Zone A.

Acknowledgements.

The first author is highly thankful to DST, Government of India, Department of Science and Technology for their financial support in the form of INSPIRE Fellowship to carry out this research work in the DST-FIST sponsored Department of Geology, Periyar University, Salem, Tamil Nadu. I convey my deep, sincere and gratitude to my mentor Prof. Dr.S.Venkateswaran Professor and Head, for giving opportunity for carry out this research. We also thank the anonymous reviewers and editors for their constructive comments.

References

APHA, 1995.Standard methods for the examination of water and wastewater (19th edn). Am Pub Heal Ass, Washington, DC

Arulbalaji, P., and Gurugnanam, B. 2017. Groundwater quality assessment using geospatial and statistical tools in Salem District, Tamil Nadu, India Appl Water Sci 7:2737–2751 DOI 10.1007/s13201–016–0501–5

Baride, M, V., Patil S, N., Golekar, R, B., 2014. Groundwater geochemistry of shallow and deep aquifers from Jalgaon district, northern Maharashtra (India) International Journal of Advanced Geosciences, International Journal of Advanced Geosciences, 2 (2) 97–104

Bernard. J and Valla. P., 1991. Groundwater Exploration in fissured media with electrical and VLF methods. Geoexploration, v.27, 81–91

Biswal, TK., Thirukumaran, V., Ratre, K., Bandyapadhaya, K., Sundaralingam, K,, Mondal, AK., 2010. A study of mylonites from parts of the Salem- Attur Shear Zone (Tamil Nadu) and its tectonic implications. J GeoSoc India 75:128–136

Gibbs, RJ., 1970. Mechanism controlling world water chemistry Science 170:795–840

Giuseppe Sappa, Sibel Ergul, Flavia Ferranti, 2014. Water quality assessment of carbonate aquifers in southern Latium region, Central Italy: a case study for irrigation and drinking purposes, Appl Water Sci 4:115–128 DOI 10.1007/s13201–013–0135–9

Ketata, M., Gueddari, M. and Bouhlila, R. 2012. Use of geographical information system water quality index to asses groundwater quality in El khairat deep aquifer (Enfidha, Central east Tunisia).Arabian Jour. Geosci.v.5(6), 1379–1390

Krumbein, W. C., and Graybill, F.A., 1965.An Introduction to Statistical Models in Geology. By xi + 475 pp., with figs. MaGraw-Hill, Volume 103, Issue 4

Maheswaran, G., and Elangovan, K., 2014. Groundwater Quality Evaluation in Salem District, Tamil Nadu, Based on Water Quality Index Nature Envi and Pollu Tec An Inter Quarterly Sci Jour Vol. 13, 3 pp. 547–552

Mahvi A.H., Nouri, J. A., Babaei A and Nabizadeh, R., 2005. Agricultural activities impact on groundwater nitrate pollution Int. J. Environ. Sci. Tech.Vol. 2, 1, 41–47, Springer

Marouane, B., Belhsain, K., Jahdi, M. E., Hajjaji, S., Dahchour, A., Dousset, and S., Satrallah A.,2014. Impact of agricultural practices on groundwater quality: Case of Gharb region-Morocco, J. Mater. Environ. Sci. 5 (S1) 2151–2155

Masoud Ei and Al-Ahmadi,2013. Hydrochemical characterization of groundwater in wadi Sayyah, Western Saudi Arabia, Appl Water Sci 3:721–732 DOI 10.1007/ s13201–013–0118-x

Nag. S.K., and Poulomi Ghosh, 2011.Groundwater quality and its suitability to agriculture – GIS based case study of Chhatna block, Bankura district, West Bengal, India, International Journal of Environmental Sciences Volume 1, 7, 1770–1784.

Oke, S A., and aladejana, J, A. 2012.Assessment of shallow groundwater quality for irrigation purposes in basement complex terrain of southwestern Nigeria, hydrology for disaster management special publication of the Nigerian association of hydrological sciences, south-eastern Tunisia) Environ Earth Sci 71:3387–3421 DOI 10.1007/s12665–013–2729–9,

Paralta E., Feranades, R., Carreira, and P, Riberiro, L.,2005. Assessing the impacts of agriculture on groundwater quality using nitrogen isotopes – preliminary results on the "Gabbros of Beja" aquifer system (South Portugal) 2nd workshop of the Iberian regional working group on hard rock hydrogeology, 18–21 May 2005, Evora, Portugal,14pp.

Pearson, K. 1896. Mathematical contributions to the theory of evolution, III: Regression, heredity and panmixia. Philos. Trans. Roy. Soc. London (, A) 187 253–318. Cambridge Univ. Press. Abstract in Proc. Roy. Soc. London (1897) 62 173–176.

Piper, A. M., 1944. A graphical procedure in the geochemical interpretation of water analysis. Am Geophys Union Trans 25:914–928

Poongodi, R., and Venkateswaran, S., 2018. Prioritization of the micro-watersheds through morphometric analysis in the Vasishta Sub Basin of the Vellar River, Tamil Nadu using ASTER Digital Elevation Model(DEM) data, Data in Brief (20) 1353–1359 Elsevier

Ragunath, H. M. 1987. Geochemical survey and water quality. Groundwater. Wiley Eastern Limited, New Delhi, pp.343–347.

Rodriguez-Estrella, T., 2012. The problems of overexploitation of aquifers in semi-arid areas: the Murcia Region and the Segura Basin (South-east Spain) case Hydrol. Earth Syst. Sci. Discuss., 9, 5729–5756,

Sarath Prasanth, S. V., Magesh, N. S., Jitheshlal, K. V., Chandrasekar, N., Gangadhar, K., 2012. Evaluation of groundwater quality and its suitability for drinking and agricultural use in the coastal stretch of Alappuzha District, Kerala, India, Appl Water Sci 2:165–175 DOI 10.1007/s13201–012–0042–5

Saravanan, K., Srinivasamoorthy, S., Gopinath R., Prakash, C, Suma S.,2016. Investigation of hydrogeochemical processes and groundwater quality in Upper Vellar sub- basin Tamilnadu, India, Arab J Geosci 9: 372 DOI 10.1007/s12517–016–2369

Satheesh Kumar, V., Amarender Ratnakar Dhakate, B., Sankaran, S., Raj Kumar, K., 2018. Assessment of groundwater quality for drinking and irrigation use in shallow hard rock aquifer of Pudunagaram, Palakkad District Kerala, Appl Water Sci DOI 10.1007/s13201–014–0214–6

Shah, S. M., and Mistry N.J., 2013. Groundwater Quality Assessment for Irrigation Use in Vadodara District, Gujarat, India, World Academy of Science, Engineering and Technology Vol:7 2013–07–23

Sharif, MU., Davis, RK., Steele, KF., Kim, B., Kresse TM., Fazio, JA., 2008. Inverse geochemical modeling of groundwater evolution with emphasis on arsenic in the Mississippi River Valley alluvial aquifer, Arkansas (USA. J of Hydrology. https://doi.org/10.1016/j. jhydr ol. 2007.11.027

Sreedevi PD, 2002. A case study on changes in quality of groundwater with seasonal fluctuations of Pageru river basin, Cuddapah District, Andhra Pradesh, India. J Environ Geol 42:414–423.

Srinivas, Y., Hudson Oliver, D., Stanley Raj A., Chandrasekar, N., 2013. Evaluation of groundwater quality in and around Nagercoil town, Tamilnadu, India: an integrated geochemical and GIS approach, Appl Water Sci 3:631–651 DOI 10.1007/s13201–013–0109-y

Srinivasamoorthy K, Nandha Kumar C, Vijayaraghavan K, Vasanthavigar M, Rajiv Gandhi R, Chidambaram S, Anandhan P, Manivannan R, Vasudevan S., 2011. Groundwater quality assessment from a hard rock terrain, Salem district of Tamilnadu, India. Arab J Geo Sci 4:91–102.

Srinivasamoorthy, K., Nanthakumar, C., Vasanthavigar, M., Vijayaraghavan, K., Rajivgandhi, R., Chidambaram, S., Anandhan, P., Manivannan, R., Vasudevan, S., 2009.Groundwater quality assessment from a hard rock terrain, Salem district of Tamilnadu, India. Arab J Geosci. https://doi.org/10.1007/s1251 7–009–0076

Subba Rao, N., Vidyasagar, G., Surya Rao, P., Bhanumurthy, P., 2014. Chemistry and quality of groundwater in a coastal region of Andhra Pradesh, India, Appl Water Sci DOI 10.1007/s13201–014–0244–0

Subba Rao, S., 2002. Geochemistry of groundwater in parts of Guntur district, Aandra Pradesh, India Envir Geology 41:552–562

Subramani T, Rajmohan N, Elango L (2010) Groundwater geochemistry and identification of hydrogeochemical processes in a hard rock region, Southern India. Environ Monit Assess: 162:123–137.

Swan A.R. H., and Sandilands, M., 1995. "Introduction to Geological Data Analysis," Blackwell, Oxford,

Tamma Rao G., Gurunadha Rao V, S., and Ranganathan K., 2013. Hydrogeochemistry and groundwater quality assessment of Ranipet industrial area, Tamil Nadu, India, J. Earth Syst. Sci. 122, No. 3, June, 855–867

Todd DK (1980) Groundwater Hydrology, 2nd edn. Wiley, New York, 535 p.

Uday Veer Singh, Amar Abhishek Kunwar, P., Singh Ratnakar, Dhakate Netra Pal Singh, 2014.Groundwater quality appraisal and its hydrochemical characterization in Ghaziabad (a region of indo-gangetic plain), Uttar Pradesh, India, Appl Water Sci 4:145–157, DOI 10.1007/s13201–013–0137–7

Vasanthavigar, M., Srinivasamoorthy, K., Vijayaragavan, K., Rajiv Ganthi, R., Chidambaram, S., Anandhan, P., Manivannan, R., and Vasudevan, S., 2010. Application of water quality for groundwater quality assessment: Thirumanimuttar Sub basin, Tamil Nadu, India. Environ Monit Assess 171(1–4):595–609

Veena Chaudhary, and Satheeshkumar, S., 2018. Assessment of groundwater quality for drinking and irrigation purposes in arid areas of Rajasthan, India Applied Water Science 8:218 https://doi.org/10.1007/s13201–018–0865–9

Venkateswaran, S., 2010. Hydrogeology and Geochemical characterisation of groundwater with special emphasis on agricultural development in Vaniyar sub basin, Ponnaiyar river, Tamil Nadu., International Journal of Recent Scientific Research vol. 1, issue, 12, 213–221

Vijayakumar, V S., Krishnakumar, S., and Vasudevan, 2016. An Environmental Quality Assessment on Groundwater Geochemistry in Western Part of Perambalur District, Tamilnadu, India, Journal of Environmental Science and Pollution Research 2(1) 54–56

WHO, 2011. WHO Guidelines for Drinking-water Quality, fourth ed. World Health Organization (Amsterdam), 228(1–2), 37–47.

Wilcox's, LV., 1955. Classification and use of irrigation waters. USDA, Circular 969, Washington, DC

William Bajjali, Kheir Al-Hadidi, and Ma'mmon Ismail, 2017. Water quality and Geochemistry evaluation of groundwater upstream and downstream of the Khirbet Al-Samra wastewater treatment plant/Jordan, Appl Water Sci 7:53–69 DOI 10.1007/s13201–014–0263-x

Journal of Geology, Geography and Geoecology

ISSN 2617-2909 (print)
ISSN 2617-2119 (online)

Journ. Geol. Geograph. Geology, 30(4), 718–728.

Journal home page: geology-dnu.dp.ua

doi: 10.15421/112166

Peculiarities of Stratigraphic Distribution and Paleoecology of Jurassic Bivalve Mollusks of the Pre-Carpathian Foredeep

Ihor V. Shaynoha, Vasyl V. Karabyn.

Ivan Franko National University of Lviv, Lviv, Ukraine. chigvos@ukr.net
Lviv State University of Life Safety, Lviv, Ukraine, vasyl.karabun@gmail.com

Received: 20.05.2021
Received in revised form: 08.08.2021
Accepted: 04.11.2021

Abstract. Pre-Carpathian region is one of the oldest oil and gas producing regions of our country, which is attracting more and more attention of scientists. In the Outer zone of the Pre-Carpathian Foredeep, Jurassic deposits occur at considerable depths (up to 3,000 m), so we obtain almost all geological information about them exclusively during the study of core material selected during drilling. A comprehensive and detailed study of the Jurassic deposits of this zone during exploration drilling in the 1950s contributed to the discovery of the Kokhanivske and Sudovovyshnianske oil deposits and Rudkivske gas deposit, as well as a number of oil and gas manifestations. After that, the interest in the conditions of formation and stratification of Jurassic deposits increased. Researchers have begun to treat them as the promising objects for oil and gas exploration. Jurassic deposits in the Pre-Carpathian Foredeep fill a single depression – the Stryi Jurassic deflection, covered by a thick layer of Cretaceous and Neogene rocks. The study of their geology and stratigraphy has acquired important applied and scientific significance, because stratigraphic research serves as a basis for clarifying the history of geological development of the region, performing tectonic constructions, reconstruction of paleogeographic and paleoecological conditions, comparison of productive horizons and specification of their stratigraphic position, search for new objects promising for hydrocarbons. Extremely rare finds of paleontological remains (which are not always well preserved) do not allow to unambiguously determining the age of the host rocks. It is still not always possible to clearly stratigraphically distinguish and correlate these rocks due to weak paleontological study and partial uncertainty in the interpretation of the geological structure of these strata. Despite the significant amount of research we have done, there are some debatable issues regarding the completeness of the section of these rocks and the presence of separate stratigraphic units in them. For many years, we have studied in detail and comprehensively bivalve mollusks found in the core of wells drilled in the Outer zone of the Pre-Carpathian Foredeep. As a result, the age of the host strata was specified and confirmed, as well as the thickness of individual stratigraphic units.

Keywords: Pre-Carpathian Foredeep, Jurassic, fauna, paleostratigraphy, paleoecology.

Особливості стратиграфічного поширення та палеоекологія юрських двостулкових молюсків Передкарпатського прогину

І. В. Шайнога, В.В. Карабин

Львівський національний університет імені Івана Франка, Львів, Україна,e-mail: chigvos@ukr.net

Анотація. Передкарпаття – один з найдавніших нафтогазодобувних районів нашої держави, який щораз більше привертає увагу науковців. У Передкарпатському прогині, в межах його Зовнішньої зони, юрські відклади залягають на значних глибинах (до 3000 м.) тому майже всю геологічну інформацію про них ми отримуємо винятково під час вивчення кернового матеріалу відібраного при проведенні бурових робіт. Всебічне і детальне вивчення юрських відкладів Зовнішньої зони Передкарпатського прогину під час проведення геолого-розвідувального буріння у 50-х роках сприяло відкриттю Коханівського та Судововишнянського нафтових і Рудківського газового родовищ, а також виявити низку нафтогазопроявів. Після відкриття цих великих покладів цікавість до умов утворення та стратиграфічного розмежування юрських відкладів посилилася., Дослідники почали сприймати їх, як перспективний об'єкт для розшуків нафти та газу. У Передкарпатському прогині вони виповнюють єдиний прогин, який має назву – Стрийський юрський прогин, перекритий потужною товщею порід крейди і неогену. Ixнє геологічне вивчення та стратиграфічне розмежування набуло важливого прикладного і наукового значення, адже стратиграфічні дослідження слугують базою при з'ясуванні історії геологічного розвитку регіону, для виконання тектонічних побудов, реконструкції палеогеографічних та палеоекологічних умов, для зіставлення продуктивних горизонтів та уточнення їхнього стратиграфічного положення, пошуку нових перспективних на вуглеводні об'єктів. Надзвичайно рідкісні знахідки палеонтологічних решток не завжди доброї збереженості не дають змоги однозначно трактувати вік вмісних порід. Через слабку палеонтологічну вивченість та часткову невизначеність у трактуванні геологічної будови цих товщ дотепер не завжди вдається чітко провести стратиграфічне розмежування та корелювати ці утворення. Незважаючи на значний обсяг виконаних нами досліджень, дискусійними є деякі питання щодо повноти їхнього розрізу та наявності в них окремих стратиграфічних

підрозділів. В результаті детального і всебічного вивчення нами упродовж багатьох років двостулкових молюсків, знайдених в керні свердловин, пробурених у Зовнішній зоні Предкарпатського прогину, уточнено і підтверджено вік вмісних товщ, та потужності окремих стратиграфічних підрозділів.

Ключові слова: Передкарпатський прогин, юра, фауна, палео, стратиграфія, палеоекологія.

Introduction

The Pre-Carpathian Foredeep is the complexly built geotectonic structure of the first order which has been formed in the Miocene during orogenesis of the Carpathian geosyncline (on its north-eastern edge). Jurassic deposits, developed in the territory of the Ukrainian Pre-Carpathian region, form the independent structural element – the Stryi Jurassic deflection, filled by the strata of terrigenous, terrigenous-carbonate and carbonate rocks with the thickness of up to 1,000 m (Vyalov, 1950; Burov, Vishnyakov, 1985).

Information obtained during drilling operations in the territory of the Pre-Carpathian Deflection in the areas of Velyki Mosty, Pidluby, Stryi, Sokal, Sudova Vyshnia, Pivnichni Medynychi, Pivnichna Kokhanivka, Boniv, and others allowed others to interpret the spread of Jurassic sediments in western Ukraine. The well revealed a thick layer of Jurassic sediments, the age of which was determined by the finds of foraminifera, mollusks, spores and pollen. On this basis, conclusions were drawn about the wider than expected Jurassic deposits within a single Jurassic depression.

The asymmetric structure of the Stryi Jurassic deflection was determined. Its western and eastern sides differ in thickness, lithological and facial features and rocks' dislocations. The south-western part is composed of a thick layer of intensively dislocated rocks of the Lower–Upper Jurassic, which are divided into blocks by a system of faults. The north-western part is composed of Oxford–Tithonian rocks, which lie monoclinally and have small thickness. A characteristic feature of the sediments is a gradual increase in the thickness and completeness of the section in the western–south-western directions. The maximal thickness of Jurassic sediments was recorded near the Krakovetskyi fault (Dulub, 1964; Leshchukh, 1978).

Conformable bedding of the Middle Jurassic deposits on the underlying Lower Jurassic strata has been determined, and it is non-conformably covered by rocks of the Upper Jurassic.

The performed studies (Gavrilishin and Karpenchuk, 1982) made it possible to improve the biostratigraphic basis of the Pre-Carpathians Jurassic sediments, which are generally poor in paleontological finds.

We have tried to investigate more fully and comprehensively some of the controversial issues related to the completeness of the section and the stratigraphic delimitation of the Jurassic strata in the Pre-Carpathian Foredeep. To do this, we used new paleontological finds discovered in the wells of Romanivska-1, Podiltsi-1, Podiltsi-2, Yurivska-1, Yurivska-2 and others (Fig. 1). As a result of the performed researches quite interesting changes in quantitative and species diversity of the revealed and defined paleontological forms are recorded.

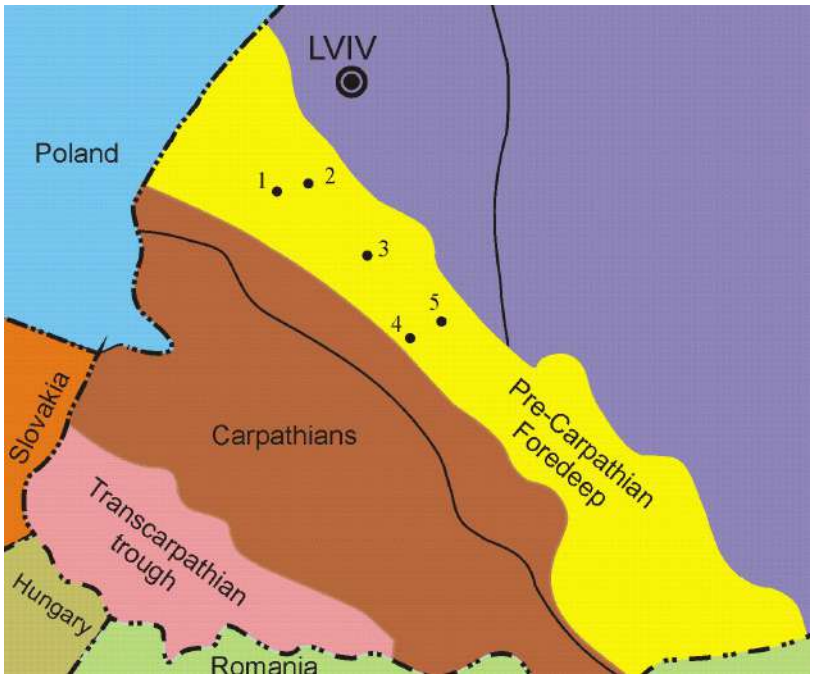


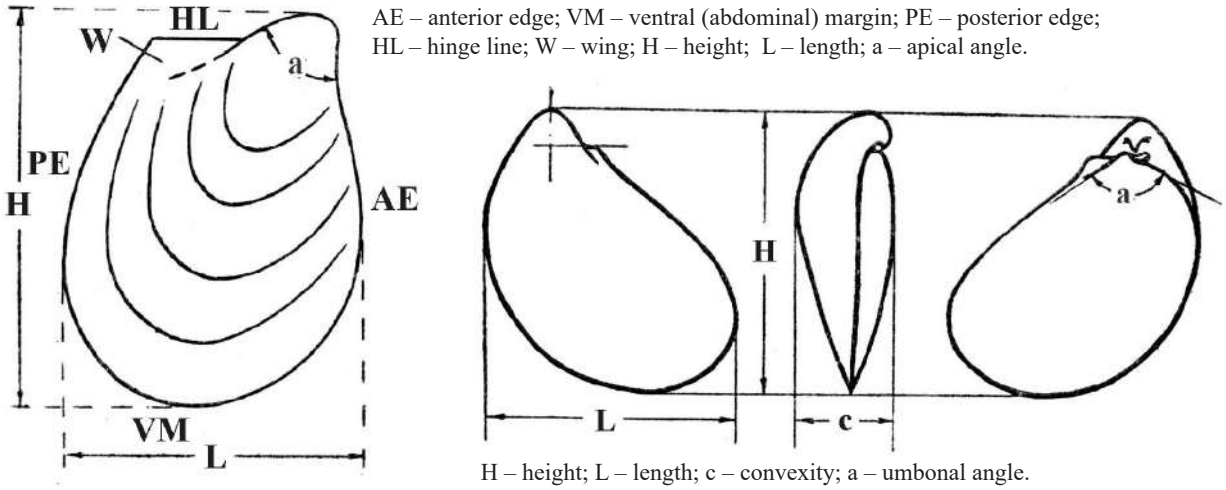
Fig. 1. Schematic map of well locations: ***1*** – Yurivska-1; ***2*** – Yurivska-2; ***3*** – Romanivska-1; ***4*** – Podiltsi-1; ***5*** – Podiltsi-2.

The available geological and geophysical material has been analyzed, which is important for the study of the vertical distribution of macrofauna. This is of scientific and applied importance for the study of the stratigraphy of Jurassic (and not only) sediments. Particular attention has been paid to the lithological composition of the host rocks, the patterns of their occurrence and the thickness of the various layers.

Materials and methods of research

Samples for research were selected during the study of the core material. In total, more than 200 samples with paleontological remains from more than 40 wells were processed. The core material from the following drilling areas was analized: Kokhanivska, Rudky, Bortiatyn, Pivnichni Medynychi, Hrushiv, Lopushna, Dashava, Verbizh, Paryshche, Verchany, Boniv, Karolina, and others (Slavin, Dobrynina, Efimova, 1967; Leshchukh, Bubnyak, 1991). A significant amount of published and fund geological and geophysical material has been studied and analyzed in detail. The performed researches are a fundamental part of the complex estimation of prospects of oil and gas potential of the Pre-Carpathian oil and gas region Jurassic deposits, a scientific basis for carrying out prospecting and geological survey works. They can be used to dissect and correlate well sections in promising areas, as well as to determine or refine the age of stratigraphic intervals and productive horizons (Shainoga, Leshchukh, Hotsanyuk, 2001).

During the monographic study of paleontological material, the terminology and systematics given in the handbook "Fundamentals of Paleontology" (1960, in Russian) edited by A. G. Eberzin have been taken as a basis (Fig. 2).



AE – anterior edge; VM – ventral (abdominal) margin; PE – posterior edge; HL – hinge line; W – wing; H – height; L – length; a – apical angle.

H – height; L – length; c – convexity; a – umbonal angle.

Fig. 2. Scheme of the bivalve mollusk shell structure.

During the research we comprehensively applied lithological and biostratigraphic methods of studying paleontological remains, which were slightly changed and supplemented in accordance with the subject of research, the main tasks and geological features of the region.

We used the lithological method to dissect and compare sediments according to a set of lithological features, described rocks, and distinguished their lithogenetic types. We performed these works taking into account the recommendations set out in many methodological works (Romanov, 1973, etc.). The relative and absolute ages of rocks have been determined in the region, sections have been compared, local lithostratigraphic units have been sorted by age and position relative to stratons of the general stratigraphic scale, and biostratigraphic characteristics of local and general stratigraphic units have been improved.

The biostratigraphic method was used to dissect and correlate sedimentary strata with the remains of paleoorganisms (fossils). We conducted biostratigraphic studies at all stages of stratigraphic study, also clarified the physical and geographical parameters of the paleoenvironment, and supplemented the facial characteristics of sediments (Merklin, 1949; Hecker, 1954).

The subject of research is the remains of paleoorganisms and host sedimentary rocks. Fossils have been studied in two directions that are closely related and are the stages of biostratigraphic research. The core and the interval location of the remains of bivalve molluscs were described in detail at the first (field) stage. At the second (laboratory) stage, we performed a morphological description of the remains of paleoorganisms, determined their species and genus composition by the morphological-comparative method, and analyzed the distribution of the defined forms in the sedimentary strata.

The source material was information on the distribution of fossils in section and laterally. The composition of fossil complexes reflects the structure of bio-

cenoses and is determined by the degree of evolutionary development of biota, ecological relations between organisms, abiotic environmental factors and taphonomic conditions of burial and fossilization of fossil forms.

Results

The basis of the comprehensive research was the study of the macrofauna of bivalve mollusks. Diagnosis of shells was based on the study of their shape, size and sculpture. During the species diagnostics, depending on the quality of material preservation, it is not always possible to find all the elements of the external and internal structure. Poor preservation of paleontological material in many cases complicates its diagnosis. It is difficult to determine one or more typical morphological features for each species, because the degree of preservation of the material in each case is very different (Shinoga, 2001).

Preservation of the material is diverse: the remains of bivalve mollusks occur mainly in the form of imprints of internal and external casts, occasionally – whole skeletons. There is a mechanically destroyed material, the bulk of which is the imprints of the valves and a large number of fragments, which is often observed in the host rocks.

Imprints of sashes: *Phaenodesmia* cf. *arzisiensis* Rom., – four specimens, *Nucula eudorae* Orb. – four, *N. subovalis* Boriss. – three, *Leda lacryma* Sow. – two, *Leda mucronata* Sow. – two, *Leda acuminata* Gold., – one; *Cucullaea cucullata* Gold. – one, *Entolium demissum* Phill. – three, *E. singulatum* Gold. – one, *Anisocardia* cf. *minima* Sow. – four, *Goniomy recta* Pčel. – three, *Goniomya* sp. – one, *Parallelodon* sp. nov. – one, *Posidonia buchi* Roem. – eight, *Lima (Plagiostoma) subrigidula* Schlippe. – one, *Pleuromya tenuistriata* Gold. – one, *Pleyromya caudata* Terg et Jourdy. – one, *Nucula jagmanica* Sibir. – one, *Nucula simetrica* Boris. – one, *Cucullaea subdecussata* Gold. – one, *Oxytoma scarburgense* Rollier. – one, *Laternula undulata* Sow. – one, *Leda acuminata* Gold. – one, *Parallelodon elongatum* Sow. – one.

Internal cores: *Pholadomya murchisoni* Sow. – two, *Pholadomya solitaria* Mor. et Lyss. – one, *Goniomya baysunensis* Gold. – three, *Astarte* cf. *orbicularis* Sow. – one, *Pinna buchi* Koech et Dunker. – one, *Pleyromya decurtata* Phill. – one, *Pleyromya balkhanensis* Pcel. – one.

Whole skeletons: *Astarte pulla* Roem. – four.

In most fossils the surface of the fossil is covered with sculpture, in some forms it is clearly expressed, in others the sculptural elements are less clear, they can be clearly seen only under binoculars, on some imprints sculpture is practically absent.

Radial sculpture: *Cucullaea cucullata* Gold., *Goniomya baysunensis* Gold., *Pholadomya murchisoni* Sow., *Pholadomya solitaria* Mor. et Lyss., *Entolium demissum* Phill., *E. singulatum* Gold., *Lima (Plagiostoma) subrigidula* Schlippe., *Pinna buchi* Koech et Dunker., *Leda lacryma* Sow., *Leda mucronata* Sow.

Concentric sculpture: *Pleuromya tenuistriata* Gold., *Pleyromya caudata* Terg et Jourdy., *Pleyromya decurtata* Phill., *Pleyromya balkhanensis* Pcel., *Nucula eudorae* Orb., *N. subovalis* Boriss., *Astarte pulla* Roem., *Anisocardia* cf. *minima* Sow., *Posidonia buchi* Roem., *Leda acuminata* Gold., *Phaenodesmia* cf. *arzisiensis* Rom.

Radial-concentric: *Parallelodon* sp. indet.; Divaricate: *Goniomy recta* Pčel., *Goniomya baysunensis* Gold., *Goniomya* sp.

Found remains of bivalve mollusks vary in shape and size. In terms of shape, most specimens have an oval-elongated shell. Oval: *Pleyromya balkhanensis* Pcel., *Pleuromya tenuistriata* Gold., *Nucula subovalis* Boriss., *Nucula eudorae* Orb., *Nucula jagmanica* Sibir., *Nucula simetrica* Boris. Round-rhombic: *Cucullaea cucullata* Gold. Oval-elongated: *Pleyromya caudata* Terg et Jourdy., *Pleyromya decurtata* Phill., *Goniomya baysunensis* Gold., *Leda lacryma* Sow., *Leda mucronata* Sow., *Phaenodesmia* cf. *arzisiensis* Rom., *Goniomya* sp. Round: *Lima (Plagiostoma) subrigidula* Schlippe., *Goniomy recta* Pčel., *Posidonia buchi* Roem., *Astarte pulla* Roem., *Anisocardia* cf. *minima* Sow. Round-triangular: *Pholadomya murchisoni* Sow., *Pholadomya solitaria* Mor. et Lyss., *Parallelodon* sp. indet., *Leda acuminata* Gold., *Entolium demissum* Phill., *E. singulatum* Gold. Cone-shaped: *Pinna buchi* Koech et Dunker. (10 %).

Large: *Cucullaea cucullata* Gold., *Entolium demissum* Phill., *E. singulatum* Gold., *Pholadomya murchisoni* Sow., *Pholadomya solitaria* Mor. et Lyss., *Goniomy recta* Pčel., *Goniomya baysunensis* Gold., *Goniomya* sp., *Leda acuminata* Gold., *Parallelodon* sp. indet., *Posidonia buchi* Roem., *Pinna buchi* Koech et Dunker., *Lima (Plagiostoma) subrigidula* Schlippe., *Pleuromya tenuistriata* Gold., *Pleyromya caudata* Terg et Jourdy., *Pleyromya decurtata* Phill., *Pleyromya balkhanensis* Pcel., *Oxytoma scarburgense* Rollier.

Medium: *Nucula eudorae* Orb., *Anisocardia cf. minima* Sow., *Cucullaea subdecussata* Gold.

Small: *Astarte pulla* Roem., *Leda lacryma* Sow., *Leda mucronata* Sow., *Phaenodesmia* cf. *arzisiensis* Rom., *Nucula subovalis* Boriss. *Nucula jagmanica* Sibir., *Nucula simetrica* Boris.

According to the degree of sashes convexity:

Very convex: *Leda mucronata* Sow., *Cucullaea cucullata* Gold., *Pholadomya murchisoni* Sow., *Pholadomya solitaria* Mor. et Lyss., *Goniomy recta* Pčel., *Goniomya baysunensis* Gold., *Goniomya* sp., *Pinna buchi* Koech et Dunker., *Lima (Plagiostoma)*

subrigidula Schlippe., *Pleyromya caudata* Terg et Jourdy., *Pleyromya decurtata* Phill., *Pleyromya balkhanensis* Pcel.

Anisocardia cf. *minima* Sow., *Leda lacryma* Sow., *Posidonia buchi* Roem., *Pleuromya tenuistriata* Gold., *Parallelodon* sp. indet., *Astarte pulla* Roem., *Phaenodesmia* cf. *arzisiensis* Rom., *Nucula eudorae* Orb., *N. subovalis* Boriss., *Nucula jagmanica* Sibir., *Nucula simetrica* Boris., *Cucullaea subdecussata* Gold., *Oxytoma scarburgense* Rollier.

Flat: *Entolium demissum* Phill., *E. singulatum* Gold.

The material is unsorted: there are shells of different sizes in one interval. The forms are oriented horizontally to the bedding plane, mainly convex upwards. There are accumulations of sashes (well Romanivska-1) or separate scattered sashes (Yurivska-1, Yurivska-2, Podiltsi-1, Podiltsi-2). A large number of shell detritus is represented by fragments of different sizes, which are located in the rock in individual spots. Findings of forms are confined to the middle part of interbeds (Shaynoga, Leshchukh, 2002).

The largest number of specimens was found in the lower part of the section, and in the middle and upper ones only remains of individual forms are available.

Imprints of the right or left sashes and individual cores predominate among the finds, with casts more common in the upper part of the section and imprints of the sashes – in the lower part. In most cases, these are imprints of the left or right sashes, which lie convex upwards.

Most of the fauna buried in aleurolites retains its shape, because during diagenesis the volume of the substance that fills the shell is almost not reduced, and the shell is not deformed. Organic remains are better preserved in more solid and denser rocks during mechanical deformations. An important factor for conservation is also the rate of sedimentation.

Selected types of mollusk burial are typical for certain hydrodynamic conditions. They can be used as indicators of changes in the aquatic environment during sedimentogenesis, which is a major factor in the formation of taphocenoses and various forms of preservation.

Stenogaline forms have been identified among the found fossils, in particular, the genus *Leda*, which was studied by R. L. Merklin (Merklin, 1949). According to him, it is a benthic form, the habitat of which was a salt basin (salinity at least 28 ‰), the conditions were calm, the soil was soft, representatives of this genus could tolerate oxygen deficiency.

Representatives of the genus *Nucula* are sedentary; they are shallowly buried in the bottom sediment and can move in it. These are mainly inhabitants of the soft sandy-clay soils of the sublittoral, most populations are observed at a depth of up to 90 m. These are fairly eurythermal organisms, living in warm temperate and cold reservoirs.

Most of the found forms are stenogaline normal-marine individuals (70 %), some of them occur in desalinated areas of the basin, in particular *Entolium demissum* Phill., *Entolium singulatum* Gold. (25 %), and subsaline water areas, such as *Astarte pulla* Roem. (5 %).

The temperature of the sea basin is important for determining the paleoecological living conditions of mollusks. The vast majority of forms are stenothermic (tropical and subtropical): *Posidonia buchi* Roem., *Pholadomya murchisoni* Sow., *Pholadomya solitaria* Moriss et Lycett. (50 %), part of mollusks – stenothermal boreal: *Astarte pulla* Roem. and stenothermal arctic: *Nucula subovalis* Gold., *Nucula cf. eudorae* Orb., *Nucula simmtrica* Boriss., *Nucula jagmanica* Sibir., *Leda lacryma* Sow., *Leda mucronata* Sow., *Cucullaea cucullata* Gold., *Cucullaea subdecussata* Gold. (Quenstedt, 1858; Roemer, 1911).

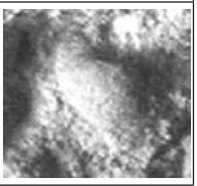
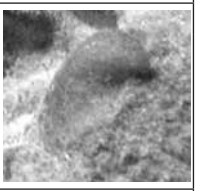
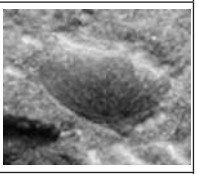
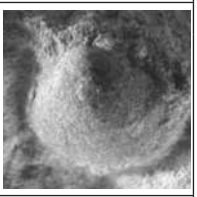
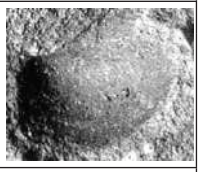
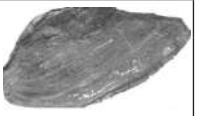
We found the fauna in narrow intervals of the section with the thickness from the first meters to 10 m. The number of fossil remains is insignificant, and they almost do not form mass accumulations. They are placed unevenly in the vertical section.

The genus and species composition of the fauna of bivalve molluscs defined by us is represented mainly by representatives of the following orders: **Desmodonta** (desmodonts) – genera: PHOLADOMYA (*Pholadomya* cf. *murchisoni* Sowerby, 1827, *Pholadomya solitaria* Morris et Lycett, 1850, *Goniomya recta* Pčelincev, 1927, *Goniomya baysunensis* Borissjak, 1910, *Goniomya* sp.); PLEUROMYA (*Pleuromya balkhanensis* Pčelincev, 1928, *Pleuromya decurtata* Phillips, 1829, *Pleuromya coudata* Terquem et Jourdy, 1869, *Pleuromya tenuistriata* Goldfuss, 1836); LATERNULA (*Laternula undulata* Sow., 1819); **Anisomyaria** (anisomyarian) – genera: OXYTOMA (*Oxytoma*, Meek, 1864, *Oxytoma scarburgense* Rollier, 1914), PINNA (*Pinna buchi* Koch et Dunker, 1837), POSIDONIA (*Posidonia(Bositra) buchi* Roemer, 1836), LIMA (*Lima (Plagiostoma) subrigidula* Schlippe, 1888), ENTOLIUM (*Entolium demissum* Goldfuss, 1834, *Entolium singalatum* Goldfuss, 1836); **Taxodonta** (taxodonts) – genera: PHAENODESMIA (*Phaenodesmia arzisiensis* Romanov 1973), LEDA (*Leda lacryma* Sowerby, 1824, *Leda mucronata* Sowerby, 1824, *Leda acuminata* Gold., 1826), NUCULA (*Nucula subovalis* Goldfuss, 1836, *Nucula eudorae* Orbigny, 1847, *Nucula jagmanica* Sibir, 1960, *Nucula simetrica* Borissjak, 1904), CUCULLAEA (*Cucullaea cucullata* Goldfuss, 1837, *Cucullaea subdecussata* Gold., 1838), PARALLELODON (*Parallelodon* sp indet., *Parallelodon elongatum* Sow., 1824) 12 species; **Heterodonta** (heterodont) – genera: ASTARTE

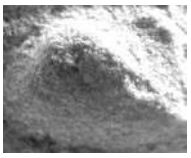
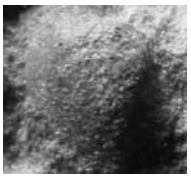
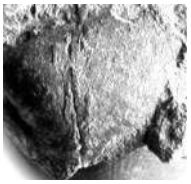
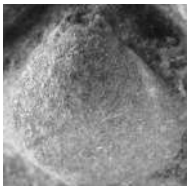
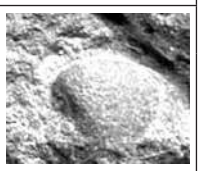
(*Astarte pulla* Roemer, 1836, *Astatre* cf. *orbicularis* Sow., 1812), ANISOCARDIA (*Anisocardia* cf. *minima* Sowerby, 1837) (Table 1).

Taking into account the significance of each paleontological find, as well as the fact that information on the composition, number and degree of preservation of mollusks was obtained during a detailed study of the core, we compared our materials with lithogenetic types and facies of potential oil and gas deposits of other regions. This approach makes it possible to obtain a comprehensive lithological-facial and paleontological characteristics of sediments – the main source material for further research and constructions (Koch et Dunker, 1837).

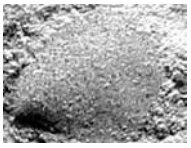
Table 1. Stratigraphic distribution of Jurassic bivalve mollusks within the Pre-Carpathian Foredeep

Name of the species	Geological age									Images of bivalves, × 2
	Bajocian			Bathonian			Callovian			
	L	M	U	L	M	U	L	M	U	
***Phaenodesmia* cf. *arzisiensis* Rom.**										
***Nucula subovalis* Boriss.**										
***Nucula eudorae* Orb.**										
***Nucula jagmanica* Sibir.**										
***Nucula simmetrica* Boriss.**										
***Leda lacrima* Sow.**										
***Leda mucronata* Sow.**										
***Leda acuminata* Gold.**										
***Cucullaea cucullata* Gold.**										

Continuation of Table 1

Name of the species	Geological age									Images of bivalves, × 2
	Bajocian			Bathonian			Callovian			
	L	M	U	L	M	U	L	M	U	
***Cucullaea subdecussata* Gold.**										
***Parallelodon elongatum* Sow.**										
***Parallelodon* sp. nov.**										
***Oxytoma scarburgense* Roll.**										
***Pinna buchi* Koech et Dunker.**										
***Posidonia buchi* Roem.**										
***Lima (Plagiostoma) subrigidula* Sch.**										
***Astarte pulla* Roem.**										
***Astarte* cf. *orbicularis* Sow.**										
***Anisocardia cf. minima* Sow.**										

Continuation of Table 1

Name of the species	Geological age									Images of bivalves, × 2
	Bajocian			Bathonian			Callovian			
	L	M	U	L	M	U	L	M	U	
***Laternula undulata* Sow.**										
***Pholadomya murchisoni* Sow.**										
***Pholadomya solitaria* Mor. et Lyss.**										
***Goniomy recta* Pčel.**										
***Goniomya baysunensis* Gold.**										
***Goniomya* sp.**										
***Pleyromya balkhanensis* Pcel.**										
***Pleyromya decurtata* Phill.**										
***Pleyromya caudata* Terg et Jourdy.**										
***Pleuromya tenuistriata* Gold.**										
***Entolium demissum* Phill.**										
***Entolium singulatum* Gold.**										

The complex of rocks in which Jurassic macrofauna has been found most often is represented by grey to black non-calcareous hard argillites and fine-grained quartz sandstones. There are greenish-grey non-calcareous aleurolitess in some places, as well as grey non-calcareous thin-layered mica quartz sandstones. Sometimes one can find calcareous argillites with organogenic detritus. Small charred plant remains and pyrite grains are found throughout the section (Fig. 3).

The results of our studies of bivalve mollusks from Jurassic deposits of the Pre-Carpathian Foredeep Outer zone indicate the following: the forms we found have a relatively narrow range of stratigraphic distribution (Bajocian–Bathonian, Callovian), so they reliably prove the wide development of the Middle Jurassic deposits in the zone and allow to perform their much more detailed stratification and correlation. The species composition of the bivalve molluscs we have identified indicates a direct or very close connection between the Pre-Carpathian Jurassic and the Pre-Dobrogea sea basins.

The distribution of fauna in the Jurassic Sea was mainly due to the presence of different facial zones. The bionomic features of these zones contributed to the formation of a complex of fauna that adapted to certain conditions.

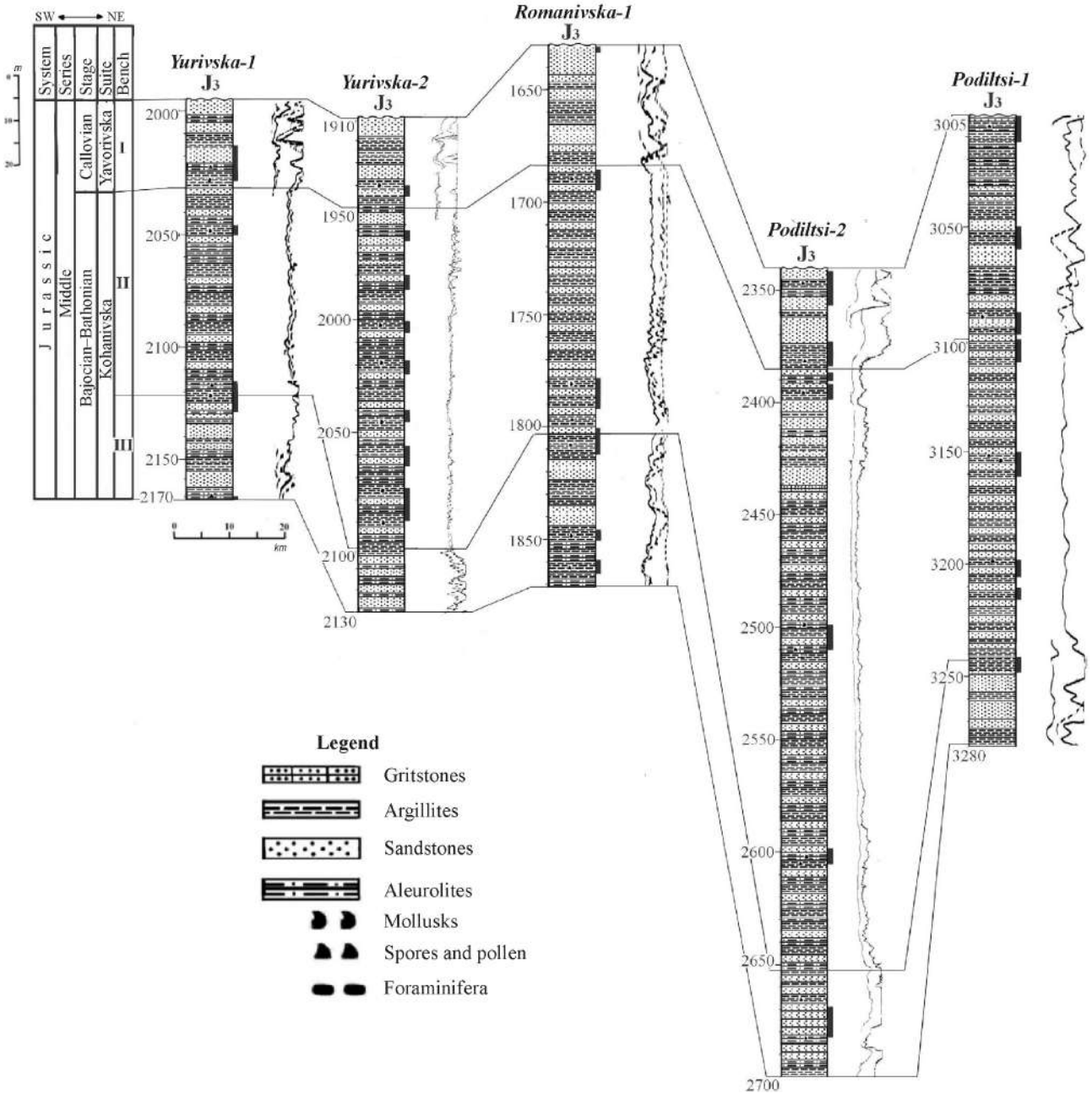


Fig. 3. Geological sections of the studied wells.

Conclusions

On the basis of a comprehensive study of bivalve molluscs, the biostratigraphic characteristics of the Jurassic stratum of the Pre-Carpathian Foredeep Outer zone have been significantly supplemented. The bivalve mollusks from Jurassic sediments were identified and monographically studied for the region first. Peculiarities of their stratigraphic distribution in the region are revealed. There are two stratigraphic levels of maximal distribution of mollusks, which differ in the saturation of fauna, its species diversity and orientation in the section. Bivalve mollusks are in the lower and upper parts of the section.

We paleontologically substantiated and confirmed the allocation of Bajocian, Bathonian and Callovian stages and defined their limits. The biostratigraphic characteristics of the studied strata have been improved, and it has also been proved that there was no significant break in the sedimentation at the Bathonian–Callovian boundary. The conditions of sedimentogenesis during the Middle Jurassic have been reproduced.

The lithostratigraphic delimitation of the Jurassic stratum with the allocation of two secondary lithostratigraphic subdivisions has been detailed, and their stratigraphic position (age) has been substantiated. The first subdivision is distinguished in the upper, larger part of the investigated section. It has a thickness of up to 200 m, and is composed of a thin rhythmic layering of sandstones, aleurolites and argillites, which are evenly represented in the section. Numerous bivalve mollusks that do not form accumulations have been identified in it. Among them, two guiding taxa for the Bathonian stage have been identified: *Goniomya baysunensis* Borissjak, *Pleuromya decurtata* Phillips. The second subdivision has been distinguished at the bottom of the stratum; it has a thickness of up to 80 m and is composed of a coarse alternation of sandstones, argillites and aleurolites benches. The distribution of rocks lithotypes here is different than in the first subdivision: sandstones form benches up to 10 m thick, between which there are layers of aleurolite-argillite composition with a thickness of 2–3 m. Numerous bivalve mollusks of different categories (background, characteristic and guiding) which form accumulations have been identified herein. Among them, two taxa, typical only for the Bajocian, were found: *Astatre orbicularis* Sow., *Pholadomya solitaria* Morris et Lycett.

References

Agasiz, L., 1840. Etuded critiques sur les mollusques fossiles. Monographie des Myes. 123–187.

Alth, A., 1881. Wapien Nizniowski and jego skamieliny. Sb. Acad. Um. W Krakowie. 6, 26–37.

Burov, V.S., Vishnyakov, I.B., et al., 1985. K voprosu o litostratygraficheskom podrazdelenii i usloviakh nakopleniia yurskih otlozhenii Predkarpatia i Volyno-Podolia. [On the issue of lithostratigraphic subdivision and the conditions of accumulation of Jurassic sediments in Ciscarpathia and Volyno-Podol]. 4, 130–136. (In Russian).

Derzhavna geologichna karta Ukrainy. 2004. Mashtab 1: 200,000, [State geological map of Ukraine, scale 1: 200,000]. Kyiv: Ministry of Environment and Natural Resources of Ukraine (In Ukrainian).

Dulub, V.G., 1964. Yurskie pestrotsvetnyie obrazovaniia Volyno-Podolskoi okrainy Russkoi platformy. [Jurassic variegated formations of the Volyn-Podolsk margin of the Russian platform]. 9, 101–105. (In Russian).

Gavrilishin, V.I., Karpenchuk, Y.R., 1982. Nakhodki makrofauny v novyh tipah yurskih razrezov Predkarpatskoho progiba. [Finds of macrofauna in new types of Jurassic sections of the Ciscarpathian trough]. Kiev: NAS of Ukraine, 34–35. (In Russian).

Glushko, V.V., 1968. Tektonika i neftegazonosnost Karpat i prilegaiushchih progibov. [Tectonics and oil and gas content of the Carpathians and adjacent troughs]. Moscow, 259 p. (In Russian).

Greppin, E., 1896. Description des fossiles du Bajocien superieur des Environa de Bale. Mem. Soc. paleont. 25–24.

Hecker, R.F., 1954. Nastavlenie dlia issledovanii po paleoekologii. [Manual for Research in Paleoecology]. Movcow: Nedra, 15–34. (In Russian).

Koch et Dunker., 1837. Beiträge zur Kenntniss des norddeutschen Oolitengebildes und dessen Versteinerungen. Braunschweig, 76 p.

Leshchukh, R.Y., 1978. O vremens proiavleniia vulkanizma yugo-vostoka Ukrainskih Karpat. [About the time of manifestation of volcanism in the southeast of the Ukrainian Carpathians]. 51, 12–17. (In Russian).

Leshchukh, R.Y., Bubnyak, I.M., 1991. Moliusky serednioyurskykh vidkladiv Zovnishnioi zony Peredkarpatskoho prohynu. [Molluscs of the Middle Jurassic species of the Outer zone of the Pre-Varpathian Foredeep [Paleontological Zbirnyk] 28, 30–34. (In Ukrainian).

Merklin, R.L., 1949. K poznaniiu paleoekologii molliuskovoi fauny verkhnetarkhanskih glin Kerchenskogo poluostrova. [To the knowledge of the paleoecology of the mollusk fauna of the Verkhnetarkhan clays of the Kerch Peninsula [Publishing house. AN SRSR] 15 p. (In Russian).

Moryc, W., 1961. Budowa geologiczna rejonu Lubaczowa. Rocznik Polskiego Towarzystwa Geologicznego 31, 47–83.

Quenstedt, A., 1858. Der Jura. Tubingen, 552 p.

Roemer, J., 1911. Die Fauna der Aspidoides Schichen von Lechstedt bei Hildesheim. Hannover, 76–140.

Romanov, L.F., 1973. Yurskie morskie dvustvorchateie molliuski mezhdurechia Dnestr–Prut [Jurassic marine bivalves of the Dniester–Prut interfluve]. Chisinau: Shtiintsa, 227 p. (In Russian).

Shainoga, I., Leshchukh, R., Hotsanyuk, H., 2001. The Ukrainian Carpathians autochton – a new oil and gas exploration object [Nowe metody i technologie naftowej, wiertnictwie, eksploatacji otworowej i gazownictwie] Krakow: 41–45.

Shaynoga, I., Leshchukh, R., 2002. Novi znakhidky dvostulkovykh moliuskiv u yurskykh vidkladakh Peredkarpatskoho prohynu [New henchmen of two-stalked molluscs in the Jurassic specimens of the Precarpathian Progin [Paleontological collection] 34, 47–54. (In Ukrainian).

Shinoga, I., 2001. Biostratyhrafichna kharakterystyka serednioiurskykh vidkladiv u sverdlovyni Romanivska-1 (Peredkarpatskyi prohyn) za moliuskamy [Biostratigraphic characteristics of Middle Jurassic specimens near Sverdlovina Romanivska-1 (Precarpathian foredeep) for molluscs [Paleontological collection] 33, 120–123. (In Ukrainian).

Slavin, V.I., Dobrynina, V.Y., Efimova, N.A., 1967. Novyie dannyie o yurskih otlozheniiah Sovetskih Karpat [New data on the Jurassic deposits of the Soviet Carpathians [Materials of the VIII Congress. KBGA] Belgrade, T. 1. 347 p. (In Russian).

Vyalov, O.S., 1950. Vremia obrazovaniia flishevogo troga Karpat i kharakter porod ego fundamenta. [Time of formation of the Carpathian flysch trough and the nature of its basement rocks]. 410–414. (In Russian).

Journal of Geology, Geography and Geoecology

ISSN 2617-2909 (print)
ISSN 2617-2119 (online)

Journ. Geol. Geograph. Geology, 30(4), 718–740.

Journal home page: geology-dnu.dp.ua

doi: 10.15421/112167

Anthropogenic impact on the shores and the bottom of the Jebriyan bay in the Northwestern part of the Black Sea

Yuriy D. Shuisky, Galina V. Vykhovanetz, Ludmila V. Organ, Mukete Theophilus N. Moto

Odessa I.I. Mechnikov National University, Odessa, Ukraine, physgeo_onu@ukr.net, muketem2002@yahoo.com

Received: 14.01.2021
Received in revised form: 25.10.2021
Accepted: 27.11.20221

Abstract. The Jebriyan Bay is located in the northern part of the Kiliya Danube Delta, at a junction of the delta cone and the indigenous coast. This is a zone of very high anthropogenic impact on the Danube Biosphere Reserve. The two opposite shores of this bay are fundamentally different. Along the northern shore, the Northwest coastal sand sediment flows discharge from the Cape of the Great Fontanne to the Jebriyan Bay. That is why the northern coast of the bay is made up of sandy forms of coastal topography (marine accumulative terrace and spit). The southern coast is deltaic; composed of a mixture of muddy, siltstone and sandy sediments. The area of the bay is limited to isobaths –11 m and is about 80 km^2. The bottom of the bay has a gentle relief, made up of smooth outlines, with an average depth of 6.2 m. The shape of the transverse profile of the underwater slope is mostly convex. The natural system of the bay was affected by fishing, recreation, shipping and industrial sand production on coastal accumulative landforms. Coastal fishing uses a system of fixed bottom seines and small motorized floating equipment. Recreational facilities are designed to serve about 350 thousand people during the warm period each year. The impact of shipping was expressed in the construction and operation of the seaport of Ust-Dunaysk, together with suitable canal and the technical canal between the sea and the branch of the delta breakthrough the system of the large Ochakov branch. The ladle port had an area of about 1.5 km^2, a maximal depth of 16 m, and an average depth of 13.7 m. The trough was connected to the Ochakov branch of the Danube Delta by a technical canal with a depth of 4 m. Vessels could enter the harbor of Ust-Danube through an access navigation channel with a depth of 11–12 m and a bottom width of 125 m. The port was used for the transshipment of large containers, general forest cargo from ocean vessels (displacement of 60–100 thousand tons) on regular sea lines from the countries of Southeast Asia to the Black Sea, to the Danube and further to the countries of Central Europe and to the ports of the North and the Baltic Seas. But it was unfortunate that the port construction site did not last as expected. Between 1980–2010 the harbor and approach canal of Ust-Dunaysk were filled with Danube river sediments. The example of Jebriyan Bay has shown that when executing any type of sustainable nature management project, it is very important to take into account the natural milieu.

Keywords: Northern Black Sea, Danube Mouth, Jebriyan bay, dynamic, sediment, economy significance.

Вплив антропогенного фактору на берег і дно Жебріянської бухти в північно-західній частині Чорного моря

Юрій Д. Шуйський, Галина В. Вихованець, Людмила В. Орган, Мукете Теофілус Н. Мото

Одеський національний університет імені І.І. Мечникова, Одеса, Україна, physgeo_onu@ukr.net, muketem2002@yahoo.com

Анотація. Жебріянська бухта знаходиться в північній частині Кілійської дельти Дунаю, на стику дельтового конуса і корінного морського берега, в зоні антропогенного впливу Дунайського біосферного заповідника. Два протилежних берега даної бухти докорінно відрізняються. Уздовж північного берега відбувається розвантаження Північно-західного вздовжберегового потоку піщаних наносів, який поширюється від мису Великий Фонтан і до Жебріянської бухти. Тому північний берег бухти представлений піщаними формами берегового рельєфу (морською акумулятивною терасою і косою). Південний берег є дельтовим, він складається з суміші мулистих, алевритових і піщаних наносів. Площа бухти обмежується ізобатою –11 м і становить близько 80 км^2. Дно бухти має пологий рельєф, з гладкими контурами, середня глибина 6,2 м, форма поперечного профілю підводного схилу в основному опукла. Природна система бухти підпала під вплив рибальства, рекреації, судноплавства, промислового видобутку піску на берегових акумулятивних формах рельєфу. Прибережний лов риби використовує систему ставних і донних неводів, малі моторні плавучі засоби. Рекреаційне господарство розраховане на обслуговування близько 350 тисяч людей протягом теплого періоду в році. Вплив судноплавства виразилося в будівництві і експлуатації морського порту Усть-Дунайськ, разом з підхідним каналом і технічним каналом між морем і дельтовим рукавом Прорва, в системі великого Очаківського рукава. Портовий ківш мав площу близько 1,5 км^2, максимальну глибину 16 м, середню 13,7 м. Ківш був з'єднаний з Очаківським рукавом дельти Дунаю технічним каналом, глибиною 4 м. Судна могли заходити в гавань Усть-

Дунайська по підхідному навігаційного каналу з глибинами 11–12 м., шириною по дну 125 м. Порт використовувався для перевалки великих контейнерів, генеральних, лісових вантажів з океанічних суден (водотоннажність 50–90 тисяч тонн) на регулярних лініях з країн Південно-східної Азії на Чорне море, в Дунай і далі в країни Центральної Європи і до портів Північного і Балтійського морів. Місце будівництва порту виявилося вкрай невдалим, і в період 1980–2010 роки гавань і підхідний канал Усть-Дунайська були заповнені дунайськими річковими наносами. Приклад Жебріянської бухти показав, як важливо враховувати природне обґрунтування будь-якого виду раціонального природокористування.

Ключові слова: Північне Причерномор'я, гирло Дунаю, Жебріянська бухта, динаміка, осадові породи, господарське значення.

Introduction.

The Jebryan bay occupies a special geographical place on the northern coast of the Black Sea. Its formation is associated with the development of the Kiliya part of the Danube Delta under the influence of a strong wave-energy with a vector in the south-west direction. During the Holocene era, giant sediments of runoff from the Danube delta led to its rapid extension into the open sea. The demolition of alluvium to the south made the northern part of the delta to form a concavity of the coastline in the form of a small bay at the junction with the indigenous coast of the sea in the Jebriyan section. The southern part of the bay is made up of a delta coast which is composed of sandy-silty and silty deposits washed by the alluvium of the Danube River. It is connected by a canal with one of the largest delta branches – Ochakovsky. Until the mid-90s of the twentieth century, it remained the main shipping port in the Kiliysky branch. Along the northern shores a coastal sandy stream of terrigenous sediment of about 150 km long are deposited. This led to the formation of the sandy embankment of the Sásyk estuary, the accumulative terrace of Volchék and the Jebriyan spit in the Southern part. The Danube silty and terrigenous coastal deposits also fill the bottom of the bay which forms a calm bottom relief with smooth outlines.

The aforementioned features created favourable conditions for vigorous economic activity developed in the bay and on its shores. Fishing remained traditional (Zaitsev *et al*., 2006) until the end of the twentieth century, 3 large fishing and processing points operated on the shores of the bay with a system of coastal fishing equipments. On the northern shore of the bay the wide sandy beaches on the Volchek terrace began to be massively used for recreational purposes. This gave birth to a sea side resort village in Primorskiy. In 2019 summer there were 123 boarding houses and recreation centres for people with the appropriate infrastructures (rescue station and boat rental, shops, regular transport, pharmacy, bank branch, medical centre, these are just a few of them). Over the past 5 years, about 350 thousand people have been using the recreational services of the Primorsky Recreation Zone. In the southern delta coast of the bay, the Lighter Fleet Base began its work in the southern delta coast of the bay in 1972, and in 1980 the seaport of Ust'-Dunaysk became operational. Floating containers passing through this port to the Danube cargo transported mostly from the ports of Saigon (Vietnam) and Calcutta (India) to the European countries through the Danube water system on regular navigation routes. A deep suitable canal for ships with a displacement of up to 100 thousand tons was built along the coastal shallow water to the port. In the Danube, containers were carried along the delta branch of the opening which was deep in the 70–80s of the 20th century. It ensured the unhindered passage of Black Sea containers to the Danube right up to the port of Passau (Federal Republic of Deutschland).

Despite this huge economic potential, for several decades now the Jebriyan Bay and its shores have been experiencing high rate of anthropogenic pressures. The natural system is subject to significant stress. It is, therefore, very important to evaluate the natural state of the bay in recent years as shown in the figure 1. Moreover, since 1998 this bay has been included in the zone of traditional permissible anthropogenic activity of the local population. It is also the part of the Danube Biosphere Reserve which requires the sustainable use of natural resources in a fragile natural delta system.

The aim of this manuscript is to identify and study the dynamics and morphological patterns of the Jebriyan bay coasts (northern coast of the Black Sea) in order to minimize the high rate of economic use of natural resources. To achieve this goal, the study set out some basic tasks: a) the physical and geographical conditions for the formation of the bay coast; b) the main features of dynamics of the bay coast; c) the lithodynamic processes in the bay; d) an assessment of the mutual influence of nature in the bay and the economic facilities on the banks and bottom of the bay. This article is prepared basing on the results of the field work carried out in the Jebriyan bay (fig. 1).

Review of previous researches.

Previous researches have shown that within the past decades there have been much concern on the degrading nature of the Danube Delta which is considered to be an economic hub and Europe's largest delta. This study highlights the contribution of some prominent authors by tracing the history of studies already carried out in this Delta. As far back as the ancient times, the Danube Delta remains the economic hub and European largest and most important river transport artery.

Although, in spite of this potential, it is unfortunate, that scientific interest on this delta is usually counted from the middle of the XIX century when scientific

Fig. 1. The location of Jebriyan bay within the boundaries of the Kiliya part of the Danube Delta: A – the arrow indicates the location of the bay; B – the contours of the coast of the bay. Digits: 1 – Belgorodskiy branch; 2 – Soloniy bay; 3 – Polunochniy bay; 4 – Prorva branch. Hydrometeorological Stations: a – Primorske; b – Ust'-Dunaysk; c – Vilkove.

research began with the purpose of developing a permanent shipping line through the Danube Delta to the Black Sea (Nikiforov and Diaconu, 1963). Some detailed research was carried out by the European Danube Commission and the Russian Corps of Railway Engineers as pointed out by Mikhailov & Morozov, 2004. In a similar manner, Lelyavsky, Lishin, Rummel, Chekhovich and a host of other authors were cited in the monograph.

The most famous studies of the Kiliya delta were carried out by the European Danube Commission (1922), the Hydrographic Service of Romania (1930 and 1943), the Hydrographic Service Navy of the USSR (1940, 1956, 1986), the Ukrainian Navy (1998, 2018) and the Danube expedition of the Black Sea Research Institute of the USSR Marine Fleet (1957, 1976, 1989, 2002). In the end of the twentieth century and at the beginning of the twenty-first century, biological and hydrological surveys in the Jebriyan bay were conducted by the Institute of Biology of the South Seas of the National Academy of Sciences of Ukraine and Odessa State Ecological University. A significant amount of research has equally been carried out by Bondar and his staff at the Delta Nature Reserve as cited by Munteianu in 2002.

Zenkovich (1943) was the first to pay a close attention to the nature of the Jebriyan bay. His findings proved that the bay is a facility of close interaction of natural systems in the delta and the adjacent coastal indigenous systems in accordance with the theory of coastal science (Fig. 1). This phenomenon made it possible to establish finally the processes of the Holocene evolution of the Danube Delta (Petrescu, 1963; Zenkovich, 1958). Its influence led to the emergence and development of the Jebriyan bay. The first research of sediment shore composition were carried out in the early 60s by Shuisky, 1966 and an article specially dedicated to the sediment shore was first published in 1969 by Shuisky. A detailed analysis of the morphology and dynamics was performed in this article with the help of the wind-wave energy flows of sediment distribution. Unfortunately, according to the Romanian researchers (Petrescu, 1963; Gaştescu, 1993) neither the bay, nor its key litodynamic significance has been given to the adequate attention it deserved from policy makers. The relationship between the structure and dynamics of the entire Danube Delta and its evolution during natural history has been highlighted by (Andrianova *et al*., 2011; Panin, Jipa, 2002). Researchers also obtained numerical data on the velocities and signs of long-term fluctuations in the Black Sea level over the past century. The coast of the bay is shown in the Fig. 2.

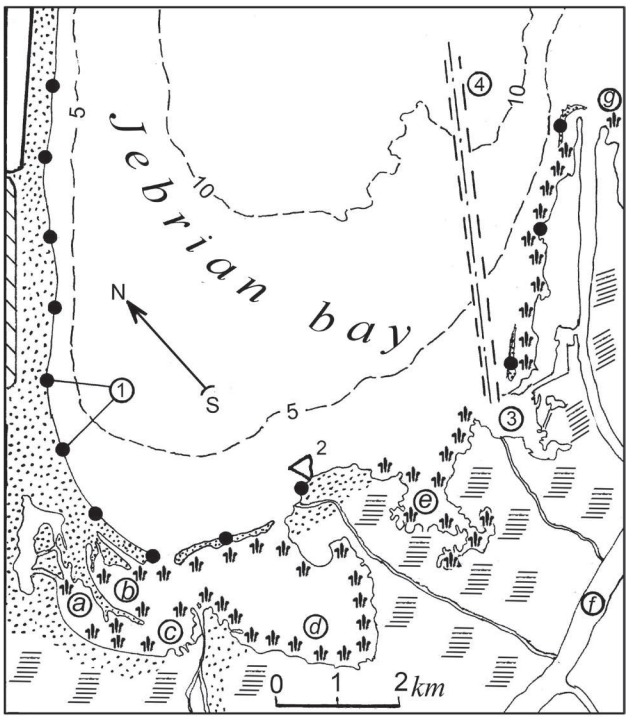


Fig. 2. The structure of the Jebriyan bay as part of the Danube estuary. Secondary "delta bays": a – Durnoy; b – Zebriansky; c – Belgorod; d – Salty; e – Polunochniy; f – Ochakov Branch; g – the mouth of the Prorva. Onshore facilities: 1 – location of coastal surveying and ground tacks; 2 – the average long-term separation point of the lithodynamic section of delta and beach sediments of the root shore; 3 – bucket of the port of Ust'-Dunaysk; 4 – route navigable approach channel; 5 and 10 – isobaths at the bottom of the bay, in meters. North point 1 is still on the Volchek terrace, and the south point is at the root of Jebriyan Spit.

The exploration of the Danube Delta and its environs including the Musura and Jebriyan bays intensified in 2003. The main objective was to create a natural waterway from the Danube to the Black Sea and vice versa. The Institute of River Transport (Kiev), the Institute of Ecological Problems (Kharkov), the Institute of Hydrobiology of the Academy of Sciences of Ukraine, the Institute of Marine Biology of the Academy of Sciences of Ukraine and others participated in these works. Various aspects of the issue were discussed at the 9th scientific conferences under the program "Problems of the Black Sea Ecology". As a resolution from the conference "The Black Sea – Danube River" waterway along the Bystriy delta branch was chosen as the optimal one. New information was obtained on the morphology and dynamics of the coasts of the Jebriyan Bay and the delta as a whole (Berlinskiy, 2012; Vykhovanets, Organ, 2010; Shuisky, Organ, 2017, 2017a). After several strong storms and intensive elaboration of the shore's relief and sediment new information regarding the nature of the bay was received from (2007–2019). This made it possible to find and understand the exogenous mechanisms of the formation of the coasts of the Jebriyan bay in particular and the Kiliysky Danube delta as a whole. This made it easier to assess the nature of anthropogenic impact on the natural coast and bottom of the Jebriyan bay.

It is, therefore, evident that many authors have carried out research on the natural coast and bottom of the Jebriyan bay for many years. In this case, a wide range of methods were used by previous authors; like the field work methods of Vykhovanets, 2003; Zenkovich, 1958; Mikhailov, Morozov, 2004; Shuisky, 1969, 1984, 2003 and Gaştescu, 1993. Stationary topographic sections were studied on 13 typical coastal bay sections for repeated Manuel surveys at a scale of 1: 1000; they are shown by large dots in the Figure 2. The length of each section is 500 m. A baseline is fixed along the coast. It is used to capture the coastline and roughness of the coast. Benchmarks are installed at the base of the ground at every 100 m. The shore is leveled and the echo sounder is measured from each reference point towards the sea and at an angle of 90° to the baseline to the depth of 6 m. The bottom samples were taken by the Peterson bottom grab. The authors took the sediment samples of the average width of the beach on the shore, one on each profile. Then, the average value over the entire stationary section was calculated (Shuisky *et al*., 2017). On the underwater slope, sediment samples were taken on average through each meter of depth. The sediment samples were subjected to water and fractional analysis (*lithological method*) in the Analytical Laboratory of the Department of Physical Geography of Odessa National University (Odessa, Ukraine). Then they were analyzed using mathematical statistics methods.

In order to determine the pattern of sediment distribution along the coast of the Jebriyan Bay, Knaps (1968), developed and verified the natural conditions of the sandy and the pelitic shores of non-tidal seas with the use of *hydrometeorological method*. For decades, this method has been tested in areas of the North-Western part of the Black Sea by comparing the results of the study with different methods. Amongst the methods used were the hydrometeorological, geomorphological and lithological methods. These methods made it possible to identify the direction and intensity of the coastal movement of sediments (Fig. 4). The first calculations according to the observations at the Primorske station were made from 1950–1966 as shown in the Figure 4a and later, for comparisons, during the period of 1984–2016 (Fig. 4 b). Over the past half century, they have shown qualitatively identical result: sediments continue to fill the top of the bay (Vykhovanetz, Organ, 2010). At the same time, at the site of convergence we noticed a shift of sediments east wards, from the distal of the Jebriyan spit to the top of the Polunochny ledge, that is almost 4 km which is approximately 10 % of the coastline of the bay, (*analytical method*).

Hundreds of researchers have carried out studies on the Danube Delta, but very few scientific works have attracted the attention of the Jebriyan Bay. The delta has already been fully explored, but as concerns the Jebriyan Bay is very little known. Materials concerning the bay are rare and scarce. There is not enough information about the impact of economic activity on the state of nature of the coast and the bottom of the bay. We hope that this article will improve and deepen our knowledge and understanding of the bay and delta as a whole and will serve as the platform to optimize nature management.

Results and their analysis.

The Jebriyan Bay is located in the northwestern coast of the Black Sea with a continuous extension of the Danube Delta towards the sea. The length of the bay along the center line became wider because of an active filling with sediment from the top of the bay. This filling led to the absorption of the Northwest coastal flow of sand deposits which originated from the northeast near the Cape Big-Fontanne as shown in the Figure 1a, which ignited a new focus on the accumulation of alluvial sediments of delta. The Kiliyskaya part of the Danube Delta was formed in the upper Holocene. Its protrusion created an obstacle for the long shore sediment flow and led to the emergence of the Jebriyan Spit and the Volchek Terrace by adjoining coastal bars to the coast, leading to the formation of a system of rampant storms and dividing the hollows separating them. Over the past decades, they have attained large sizes and represent a new "*grindu*", which is called Jebriyan grindu according to Zenkovich, 1943; Nikiforov &

Diyakonu, 1963. The length of the bay along the center line is about 9 km while the length of the coastline is about 45 km if we take into account the Salt, Jebriyan and Durnoy small delta bays. With such values and an average long-term water level, the bay area does not exceed 80 km^2. In this area, the maximal depth is 11 m, with an average depth of 6.2 m, and the water volume is about 0.5 km^3. Hydrometeorological regime along the shores was studied by current period monitoring in HM-stations "Primorske" and "Ust'-Dunaysk" on the bay-coast (fig. 3), and special geographical literature from (Andrianova *et al*., 2014; Vykhovanetz, 2003; Il'in, *et al*., 2012; Panin, Jipa, 2002).

The coasts of the Jebriyan Bay had such coordinates at four points on the coastline: a) the northern point on the adjacent shore of the Sasyk embankment is 45º 32′ 30′′ N – 29º 40′ 18′′ E; b) the southern point on the Belgorod bar is 45º 28′ 44′′ N – 29º 36′ 18′′ E; c) the final target of the Delta Channel Prorva is 45º 30′ 45′′ N – 29º 45′ 40′′ E; d) and the harbor bucket of the seaport of Ust-Dunaysk is 45º 28′ 06′′ N – 29º 42′ 18′′ E. The difference between the values is small; this confirms the small size of the bay. Coordinates may be needed in the future for comparisons, in order to determine the exact dynamics of the coast and the bottom as shown in the Figure 2. The recreational site in the bay is located in the northern sandy shore, about 8 km long between the middle part of the Sasyk Beach barrier and the distal section of the Jebriyan Spit which is based on the balneological resources of the regions. The medicinal properties of sea water, sand cover of beaches, a mixture of sea and steppe air, local mineral waters, etc. are actively used. Food products are highly valued, in particular, vegetables, fruits, grapes, dairy products, and sea food. The duration of the swimming season is from 130 to 145 days for different years. During fishing, the bottom trawl methods are used often. This leads to disruption of the structure of bottom sediments and the physical destruction of soils, plants and animals. At the same time, the turbidity of the water increases, and this leads to a slowdown in photosynthesis and a decrease in the oxygen content in the water.

The materials we have obtained from the physical and geographical studies of the Jebriyan bay are much more numerous than those presented in the article. This is because we have applied the methods of preliminary selection in accordance with the goals and objectives of the article and used the most significant information necessary for the presentation of the results and conclusions.

The hydrodynamic elements of the near shore waters.

Firstly, we used original datum of direct monitoring on hydrometeorological stations "Ust'-Dunaysk" and "Primorskoye" from current work observation diaries by direct separation. Continuous number of the observation years were 1984–2015 and near Zmeiniy Island in opened aquathory of the Northern Black Sea (Il'in *et al*., 2012) (fig. 3). Secondly, for its elaboration was used mathematical and statistics method and hydrometeorological method by R. Knaps [1985], the result shown in the fig. 4.

It is possible to see from the location and contours of the shores of the bay, that its water area is open to the action of winds and wind waves from the N, NE, E and partially the SE, rhombuses (Fig. 2). With the use of a wind rose for the gradation of wind speeds in individual particular points (Fig. 3), the result clearly shows that the coasts are significantly affected by strong and gale winds with speeds of more than 10 m/s. Such winds produce waves with a height of more than 1.5 m depending on the acceleration length and the depth of the water aquatory. At the entrance to the bay, the maximal height of the waves can reach 4–5 m as much as possible, and this leads to a significant abnormal force of the wave flows in different parts of the water area. At the same time, a synoptic wind surge of at least 1.2 m above the ordinary is possible at the top of the bay (Nikiforov and Djakonu, 1963; Mikhailov and Morozov, 2004). Such phenomena lead to the appearance of a surge lens of water, its saturation with suspended sediment, flooding of the low coast, and an increase

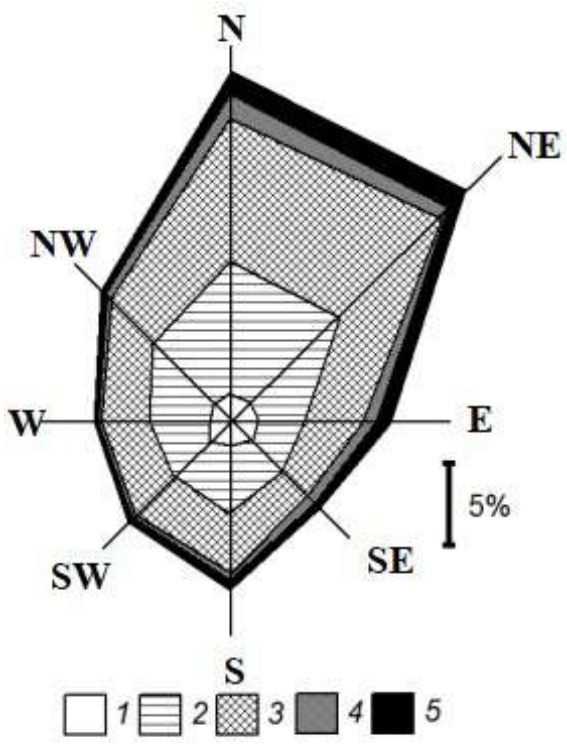


Fig. 3. Wind rose, constructed according to observations in the North-Western Black Sea hydrodistrict from 1923 to 2006. Wind speeds: 1 – ≤ 1 m / s; 2–2–5 m / s; 3–6–10 m / s; 4–11–15 m / s; 5 – ≥ 16 m / s. The circle in the center of the rose is calm, 4.5%.

in the wave effect on it. At this time, the shore most often erodes, but subsequent minor disturbances usually restore the shore. Post-storm water level depletion is accompanied by the removal of a water lens, and its suspended sediment which is usually pelitic fractions. This process can be very powerful, especially with fast denivelation. An injection effect develops, which does not allow sufficient amount of alluvium from Danube to accumulate and fill the Jebriyan bay. Indeed, unusually large sediment with an average size of 204 million tons / year flows from the Danube.

Its main part moves south wards along the sea edge, and only about 6 % in suspension might fall into the bay with the corresponding wind directions. However, this quantity is also pumped out by driven currents. There is enough sediment that fills the plains and shallow lakes which lead to the formation of primary accumulative forms, bars and streamers.

The wind regime, the presence of the Jebriyan Bay and the interaction of the Danube and the adjacent part of the sea led to a typical system of currents. The stock stream from the Dnipro and Dniester flows into the northern branch of the Circular current of the Black Sea. On a beam traverse of 15 km from the coast, this branch meets the stream of the Danube runoff. As a result, part of the branch is pressed to the shore and invades the bay, where it takes the form of a clockwise circulation. Such a local Jebriyan circulation is not very stable; its repeatability is about 55 %, although it can be up to 85 % in some years. Together with the overtaking effect, this circulation prevents strong shallowing and helps to clean the bay from pollutants.

Furthermore, the wind regime, the contours of the coast and depths in the bay led to a high degree of mixing of water and its saturation with oxygen. The mixing of fresh river water and salt water led to the saturation of water with vital substances. All this contributed to a high primary production with a rich forage base. According to hydrobiological and hydrochemical studies (Zaitsev et al., 2006; Mikhailov and Morozov, 2004), the waters of the bay have a high intensity of self-purification. At the same time, the Danube water has a significant influence on the hydrochemical regime of the Jebriyan Bay, which in general is permanently polluted.

The distribution of mass sediment along the shore flow paths is controlled by the wind-wave energy flows (Zenkovich, 1958; Knaps, 1985; Shuisky and Organ, 2017). Taking into consideration the advantage of the natural relationship established between the wind and wave regimes in the sea according to which the dimensions of wind waves become larger, the greater the speed and the duration of the wind, the longer the acceleration of wavelength and the depth of the water area and the lower the viscosity of the water. This connection has a tangential regularity and makes it possible to calculate the elements of energy triangles (Fig. 4). Integral alongshore nano-motive force T shows the direction of effective sediment movement to the top of the bay along both the northern and the southern coasts (Fig. 4 *A, B*). This means that the accumulation focus has moved to the Belgorod bar, and wave shafts continue to adjoin the Jebriyan spit. The process of coastal buildup in the Volchek and sand spit areas continues, and the reformation of the named bar has intensified. It occurs continuously, intensifying or weakening, under the influence of sediment accumulation from the coastal stream, which begins in the northeast, closed to the Big Fontanne Cape.

The greater the T_{res}, the greater the nanosized ability of the wind-wave energy flow, the greater the amount of sediment that moves along the coast to the accumulation sites in the Jebriyan bay. Along the coastal route, the ability of sediment to constantly change depends on the exposure of the coast with respect to E, the slopes of the underwater slope, the relief of the coastal bottom, the strength of the storm, the shape of energy triangles and the productivity of sediment sources for the coastal zone, etc. Therefore, the change of each component of the coastal zone immediately affects the value of the T_{res}. According to the values of T_{res}, it is possible to see that earlier in the middle of the 20th century (Fig. 4 *A*), sediment freely passed along the Sasyk sandy bar, but actually accumulated on the distal part of the Jebriyan spit. Over the past decade, sediments supply to point T_2 have increased (fig. 4 *B*), to the south on the distal spit. These sediments accumulate and at the same time they increase the size of grindu. The same scheme of the natural process was developed during the Holocene and earlier, when large grindu were formed: Krasnikol, Sereturile, Karaorman, Letia.

The dynamics of the relief and sediments. Based on the results of our field work and stationary studies, the main features of the morphology and dynamics of the coasts of the Jebriyan bay were identified. The shores are generally low; they rise above the ordinary by ≤ 3 m. The southern shore is bordered by low sand and pelitic beaches, peculiar wave shafts that are underlain by sandy-mud strata in the Würm and Holocene ages. As a rule, they are flooded during wind surges. The back side of the coast is overgrown with cattail, a water lily, reed sediment developing everywhere. Mud-silt sediments are actively accumulating inside the delta during floods and strong wind surges. Such conditions are typical for the top of the bay. Wave bars are built up by sediments from the underwater slope, and small bays, which they fence off from the sea, turn into delta lakes. These lakes can be preserved for a long time, but their depth is rarely significant, and most often does not exceed 1 m, hence, it turns into floodplains. Few lakes dry off and their traces are preserved in the form of overgrown clay-silty sections.

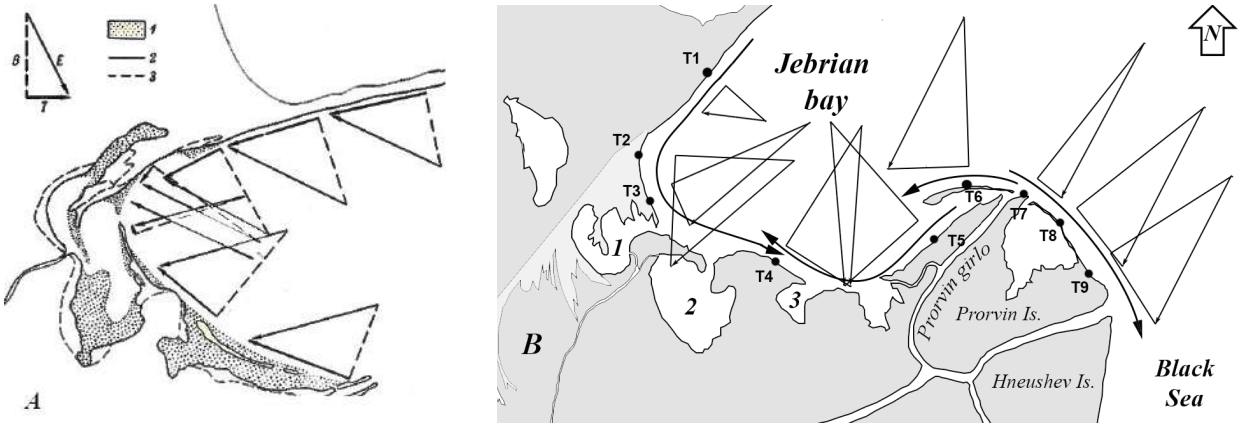


Fig. 4. Wind-Energetic characteristics: *A* – by Yu. D. Shuisky (1969); *B* – average per 1 year by datum for the period of 1984–2016; *E* – wave energy resultant; $T_{рез}$ – alongshore nanomotive force; B – a component normal to the coast – "breaking force"; The Deltaic Small Bays (local name is "Kuts"): 1 – Durnoy Kut; 2 – Soloniy Kut; 3 – Polunochniy kut.

The southern coast with its indigenous plot overlooks the sea on a short stretch of about 2.5 km, under the Volchek shore terrace. The extreme part of the Sasyk sandy embankment to the north-east. Its peculiar "continuation" is a sandy terrace adjoining a clay root bank. The Jebriyan spit is to the south-west of it (Fig. 2). All of them form a discharge area of the Northwest alongshore sediment flow. Moreover, the sediments that come to the bay are primarily deposited on the underwater slope (Fig. 5 *A* and *B*). This means that (Fig. 5) during sedimentation drag-fault along the detritus flows and accumulate near the edge. Here they form up to 3–4 submarine shafts that look like a terrace near the sandbank. From the sea, it ends with a dump of depths in the range of 1–4 m and to the bottom of the bay at depths of 4–7 m. During wind waves over the near-sandy terrace, the waves increase the sediment supply to the coastline and the beach.

This phenomenon is continuous, because it is ensured by a continuous flow of sediments from the sandy alongshore sediment flow. Due to the development of wave transformation in the shallow water there is an accelerated formation of submarine shafts which are attached to the coast and influences the growth of the coast and the increase in the width of the beaches.

This is an example of the high dynamics of sand accumulation processes presented for two typical sites: that is in the northern part of the Volchek terrace (Fig. 5 *A*) and in the middle of Jebriyan Bay (Fig. 5 *B*). It shows that shoreline can grow at very significant high speeds which can reach 15 m during a year on the distal section of the Jebriyan spit.

In general, along the northwestern coast, velocities from 2 to 7 m / year are most often found. The average long-term value according to field studies in 9 stationary sites (Fig. 2) was 5.2 m / year during the period of 1982–2019. This trend is clearly traced by the increase in the width of the Volchek sand terrace. Taking into consideration the increment of sediments on the coast and underwater slope, the average specific accumulation value was 45 m^3 / m • year in section A and 66 m^3 / m • year in section B, which is 6.5 km to the south. It is clear that with the advancement from the central part of the Sasyk beach barrier to the Jebriyan Spit distal, the amount of accumulation becomes larger. At the same time, a simple wave sediment deposition is replaced by a massive movement of bottom shafts to the coast and their attachment to the beach. As a result of

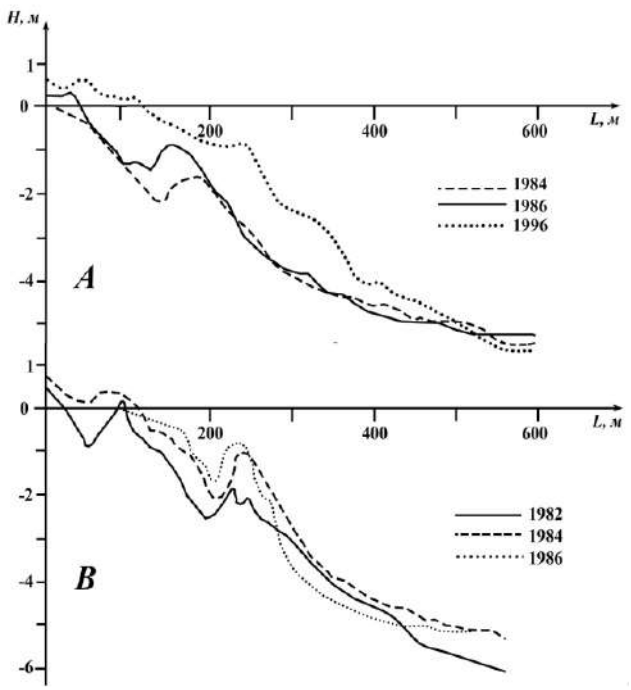


Fig. 5. *A*) – Dynamics of submarine slope profiles within the western side of Jebriyan Bay in different dates: *B*) -Dynamics of the transverse profile of the beach and the underwater slope in the northwestern part of the Jebriyan bay in the Black Sea coast. Repeated surveys of profiles: *A* – at the northern part of the Volchek terrace in 1984, 1986 and 1996; – In the middle part of the Jebriyan spit in 1982, 1984 and 1986. Height *H* and horizontal layering *L,* in meters.

this, the frontal outer coast of the Jebriyan spit extends towards the sea, and the distal extremity becomes longer, which we consider as the main dynamic feature of the spit. Such phenomena form the values of the slopes of the underwater tilt in the wave energy field. The most common integral slope of the underwater tilt along the central axis of the bay is 0.0011.

With such a slope, the effect of wind waves on the top of the bay is very insignificant. However, at the same time, on the northern (Jebriyan) flank of the bay, slopes range from 0.0143 to 0.0227; and in the southern (pro-Prinian) region, about 0.008–0.010, i.e. 1.5–2.9 times less to a depth of –7 m. This means that the north coast is mainly affected by the wave (bottom stream), and the south coast is mainly affected by the overtaking processes and wave currents. There is a strong over taking processes at the top of the bay, where today the following delta lakes can be found: Jebriyan Kut, Durnoy Kut, Soleniy Kut, Kut Shábosh. Therefore, using the Jebriyan bay as an example, it is very easy to determine the structure and patterns of formation of sediment discharge areas.

The Beaches and Sediment composition. The beaches of the northwestern coast of the Jebriyan bay took their shapes from the prevailing historical environmental conditions. Their sizes were determined by the wind wave regime action, wave currents and synoptic fluctuations of the sea level with a constant supply of sand deposits from the coastal stream. The usual width of the beach attained about 40–55 m with a height of 1–2 m above the ordinary (Fig. 6, A, B, C). Generally, in a tidal sea condition, it is a fairly large beach, moderate influence of wind waves, a noticeable effect of storm-surges and wind-driven fluctuations in the water level and an abundance of coastal-marine sediments. In addition, an accumulative formation of Aeolian hummocks and rows (Fig. 6, C) takes place from the beginning of the Volchek coastal accumulative terrace and to the south of the distal of the Jebriyan spit. The natural system of the Jebriyan bay is becoming more diverse and requires a particularly careful attitude on the part of human. All sediment datum made by authors during many natural expeditions with direct sampling and elaboration in the Department Laboratory, have decimal enlistment of sieves.

The differences in the structure and development of the southeastern and northwestern shores of the Jebriyan bay gives rise to a different composition of coastal sediments. The removal of the Danube alluvium is accompanied by its hydrogenic separation towards a certain increase in the size of coastal sediments. Concerns to the Danube, since the leading fraction are aleurite and pelitic, ≤ 0.1 mm (Shuisky, Organ, 2017, 2017a), as the authors reported. Its content in pioneer coastal shafts ranges from 79.42 % to 91.45 %. Although, unlike channel deposits in these forms, there

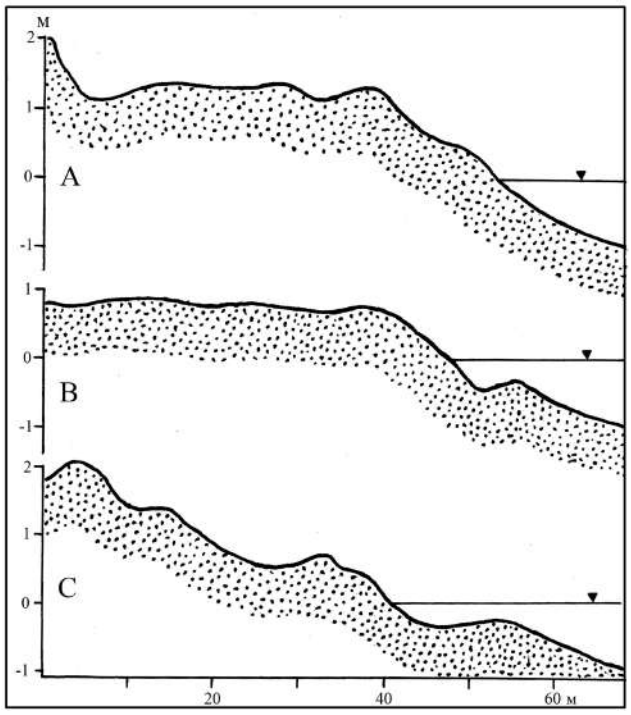


Fig. 6. The different types of transverse profiles of sandy beaches relative to the mean long-term sea level on the northern shore of the Jebriyan bay: A – the southwestern part of the Sasyk liman; B – the central part of the Volchek terrace; C – the middle part of the Jebriyan spit in the area of active accumulation of sediments and the formation of coastal dunes.

is a much larger fraction of 0.1–0.25 mm (from 6.05 % to 13.97 %). The 0.25–0.5 mm fraction even increased by 2.5 times – from 1.67 % to 2.62 %. Such indicators of the separation of the river sedimentary materials are typical for the conditions of the delta of a large river flowing into the non-tidal sea and delta coast. The presented ratio of the concentration of fractions remains during the past 50 years of our different observations and measurements in natural conditions.

The study of coastal sediments along the northwestern coast of the Jebriyan Bay showed their significant changes over the same past 50 years. Therefore, on the adjacent part of the Sasyk creek and on the Volchek terrace, the sediments were larger (≥ 10 mm and 7–5 mm) than today, mainly due to the high content of shell and shell detritus (CaCO3 up to 70 %). At the same time, in general, the content of large particles (≥ 1.0 mm) decreased almost 2-fold over the entire northwestern coast of the bay, but along the Sasyk cess, the size of the sediments decreased by 55 %. At the same time, on the beaches (Fig. 6 A, B, C), the content of the fraction 0.25–0.5 mm increased from 28.87 % to 56.72 %. On all sandy form coasts, the amount of the 0.1–0.25 mm fraction decreased from 35 % to 22 % on average, and the 0.25–0.5 mm fraction remains the leading fraction on the spit and on the terrace, but to the north, on the census Sasyk its amount is 0.1–0.25 mm (up to 57 %). All these changes indicate a high

dynamism not only of the topography, but also of the sediment composition in the system of the Jebriyan bay, which is far not always taken into account in the economic practice of nature management. It is necessary to take into account the complexity of the physical and geographical conditions which includes the hydrogenic river and marine, morphological and morphometric, lithogenic and lithodynamical, hydrobiological, in their close genetic and very fast interaction. Original information on beaches and shore sediment was received along the southern deltaic and northern sandy shores of Jebriyan bay within Danube river region.

The Main Impact and Peculiarities of Anthropogenic Activities on the Shores of the Bay

The anthropogenic impact on the nature of the bay. Despite the relatively small size of the Jebriyan bay (Fig. 1, 2), as per its surface area, there are equally centers of significant influence of anthropogenic impact. As it is noted earlier in this article, anthropogenic impacts can be traced from the structures of fisheries, sand production for construction, recreation bases, navigation and most especially the seaport of Ust'-Dunaysk (Fig. 7, 8). These figures are drawn by Yu. Shuisky with the use of the navigation base map with the scale of 1: 50.000. Fisheries structures comprises of three points where fishing boats are located, rooms for storing and initial processing of fish, warehouses for storing nets, equipment, fuel, rigging, spare parts, and a fisherman's rest house. Fishermen use fixed nets and hooks. These activities do not cause significant harm to the Danube Delta and the shores of the Jebriyan Bay because it is a traditional economy for a small number of indigenous local people.

As postulated by Nikiforov, Diyakonu, 1963; Petrescu, 1963; Shuisky, 1966, 2003, is due to the formation of the "grindu" that large accumulations of sand deposits were created. The new accumulations created the Jebriyan spit, while the old accumulations created the deltaic sand ridge. Moreover, the old ridge of the Jebriyan grindu is used for industrial sand extraction, while it is assigned to the most valuable part of the Danube Biosphere Reserve (according to the conclusions of Ramsar experts). We believe that the active use of grindu sands also violates the European Charter of the ESPOO. Access here by any road transport is free. But modern cars, for the most part, are SUVs and often move along the surface of a rare natural landscape, and, therefore, seriously violate the structure of a unique natural system of various levels of organization. They destroy the protective vegetation cover, intensify the destruction of the Aeolian and coastal-marine relief, and destroy the living conditions of vegetation and

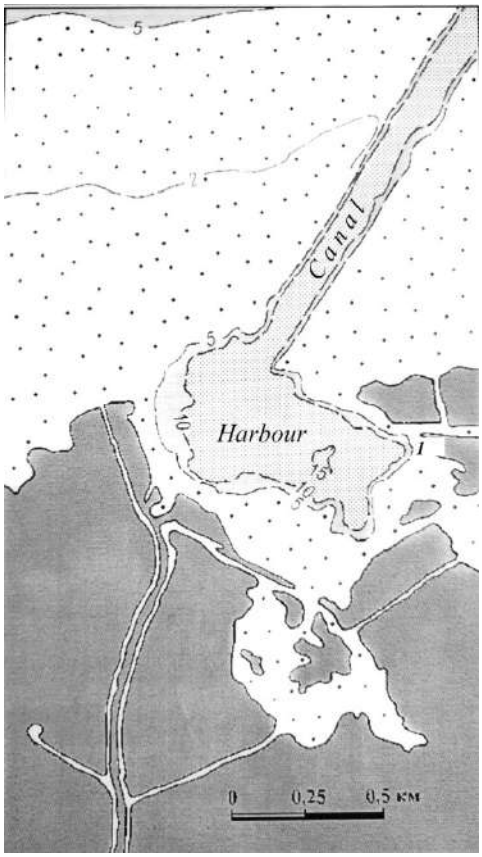


Fig. 7. Scheme of the port harbor of Ust-Danube and the approach channel to it. A dark fill indicates the Danube Delta; 1 – the beginning of the technical channel.

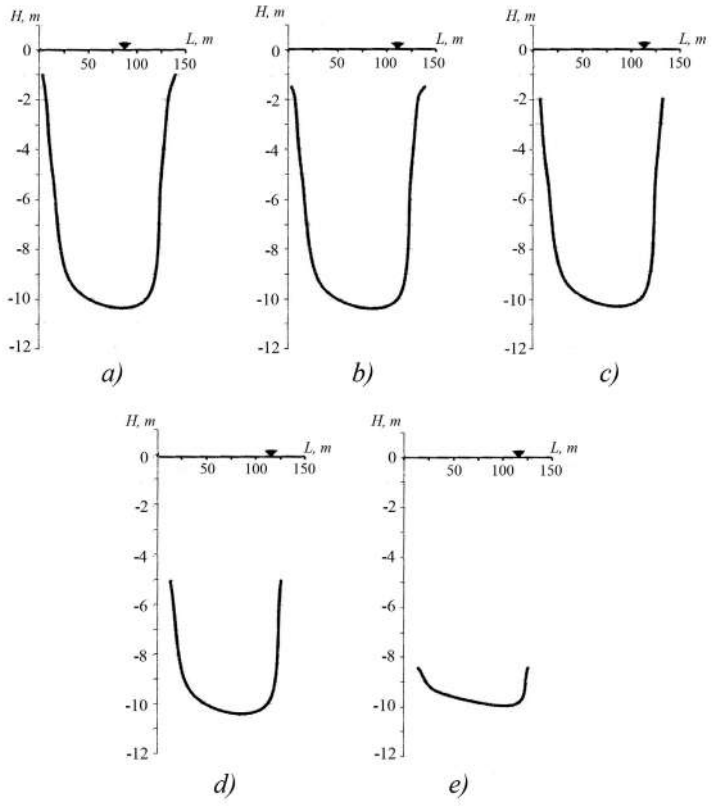


Fig. 8. Curves of transverse profiles on the approach channel of Ust-Danube, located at the bottom of the bay relative to mean sea level.

animals, including those from the Red Book of Europe. The physical and geographical conditions described in this article cannot prevent the negative impact of the anthropogenic factor.

Over the past 25–30 years, a large recreational complex, called Kiliysky was formed on the northwestern coast of the Jebriyan bay. In 2019, 123 large and small recreational facilities were created. In 2017–2019, during each summer, up to 350 thousand people visited it, about 20% of which were on their own off-road vehicles. On the Volchek section, between the residential buildings and the sea, a distance of about 600–800 m is maintained, which is equally tampered by pedestrians on foot or on off-road vehicles. Therefore, the surface of the Volchek terrace is destroyed continuously, and most of the plants and animals died. In addition, our calculations in July 2017, 2018 and 2019 showed that each pedestrian carries along sand with their shoes from the beach, in clothes or in cars in an amount of 5 to 68 grams, an average of 41.6 grams each. Taking into consideration the fact that during 110 days of the swimming season 1 pedestrian takes an average of 4.6 kg of sand from the beach, then the total number of pedestrians estimated at (350 thousand people) directly takes from 1.5% to 3.5% of beach sediments from the terrace and braids (as a). It is important to note that the violation of the structure of the sand surface activates the aeolian removal of sand in the sea or in the floodplains. The size of the surface beach reduces to a much greater extent and slows down the extension of the coastline towards the Jebriyan bay.

The most powerful anthropogenic influence on the the Jebriyan bay shores was the construction of a port. It was caused by the need to build a new port harbor, with a depth of 15 m and an access channel with a depth of 10–12 m. Until late 90s of the XX century, the ships from Ukraine entered the Danube along Bratul (*branch*: in Romanian) Prorva (Fig. 1). However, its considerable channel extension 40–45 years ago led almost to the complete mudding of this Bratul, and it became clear that it was necessary to build a new port and connect it with the deep sleeve of the Danube. Therefore, at first, a technical channel was dug from the deep part of the Breakthrough into the bay and a deep harbor bucket was dug at the exit. This was very sufficient for a large container ship (draft up to 10–11 m). An access navigable canal was built from the bucket in the sea to a depth of 12 m (Fig. 7). Thus, a powerful artificial influence was exerted on the banks and bottom of the Jebriyan Bay which changed the mode of action of the sea waves and wave currents, as well as the movement and accumulation of sediment from the Danube River. As a result of this, the state of plants and animals in the bay, especially benthos were seriously affected. The constant movement of cargo and auxiliary vessels, regular cleansing of the bottom of the port water area, approach and technical channels from the mass of sediment violates the bottom layer as a living environment for mollusks, arthropods, worms and others, which are food for game animals. Sedimentation work increases the concentration of suspended sediment, which increases the scattering of light in water, reduces the intensity of photosynthesis and the concentration of oxygen in water, and reduces the self-purification of water, especially when water comes from the Danube.

The construction of the port harbor and two channels (technical and approach) created another problem. It includes the storage of mass sediment that is released during excavation. Before designing in the 60–70s of the twentieth century, the researchers predicted that the influence of winds from the northern and northwestern sectors would almost completely carry out the river alluvium from (Prorva) Prorva, (Potapovsky) Potapov and (Gneushev) Gneushev branches to the South towards the southern part of this delta. They did not take into account the long-term changes in the wind regime under the influence of modern climate changes at the end of the 20th century, the frequency of east and south winds (especially storms) over the north-western Black Sea that have increased significantly, in the conditional squares 4, 5, 10, 11 **(**Andrianova *et al*., 2014; Il'yin *et al*., 2012**)**. This led to incorrect long-standing forecasts of the movement of Danube sediments. Calculations of the structure of energy triangles (Fig. 4) showed that about 10% of the alluvium of the Ochakov branch both directly and through the technical channel is carried to the top of the Jebriyan bay.

The consequences of anthropogenic impact. The presented human actions on the nature of Zhebriyanskaya Bay are characterized by a certain variety. All types of influence, except for transport influence from road and sea transport, are within the permissible limits. Therefore, we made estimates of anthropogenic influence for two reasons.

The sandy natural systems composed of accumulative forms are unique in structure, dynamics, and the ratio between the individual components. These systems are very fragile, able to collapse quickly, but recover very slowly. All over the World they are under protection and are part of national parks and reserves, such as on the coasts of Lietuva, Denmark, the Netherlands, Belgium, and the western shores of France. However, in the north of the Jebriyan bay, sandy beaches are not protected; they are subject to constant violation especially when sand is extracted for construction, during continuous development by road. This activity leads to continuous degradation, loss of landscape diversity, extinction of species from the Red Book of Ukraine and the entire European continent.

Of course, such violations of coastal systems are

seasonal in nature. Since the end of September to the beginning of May, sand forms within the boundaries of the Kiliysk resort zone are partially restored. However, every year they come to a second violation. Based on similar experience on the sandy shores of Latvia, Lithuania and Poland, the aeolian and beach topography is experiencing a reduction of up to 3–5 % per year. Only after special protective wooden dams, levees and pavements were arranged that the gradual artificial destruction of the coastal relief forms ceased. It is precisely such ameliorative actions that are also needed on the northwestern shores of the Jebriyan bay of the Black Sea coast.

During the design of the Ust'-Dunaysk port, scientists of Odessa State University named after I. I. Mechnikov (Department of Physical Geography in 1995), led by Prof. Yuriy Shuisky, made a forecast for the port's operating hours. Taking into account the influence of alluvial sediments from the Danube and the mode of their distribution in the Jebriyan Bay, the regularities of the evolution of the Ochakov branch deltaic system, the period of duration of this is port is limited to 25–30 years. Such a short period is caused by the action of extremely dense saturation with river and delta sediments, in which not only artificial, but also natural negative forms of relief are impossible. Even according to research studies of the 60s in the XX century (Shuisky, 1969), including the works of I. Petrescu (1963), the final movement of the Danube sediment along the southeastern coast of the Jebriyan bay towards its peak was clearly established. This trend was confirmed at the beginning of the XXI century (Shuisky, 2003), and also today with the example of Fig 4. However, sufficient funding and powerful dredging equipment in the USSR made it possible to cope with the introduction of negative landforms.

In fact, since the advent of the technical channel, the port bucket and the approach channel, initially for the container terminal in 1972, have started experiencing great difficulties with the insertion of artificial negative landforms (Fig. 7). During the initial period of the creation of artificial negative relief forms, the drift was small, which made it possible to cope with a dredging technique. Although, after the creation of design depths, the fight against alienation became so difficult that it was economically unprofitable. In the USSR, this was not an obstacle, since the issue was political. In the early 90s of the twentieth century, Ukraine abandoned the port of Ust'-Dunaysk, and in order to get out of an unfavorable situation, the port's leadership ordered to extract sand on an ancient grind and sell it to other countries. Nevertheless, by the end of the twentieth century, the excavation was 4.5 million tons / year. All artificial negative landforms, except for the technical channel (Fig. 7, 1), were filled with sediments.

Today and since 2015, the approach channel and most of the port bucket (depth 4 m) are filled with sediments. The authors used a marine navigational chart with a scale of 1: 25000 and with a bathymetric image of the approach channel. Five typical profiles a – e were chosen with an equidistance of 1 km (Fig. 8). According to the construction of the curves of the transverse profiles, sediment volumes were collected on each segment of the channel. At a distance of 1 km from the port bucket, the excavation was the deepest, and therefore the specific amount of sediment entering it amounted to about 950 thousand m^3. In the second 1-km section (Fig. 8, b), 870 thousand m^3 of materials have already entered the excavation and in the third segment – about 810 thousand m^3, etc. In total, the approach channel was filled with about 4.2 million m^3 of sedimentary materials; such is its "sedimentary capacity". This size of introduction even in the time of the former USSR was not justified from an economic point of view, and even more so during the deliberate destruction of Ukraine's industry and transport. For Ukraine, the port of Ust'-Dunaysk was "too expensive". The question was raised about the search for another waterway through the Ukrainian part of the Danube Delta. In this difficult struggle, the natural forces of Jebriyan Bay won.

Conclusion.

The creation of a small Jebriyan bay depends on the development of the Kiliya part of the Danube Delta. Today, it is determined by the peculiarities of the location, the influence of the Black Sea, Danube sediments, sediments from the alongshore sediment flow and the underlying delta substrate. Significant anthropogenic impact is expressed in the form of: a) unsystematic creation of a recreational zone; b) incomplete design and construction of the port of Ust-Dunaysk.

According to the structure of the Jebriyan bay, two banks can be clearly distinguished from their dynamics of the waters, their topography and their sediments: a) low, flooded, silty southeast; b) low sand. Their physical and geographical sphere is influenced by a large river that flows into the non-tidal sea. These features determine the types of economic development and the use of natural resources. The main activities include fisheries, the extraction of building sand in the vicinity of the port and the aeolian ridge of the Jebriyan grindu, and recreational activities.

The seaport of Ust-Dunaysk was built to transport river containers from the sea to the ports of the Danube and to load containers from the Danube ports to the sea container ship. Its creation was facilitated by the active influence of many million tons of alluvium, the rapid growth of the size of the Danube Delta and wide coastal shallow water. Although, experts feared its "short life span", it was still built. After 25 years,

serious difficulties arose to maintain the necessary depths in the harbor and access to the navigation channel. The occupancy of the harbor bucket and the approach channel to the port exceeded the capabilities of Ukraine to ensure a normal navigational situation.

Almost 50 years after the existence of the seaport of Ust'-Dunaysk in the Jebriyan bay, the correctness and reality of forecast made in late 60s, which stated that the port will be sustainable for duration of 25–35 years, became a reality. Approximately 90 % of the scientific materials in the article belong to the authors, including the analysis, discussion and results.

References

Andrianova, O. R., Belevich, R. R., Peychev, V.D., Skipa, M.I., 2014. Dinamika zemli i urovnja Chernogo morja v techenie XX i XXI stoletij. [The land and the Black Sea level dynamics during XX and XXI centuries]. Geophysical Journal. Vol. 39. 3, 3–13 (In Russian).

Berlinskiy, N.A., 2012. Dinamika tehnogennogo vozdejstvija na prirodnye kompleksy ust'evoj oblasti Dunaja [Dynamic of antropogeous impact to evolution of the Danube delta]. Odessa: Astroprint Publ. Co., 252 p. [In Russian].

Gaştescu, P., 1993. The Danube delta: Geographical Characteristics and Ecological Recovery. Geojournal. Vol. 29, 1, 57–67.

Knaps, R. Ya., 1985. On methods of definition of sediment movement regime along shores of non-tidal seas. Riga: Latvija State Publ. Co., 85 p. (In Latviyan).

Ill'in, Yu.P., Repetin, L.N., Belokopytov, V.N., Goryachkin, Yu.N., Diakov, N.N., Kubryakov, A.A., Stanichnyy, S.V. 2012. Gidrometeorologicheskie uslovija Chjornogo morja. Tom2: Chernoe more. [Hydrometeorological Conditions of Ukrainian Seas Vol. 2: the Black Sea]. Sebastopol: ECOSI Publ. House. 421 pp. (In Russian).

Mikhailov, V.N., Morozov, V.N., 2004. *Hydrology of the Danube delta*. Moskow: GEOS Publ., 448 pp. (In Russian).

Munteanu, I., 2002. Ecological characteristics of soils in the Danube Delta Biosphere Reserve. Annals Valahia University, Romania. Geography Ser. 2002. V.. 22, 2. 281–285.

Nikiforov, Ya. and Diyakonu K., eds, 1963. Gidrologija del'ty Dunaja. [Hydrology of mouth area of the Danube delta]. By ed. Ya. Nikiforov and K. Diyakonu. Moskow: Gidrometeoizdat Publ. Co., 383 pp. (In Russian).

Panin, N. S., Jipa, D., 2002. Danube River sediment input and its interaction with the North-Western Black Sea. Estuarine, Coastal and Shelf Sciences. Vol. 54, Issue 3*,* 551–562.

Petresku, I.G.,1963. Del'ta Dunaja: proishozhdenie i jevoljucija. [The Danube delta: origin and evolution]. International Literature Publ. Co., Moskow, 279 pp. (In Russian).

Shuisky, Yu.D., 1966. Pribrezhnye akkumuljativnye formy rel'efa vdol' berega morja Kilijskoj chasti del'ty Dunaja. [Coastal accumulative relief forms along marine margin of Kiliya part of the Danube delta]. Izvestiya Academy Sciences of the USSR. 3. 95–100. (In Russian).

Shuisky, Yu.D., 1969. The Jebriyan Bay coasts. USSR Geography Soc. Herald. Vol. 101, 4, 362–365 (In Russian).

Shuisky, Yu.D., 1972. Dinamika morskoj granicy vdol' Kilijskoj chasti del'ty Dunaja. [Marine margin dynamic along Kiliya part of the Danube delta]. Proceeding State Oceanographycal Institute. 172, 50–60 (In Russian).

Shuisky Yu.D., 2003. Gidromorfologicheskie harakteristiki jevoljucii sovremennosti. [Hydro-morphological characteristics of evolution of contemporary]. Odessa´ National University Herald. Ser. Ecology. Vol. 8, Issue 11, 4–17 (In Russian).

Shuisky, Yu.D., Organ, L.V., 2017. Basic evolution peculiarities of alongshore sediment drifting within coastal zone of the Black Sea. Austria Science International Journal. *6,* 4–8.

Shuisky, Yu.D., Organ, L.V., 2017a. Pervichnye formy rel'efa vdol' morskoj granicy Kilijskoj chasti del'ty Dunaja. [Primary relief forms along marine margin of Kiliya part of the Danube delta]. Scientific Herald of Vinnitza State Pedagogical University. Ser. Geography. Issue 29. 3–4. 15–25 (In Russian).

Vykhovanetz, G.V., 2003. Jeolovyj faktor vozdejstvija na del'tu Dunaja. [Aeolian factor impact on evolution of the Danube delta]. Herald of Mechnikov's National University of Odessa. Ser. Ecology. Vol. 8. Issue 11, 29–54 (In Russian).

Vykhovanetz, G.V., Organ, L.V., 2010. Korreljacija mezhdu obemom i real'nym kolichestvom pribrezhnogo stoka nanosov v pribrezhnoj zone Chernogo morja. [Correlation between volume and real quantity of alongshore sediment flow within coastal zone of the Black Sea]. Black Sea Ecological Bulletin. 1 (35), 34–39 (In Russian).

Zaytzev, Yu.P., Alexandrov, B.G., Minicheva, M.M., 2006. Severo-zapadnaja chast' Chernogo morja: biologija i jekologija. [North-Western Part of the Black Sea: Biology and Ecology]. Kiev: Naukova Dumka Publ. Co., 703 (In Russian).

Zenkovich, V.P., 1943. Del'ta reki Dunaja. [Delta of the Danube river]. State Geographycal Society Herald. Volume 4, 21–30 (In Russian).

Zenkovich, V.P., 1958. Morfologija i dinamika sovetskogo poberezh'ja Chernogo morja. [Morphology and Dynamic Soviet Coasts of the Black Sea]. Moscow: Acad. Sci. USSR Publ. Co., 215 pp. (In Russian).

Journal of Geology, Geography and Geoecology

ISSN 2617-2909 (print)
ISSN 2617-2119 (online)

Journ. Geol. Geograph. Geology, 30(4), 741–753.

Journal home page: geology-dnu.dp.ua

doi: 10.15421/112168

Levels of changes in the genus *Pinus* Linné in the composition of Mesozoic and Cenozoic flora and vegetation as an additional criterion for the division of sediments by the Mesozoic and Cenozoic of Ukraine

Olena A. Sirenko[1], Olena A. Shevchuk[2]

[1]*Institute of Geological Sciences of the National Academy of Sciences of Ukraine, Kyiv, Ukraine,* o_sirenko@ukr.net
[2]*Institute of Geological Sciences of the National Academy of Sciences of Ukraine, Kyiv, Ukraine,* hshevchuk@ukr.net

Received: 20.09.2021
Received in revised form: 05.10.2021
Accepted: 16.11.2021

Abstract. The article presents an analysis of a large array of results of palynological studies of Mesozoic and Cenozoic sediments of Ukraine and adjacent regions of Belarus and Russia. Numerous literature data on the palynological characteristics of Meso-Cenozoic sediments and the materials of the authors are summarized according to the results of spore-pollen analysis of Mesozoic and Cenozoic sediments within the main tectonic structures of Ukraine. It has been established that the genus *Pinus* (Pinaceae) is an integral part of the Meso-Cenozoic flora of Ukraine. Although, the participation in the flora and vegetation of the genus *Pinus* and its species diversity in different periods of geological time were different. Despite the long history and significant achievements of palynological research of Meso-Cenozoic sediments of Ukraine, no attention has been paid to the historical aspect of *Pinus* development in the Meso-Cenozoic flora. This work is presented as the first stem to fill this gap. The genus *Pinus* has a large stratigraphic range, but its species diversity and quantitative changes in the composition of Mesozoic and Cenozoic flora of different ages are markedly different. The analysis of these changes made it possible to trace the emergence and main levels at which the species composition was renewed and the role of *Pinus* in flora increased during the Mesozoic and Cenozoic. According to the results of the research, 5 levels of increasing the participation of the genus *Pinus* and changes in its species affiliation in the Mesozoic flora were established: Aalenian period of the Middle Jurassic (appearance of the first representatives of *Pinus*); Oxfordian time of the Late Jurassic; Valanginian – Early Barremian times of the Early Cretaceous; Albian time of the Early Cretaceous; Late Campanian time of the Late Cretaceous. 5 levels of increasing the role of *Pinus* and its species diversity for the flora and vegetation of the Cenozoic were also established: Oligocene time of the Paleogene, Konkian-early Sarmatian time of the Middle Miocene; early Pontian (Ivankov) time of the Late Miocene; early Kimmerian time (early Sevastopol) of the Early Pliocene and Martonosha time of the Early Neopleistocene. Certain levels have been traced for the similar age of Cenozoic flora of Belarus and Russia.

Keywords: spore-pollen analysis, Mesozoic, Cenozoic, flora, vegetation, Ukraine.

Рівні змін роду *Pinus* Linné у складі мезо-кайнозойської флори та рослинності як додатковий критерій розчленування відкладів мезозою та кайнозою України

О.А. Сіренко[1], О.А. Шевчук[2]

[1]*Інститут геологічних наук НАН України, Київ, Україна,* o_sirenko@ukr.net
[2]*Інститут геологічних наук НАН України, Київ, Україна,* hshevchuk@ukr.net

Анотація. У статті представлено аналіз великого масиву результатів палінологічних досліджень мезозойських та кайнозойських відкладів України і суміжних регіонів Білорусі та Росії. Узагальнено як численні літературні дані з палінологічної характеристики мезо-кайнозойських відкладів, так і матеріали авторів за результатами спорово-пилкового аналізу мезозойських та кайнозойських відкладів в межах основних тектонічних структур України. Встановлено, що рід *Pinus* (Pinaceae) є невід'ємною складовою мезо-кайнозойських флор України. Але участь у складі флори та рослинності представників роду *Pinus* та його видове різноманіття у різні відрізки геологічного часу була різною. Незважаючи на тривалу історію та значні здобутки палінологічних досліджень мезо-кайнозойських відкладів України донині не акцентувалась увага на історичному аспекті розвитку *Pinus* у складі мезо-кайнозойських флор. Представлена робота є першим кроком до заповнення цієї прогалини. Рід *Pinus* має великий стратиграфічний діапазон, але його видове різноманіття та кількісні зміни у складі різновікових мезо-кайнозойських флор помітно відрізняються. Аналіз зазначених змін надає можливість простежити появу та основні рівні, на яких відбувалось оновлення видового складу та збільшення ролі *Pinus* у флорах на протязі мезозою та кайнозою. За результатами проведених досліджень встановлено 5 рівнів збільшення участі роду *Pinus* та змін його видової приналежності у складі мезозойських флор: ааленський час середньої юри (поява перших представників *Pinus*); оксфордський час пізньої юри; валанжин-ранньобаремський час ранньої крейди; альбський час ранньої крейди; пізньокампанський час пізньої

крейди. Для флори та рослинності кайнозою також встановлено 5 рівнів збільшення ролі *Pinus* і його видового різноманіття: олігоценовий час палеогену, конксько-ранньосарматський час середнього міоцену; ранньопонтичний (іванківський) час пізнього міоцену; ранньокімерійський (ранньосевастопольський) час раннього пліоцену та мартоноський час раннього неоплейстоцену. Визначені рівні простежено і для одновікових кайнозойських флор Білорусі та Росії.

Ключові слова: спорово-пилковий аналіз, мезозой, кайнозой, флора, рослинність, Україна.

Introduction

Pinus is an integral part of the coniferous and mixed forests of the Northern Hemisphere. An important role in the modern vegetation of Ukraine also belongs to the genus *Pinus*, which refers mainly to *Pinus sylvestris* L. The forests of the western part of Ukraine (Carpathian region) also include *Pinus cembra* L. and *Pinus mugo* Turra.

Palynological studies of Mesozoic and Cenozoic sediments of Ukraine have a long history. First of all, these are the works of E.V. Semenova, G.V. Shramkova, G. G. Yanovska, N. A. Orlova-Turchyna, M.A. Voronova, M.E. Ohorodnik, O.A. Shevchuk on the study of Mesozoic sediments of Ukraine; as well as R.N. Rothman, N.O. Shchekina A.A. Michelis, O.B. Stotland – Paleogene-Neogene sediments; V. Yu. Ochakovskiy concerning Paleogene sediments; O.P. Ahulov, I.B. Maslova, V.S. Sopina, S.V. Syabryaj on Neogene sediments, S.I. Parishkury-Turlo, N.P. Gerasimenko – continental Pliocene – Quaternary sediments; O.A. Sirenko on various facies Upper Miocene-Pliocene sediments; O.T. Artyushenko, G.O. Pashkevich, R. Ya. Arap, L.G. Bezusko, E.T. Lomaeva, T.F. Christoforova, M.S. Komar, O.A. Sirenko, N. Kalynovych – continental Pleistocene sediments. According to research, the genus *Pinus* (Pinaceae) is an integral part of the Mesozoic and Cenozoic flora of Ukraine. However, the participation in the composition of flora and vegetation of the genus *Pinus* and its species diversity in different periods of geological time was different. Despite the long history and significant achievements of palynological research of Mesozoic and Cenozoic sediments of Ukraine, no attention has been paid to the historical aspect of *Pinus* development in the Mesozoic and Cenozoic flora. In this regard, the proposed work is pioneering.

The purpose of this study is to analyze and summarize a large array of literature materials and personal data of authors on palynological studies of Jurassic, Cretaceous, Paleogene, Neogene and Lower Quaternary sediments of Ukraine to identify levels of increasing role and species diversity of *Pinus* in Mesozoic and Cenozoic flora and the use of these levels for stratigraphic and correlation constructions.

The purpose of this study is to analyze and summarize a large array of literary materials and personal data of authors on palynological studies of Jurassic, Cretaceous, Paleogene, Neogene and Lower Quaternary sediments of Ukraine to identify levels of increasing role and species diversity of *Pinus* in Mesozoic and Cenozoic stratigraphic and correlation constructions.

Materials and methods of research

During the study, materials on the palynological characteristics of various Jurassic and Cretaceous rocks obtained by O.A. Shevchuk for sections of Mesozoic sediments located within almost all major tectonic structures of Ukraine (Fig. 1) (Shevchuk 2004–2013, 2016, 2018, 2020; Dorotyak et al., 2009; Stratigraphy, 2013; Shevchuk et all., 2018), literature data on the results of palynological studies of the most representative sections of Paleogene and Neogene sediments of the northern and southern parts of Ukraine (Fig. 1) (Zosimovich, Savron, Rothman, 1980; Stotland, 1984, 1985; Michelis, 1976; Syabryaj, Shchekina, 1986; Korallova, 1962, 1968; Sopina, 1974; Shchekina 1964a, b, 1974; Shchekina, 1975, 1979), as well as the results of palynological research by O.A. Sirenko of Oligocene, various-facies Miocene and Pliocene, subaerial Eopleistocene and Lower Neopleistocene sediments of platform Ukraine (Fig. 1) (Sirenko, 2000 a, b, 2003 a, b, 2004, 2006, 2007 a, b, 2009 a, b, 2016, 2017 a-c, 2019 a, b, 2021). In order to reconstruct the Meso-Cenozoic flora and perform interregional correlations, the materials of M.A. Voronova, G.G. Yanovska, G.A. Orlova-Turchyna, D. Rekhakova and others according to the results of the study of Jurassic and Cretaceous deposits of Ukraine (Orlova-Turchyna, 1966; Voronova, Yanovska 1973, 1982, 1991; Yanovska, 1973; Shramkova, 1982; Voronova, 1994; Ogorodnik, 2006; Rehakova et all., 2011), as well as results of palynological studies of Paleogene, Neogene and Pleistocene sediments of adjacent regions of Belarus and Russia (Ananova, 1974; Linkina, 2006; Rylova, 1996, 2001, 2002; Tregub, Starodubtseva, 2005; Filippova, 2002; Shpul, 1990, 2004, 2005).

The main research method was palynological: spore-pollen analysis. Stratigraphic, paleoecological and morphological methods are also used in the work.

The main problem in studying the flora of the Mesophyte is that there is currently no generally accepted classification for fossil spores and pollen of the Mesozoic. The issue of systematization and nomenclature of spores and pollen is one of the most relevant, unresolved in Mesophyte palynology. There are a large number of artificial systems that prevail today in the literature on the Mesozoic. As a result, the same taxa in different authors are listed under different

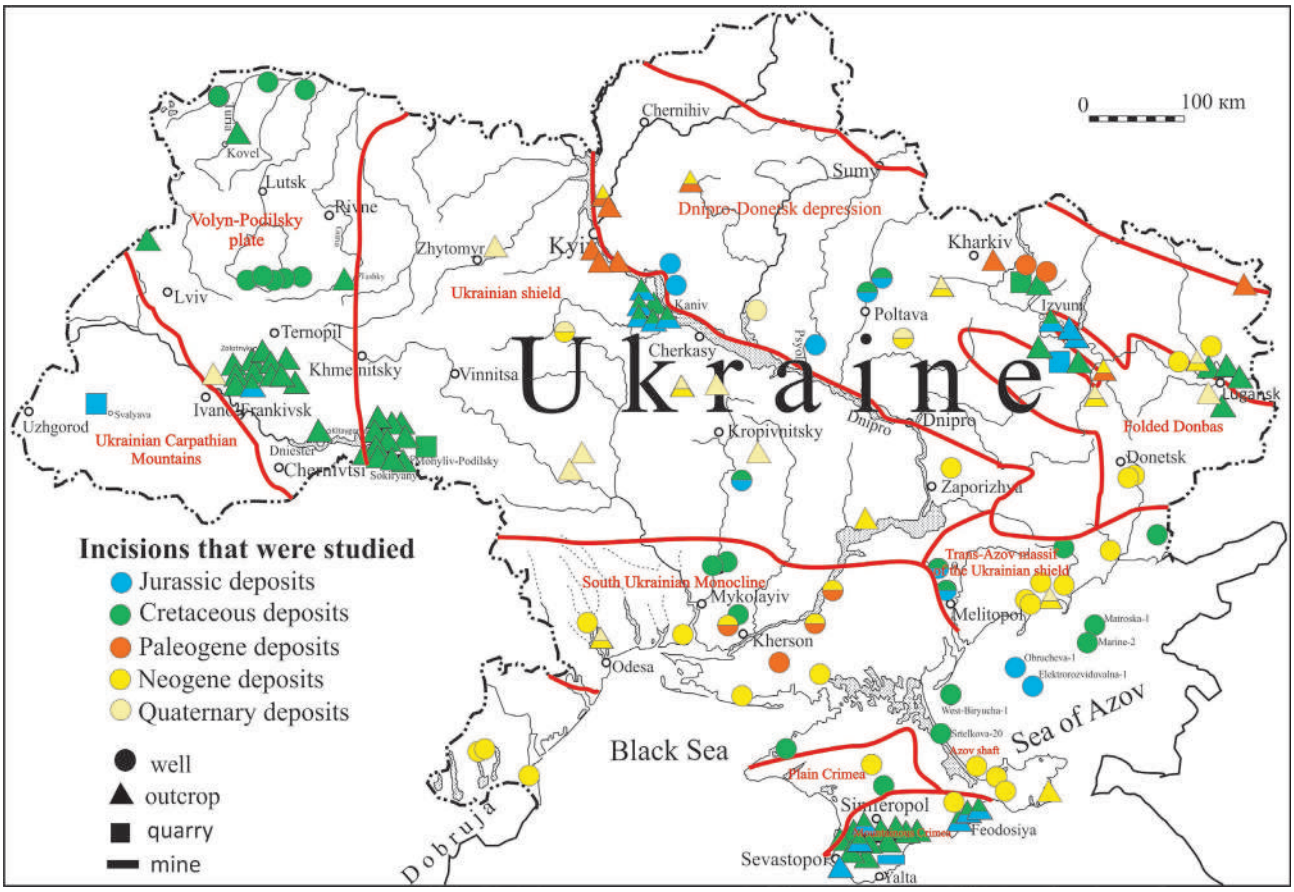


Fig. 1. Map scheme of the studied area. The map of the actual material is made according to the results of palynological researches of the Mesozoic – O.A. Shevchuk, Paleogene – O.B. Stotland, N.O. Shchekina, A.A. Michelis, O.A. Sirenko, Neogene – N.O. Shchekina, V.V. Korallova, A.A. Michelis, O.A. Sirenko and Quaternary – O.A. Sirenko.

generic and species names, and many already known species are described as new. An example of this is the genus *Pinus*. As an example, established and described by N.A. Bolkhovitina species *Pinus divulgata* subsequently described in the artificial classification as *Pinuspollenites divulgatus*. And there are many such examples. In this article, we used primary sources when the species is not re-described by artificial classification.

It is necessary to emphasize a number of important points regarding the reconstructions of the participation of the genus *Pinus* in the Cenozoic flora. The following factors were taken into account during the reconstruction of flora and paleovegetation. The high content of pine pollen in the spectra of certain sections of marine and continental sediments does not always provide an opportunity to reconstruct the level of increase of this genus in the vegetation within the entire region. In particular, it is necessary to take into account in which part of the marine paleobasin the section is located. Since the general increase in tree pollen is characteristic of deep-water sediments (Malyasova, 1976) and, accordingly, the most diverse composition of the spectra is characteristic of sediments of the central part of sea basins and the slope of the shelf. The spectra of shallow sediments are markedly depleted, and their composition is dominated by 1–2 components. A characteristic feature of these spectra is the significant presence of pollen from aquatic and coastal aquatic plants, which may change the ratio of the main groups of pollen in the spectra. Thus, some decrease in the role of pine pollen in the spectra of the Late Oligocene complex, which characterizes the Berekian deposits of some areas of northern Ukraine, is associated with an increase in the role of Taxodiaceae, which are usually markers of local conditions. N.O. Shchekina (1983) found that fossil spectra from Upper Oligocene – Miocene sediments of the southern part of Ukraine well reflect the distance of the section from the sea shore. The farther from the shore to the depths of the sea, the more gymnosperms with air sacs and the less pollen of angiosperms and gymnosperms without air sacs. When studying subaerial sediments, it is important to take into account the geomorphological location of sections, because in the composition of spore-pollen spectra from section sediments located on river terraces and steep coasts there is always an increased content of *Pinus* pollen (Sirenko, 2017 c). Therefore, during the reconstruction of the levels of *Pinus* changes in the Cenozoic flora, materials were analyzed from sections of age-old sediments located in different parts of Ukraine

and in different geomorphological conditions. Emphasis was made on changes in the species diversity of pines and the ratios in the composition of the pollen spectra of *Pinus* spp. subg. *Haploxylon* Koexne. and *Pinus* spp. subg. *Diploxylon* Koexne. Materials of palynological researches of Cenozoic deposits of adjacent regions of Belarus and Russia were taken into account for the purpose of establishment of levels which would be traced also in the specified territories.

Main results and discussion

Mesozoic

Representatives of the genus *Pinus* originated in the Middle Jurassic period and are clearly recorded according to O.A. Shevchuk is a part of flora of all regions of Ukraine (Carpathians, Dnipro-Donetsk depression, Ukrainian shield – Bajocian, Mountain Crimea – Aalenia).

Ancient representatives of pine *Pseudopinus* spp., *Protopinus* spp. studied in the territory of Ukraine by G.G. Yanovska (Jurassic), S.B. Kuvaeva, H.A. Orlova-Turchyna, M.A. Voronova (Cretaceous) et all. (Orlova-Turchyna, 1966; Voronova, Yanovska 1973, 1982, 1991; Yanovska, 1973; Kuvaeva et all., 1973). A systematic description of species *Pseudopinus* spp., *Protopinus* spp. is given in the works of N.A. Bolkhovitina (Bolkhovitina, 1953). The results of palynological studies of Mesozoic sediments of Ukraine are compared with the materials of the study of similar age sediments of Russia and Sweden. (Chlonova, 1974; Vajda, 2001; Rostovtseva, 2014).

Aalenian to Bathonian time is famous due to a large number of ancestral forms of *Pseudopinus* spp. and *Protopinus* spp. The most common species are *Pseudopinus pectinella* Bolch., *Pseudopinus pergrandis* Bolch., *Pseudopinus contigua* Bolch., *Pseudopinus oblatinoides* (Mal.) Bolch., *Protopinus subluteus* Bolch., *Protopinus vastus* Bolch., *Protopinus scanicus* Nilsson. At the border of Barremian and Aptian times, some single representatives of the ancestral forms of *Pinus* are noted, and then in the time range starting from the Cenomanian, they are not established (Fig. 2).

Pinuspollenites similis (Balme) M. Petr., *P. minimus* (Couper) Kemp., *P. divulgatus* Bolch. and *Pinus pernobilis* Bolch were noticed in the Middle Jurassic flora. Thus, as the first level of *Pinus* participation in the Mesozoic flora, it is possible to determine the Aalenian time.

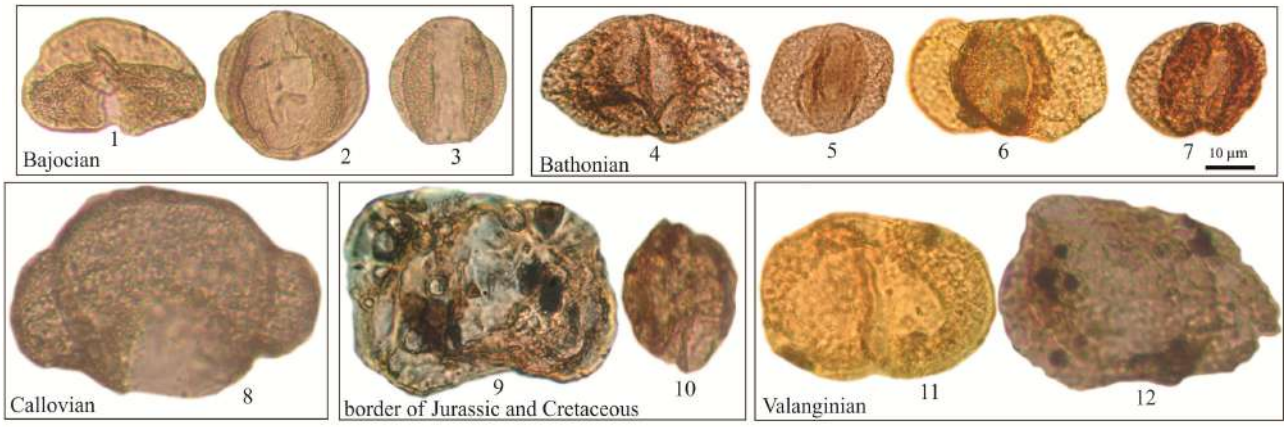


Fig. 2. Ancestral forms of the genus *Pinus* from the Mesozoic. Photos by O.A. Shevchuk. *1. Protopinus* sp.1, Dnipro-Donetsk depression, well 8561, 191.75 m; *3. Protopinus* sp.2, Dnipro-Donetsk depression, well 8561, 191.75 m; *2. Pseudopinus oblatinoides* (Mal.) Bolch., Dnipro-Donetsk depression, well 8561, 191.75 m; 4. *Pseudopinus* sp., North-western outskirts of Donbas, Shevchenko hamlet, Seversky Donets river, sample 0 (1); *5. Protopinus subluteus* Bolch., North-western outskirts of Donbas, Shevchenko hamlet, Seversky Donets river, sample 1(в)1; 6, 7. *Pseudopinus contigua* Bolch., North-western outskirts of Donbas, Shevchenko hamlet, Seversky Donets river, sample 0 (1); *8. Protopinus* sp.3, Ukrainian Shield, Maryanyn Yar, Kaniv, Cherkasy Region, sample 08; *9. Pseudopinus pergrandis* Bolch., Carpathians, Pryborzhavsky quarry, sample 5; *10. Protopinus* sp.4, Mountain Crimea, Krasnoselivka township, Kuchuk-Uzen river, pack 7, sample 3; *11. Pseudopinus* sp., Mountain Crimea, Kuibyshev town, sample 5k; *12. Protopinus scanicus* Nilsson, Mountain Crimea, Verkhorichchya village, sample 1.

Pinus pernobilis Bolch and *Pinuspollenites divulgatus* Bolch. played a significant role in the composition of the Late Jurassic flora of Ukraine (Fig. 3). The species composition of pines mostly remained unchanged from Oxfordian to Tithonian, except for some new species *Pinuspollenites verrucosus* Zhang., *Pinuspollenites* spp. It is possible to establish the second level of increase in participation of *Pinus* by emergence of new types of pine as a part of flora of Oxfordian.

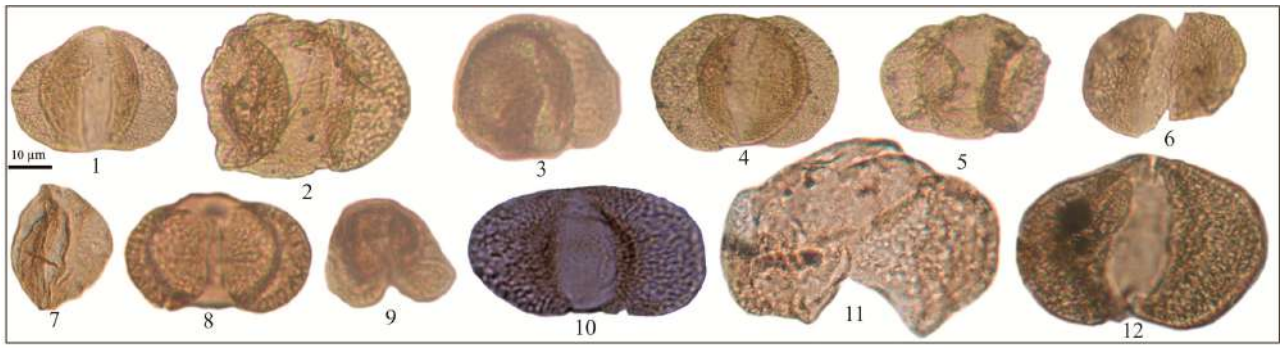


Fig. 3. Typical species of *Pinus* pollen of the Middle-Late Jurassic*:* Photos by O.A. Shevchuk. *1, 4. Pinuspollenites similis* (Balme) M. Petr., Dnipro-Donetsk depression, well 8561, 191.75 m, Bajocian; *2, 5. Pinuspollenites* sp.1, Dnipro-Donetsk depression, well 8561, 191.75 m, Bajocian; *3. Pinuspollenites* sp., North-western outskirts of Donbas, village of Kamyanka, sample 3k (2), Tithonian; *6. Pinuspollenites* sp.2, Dnipro-Donetsk depression, well 8561, 191.75 m, Bajocian; *7. Pinuspollenites divulgatus* Bolch., North-western outskirts of Donbas, Shevchenko hamlet, Seversky Donets river, sample 5a(1), Bathonian; *8. Pinuspollenites* sp.3, Dnipro-Donetsk depression, well 24673, sample 2016, Bajocian; 9. *Pinuspollenites verrucosus* Levet-Carette, North-western outskirts of Donbas, village of Kamyanka, sample 3к (2), Tithonian; *10, 12. Pinuspollenites* sp.4, well. 8562, depth. 145,25 m, Callovian; *11. Pinus pernobilis* Bolch., North-western outskirts of Donbas, Shevchenko hamlet, Seversky Donets river, sample 1a (1), Bathonian.

At the turn of the Jurassic and Cretaceous periods, there was a decrease in the role of pine.

During the Cretaceous, the role of *Pinus* in the flora grew from Valanginian to Barremian. The flora of this time is characterized by the greatest species diversity and number of pines: *Pinus* spp., *Pinus incrassate* Boch., *P. vulgaris* Boch., *P. exeguus* Boch., *P. vulandjensis* (Naum.) Bolch. *P. exilioides* Boch., *P. insiguis* (Naum.) Bolch., *P. subcohcinua* (Naum.) Bolch., *Pinuspollenites divulgatus* Bolch. Therefore, this interval can be considered a surge in the development of *Pinus* and attributed to the third level.

The timing of pine diversification coincides with the evolution of angiosperms, and it is likely that competition between flowering plants and gymnosperms played a role in adaptation, which reduced species diversity and pine participation in the Late Barremian – Aptian period. In the Aptian period there was also a decrease in the participation and the role of the genus *Pinus* due to their displacement by other important members of the group of gymnosperms – in particular *Cedrus*.

By the middle of the Cretaceous period, morphological features identified two subgenera *Pinus*: *Haploxylon* and *Diploxylon* (Millar, 1998). Pines of two subgenera have also been reconstructed for the Albian flora of Ukraine (Fig. 4). Increasing the role of *Pinus* spp. as part of the flora, especially due to the representatives of the subgenus *Diploxylon* can be traced in the Albian period of the Volyn-Podilska plate, the Ukrainian Shield, the Dnipro-Donetsk basin and the Mountainous Crimea. According to M.A. Voronova, in the Albian period there are representatives of a new species *Pinus aequalis* (Naum.) Bolch. (Voronova, 1994). Therefore, the Albian period can be attributed to the fourth level of *Pinus* participation in the Mesozoic flora.

Fig. 4. Two subgenera of *Pinus*: A – *Haploxylon*, B – *Diploxylon* (photos by Shevchuk O.A.).

No significant increase of the role of *Pinus* in the flora and vegetation composition of the Cenomanian-Santonian interval was recorded. The following species are characteristic of the Cenomanian flora of Donbas: *Pinus concessa* (Naum.) Bolch, *P. trivialis* Naum., *P. subconcinua* (Naum.) Bolch., *P. minutula* Chl., *P. vulgaris* Naum., *P. pernobilis* Bolch.; Turonian and Santonian flora of the Volyn-Podilska plate: *Pinus trivialis* Naum., *P. vulgaris* Naum., *P. nigraeformis* Bolch., *P. exequus* Bolch. (Fig. 5).

Fig. 5. Typical species of *Pinus* pollen of the Cretaceous: Photos by O.A. Shevchuk. *1. Pinuspollenites* sp., Ukrainian Shield, Melanchine Stream, Vyrzhykivsky layers, sample 6, Albian; *2. Pinus concessa* (Naum.) Bolch., Ukrainian Shield, Kholodnyy ravine, sample 07, Albian; *3, 5. Pinuspollenites* sp., Volyn-Podilska plate, well 42, sample 9, Turonian; *4. Pinus exequus* Bolch., Volyn-Podilska plate, well 42, sample 9, Turonian; *6. Pinus vulgaris* Naum, Donbas, Glafirovka village, Luhansk region, sample 2, Cenomanian; *7. Pinus subconcinua* (Naum.) Bolch., Volyn-Podilska plate, well 4606, sample 1, Santonian.

The fifth level of increase in the composition of pines in the Mesozoic flora, as well as a slight change in their species composition is timed to the end of the Campanian. The flora of the Late Cretaceous period is characterized by a significant participation of *Pinus vulgaris* Boch., *P. subconcinua* (Naum.) Bolch., *P. concessa* (Naum.) Bolch. Representatives of *Pinus* cf. *minor* Loudon appeared during the Campanian – Maastrichtian times.

At the boundary of the Cretaceous and Paleogene both the number and the species of pines decreased.

Cenozoic

Studies show that that a significant place in the composition of the Cenozoic flora belonged to the genus *Pinus*, especially in the Late Oligocene, Early and Middle Miocene flora.

The role of *Pinus* in the flora grew from the Early to the Late Paleogene (Stotland, 1974). The beginning of the dominance of this genus corresponds to the Eocene-Oligocene boundary. However, the largest species diversity of *Pinus* is typical for the Oligocene. The flora of this period is characterized by a significant participation of *Pinus* spp. subg. *Haploxylon*, and among them – *Pinus* sect. *Mirabilis.* Anan. At the same time, it should be noted that the dominant role in the pine forests of Ukraine belonged to the subgenus *Diploxylon*. However, according to N.O. Schekina (1986), the number of representatives of this subgenus increased from the Oligocene by the end of the Pliocene, and the presence of *Pinus* subg. *Haploxylon* decreased accordingly in this direction. According to the study of Paleogene and Neogene sediments of the north-western part of the Dnipro-Donetsk depression, as the part of the Late Oligocene flora *Pinus* subg. *Haploxylon* recorded a significant involvement (Sirenko, 2003 b). The dominance of pines in the Late Oligocene flora of the south-eastern slope of the Voronezh anteclisis is indicated by V.G. Shpul (2005). According to T.B. Rylova (2001) in the Late Oligocene flora of Belarus is also dominated by various species of *Pinus*, but they belong largely to the subgenus *Haploxylon*. Analyzing the materials regarding the increasing role of representatives of thermophilic species *Pinus* subg. *Haploxylon* in the Oligocene flora of the north-western part of the Dnipro-Donetsk depression (Sirenko, 2003 b) and Belarus in comparison with other regions of Ukraine, it is possible to assume that the number of representatives of this subgenus in the composition of the same age flora increases in the western direction and may be associated with an increase in humidity. We have observed the same pattern for the Pliocene and Early Neopleistocene flora of Ukraine and Belarus (Sirenko, 2017 c).

Thus, the Oligocene time can be determined as the first significant level of *Pinus* participation in the Cenozoic flora. This level is clearly visible, both for the flora of different parts of Ukraine and for adjacent regions. The following representatives of *Pinus* are typical for the Oligocene flora: *Pinus cembraeformis* Zakl., P. cf. *protocembrae* Zakl., *P.* cf. *sibirica* Mayr. *P.* cf. *singularts* Mayr., *P* cf. *koraiensis* Sieb. at Succ., *P.* cf. *cristata* Panova, *Pinus* sect. *Mirabilis* Anan., that according to the classification of O.A. Ananova (1974) and T.B. Rilova (1980) includes *Pinus mirabilis* (Rudolph.) Anan., *Pinus tertiaria* (Moreva) Anan. and *Pinus pusillus* Rilov. Dendroflora were also components *P.* sp. sect. *Cembrae* Spach, *P.* sp. sect. *Strobus* Shaw., *P.* sp. sect. *Taeda* Spach.; *Pinus* spp. subg. *Haploxylon* Koehne., *Pinus* spp. subg. *Diploxylon* Koehne.

Pinus also played a significant role in the flora of the Early and Middle Miocene. The species composition of pines has largely remained unchanged since the Oligocene, with the exception of some species (for example, *Pinus* cf. *koraiensis* Sieb. at Succ. was practically absent in the Miocene flora, and *P.* cf. *cristata* Panova after the Karaganian time of the Middle Miocene, was only a single representative of the dendroflora of the middle Sarmatian time).

The second level of significant increase in the composition of pines in the Cenozoic flora, as well as a marked change in their species composition is timed to the end of the Middle Miocene (Konkian and, especially, early Sarmatian times). *Pinus baileyana* Trav., *P. veronica* Anan., *P. gigantea* Anan. appear at the Konkian time. The flora of early Sarmatian times has

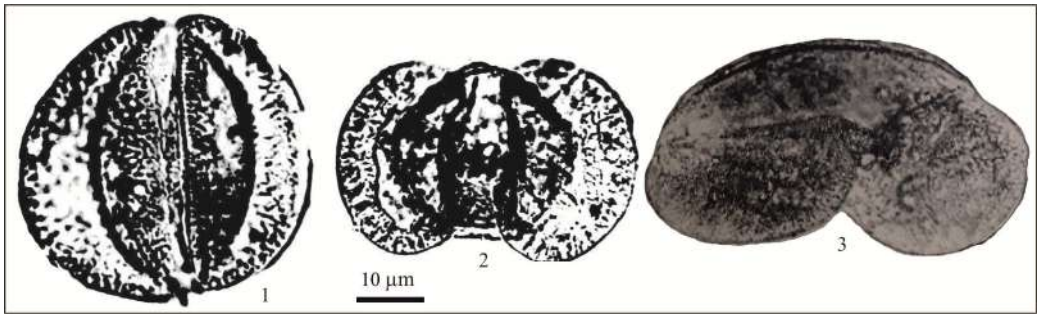


Fig. 6. Typical species of *Pinus* pollen of the Oligocene deposits. Photos by O.B. Stotland: *1. Pinus* cf. *mirabilis* (Rudolf.) Anan. Dnipro-Donetsk depression, Oligocene; *2. Pinus* cf. protocembra Zakl., Dnipro-Donetsk depression, Oligocene; photos by N.O. Shekina: *3. Pinus* cf. *sibirica* (Pall) Mayr., South Ukrainian Monocline, Oligocene.

the greatest species diversity and number of pines: *Pinus mirabilis* (Rudolf.) Anan, *P. baileyana*, *P. Ruthenica, P. veronica* Anan., *P. minutus* Zakl. (Korallova, 1962; Syabryaj, Shchekina, 1983; Shchekina, 1979). According to N.O. Shchekina in the early Sarmatian pine forests of the subgenus *Diploxylon* belonged to the *Sula*, *Banksia*, *Taeda* sections (Shchekina, 1979). Similar patterns of flora have been observed for the territory of the North-Eastern Priazovye and the Lower Don (Ananova, 1974). According to V.G. Shpul (1990), the flora of the late Ivlinsky and early Gurivsky times of Middle Miocene of the Volga-Hopper interfluve, which correspond to the Konkian and early Sarmatian in Ukraine, is dominated by various *Pinus*, similar in composition to the Konkian and early Sarmatian of Ukraine. This level can also be traced for the Miocene flora of Belarus (late Burnosky time) (Palinozone brns5) (Rylova, 2001, 2002), which corresponds to the early Sarmatian in Russia. Regarding the participation of *Haploxylon* and *Diploxylon* in the flora, the materials of different researchers differ slightly. In particular, N.O. Shchekina (1979) in the characterization of spore-pollen complexes corresponding to the lower Sarmatian sediments of Ukraine indicated the predominance of pollen of the subgenus *Diploxylon* (which was up to 40%), as well as a slightly lower content of pollen *Pinus* subg *Haploxylon* (without specifying its percentage). Instead, O.M. Ananova (1974), in characterizing the similar age complexes of the southern part of the Russian plain, noted the predominance of pollen *Pinus* subg. *Haploxylon*, which belonged to 5 species (including *Pinus mirabilis* and *Pinus tertiaria*) in contrast to the three species *Pinus* subg *Diploxylon*. This conclusion is confirmed by the materials of V.G. Shpul according to the characteristics of the Lamkinska series of the Oka-Don plain (spore-pollen complex III, which corresponds to the Lower Sarmatian deposits of Russia and Ukraine) (Shpul, 2004). The common thing to all analyzed materials is that the flora of early Sarmatian times differed significantly in the number of pine and their species diversity.

Fig. 7. Typical species of *Pinus* pollen of the Middle Miocene deposits (Konkian-lower Sarmatian). Photos by N.O. Shekina*: 1. Pinus* cf. *rutenica* Anan., Ukrainian shield, lower Sarmatian; *2. Pinus* cf. *tertiaria* (Moreva) Anan., South Ukrainian Monocline, lower Sarmatian; *3. Pinus* cf. *veronica* Anan., South Ukrainian Monocline, lower Sarmatian; *4. Pinus* cf. *mirabilis* (Rudolph). Anan., South Ukrainian Monocline, lower Sarmatian; *5. Pinus* cf. *banksiana* Lamb., Ukrainian shield, lower Sarmatian.

The next level of increase in the role of *Pinus* was traced at the end of the Miocene (Novorossiysk time of the Pontian of the southern part of Ukraine and Ivankiv time – in Northern Ukraine). This period is characterized by the dominance of pines in the flora, as well as their significant species diversity. It should be noted that the species of pines typical for the flora of the Konkian and early Sarmatian times, namely: *P. baileyana, P. ruthenica, P. veronica*, are no longer typical for the early Pontian flora. *Pinus mirabilis* Anan. is singly noted only in the dendroflora of the Kerch Peninsula (Sirenko, 2003 a). The flora of these stages was dominated by representatives of the subgenus *Diploxylon*: *Pinus* sp. sect. *Eupitys* Spach (dominated) *P.* sp. sect. *Sula* Mayr., *P.* sp. sect. *Taeda*, *P.* sp. sect. *Pseudostrobus*., *P.* sp. sect. *Banksia* Mayr*., P. longifoliaformis* Zakl., but the role of *Pinus* spp. subg. *Haploxylon*. in the composition of forests was still quite significant: *P. pusillus*., *P.* sp. sect.

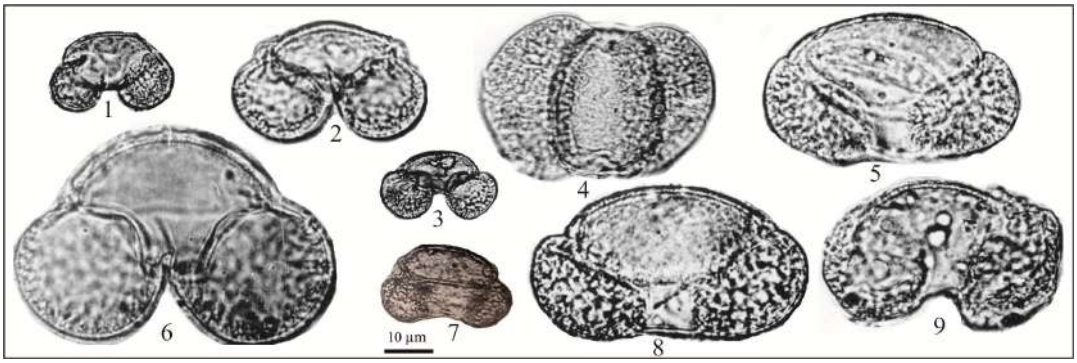


Fig. 8. Typical species of *Pinus* pollen of the Upper Miocene (lower Pontian (Novorossiysk), (Ivankiv)) and Lower Pliocene deposits (lower Kimmerian (early Sevastopol)). Photos by O.A. Sirenko: *1. Pinus minutus* Zakl., Dnipro-Donetsk depression, Upper Miocene; *2*. *Pinus* sp. subg. *Diploxylon* Koehne., Dnipro-Donetsk depression, Upper Miocene; *3*. *Pinus* cf. *longifoliaformis* Zakl., Folded Donbas, Upper Miocene; *4*. *Pinus* sp. subg. *Haploxylon* Koehne., Dnipro-Donetsk depression, Upper Miocene; 5. *Pinus* sp. sect. *Cembrae* Spach., Folded Donbas, Lower Pliocene; *6. Pinus* sp. sect. *Strobus* Shaw., Folded Donbas, Upper Miocene; *7*. *Pinus* sp. sect. *Sula* Mayr., Dnipro-Donetsk depression, Upper Miocene; *8. Pinus* sp. sect. *Taeda* Spach., Dnipro-Donetsk depression, Upper Miocene; *9. Pinus* sp. sect. *Cembrae* Spach., Dnipro-Donetsk depression, Lower Pliocene.

Cembrae., *P.* sp. sect. *Strobus.* This level is well traced both within Ukraine (Shchekina, 1979) and Russia (Taman Peninsula) (Ananova, Volkova, Zubakov, etc., 1985).

The next level of increase in the participation and species diversity of *Pinus* in the flora corresponds to the early Kimmerian Pliocene of southern Ukraine and the early Sevastopolsky time of northern Ukraine. Within the southern and northern parts of platform Ukraine and within the Kerch Peninsula at this time the forest type of vegetation prevailed, the dominant role in the forests belonged to pines, in species composition close to the forests of early Pontian time: *Pinus* spp. subg. *Diploxylon*, *P.* sp. sect. *Banksia*, *P.* sp. sect. *Eupitys, P.* sp. sect. *Taeda*, *P.* sp. sect. *Sula, P. longifoliaformis, P. minutus* Zakl., *P.* sp. sect. Cembrae, *P*. sp. sect. Strobus. It should be noted that *P.* sp. sect. *Taeda*, *P. minutus* are no longer typical for the flora of the Late Pliocene and Pleistocene of Ukraine. This level is also observed for the early Kimmerian flora of Russia (Taman Peninsula) (Filippova, 2002).

Increasing of the role of *Pinus* spp. as a part of flora, especially at the expense of representatives of the subgenus *Diploxylon* is traced in the early Kuyalnik time of the Late Pliocene of the southern part of Ukraine and the Kyzylyar and early Bogdanivka time of its northern and northeastern parts. It should be noted that analogues of the spore-pollen complex from Kyzylyar sediments have not been established among the complexes that characterize the lagoon-marine sediments of Ukraine. In the Neogene section of the Trans Asov massif, there is a break in sedimentation between the Kimmerian and Kuyalnik deposits (Semenenko, 1987). The composition of the dendroflora changed dramatically during the Kuyalnik time. The main component of forests was *Pinus* spp. subg. *Diploxylon*, heat-loving species of the subgenus *Haploxylon* were almost completely absent. This level correlates well with the level of dominance of pine and the general impoverishment of the flora of the early Sokolsky time (SPC VII) of the Middle Volga region. (Linkina, 2006). In the early Bogdanivka time, there was also an increase in the role of pines in the dendroflora, but in the forests dominated by *Pinus* spp. subg. *Diploxylon*, a few members of the subgenus *Haploxylon* already appear. A similar pattern is inherent in the dendroflora of the early Kuyalnik time of southern Ukraine, as well as the middle Sokolsky time (SPC VIII) of the Middle Volga region (Linkina, 2006) and the early Sukhodolsky time of the Volga-Hopper interfluve (SPC X) (Shpul, 1991). Thus, the established regularity of significant impoverishment of the dendroflora of the Late Pliocene of Ukraine, which also concerns its main component – the genus *Pinus*, is well compared with that for the European part of Russia. According to A.O. Velichko and co-authors (2011) in the landscape of the territory of the European part of Russia clearly records the cooling at the turn of 3.4 million years, which is probably traced in Ukraine in the Kyzylyar time. Although, given the lack of analogues of Kyzylyar sediments in the marine context of the Pliocene of Ukraine at this stage of research, we consider it appropriate to identify a combined Kyzylyar early- Bogdanivka level of changes in the role of *Pinus* in the dendroflora, which generally corresponds to the early Kuyalnik stage of the Black Sea region of Ukraine and the early Akchagylian stage of the Caspian region of Russia.

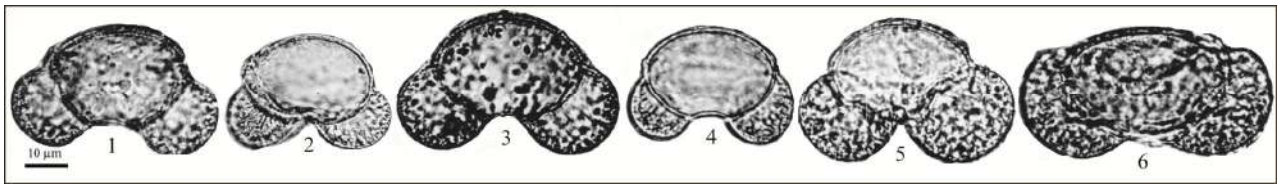


Fig. 9. Typical species of *Pinus* pollen of the Upper Pliocene and Lower Pleistocene deposits. Photos by O.A. Sirenko: *1. Pinus* sp. sect. *Eupitys* Spach., Dnipro-Donetsk depression, Upper Pliocene; *2. Pinus* aff. sylvestris L., Folded Donbas, Upper Pliocene; *3. Pinus* sp. sect. *Eupitys* Spach., Folded Donbas, Upper Pliocene; *4. Pinus* aff. *sylvestris* L. Folded Donbas, Lower Pleistocene; *5. Pinus* sp. sect. *Strobus* Shaw., Folded Donbas, Upper Pliocene; *6. Pinus* sp. sect. *Cembrae* Spach., Folded Donbas, Upper Pliocene.

A significant increase in the role of *Pinus* in the composition of flora and vegetation is also recorded in the Kryzhanivka time of the Eopleistocene. However, due to the fact that in Kryzhanivka time there was a fairly pronounced zonation of plant cover and the established pattern was not observed for all regions of Ukraine, we consider it acceptable not to allocate this level as a benchmark.

The next level of increasing the role of *Pinus* in the dendroflora is timed to the first warm stage of the Early Neopleistocene (Martonosha). The vegetation type of the central, north-eastern and western parts of Ukraine was dominated by forest vegetation. Pines played a dominant role in the dendroflora of all, without exception, regions of Ukraine: *Pinus* spp. subg. *Diploxylon* (prevailed), *P*. spp. sect *Eupitys*, *P. longifoliaformis*, *P.* spp. sect. *Strobus*, *P.* spp. sect. *Cembrae*. This level is well traced both for the territory of Ukraine and adjacent regions of Russia (Tregub, Starodubtseva, 2005) and is characterized by the most significant representation of the genus *Pinus* in the Early Neopleistocene flora, its diversity and noticeable presence of *Haploxylon*.

Conclusions

The genus *Pinus* has a large stratigraphic range, but its species diversity and quantitative changes in the composition of different ages of Mesozoic and Cenozoic flora differ markedly. The analysis of these changes makes it possible to trace the emergence and the main levels at which the species composition was renewed and its role in the flora increased during the Mesozoic and Cenozoic.

The Mesozoic flora has 5 levels, which characterize the increase in the participation of the genus *Pinus* at different ages, among which the two levels are most pronounced. In particular, the appearance of the first representatives of *Pinus*, the Aalenian time (Middle Jurassic), is clearly recorded in the flora of the territory of Ukraine. Also, an important moment in the development of Mesozoic flora – the Albian time (Early Cretaceous), when the representatives of *Pinus* split into two generic groups – subgenus *Haploxylon* and *Diploxylon*.

5 levels of increasing the role of *Pinus* and its species diversity for the flora and vegetation of the Cenozoic were also established: Oligocene time of the Paleogene, Konkian-early Sarmatian time of the Middle Miocene; early Pontian (Ivankiv) time of the Late Miocene; early Kimmerian time (early Sevastopol) of the Early Pliocene and Martonosha time of the Early Neopleistocene.

Participation of representatives of *Pinus* spp. subg. *Haploxylon* and *Pinus* spp. subg. *Diploxylon* in the composition of the Cenozoic flora was different. In general, the tendency to reduce the role of pines of the subgenus *Haploxylon* in the composition of flora from the Paleogene to the Pliocene, established by N.O. Schekina (1986) is traced, but at certain stages of nature development (early Sarmatian and early Pontian of Miocene, early Kimmerian of Pliocene) recorded an increase in the number of representatives of this subgenus and its species diversity compared to the older flora.

A comparison of the composition of the Cenozoic flora of Ukraine and the adjacent regions of Belarus and Russia indicates the existence of a pattern of growth of the role of *Pinus* in the composition of forests from southwest to east and northeast.

The determined levels of changes in the composition of *Pinus* in the development of Mesozoic and Cenozoic flora are well traced not only within different regions of Ukraine, but also typical for the flora of adjacent regions of Belarus and Russia.

The traced levels can be used as benchmarks for stratigraphic divided of Mesozoic and Cenozoic sediments of Ukraine and their correlation with the similar sediments of other regions.

Acknowledgment

The article highlights the results of research funded by the budget program «Substantiation of the boundaries of regional and local stratigraphic units of the Phanerozoic of Ukraine for geological maps of the new generation» (KPKVK 6541030).

References

Ananova, E.N., 1974. Pyltsa v neogenovykh otlozheniyakh Russkoy ravniny [Pollen in Neogene deposits of the Russian Plain] Leningrad: Leningrad State University, 228 (In Russian).

Ananova, E.N., Volkova, N.S., Zubakov, V.A. et al., 1985. Novyye dannyye po Tamanskomu opornomu razrezu mio-pliotsena Prichernomor'ya [New data on the Taman reference section of the Mio-Pliocene of the Black Sea region] Dokl. Academy of Sciences of the USSR. T. 284, № 4. 925–928 (In Russian).

Bolkhovitina, N.A., 1953. Sporovo-pyl'tsevaya kharakteristika melovykh otlozheniy tsentral'nykh oblastey SSSR [Spore-pollen characteristics of Cretaceous sediments of the central regions of the USSR]. Proceedings of the Institute of Geol. Sciences of the USSR Academy of Sciences. Geological series. Issue. 145, № 61. 253 (In Russian).

Chlonova, A.F., 1974. Palinologiya melovykh otlozheniy Sibiri i Dal'nego Vostoka [Palynology of Cretaceous deposits of Siberia and the Far East]. Proceedings of the Institute of Geology and Geophysics of the Siberian Branch of the USSR Academy of Sciences. Novosibirsk, Issue. 96.1–166.

Dorotyak, Yu.B., Matveev, A.V., Shevchuk, E.A., 2009. Kharakteristika pogranichnykh otlozheniy yury i mela v Gornom Krymu (foraminifery, izvestkovyy nannoplankton, dinotsisty, palinokompleksy) [Characteristics of the Jurassic and Cretaceous boundary deposits in the Crimean Mountains (foraminifera, calcareous nannoplankton, dinocysts, palynological complexes)]. Collection of Scientific Works for the Institute of Geological Sciences of the National Academy of Sciences of Ukraine. Fossil fauna and flora of Ukraine: Paleoecological and stratigraphic aspects. Kyiv, 108–117 (In Russian).

Filippova, N. Yu., 2002. Spory, pyl'tsa i organikostennyy fitoplankton iz neogenovykh otlozheniy opornogo razreza Zheleznyy Rog (Tamanskiy poluostrov) [Spores, pollen, and organic-walled phytoplankton from the Neogene sediments of the Zhelezny Rog reference section (Taman Peninsula)]. Stratigraphy. Geological correlation. V.10. 2, 80–92 (In Russian).

Gozhyk, P.F., Semenenko, V.M., Maslun, N.V., Poletayev, V.I., Ivanik, M.M., Miknitskaya, T.M., Velikanov, V. Ya., Melnychuk, V.G., Konstantinenko, L.I., Kirianov, V.V., Tsegelynuk, P.D., Kotlyar, O. Yu., Berchenko, O.I., Vdovenko, M.V., Shulga, V.F., Nemirovskaya, T.I., Shchegolev, O.K., Boyarina, N.I., Pyatkova, D.M., Plotnikova, L.F., Leschukh, R. Ya., Zhabina, N.M., Shevchuk, O.A., Yakushin, L.M., Anikeeva, O.V., Veklych, O.D., Prikhodko, M.G., Tuzyak, Y.M., Matlay, L.M., Dorothyak, Yu.B., Shaynoga, I.V., Klymenko, Yu.V., Gotsanyuk, G.I., 2013. Stratyhrafiya verkhnoyi proterozoyskoyi ta fanerozoyskoyi Ukrayiny. Stratyhrafiya verkhnoyi proterozoyskoyi, paleozoyskoyi ta mezozoyskoyi Ukrayiny [Stratigraphy Upper Proterozoic and Phanerozoic Ukraine. Stratigraphy Upper Proterozoic, Paleozoic and Mesozoic Ukraine]. Institute of Geological Sciences. National Academy of Sciences of Ukraine. Logos. Kyiv, Vol. 1, 1–637 (In Ukrainian).

Korallova, V.V., 1962. Sporovo-pylkovi kompleksy verkhn′oho ta seredn′oho miotsenu pivnichnoyi chastyny Prychornomors′koyi zapadyny [Spore-pollen complexes of the upper and middle Miocene of the northern part of the Black Sea basin. Ukrainian]. Botanical Journal. V. 19, 4, 55–62 (In Ukrainian).

Korallova, V.V., 1968. Kompleksy pyl'tsy i spor iz paleogenovykh otlozheniy Prichernomorskoy vpadiny i ikh znacheniye dlya korelyatsii Geologiya i rudonosnost' yuga Ukrainy [Pollen and Spore Complexes from Paleogene deposits of the Black Sea depression and their significance for correlation geology and ore content of the South of Ukraine]. Collection of scientific papers of the National Academy of Sciences of Geology of Dnepropetrovsk University. Issue 1, 21–28 (In Russian).

Kuvaeva S.B., Yanin B.T. 1973. Palinologicheskaya kharakteristika nizhnemelovykh otlozheniy Gornogo Kryma. [Palynological characteristics of the Lower Cretaceous deposits of the Mountain Crimea]. Moscow State University Bulletin. Moscow, 5. 49–50 (In Russian).

Linkina, L.I., 2006. Izmeneniye rastitel'nosti i klimata tsentral'noy chasti Srednego Povolzh'ya v neogene (po dannym sporovo-pyl'tsevogo analiza) [The change of vegetation and climate of the central part of the Middle Volga region in the Neogene (according to the spore-pollen analysis)]. Scientific Notes. Kasane. state. Univ., Vol 148, book 2, 150–161 (In Russian).

Millar, C.I., 1998. Early evolution of pines. In: Richardson DM (ed) Ecology and biogeography of ***Pinus***. Cambridge University Press, Cambridge, 69–91.

Malyasova, E.S., 1976. Palinologiya donnykh osadkov Belogo morya [Palynology of bottom sediments of the White Sea]. Leningrad. Ed. Leningrad State University. 119 (In Russian).

Michelis, A.A., 1976. Raschleneniye paleogena i neogena Artemovskoy antiklinali na osnovanii palinokompleksov [Dissection of the Paleogene and Neogene Artemovskaya anticlines on the basis of palynocomplexes]. Reports of the Academy of Sciences of the USSR, 6, 508–512 (In Russian).

Ogorodnik, M., 2006. Zonal′na shkala biostratyhrafichnykh pidrozdiliv tytonu-senomanu Peredkarpattya za palinolohichnymy danymy ta perydyneyevymy vodorostyamy [Zonal scale of biostratigraphic subdivisions of Tithonian-Cenomanian of Precarpathia according to palynological data and peridinea algae]. Paleontol. zb. Lviv, № 38, 65–71 (In Ukrainian).

Orlova-Turchina, G.A., 1966. Sporovo-pyltsevyye kompleksy goteriva i barrema zapadnoy i tsentralnoy chastey Ravninnogo Kryma [Spore-pollen complexes of Hauterivian and Barremian of the westernand central parts of the Plain Crimea]. *Paleontol. collection*, 3, 1, 90–96 (In Russian).

Rehakova, D., Matyja, B., Wierzbowski A, Schlogl, J., Krobicki, M., Barski, M., 2011. Stratigraphy and microfacies of the Jurassic and lowermost Cretaceous of the Veliky Kamenets section (Pieniny Klippen Belt, Carpathians, Western Ukraine). Volumina Jurassica. Vol. 9, № 9, 61–104 (In English).

Rostovtseva, Yu.I., 2014. Palinokompleksy iz sredneyurskikh otlozheniy tsentra yevropeyskoy chasti Rossii [Palynological complexes from the Middle Jurassic deposits of the center of the European part of Russia}. Dissertation for the degree of candidate of geological and mineralogical sciences. Paleontology and Stratigraphy. Moscow. 205 (In Russian).

Rylova, T.B., 1980. Palinologicheskaya kharakteristika neogenovykh otlozheniy Belorusskogo Poneman'ya [The Palynological characterictic of the Neogene deposits of the Belarusian Ponemanie]. Minsk: Science and Technology. 216 (In Russian).

Rylova, T.B., 1996. Pozdneoligotsenovyye palinoflory Belarusi [Late Oligocene palynoflora of Belarus]. Litasfera. 5, 43–58 (In Russian).

Rylova, T.B., 2001. Osobennosti evolyutsii palinoflory Belarusi v kontse paleogena i v Neogene [Features of the evolution of palynoflora in Belarus at the end of the Paleogene and in the Neogene]. Reports of the National Academy of Sciences of Belarus. V. 45, 1, 96–100 (In Russian).

Rylova, T.B., 2002. Palinostratigrafiya otlozheniy verkhnego oligotsena i neogena Belarusi i zakonomernosti razvitiya flory i rastitel'nosti [Palynostratigraphy of the Upper Oligocene and Neogene deposits of Belarus and the patterns of flora and vegetation development]. Abstract of the dissertation for the degree of Doctor of geol.-min. sciences. Minsk, 40 (In Russian).

Semenenko, V.N., 1987. Stratigraficheskaya korrelyatsiya verkhnego miotsena-pliotsena Vostochnogo Paratetisa i Tetisa [Stratigraphic correlation of the Upper Miocene and Pliocene of the Eastern Paratethys and Tethys]. Kyiv, Naukova dumka, 232 (In Russian).

Shchekina N.*O.* 1964в. Do vyvchennya flory i roslynnoho pokryvu pivdnya Ukrayiny u kuyal′nyts′komu vitsi [To study the Kuyalnik flora and plant cover of southern Ukraine]. Ukrainian Botanical Journal, Vol 21, 84–90 (In Ukrainian).

Shchekina, N.A., 1975. Istoriya razvitiya rastitel'nogo pokrova Khersonskoy i Nikolayevskoy oblastey v sarmatskom veke [History of vegetation development of Kherson and Nikolaev regions in the Sarmatian century]. Flora, systematics and phylogeny of plants. Kyiv. Nauk. opinion, 265–276 (In Russian).

Shchekina, N.A., 1979. Istoriya flory i rastitel'nosti yuga Yevropeyskoy chasti SSSR v pozdnem miotsene–rannem pliotsene [The history of the flora and vegetation of the South European part of the USSR in the Late Miocene–Early Pliocene]. Kyiv, Naukova dumka, 200 (In Russian).

Shchekina, N.O., 1964a. Materialy do flory i roslynnosti kimeriys′koho viku Pivnichnoho Pryazov″ya [Materials to flora and vegetation of the Kimmerian age of the North Azov region]. Ukrainian Botanical Journal, Vol 21, (2), 61–68 (In Ukrainian).

Shchekina, N.O., 1977. Rezul′taty sporovo-pylkovoho analizu kimeriys′kykh vidkladiv Kerchens′koho pivostrova [Results of spore-pollen analysis of Kimmerian deposits of the Kerch Peninsula]. Ukrainian Botanical Journal, Vol 34, (1), 76–81 (In Ukrainian).

Shevchuk, O., Slater, S.M., Vajda, V., 2018. Palynology of Jurassic (Bathonian) sediments from Donbas, northeast Ukraine. Palaeobiodiversity and Palaeoenvironments, 98(1), 153–164. DOI: 10.1007/s12549–017–0310–3.

Shevchuk, O.A., 2004. Korelyatsiya riznofatsial′nykh apt·s′kykh vidkladiv Prychornomors′koyi zapadyny za palinolohichnymy danymy [Correlation of different facies Aptian sediments of the Black Sea basin according to palynological data]. Collection of scientific works of the Institute of Geological Sciences of the National Academy of Sciences of Ukraine. Problems of Phanerosis stratigraphy of Ukraine. Kyiv, 94–98 (In Ukrainian).

Shevchuk, O.A., 2005. Biostratyhrafiya kreydovykh vidkladiv Volyni za palinolohichnymy danymy [Biostratigraphy of Cretaceous sediments of Volyn according to palynological data]. Collection of scientific works of the Institute of Geological Sciences of the National Academy of Sciences of Ukraine. Biostratigraphic criteria for divided and correlation of sediments of the Phanerozoic of Ukraine. Kyiv, 84–91 (In Ukrainian).

Shevchuk, O.A., 2006. Palinolohichni doslidzhennya verkhn′okreydovykh vidkladiv Podillya [Palynological research of Upper Cretaceous sediments of Podillya]. Paleontological collection. Lviv, 38. 81–87 (In Ukrainian).

Shevchuk, O.A., 2007. Novi palinolohichni dani do kharakterystyky seredn′oyurs′kykh vidkladiv pivdennoho bortu Dniprovs′ko-Donets′koyi zapadyny [New palynological data on the characteristics of Middle Jurassic deposits on the southern side of the Dnieper-Donetsk basin]. Paleontological collection. Lviv, 39. 56–65 (In Ukrainian).

Shevchuk, O.A., 2008. Paleoheohrafichni umovy na skhidnomu skhyli Ukrayins′koho shchyta v keloveys′kyy ta rann′okreydovyy chas (za palinolohichnymy danymy) [Paleogeographical conditions on the eastern slope of the Ukrainian Shield in the Kelovei and Early Cretaceous times (according to palynological data)]. Collection of scientific works of the Institute of Geological Sciences of the National Academy of Sciences of Ukraine. Biostratigraphic bases of construction of stratigraphic schemes by the Phanerozoic of Ukraine. Kyiv, 101–106 (In Ukrainian).

Shevchuk, O.A., 2009. Palinolohichne obgruntuvannya stratyhrafichnoho rozchlenuvannya kreydovykh vidkladiv Hirs′koho Krymu [Stratigraphically subdivided palynological argumentation of the Cretaceous sediments of the Crimea Mountains]. Collection of scientific works of the Institute of Geological Sciences of the National Academy of Sciences of Ukraine. Kyiv, Issue 2. 223–234 (In Ukrainian).

Shevchuk, O.A., 2010. Palinolohichni materialy do stratyhrafiyi mezozoys′kykh vidkladiv Podillya (dolyny r. Zolota Lypa) [Palynological materials to the stratigraphy of Mesozoic deposits of Podillya (valleys of the Golden Linden River)]. Bulletin of Lviv University. Geological series. Lviv, № 24. 160–170 (in Ukrainian).

Shevchuk, O.A., 2011. Palinostratyhrafiya ta korelyatsiya riznofatsialnykh albskykh vidkladiv Ukrayiny [Palynostratigraphy and correlation of different facies Albian deposits of Ukraine]. Paleontological collection. Lviv. 43, 3–13 (In Ukrainian).

Shevchuk, O.A., 2012. Palinostratyhrafiya senomans′kykh vidkladiv Ukrayiny [Palinostratigraphy of Cenomanian sediments of Ukraine]. Paleontological collection. Lviv. 44. 3–13 (In Ukrainian).

Shevchuk, O.A., 2013. Palinostratyhrafiya kreydovykh vidkladiv ukrayinskoyi chastyny akvatoriyi Azovskoho morya [Palynostratigraphy of Cretaceous deposits of the Ukrainian part of the Azov Sea]. Tectonics and stratigraphy. Kyiv. 40, 118–124. DOI: 10.30836/igs.0375–7773.2013.94062 (In Ukrainian).

Shevchuk, O.A., 2016. Biostratyhrafiya seredn′oyi yury tsentralnoyi ta skhidnoyi chastyny platformnoyi Ukrayiny [Biostratigraphy of the middle Jurassic of central and eastern platform Ukraine]. Visnyk of V.N. Karazin Kharkiv National University-series Geology. Geography. Ecology. Kharkiv, Issue 45, 86–99 (In Ukrainian).

Shevchuk, O.A., 2018. Spore-pollen biostratigraphy Jurassic and Cretaceous of Ukraine. Paleontological collection. Lviv. 50, 60–72.

Shevchuk, O.A., 2020. Stratyhrafiya serednoyi Yury – Kreydy Ukrayiny za mikrofosyliyamy [Stratigraphy of the Middle Jurassic – Cretaceous of Ukraine on microfossils]. Abstract of the dissertation for the degree of Doctor of Geological sciences. Institute of Geological Sciences. National Academy of Sciences of Ukraine. Specialty 04.00.01 – general and regional geology. Kyiv. 44 p. 4 applications (In Ukrainian).

Shpul, V.G., 1990. Sporovo-pyl'tsevyye kompleksy neogenovykh otlozheniy Vostochnogo paratetisa (Volgo-Khoperskoye mezhdurech'ye) i ikh stratigraficheskoye znacheniye [Spore-pollen complexes of the Neogene deposits of the Eastern paratethys (Volga-Khoperskoe interfluve) and their stratigraphic significance]. Abstract of the dissertation for the degree of candidate geol.-min. sciences. Kyiv, 25 (In Russian).

Shpul, V.G., 2004. K palinostratigrafii lamkinskoy serii Oksko-Donskoy ravniny (po razrezu s. Ignat'yevki tambovskoy oblasti) [Palynostratigraphy of the Lamka Group of the Oka-Don Plain (along the section of the village of Ignatievka, Tambov Region)]. Bulletin of Voronezh University. Geology, 1, 52–67 (In Russian).

Shpul, V.G., 2005. Novyye dannyye po fitostratigrafii eotsen-oligotsena yugo-vostochnogo sklona Voronezhskoy anteklizy [New data on the phytostratigraphy of the Eocene-Oligocene of the southeastern slope of the Voronezh anteclise]. Voronezh University. Bulletin 1, 55–69 (In Russian).

Shramkova, G.V., 1982. Etapnost' v razvitii paleoflor i korrelyatsiya razrezov pozdney yury i rannego mela Voronezhskoy anteklizy i Dneprovsko-Donetskoy vpadiny [Stages in the development of paleofloras and correlation of the Late Jurassic and Early Cretaceous sections of the Voronezh anteclise and the Dnieper-Donetsk depression]. Paleontology and biostratigraphy of the Mesozoic of Ukraine. Kyiv, Preprint 82–9. 55–56 (In Russian).

Sirenko, E.A., 2000 a. Microrhytms in the Evolution of Pliocene and Early Pleistocene vegetation in Eastern Ukraine Paleontological Journal, Vol.34, Suppl.1, Moscow, 581–586.

Sirenko, E.A., 2000 b. Palynolohycheskye dannye k kharakterystyke pohranychnykh olyhotsen-myotsenovykh otlozhenyy severnoy Ukrayny [Palynological data on the characteristics of border Oligocene-Miocene sediments of northern Ukraine]. Biostratigraphic and paleoecological aspects of event stratigraphy. Collection of scientific works of Institute of Geological Sciences. Kyiv. 53–54 Iin Russian).

Sirenko, E.A., 2003 a. K palinologicheskoy kharakteristike ponticheskikh otlozheniy Vostochnogo Paratetisa [On the palynological characteristics of the Pontic deposits of the Eastern Paratethys]. Geological journal. 4, 54–58 (In Russian).

Sirenko, E.A., 2003 b. Novyye dannyye k palinologicheskoy kharakteristike verkhneoligotsenovykh otlozheniy Severnoy Ukrainy [New data on the palynological characteristics of the Upper Oligocene deposits of Northern Ukraine]. Reports of the National Academy of Sciences of Ukraine, 4, 118–121 (In Russian).

Sirenko, E.A., 2004. Palinologicheskiye dannyye k obosnovaniyu vozrasta boyarskoy tolshchi [Palynological data to determine the age of the Boyarka sequence]. Problems of the Phanerozoic stratigraphy of Ukraine. Scient. Papers of the Institute of Geological Sciences, Kyiv, 174–180 (In Russian).

Sirenko, E.A., 2006. Pervyye rezul'taty palinologicheskikh issledovaniy raznofatsial'nykh otlozheniy verkhnego pliotsena Vostochnogo Priazov'ya [First results of palynological examination of multifacial Upper Pliocene sediments of Eastern near-Azov region]. Contemporary Trends in Ukrainian Geological Science. Collection of Scientific Works of IGS NAS of Ukraine, Kyiv, 277–283 (In Russian).

Sirenko, E.A., 2007a. Palinologicheskiye dannyye k kharakteristike kimmeriyskikh otlozheniy Vostochnogo Priazov'ya [Palynoligical evidences for characterization of the Kimmerian sediments of the Eastern Azov coast]. Paleontological studies in Ukraine: history, present–day state and prospects. Collection of Scientific Works of the Institute of Geological Sciences. Kyiv, 342–348 (In Russian).

Sirenko, O.A., 2007 b. Pershi palinolohichni dani z kharakterystyky pliotsenovykh vidkladiv tsentral′noyi chastyny Ukrayins′koho shchyta [First palynological data towards the Pliocene deposits of the central part of the Ukrainian shield]. Geological Journal, 1, 92–98. (In Ukrainian).

Sirenko, E.A., 2009 a. Fitostratigraficheskiy aspekt izucheniya verkhnepliotsenovykh–neopleystotsenovykh otlozheniy Ukrainskogo shchita [Phytostratigraphic aspects of studying the Upper Pliocene-Neopleistocene deposits of the Ukrainian Shield]. Geological Journal, National Academy of Sciences of Ukraine. 3, 65–78 (In Russian).

Sirenko, O.A., 2009 b. Zminy roslynnoho pokryvu platformnoyi Ukrayiny naprykintsi pizn′oho miotsenu ta u pliotseni [Development of vegetation cover of Platform Ukraine during end Miocene-Pliocene]. Gelogical Journal. 2, 48–57 (In Ukrainian).

Sirenko, E.A., 2016. Kontynental′nye verkhnemyotsenovye-plyotsenovye otlozhenyya Severnoy Ukrayny Heolohiya ta rudonosnist′ Ukrayiny [Continental Upper Miocene-Pliocene deposits of the Northern Ukraine]. Geology and ore content of Ukraine 2, (1), 107–126. DOI 10.15421/121607 (In Russian).

Sirenko, E.A., 2017 a. Izmeneniye rastitel'nosti i klimata Ukrainy v intervale 2,56–1,8 mln let (gelazskiy vek) [Changes in vegetation and climate of Ukraine in the interval of 2.56–1.8 million years (Gelazian age)]. Actual problems of earth sciences: use of natural resources and preservation of the environment. Collection of materials of the International scientific-practical conference dedicated to the Year of Science in the Republic of Belarus. Ch. 1 Brest, 121–124 (In Russian).

Sirenko, O.A., 2017 b. Subaeral′ni vidklady eopleystotsenu–nyzhn′oho neopleystotsenu rivnynnoyi chastyny Ukrayiny ta yikh palinolohichna kharakterystyka [Subaeral Eopleistocene–Lower Neopleistocene deposits of the plain part of Ukraine and their palynological characteristic]. Dniprop. Univer. Bull. Ser.: Journal of Geology, Geography and Geoacology. 25 (1) 101–118. Doi: 10.15421/111712 (In Ukrainian).

Sirenko, E.A., 2017 c.. Palinostratigrafiya kontinental'nykh verkhnepliotsenovykh-nizhneneopleystotsenovykh otlozheniy yuzhnoy chasti Vostochno-Yevropeyskoy platformy [Palynostratigraphy of Continental Upper Pliocene – Lower Neopleistocene deposits of Southern part of the East European Platform]. Kyiv, Naukova dumka. 167 (In Russian).

Sirenko, O., 2019 a. Changes in Pleistocene vegetation and climate of Ukraine in the range of 1.8–0.4 million years. Journal of Geology, Geography and Geoacology 28 (2), 355–366 (In English).

Sirenko, O., 2019 b. Palynological data on the description of the Gelasian and Calabriane analogues in the stratotype section of the Kuyalnik deposits near Kryzhanivka village (Odessa region). Journal of Geology, Geography and Geoecology. 28 (4), 727–737.

Sirenko, O, 2021. Palaeoenvironmental conditions of the formation of sediments of the Early Pliocene of Ukrainian Plain and the vegetation cover dynamics. Geological Journal. Special issue. Biodiversity and floral patterns in the course of Cenozoic climate change. Handling Editor T. Utescher. Vol. 56, Issue 2, 839–850.

Sopina, V.S., 1974. Sporovo-pylkovi kompleksy seredn′omiotsenovykh vidkladiv Kerchens′koho pivostrova [Spore-pollen complexes of Middle Miocene sediments of the Kerch Peninsula]. Ukrainian Botanical Journal. V. 31, № 3, 299–303 (In Ukrainian).

Stotland, A.B., 1984. Mikrofitofossilii pozdnego eotsena – srednego miotsena Dneprovsko-Donetskoy vpadiny i ikh stratigraficheskoye znacheniye. [Microfytofossils of the Late Eocene – Middle Miocene of the Dnieper-Donets Basin and their stratigraphic significance]. Abstract of the dissertation for the degree of candidate geol.-min. sciences. Kyiv, 25 (In Russian).

Stotland, A.B., 1985. K voprosu o vozraste berekskoy svity Dneprovsko-Donetskoy vpadiny [On the question of the age of the Berekskaya suite of the Dnieper-Donetsk depression] Fossil organisms and stratigraphy of the sedimentary cover of Ukraine. Kyiv: Naukova dumka, 140–142 (In Russian).

Syabryaj, S.V., Shchekina, N.A., 1983. Istoriya razvitiya rastitel'nogo pokrova Ukrainy v miotsene [The history of the development of the vegetation cover of Ukraine in the Miocene]. Kyiv. Naukova Dumka, 172 (In Russian).

Tregub, T.F., Starodubtseva, N.V., 2005. Palinologicheskoye obosnovaniye stratigraficheskogo raschleneniya otlozheniy nizhnego pleystotsena [Palynological substantiation of the stratigraphic subdivision of the Lower Pleistocene sediments]. Vestnik Voronezh State University, Series Geology, № 1, 38–55 (In Russian).

Velichko, A.A., Pisareva, V.V., Faustova, M.A. 2011. K probleme paleogeografii pozdnego pliotsena i rannego neopleystotsena Vostochnoy Yevropy [On the problem of paleogeography of the late Pliocene and early Neopleistocene of Eastern Europe]. Quarter in all its diversity. Fundamental problems, the results of the study and the main directions of further research: materials of the VII All-Russian. meetings on the study of the Quaternary period, Apatity, St. Petersburg: RAS, V.1, 104–107 (In Russian).

Vajda, V. 2001. Aalenian to Cenomanian terrestrial palynofloras of SW Scania, Sweden. Acta Palaeontologica Polonica. Vol. 46. № 3. 403–426.

Voronova, M.A., 1994. Palinostratigrafiya nizhnego mela i razvitiye rannemelovykh flor Ukrainy [Palinostratigraphy of the Lower Cretaceous and the development of early Cretaceous flora of Ukraine]. Scientific thought. Kyiv, 219 (In Russian).

Voronova, M.A., Yanovskaya, G.G., 1973. Sopostavleniye sporovo-pyl'tsevykh kompleksov pogranichnykh i melovykh obrazovaniy Dneprovsko-Donetskoy vpadiny i mezhdurech'ya Prut-Dnestr [Comparison of spore-pollen complexes of border and Cretaceous formations of the Dnieper-Donetsk depression and the Prut-Dniester interfluve]. Palynology of the mesophyte. The science. Moscow. 101–104 (In Russian).

Voronova, M.A., Yanovskaya, G.G. 1982. Etapy razvitiya yurskoy i rannemelovoy flory yuga Ukrainy i Moldavii [Stages of development of the Jurassic and Early Cretaceous flora of the south of Ukraine and Moldova]. New data on the stratigraphy and fauna of the Phanerozoic of Ukraine. Naukova dumka. Kyiv, 37–40 (In Russian).

Voronova, M.A., Yanovskaya, G.G., 1991. Zonal'nost' rastitel'nogo pokrova v yure i rannem melu Ukrainy [Zonation of vegetation cover in the Jurassic and Early Cretaceous of Ukraine]. Reports of the Academy of Sciences. Ukr. SSR, Series B. 3, 64–71 (In Russian).

Yanovska, G.G., 1973. Etapy razvitiya yurskoy i rannemelovoy flory mezhdurech'ya Prut-Dnestr [Stages of development of Jurassic and Early Cretaceous flora of the Prut-Dniester interfluve]. Fossil fauna and flora of Ukraine. Science. opinion. Kyiv, Issue. I. 63–70 (In Russian).

Zosimovich, V. Yu., Savron, E.B., Rotman, R.N., 1980. Zmiyevskiye sloi v Novopetrovskom i Vyshgorodskom razrezakh [Zmievskie layers in the Novopetrovsky and Vyshgorodsky sections]. Reports of the Academy of Sciences of the Ukrainian SSR, Series B, 1, 12–15 (In Russian).

Journal of Geology, Geography and Geoecology

ISSN 2617-2909 (print)
ISSN 2617-2119 (online)

Journ. Geol. Geograph. Geology, 30(4), 754–761.

Journal home page: geology-dnu.dp.ua

doi: 10.15421/112169

A new species of palaeosiphonocladal algae *Kamaena gigantea* from the Lower–lowermost Middle Mississippian sediments of the Donbas (Upper Tournaisian–Lower Visean)

Oleh A. Sukhov

Institute of Geological Sciences, NAS of Ukraine, 55-b O. Honchara St., Kyiv, Ukraine, 01601 osukhow74@ukr.net
osukhow7480@gmail.com

Received: 09.08.2020
Received in revised form: 05.09.2021
Accepted: 01.10.2021

Abstract. A new species of green paleosiphonocladal algae *Kamaena gigantea* from the Lower–lowermost Middle Mississippian sediments of the Donbas has been described. This species was distinguished from other representatives of the genus *Kamaena* Antropov by its extremely large size, tortuous shape of the thallus and convex partitions. The species belongs to an artificial taxonomic unit of the Kamaenae Shuysky tribe, 1985 , of the family Palaeoberesellaceae Mamet et Roux , a systematic grouping which is still controversial. The attribution of this family to green siphonocladal algae is controversial and quite conditional, the opinions of different authors being based on personal vision, and varying in range from the plant to the animal kingdom. A characteristic feature of the family is the tubular shape , the segments of which are connected by partitions with a large central pore, sometimes with additional small pores. The thallus wall (fossilized remains of the body) is porous or non-porous and has simple or branched pores. It has been emphasized that study of Paleoberezellides in thin sections, the sometimes fuzzy images of the typical material in publications and ignorance of other researchers' publications have caused confusion and led to the selection of an unreasonably large number of genera and species within the family. It has been noted that in previous works, representatives of this species were mistakenly identified as *Anthracoporellopsis* Maslov, a genus characteristic of the Lower–Middle Pennsylvanian sediments. This erroneous definition was based mainly on general external similarity, a poorly illustrated description of the type species, and did not take into account the morphological features that were characteristic for the genus. It has been found that representatives of the new species had a rather limited stratigraphic distribution: the Upper Tournaisian (Dokuchaevskian horizon) and the Lower Visean (Hlybokian–Sukhinskian horizons), and the most similar specimens found in the Ural region in underlying Tournaisian sediments were, unfortunately, poorly illustrated and smaller in size and had a narrower thallus. It has been noted that a characteristic feature of the tribe Kamaenae Shuysky, 1985 was the tubular shape, its inter-segmental partitions were perpendicular to the walls and were at the approximately same interval from each other. It has been pointed out that representatives of the new species were found mainly in grainstones, packstones, and wackstones − organogenic-detrital limestones along with such groups of microfauna as echinoderms and ostracods, isolated spicules of sponges and remains of worms. The material for illustrations was mainly taken from the borehole 74 (near the village of Rodnikove, Starobeshiv district, Donetsk region) , which most fully revealed the Lower–Middle Pennsylvanian deposits of the southern part of the Donbas. The knowledge of the systematic composition of the Early Carboniferous algoflora has been expanded. This has helped us to conclude that the tribe *Kamaeneae* Shuysky, 1985 ,includes 6 genera and at least 22 species that were found in the layers from the Early Devonian to the Early Visean of the Lower Carboniferous.

Keywords: Lower−lowermost Middle Mississippian, Upper Tournaisian−Lower Visean, Donbas, green algae, new species.

Новий вид палеосифонокладової водорості *Kamaena gigantea* з верхньотурнейських–нижньовізейськихв відкладів нижнього–самих низів середнього міссісіпію Донбасу

О.А. Сухов

Інститут геологічних наук НАН України, вул. О. Гончара, Київ, Україна, 01601 osukhov74@ukr.net
osukhow7480@gmail.com.

Анотація. З верхньотурнейських–нижньовізейських відкладів нижнього–самих низів середнього пенсильванію Донбасу описано новий вид зеленої палеосифонокладової водорості *Kamaena gigantea*. Від інших представників роду *Kamaena* Antropov, 1967 даний вид відрізняється надзвичайно крупними розмірами, звивистою формою талліта та випуклими перегородками. Проведено історичний екскурс та розглянуто загальні питання систематичної належності родини Palaeoberesellaceae Mamet et Roux. Зазначено, що систематична належність цієї родини є дискусійною і досить умовною, а думки різних авторів дуже різняться в залежності від особистого бачення і варіюють від рослинного до тваринного царства. Наголошено, що вивчення палеоберезелід в тонких шліфах, іноді погані зображення типового матеріалу в публікаціях та незнання самих публікацій інших дослідників стало причиною плутанини та призвело до виділення невиправдано великої

кількості родів та видів всередині родини. Встановлено, що представника нового виду мають досить обмежене стратиграфічне поширення: пізній турне (докучаєвський горизонт) та ранній візе (глибокинський–сухинський горизонти), а найбільш подібні екземпляри зустрінуті в Уральському регіоні у нижчезалягаючих відкладах турне, проте вони погано проілюстровані, мають відчутно менші розміри та вужчий таліт. Початкове помилкове визначення виду базується головним чином на загальній зовнішній схожості, погано проілюстрованому опису типового виду та не бере до уваги морфологічних ознак, які характерні для роду *Anthracoporellopsis* Maslov, 1956 з відкладів середнього та пізнього карбону. Вказано на те, що представники нового виду виявлені переважно у грейнстоунах, пакстоунах, вакстоунах. Розширено пізнання про систематичний склад ранньокам'яновугільної альгофлори. Вказано, що на сьогодні до тріби *Kamaeneae* Shuysky, 1985 входять 6 родів і щонайменше 22 види, представники яких зустрічаються від верхнього девону до верхнього візе середнього міссісіпію.

Ключові слова: міссісіпій, верхній турне−нижній візе, Донбас, зелені водорості, новий вид.

Introduction.

The family Palaeoberesellaceae Mamet et Roux are microorganisms that have the form of perforated calcareous tubes segmented inside the partitions in thin sections. These organisms were an important biotic component of the shallow areas of the Late Devonian and the Early Carboniferous seas, and sometimes they had rock-forming importance along with other organisms.

The history of study of Paleoberezellides dates back to the 19-th century when they were identified as foraminifera *Nodosinella* (Brady, 1876). In the process of further study, the group was attributed to both plant and animal kingdoms (Maslov, 1956; Antropov, 1968; Termier, Vachard, 1977; Bassoulet, 1979; Berger, Kaever, 1992).

Paleoberezellides were first revised by B. Mamet and A. Roux (Mamet et Roux, 1974). Based on the existing genera − *Kamaena* Antropov 1967 *Pseudokamaena* Mamet (in Petryk et Mamet 1972), *Exvotarisella* Elliot 1970,? *Anthracoporellopsis* Maslov 1956 and three new genera *Kamaenella, Palaeoberesella* and *Parakamaena*, they classified this tribe as Palaeobereselleae. The tribe, with some doubt, was included in the Dasycladales order. According to these authors, the taxonomy of the proposed Palaeobereselleae tribe was based mainly on the general appearance of "cells" and transverse partitions, the type of wall porosity and their size (Fig. 1).

Based on the method of studying Paleoberezellides in thin sections, sometimes poor images of typical material and ignorance of the publications of other researchers caused confusion and led to the establishment of an unreasonably large number of genera and species within the family. Among such examples was the genus *Exvotarisella* Elliot originally described as the foraminifera *Nodosinella index* (Brady, 1876). G. Elliott (Elliott, 1970) described a new species of *Exvotarisella maponi* from the Visean sediments of England, referring it to the family Dasycladaceae (Kützing, 1843). The species was well illustrated and among its characteristic features was branching of the pores of the first and second order. B. Mamet and A. Roux (Mamet, Roux, 1974) re-described the genus, making the species *E. index* the type species and introducing the species *E. maponi* into the synonym. Moreover, among numerous images only the Figure 24 from the Table 5 has porosity of the wall and branching of the first order.

Currently, the family includes 15 genera and about 42 species (Chuvashov, Luchinina, Shuisky, 1987), some of which are obviously synonymous.

The issue was well covered by P. Brenckle (Brenckle, 1985) who supported combining Paleoberezelides and their descendants Berezellides into a new family or group of higher taxonomic rank inside the green algae as long as their true taxonomic status remained to be discovered.

Research materials and methods.

The material of the study was several dozen specimens of Paleoberezellides previously identified as *Anthracoporellopsis* Maslov and mostly satisfactorily preserved. They were found in thin sections of boreholes and outcrops in the Donbas. Samples for the study were taken from the following locations: boreholes 9, 74, quarry near Dokuchaevsk – Central; Stylsk quarry in Volnovakha and Starobeshiv districts in Donetsk region. Based on this material, the biological diversity of the family Palaeoberesellaceae Mamet et Roux in the Visean sediments of the Donbas has been studied for the first time, and their vertical distribution and taxonomic diversity have been analyzed.

Considering the degree of preservation of the material, only specimens from the borehole 74 have been presented in this paper (Fig. 2).

The main research methods were micropaleontological and biostratigraphical. The calcareous algae have been studied in thin sections under the MBI-3 microscope.

Results and their analysis

As a result of the study of the Late Tournaisian-Early Visean algae in the southern part of the Donbas, calcified remains of tubular algae previously mistakenly identified as *Anthracoporellopsis machaevi* Maslov were found. This initial judgment was based on their large size, massive oblique walls and uneven partitions separating the inner cavity. The stratigraphic distribution of these forms includes the deposits of Dokuchaevskian horizon of the Lower Tournaisian to Sukhinskian hori-

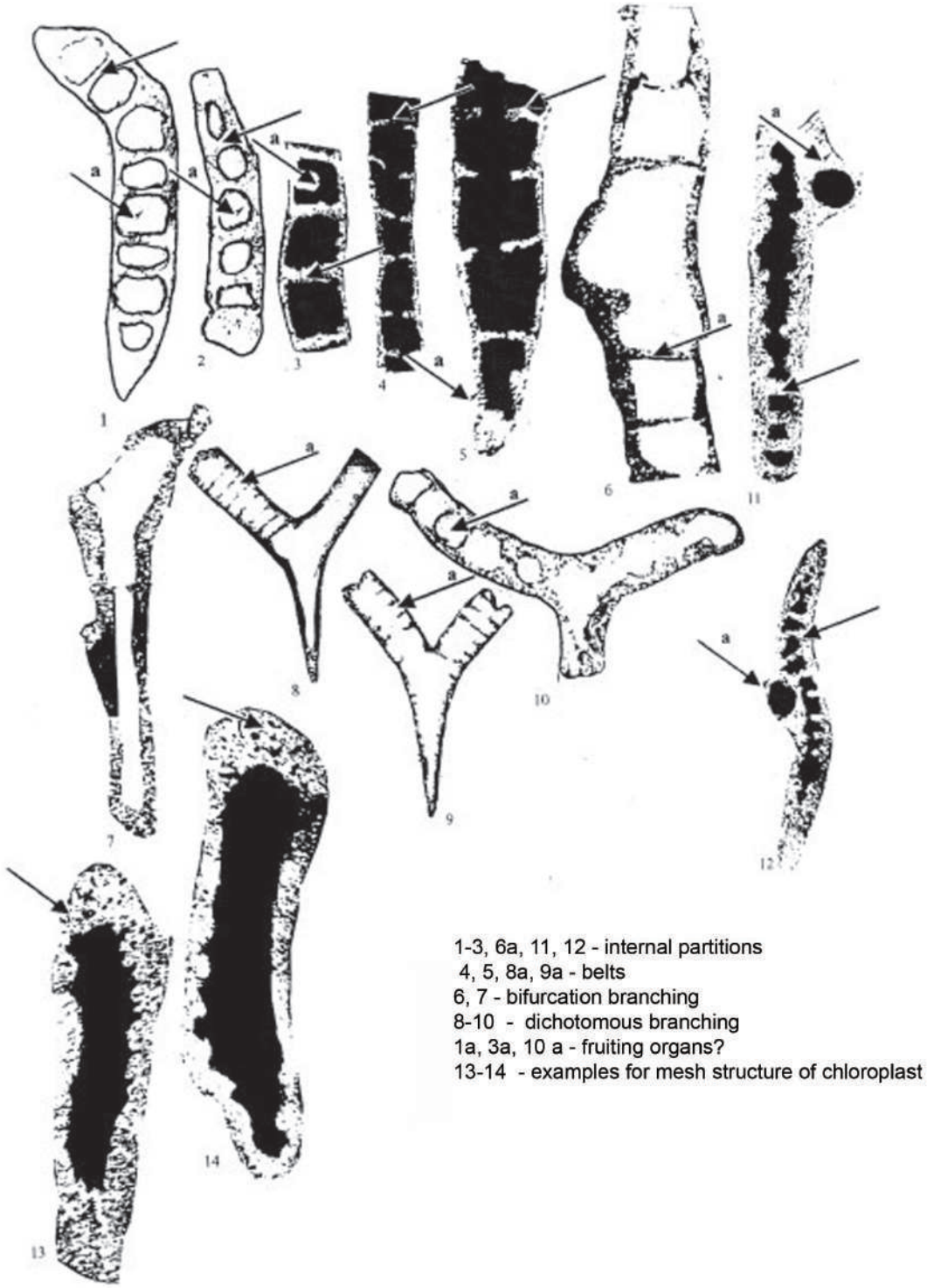


Fig. 1. Some examples of morphological elements (features) of the family Palaeoberesellaceae Mamet et Roux

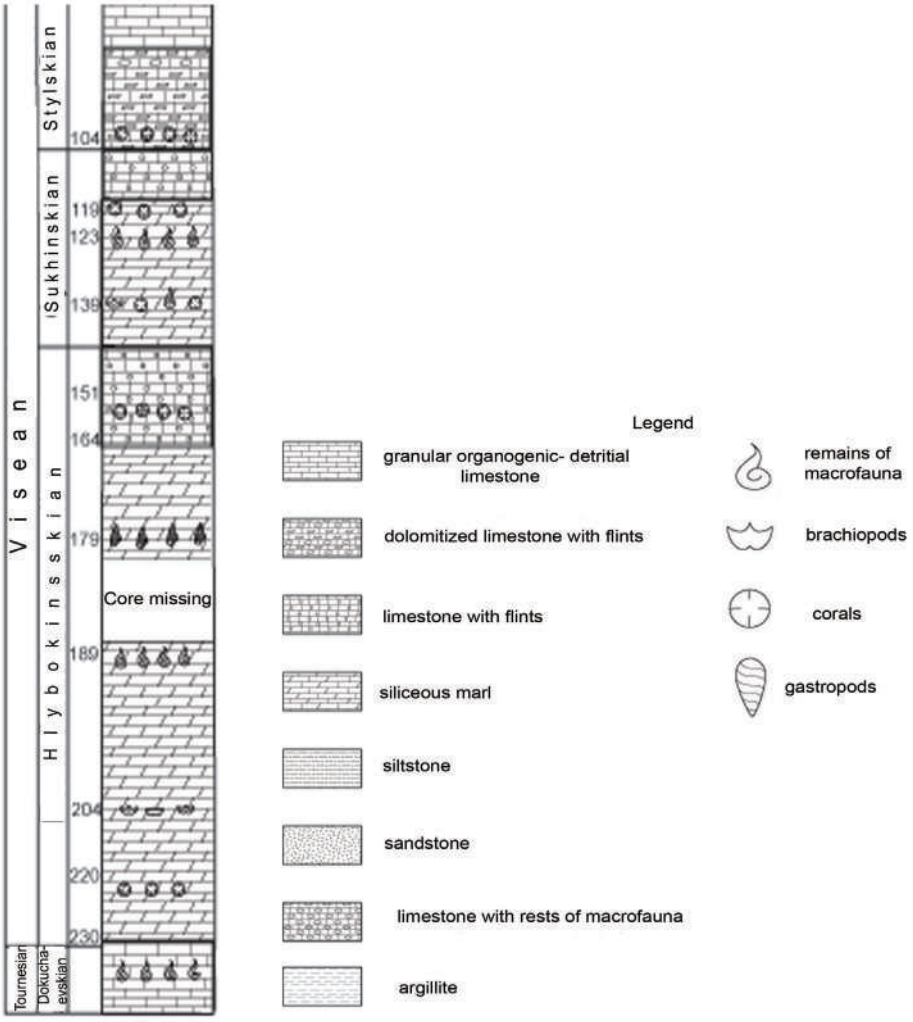


Fig. 2. Lithological section of borehole 74

zon of the Middle Mississippian. However, studying of the algae of the family Palaeoberesellaceae Mamet et Roux showed that such judgements were wrong according to the latest ideas about the taxonomic belonging of the family and its individual genera. In addition, a discrepancy was revealed between our and other specimens and the underlying sediments with typical specimens.

The genus *Anthracoporellopsis* described by Maslov (Maslov, 1956) apparently taken from Bashkirian deposits of the Donbas is characterized as a tubular organism with partitions and channels, with a double dichotomous branching of pores in the walls. Typical material had channels in the partitions which were of curved shape, often with protuberances going into the internal cavity of the body (Fig. 3). Their important additional characteristic was walls made of light calcite and pores-channels filled with dark carbonate. The author also described a thin, light carbonate crust on the outside of the walls that brought the genus closer to the Beresellaceae family Maslov et Kulik, 1956, and indicated the likelihood of their close phylogenetic links. However, the description of the typical species was poorly illustrated by photographs, and has more hypothetical sketches that later led to confusion and erroneous definitions.

Our material is a large tubular alga with partitions. The wall is composed mainly of light calcite and has no additional layer. Pseudopores are thin and composed of light carbonate with dichotomous branching on some specimens. Such features gave grounds to redescribe the existing specimens and refer them to the genus *Kamaena* Antropov , which is very similar to them. The stratigraphic distribution of the taxon in the Donbas is quite limited: the Upper Tournaisian (Dokuchaevskian horizon) – the Lower Visean (Hlybokinskian and Sukhinskian horizons). Moreover, the most widespread representatives of the taxon are in the deposits of Hlybokinskian horizon. The specimens of this taxon are found mainly in packstones, wackstones, rarely grainstones − organogenic limestones with predominance of foraminifera, tubular green algae with

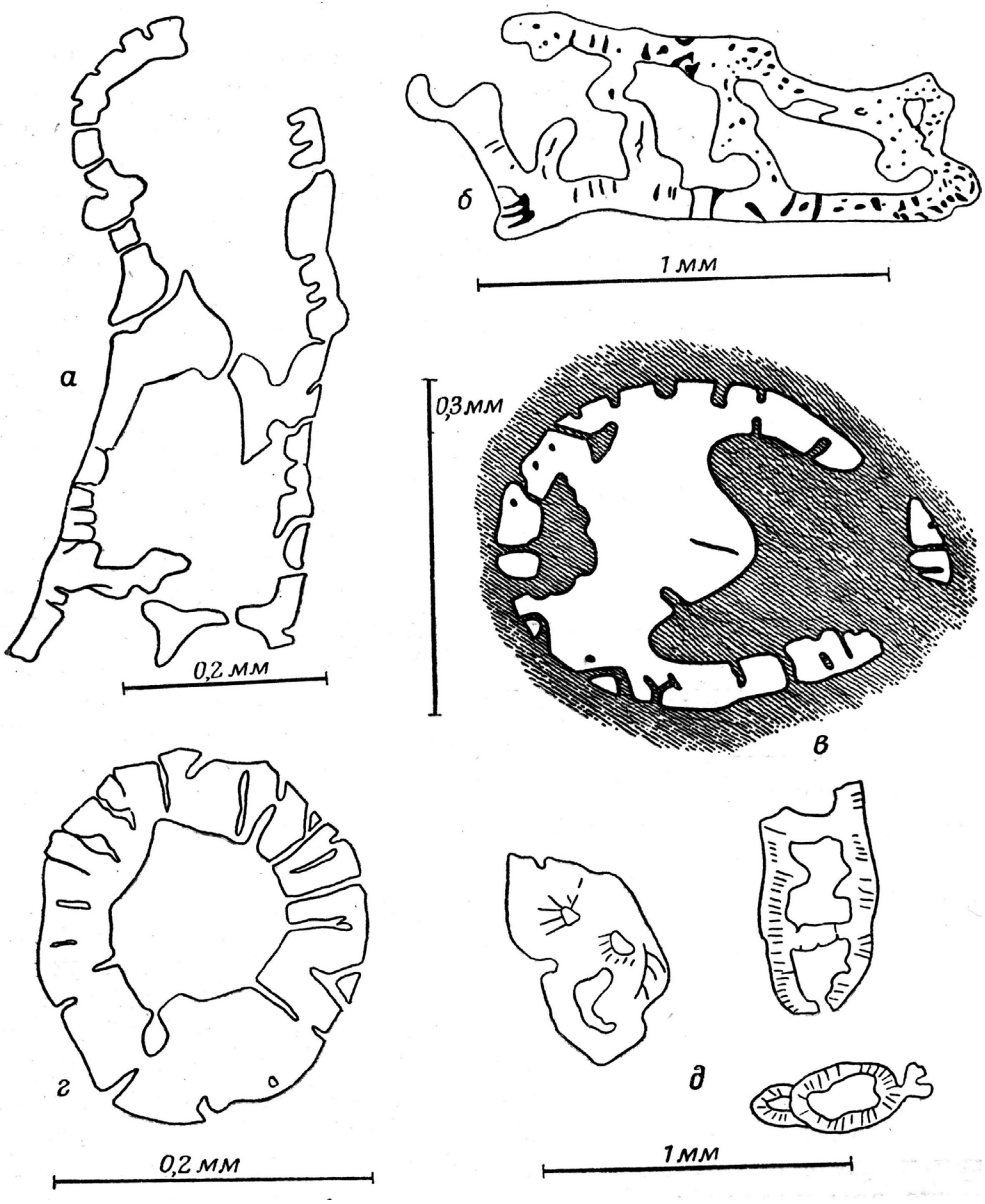


Fig. 3 Schematic representation of the genus Anthracoporellopsis (Maslov, 1956)

septa, occasionally there are remains of echinoderms and ostracods and isolated spicules of sponges and remains of worms.

Family PALAEOBERESELLACEAE Mamet et Roux, 1974

Intersegmental partitions with large central pore, sometimes with additional small pores; thallus wall is porous or non-porous, its pores are simple or branched.

Tribe KAMAENAE Shuysky, 1985

Intersegmental partitions are perpendicular to the wall and are at approximately the same distance from each other. The pores in the wall are straight, unbranched.

Representatives of the Kamaenae Shuysky tribe are widely represented in the limestone strata of the Visean deposits of the Donbas. The systematic position of this tribe, as well as the whole family Palaeoberesellaceae, still remains uncertain. This group includes calcareous tubular microorganisms having an internal cavity divided by transverse partitions into chambers. Today, the tribe Kamaeneae Antropov includes 6 genera and at least 22 species, representatives of which are found from the Lower Devonian to the Upper Visean (Serpukhov?) of the Mississippian– Lower Pennsylvanian?

Genus Kamaena Antropov, 1967

Type species: *Kamaena delicata* Antropov, 1967; Tournaisian, the Zavolgian horizon of the Tatar AR. **Diagnosis**. Thallus is cylindrical, tortuous, in the cross section it is rounded, dichotomously and alternately branched. Its inner partitions in the longitudinal section are straight and placed perpendicular to the wall.

Species composition and distribution.

The genus has 10 species:

Kamaena delicata Antropov was found in upper part of Famennian stage of the Devonian and the Mississippian of the Eastern European Platform, of the Tournaisian and Visean stages of the Donbas, Western Europe, Poland, North America;

K. awirsi Mamet et Roux was found in the Tournaisian and Visean stages of the Donbas, Urals, Siberia and Northeastern Russia, the Visean stage of the Eastern slope of the Urals, Western Europe, Poland;

K. itkillikensis Mamet et Rudloff was found in the Upper Famennian of Russia, the Tournaisian and Visean deposits of Western Europe, Donbas, North America, Visean of the Urals;

K. maclareni Memet et Rudloff was found in the Tournaisian deposits of the North America (Keokuk Formation);

K. minuta R. Ivanova was found in the Upper Famennian–Lower Tournaisian of North-Eastern Russia;

K. lata R. Ivanova was found in the Lower Touraisian of the Urals and the Kolyma Massif of North-Eastern Russia, in the Upper Famennian–Lower Tournaisian of the Momsky Ridge and the Omolon Massif, Upper Tournaisian of the Siberian Platform, the Lower Visean of Ukraine;

K. omolonica R. Ivanova was found in the Visean stage of the Omolon Massif (Russia), the Lower Visean of Donbas (Ukraine);

K. magna R. Ivanova was found in the Visean sediments of the Kolyma Massif, the Urals, the Eastern European Platform (Russia), Ireland, Morocco; the Tournaisian of Ukraine and the Ural-Kazakh depression (Russia); the Famennian and Tournaisian of France;

K. tobolensis R. Ivanova was found in the Lower Tournaisian of the Ural-Kazakh depression (Russia);

K. maclareni Mamet et Rudloff was found in the Tournaisian sediments of North America.

Kamaena gigantea sp. nov.
Plate 1, Fig. 1-8; Plate 2, Fig.1-4

Derivatio nominis. From gigantea (lat.) − huge.

Holotype: IGS NAS of Ukraine, brh. 74, area near village Rodnikove, Starobeshiv districts in Donetsk region, dth. 231−233.7 м, sample. 98, Dokuchaevskian horizon, zone $C_1^v{}_a$.

Anthacoporellopsis machaevi Maslov: OI Berchenko, 1981, Table. 28 Figure 1 *Anthacoporellopsis machaevi* Maslov: O.I. Berchenko, O.A. Sukhov, table. 13, Fig. 1 1-3, 5-7, 11

Name derivation: from the gigantea (lat.) − huge.

Description. The thallus is large, tubular, curved, its shape varies from subcylindrical, subconical and subrectangular depending on the cross section. Its wall is quite thick, uneven, "porous", sometimes with protuberances, mostly on the outside, and has irregular "pores". "Pores" are mostly straight, not branched and not all specimens have them. Pores are located perpendicular to the wall. Partitions are infrequent, straight or curved to the central part of the thallus. They are placed at approximately the same distance from each other and perpendicularly or at an angle to the wall and have approximately the same thickness. Their inner cavity is wide.

Dimensions in microns. The thallus diameter is 270-630, wall thickness is 30 - 70, thickness of partitions is 25-70, distance between partitions is 110-420, diameter of the "pores" is 3-10, diameter of the inner cavity is 100-600.

Comparison. Our specimens are most similar to the species *Kamaena lata* R. Ivanova and *Kamaena magna* R. Ivanova from the Tournaisian sediments of the Urals, but they differ from Tournaisian ones by greater width of the inner cavity and much greater distance between partitions and larger size of all elements of the thallus. In addition, unfortunately, R. Ivanova's material is poorly illustrated: K. *lata* has two specimens, *K. magna* has three specimens that make it impossible to clearly identify them.

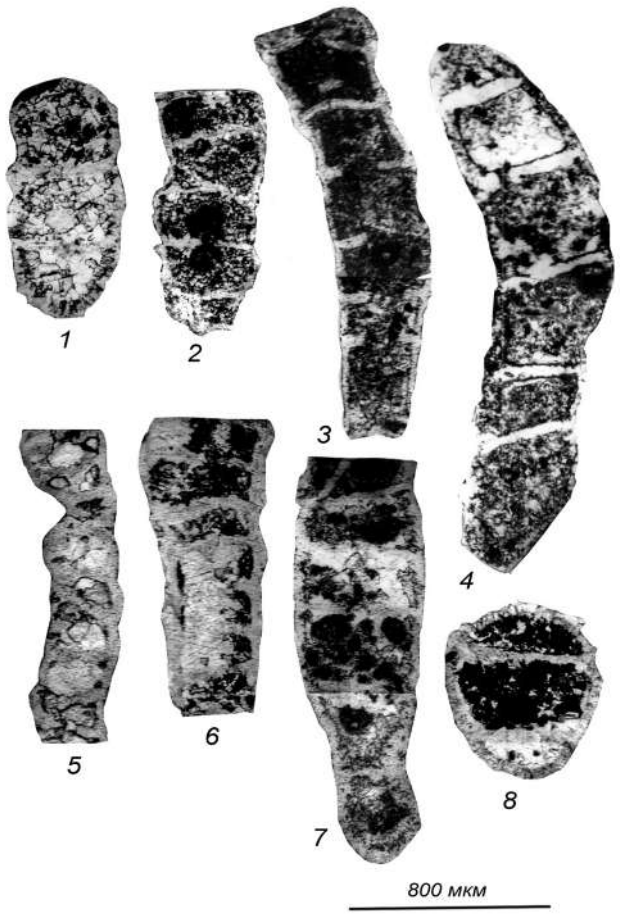
Distribution. The Late Tournaisian−Early Visean stage of Donbas (Ukraine).

Location and material. Donbas, Dokuchaevskian-Sukhinskian horizons, area near village Rodnikove, 74, dth. 231-233 m, 216.6-218.0 m, 206.8-209.0 m, 203.9-205.6 m, 188.5 m, 144.4-148.2 m, 142.4-144.4 m, 139.2-142.4 m, 138.0 m, 133.5 m, 124 m, 55.8-58.2 m, Dokuchaevskian − Hlybokianskian horizons (zones $C_1^v{}_a$, $C_1^v{}_{b\text{-}c}$, $C_1^v{}_d$); near village of Styla, borehole. 30, dth. 229.3 m, 228.8 m, 226.0 m, 224.8 m, Dokuchaevskian horizon (zone $C_1^v{}_a$), the area of the town of Novotroitske, borehole 9, dth. 294.5 m, 292.5 m, 291.6 m, Dokuchaevskian horizon (zone $C_1^v{}_a$), the area of the town of Dokuchaevsk, quarry Central zone, Dokuchaevskian−Hlybokianskian horizons (zones $C_1^v{}_{b\text{-}c}$, $C_1^v{}_d$). More than 40 specimens in longitudinal and cross sections.

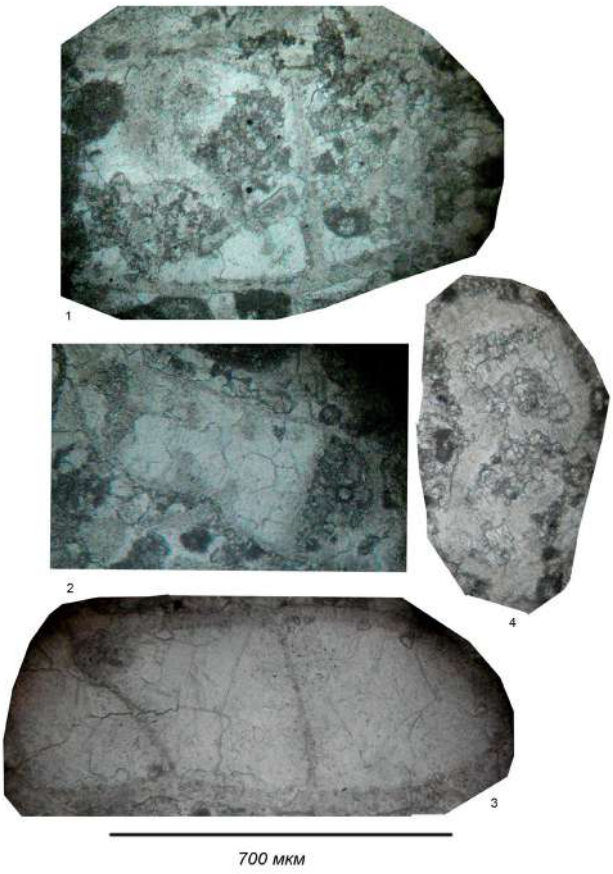
Conclusion.

This article presents a revision of the systematic position and a description of a new species of Palaeosiphonocladal algae *Kamaena gigantea* from the Lower Carboniferous deposits of the Donbas . We established that its stratigraphic distribution is limited to the deposits of the Dokuchaevskian or Late Tournaisian and Sukhinskian horizons of the Early Visean .We analysed previous publications from the history of study and gave an explanation why the new species was identified .We made a comparison of similar species in other territories and carried out a revision. We widened the knowledge on the palaeoalgal flora of the Donetsk Seas of the Carboniferous and established the facies position of the new species.

Pl. 1



Pl. 2



Pl.1

Fig. 7, 8 depth 144.4 m, Hlybokinsky horizon, zone $C_{1}^{v}{}_{c,}$,

Fig. 1, 4 depth 203.9-205.6 m, Hlybokinsky horizon, zone $C_{1}^{v}{}_{b\text{-}c}$,

Fig.3 depth 231-233.7 m, Dokuchaevskian horizon, zone $C_{1}^{v}{}_{a,}$

Fig. 2 depth 138 m, Hlybokinsky horizon, zone $C_{1}^{v}{}_{d}$,

Fig. 6 depth 139.2 -142.4 m, Hlybokinsky horizon, zone $C_{1}^{v}{}_{d}$,

Fig 5 depth 188.5 m, zone $C_{1}^{v}{}_{d}$.

Pl. 2

Fig. 1 depth 188. 4 m, Hlybokinsky horizon, zone $C_{1}^{v}{}_{c,}$,

Fig. 2, 4 depth 156. 4-160 m, Hlybokinsky horizon, zone $C_{1}^{v}{}_{c,}$,

Fig. 3 depth 154.4-156.4 m Hlybokinsky horizon, zone $C_{1}^{v}{}_{d.}$

References

Antropov, I.A., 1968. Vodorosli devona i nizhnego carbona /turne/ Tsentralnoi chasti vostoka Russkoi platformy. Isskopajemyje vodorosli SSSR [Devonian and Lower Carboniferous /Tournai/ algae of Central Part of Russian Platform. Fossil algae of the UdSSR]. Nauka, Moskwa (In Russian).

Bassoulet. J.-P., 1979. Essai de classification des Dasycladales en tribue. Bull. Centr. Rech, Explor. 3(2), 429-442.

Berchenko, O.I. 1981. Izvestkovyje vodorosli turneiskikh otlozhenii Donbassa [Tournaisian calcareous algae of Donbass]. Naukova Dumka, Kyiv (In Russian).

Berchenko, O.I., Sukhov, O.A., 2013. Izvestkovyje vodorosli vizeiskikh otlozhenij Dono–Dneprovskogo progiba [Visean calcareous algae of Don-Dnipro depression]. Naukova Dumka, Kyiv (In Russian).

Berger, S., Kaever, M.J., 1992. Dasycladales, an illustrated monograph of a fascinating algal order. Stutt.: Georg Tiem Verlag.

Brady, H.B., 1876. A monograph of Carboniferous and Permian Foraminifera (the genus Fusulina excepted). The Paleontolographical Soc. 30.

Chuvashov, B.I., Luchinina, V.A., Shuisky, V.P., 1987. Iskopajemyje izvestkovyje vodorosli [Fossil calcareous algae]. Nauka, Novosibirsk. (In Russian).

Elliott, G.F., 1970. Calcareous algae new to the British Carboniferous. Paleontology. 13(3), 443-450).

Ivanova, R.M., 2013. Izvestkovyje vodorosli karbona Urala [Carboniferous calcareous algae of the Urals]. Ekaterinburg: Ural Division RAS (In Russian).

Maslov, V.P., 1956. Iskopajemyje izvestkovyje vodorosli SSSR [Fossil calcareous algae of the UdSSR] Trudy Inst. Geol. Nauk AN SSSR 160, 1−301. Moskva. (In Russian).

Mamet, B. et Roux A., 1974. Sur quelques algues tubulaires scalariformes de la Tethys Paleozoïque. Rev. de Micropaleontol 17(3), 134-156.

Skompsky, S, 1987. The dasycladacean nature of Late Paleozoic palaeoberesellid algae. Acta geologica Polonica. 37 (1-2), 21-31.

Skompski, S., 1996. Stratigraphic position and facies significance of the limestone bands in the the subsurface Carboniferous succession of the Lublin Upland. Acta geologica Polonica. 46 (3−4), 171-268.

Termier H. G., Vachard D., 1977. On Moravamminida and Aoujqalida (Porifera, Ischyrospongio) Upper Paleozoic, Pseudo-Algae. Fossil Alqae, 215-219.

Journal of Geology, Geography and Geoecology

ISSN 2617-2909 (print)
ISSN 2617-2119 (online)

Journal home page: geology-dnu.dp.ua

Journ. Geol. Geograph. Geology, 30(4), 762–771.
doi: 10.15421/112170

Methodological principles of systematics of recreational goods

Alexandr G. Topchiyiv[1], Vitalii A. Sych[1], Victoria V. Yavorska[1], Kateryna V. Kolomiyets[1], Alexander V. Hryhoriev[1], Ihor V. Hevko[2]

[1]*Odesa I.I. Mechnykov National University, Odesa, Ukraine,* yavorskaya@onu.edu.ua
[2]*Ternopil Volodymyr Hnatiuk National Pedagogical University*

Received: 23.02.2021
Received in revised form: 23.04.2021
Accepted: 08.09.2021

Abstract. The article presents an overview of modern directions and approaches to systematics of recreational resources (goods). The purpose of our study is to develop methodological principles of systematics of recreational goods, taking into account their subject specificity and modern research approaches to the systematics of natural, historical, cultural and socio-economic conditions and resources. The article has been used development by domestic and foreign scientists, as well as preliminary author's studies. Working-out of a scheme of recreational goods systematics took place on the basis of a dialectical approach, which requires all phenomena and processes in their development, interconnection, and interdependence. The article presents an overview of modern directions and approaches to the systematics of recreational goods and provides a general methodological scheme of systematics of recreational goods. The proposed scheme includes the division of recreational goods to natural, cultural and historical and socio-economic, as well as directions of use by recreational goods – public, collective and personality. The intersections of these categories are marked by the main methodological approaches to the evaluation of recreational conditions and recreational resources. For each direction of the classification and systematics of recreational goods, it is necessary to develop methodological principles and methodological means of inventory and assessing the corresponding combination of recreational conditions and resources with forms of use by recreation goods. Such justification also requires enclosed blocks of recreational conditions and resources and social varieties of use. Recreational conditions and resources of public usage are available for all users without restrictions of property rights; they are considered as global civilization goods as the "property" of the world community; they do not have the content of the goods and do not form appropriate market relations, as a rule, a global or regional spatial scale. Recreational conditions and resources of collective usage form natural and geographical objects and phenomena with different forms of ownership (state, corporate) and collective (group) use. They can be shared by common goods, do not have a form of commodity and not take part in market commodity-money circulation. Recreational conditions and resources of individual usage are private or group property of vacationers. They remain outside the economic assessment, but can also form their market environments with competitive relations and be objects of commodity-money circulation.

Keywords: recreational resources, recreational conditions, systematics of recreational goods, natural environment, recreational and tourist potential.

Методологічні принципи систематики рекреаційних благ

О.Г. Топчієв[1], В.А. Сич[1], В.В. Яворська[1], К.В. Коломієць[1], О.В. Григор'єв[1], І.В. Гевко[2]

[1]*Одеський національний університет імені І.І. Мечникова, yavorskaya@onu.edu.ua*
[2]*Тернопільський національний педагогічний університет імені Володимира Гнатюка*

Анотація. У статті наведено огляд сучасних напрямів і підходів до систематики рекреаційних ресурсів (благ). Метою нашого дослідження є розробка методологічних принципів систематики рекреаційних благ з урахуванням їх предметної специфіки та сучасних пошукових розробок і підходів до систематики природних, історико-культурних та соціально-економічних умов і ресурсів. При написанні статті використано розробки вітчизняних та зарубіжних вчених, а також попередні авторські дослідження. Розробка схеми систематики рекреаційних благ відбувалася на основі діалектичного підходу, який вимагає розглядати всі явища і процеси в їх розвитку, взаємозв'язку, взаємозалежності і взаємозумовленості. У статті наведено огляд сучасних напрямів і підходів до систематики рекреаційних благ та представлена загальна методологічна схема систематики рекреаційних благ. Пропонована схема включає поділ рекреаційних благ на природні, культурно-історичні та соціально-економічні, а також напрями користування рекреаційними благами – громадське, колективне, індивідуальне. На перетинах зазначених рубрикацій позначені головні методологічні підходи до оцінки рекреаційних умов та рекреаційних ресурсів. Для кожного напряму класифікації та систематики рекреаційних благ необхідно розробляти методологічні принципи та методичні засоби інвентаризації та оцінки відповідного поєднання рекреаційних умов і ресурсів з формами користування рекреаційними

благами. Подібного обґрунтування потребують і укрупнені блоки рекреаційних умов і ресурсів та соціальні різновиди користування ними. Рекреаційні умови та ресурси суспільного користування доступні всім користувачам без обмежень правами власності; їх розглядають як глобальні цивілізаційні блага, як «власність» світового співтовариства; вони не мають змісту товару і не формують відповідних ринкових відносин; як правило, глобального чи регіонального просторового масштабу. Рекреаційні умови та ресурси колективного користування формують природно-географічні об'єкти і явища, що мають різні форми власності (державна, корпоративна) та колективне (групове) використання. Вони можуть лишатися спільним благом, не мати форми товару і не брати участі у ринковому товарно-грошовому обігу. Рекреаційні умови та ресурси індивідуального користування перебувають у приватній або груповій власності рекреантів; залишаються поза економічною оцінкою, але також можуть формувати свої ринкові середовища з конкурентними відносинами і бути об'єктами товарно-грошового обігу.

Ключові слова: рекреаційні ресурси, рекреаційні умови, систематика рекреаційних благ, природне середовище, рекреаційно-туристичний потенціал.

Introduction

The problem of taxonomy and classification of recreational goods remains complicated and actual. Traditionally recreational goods are divided into recreational conditions and recreational resources. It becomes necessary to develop a general systematic of conditions and resources of recreation and tourism activity (RTA) and relevant classifications of conditions of RTA and resources of RTA. The new approach in the taxonomy of recreational conditions and recreational resources is their distribution by socio-economic types of usage – individual, group (public), social (national). The first developments in this direction certify its complexity, content and relevance.

The general trend in the development of RTA is the unconscious and consistent expansion of the content and forms of recreational conditions and recreational resources. Until recently, they were divided into natural, historical and cultural varieties. Today, a peculiar standard of recreational and tourist potential (RTP) became its rubrication on natural and geographical, historical and cultural, and socio-economic components (Horyn, 2014; Gudkovskih, 2012; Dashhuk, 2012; Pokolodna, 2012, etc.).

It is necessary to note enough attentive and purposeful development of taxonomy problems and resource assessment of natural, historical and cultural potential in domestic tourism science (Bejdyk, 2001; Horun, 2013; Kuzyk, 2011; Hrodzyns'kyy, 2014; Onufriv, 2015; Polyvach, 2012; Alyeshuhina, Baranovs'ka & Baranovs'kyy, 2015, etc.). Comparative analysis of cultural heritage assessment techniques (Polyvach, 2012; Kuzyk, 2011) certifies their general orientation on the number and density of placement of cultural and historical objects, which in terms of significance are divided into international, state, regional and local ones. The simplest score assessments of historical and cultural potential (3- or 5-point scale) are also common. The estimates of recreational and tourist objects at the frequency of their encyclopedia (Kuskov, 2011) are offered. The assessment of natural recreational resources is a reflection of the relationship between human and elements of the surrounding environment or the environment as a whole, as well as reflecting the links between them in recreational activities. Consequently, the assessment always has an element of subjectivity, since reflects the attitude of the subject (person) to recreational conditions and resources. The boundary between what is good and that bad for one or another subject are determined not by the properties of the object, but the needs of the subject. Noticeable development of principles and methods for establishing esthetic and psycho-emotional value of natural and natural-anthropogenic landscapes are among the search and latest directions of assessment of natural recreational resources. Vacationers and tourists enjoy their own estimates of natural and cultural landscapes. At the same time, geographical science does not have sufficiently clear and methodically developed principles and methods of such assessments, and this is one of the topical tasks of recreational geography.

The main difficulties in systematics and evaluation of recreational conditions and recreational resources are due to their progressive expansion and complication. The list of recreational goods is increasing, and their rating orderliness is updated again. On the one hand, the nomenclature of recreational conditions and resources was developed in detail, and from the other – there are all new varieties of recreational goods that significantly change their traditional lists. The purpose of our study is to develop methodological principles of systematics of recreational goods, taking into account their subject specificity and modern search direction and approaches to the systematics of natural, historical and cultural, and socio-economic conditions and resources.

Materials and methods of research

The methodological basis of the study is the fundamental provisions of the theory of social geography in the field of recreation and tourism. The development of domestic and foreign scholars set out in scientific works (Bejdyk, 2001; Horyn, 2014; Kuskov, 2011; Ljubiceva, Mal's'ka & Zin'ko, 2011; Muska, 2018; Barriere, 2019; Hall & Page, 2014; Ostrom, 2010; Stamboulis & Skayannis, 2003; Pokolodna, 2012; Polyvach, 2012, etc.) were used while writing articles, as well as previous author's developments (Topchijev, Sych, Javors'ka & Dolyns'ka, 2019; Topchijev, Kolomijec', Sych & Javorska, 2020; Topchijev, Sych

& Javorska, 2020a; Topchijev, Sych & Javorska, 2020b). The development of a scheme for systematics of recreational goods took place on the basis of dialectical and system-structural methods focused on consideration of all phenomena and processes in their development, interconnection, and interdependence. The methods used in the study caused by the interdisciplinary status of the chosen topic, the need to use the methodical arsenal of social geography, tourism nature, economics, sociology.

Results and their analysis

Resource potential of RTA is traditionally determined by combining recreational conditions and recreational resources (Kuzyk, 2011; Kushniruk, 2012; Pokolodna, 2012; Fomenko, 2007; Muska, 2018). According to the subject, the conditions and resources are distinguished by their role and functions in the formation of RTA. Recreational resources are defined as components of the environment of RTAs that are used by vacationers and tourists. In this case, the usage of recreational resources can be direct when the resource is used by each vacationer individually, or indirect, if the resource is used impersonally, collectively. It is distinguished the recreational resources of individual, group (collective) and public usage (Pahomova, Rihter & Rumjanceva, 2000). Recreational resources have qualitative and quantitative characteristics.

Recreational conditions are not used. They provide the possibility of the RTA functioning, create more or less favorable circumstances to use existing recreational resources. Recreational conditions determine the best-worse opportunities for the use of recreational goods. They can have qualitative and quantitative assessments of its role in forming of the general recreation potential.

Recently, the characteristic and evaluation as the recreational goods of the natural environment are launched. Naturalists traditionally consider the natural environment as a source of all kinds of natural goods in the form of natural conditions and natural resources, but its understanding as a global recreational resource is still in the stage of formation. In relation to society, nature has functions of the life environment that "gives" it air, water, land, mineral raw materials, biological resources, natural landscapes, territories and water areas. Such "supplement functions" of the natural environment were also traditionally considered and studied. Significantly later the environment has been considered as a man's waste collector, as a compensator of various anthropogenic-technogenic loads on the environment. The assimilation resource of the natural environment is characterized by such a function. Researchers are already considering and evaluating the assimilation potential of the environment in its ability to accept and neutralize various waste of life and its economic activity.

A relatively new variety of recreational resources is the quality of the environment. According to traditional environmental approaches, it was characterized by its various components with the relevant estimates of their contributions to the quality of the environment. The problem of the general (integral) assessment of environmental quality for recreational and tourism activities became actual. The world science researchers actively develop a concept of natural capital. The environment is considered as natural capital of society among other basic means of economic activity. Natural capital includes natural resources and natural conditions and carry out such social functions: 1) resource – provides production of goods and services; 2) ecological (ecosystem) – preservation of the environment; 3) cognitive-cultural functions. In the mid-1990s, the World Bank has developed an updated concept of national wealth with three forms of capital – reproductive, natural and human.

The assessment of natural territorial complexes was marked insufficiently in the systematics of natural resources, and at the same time only marked the estimation of landscapes as typical and peculiar natural complexes. The landscape direction must also be distributed on the systematics of recreational conditions and resources: along with the widespread estimates of personal natural components that form the recreation potential of territories and water areas, integral recreational estimates of territorial natural complexes in general should be developed. This is a relatively new variety of assessment of recreational potential, which is already called landscape assessment (Hrodzyns'kyy, 2014; Hrodzyns'ka, Nezdoyminov & Husyeva, 2014; Onufriv, 2015). The level of scientific and methodological development of natural complexes assessment (landscapes) as a whole is still searched. It is about a less or more esthetical and psycho-emotional value of landscapes, a typical combination of certain recreational conditions and resources in various complexes, etc.

Along with the natural, social and economic estimates of recreational goods, the ecological assessment of recreational conditions and recreational resources attracts considerable attention. Researchers emphasize the complexity of evaluation of environmental goods and call the main methodological problems of ecological and economic estimates:

– physiological, social and economic functions of nature are invaluable and can not be in principle worth of valuation: any kind of money can replace them;

– natural factors providing these functions can not be economically reproduced;

– such functions can not be compensated by other goods: they are unmatched;

– a significant part of natural factors that perform these functions is not subject to appropriation and can not participate in commodity exchange.

Environmental resources are defined as a set of environmental elements that provide environmental balance in the biosphere, and therefore and the normal environment of vital activities. Most of such resources provide public goods as having a public (compatible) use.

Peculiar characteristics of recreational goods of public and compatible use attract peculiar attention of researchers. In particular, social environmental goods have the following properties (Pahomova, Rihter & Rumjanceva, 2000):

– they are relatively inexhaustible (according to modern views);

– are in state or collective ownership;

– do not have a form of classical goods and do not form appropriate markets;

– can mark potential (future) rental ratios due to different quality and different locations of environmental goods.

We emphasize that environmental conditions and resources are considered as one of the main factors that form recreational potential. The environmental situation contributes or limits the use of existing recreational conditions and resources.

In a market economy, the importance of socio-economic factors in the formation of general potential is intensified. Researchers note that recently, two traditional groups of recreational and tourist resources – natural and historical and cultural, adding another group – socio-economic resources of RTA.

The understanding of participation in the formation of recreational goods of the so-called "quasi nature" – an artificial material world created by man is deepening. Geographers consider it as one of the earth's shells – a Technosphere that has global distribution and produces a variety of impacts of social life on a natural environment, which is called anthropogenic-technogenic load (ATL). In relation to the RTA, it is considered as recreational "anti-resource", which limits recreational potential and limits the use of recreational goods, at the same time, the technosphere forms recreational infrastructure, which is considered among the main factors of development of RTA and the use of recreational potential. The artificial material world has its own nomenclature of recreational goods that grows rapidly. It is about industrial, port-logistics, engineering, architectural and construction facilities, complexes, systems and landscapes that became objects of RTA. It is also about artificial (unnatural) objects of recreation and tourism, such as Disneyland, water parks, amusement attractions, etc., whose share in RTA is tirelessly increases.

Recently, the attention of researchers attracts the problem of social recreational goods mentioned by the authors of this article in the characteristic of environmental resources. It has been established that a significant part of recreational goods has no form of individual usage and use as conditions and resources of compatible and social usage. Resources of public (compatible) use are also free (uneconomic) goods. Researchers emphasize the economic paradox associated with the use of such resources as: mass and free use of public goods exacerbates the problem of relevant compensation and protection of compensatory resources from exhaustion, this is the so-called "tragedy of collective": common goods are accelerated, and the problems of their preservation or recovery remains out of sight. In the economy of nature use (Pahomova, Rihter & Rumjanceva, 2000), natural resources for their availability and properties of competition (competitive exception) are ranking to: free access goods; resources of compatible usage; natural resources of compatible usage.

In a market economy, the significance of socio-economic factors in the classifications and systematics of recreational goods is intensified. In domestic resource science, recently recreational and tourist potential was evaluated by recreational conditions and recreational resources. Currently, it has become necessary to characterize it under property relations and the possibilities of using it as a public, collective or community goods. According to modern approaches, the assessment of recreational goods should take into account their possible participation in the formation of market relations. The realization of market relations may be direct if the recreational resource has the status of a sales object or mediated (indirect), if the purchase and sale object is not a resource, but its action (impact) – the so-called resource function.

It should be noted that in modern developments, the attention is increasingly paid to the physiological and social functions of the natural environment as opposed to traditional economic functions. Given the global ecological crisis in any strategies and concepts of socio-economic development criteria for environmental safety – the so-called "ecological imperative" becomes the main one. In relation to the problem of systematics of recreational goods, the ecological imperative is indicated by numerous developments of environmental goods, which are considered as the main recreational resource (Topchijev, Sych, Javors'ka & Dolyns'ka, 2019).

The authors of the article have developed a general methodological scheme of systematics of recreational goods (Table 1), which includes the division of recreational goods to natural, cultural, historical and socio-economic, as well as forms of usage by recreational goods – public (society), collective (group, community), individual (private). The intersections of these headings are marked by the main.

Table 1. Methodological scheme of systematization of recreational goods

Directions of evaluation of recreational goods	Components of recreational goods	Using recreational goods		
		(A) public (society)	(B) collective (community)	**(C) individual (private)**
(I) Recreational conditions	(1) natural	I.1.A (natural recreational conditions of public use) can be estimated by the general influence on the better/worse functioning of RTA (Earth's atmosphere, World ocean, ozonosphere, outer space …)	I.1.B (natural recreational conditions of collective use) may have the status of purchase-sales objects (areas of recreation with regulated usage, objects of the natural reserve funds …)	I.1.C (natural recreational conditions for individual use) combine the properties of social-economic goods and private goods with economic evaluation (areas of domestic recreation and backpacking))
	(2) cultural and historical	I.2.A (historical and cultural recreational conditions of public use) don't have a form of goods (areas of distribution of confessions and ethnonational groups…)	I.2.B (historical and cultural recreational conditions of collective use) preferably have a form of goods (historical and cultural objects and monuments …)	I.2.C (historical and cultural recreational conditions of individual use) have an economic assessment, the possibilities of using by other individuals are subject to economic assessment (collections and libraries of manuscripts, old maps …)
	(3) socio-economic	I.3.A (socio-economic recreational conditions of public use) possible ranked assessments (global economic system and national economies)	I.3.B (socio-economic recreational conditions of collective use) can have qualitative and semi-quantitative (rating) assessments (safety of recreants, quality of the population life …)	I.3.C (socio-economic recreational conditions of individual use) have a commodity form, qualitative and semi-quantitative ratings (renting country house and land plots, hostels …)
(II) Recreational resources	(1) natural	II.1.A (natural recreational resources of public use) can be evaluated by the overall impact on the better/worse functioning of RTA (precipitation, wind energy, biocenoses of ecosystems…)	II.1.B (natural recreational resources of collective use) have a form of goods, cause rental relationships (natural components of sanatorium and health and sports institutions, summer cottage societies …)	II.1.C (natural recreational resources of individual use) have an economic assessment (land spots, summer cottage ("dacha"), garden areas, aquatic berths …)
	(2) cultural and historical	II.2.A (historical and cultural recreational resources of public use) value of such resources is determined by their historical and cultural "weight" with the use of perceptual assessment techniques (artifacts of material culture, historical sites of international level, etc.)	II.2.B (historical and cultural recreational resources of collective use) value of such resources is determined by their historical and cultural "weight" with the use of perceptual assessment techniques (artifacts of material culture, historical sites etc. of national level)	II.2.C (historical and cultural recreational resources of individual use) have material values and subject to economic assessment (private collections …)
	(3) socio-economic	II.3.A (socio-economic recreational resources of public use) have an economic assessment (global transport networks …)	II.3.B (socio-economic recreational resources of collective use) have an economic assessment (recreational and tourist infrastructure …)	II.3.C (socio-economic recreational resources of individual use) have an economic assessment (material and technical base of individual and family forms of garden activities, mass unorganized recreation, amateur tourism …)

methodological directions of evaluation of recreational conditions (I) and recreational resources (II). The directions of classification and systematics of recreational goods are presented in the Table 1, marked with symbolic codes. It is worth to consider briefly such headings, emphasizing the special features of each direction and its orientation.

The first group of recreational goods in the above systematics (block I.1.A) forms natural recreational conditions of public (society) use. Such recreational conditions have a global or planetary scale of their manifestations. They are considered as global civilization goods as the "property" of the world community, which has exclusively public and compatible use. Such recreational goods can not be privatized or restricted by individuals and societies in favour of others. Natural recreational conditions of social (public) use cannot be a commodity – the object of purchase and sale and do not take direct participation in the formation of market relations. The Earth's atmosphere, the World's ocean, ozoneosphere, Space are the examples of such recreational goods. Natural recreational conditions of the planetary level are the biosphere – a shell of life, a landscape membrane of the Earth, which forms a natural environment of mankind life.

The second group (block I.1.B) forms natural recreational conditions of collective (group, community) use. Such recreational goods form natural and geographical objects and phenomena used by various forms of ownership (state, corporate) and collective (group). Examples of such goods may be the territories and aquaria used for recreational and tourist activities of limited social groups. Among them there are the land of fishing and hunting, the use of which are issued by membership in the relevant unions, areas of water recreation with limited and regulated use, objects and territories of the natural reserve fund, areas of mass unorganized rest with established regulations and standards of use. Natural recreational conditions of collective (group) use can be shared, do not have a form of goods and not participate in market commodity-money circulations. However, a significant part of such recreational goods is already included in market turnover, has the status of purchase and sale objects, forms appropriate rental relations due to better-worse qualities and locations, acquires competitive properties and possibilities of alienation to use some of the consumers.

The next group of recreational goods (block I.1.C) constitute natural recreational conditions for individual (private) use. Such recreational goods are characterized by natural geographical objects and sites in private ownership of vacationers. But the real list of such goods is much wider. It covers natural conditions of recreational and tourist activity in all its varieties. In particular, this is one of the main characteristics of household recreation and mass self-recreation and recreation of the population. Natural recreational conditions of individual use are currently combining the properties of social economic goods and private goods. Geographical resource research pays more attention to the natural conditions that have private ownership status and require appropriate economic estimates. Natural conditions of individual use that retain the status of common property remain outside the economic assessment.

Unlike the natural conditions of RTA, historical and cultural recreational conditions were investigated in domestic recreational geography. The first group of such recreational goods constitute historical and cultural recreational conditions of public (society) use (block I.2.A). These are recreational goods available to all users without restrictions rights. They do not have the content of the goods and do not form appropriate market relations. Consequently, historical and cultural recreational conditions can not be subject to resource evaluation, although they retain cognitive and perception (sensual) value. Examples of such recreational goods can serve as regional world civilization, historical, geographical and geopolitical regions, area of the distribution of different confession and ethno-national cultures.

Recreational historical and cultural conditions of collective (group, community) use (block I.2.B) have a form of corporate, collective ownership. By affiliation, they may be associated with various companies and firms, with political, confessional and public organizations and structures. Recreational conditions form historical and cultural facilities, monuments and artefacts belonging to such owners. The nomenclature of historical and cultural objects and monuments is quite known. It should be remembered only that characteristics and evaluation of recreational historical and cultural conditions of collective use require not only individual objects and events, but also a spatial combination of such recreational goods that forms a recreational environment. Recreational historical and cultural conditions of collective use predominantly in the form of goods, take part in the creation of relevant markets serving objects of sale. Currently, this direction of evaluation of recreational goods is not enough developed.

If historical monuments and artefacts have private affiliation, then this situation is represented by the following group of recreational goods – historical and cultural conditions of individual (private) use (block I.2.C). Such recreational goods usually have an appropriate economic assessment in the value of existing historical and cultural objects and artefacts. It is about

cultural artefacts that have museum value, as well as various collections and libraries of manuscripts, books, maps. It should be remembered that the assessment is not the same objects, but their perceptual impact (impression, evaluation), as well as the conditions and capabilities of using other individuals. As already were emphasized, socio-economic conditions of recreation and tourism activity also require classification and evaluation. It is indicative that until recently socio-economic factors were considered as components of recreational potential. Presently, this barrier has been overcome, but the general level of development of economic assessment of resource potential according to its socio-economic components remains extremely insufficient.

Recreational socio-economic conditions of public (society) use (block I.3.A) are represented by the global economic system and national economies. The general level of the world economy, the farms of particular countries and their regional integration largely determine the conditions and possibilities of functioning of recreational and tourist activities. Sustainable socio-economic development of countries and regions is one of the main conditions for dynamic growth of recreation and tourism. Socio-economic conditions of public use are not of cost assessments as a recreational resource. Possible relative (ranked) assessments of socio-economic conditions by comparison of the relevant indicators of the levels of development of recreational regions and countries with the global economy and among themselves.

Recreational socio-economic conditions of collective (group, community) use (block I.3.B) mainly have the status of collective property, can form relevant market relations and be objects of sale. In this case, they do not have direct cost estimation as a resource, but can be evaluated by a larger less promotion of recreation and tourism activities. Recreational socio-economic conditions of collective use may have qualitative and semi-ranking (serial, rating) evaluation as factors for forming RTP. In the first case, the evaluation characterizes a greater-less perception of socio-economic conditions of the RTA functioning, and such assessments are ordered only qualitatively in relation to more than less. For example, according to the characteristic of the personal safety of recreation and tourists, the region A has a relatively better condition than regions B and C. Or the city among other tourist cities is highlighted by a higher quality of the population life, which enhances its functions as a tourist centre.

According to the second approach, the characteristics of socio-economic conditions can be compared and collate according to certain indicators that are quantified them. In this case, we have a certain "reference point" (for regions – the average level in the country, for the centres of RTA – an average level for the cities of this group), which allows to arrange and rank the socio-economic conditions for their relative estimates. Such an assessment has a quantitative character of the ratio to the point of reference, but the quantitative indicators do not have metric relations: they can not be added, to compile, to minus. In mathematical statistics, they are called "inoperative", such that are not subject to transactions.

A group of recreational socio-economic conditions of individual (private) use (block I.3.C) is substantially close to the previous group (I.3.B) and retains its main properties. The main difference between the recreational goods of this group is a clear private affiliation. It is about the resource assessment of the socio-economic conditions of particular recreational users. The privatized socio-economic conditions of RTA in many situations have a commodity form and form relevant markets for recreational services. Examples of such markets can be renting a cottage and areas for recreation, a newly-known hostel, designed for "cheap tourists" and others.

The above review represents the grouping of recreational conditions. In such principles, there These principles were also used to systematize recreational resources (Table 3.1). A group of natural recreational resources of public (society) use (block II.1.A) components and phenomena (processes) of the natural environment directly or indirectly used in recreational and tourist activities as its resources. Such recreation goods are usually a global or regional spatial scale. They are available for public use without any restrictions, without exception from such use of individuals and societies in favour of others. Natural recreational resources of public use can not be a commodity. They do not form relevant markets and do not have its valuation. They can be evaluated only by general influence on the better-worse functioning of the RTA. And in this context, they are similar to the natural conditions that we have already considered. The natural resources themselves as well as their spatial scale approaches "natural conditions" are yet subject to assessment.

Examples of recreational natural resources of public use may be the resources of the atmosphere – air, precipitation, solar and wind energy, climatic potential. Resource functions and capabilities of the oceans can be submitted in the same way. The resource potential of the public use of biosphere covers not only recreational components of the plant and animal world, but also their territorial combinations in the form of biocenoses of ecosystems that have recreational value. Landscape member as a natural recreational resource is represented by natural and natural-anthropogenic complexes, as well as the environment of society life, which is already

considered as a global ecological and recreational resource.

The following group allocated natural recreational resources of collective (group) use (block II.1.B). This is the common variant of recreational nature management, according to which natural recreational resources have a collective form of ownership and respectively group them. Currently, natural recreational resources have establishments of sanatorium, recreation and sports profile, numerous summer and garden societies and cooperatives. Ownership of separate recreational resources transferred to local governments – oblast, district and city councils, local communities.

Accounting and evaluation of natural recreational resources remains the most developed direction in recreational geography and resource, and the main methodological problem of its further development is the methodical searches of general and integral estimates of the natural resource potential of recreational objects and territories. In most cases, the indicators of the recreational value of natural components are established, developed methodological approaches to their economic assessment.

Natural recreational resources of collective use have the form of goods served as objects of purchase and sale and form relevant markets of recreational resources. Natural resources that have established market value create peculiar rental relations that fix their various qualities and cancellations. Such a status of natural recreational resources generates competition and leads to the right to exclude the use of them for some vacationers at the expense of other – winners in competitive competitions.

Natural recreational resources of individual (private) use (block II.1.C) are distributed at the level of households in rural areas, as well as domestic recreation of urban population on the cottage settlement and garden activities. Private property and non-consumer form of recreational goods are typical for them. However, it increases the use of individual natural recreational resources as buying objects. Commodity forms have land spots, summer cottage ("dacha"), garden areas, aquatic berths and so-called "chalet" by the sea. It was noted that the economic assessment of natural recreational resources is one of the most developed areas of resource studies. At the level of individual use of natural recreational goods, mainly market methods of assessment are widespread.

Historical and cultural (socio-historical) recreational resources are sufficiently developed by their nomenclature and intermediate taxonomies. It is about historical and cultural attractions and objects, archaeological monuments of material culture (artifacts), architecture and construction, events and memorable places vital activity of cultural figures and politicians.

Insignificant and rather conditional separation of recreational historical and cultural resources of public (block II.2.A) and collective (group) use (block II.2.B.). Methodologically, they are distinguished by levels of culturally historical events and monuments – international and national. Such delimitation is not easy in reality. Since a significant part of cultural-historical resources is represented by objects (artefacts), which, as a rule, have a form of collective or private property, then such recreational goods form the relevant markets of historical and cultural resources. They can be involved in the processes of buying and selling, renting, etc. Historical and cultural resources do not have a direct economic assessment. The value of such resources is determined by their civilizational and historical and cultural "weight" and significance with the use of perceptual assessment techniques – evaluations for "impressions."

Historical and cultural recreational resources of individual use (block II.2.C) have the form of private collections. Such recreational goods have material values and subject to economic assessment as recreational resources. The practice of collective use of such resources on thematic seminars and congresses, exhibitions and festivals wide spread. In this case, the delimitation of historical and cultural recreational resources by the level of use is relatively blurred.

Completes the systematics of recreational goods (Table 1) A grouping of socio-economic resources completes the systematics of recreational goods (Table 1). It was emphasized that socio-economic factors of resource potential in the vast majority are considered as the conditions of RTA. However, they perform and important resource functions – functions of direct usage by vacationers and tourists. Once again we emphasize that such a direction for evaluating the resource potential of the RTA has not yet long history and needs further development.

Recreational socio-economic resources of public use (block II.3.A) are represented mainly by global transport networks serving international tourism activities. It is about the global system of waterways and communications, a global network of air combinations, on continental systems of railway and motor transport. World transport infrastructure has its economic assessment – differentiated by continents, ocean basins, countries, and integral. It has been formed powerful markets for international and global transport services, developed relevant competitive relationships. We emphasize that the global transport and logistics system is considered as a global recreational resource (in terms of infrastructure), and as a condition for recreational and tourist activities (for providing transport services).

The second group of recreational socio-economic resources of collective (group, community) use

(block II.3.B) forms the socio-economic factors of the RTP of different levels – the international, national (country) and regional. Recreational socio-economic resources have a major component – recreational and tourist infrastructure, which includes institutions and systems of placement and service of recreation and tourists. All infrastructure objects, complexes, systems have a collective private property with a certain value. There are formed powerful markets for recreational infrastructure with a developed competitive environment. A rent approach is actively involved in the economic assessment of recreational infrastructure: complexes and systems of recreational infrastructure have significant amplitude of recreational estimates, depending on the qualitative characteristics of infrastructure and location. Like all material benefits, recreational infrastructure is evaluated as a component of resource potential (at its cost), as well as a component of recreation and tourism activity (according to its perceptual influence and consequences).

Recreational socio-economic resources of individual use (block II.3.C) are allocated to a separate group. In its composition material components and factors of household recreation and short-term recreation, as well as the material and technical base of individual and family forms of recreation including cottage and garden activities, mass unorganized recreation, amateur tourism. Recreational socio-economic resources of individual use are the objects of private property and have appropriate economic assessments. Such recreational goods form their market environments with competitive relations and may be objects of commodity-money circulation.

Conclusions

The above review of the directions and approaches to the systematics of recreational goods gives an opportunity to extend the classical division of recreational goods to conditions and resources designed for natural components, to other components of recreational potential – to historical and cultural and socio-economic blocks. The invented systematics takes into account the substantive peculiarity of cultural, historical and socio-economic conditions and resources, compared with the traditional natural bloc. In many developments, the principles of classification of natural conditions and resources will automatically transfer to historical, cultural and socio-economic components without taking into account their substantive specificity. In developing systematics of recreational goods, modern theoretical and methodological developments of socio-economic goods are taken into account with the distribution of property relations (public), collective (group) and private use. The combination of these features presents the main directions of assessment of recreational conditions and recreational resources. For each of the 18 directions it is necessary to develop methodological principles and methodological tools of inventory and assessing the corresponding combination of recreational conditions and resources with the forms of use by recreational goods.

References

Alyeshuhina, N. O., Baranovs'ka, O. V., & Baranovs'kyy, M. O., 2015. Rekreatsiyno-turystychni resursy Ukrayiny z osnovamy turystychnoho resursoznavstva [Recreational and tourist resources of Ukraine with the basics of tourist resource science]. ChNTU, Chernihiv (In Ukrainian).

Bejdyk, O. O., 2001. Rekreacijno-turysts'ki resursy Ukrai'ny: metodologija ta metodyka analizu, terminologija, rajonuvannja [Recreational and tourist resources of Ukraine: methodology and methods of analysis, terminology, zoning]. Kyi'v. un-t, Kyi'v (In Ukrainian).

Vuytsyk, O. I., 2012. Rekreatsiyno-turystychnyy kompleks: pytannya terminolohiyi [Recreational and tourist complex: questions of terminology]. Visnyk sotsial'no-ekonomichnykh doslidzhen'. 3(2), 39–44 (In Ukrainian).

Horyn, H. V.. 2014. Systematyzatsiya metodolohichnykh pidkhodiv do vyznachennya sutnosti ponyattya «rekreatsiyno-turystychnyy potentsial rehionu» [Systematization of methodological approaches to defining the essence of the concept of "recreational and tourist potential of the region"]. Rehional'na ekonomika. 2, 187–199 (In Ukrainian).

Horun, V., 2013. Otsinka rekreatsiyno-resursnoho potentsialu terytoriyi Odes'koyi oblasti [Assessment of recreational and resource potential of the territory of Odessa region.]. Visnyk L'vivs'koho universytetu. Seriya heohrafichna. 43(1), 24–31 (In Ukrainian).

Hrodzyns'ka, I. O., Nezdoyminov S.H., & Husyeva O.V., 2014. Osnovy rekrealohiyi (ekonomiko-ekolohichnyy ta marketynhovyy aspekt) [Fundamentals of recreation (economic, environmental and marketing aspects)]. Tsentr uchbovoyi literatury, Kyiv (In Ukrainian).

Hrodzyns'kyy, M. D., 2014. Landshaftna ekolohiya [Landscape ecology]. Znannya, Kyiv (In Ukrainian).

Gudkovskih, M. V., 2017. Metodika kompleksnoj ocenki turistsko-rekreacionnogo potenciala [Methodology for a comprehensive assessment of tourist and recreational potential]. Geographical bulletin. 1(40), 102–116 (In Russian).

Dashhuk, J. J., 2012. Analiz skladovyh rekreacijnogo potencialu regionu [Analysis of the components of the recreational potential of the region]. Visnyk Shidnoukrai'ns'kogo nacional'nogo universytetu imeni Volodymyra Dalja. 7(178), 71–78 (In Ukrainian).

Kuzyk, S. P., 2011. Geografija turyzmu: navch. posib. [Geography of tourism: textbook]. Znannja, Kyiv (In Ukrainian).

Kuskov, A. S., 2011. Turistskoe resursovedenie: uchebnik [Tourism resource studies: textbook]. Universitetskaja kniga, Moskva (In Russian).

Kushniruk, J. S., 2012. Rekreacija ta kurortologija [Recreation and balneology].: NUVGP, Rivne (In Ukrainian).

Ljubiceva, O. O., Mal's'ka, M. P., & Zin'ko, Ju. V., 2011. Konceptual'ni zasady geografii' rekreacii' i turyzmu [Conceptual principles of geography of recreation and tourism]. Geografija ta turyzm. 11, 3–14 (In Ukrainian).

Muska, K. K., 2018. Teoretychni pidhody do rozuminnja sutnosti definicij "rekreacijni resursy" ta "rekreacijnyj potencial" [Theoretical approaches to understanding the essence of the definitions of "recreational resources" and "recreational potential"]. Global'ni ta nacional'ni problemy ekonomiky. 21, 521–526 (In Ukrainian).

Onufriv, Ja. O., 2015. Rozvytok rekreacijnyh terytorij v strukturi landshaftu Skolivs'kogo rajonu L'vivs'koi' oblasti [Development of recreational areas in the landscape structure of Skole district of Lviv region]. Visnyk Nacional'nogo universytetu «L'vivs'ka politehnika». 816, 143–153 (In Ukrainian).

Pahomova, N., Rihter, K., & Rumjanceva, S., 2000. Ekologicheskie blaga kak resursy sovmestnogo potreblenija [Environmental goods as resources for shared consumption]. Vestnik Sankt-Peterburgskogo universiteta. 5(1), 26–43 (In Russian).

Pokolodna, M. M., 2012. Rekreacijna geografija [Recreational geography]. HNAMG, Harkiv (In Ukrainian).

Polyvach, K. A., 2012. Kul'turna spadshhyna ta i'i' vplyv na rozvytok regioniv Ukrai'ny [Cultural heritage and its impact on the development of the regions of Ukraine]. In-t geografii' NAN Ukrai'ny, Kyiv (In Ukrainian).

Topchijev, O. G., Kolomijec', K. V., Sych, V. A., & Javors'ka, V. V., 2020. Strukturuvannja rekreacijno-turystychnogo potencialu na zasadah geografichnogo seredovyshha: Monografija [Structuring recreational and tourist potential on the basis of geographical environment: Monograph]. Pan'kova A.S., Kam'janec'-Podil's'kyj (In Ukrainian).

Topchijev, O. G., Sych, V. A., & Javors'ka, V. V., 2020a. Koncepcija rekreacijnogo seredovyshha regionu ta i'i' ponjatijno–terminologichne strukturuvannja [The concept of the recreational environment of the region and its conceptual and terminological structuring]. Visnyk Odes'kogo nacional'nogo universytetu. Serija Geografichni ta geologichni nauky. 25(1), 157–172. DOI:10.18524/2303–9914.2020.1(36).205177 (In Ukrainian).

Topchijev, O. G., Sych, V. A., & Javors'ka, V. V., 2020b. Naprjamy systematyzacii' rekreacijnyh blag [Directions of systematization of recreational goods]. Visnyk Odes'kogo nacional'nogo universytetu. Serija Geografichni ta geologichni nauky. 25(2), 199–212 DOI:10.18524/2303–9914.2020.2(37).216571 (In Ukrainian).

Topchijev, O. G., Sych, V. A., Javors'ka, V. V., & Dolyns'ka, O. O., 2019. Ekologichnyj imperatyv u koncepcijah social'no-ekonomichnogo rozvytku i jogo geografichni skladovi [Ecological imperative in the concepts of socio-economic development and its geographical components]. Visnyk Odes'kogo nacional'nogo universytetu. Serija: Geografichni ta geologichni nauky. 24(2), 96–112. DOI: 10.18524/2303–9914.2019.2(35).183734 (In Ukrainian).

Fomenko, N. V., 2007. Rekreacijni resursy ta kurortologija: navch. posibnyk [Recreational resources and balneology: textbook]. Centr navchal'noi' literatury, Kyiv. (In Ukrainian).

Barriere, O., 2019. Coviability of Social and Ecological Systems: Reconnecting Mankind to the Biosphere in an Era of Global Change. Vol. 1: The Foundations of a New Paradigm. Springer International Publishing.

Hall, C. M., & Page, S. J., 2014. The Geography of Tourism and Recreation: Environment, Place and Space. Routledge, London.

Ostrom, E., 2010. The Challenge of common-pool resources. Environment: Science and Policy for Sustainable Development. 50(4), 8–21

Stamboulis, Y., & Skayannis P., 2003. Innovation strategies and technology for experience-based tourism. Tourism Management. 24, 35–43.

Tourism for Development, 2018. Volume I: Key Areas for Action. UNWTO, Madrid.

Journal of Geology, Geography and Geoecology

ISSN 2617-2909 (print)
ISSN 2617-2119 (online)

Journ. Geol. Geograph. Geology, 30(4), 762–780.

Journal home page: geology-dnu.dp.ua

doi: 10.15421/112171

Life quality as an indicator of sustainable development: international statistical research

Iryna M. Trunina[2], Inna V. Khovrak[1], Kateryna A. Pryakhina[2], Olga P. Usanova[2]

[1]*State Tax University, Irpin, Ukraine,* inna.khovrak@ukr.net
[2]*Kremenchuk Mykhailo Ostohradskyi National University, Kremenchuk, Ukraine*

Received: 28.01.2021
Received in revised form: 08.02.2021
Accepted: 11.02.2021

Abstract. The purpose of the article is to substantiate the methodology for determining the European quality of life index. The theoretical and methodological basis of research is the ideas of the interdependence of life quality and sustainable development. To achieve the desired goal, the following research methods were used: analysis and synthesis (for determining theoretical and practical aspects of ensuring the life quality); statistical (for determining standardized indicators and a European Quality of Life Index for Sweden and Ukraine); abstract-logical (for theoretical summarization and conclusion). As a result, the authors created the European Quality of Life Index based on the comparison of the characteristics of international life quality assessment systems (calculation principle, number and composition of indicators, number of countries covered for calculation), as well as systematization of research by Ukrainian and foreign authors. Therefore, the authors selected twelve main indicators. The indicators are divided into two groups: stimulants (prosperity index, basic human needs index, welfare bases, availability of nutrition and basic health care, GDP per capita, population, global competitiveness index, personal security, access to basic knowledge, ecosystem status) and disincentive (government debt, unemployment). To determine the "European life quality index", the authors used the formula for calculating the arithmetic mean, as all selected indicators can be considered equivalent as a result of standardization by the method of "minimum-maximum". In addition, for in-depth analysis, the authors calculated the growth rates of indicators, as well as coefficients of variation. The authors made calculations based on data of 2013–2019 for two countries, namely Sweden and Ukraine. Sweden occupies a much better position in achieving the Sustainable Development Goals, so studying the impact of life quality on sustainable development in this country will suggest ways to achieve the chosen strategic priorities for Ukraine.

Keywords: life quality, sustainable development, indicators, Ukraine, Sweden

Якість життя як індикатор сталого розвитку: міжнародне статистичне дослідження

І.М. Труніна[2], І.В. Ховрак[1], К.А. Пряхіна[2], О.П. Усанова[2]

[1]*Державний податковий університет, Ірпінь, Україна,* inna.khovrak@ukr.net
[2]*Кременчуцький національний університет імені Михайла Остроградського, Кременчук, Україна*

Анотація. Метою статті є обґрунтування методології визначення європейського індексу якості життя. Теоретичною та методологічною основою дослідження є ідеї взаємозалежності якості життя та сталого розвитку. Для досягнення бажаної мети використовувались наступні методи дослідження: аналіз та синтез (для визначення теоретичних та практичних аспектів забезпечення якості життя); статистичні (для визначення стандартизованих показників та європейського індексу якості життя для Швеції та України); абстрактно-логічний (для теоретичного узагальнення та висновків). В результаті на основі порівняння характеристик міжнародних систем оцінювання якості життя (принцип розрахунку, кількість та склад індикаторів, кількість охоплених країн для розрахунку), а також систематизації досліджень українських та закордонних авторів біло розроблено власну методику обчислення європейського індексу якості життя. Показники розділено на дві групи: стимулятори (індекс процвітання, індекс основних потреб людини, основи добробуту, доступність харчування та базової медичної допомоги, ВВП на душу населення, чисельність населення, індекс глобальної конкурентоспроможності, особиста безпека; доступ до базових знань, стан екосистеми) та дестимулятори (державний борг, рівень безробіття). Для визначення узагальнюючого показника «європейський індекс якості життя» було використано формулу розрахунку середнього арифметичного значення, оскільки всі обрані індикатори можна вважати рівнозначними між собою в результаті стандартизації за методом «мінімум-максимум». Додатково для поглибленого аналізу автори розрахували темпи приросту індикаторів, а також коефіцієнти варіації. Розрахунки проведено з урахуванням даних за 2013–2019 роки для двох країн, а саме Швеції та України. Швеція займає набагато кращі позиції за індексом досягнення Цілей сталого розвитку, тому вивчення впливу якості життя на сталий розвиток у цій країні дозволить запропонувати шляхи досягнення обраних стратегічних пріоритетів для України.

Ключові слова: якість життя, сталий розвиток, індикатори, Україна, Швеція

Introduction.

Quality of life can be defined in many ways, that is why it is the center of sociological, economic and political research. For the vast majority of countries, quality of life is a key indicator of sustainable development being «as a desired outcome of service delivery in mainstream and special needs education, health care, social services (particularly for disabled and elderly people) and, increasingly, for cross-cutting public sector partnership policy at all levels» (Galloway, 2005). In addition, the UN Sustainable Development Goals (UN, 2020) also work in a spirit of partnership and pragmatism, and aim at the right choice in order to steadily improve the quality of life for future generations.

According to scientists, measuring the life quality in a behavioral economy is much more complicated (Glonti, 2020; Nenkov, 2017). In the context of globalization and digitalization, the priorities of countries' development and the tools to achieve them continue changing. That is why much attention is paid to the social, cultural and environmental living conditions of the population of European countries (Chernega, 2019; Gorina, 2019; Khomenko, 2019; Sushchenko, 2019). At the same time, the existence of democratic mechanisms for the transformation of society (Calinescu, 2018), social dialogue (Calinescu, 2017), a sufficient level of education of the population (Sitnicki, 2018; Trunina, 2019), a developed and powerful education system contribute to the processes of improving the quality of life of the population (Kasych, 2018; Sitnicki, 2020). At the same time, economic factors do not lose their relevance, in particular innovation (Kasych, 2017; Khovrak, 2013), and financial stability of enterprises (Polinkevych, 2016). The economic growth of the state is closely linked to the population life quality (Kaigorodova, 2018). It is also worth remembering that "interpersonal sensitivity and social support satisfaction predicted quality of life" (Wedgeworth, 2017). The empirical studies prove a direct correlation between starting a business and quality of life for late-career individuals (Kautonen, 2017). At that time, workspace design and environmental features effects on an employee's morale and productivity, which, in turn, affects the Quality of Life (Vischer, 2017). The concept of Quality of Life is significantly impacting research and service delivery in the field related developmental disabilities (Schalock, 2016). Therefore, all the factors that affect the level and Quality of Life of the population should be divided into groups depending on the level of influence: internal (personal characteristics of a person; the desire to work, the level of education, qualifications and income), family (material resources and social status of the family) and external (influence of society, market and state regulatory mechanisms: natural, economic, state managerial mechanism, social, medical prerequisites, etc.). As a result of these changes, society needs to strengthen social responsibility (Glonti, 2020), awareness of the transformation of development priorities of countries (Calinescu, 2018; Onyshchenko, 2020), as well as an effective system of strategic management (Buzko, 2019; Maslak, 2018) and training of highly qualified professionals (Pochtovyuk, 2017; Polishchuk, 2019). **The purpose of the article** is to substantiate the methodology for determining the European life quality index.

Materials and methods of research.

Research methods: analysis and synthesis (for determining theoretical and practical aspects of ensuring the quality of life); statistical (for determining standardized indicators and a European Life Quality Index for Sweden and Ukraine); abstract-logical (for theoretical summarization and conclusion). The importance of this paper is confirmed by the review and analysis of scientific publications.

Quality of life can be measured by a set of features that can be weighted by some metric that reflect "well-being", "social welfare" or "sustainable development" (Slottje, 2019). At the same time, the vast majority of scientific publications closely link such concepts as Health, Health-Related Quality of Life, and Quality of Life (Karimi, 2016). The main quality of life assessment systems and indices are the EIU Life Quality Index, the methodology of the European Statistical System Committee, the Better Life Initiative, the International Living Life Quality Index, and the general methodological concept of standards and quality of life (Table 1 (Measuring the life quality in Ukraine, 2013)).

Table 1. Characteristics of international quality assessment systems *(compiled by the authors)*

System	Calculation principle	Indicators
EIU Life Quality Index (Economic Intelligence Unit)	Equal consideration of quantitative and subjective indicators	Health, family, social life, financial well-being, political stability and security, climate, employment guarantee, political freedom, gender equality
The methodology of the European Statistical System Committee	Equal consideration of quantitative and subjective indicators	Financial and living conditions, productive or basic activity, health, education, leisure (recreation) and social communications (interaction), economic and physical security, public administration (power) and fundamental rights, nature and environment, general perception of life
Better Life Initiative (OECD)	Integral parameter estimation	Living conditions, income, employment, education, ecology, health, management efficiency, social life, safety, satisfaction with living conditions, work-life balance
The International Living Life Quality Index	Equal consideration of quantitative and subjective indicators	Cost of living, culture, economy, environment, freedom, health, infrastructure, security and risk, climate
The general methodological concept of standards and quality of life	Differentiation of macroeconomic indicators and sociological indicators	GDP per capita, consumer price index, consumer basket, household expenditures, GFK basket, poverty rate, income inequality, life and happiness satisfaction, deprivation, optimism about the future, etc.

The systems shown in Table 1, have different indicators, index calculation methods and the number of covered countries. Therefore, we selected twelve main indicators, which were used to obtain a standardized assessment of each indicator and to calculate the life quality index in 2013–2019 for the two countries, namely Sweden and Ukraine. Sweden occupies a much better position in achieving the Sustainable Development Goals, so studying the impact of life quality on sustainable development in this country will suggest the ways to achieve the chosen strategical priorities for Ukraine.

The calculation of indicators according to the proposed methodology was based on open statistics on the socio-economic development of countries (Global Competitiveness Index, 2019; Social Progress Index, 2019; Statistics of the countries of the world, 2019).

To calculate the European Quality of Life Index, we have chosen a method based on the magnitude of variation. The indicators are divided into two groups: stimulants (prosperity index, basic human needs index, welfare bases, availability of nutrition and basic health care, GDP per capita, population, global competitiveness index, personal security, access to basic knowledge, ecosystem status) and disincentive (government debt, unemployment). "The prosperity index" is marked as I_{LP}, "basic human needs index" – as I_{Δ}, "welfare bases" – as W_b, "availability of nutrition and basic medical care" – as A_m^n, "GDP per capita" – as G_C, "population" – as P, "global competitiveness index" – with I_{GC}, "personal security" – as S_P, "access to basic knowledge" – as A_{bK}, "ecosystem status" – as E; "government debt" – as D_G, "unemployment" – as R_U. "European quality of life index" is marked as E_i.

The standardized evaluation procedure (X′) was performed using the following formulas:

for stimulants:

$$X' = \frac{\max X - X}{\max X - \min X} \quad (1)$$

for disincentive:

$$X' = \frac{\max X - X}{\max X - \min X} \quad (2)$$

where X – is the indicator value, min X and max X – are the minimal and maximal values of the sample indicator respectively.

In order to bring standardized estimates of indicators into a generalized European index (Ei), the arithmetic mean formula was used based on the fact that all selected indicators can be considered equivalent to each other:

$$E_i = \frac{\sum X_i'}{n} \quad (3)$$

where n is the number of indicators taken into account, i is the segment of the study period and is equal {2013–2019}.

The following synthetic indicators were used for the analysis of indicators of stimulation and disincentive of life quality: "chain growth rate of prosperity index" – T_{gr}^{LP}, "chain growth rate of basic human needs index" – $T_{gr}^{I\Delta}$, "chain growth rate of welfare bases" – $T_{gr}^{W_b}$, "chain growth rate of availability of nutrition and basic health care" – $T_{gr}^{A_m^n}$, "chain growth rate of GDP per capita" – $T_{gr}^{G_C}$, "chain growth rate of population" – T_{gr}^{P}, "chain growth rate of global competitiveness index" – $T_{gr}^{I_{GC}}$, "chain growth rate of personal security" – $T_{gr}^{S_P}$, "chain growth rate of access to basic knowledge" – $T_{gr}^{A_{bK}}$, "chain growth rate of ecosystem status" – T_{gr}^{E}, "chain growth rate of government debt" – $T_{gr}^{D_G}$, "chain growth

rate of unemployment" – T_{gr}^{RU}, "chain growth rate of European quality of life index" – T_{gr}^{Ei}.

Results and their analysis.

As a result of the application of the proposed methodology, standardized values of indicators and the European Quality of Life Index for Sweden (Table 2–3) and Ukraine (Table 4–5) were calculated.

Table 2. Quality level indicators in Sweden, 2013–2019 *(developed by the authors)*

Indicators	2013	2014	2015	2016	2017	2018	2019	min	max	max-min
I_{LP}	77.62	77.61	77.43	77.43	79.20	79.15	79.10	77.43	79.2	1.77
T_{gr}^{LP},%	-	–0.01	–0.23	0.00	2.29	–0.06	–0.06	-		
I_{Δ}	63.61	94.59	94.83	95.42	95.36	96.34	96.39	63.61	96.39	32.78
$T_{gr}^{I\Delta}$,%	-	48.70	0.25	0.62	–0.06	1.03	0.05	-		
W_b	61.73	84.71	86.43	88.61	90.40	88.31	89.88	61.73	90.40	28.67
T_{gr}^{Wb},%	-	37.23	2.03	2.52	2.02	–2.31	1.78	-		
A_m^n	61.52	98.26	99.42	99.43	99.46	98.57	85.84	61.52	99.46	37.94
T_{gr}^{Anh},%	-	59.72	1.18	0.01	0.03	–0.89	–12.91	-		
G_C, $	44907	46408	48310	49836	51180	52984	47193	44907	52984	8077
T_{gr}^{Gc},%	-	3.34	4.10	3.16	2.70	3.52	–10.93	-		
D_G,% of GDP	39.8	44.6	42.9	41.7	40.7	38.8	37.7	37.7	44.6	6.9
T_{gr}^{Dc},%	-	12.06	–3.81	–2.80	–2.40	–4.67	–2.84	-		
P, mln	9.645	9.747	9.851	9.995	10.120	10.230	10.330	9.645	10.33	0.685
T_{gr}^{P},%	-	1.06	1.07	1.46	1.25	1.09	0.98	-		
R_U,%	8.0	7.9	7.4	7.0	6.7	6.3	6.8	6.3	8.0	1.7
T_{gr}^{RU},%	-	–1.25	–6.33	–5.41	–4.29	–5.97	7.94	-		
I_{GC}	5.48	5.41	5.43	5.53	5.52	5.50	5.50	5.41	5.53	0.12
T_{gr}^{IGc},%	-	–1.28	0.37	1.84	–0.18	–0.36	0.00	-		
S_P	70.28	93.35	93.48	94.04	94.02	88.75	88.91	70.28	94.04	23.76
T_{gr}^{SP},%	-	32.83	0.14	0.60	–0.02	–5.61	0.18	-		
A_{bK}	63.68	98.16	98.89	95.68	95.04	92.82	92.37	63.68	98.89	35.21
T_{gr}^{AbK},%	-	54.15	0.74	–3.25	–0.67	–2.34	–0.49	-		
E	45.61	60.42	71.54	92.68	92.81	84.29	84.55	45.61	92.81	47.20
T_{gr}^{E},%	-	32.47	18.40	29.55	0.14	–9.18	0.31	-		

According to the Table 2 the value of indicator I_{LP} in 2013 was 77.62, it had the trend of increasing and in 2017 gained maximal value, in 2018 it was 79.15, in 2019–79.10.The same pattern can be found in the change of other indicators: W_b increased from 61.73 in 2013 to 90.40 in 2017, in 2018 indicator T_{gr}^{Wb} was equal –2.31, in 2019 was equal 1.78; T_{np}^{AbK} reached a significant value 54.15%, but since 2016 it ranged –3.25 to –0.49; S_P in 2013 was equal to 70.28, then gained maximal value 94.04 in 2016, and decreased in 2018 to 88.75, and increased to 0.18 in 2019.

The indicator A_m^n has changed most significantly: in 2013 it was 61.52, in 2014–98.28, and indicator $T_{np}^{A_m^n}$ was 59.72, and during 2014–2017 remained almost unchanged, gaining a value of –0.89 in 2018, and12.91 in 2019.

These indicators have affected the value of indicator *P.* Despite some reductions in previous indicators, the indicator T_{gr}^{P} constantly increased and in 2016 has gained maximal value – 1.46%, that indicator *P* in 2013 was 9.645 million people, and in 2019–10.330 million people.

The positive dynamics can be seen in the growth of the indicator G_C from 44907 USD in 2013 to 52984 USD in 2018 (the value of indicator T_{gr}^{GC} has reached the maximal value in 2015–4.10), but the value of the indicator G_C in 2019 was 47193 USD and it affected the indicators T_{gr}^{GC} = –10.93. The indicator D_G changed as follows: in 2013–39.8 % to GDP, in 2014 has gained maximal value 44.6 % to GDP, in 2019 decreased by 37.7 % to GDP, which contributed to a decrease in the score of indicator R_U to 1.7 % and increasing I_{GC} (maximal value in 2016–5.53, in 2018 and 2019–5.50).

In this regard, the increase in the indicator I_Δ was explained: in 2013 it was 63.61, in 2014–94.59, and in 2019 has gained maximal value – 96.39.

According to the Table 3 indicators are defined, summarized by a standardized value E_i, show dynamics to improve life quality index from 0.48 in 2013 to 0.89 in 2017 due to rising socioeconomic indicators, which indicates a better quality of life. Although, in 2019 the value of the indicator E_i=0.83 which indicates a slight decrease in the life quality in Sweden.

Table 3. Standardized values of living quality indicators in Sweden, 2013–2019 *(developed by the authors)*

Indicators	2013	2014	2015	2016	2017	2018	2019
I_{LP}	0.94	0.94	0.93	0.93	1.00	1.00	1.00
I_Δ	0.38	0.97	0.97	0.98	0.98	1.00	1.00
W_b	0.41	0.88	0.92	0.96	1.00	0.96	0.99
A_m^n	0.14	0.97	1.00	1.00	1.00	0.98	0.69
G_C	0.82	0.85	0.90	0.93	0.96	1.00	0.87
D_G	0.95	0.84	0.88	0.91	0.93	0.97	1.00
P	0.00	0.00	0.01	0.01	0.01	0.02	0.02
R_U	0.50	0.53	0.68	0.79	0.88	1.00	0.85
I_{GC}	0.97	0.92	0.93	1.00	0.99	0.98	0.98
S_P	0.41	0.98	0.99	1.00	1.00	0.87	0.87
A_{bK}	0.10	0.98	1.00	0.92	0.90	0.84	0.83
E	0.16	0.42	0.62	1.00	1.00	0.85	0.85
E_i	0.48	0.77	0.82	0.87	0.89	0.87	0.83

According to the calculations given in the Table 4, the value of the indicator *P* during 2013–2019 has a tendency to a constant decline: T_{gr}^{P} in 2014 it was 5.49 %, in 2019 –0.75 %. The reason for this was the instability of values S_P (in 2014 was 57.48, in 2016–61.05, in 2019–58.83) and indicator A_{bK}: the value of indicator T_{gr}^{AbK} in 2014 was 63.03 %, in 2016 – –0.81 %, in 2018 indicator was –8.46 %). Educational reforms implemented during 2013–2019 negatively affected the quality of educational services and caused dissatisfaction among the population, but the results of the study period indicate that education in Ukraine remains at a fairly high level.

An equally important indicator, which affects the decrease of *P* is R_U: the level of value of this indicator ranges 7.2–9.7 %. The reduction of the number of industrial enterprises, and as a consequence – the reduction of jobs, the inability to maintain their own families – all this has led to a decrease in fertility and labor migration of young people.

Table 4. Quality level indicators in Ukraine, 2013–2019 *(developed by the authors)*

Indicators	2013	2014	2015	2016	2017	2018	2019	min	max	max-min
I_{LP}	54.08	53.53	52.74	52.59	53.65	53.96	53.90	52.59	54.08	1.49
T_{gr}^{LP},%	-	–1.02	–1.48	–0.28	2.02	0.58	–0.11	-		
I_Δ	43.65	77.98	78.28	81.23	79.91	81.93	81.92	43.65	81.93	38.28
T_{gr}^{Δ},%	-	78.65	0.38	3.77	–1.63	2.53	–0.01	-		
W_b	41.93	61.42	61.74	64.29	68.62	64.03	64.22	41.93	68.62	26.69
T_{gr}^{Wb},%	-	46.48	0.52	4.13	6.74	-6.69	0.30			

Indicators	2013	2014	2015	2016	2017	2018	2019	min	max	max-min
A_m^n	55.47	95.11	97.84	97.99	98.47	92.87	55.56	55.47	98.47	43.00
$T_{gr}^{A_m^n}$,%	-	71.46	2.87	0.15	0.49	–5.69	–40.17	-		
G_C,$	8676	8733	7996	8305	8754	9283	7906	7906	9283	1377
$T_{gr}^{G_C}$,%	-	0.66	–8.44	3.86	5.41	6.04	–14.83	-		
D_G,% of GDP	40.50	70.03	79.30	81.20	71.90	63.90	49.50	40.50	81.20	40.70
$T_{gr}^{D_G}$,%	-	72.91	13.24	2.40	–11.45	–11.13	–22.54	-		
P, mln	45.246	42.760	42.591	42.501	42.217	42.047	41.733	41.733	45.246	3.513
T_{gr}^{P},%	-	–5.49	–0.40	–0.21	–0.67	–0.40	–0.75	-		
R_U,%	7.20	9.30	9.10	8.80	9.70	9.00	8.50	7.20	9.70	2.50
$T_{gr}^{R_U}$,%	-	29.17	–2.15	–3.30	10.23	–7.22	–5.56	-		
I_{GC}	4.05	4.14	4.03	4.00	4.11	4.10	4.00	4.00	4.14	0.14
$T_{gr}^{I_{GC}}$,%	-	2.22	–2.66	–0.74	2.75	–0.24	–2.44	-		
S_P	53.92	57.48	57.96	61.05	57.32	57.68	58.83	53.92	61.05	7.13
$T_{gr}^{S_P}$,%	-	6.60	0.84	5.33	–6.11	0.63	1.99	-		
A_{bK}	59.89	97.64	97.76	96.97	97.52	89.27	89.25	59.89	97.76	37.87
$T_{gr}^{A_{bK}}$,%	-	63.03	0.12	–0.81	0.57	–8.46	–0.02	-		
E	44.63	39.13	36.73	44.44	50.37	39.48	40.46	36.73	50.37	13.64
T_{gr}^{E},%	-	-12.32	-6.13	20.99	13.34	-21.62	2.48	-		

The low level of the indicator *E*: T_{gr}^{E} in 2014 was –12.32%, in 2016 was 20.99%, in 2018 – –21.62%, in 2019 was 2.48. It indicates to a negative impact on the health of the population and also leads to a decrease in value P, even at a sufficiently high level of the indicator A_m^n: till 2018 there was an increase in values, and in 2017 the metric reached its maximal value – 98.47, in 2018 – decreased to 92.87, in 2019 – decreased to 55.56. Decreasing the indicator A_m^n was due to the poor-quality reforms of the Ministry of Health of Ukraine and low qualification of medical personnel.

Despite the fact that there is an increase in the index G_C: only in 2015 the indicator $T_{np}^{G_C}$ was –8.44%, compared to Sweden in Ukraine the indicator G_C remains at the low level, but a decrease of the indicator D_G from 2017 (in 2013 the indicator was 40.50% to GDP, in 2016 it has gained maximal value – 81.20% to GDP, in 2017–71.90% to GDP, in 2019–49.50% to GDP) was probably caused by the devaluation of the national currency.

Thus, against the background of an indicator I_Δ that had grown (only in 2017 the indicator T_{gr}^{Δ}, was –1.63%, in 2018 it was equal to its maximum during the study period – 81.93, but in 2019 there was a slight decrease of indicator to 81.92), but in 2018 the indicator W_b declined sharply ($T_{np}^{W_b}$ in 2014–46.48%, in 2018 – –6.69%, in 2019–0.30), the indicator I_{GC} almost didn't change (during the study period, the minimal value is 4.00, and maximal – 4.14).

All previous indicators affected the value of indicator I_{LP}, the values of which also, as in the previous indicators, decline, increasing only by 2017 (T_{gr}^{LP} in 2015 – –1.48%, in 2017 – 2.02%), which is likely to be associated with a small recovery in values A_{bK} and A_m^n. The value of the indicator A_m^n critically decreased from 92.87 in 2018 to 55.56 in 2019.

Table 5. Standardized values of living quality indicators in Ukraine, 2013–2019 *(developed by the authors)*

Indicators	2013	2014	2015	2016	2017	2018	2019
I_{LP}	0.06	0.04	0.01	0.00	0.04	0.05	0.05
I_{Δ}	0.00	0.65	0.66	0.71	0.69	0.73	0.73
W_b	0.00	0.40	0.41	0.46	0.55	0.46	0.46
A_m^n	0.00	0.90	0.96	0.97	0.98	0.85	0.00
G_C	0.02	0.02	0.00	0.01	0.02	0.03	0.00
D_G	0.94	0.26	0.04	0.00	0.21	0.40	0.73
P	1.00	0.93	0.93	0.92	0.91	0.91	0.90
R_U	0.74	0.12	0.18	0.26	0.00	0.21	0.35
I_{GC}	0.03	0.09	0.02	0.00	0.07	0.07	0.00
S_p	0.00	0.09	0.10	0.18	0.08	0.09	0.12
A_{bK}	0.00	0.97	0.97	0.95	0.96	0.75	0.75
E	0.14	0.04	0.00	0.14	0.24	0.05	0.07
E_i	0.24	0.38	0.36	0.38	0.40	0.38	0.35

The data given in the Table 5, show the main problems of Ukraine in recent years, such as a decline in the prosperity index of the country, a decline in GDP per capita, a decrease in population, and deteriorating ecosystem status. The reasons for this decline in the social and economic life of the country were the unstable political situation in eastern Ukraine, the worsening of foreign relations with Russia and the loss of markets, the weakening of the country's position in the world market. However, the negative factors have given impetus to raising the level of basic human needs and availability of nutrition and basic medical care, which shows the E_i indicator, which during 2013–2019 showed both negative and positive dynamics of the country's development. As of 2019, the value of indicator E_i was 0.35 (Fig. 1). The results of statistical evaluation of indicators in 2013–2019 are shown in the Table 6.

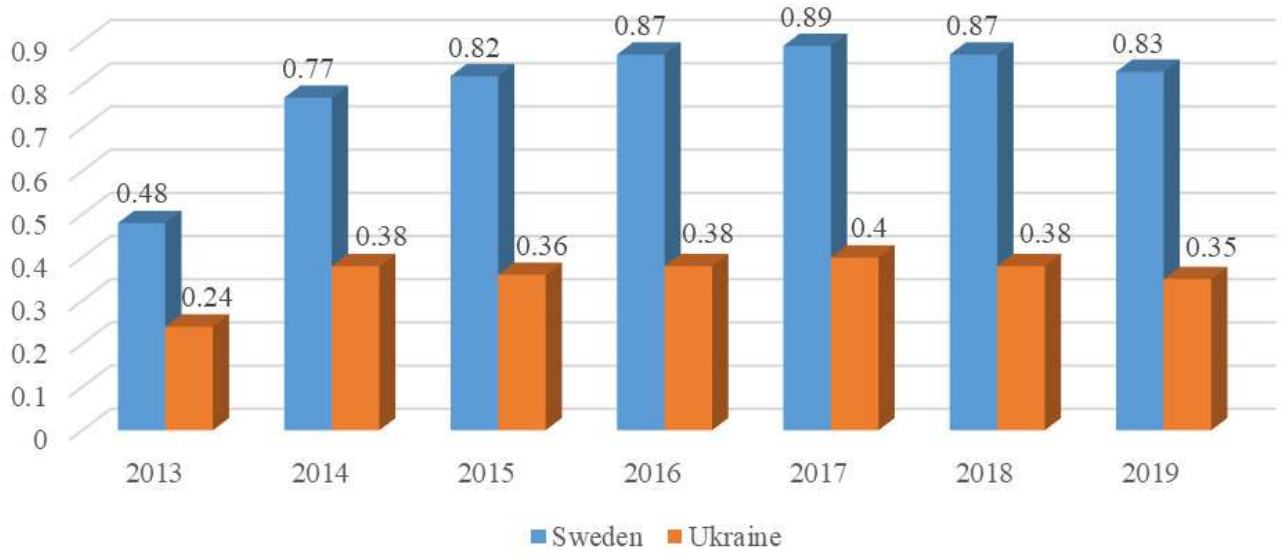


Fig. 1. Dynamics of the standardized values of European life quality index, 2013–2019 *(developed by the authors)*

Table 6. The results of statistical evaluation of indicators of Sweden and Ukraine for 2013–2019 *(developed by the authors)*

Indicators	min	max	max-min	coefficient of variation
I_{LP}	52.59	79.20	26.61	19.51
I_{Δ}	43.65	96.39	52.74	18.08
W_b	41.93	90.40	48.47	20.88
A_m^n	55.47	99.46	43.99	19.38
G_C	7906	52984	45078	73.18
D_G	37.70	81.20	43.50	30.86
P	9.645	45.246	35.601	64.52
R_U	6.30	9.70	3.40	13.78
I_{GC}	4.00	5.53	1.53	15.48
S_p	53.92	94.04	40.12	23.55
A_{bK}	59.89	98.89	39.00	13.86
E	36.73	92.81	56.08	36.41
E_i	0.24	0.89	0.65	43.28

The results of a statistical study show that the biggest differences between the two countries are observed in such indicators as “GDP per capita”, “population”, “ecosystem status”. Given the relatively high correlation between the index of sustainable development goals and the proposed index (>0.7), it should be argued that there is a close interaction. Considerable attention in Ukraine should be paid, accordingly, to the issue of restoring the country’s economic potential, as well as the protection of the natural environment.

Conclusion.

The proposed methodology is universal and provides an opportunity to determine the life quality index for any country, and its application allows to conduct rapid diagnostics and identify trends of further changes in the quality of life of the population. Also, this methodology allows for a comparative analysis of quality of life for selected countries and made it possible to compare the results obtained in dynamics. It is worth adding that the high population life quality is an indicator of sustainable development of the country. That is why active cooperation of the government of the country and the citizens is needed in order to support their own production, improve the infrastructure and create attractive living and working conditions for the population.

References

Buzko, I., Vartanova, O., Trunina, I., Khovrak, I., 2019. Theoretical aspects of regional sustainable development in the EU and Ukraine. Innovative Economic Symposium. 61, 01001. https://doi.org/10.1051/shsconf/20196101001

Calinescu, T., Likhonosova, G., Zelenko, O., 2017. Diagnostics of tearing away the democratic mechanisms of socio-economic development and adjusting of social dialogue in society. Journal of Economics, Management and Trade. 20 (3), 1–12. https://doi.org/10.9734/JEMT/2017/39657

Calinescu, T., Likhonosova, G., Zelenko, O., 2018. Estimation of conditions the realization of democratic mechanisms the transformation of society: tearing away and social dialog. Montenegrin Journal of Economics. 14 (1), 93–107. https://doi.org/10.14254/1800–5845/2018.14–1.7

CEIC Data: Macro & Micro Economic Data. Retrieved from https://www.ceicdata.com/en/indicator/

Chernega, O. B., Gorina, G. O., Romanukha, O. M., Bohatyryova, G. A., Nikolenko, K. V., 2019. Comparative analysis of the regional markets of cultural and cognitive tourism development in Ukraine. Journal of Geology, Geography and Geoecology. doi:10.15421/111904

Galloway, S., Bell, D., Hamilton, C., Scullion, A., 2005. Quality of Life and Well-being: Measuring the Benefits of Culture and Sport: Literature Review and Thinkpiece. Glasgow, Scottish Executive Social Research. 160.

Global Competitiveness Index. Retrieved from https://nonews.co/directory/lists/countries/global-competitiveness-index

Glonti, V., Trynchuk, V., Khovrak, I., Mokhonko, G., Shkrobot, M., Manvelidze, L., 2020. Socialization of Organization Sustainable Development Based on the Principles of Corporate Social Responsibility. Montenegrin Journal of Economics. 16 (1), 169–182. doi:10.14254/1800–5845/2020.16–1.11

Gorina, G., Barabanova, V., 2019. Marketing Aspects Of Developing Tourism Services Market In Ukraine & The Baltic Countriesweb Of Science. Baltic Journal of Economic Studies. doi:10.30525/2256–0742/2019–5–1–39–47

Kaigorodova, G., Alyakina, D., Pyrkova, G., Mustafina, A., Trynchuk, V., 2018. Investment Activity of Insurers and the State Economic Growth. Montenegrin Journal of Economics. 14 (4), 109–123. https://doi.org/10.14254/1800–5845/2018.14–4.8

Karimi, M., Brazier, J., 2016. Health, Health-Related Quality of Life, and Quality of Life: What is the Difference? Pharmacoeconomics. 34 (7). 645–649. https://doi.org/10.1007/s40273–016–0389–9

Kasych, A., Breus, S., Khaustova, Ye., 2018. The Economic Security of Higher Education Institutions from the Perspective of International Competition. Baltic Journal of Economic Studies. 4 (5). 1–9. https://doi.org/10.30525/2256–0742/2018–4–5–1–9

Kasych, A., Vochozka, M., 2017. Conceptual provisions of the development of Ukrainian national innovation system. Scientific Bulletin of Polissia. 2, 16–23. https://doi.org/10.25140/2410–9576–2017–2–2(10)16–23

Kautonen, T., Kibler, E., Minniti, M., 2017. Late-career entrepreneurship, income and quality of life. Journal of Business Venturing. 32 (3), 318–333. https://doi.org/10.1016/j.jbusvent.2017.02.005

Khomenko, M., Pryakhina, K., Latyshev, K., 2019. Prospects for Development of Ukraine and EU in the Field of Renewable Energy Sources. RPTSS – International Conference on Research Paradigms Transformation in Social Sciences. doi:10.1051/SHSCONF/20196101008

Khovrak, I., 2013. Financing of innovative development: realities and prospects. Marketing and Management of Innovations 1, 229–235.

Maslak, O., Grishko, N., Vorobiova, K., Hlazunova, O., 2018. The optimization of the management mechanism of the intellectual capital of Ukraine. Marketing and Management of Innovations. https://doi.org/10.21272/MMI.2018.1–12

Nenkov, N., Sushchenko, O., Dyachenko, Y., 2017. Role of chief information officer within the system of human resource development in service organizations (tourism). Economic Annals-XXI. https://doi.org/10.21003/EA.V165–20

Onyshchenko, O., Yudenko, Y., Levytska, I., Rarok, O., Pokotylska, N., Korbutiak, A., 2020. Logistical component of sustainable development of regions in the context of decentralization processes: Ukranian case. Independent Journal of Management & Production. 11 (9). doi:10.14807/IJMP.V11I9.1423

Pochtovyuk, A., Zagirniak, D., Pryakhina, K., 2017. The Problems of Training of Highly Skilled Engineers in Ukraine in the Context of International Tendencies. International Conference on Modern Electrical and Energy Systems (MEES). doi:10.1109/MEES.2017.8248927

Polinkevych, O., 2016. Factors of enterprises' outstripping development in conditions of global economic crisis. Economic Annals-XXI. doi:10.21003/EA.V156–0013

Polishchuk, Y., Kornyliuk, A., Britchenko, I., 2019. University as a core of e-learning ecosystem. 14th Conference on E-Learning – Unlocking the Gate to Education around the Globe. 309–319.

Schalock, R. L., Verdugo, M. A., Gomez, L. E., Reinders, H. S., 2016. Moving Us Toward a Theory of Individual Quality of Life. American Journal on Intellectual and Developmental Disabilities. 121 (1), 1–12. https://doi.org/10.1352/1944–7558–121.1.1

Sitnicki, M., 2018. Determining the Priorities of the Development of EU Research Universities Based on the Analysis of Rating Indicators of World-Class Universities. Baltic Journal of European Studies. 8/1 (24), 76–100. doi:10.1515/bjes-2018–0006

Sitnicki, M., Netreba, I., 2020. Interdependence Assessing for Networked Readiness Index Economic and Social Informative Factors. Baltic Journal of Economic Studies. 6 (2), 47–53. doi:10.30525/2256–0742/2020–6–2–47–53

Slottje, D., 2019. Measuring The Quality Of Life Across Countries: A Multidimensional Analysis. London: Routledge, 290.

Social Progress Index, 2013–2019. Retrieved from https://www.socialprogress.org/

Statistics of the countries of the world. Retrieved from http://svspb.net/sverige/statistika-stran-mira.php

Sushchenko, O., Trunina, I., Klok, O., Loseva, O., 2019. Management technologies of ensuring environmental protection as the territory development strategic priority. in RPTSS – International Conference on Research Paradigms Transformation in Social Sciences. doi:10.1051/SHSCONF/20196101026

Trunina, I., Khovrak, I., 2019. Harmonization of the Interests of Employers and Institutions of Higher Education as a Basis for the Sustainable Regional Development. in Proceedings of the Ieee International Conference on Modern Electrical and Energy Systems. https://doi.org/10.1109/MEES.2019.8896688

UN Sustainable Development Goals. Retrieved from https://sustainabledevelopment.un.org/?menu=1300

Vischer, J. C., Wifi, M., 2017. The Effect of Workplace Design on Quality of Life at Work. In: Fleury-Bahi, G., Pol, E., Navarro, O. (eds). Handbook of Environmental Psychology and Quality of Life Research. International Handbooks of Quality-of-Life. Springer, Cham, 387–400.

Vymiriuvannia yakosti zhyttia v Ukraini analitychna dopovid. 2013. [Measuring the quality of life in Ukraine: an analytical report]. Kyiv. Ptoukha Institute for Demography and Social Studies of the National Academy of Sciences of Ukraine, 50. (In Ukrainian)

Wedgeworth, M., LaRocca, M., Chaplin, W., Scogin, F., 2017. The role of interpersonal sensitivity, social support, and quality of life in rural older adults. Geriatric Nursing. 38 (1), 22–26. https://doi.org/10.1016/j.gerinurse.2016.07.001

Journal of Geology, Geography and Geoecology

ISSN 2617-2909 (print)
ISSN 2617-2119 (online)

Journal home page: geology-dnu.dp.ua

Journ. Geol. Geograph. Geology, 30(4), 781–793.
doi: 10.15421/112172

From paleontological collections to the Paleontological Museum of Lviv University as an object of historical, cultural and natural values

Yaryna M. Tuzyak, Antonina V. Ivanina, Halina I. Hotsanyuk, Ihor V. Shaynoha, Andrii Ya. Cherniak

Ivan Franko National University of Lviv, Lviv, Ukraine, yarynatuzyak@gmail.com

Received: 02.10.2021
Received in revised form: 26.10.2021
Accepted: 09.11.2021

Abstract. The creation of the Paleontological Museum of Lviv University is the implementation of one of many projects of scientists of geologists and paleontologists in the territory of first Eastern Europe, and later modern Western Ukraine. The foundation of the «temple of muses» of geological sciences (natural sciences, Earth sciences) and their component of paleontology in the West of Ukraine is the stage of formation of geological (paleontological) research and the Lviv geological (paleontological-stratigraphic) school at the Lviv University. The beginning and development of natural sciences – geology and paleontology on a global scale became the basis for the creation of the Geological Faculty and the Department of Historical Geology and Paleontology (1945) at the Lviv University, and the Geological/Paleontological Museum acquired importance in the study, collection, conservation, protection, and popularization of Earth Sciences among various segments of the population. The history of the foundation and the development of the Geological/Paleontological Museum of Ivan Franko National University of Lviv is covered. Prerequisites that contributed to the foundation of the Paleontological Museum are given, the scientific and theoretical concept based on it, the directions of research and the results of achievements of each stage are substantiated. The museum place in the «spectrum» of historical, cultural and natural values has been clarified. The scientific research works of different generations of geologists and paleontologists over the 200-year history and their contribution to the development of Earth Sciences were analyzed. Its significance as a cultural and spiritual center for the development of society is highlighted. The description of the activity of the scientific goals of various political systems in which the territories of the West of Ukraine were located and their contribution to the development of the Paleontological Museum is given. The structure and classification of natural objects (fossils, naturals) of museum collections and foundations by purpose and significance have been determined. Modern and further trends in the development of the Paleontological Museum have been clarified. Fundamental, research, educational and informative, cultural, propaganda aspects of the Paleontologic Museum are shown.

Keywords: Paleontological Museum of Lviv University, fossils, naturalia, museum collections, expositions, foundations.

Від палеонтологічних колекцій до Палеонтологічного музею Львівського Університету як об'єкта історичних, культурних і природних цінностей

Я. М. Тузяк, А. В. Іваніна, Г. І. Гоцанюк, І. В. Шайнога, А. Черняк

Львівський національний університет імені Івана Франка, Львів, Україна, yarynatuzyak@gmail.com

Анотація. Створення Палеонтологічного музею Львівського Університету – це втілення в життя одного із багатьох проектів науковців геологів й палеонтологів на теренах спочатку Східної Європи, а згодом сучасної Західної України. Заснування «храму муз» геологічних наук (природничих наук, Наук про Землю) і їх складової палеонтології на Заході України – це етап становлення геологічних (палеонтологічних) досліджень та Львівської геологічної (палеонтолого-стратиграфічної) школи у Львівському Університеті. Започаткування і розвиток природничих наук – геології й палеонтології у світовому масштабі стало підгрунтям для створення Геологічного факультету й Кафедри історичної геології та палеонтології (1945) у Львівському Університеті, а Геологічний/Палеонтологічний музей набув важливого значення з вивчення, колекціонування, збереження, охорони, і популяризації Наук про Землю серед різних верств населення. Висвітлено історію заснування і розвитку Геологічного/Палеонтологічного музею Львівського національного університету імені Івана Франка. Наведено передумови, які сприяли закладенню Палеонтологічного музею, обгрунтовано науково-теоретичну концепцію, покладену в його основу, напрями досліджень і результати досягнень кожного етапу. З'ясовано місце музею у «спектрі» історико-культурних і природних цінностей. Проаналізовано науково-дослідний доробок різних поколінь геологів й палеонтологів за 200-річну історію та їхній внесок у розвиток Наук про Землю. Висвітлено його значення як культурного й духовного центру для розвитку суспільства. Схарактеризовано діяльність наукових осередків різних державних устроїв, в яких перебували терени Заходу України, та їхній внесок у розвиток Палеонтологічного музею. Визначено структуру й класифікацію природних об'єктів (фосилій, натуралій) музейних колекцій і фондів за призначенням та значимістю. З'ясовано сучасні й подальші тенденції розвитку Палеонтологічного музею. Показано фундаментальний, науково-дослідний, навчально-пізнавальний, культурно-освітній, просвітницький, пропагандистський аспекти Палеонтологічного музею.

Ключові слова: Палеонтологічний музей Львівського Університету, фосилії, натуралії, музейні колекції, експозиції, фонди.

The Nature has taken care of everything, that everywhere you find something to learn.

Leonardo da Vinci

We are becoming less university museums and more universities in museums.

M. King

The highest value of human knowledge is to understand the Creator's purpose.

Ya. Tuzyak

Introduction

Museums are a treasury of historical, natural and cultural heritage, and museum exhibits are carriers of invaluable information about the history, nature and culture of the region. The main task of museums of a new type or «third generation museums» is to fulfill not only the traditional function of being scientific and spiritual centers, but also museums that offer a new vision, a new understanding, new acknowledgement of a particular problem, museums that develop, produce and promote new ideas.

The Paleontological Museum of Lviv University is the «Temple of Muses» of the Earth Sciences, collecting, storing, exhibiting the remains of flora and fauna (95 %) – the creations of Nature, most of which are preserved in stone. They represent a value as an evidence of life existing on the planet Earth hundreds, millions and billions of years ago, are reliable indicators of habitats, tools for reconstructing paleoecosystems of past geological eras and their position in space and time, tools for determining the relative geological age of rocks. In addition, well-preserved fossils create an idea of the morphological features of organisms that lived in the distant past, their way of life. They also play a major role in elucidating the «biography» of the Earth – a sequence of events reproduced by scientists in the completeness of the geological and paleontological record. And at the present stage, biotic events occupy an important place (out of 100 stages of the International chronostratigraphic chart (ICC) in 77, the geological boundary is determined by biotic criteria, most of which are primary, and in other cases, when the primary marker is abiotic, paleoorganisms have the role of secondary markers). Sedimentary rocks of biogenic origin (organogenic limestones, marbles) are a unique natural decorative stone that has been widely used later in architecture and construction (lining, decoration, paving, construction, carving sculptures, interior objects, etc.). Historical and architectural monuments have been erected from this material that belong to the historical and cultural heritage of the national and world importance (UNESCO). In particular, the ensemble of the historical center of Lviv was included into the the UNESCO World Heritage Register in 1998. A significant part of the city's engineering structure has been erected or has a natural decorative stone in its interiors. Fragments (samples) of these stones form a separate exposition in the Paleontological Museum of the Lviv University.

Today, as a result of the temporarily occupied territories (in particular, the annexation of the Autonomous Republic of Crimea by the Russian Federation) and the introduction of quarantine restrictions due to the spreading of the COVID-19 pandemic, visiting and studying the natural eco-morphodynamic systems of certain regions of Ukraine during training practices (field stage) and research expeditions has become limited or impossible. Also, the territories of the Nature Reserve Fund of Ukraine become difficult to study and select individual paleontological objects. Active business development and excessive use of the Earth's subsoil in order to seize the natural resources of various origins for the growth and strengthening of the mineral resource base of Ukraine led to the destruction, and in some cases complete extinction, of unique and unrepeatable natural eco-morphodynamic systems that cannot be recreated. All this increases the importance of museum collections as the sources of information and natural monuments. In addition, Paleontological museums store unique and rare fossil forms that exist on planet Earth in a single copy, or are known only in a few places. And this, in turn, makes it possible to consider museum collections and museums in general, not only as a national scientific asset (historical, memorial), but also as a separate type of geological property objects – paleontological natural monuments.

In the process of analyzing published sources, it was found that the emergence of the Geological/ Paleontological Museum, first in Eastern Europe, and subsequently in the West of Ukraine at Lviv University, has a long history, is closely connected with the stage of formation of geology and its component of paleontology on a global scale (Bilonizhka, Matkovsky, Pavlun', Slyvko, 2010; Bilonizhka, Matkovsky, Pavlun', Slyvko, Ivanina, 2020; Vyalov, Venglinsky, Golev, Goretsky, Gorbach, Kudrin, 1956; Leschukh, Ivanina, Hotsanyuk, Shainoha, Tuzyak, 2006; Tuzyak, 2021; Tuzyak, 2021a; Tuzyak, 2021b, etc.). An outstanding role in the establishment of these studies belongs to the city of Lviv – the main cell where the institutions involved in the geological study of the territory of Eastern Europe, the creation of the Geological Atlas of Galicia ("Atlas geologiczny Galicyi". 1884–1911. Scale 1:75 000), the first finds and collections of fossils are concentrated (19th century, 1825–1850).

The aim of the study.

The purpose of the article is to highlight the foundation first of the Geological and later the Paleontological Museum of Lviv University in Western

Ukraine, the history of the formation and development of the «temple of muses» of geological/paleontological sciences, the contribution of researchers in geology and paleontology of different generations and periods in the development of Earth sciences, modern trends and the place of the Paleontological Museum in the system of historical, cultural and natural values.

The article states:

1. Prerequisites for the emergence of the Geological and later Paleontological Museum of Lviv University.
2. Stages of formation and development of the Geological/Paleontological Museum in the West of Ukraine.
3. Directions of development and activity of the Geological/Paleontological Museum of Lviv University for 200-year period.
4. Analysis of published works using museum funds (collections) as research objects.
5. The results of research on fossils in the West of Ukraine and beyond.
6. Contribution of researchers in geology and paleontology of different generations and periods in the process of formation and development of the Geological/Paleontological Museum.
7. Classification of museum collections and foundations by purpose and significance.
8. Substantiation of the uniqueness, rarity and value of museum exhibitions and collections.
9. Modern and further trends in the development of the Paleontological Museum.
10. The place of the Paleontological Museum of Lviv University in the system of historical, cultural and natural values.

Materials and methods

The material for writing the article was a review and analysis of the collections and funds of the Paleontological Museum of Lviv University, publications on these topics, regulatory acts, laws and regulations.

In the study of the history of systematization of fees and funds of the Paleontological Museum, classification of exhibition and exhibition collections, determination of their significance and justification as the objects of National and Natural (Geological) Heritage, the main methods were statistical, comparative-historical, regulatory, modern information technologies.

Over the almost 200-year history of the formation of the Geological/Paleontological Museum of Lviv University, information about it was published in the form of short messages – theses of conferences (Voloshynovska, Hotsanyuk, Ivanina, Leschukh, Maryash, 2015; Voloshynovska, Hotsanyuk, Leschukh, Ivanina, 2004; Tuzyak, 2021; Tuzyak, 2021a; Tuzyak, 2021b, etc.), articles in periodicals and reference publications (Bilonizhka, Matkovsky, Pavlun', Slyvko, 2010; Bilonizhka, Matkovsky, Pavlun', Slyvko, Ivanina, 2020; Leschukh, Ivanina, Hotsanyuk, Shainoha, Tuzyak, 2006, etc.), guides (Vyalov, Venglinsky, Golev, Goretsky, Gorbach, Kudrin, 1956), popular scienticif publications. However, there is insufficient information about museum collections and funds among the published materials, which are replenished annually due to the field stages of training practices, research expeditions, geological excursions, gifts, etc., the issue of assessing their value is not adequately covered. At the present stage, the disclosure of various areas of activity of the Paleontological Museum is relevant in order to clarify its place in the system of historical, cultural and natural values to justify the granting of the status of the National Heritage. The priority in this direction is to highlight the importance of museum funds and collections at the national level, for universities and various segments of the population. At the national level, these are unique fees and territories, unique in their kind. Each individual Paleontological Museum (or paleontological department in the Natural Museum) has its own history of formation and development, the number and value of collections, consisting in their uniqueness, and its own research work with outstanding figures. For higher education institutions – this institution which should be stored and protected for the real and future generations for the purpose of carrying out research, educational and informative, educational and cultural, popularizing activity. Museums are one of the means of combating the deculturation of the population – an understanding of the culture of their people, natural wealth and historical values, outstanding figures of a particular field of sciences.

At the present stage, the cultural and creative function of higher education institutions (including museums as their components) is to combine three elements: technology (widespread introduction of innovative technologies), talent (attracting creative personalities who can produce new knowledge) and tolerance (perception of new ideas and concepts). It is gaining active development in those regions that are the cells of universities where the so-called concept of «Three T» by Richard Florida is present (Muravska, 2018). The creation of a creative personality is possible provided that the development of an innovative infrastructure is ensured as a means of transmitting research, ideas and approaches. Such centers are institutions of higher education (including museums), which accumulate monuments and treasures of nature, human culture, etc., promote knowledge not only for their community, but also for various segments of the population, innovative means. Such institutions support local communities with their experience and knowledge, promote scientific

knowledge, contribute to the development of academic values, and revive urban life, in particular by organizing exhibitions and events. These projects, in turn, contribute to the development of cultural tourism. And the greater the share of university representatives in the demographic structure of the city, the greater the role the institution will play in outlining its cultural image. It should be added that the Paleontological Museum, on a limited area, presents such a variety of fossils «in space and time» that is impossible in a natural environment. This helps to attract museum collections to the educational process.

Results

Milestones of the history of formation and stages of development of the Paleontological Museum of Lviv University. The Paleontological Museum of Lviv University is one of the oldest museums in Eastern Europe, the foundations of which were laid in the first half of the 19th century, and the only institution in Ukraine with the largest number of exhibits (in other Natural Museums of Ukraine, collections of fossils form separate departments or exhibitions). Museum funds and collections count more than 18 thousand units of rare, valuable and unique paleontological and geological samples found in different-age sediments of all continents. They reflect the research developments of more than one generation of geologists and paleontologists working at Lviv University from the time of its foundation until today and can be considered as the scientific, cultural and memorial Heritage of Ukraine.

Four prerequisites contributed to the emergence of the Paleontological Museum – as an independent structural unit of Lviv University: 1) the first paleontological collections begun in the first half of the 19th century, related to the geological study of the territory of Eastern Europe and the creation in the second half of the 19th century. Geological Atlas of Galicia, the accumulation of the first actual (geological and paleontological) material; 2) replenishment of museum funds with collections of famous geologists and paleontologists of various periods, creation of new expositions; 3) the formation of geology and its component of paleontology as a science at Lviv University; 4) the foundation of the Lviv Paleontological and Stratigraphic School, the Lviv branch of the Paleontological Society (1951), the beginning of the publishing house «Paleontological Collection» (1961) in the West of Ukraine.

The prerequisites for the development of Natural Museums in general and the Geological/Paleontological Museum in particular, in the world and domestic dimension, laid the foundation for the first educational centers with the awareness of the museum as an educational institution and the promotion of natural values and natural sciences. Today, the activities of the Paleontological Museum can be outlined by a model: science – education – popularization.

The formation of the Geological/Paleontological Museum covers a 200-year development period and has the following characteristics:

A long (almost 200 years) and complex history of formation and development. According to state devices political systems in the region (Austro-Hungarian – 1772–1918, Polish – 1918–1939, Soviet – 1939–1991, and modern, Ukrainian – since 1991 until now), the collection and study of fossils were carried out by researchers of different generations and nationalities – Austro-Hungarians, Poles, Russians, Ukrainians, etc. Among them are Z. Pazdro, V. Zych, V. Rogala, R. Zuber, Ya. Charnotsky, B. Kokoshynska, L. Gorbach, V. Kudrin, V. Sheremeta, O. Vyalov, V. Goretsky, Ya. Kulchitsky, R. Leshchukh, A. Ivanina, V. Uziyuk, etc.

A significant stratigraphic range of deposits in which paleoorganisms (macro- and microfossls) are found. Museum collections and works published over 200 years contain information about fossils floras and faunas, the age-old interval of which covers almost the entire Phanerozoic part and the upper part of the Precambrian (Vendian/Ediacaran) and ranges from 670–540 Ma ago to this day.

Research and identification of remains in various structural-tectonic elements of the sedimentary cover of Ukraine and the World (platform and complex areas).

Significant geography of paleontological remains – come not only from the territory of Ukraine, but also from regions of other continents.

Use of museum exhibits for research, educational and popularization purposes.

Since foundation until present time, three stages in the history of the Geological/Paleontological Museum can be distinguished.

1. Austro-Hungarian-Polish (early 19th centuries – 1939). The basis of museum foundation at that time was the collection of remains of paleoorganisms, founded in the first half of the 19th century (in 1825). The collections of the ancient fauna of the famous Austrian geologist Ludwig Zeischner were the first paleontological foundations, first (since 1852) exhibited in the Mineralogical Museum, and subsequently in the newly created Geological Museum. In 1905, on the basis of paleontological and geological collections, the foundation of the «temple of muses» of natural (geological) sciences was laid and an independent structural unit was created – the Geological Museum, initiated by Professor R. Zuber (the first head of the Department of Geology). During this period, museum collections were replenished with samples originating

from the expanses of Western and Eastern Europe and other continents.

2. Soviet (1939–1991). Museum funds were replenished as a result of educational and production practices, conferences, symposia, colloquiums and monographic collections of research works. At the same time, the museum's collections and exhibitions are used for research, educational and popularization purposes. Thanks to the events of this period, museum funds were replenished with exhibits originating from the regions of the former USSR.

3. Modern, Ukrainian (since 1991 until now). In 2004, by decision of the Academic Council of the University, the Geological Museum was renamed to the Paleontological Museum, since 95% of its museum exhibits are diverse remains of micro- and macrofossils of different age ranges. Collections of paleontological objects collected in the territory of Ukraine in the process of research, field stages of educational practices, conferences and gifts continue to be replenished. New expositions are decorated – «Routes of educational practices», «Fossils of the Neogene of Lviv and its environs». Every year, the museum is visited by more than 4 000 visitors – students of various educational institutions, students of schools, lyceums, colleges, tourists and guests of the city, Lviv residents.

Geological, and subsequently Paleontological Museum in different years was headed by (Fig. 1): R. Zuber (1905–1924), J. Siemiradzki (1924–1933), J. Samsonowicz (1935–1939), B. Kokoshynska (1939–1946), V. Goretsky (1946–1949), I. Venglinsky (1949–1953), Z. Khmilevsky (1953–1977), L. Kosarchyn (1979–1986), O. Voloshynovska (1986–2015), A. Danyliv (2015–2021).

Rudolf ZUBER
(1905–1924)

Józef SIEMIRADZKI
(1924–1933)

Jan SAMSONOWICZ
(1935–1939)

Bronisława KOKOSZYŃSKA
(1939–1946)

Vasil GORETSKY
(1946–1949)

Ivan VENGLINSKY
(1947–1953)

Zinovy HMILEVSKY
(1958–1978)

Ludmila KOSARCHYN
(1980–1985)

Olga VOLOSHYNOVSKA
(1986–2016)

Andriy DANYLIV
(2016–2021)

Hrystyna MEDVEDYEVA
senior laboratory assistant
(1962–1999)

Oxana KIRCHANOVA
leading custodian of funds
(since 1986)

Fig. 1. Heads and support staff of the Geological/Paleontological Museum of Lviv University.

The funds of the Paleontological Museum number more than 18 thousand exhibits from different parts of the world, the age range is from more than 600–540 Ma to modern representatives of fauna and flora.

Collections are exhibited in 6 halls (Departments of Systematic Paleontology, Historical Geology, Regional Paleontology, Anthropogen Biota, Paleoecology, Monographic Department, and new expositions are being prepared) (Fig. 2–7). The total area is 300 m^2, 72 windows and 16 stock cabinets are involved.

Fig. 2. Department of Systematic Paleontology. The exposition demonstrates the organization of life from the simplest (unicellular) forms to more complex (multicellular chord).

Fig. 3. Department of Historical Geology or Earth History. The exposition demonstrates the variety of forms and morphological features of the fossil of the corresponding geological era from Vendian (Ediacaran), Cambrian to Anthropogen.

Fig. 4. Anthropogenic Biota Department. The exposition demonstrates the variety of forms and morphological features of representatives of the modern world.

Fig. 5. Department of Paleoecology. The exposition demonstrates the variety of traces of vital activity (bioglyphs) and traces of the activity of physical factors of the environment (mechanoglyphs).

Fig. 6. Department of Regional Paleontology. The exposition demonstrates the fauna and flora complexes of the corresponding period of time of a single territory of Ukraine.

Fig. 7. Monographic department. The exposition shows collections gathered and studied in the process of research by geologists and paleontologists of different generations and periods.

At the present stage, the Paleontological Museum with a long history, unique exhibits and their number, attractions constitutes a system of material culture, the key elements of which are cultural (historical, memorial) and Natural Heritage. In addition, the Paleontological Museum can be considered as a component of museum studies (or museology). This is an interdisciplinary science that studies the laws of the development and functioning of museums, or a science that forms at the intersection of social and humanitarian knowledge and studies the laws of the genesis and functioning of the museum, its interaction with cultural and natural heritage, as well as society. One of the priority areas of research of the Paleontological Museum as a scientific and educational-cultural institution is the generalization of accumulated empirical material, the systematization of conclusions, the formation of the ideology of the modern museum. As R. Man'kovska (Man'kovska, 2009) notes today, the approach to understanding the subject of the museum has changed. Previously, the museum's significance of the subject was predetermined by its rarity, aesthetic value, memoriality, informativity, and the museum became more important for the subject. Today, a significant part of museologists believes that the museum should not be based on objects that belong to it, but on ideas that he wants to convey to the visitor. Therefore, recently, museology has more and more decisively brought to the fore the issues of the museum's content as an educational institution, its prospects, the influence on society and on the formation of public consciousness.

Paleontological Museum of Lviv University as an object of historical, cultural and natural values.

Museum collections formed in the walls of universities in different countries of the world have often become and become the basis of great modern national museums, that is, they first arose in universities and thanks to universities.

L. Samoylenko

Cultural heritage. In this context, the Paleontological Museum reflects the aspect of the formation of natural sciences at Lviv University and in the West of Ukraine, the contribution of a single generation of geologists to the development of geological and paleontological sciences. Museum funds document the processes and phenomena that occurred in the natural environment at different periods of geological time and had an influence on living organisms. The use of a materialistic worldview and a systemic approach in the knowledge of the Universe and planet Earth as a component of macro- and microspase contributed to the study of its structure, composition, processes and phenomena, and also influenced the formation of the main scientific concept of the Paleontological Museum, which consists in understanding and presenting:

1. Patterns of origin, organization, accumulation and localization of matter in space and time.
2. Patterns of emergence, development, functioning and interaction of modern and fossil ecosystems of various levels of organization and subordination.
3. Patterns of evolution of the biosphere and the biotic development on the Earth (in particular, morphology, lifestyle and environments of ancient organisms, their appearance and disappearance).
4. General patterns of the influence of environmental factors on living organisms, including humans.

Knowledge and understanding of these patterns, identification and assessment of threatening factors are the key to the conservation of natural resources and the health of the population with the prediction of their development and negative consequences.

Today, the collections of the Paleontological Museum can be classified by purpose into monographic, exposition, exhibition and educational ones; in importance – unique, rare and valuable.

Monographic paleontological collections (Fig. 7) are collections that have become the basis for paleontological studies of various scientific areas of natural disciplines (in particular, Earth Sciences) and are covered in publications (articles, review works, regional paleontological reports, monographs, atlases, directories, as well as manuscripts and reports) of scientists. Their uniqueness is determined by the presence of reference specimens of international importance – holotypes, lectotypes, neotypes, paratypes of fossil species, first discovered and described from the territory of Ukraine. The scientific and practical significance of monographic paleontological collections is the use of new paleontological collections in determining residues, substantiating the age of sediments, in further studying and comparing with them, and building models of sedimentary basins of different ranks.

Exposition and exhibition – collections that correspond to the thematic departments of the Paleontological Museum. For example, the department of systematic paleontology demonstrates the organization of life from the simplest (unicellular) forms to the more complex (multicellular chord) (Fig. 2). Department of Historical Geology – the exposition demonstrates the variety of forms and morphological features of the corresponding geological era from Vendian (Ediacaran), Cambrian to Anthropogen (Fig. 3). Department of Anthropogen Biota – the exposition demonstrates the variety of forms and morphological features of representatives of the modern world (Fig.

4). Department of Paleoecology – the exposition shows a variety of traces of vital activity (bioglyphs) and traces of the activity of physical factors of the environment (mechanoglyphs) (Fig. 5). Department of Regional Paleontology – the exposition demonstrates the fauna and flora complexes of the corresponding period of time of a single territory of Ukraine (local level) (Fig. 6).

Educational collections – individual fossils or their associations, which are used for independent (creative) work by students. The study of fossils complexes is of fundamental and applied importance. The fundamental is the justification of the allocation of local and regional stratigraphic units of various ranks and subordination, the determination of biostratigraphic criteria when comparing with the units of the ICC and the construction of models of sedimentary basins. It is applied in search of mineral deposits. In this context, fossils and geological sections (stratotypes) are a reference material that serves as an object for comparison with other analogues of the regions of Ukraine and the world, and forms a scientific and theoretical base for stratons allocation by stratigraphic methods, accumulation and localization of industrial mineral deposits in the lithosphere. This aspect determines the value and uniqueness of collections of regional paleontology. Such sections with a complex of fossils remains should have natural conservation status directly in the natural environment, presentation, and preservation in the Paleontological Museum for study, comparison and refinement in future studies.

Educational collections are individual fossils or their associations, which are the objects of study in the process of independent (creative) work of students. The collections of fossil remains of the Paleontological Museum are used in the educational process by students of geological, biological, geographical faculties and the Natural College of Lviv University, pedagogical specialties of other educational institutions. The structure and subjects of the Paleontological Museum are consistent with the training programs of courses on the basis of paleontology, systematic paleontology, historical geology, evolution of the biosphere, interesting paleontology, stratigraphy, biostratigraphy, paleoecology, sedimentology, paleogeography, methods of paleontological research, geoecology. The museum funds are constantly used in the educational process and during scientific work at the Geology Faculty.

Historical and memorial heritage. Paleontological (geological) objects are actual material or objects of scientific research, studied with the subsequent publication of the results in the field of natural sciences (in particular Earth Sciences) rightly form a scientific, historical and memorial heritage. Museum funds (collections, research works, old printed books) and other objects of the Paleontological Museum form the cultural and national treasure. They reflect not only the foundations of the foundation of the «temple of muses» of geological sciences in Eastern Europe, but also, starting from the 19th century, keep scientific research improvements (more than 250 scientific works) of more than one generation of world-class geologists (paleontologists) working at Lviv University for 200 years.

The publications can be classified according to the content as follows: 1) paleontological, devoted to the systematics and classification of fossil organisms, the description and illustration of new taxa (holotypes, neotypes, lectotypes, paratypes), the creation of atlases of taxa with their comparison with analogues of other regions; 2) stratigraphic, highlighting the problems of dismemberment and correlation of formations by fossils complexes, substantiation of rock age by comparison with ICC, determination of biostratigraphic value of fossil groups for the corresponding segment of geological time; 3) litho-facial, paleoecological and paleogeographic, the purpose of which is to clarify the habitat conditions of paleoorganisms, reproduce sedimentation and reconstruct the situation of continents and oceans; 4) climatic, dedicated to determining the distribution and position of climatic zones in space and time; 5) works of geological content clarifying the idea of structural-tectonic units of the territory of Ukraine and adjacent regions, an understanding of the processes and mechanisms of their formation; 6) works revealing the problems of nature conservation maintenance of the territory of Ukraine. These are, in particular, publications on geotouristic objects of natural origin (paleontological, stratigraphic) and historical and architectural monuments erected from natural decorative stones that form or can claim the status of a National or World Heritage. 7) Works of biographical content that illuminate the life and creative path of prominent figures, famous scientific researchers who have made a significant contribution to the development of the Earth Sciences; 8) popular science articles, the main purpose of which is the promotion of the university and museum.

At the present stage, the scientific and cultural refinement of the Paleontological Museum consists of more than 250 scientific (monographs, atlases, articles) (Vyalov, 1966; Goretsky, Venglinsky, 1979; Venglinsky, 1975; Leschukch, 1982; 1987; 1992; 1999; 2020; Sheremeta, 1969, etc.), educational and methodological (determinants, manuals), information and reference publications, guides, biographical messages. All this together reproduces the history of the formation and periods of development of natural sciences in the West of Ukraine, which should be preserved for the next generations, each time replenishing with new artifacts.

Nature-conservation heritage. In this context, the paleontological collections of Natural (Paleontological)

museums as natural monuments have a significant advantage (Anfimova, 2011). The museum, on a limited area, presents such a variety of fossil remains «in space and time» that it is not possible to detect in a natural environment. This contributes to the involvement of museum collections in research, educational and cognitive processes and the popularization of the scientific direction of paleontology among various segments of the population. The nature-conservation significance of the paleontological collections of the Paleontological Museum of LNU is that they: 1) contain objects not only discovered on the territory of Ukraine, but also beyond its borders – significant geography of the remains distribution; 2) cover a significant age (stratigraphic) interval – from billions of years to modern representatives of fauna and flora; 3) found in various structural-tectonic elements of the sedimentary cover of Ukraine and the World (platform and complex areas); 4) retain representatives of the organic world of those territories that are impossible to access at the present stage as they are destroyed (natural or artificial) outcrops, reforming the coal industry and creating industrial parks based on them (The concept of reforming the coal industry…, 2020), features of the geological structure – «closeness» of the territory (deposits at significant depths and opened exclusively with the help of wells), limited access to the territories of the nature reserve fund, the location of sections from which fossils were selected, in the territories of other countries; 5) constitute the scientific-theoretical (fundamental) and applied base of geological sciences (Earth sciences).

The Paleontological Museum stores reference samples (holotypes) – first discovered and described from the territory of Ukraine, which are of the world importance. Among them there is the collection of traces of the life of O.S. Vyalov, the objects discovered and described come from the Miocene molasses of the Pre-Carpathian region (Vyalov, 1966, etc.). Today, only a few of such places are known – these are Hungary, Death Valley (USA), Kazakhstan). The remains of the mammoth (teeth, tusks, blades, ribs, feet, cervical vertebrae, parts of the spine, front and hind limbs), found in the vicinity of Lviv and in the quarry with Alekseevka, Mykolayiv region; the variety of fossils from Silurian of the Volyn-Podillya, the sections of which are considered the reference for the East European platform and the best in the world, and can claim world recognition; a collection of fossils from Jurassic lithographic shales, Zolengofen (Germany), an exhibit of one of which is stored in the Paleontological Museum of LNU; fossils from the global stratotype of Devonian deposits of the Czech Republic in the exposition of the Paleontological Museum of the LNU; collections of Mesozoic and Cenozoic invertebrates from the Paris basin, Western and Eastern Carpathians (Leschukch, 1982; 1992), Mountain and Plain Crimea (Leschukch, 1987; 1992; 1999; 2020); a collection of flora samples from coal deposits in the Czech Republic, England, USA, Canada; a collection of fish from deposits from different countries of the World (remains of shellfish from the lower Devonian of Scotland, a cemetery of Devonian primitive fishes from Volyno-Podillya; a collection of fish remains from the menilite shales of the Carpathians a collection the tools of an ancient man (flint nuclei, pointed arrows, knives, scrapers, sickles, incisors, hammers). etc.) found in different places in Western Ukraine, etc.

Conclusions

In the modern sense, the Paleontological Museum is a structural unit of Ivan Franko National University of Lviv – a special socio-cultural multifunctional institution in the natural science field, which collects, explores, studies, exhibits and preserves natural monuments (paleontological exhibits) – collections of fossils (fossils of biogenic origin) (the vast majority) and other natural objects (geological and mineralogical), etc. for the purpose of implementation research, educational and informative, cultural and educational, popularization and propaganda (advertising) and environmental activities, as well as it can be considered as a center of innovative technologies.

Over the almost 200-year history of the existence of the Paleontological Museum of Lviv University, its museum funds and collections have been significantly replenished. Every year, the museum receives interesting, unique and rare exhibits that deserve the attention not only of scientists as the objects of research, but also of ordinary visitors as evidence of life. In recent years, Natural Museums (including Paleontological ones) have become relevant as various segments of the population familiarize themselves with the creations of Nature and evidence of life. In a limited area (several hundred square meters), an incredibly rich variety of fossils (naturals) are concentrated – natural objects of various degrees of the matter organization (life). Given this, museums can be considered as a separate category of natural monuments as a part of the Geological Heritage of Ukraine (Anfimova, 2011) or, even, the World Heritage.

According to all criteria – the long history of formation and development, the scientific and theoretical concept underlying the functioning of the museum, the uniqueness, rarity and value of museum collections and foundations, research potential, significance for society and science, the Paleontological Museum deserves an honorary place in the Historical, Cultural and Natural Heritage of Ukraine. The loss of such an object will have negative consequences for the development of science and society.

Referenses

Anfimova, H. V., 2011. Paleontologichni kolekciyi yak geologichni pam'yatnyky (na prykladi Krymc'kogo region). [Paleontological collections as geological monuments (using the example of the Crimean region)]. Geologichni pam'yatky – yaskravi svidchennya evoluciyi Zemli: zb. mater. II Mizhnar. nauk.-prakt. konf. Kyiv: Logos. 14 (In Ukranian).

Bilonizhka, P., Matkovsky, O., Pavlun', M., Slyvko, E., 2010. Geologichny fakultet Lvivskoho natcional'noho universytetu imeni Ivana Franka (1945–2010). [Geological Faculty of Ivan Franko National University of Lviv (1945–2010)]. Dovidkovo-informaciyne vydannya. Lviv: Vydavnychy tcentr LNU im. I. Franka. 518 p. (In Ukranian).

Bilonizhka. P., Matkovsky, O., Pavlun', M., Slyvko, E., Ivanina, A., 2020. Geologichny fakultet Lvivskoho natcional'noho universytetu imeni Ivana Franka (1945–2020). [Geological Faculty of Ivan Franko National University of Lviv (1945–2020)]. Dovidkovo-informaciyne vydannya. Lviv: Vydavnychy tcentr LNU im. I. Franka. 208 p. (In Ukranian).

Venglinsky, I. V., 1975. Foraminifery I biostratigraphiya miocenovych otlozheniy Zakarpatskogo progiba. [Foraminifera and biostratigraphy of Miocene deposits of the Transcarpathian deflection.]. Kiev: Nauk. dumka, 1975. 263 p. (In Russian).

Voloshynovska, O., Hotsanyuk, H., Ivanina, A., Leschukh. R., Mar'yash, I., 2015. Paleontologichnomu muzeyu u Lvivskomu natcional'nomu universyteti imeni Ivana Franka – 110 rokiv. [Paleontological Museum at Ivan Franco National University of Lviv – 110 years]. Materialy XXXVI sesiyi Paleontologichnoho tovarystva NAN Ukrainy "Stratotypovi rozrizy phanerozoyskyh vidkladiv Ukrainy: suchasny stan paleontologichnoyi vyvcheyjsti ta perspektyvy podalshyh doslidzhen'" i "Paleontologichna osvita ta paleontologichni kolekciyi", 24–26 veresnya 2015 r., Lviv. Kyiv, 10–11 (In Ukranian).

Voloshynovska, O., Hotsanyuk, H., Leschukh. R., Ivanina, A., 2004. Paleontologiya at Ivan Franco National University of Lviv (80 rokiv kafedri istorychnoyi geologiyi ta paleontologiyi). [Paleontology at the I. Franko National University of Lviv (80 years in the Department of Historical Geology and Paleontology)]. Problemy stratygrafiyi phanerozoyu Ukrainy. Kyiv, 268–271 (In Ukranian).

Vyalov, O.S., Venglinsky, I. V., Golev, B. T., Goretsky, V. A., Gorbach, L. P., Kudrin, L. N., 1956. Geologichesky muzey Lvovskogo gosudarstvennogo universiteta im. Iv. Franko. (Kratkiy putevoditel'). [Geological Museum of Iv. Franko State University of Lvov (Short Guide).]. (In Ukranian).

Vyalov, O. S., 1966. Sledy zhyznedeyatelnosti organizmov i ich paleontologicheskoe znachenie. [Traces of the life of organisms and their paleontological significance.]. Kiev: Nauk. dumka, 165 p. (In Russian).

Goretsky, V. A., Venglinsky, I. V., 1979. Stratotipy miocenovych otlozheniy Karpatskich progibov I Volyno-Podolskoy plity. [Stratotypes of Miocene deposits of the Carpathian foredeeps and the Volhyn-Podolian plate.]. Kiev: Nauk. dumka, 264 p. (In Russian).

Koncepciya reformuvannya vugilnoi galuzi ta ekonomichnoyi I ekologichnoi transformaciyi vugilnyh regioniv Ukrainy do 2027 r. Zasidannya Koordynaciynoho tcentru z pytan' transformaciyi vugilnyh regioniv Ukrainy, 08.10.2020. [The concept of reforming the coal industry and the economic and environmental transformation of coal regions of Ukraine until 2027 Meeting of the Coordination Center for the Transformation of Coal Regions of Ukraine, 08.10.2020.]. 23 p. (In Ukranian).

Leschukh, R., Ivanina, A., Hotsanyuk, H., Shainoha, I., Tuzyak, Ya., 2006. Kafedra istorychnoyi geologiyi ta paleontologiyi. [Department of Historical Geology and Paleontology]. Dovidkovo-informaciyne vydannya. Lviv: Vydavnychy tcentr LNU im. I. Franka. 68 p. (In Ukranian).

Leschukh, R., 1982. Nyzhnyokreydovi amonity Ukrayinskych Karpat. [Lower Cretaceous ammonites of the Ukrainian Carpathians.]. Kyiv: Nauk. Dumka. 164 p. (In Russian).

Leschukh, R., 1987. Rannyokreydova fauna Rivnynnogo Krymu I Pivnichnogo Prychornomor'ya. [Early Cretaceous fauna of the Plain Crimea and the Northern Black Sea region.]. Kyiv: Nauk. dumka. 220 p. (In Ukranian).

Leschukh, R., 1992. Nyzhnya kreyda Zachodu I Pivdnya Ukrayiny. [Lower Cretaceous of the West and South of Ukraine.]. Kyiv: Nauk. dumka, 208 p. (In Ukranian).

Leschukh, R., 1999. Yurski vidklady Pivdnya Ukrayiny. [Jurassic deposits of the South of Ukraine.]. Lviv: Yevrosvit. 335 p. (In Ukranian).

Leschukh, R., Starzhynsky O., 2020. Mezozoyski vidklady pivdenno-zachidnoyi Ukrayiny i pryleglogo shelfu. [Mesozoic deposits of south-western Ukraine and the adjacent shelf]. Lviv: LNU imeni Ivana Franka. 220 p. (In Ukranian).

Man'kovska, R, 2009. Muzeologiya yak naukova galuz': suchsny dyskurs ta problema teoretychnogo integruvannya. [Museology as a scientific branch: modern discourse and the problem of theoretical integration]. Krayeznavstvo: naukovy zhurnal. Ch. 3–4. Kyiv, 136–144. (In Ukranian).

Muravska, S. V., 2018. Muzeyni zaklady u systemi vyschoyi osvity Zachidnoi Ukrainy na tli svitovyh tendentciy. [Museum institutions in the system of higher education of Western Ukraine against the background of world trends]. Tcentr pam'yatkoznavsnva NAN Ukrainy i UTOPIK. Lviv. 244 p. (In Ukranian).

Tuzyak, Ya. Paleontologichny muzey Lviv Natcionalnoho Universytetu na mezhi tysyacholit': istoriya, etapy stanovlennya, suchasny stan. [Paleontological Museum of Lviv National University on the verge of millennia: history, stages of formation, modern state]. International scientific and practical conference "Challenges, threats and developments in biology, agriculture, ecology, geography, geology and chemistry": conference

proceedings, July 2–3, 2021. Lublin,: "Baltija Publishing", 2021, 186–190 (In Poland).

Tuzyak, Ya. Conceptual and theoretical model of Natural Museums in the paradigm of modern education. The XXVI International Science Conference «Topical issues of practice and science», May 18–21, 2021, London, Great Britain. 2021, 150–153.

Tuzyak, Ya. Paleontological Museum of LNU: prerequisites for creation, formation stages, substantiation of the value of collections and expositions, its importance to society. The 2 nd International scientific and practical conference "Modern directions of scientific research development" (August 4–6, 2021) BoScience Publisher, Chicago, USA. 2021, 133–143.

Sheremeta, V. G., 1969. Ostrakody paleogena Ukrainy. [Ostracod of the Paleogene of Ukraine.]. Izd-vo Lvovskogo universiteta imeni Ivana Franko, Lvov. 261 p. (In Russian).

Journal of Geology, Geography and Geoecology

ISSN 2617-2909 (print)
ISSN 2617-2119 (online)

Journ. Geol. Geograph. Geology, 30(4), 794–807.

Journal home page: geology-dnu.dp.ua

doi: 10.15421/112173

Ukrainians in Belarus: distribution and ethnolinguistic processes

Andrii I. Zubyk

Lviv National Ivan Franko University, Lviv, Ukraine, andriy.zubyk@lnu.edu.ua

Received: 28.01.2021
Received in revised form: 08.02.2021
Accepted: 11.02.2021

Abstract. The article analyzes the distribution and ethnolinguistic processes in the environment of the Ukrainian diaspora in Belarus. Because of the fact that the part of Ukrainian ethnic territory (currently Brest region) is located in Belarus, not all Ukrainians living in the country can be correctly named a diaspora. To avoiding terminology-related complications, in the article we use the general term Ukrainian diaspora. The study is based on the results of censuses conducted in Belarus after 1991. The article analyzes the ethnic environment of residence of the Ukrainian diaspora based on the ethnocultural and ethnolinguistic criteria of the censuses. In particular, using mathematical and statistical methods of analysis of the ethnic composition of the country's population, we estimated such indicators as the index of ethnic diversity, ethnic mosaic, socio-ethnic density, etc. These indicators were estimated for districts and the largest cities of Belarus, taking into account the largest ethnic groups living in the country. The result of these estimations was the creation of a number of thematic maps that complement the article. The study highlights the areas of compact residence of Ukrainians, identifies districts and cities where the number of Ukrainians changed the most and the least during the inter-census periods of 1999–2009 and 2009–2019. The dynamics of the number and settlement of Ukrainians in the Ukrainian ethnic territories is analyzed. In this context, it was found that in addition to the Brest region, there is a dense concentration of Ukrainians in the capital, major cities of the country, a number of district centers in the southwestern part of the country. It was determined that the share of Ukrainians living in cities is growing. The growth rate of the number of Ukrainians for the period between 2009 and 2019 in the largest cities of the country ranges from + 7% (Mogilev) to 77.45% (Novopolotsk). It was found that the country is monoethnic in its ethnic composition based on the analysis of a number of indicators related to the ethnic composition of the population of Belarus. A more diverse ethnic composition of the population and therefore higher rates were recorded in large cities and areas densely populated with individual ethnic groups (Russians, Poles and Ukrainians). The Ukrainian diaspora in the country is undergoing processes of Russification, the share of Ukrainians who indicate Ukrainian as their mother tongue is declining. The share of Ukrainians whose native language is Belarusian is also declining. That is, it can be argued that Russification affects not only Ukrainians in Belarus, but also the Belarusians themselves. The research also revealed that villagers are more resistant to language assimilation, and Ukrainians in cities most often indicate Russian as their native language.

Keywords: Ukrainian diaspora, census of population, distribution, nationality, assimilation, ethnolinguistic processes.

Українці в Білорусі: розселення та етномовні процеси

Зубик А. І.

Львівський національний університет імені Івана Франка, Львів, Україна, andriy.zubyk@lnu.edu.ua

Анотація. Стаття присвячена дослідженню розселення та етномовних процесів в українській діаспорі Білорусі. Вихідними даними для цієї статті є результати переписів населення країни, проведених після розпаду Радянського Союзу. Аналіз здійснено за такими критеріями перепису населення, як «національність», «рідна мова» та «мова, якою розмовляють удома». Дані про національний склад населення в розрізі районів та найбільших міст Білорусі дали змогу обчислити та закартографувати індекс етнічного різноманіття, етнічної мозаїчності, показника соціоетнічної щільності, коефіцієнта етнічної спільності та етнічної компактності. У процесі дослідження встановлено, що попри тенденції скорочення чисельності української діаспори у країнах колишнього Радянського Союзу, чисельність українців у Білорусі зросла. Проаналізовано відносні та абсолютні зміни в розселенні українців у розрізі районів та найбільших міст країни, виділено території, де зафіксовано найбільші та найменші показники. Вдалося визначити, що порівняно з 2009 р. зросла частка українців, які проживають у містах. Виявлено, що найбільше частка українців, які проживають у містах, зростала на півночі країни та в Мінську. Це пов'язано з пошуком роботи та навчанням, тому осередками притягання є обласні центри та столиця країни, рідше – районні центри. В контексті дослідження етнічного складу з'ясовано, що Білорусь – моноетнічна країна, імовірність того, що у двох випадково обраних людей буде різна етнічна належність у більшості районів не перевищує 30%. У процесі дослідження етномовних критеріїв перепису (рідна мова та мова, якою розмовляють удома) виявлено, що відбуваються значні асиміляційні процеси в середовищі української діаспори. Передусім це втілюється в тому, що частка українців, які вважають українську мову рідною, зменшується, натомість позиції російської мови як рідної та мови домашнього спілкування лише посилюються. Також

встановлено відмінності щодо етномовних критеріїв за статтю та територією проживання. Зокрема українську рідною мовою частіше називають жінки, а українці, які проживають у містах, є більш русифікованими порівняно із сільськими жителями.

Ключові слова: українська діаспора, перепис населення, розселення, національність, асиміляція, етномовні процеси.

Introduction.

The Ukrainian Diaspora - as a phenomenon and integral part of the Ukrainian population - began emerging in the late XIX century when the first migrants from Ukraine started to seek a better life abroad. Two world wars, emigration because of fear of repression for political views and participation in armed struggle for independence only strengthened the emigration. It has not stopped even following the the declaration of independence, because Ukrainians had to emigrate due to economic problems. These processes have resulted in development of communities of Ukrainian migrants in Italy, Spain, Portugal and other countries. Modern migration of Ukrainians was at first illegal, complicating provision of legal help for them in the countries where they resided. Liberalization of immigration legislation in the recipient countries for Ukrainians has brought Ukrainian guest workers out of the shadows and provided them with legal status.

Communities of Ukrainian guest workers are beginning to transfer from marginal groups to diaspora. They obtained legal status and started receiving working or residency permits in the countries where they were staying, and soon afterwards – official employment. Those steps have increased the protection of their access to social services: legal and medical help, paid vacation, insurance of health and life, possibility of receiving pensions in the future.

Some Ukrainians became a diaspora as a result of ill-conceived processes of border division, when political interests of countries led to some ethnic territories of Ukraine being outside the Ukrainian border. Such communities were called “accidental diasporas” by American scientist R. Brubaker, who opposed those communities to labour migrants and “classic’ diasporas”.

One of the countries with numerous Ukrainian diasporas is Belarus. Despite the factors of a common border and old historical relationships between Ukraine and Belarus, the problems of distribution of Ukrainians in this country have not been studied sufficiently.

As a result of the processes of division between the countries which came about in the XX century, modern-day Belarus includes Berestia (currently Brest Oblast), which was incorporated into the country after a number of territories had been assigned to the Russian Federation. The issue of the Ukraine-Belarus border in the southwest and south parts of the country is still complex and not solved completely.

In view of the autochthonous Ukrainian population in Belarus, a pertinent question is also whether or not to consider the Ukrainians in this country a diaspora. To avoid confusion in naming groups of Ukrainians which live in Belarus, hereinafter we shall use term “Ukrainian diaspora” to indicate people who called themselves Ukrainians during the census.

Materials and methods.

The paper was based on the analyses of censuses of the population carried out in the 2020s round (Results of population census 1999, Results of population census 2009, Results of population census 2019), where, contrary to the tendencies toward decrease in the populations of Ukrainians in all the countries of the former Soviet Union, the number of Ukrainians in Belarus has gradually increased compared with the previous census. Such a tendency led us to analyze the results of the recent census in more detail and determine the factors that could influence this result.

Ethnicity is a characteristic of population which is difficult to measure statistically. This may be explained by the fact that ethnic identification depends on a number of external factors (state policy, prejudice toward certain nationalities, etc). Another aspect of this problem is the fact that ethnic identification is not a priority to many people, they do not think about whether or not they easily can unequivocally identify themselves (this concerns children born in mixed marriages).

Ukrainian sociologist and ethnologist Yevtukh V. B. gives the following definition of this term: ethnicity (Greek ethnos – people, tribe) is a term that indicates qualitative characteristics of a person or a group of people related to their ethnic origin, which manifest in everyday life, culture, behaviour, and mentality in general, confirming their origin and distinguishing them from among others. The term is often used to define an ethnic community, language and culture identity of a group of people (Yevtukh, 2012).

Tools that would be useful for such research are the methods of data analysis which can provide the index of ethnic diversity, indicator of socioethnic density, index of ethnic mosaic, coefficient of ethnic similarity, etc. Using ethnic diversity index (EDI) as a mean of researching racial and ethnic diversity in the USA was proposed by researchers P. Meyer and S. McIntosh. Unlike the indicator of the share of one or the other ethnicity in the population of a certain territory, this index allows a researcher to most efficiently use and interpret the results of censuses. This indicator shows the possibility of two randomly selected people in one city, region or country having different ethnic belongings.

Methods of estimating this index are based on two fundamental principles of probability theory: first, the likelihood of simultaneous occurrence of two independent events equals the derivative of possibilities of those events: P(AB)=P(A)*P(B); secondly, the probability that at least one of the two independent events will take place equals the sum of those probabilities: P(A+B)=P(A)+P(B). That is, based on those principles, the index of ethnic diversity is determined.

The index itself is calculated in several stages. The first is determining the share of each ethnic group in the population of the territory. The second is to the square this share. This parameter characterizes the probability that two randomly selected people would be of the same nationality. The third stage is summing the squared probabilities for each nationality and obtaining the final probability that two randomly selected people are of one and the same nationality.

The last stage is subtracting the previous stage from 1. The obtained parameter will be the probability that two selected people are the representatives of different ethnicities. If this value is multiplied by 100, integers can be used for convenience of further analysis:

$$EDI_j=(1-\sum_{i=1}^{E} P_{ij}2)*100 \quad (1)$$

where j – region, i – ethnic group in the region, E – overall number of ethnic groups in the regions.

Ethnic diversity index (EDI) may vary 0 (ethnically homogenous region) to 100 (complete diversity). Specifically, 0 value means that only one ethnic group is represented in the region, whereas an index equaling 100 may be interpreted as follows: the probability that two randomly selected people will be of the same ethnicity is zero. This index is often used to study the ethnic structure of a population and is usually considered as a statistical characteristic, because the analysis of the dynamics of ethnic groups requires additional estimations. It has to be noted that it is the simplest for estimation, but at the same time the least perfect, and therefore must be used in combination with other indicators.

The simplest statistical method of assessing component and territorial structures of a country's population is estimation and evaluation of absolute values and relative shares of ethno-national groups or groups of population according to mother tongue within the framework of country and regions, and also indices of their quantitative ratios. For this purpose, one may also use more complex indicators, which are based on ratio of specific weight of different subjects of ethnogeographic relations, specifically B. Eckel's index of ethnic mosaic, which is calculated using the following formula:

$$P_j=1-\sum_{i=1}^{k}(\pi)^2, \quad (2)$$

where P_j – index of ethnic mosaic, π – share of j ethnic group in the region's population, k – number of ethnic groups.

The advantage of Eckel`s index is its unambiguousness. Every settlement and administrative unit has a particular value of mosaic index regardless of complexes they are analyzed in. Eckel's index is interesting for comparing whether it is the dynamics of parameter or comparison of separate territories or settlements. It takes into account all ethnicities that live in this territory, but its value is affected only by the most numerous ones. This index is one of modifications of ethnic diversity index.

Similar methodological tasks may be solved using the index of socioethnic density:

$$I=(\sum_{i=1}^{k} n^2/N^2)*100, \quad (3)$$

where I is value of socioethnic density; n – number of population of an ethnic group in the country (region); k – number of ethnic groups; N – overall population of country (region).

Unlike the index of ethnic diversity that estimates the probability of contacts and takes into account relative indicators, the absolute indicators are used to estimate the indicator of socioethnic density. The closer this indicator is to 100, the more ethnically homogenous is the researched territory. This indicator of socioeconomic density is more useful than using the share of one or another ethnicity in the population, because it takes into account the number of other ethnicities and population of the entire country.

To study the compactness of distribution of ethno-national communities and groups, especially minorities, it would be efficient to use the coefficient of ethnic similarity which was proposed by Y. Lipiets:

$$K=K_1*K_2, \quad (4)$$

where K_1 is share of population of a certain ethnic group in the population of the entire region; K_2 – share of an ethnic group that lives in this region in the total number of this group in the country.

Differentiation of this indicator allows districts to be distinguished with high and low concentrations of the population of an ethnic group (Dnistrjans`kyj, 2008). Its application in researching the diaspora is more effective than using the share of Ukrainians in the overall population or share of Ukrainians living in the territory of a certain administrative unit in the overall number of Ukrainians in this country. That is, the coefficient of ethnic similarity depends on what share in the population one or the other ethnicity makes and what share of the entire population of this ethnicity is living in the territory.

A clear picture of distribution of Ukrainians in another country may be obtained using the coefficient of

ethnic compactness (K_{ek}). It complements the shares of Ukrainians in the overall population or share of Ukrainians in a certain region of the overall number of Ukrainians in the country, which we estimated. This coefficient is a modification of the previous formula:

$$K_{ec}=K_1/K_2, \quad (5)$$

where K_1 is the share of a certain ethnicity in a region's population; K_2 – share of representatives of this ethnicity in the region's population. If $K_{ec}\leq 0.5$ – ethnic compactness is expressed indistinctly; if $0.5<K_{ec}\leq 1$ – compactness is expressed quite distinctly; if $1<K_{ec}\leq 2$ – ethnic compactness is expressed distinctly.

Using the share of representatives of a certain ethnicity in the region`s population, in our opinion, is more practical than using this indicator for a country, because it somewhat alters the ultimate results.

Results and their analysis.

After declaring independence, three censuses were carried out in the country – in 1999, 2009 and 2019. Belarus is one of the few countries of the former USSR which follows the recommendations of the Eurostat (European Statistical Office) regarding the methods and time of conducting censuses. According to the results, 237,014, 158,723 and 159,656 Ukrainians were living in the country, respectively. Compared with the census of 1999, the number of Ukrainians in 1989 decreased by 18.6%, and in the inter-census period of 1999–2009, this parameter reached 33% (Results of population census 1999, Results of population census 2009, Results of population census 2019). However, the next period between the censuses, 2009–2019, indicated 0.6% increase in the Ukrainian diaspora.

The number of Ukrainians among the population of the country has been gradually decreasing since 1999 (according to the results of 1999 census, Ukrainians accounted for 2.36% of the overall population of Belarus). According to the results of the recent censuses, the share of Ukrainians was 1.67 and 1.7%, respectively. It has to be noted that the population of Belarus decreased from 10.045 M to 9.413 M people over the period from 1999 to 2019.

Despite living in ethnic Ukrainian territories, the share of Ukrainians in the population is stably low, as indicated by the results of censuses carried out in the Soviet Union. According to 1959 census, 133.1 thou Ukrainians were living in the country (1.6% of the overall population), 190.8 thou (2.1%) in 1970, 231 thou (2.4%) in 1979, 291 thou (2.9%) in 1989 (Zubyk, 2019).

That is, according to the most recent census, performed in 2019, the number of Ukrainians and their share in the population are similar to such of 1959. The population of Belarus in 1959 was 8.055 M people. Over the 60 years that passed between the censuses of 1959 and 2019, the country's population increased by 1.358 M people in absolute values, the number of Ukrainians – by 26.5 thou people. Taking into account the long period between those censuses, such an increase is insignificant. According to the results of the recent census, Ukrainians are the fourth ethnic group by number, after Belarusians, Russians and Poles (Ethnic composition…to the 1999 census, Ethnic composition…to the 2009 census, Ethnic composition…to the 2019 census). Ukrainians mostly live in Brest and Gomel Oblasts and Minsk, comprising 61% of all Ukrainians in the country (according to 2009 census, this parameter equaled 62%) (Fig. 1–3).

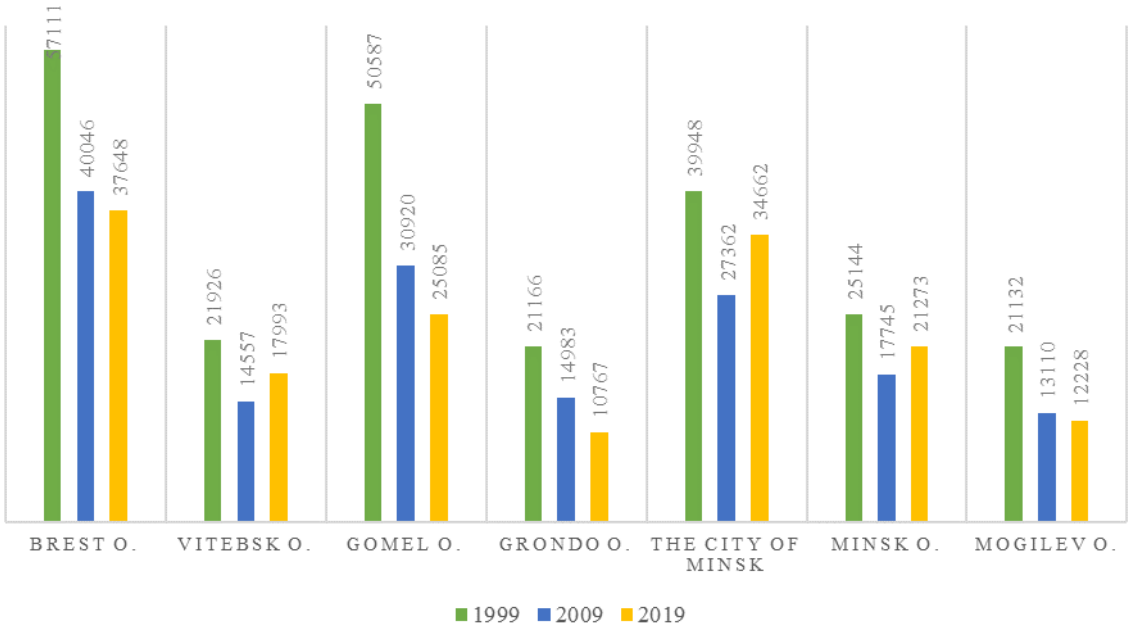


Fig. 1. Distribution of Ukrainians in the oblasts of Belarus according to the censuses of 1999, 2009, and 2019.

The areas of dense concentrations of Ukrainians are the southwest part of the country (districts of Brest Oblast which border with Ukraine), a strip of districts between cities of Minsk and Gomel with ramification to cities of Salihorsk and Mazyr. Also, there are concentrations of Ukrainians in the cities of Grodno, Lida, Barysaw, Vitebsk, Orsha and Polotsk, which are the centers of districts of the same names, where numbers of Ukrainians are large as well. In the largest cities – Brest, Baranovichy, Pinsk, Vitebsk, Novopolotsk, Orsha, Polotsk, Gomel, Grodno, Mogilev, Babbruysk and Minsk – 83,376 Ukrainians live, accounting for 68% of the overall number of Ukrainians who live in cities. According to the 2019 census, 90,418 Ukrainians were living in 11 cities, i.e. 72.5% of the overall Ukrainian population in cities (Zubyk, 2019).

According to the 2009 census, the urbanization of the Ukrainian diaspora was 77.2% (78.1% in 2019). In 51 districts, majority of the Ukrainians were living in villages, particularly 12 of 16 districts of Brest Oblast (12), 15 of 21 districts of Vitebsk (13), 7 of 21 districts of Gomel (7), 9 of 17 districts of Grodno (9), 7 of 22 districts of Minsk (12) and 8 of 21 districts of Mogilev oblasts (8), where 64.3% of the overall number of the Ukrainian rural population was living (*according to the 2009 census*).

Brest and Minsk oblasts qualitatively differ among the structures of the oblasts. In Brest Oblast, Ukrainians live in ethnic Ukrainian lands. The lowest level of urbanization of Ukrainians in Minsk Oblast is explained by the fact that most Ukrainians live in Minsk, which as the capital attracts people not only from the Oblast but from the whole country. Application of the similarity factor to Minsk or any other large city of the country shows that people prefer travelling to these places for study, work, services, etc.

Compared with the results of the 2009 census, the urbanization level manifested to a different extent across the districts. Increase in the share of Ukrainians living in cities was observed in the north of the country. In Brest Oblast and districts that border with Ukraine, the share of the Ukrainian urban population decreased. Across the largest cities of the country, the number of Ukrainians increased in Novopolotsk (+77.45% compared with 2009), Polotsk (+53.8), Orsha (+42.2), Zhodzina (+39.4), Minsk (+26.7), Vitebsk (+26), Brest (+16) and Mogilev (+7). The Ukrainian populations decreased in the cities Baranovichy (-10.1%), Babbruysk (-11.6), Pinsk (-11.9), Gomel (-22.4) and Grodno (-32.9) (Fig. 4).

Large oblast centers and the capital remain the centers of attraction for Ukrainians: Minsk, Vitebsk, Polotsk, Novopolotsk, Orsha. In ethnic territories and the Belarus-Ukraine border, such a city is Brest – the oblast center and the heart of the ethnic Ukrainian territory.

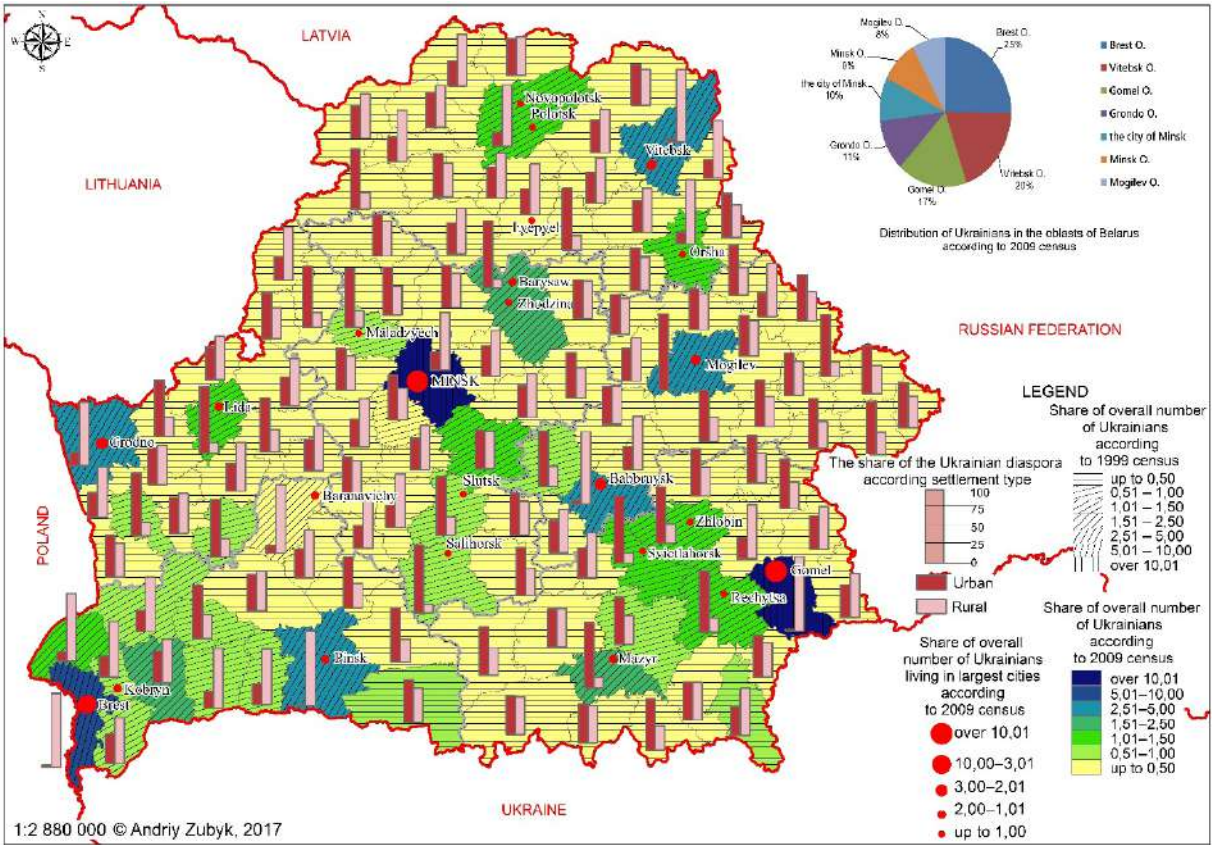


Fig. 2. Distribution of Ukrainians in districts of Belarus according to the censuses of 1999 and 2009 (Zubyk, 2019).

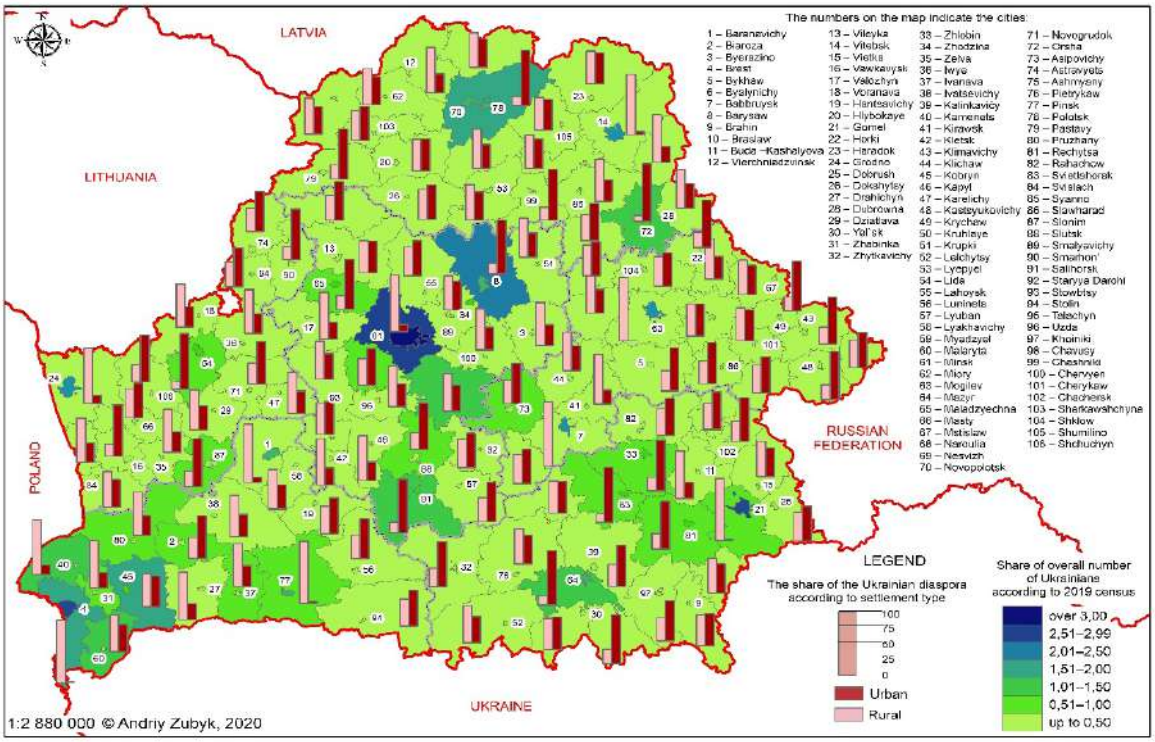


Fig. 3. Distribution of Ukrainians in districts of Belarus according to the 2019 census.

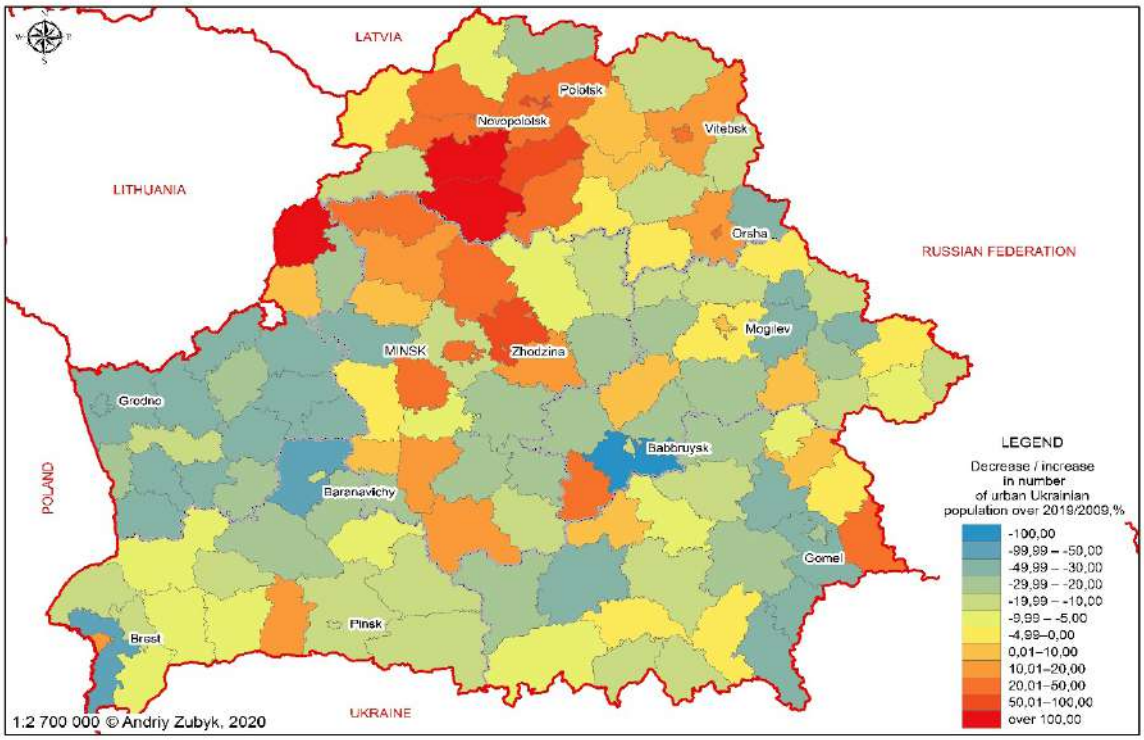


Fig. 4. Change in the share of the urban Ukrainian population in districts and the largest cities of Belarus according to the censuses of 2009 and 2019.

Ukrainians living in the oblasts that include ethnic Ukrainian lands within Belarus, and distribution of Ukrainians and territories of Gomel Oblast which border Ukraine. Ukrainians are autochtonous inhabitants of Brest Oblast. The specifics of life of Ukrainians in the territories that are influenced by the Belarusian language, as well as weak integration into Ukrainian cultural and political life, have caused insignificant level of Ukrainian self-awareness. After Beresteishyna and Pinshchyna had been incorporated into the Belarus SSR,

the Ukrainians began to be identified as Belarusians in legal documents (Dnistrjans`kyj, 2008).

If in 2009, 25.2% of the country's overall Ukrainian population were living in Brest Oblast, in 2019, this figure had fallen to 23.6. The share of Ukrainians in the population according to the 2019 census was 2.79%, whereas in the previous period it was 2.86%. Over a half of Ukrainians of Brest Oblast (53.1%) were living in cities of Brest, Baranovichy and Pinsk, as compared with 46.3% according to the 2009 census.

Across the districts, the share of Ukrainians decreases from southwest to northeast, i.e. the further from Belarus-Ukrainian border ,the lower the number of Ukrainians . By share of Ukrainians in the population, districts of Brest Oblast may be conditionally divided into 5 groups: 1. Brest, Kamenets, Malaryta districts (share of Ukrainians in the population equals over 5%, i.e. on average each 20th resident in those districts identifies him or herself as Ukrainian); 2. Zhabinka, Kobryn and Pruzhany districts (share of Ukrainians in the population equals 2.51 to 5%); 3. Drahichyn, Ivanava, Pinsk and Stolin districts (2 to 2.5%); 4. Berezivka district (1.67%); 5. Baranavichy, Ivatsevichy, Lyakhavichy, Hantsavichy, Luninets (up to 1%, i.e. less than one in a hundred considers him or herself as Ukrainian).

Across the largest cities of the Oblast – Brest, Baranavichy and Pinska – shares of Ukrainians in the populations equal 4.41, 1.37 and 2.09% respectively. While the shares of Ukrainians in the entire populations of Pinsk and Pinsk district are approximately the same – 2.09 and 2.12% respectively, the parameters for Brest and Baranavichy vary. The smaller share of Ukrainians in Brest, compared with Brest District, may be explained by the fact that, as the Oblast center, Brest has a more diverse ethnic composition, a larger population. Instead, Baranavichy as a district center attracts population from the villages.

Tempos of decrease in the number of Ukrainians in Brest Oblast were not as intense as in the rest of the country, though the number of Ukrainians decreased almost by a third (29.9%) over 1999–2009. In most districts of the oblast, the decline in the Ukrainian population was lower than the average decrease across the country. The share of the Ukrainian rural population in Brest Oblast is almost twice larger than the average value in the country – 40.2 and 22.8% respectively.

Over the period between the censuses of 2009 and 2019, the number of Ukrainians living in Brest Oblast decreased by 6%. Compared with the previous period, the tempos of decrease in the Ukrainian population have slowed by 5 times. In a number of districts, the dynamics of decrease in the Ukrainian population corresponded to the tendency across the country or was better. Over 2009-2019, the share of Ukrainians living in cities increased: 67.8% compared with 59.8 in 2009. Increase in the share of the urban Ukrainian population in the oblast is associated with the cities Brest, Baranovichy and Pinsk. Across the districts of the oblast, there are 3 of 16 where most Ukrainians live in cities: Berezivka, Luninets and Stolin.

Of all the districts and cities of Brest Oblast, the positive dynamics of increase in the Ukrainian population was seen in Hantsavichy district and Brest. The absolute changes in the population of Ukrainians over 2009–2019 ranged +2,059 Ukrainians (city of Brest) to -804 Ukrainian (Kamenets district). The relative values for this same period ranged +16% (city of Brest) to -20 (Kobryn district), -22 (Lyakhavichy district), -28 (Kamenets district), -30.9 (Pinsk district) and -46.1 (Baranovichy) (Fig. 5).

Ukraine borders with Lyelchytsy, Yel`sk, Naroulia, Khoiniki, Brahin, Loyew, Gomel and Dobrush districts of Gomel Oblast. According to the 2009 census, 4,513 Ukrainians were living (14.6% of the overall number of Ukrainians who were living in the Oblast) in those districts. Relative changes in the number of Ukrainians in those territories over the period of 1999–2009 ranged -32.42% (Naraulianski district) to -65.6% (Brahinski district).

In 2019, 3,261 Ukrainians were living in those territories (13%). Over 2009–2019, the absolute values of Ukrainians decreased by 1,252 people, relative values – by -27%. While the city of Brest is a "magnet" that attracts Ukrainians from the oblast, in 2009–2019, the Ukrainian population in Gomel and cities of the oblast became smaller (see Fig. 4). Ukrainians live in villages, the share of rural Ukrainian population is three times larger than in the oblast on average (Results of population census 1999, Results of population census 2009, Results of population census 2019).

The analysis of decrease in the number of Ukrainians in districts and the largest cities (Fig. 6-7) suggests that the lowest values were observed in the ethnic Ukrainian territories, partly fewer relative changes in the number of Ukrainians were determined for the districts that border with Ukraine. Such processes may be explained by the fact that the level of urbanization of Ukrainians in Brest Oblast is lower than the average parameter for the country. Living in rural areas somewhat slows the processes of ethnic assimilation, unlike life in the cities, where ethnic compositions are more diverse.

Decrease in the Ukrainian population in the largest cities is lower compared with the mean parameter for the country. The cities face internal migration due to education, search for work, etc. A bright example is the city of Minsk. In districts that border with the capital, the tempos of decrease in population of Ukrainians over the inter-census period of 2009-2019 between the censuses were also lower.

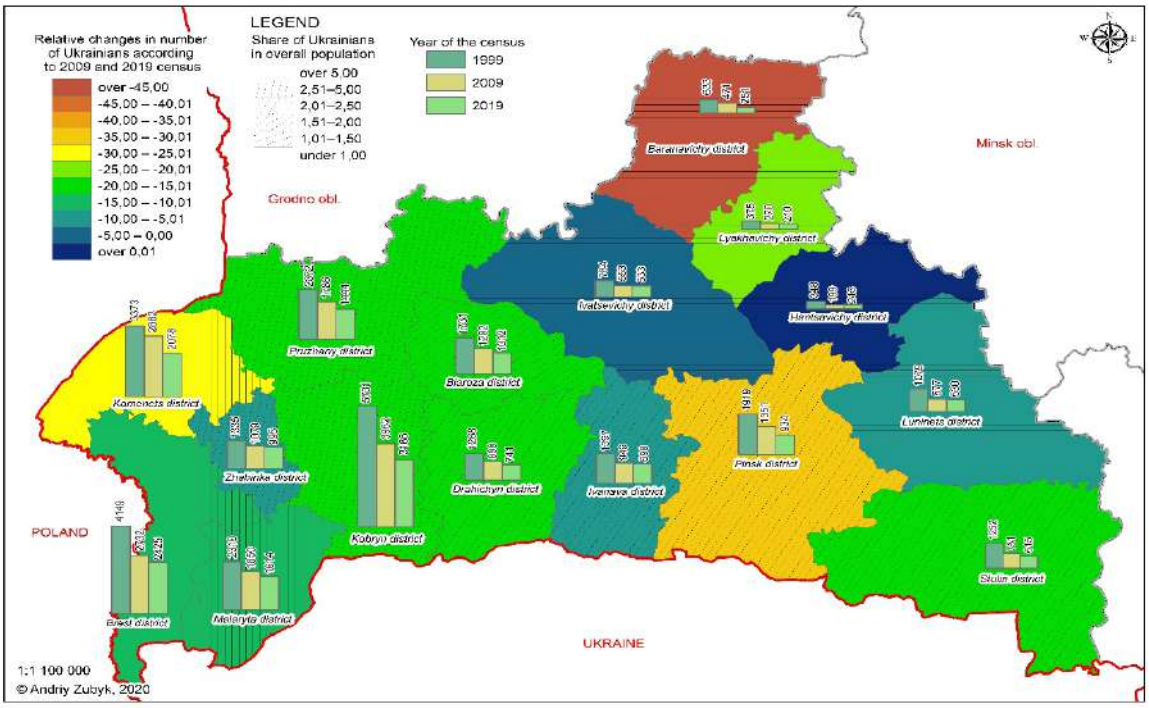


Fig. 5. Number and relative changes in the distribution of Ukrainians in the districts of Brest Oblast according to 2009 and 2019 censuses.

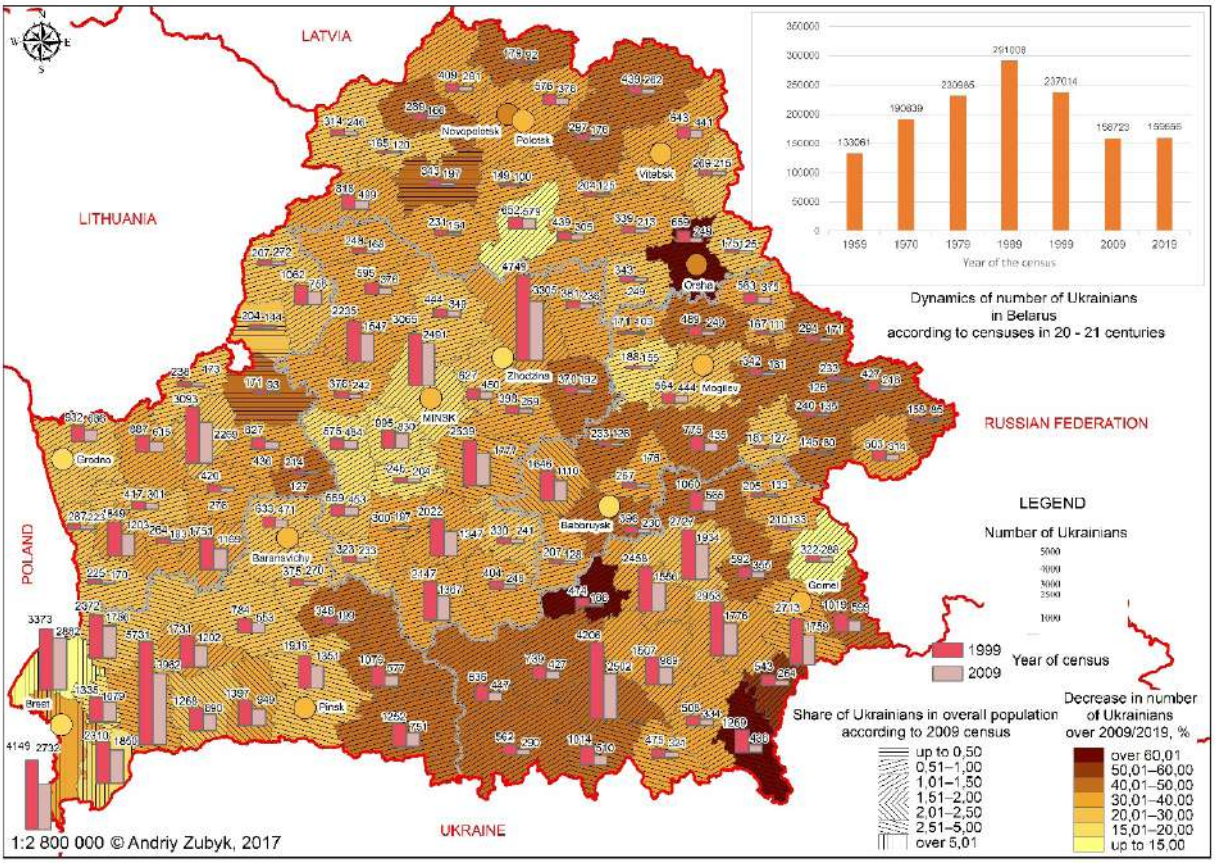


Fig. 6. Number and relative changes in number of Ukrainians in districts of Belarus according to 1999 and 2009 censuses (Zubyk, 2019)

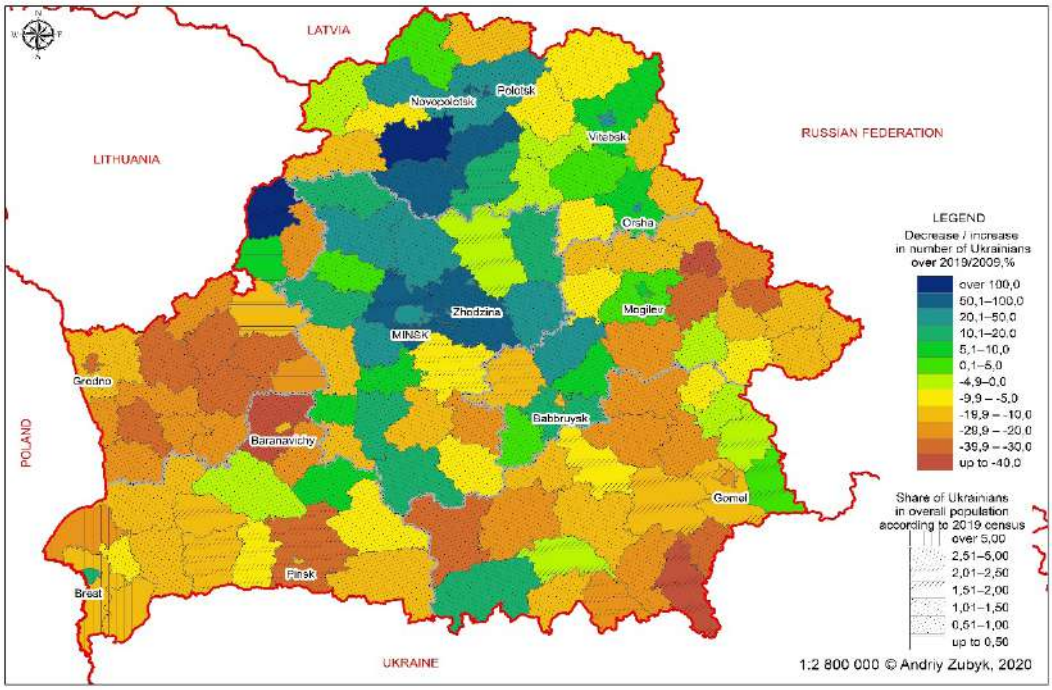


Fig. 7. Share of Ukrainians in population and relative changes in number of Ukrainians in districts according to 2009 and 2019 censuses.

As indicated in Fig. 7, more relative changes in the number of Ukrainians occur in the center and in the north of Belarus, particularly the strip of districts between the capital and cities Novopolotsk and Polotsk with ramification toward Mogilev. The strip comprises Dzyarzhynsk, Valozhyn, Maladzyechna, Vileyka, Lahoysk, Smalyavichy, Minsk, Chervyen, Klichaw, Byerazino and other districts. In this group, the share of Ukrainians living in cities increased (see Fig. 4). During the period between the 2009 and 2019 censuses, the greatest relative changes in the population of Ukrainians were determined across the entire Grodno oblast; though taking place more slowly, the number of Ukrainians living in ethnic Ukrainian territories and in the Belarus-Ukraine border zone has been decreasing.

Despite the insignificant increase in the number of Ukrainians in several districts of Gomel Oblast, districts near the Belarus-Russia border were observed to have negative tendencies in the dynamics of Ukrainians. In the context of relative changes in the size of the Ukrainian population over 2009-2019, we can state that Ukrainians move out of border, oftentimes poorly developed, districts to the center of the country, to which the location of the capital contributes.

It should be noted that determining the share of Ukrainians in the overall population, share of Ukrainians who live in a certain district or city in the overall number of Ukrainians in the country, analysis of absolute and relative values and their number during the period between the censuses do not provide objective understanding of such a complex notion as ethnic assimilation and its influence on the ethnic population in the future.

For detailed analysis of ethnic composition of the country's population, we calculated several mathematical-statistical parameters, namely: index of ethnic diversity, index of socioethnic density, coefficients of ethnic community and ethnic compactness in the largest cities and districts. The first two parameters were determined for five nationalities: Belarusians, Russians, Poles, Ukrainians and other. Such an approach was chosen because of the significant quantitative difference between the four most numerous ethnicities, therefore the remaining ethnicities were identified to the "other" category.

Fig. 8 demonstrates that Belarus is a monoethnic country, and the probability that both of two randomly chosen people would have different ethnicity is quite low – in the majority of districts it does not exceed 30%. Ethnic diversity of the population of the country's largest cities does not exceed the mean value for the country. Large cities and the capital should be "magnets" attracting not only representatives of the titular ethnicity, but also the representatives of ethnic minorities. Most border districts are not ethnically diverse. In most of those districts, Belarusians dominate in the structure of the population. Also, such parameters may be explained by the prevalence of the rural population, whereas representatives of ethnic minorities are more "urbanized" compared with the titular ethnicity, except for the au-

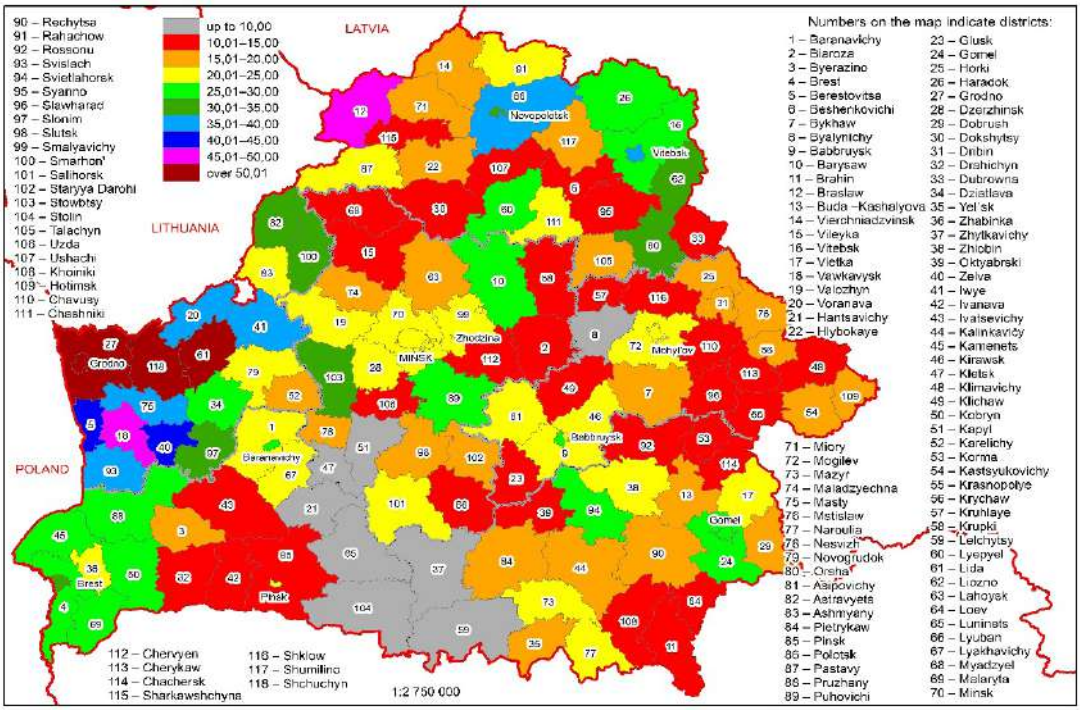


Fig. 8. Index of ethnic diversity in districts of Belarus according to the results of 2019 census.

tochtonous population that prefers living in its own ethnic territory (for example, Ukrainians in Brest Oblast).

Across the largest Belarusian cities, the most diverse ethnic composition is in Grodno. The parameter of ethnic diversity in this city means that the probability of different ethnicities of two randomly selected people in Grodno equals over 50%.

The highest index of ethnic diversity was determined for districts of Grodno Oblast (Grodno, Lida and Shchuchyn districts); such parameters may be explained by the border with Poland and Lithuania and higher share of Poles in the district's population compared with the rest of the districts. The most ethnically diverse districts of Belarus are in the southwest part of the country (already mentioned districts of Grodno Oblast and some districts of Brest Oblast). In the rest of the country's territory, the index of ethnic diversity does not exceed 20%. An eloquent example is decrease in the value of ethnic diversity in Brest Oblast oriented "west-east", i.e. the following is seen: lower share of Ukrainians in the population means lower parameter of ethnic diversity. Greater ethnic diversity oftentimes is related to the factor of oblast center or district center, for example the city of Gomel and the district of the same name, Novopolotsk and Polotsk district, Vitebsk and Vitebsk district.

Calculation of the socioethnic density index also confirmed that Belarus is a monoethnic country; in most districts and large cities, this parameter is higher than 70 (the closer the parameter is to 100, the more ethnically homogenous is the territory). As with previous parameter, lower socioethnic density is seen in some districts of Brest and Grodno Oblasts and large cities of the country. This is because Ukrainians and Poles densely live there, while ethnic composition in large cities is more diverse compared with rural areas, - this affects the value of this parameter. Having determined this parameter, we can see that the country's territory is actually homogenous in its ethnic composition (Fig. 9).

Dense inhabitation in the ethnic Ukrainian territories and large cities of the country led to comparatively low coefficient of ethnic similarity in most regions (Fig. 10). This is also due to the insignificant presence of Ukrainians, which had contributed to their share in the overall population, and larger population in a district or city. Another factor this parameter depends upon is the presence of one or several centers where a large part of representatives of one ethnicity lives (for example, autochthonous population, attraction of migrants to labour markets, etc). The highest values of this parameter were determined in the ethnic Ukrainian territories (Brest, Kamenets, Kobryn, Malaryta districts and the city of Brest). Also, this category includes the capital and Minsk district, cities Gomel and Zhodzina. In the majority of territories with high coefficient of ethnic similarity, this fact is explained by attraction of population to large cities or oblast centers.

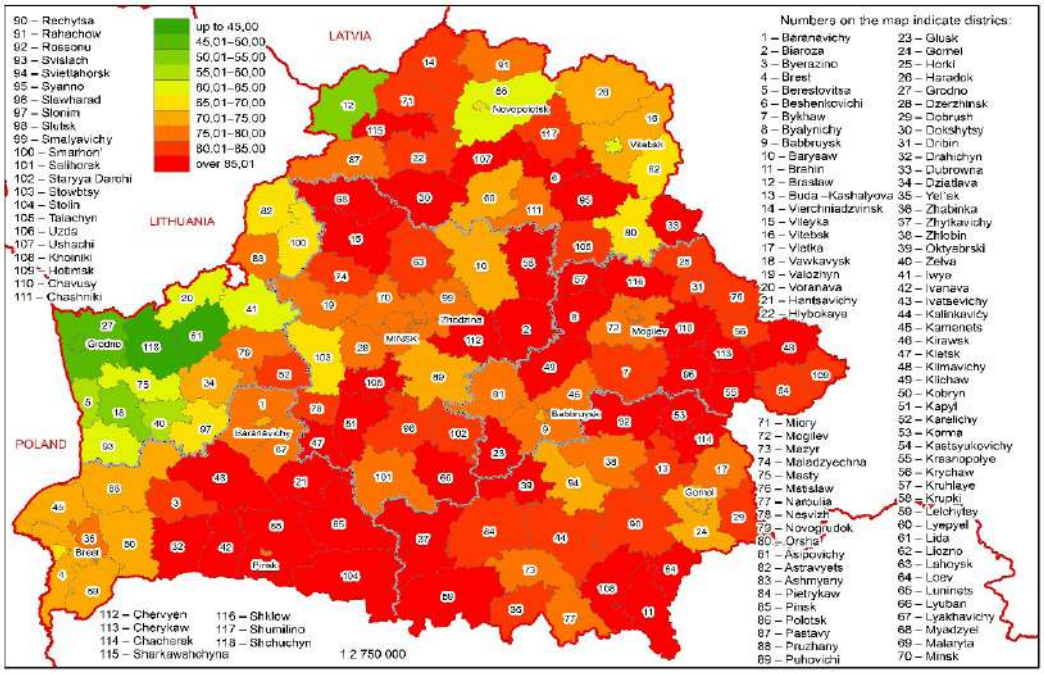


Fig. 9. Parameter of socio-ethnic density in districts of Belarus according to 2019 census.

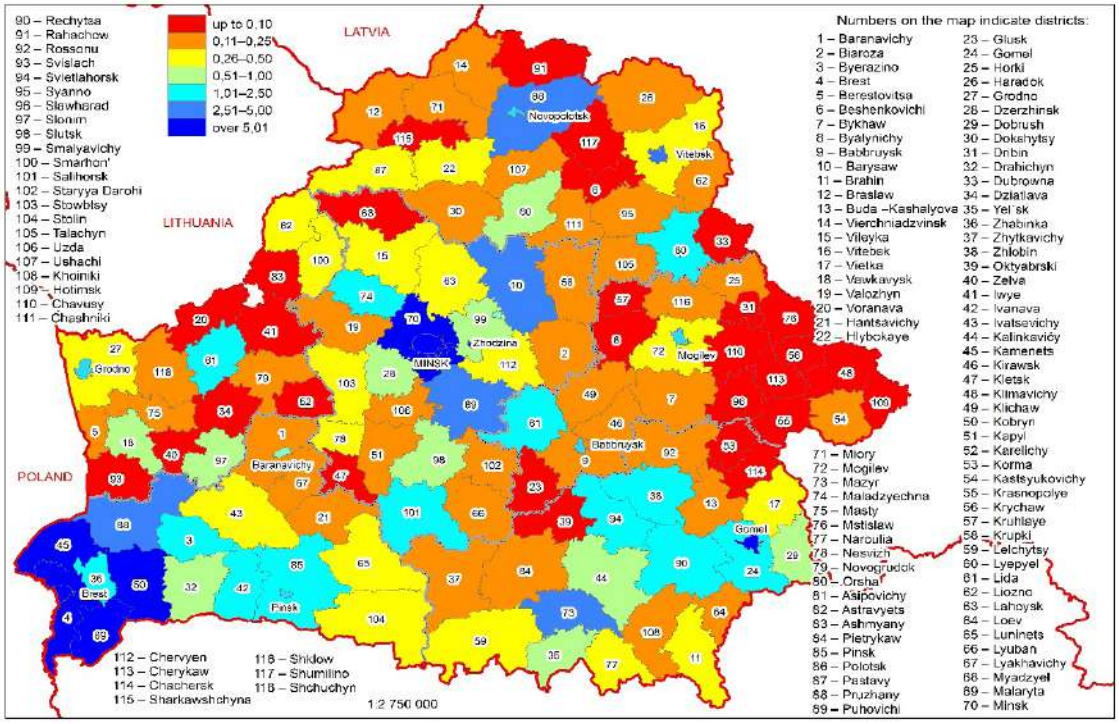


Fig. 10. Coefficient of ethnic similarity in districts of Belarus according to results of 2019 census.

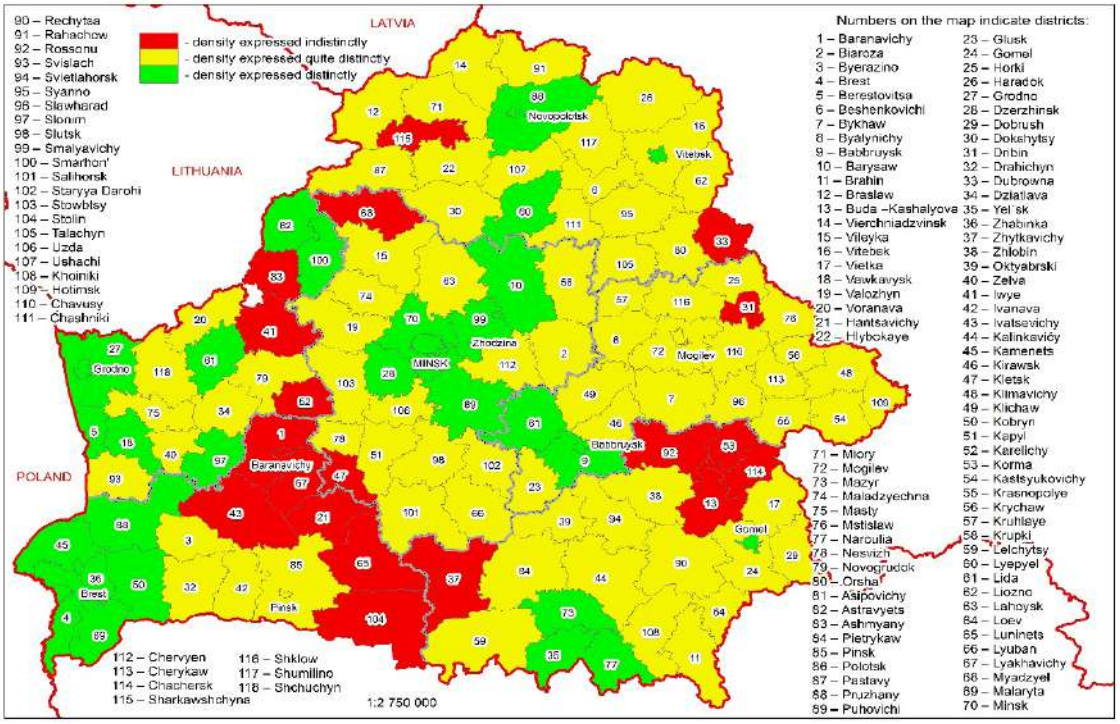


Fig. 11. Coefficient of ethnic compactness of Ukrainians in districts of Belarus according to results of 2019 census.

According to the coefficient of ethnic density which we obtained for districts and large cities, we determined that most of districts are characterized by correspondence of share of Ukrainians in the district population to share of Ukrainians in the Oblast population. In many districts of the country, ethnic density of Ukrainians is quite distinct (Fig. 11). This parameter is best expressed in the ethnic Ukrainians territories and large cities of Belarus. Also, to this category, we can classify districts around the closest cities and several border districts.

Among the ethnolinguistic parameters that are being collected during the censuses of the Belarus population, there are mother tongue and the language the respondent speaks at home (home language). According to the 1989 census, ethnolinguistic correspondence of Ukrainians accounted for 45.4%, whereas 48.7% named the Russian language as their native tongue. The language of the titular ethnicity was named by 5.9% of all Ukrainians. The highest ethnolinguistic correspondence of Ukrainians was in Brest Oblast – 55.6% of the overall population of Ukrainians named Ukrainian as their mother tongue (Fig. 12) (Zubyk, 2019).

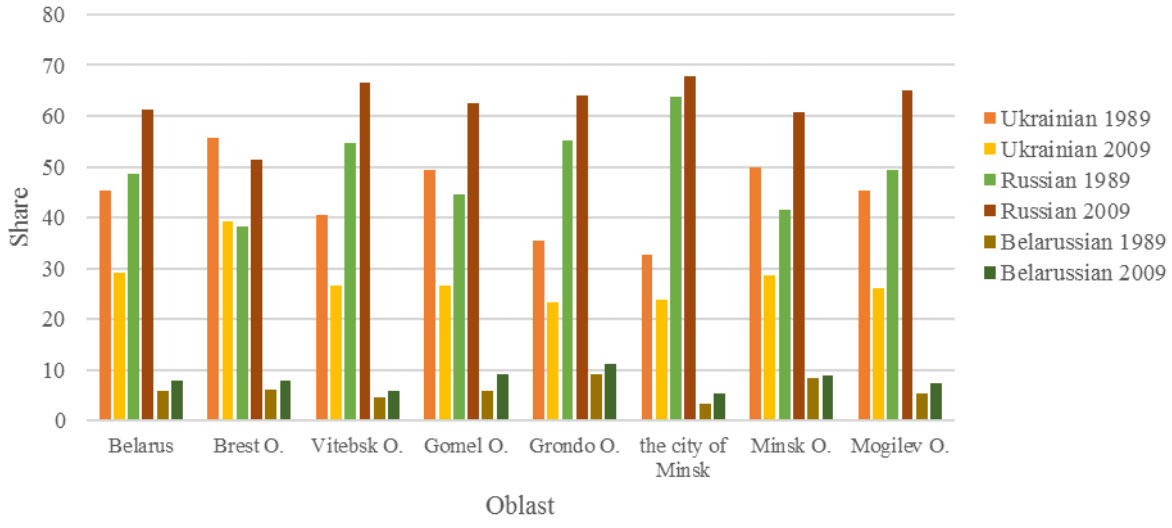


Fig. 12. Ethnolinguistic correspondence of Ukrainians in oblasts of Belarus according to 1989 and 2009 censuses.

At the time of writing this, the Statistical Committee of Republic of Belarus has not presented the data on ethnolinguistic criteria of the 2019 census for the Oblasts. The research is also complicated by the fact that no results of ethnolinguistic criteria of censuses are available for districts.

As we see in Fig 12, during 1989–2009, language assimilation of Ukrainians occurred. First of all, this meant decrease in the share of Ukrainians who considered the Ukrainian language their mother tongue, – -16.2% across the country. By oblasts, changes in the share vary -9% (city of Minsk) to -22.8% (Gomel Oblast). As a result of mixed marriages and ethnic assimilation, Ukrainians in Belarus become Russianized – over 1989–2009, the share of Ukrainians that consider the Russian language as their own increased by 12.5%. Across the oblasts, Russianization had the greatest impact on Ukrainians who live in Minsk Oblast – compared with the 1989 census, the share of Ukrainians who consider the Russian language their mother tongue increased by 19.3%. The language of the titular nation was considered mother tongue by 2.05% more Ukrainians than during 1989 census. This parameter has increased the most in Gomel Oblast – 3.2%.

According to the results of the 1999 census, Ukrainian was named as mother tongue by 42.9% of the Ukrainians, Belarusian – by 14.3% and 42.8 namedthe Russian language as their mother tongue. Languages spoken at home were Russian – 83.6%, Belarusian – 10.2 and other – 6.2% (Tables 1–2).

In 2009, Ukrainian was mother tongue for almost every third Ukrainian (29.3%). The highest parameter of ethnic language correspondence of Ukrainians was in Brest oblast (39.3%), in the remaining oblasts – 23.4% (Grodno oblast) to 28.7% (Minsk oblast). The Russian language was considered mother tongue by 61.2% of Ukrainians, the highest this parameter being in Minsk – 67.9%, the lowest – in Brest Oblast (51.9%). Belarusian was considered mother tongue by 7.9% of Ukrainians. This parameter was the highest in Grodno Oblast – 11.2%. In rural areas, the proportion of people speaking Ukrainian remained higher than in the cities (Results of population census 1999, Results of population census 2009, Results of population census 2019).

Women named Ukrainian as their mother tongue more often – 30.2%, men – 28%. The share of men for whom the mother tongue was the Russian language equaled 47.5% among the rural Ukrainian rural population and up to 66.9% among the urban population, whereas among women this parameter was 44.2% and 64.8% respectively. A similar situation exists with Belarusian language: in cities it was mother tongue for 6.7% of the Ukrainians. Over 3% of the Ukrainians named the Ukrainian as the language of home communication. This parameter was the highest in Brest Oblast – 7.7%, the lowest – 1.6% – in the city of Minsk. Almost half of the Ukrainians did not speak other languages – 48.4%. Among fluently spoken languages, Ukrainians most often mentioned Ukrainian (14.4%) and Belarusian (18%). The Russian language was named as a fluently spoken language by 5.62% of the Ukrainians.

The most recent census of the country's population in 2019 indicated significant language assimilation of the Ukrainians (dynamics of ethnic language correspondence of Ukrainians by mother tongue and home language according to censuses carried out in 1999, 2009 and 2019 are given in Tables 1–2).

Table 1. Dynamics of ethnolinguistic correspondence of Ukrainians (mother tongue) according to censuses of 1999, 2009 and 2019

Year of census	Number of Ukrainians	Mother tongue		
		Ukrainian	Russian	Belarusian
1999	237,014	42.8	42.8	14.3
2009	158,723	29.2	61.2	7.9
2019	159,656	29.1	62.4	8.2

Table 2. Dynamics of ethnolinguistic correspondence of Ukrainians (language they speak at home) according to censuses of 1999, 2009 and 2019.

Year of census	Number of Ukrainians	Home language		
		Ukrainian	Russian	Belarusian
1999	237,014	6.2	83.5	10.2
2009	158,723	3.5	88.4	6.1
2019	159,656	4.0	89.1	6.5

Tables 1 and 2 indicate that changes and ethnic language criteria throughout the period of 2009–2019 were smaller compared with the period 1999–2009. This may to some extent be explained by the change in the generations and types of areas where Ukrainians were living at the moment of census. Increase in the urbanization level in Belarus in general and in the environment of the Ukrainians in particular leads to faster transfer of Ukrainians to other languages in large cities, and mixed marriages and staying in a setting where another language is spoken only accelerate this process.

Similar is the situation with the criterion "Language spoken at home".

Conclusions.

Despite the insignificant increase in the number of Ukrainians which was recorded by the 2019 census, the overall populationof Belarus and the Ukrainian diaspora correspond to the parameters of 1959. Despite the fact that Belarus includes ethnic Ukrainian territories, the share of Ukrainians in the country's population is stably low and does not exceed 2%. Areas densely inhabited by Ukrainians are the southwest part of the country, oblast centers and a number of district centers outside the ethnic Ukrainian territories. Compared with 2009, the level of urbanization of the Ukrainian diaspora has increased (to the highest degree in districts north of Minsk), though in over 50 districts the Ukrainians predominantly live in villages. The Ukrainian diaspora in Belarus experiences outflow of Ukrainians from the border districts to the center of the country. Most often, the centers of "attraction" of Ukrainians are the capital, some oblast centers, more rarely district centers, as indicated by the analysis of the dynamics of the number of Ukrainians during the period between the censuses of 2009-2019. Particularly, we determined that the greatest relative changes (toward increase) during that period occurred in the strip of districts between Minsk and Novopolotsk with ramification in the direction of the Belarus-Lithuania border on one side and a number of districts between Minsk toward Babbruysk and Mogilev. Analysis of a number of mathematical-statistical parameters confirmed that Belarus is a monoethnic country. Those parameters are lower in places that are densely populated by other ethnicities and a number of border districts. We can state that the relatively close cultural distance between Ukrainians, Belarusians and Russians in Belarus has no effect on the ethnic identification of Ukrainians, though Ukrainians in Belarus do experience Russianization. Also, we have to note that the changes according to ethnic language criteria during the inter-census period of 2009-2019 were less significant compared with the period of 1999-2009.

Referenses

Dnistrjans'kyj, M. S., 2008. Etnogeografija Ukrai'ny [Ethnogeography of Ukraine]. Vydavnychyj centr LNU imeni Ivana Franka, L'viv (In Ukrainian).

Ethnic composition of the population of Belarus according to the 1999 census. Retrieved from http://pop-stat.mashke.org/belarus-ethnic1999.htm (In Belorussian).

Ethnic composition of the population of Belarus according to the 2009 census. Retrieved from http://pop-stat.mashke.org/belarus-ethnic2009.htm (In Russian).

Ethnic composition of the population of Belarus according to the 2019 census. Retrieved from http://pop-stat.mashke.org/belarus-ethnic2019.htm (In Russian).

Results of population census 1999 (table data). National Statistical Committee of the Republic of Belarus. Retrieved from https://www.belstat.gov.by/informatsiya-dlya-respondenta/perepis-naseleniya/perepis-naseleniya-1999-goda/tablichnye-dannye/ (In Russian).

Results of population census., 2009. National Statistical Committee of the Republic of Belarus. Retrieved from https://www.belstat.gov.by/informatsiya-dlya-respondenta/perepis-naseleniya/perepis-naseleniya-2009-goda/(In Russian).

Results of population census 2019. National Statistical Committee of the Republic of Belarus. Retrieved from https://www.belstat.gov.by/informatsiya-dlya-respondenta/perepis-naseleniya/perepis-naseleniya-raunda-2020-goda/itogi-perepisi-naseleniya-respubliki-belarus-2019-goda/ (In Russian).

Troshhyns'kyj, V. P., 1999. Ukrai'nci v sviti [Ukrainians in the world]. Al'ternatyvy, Kyiv (in Ukrainian).

Vynnychenko, I. I., 1992. Ukrai'nci v derzhavah kolyshn'ogo SRSR: istoryko-geografichnyj narys [Ukrainians in states of former USSR: historic-geographical essay]. L'onok, Zhytomyr (In Ukrainian).

Yevtukh V. B., 2012. Etnichnist': entsyklopedychnyy dovidnyk [Ethnicity: an encyclopedic reference book]. Feniks, Kyyiv (In Ukrainian).

Zastavnyj, F. D., 1992. Shidna ukrai'ns'ka diaspora [East Ukrainian diaspora]. Svit, L'viv (In Ukrainian).

Zubyk, A. I., 2019. Ukrai'ns'ka diaspora: suspil'no-geografichne doslidzhennja [Ukrainian diaspora: socio-geographical research]. Prostir-M, L'viv (In Ukrainian).

Journal of Geology, Geography and Geoecology

ISSN 2617-2909 (print)
ISSN 2617-2119 (online)

Journ. Geol. Geograph. Geology, 30(4), 808–809.

Journal home page: geology-dnu.dp.ua

doi: 10.15421/11217301

CONTENTS

JOURNAL OF GEOLOGY, GEOGRAPHY AND GEOECOLOGY

The Journal was founded in 1993 under the title
«Dnipropetrovsk University Bulletin. Series: Geology»
The journal, beginning in June 2018, is published under the title
«Journal of Geology, Geography and Geoecology».

Volume 30 (4)

English

Certificate of state registration of a series of KV № 23167-13007 dated February 26, 2018 in accordance with the order of the Ministry of Education and Science of Ukraine dated 24.05.2018 №527 (Annex 5), a printed (electronic) publication "Journal of Geology, Geography and Geoecology" is included in the List of Scientific Specialized Publications of Ukraine in the Field of Geological Sciences
(included in professional editions since 2003).
The international level of the Journal obtained recognition in 2017 when it was included in the Web of Science and over 20 well-known scientific citation databases

Literary editors: Paul W. Bradbeer, Michael O. Tikhomyrov
Text Layout: Volodymyr V. Manyuk, Volodymyr A. Sytnyk
Cover design: Volodymyr A. Sytnyk

Підписано до друку 20.12.2021. Формат 60x84 $^{1}/_{8}$.
Друк цифровий. Папір офсетний. Ум. друк. арк. 24,12.
Тираж 100 пр. Зам. № 317.

ПП «Ліра ЛТД», вул. Наукова, 5, м. Дніпро, 49107.
Свідоцтво про внесення до Державного реєстру
серія ДК № 6042, від 26.02.2018 р.